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Course on Renewable Energy How to Revamp the Content

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Abstract

The field of renewable energy is constantly changing and adapting to the needs of our society as new developments and knowledge are presented. As a result, courses that focus on and provide insight into these topics can quickly become outdated. Thus, updating and managing the information presented in those courses becomes necessary to prepare future engineers and scientists and share the process used to provide students with the current state of renewable energy generation methods and their histories. To achieve this goal, new resources are created to facilitate the students' learning and understanding. These resources include multimedia elements, interactive activities, and new assignments that focus on the practical applications of these technologies. The rationale for the inclusion of these materials is provided in this document.

Utilizing in-class discussions with the students that occurred in the first two weeks of the semester guided the approach to teaching and the layout of the course. Following these discussions, specific areas in each renewable energy topic were selected for inclusion in the course. The work shared in this document provides an outline of how this was done and how the construction of the course using scaffolding allows students to learn more about the subjects they're interested in. By increasing focus on those things that engage the student, the desire to learn improves and the subjects align with current issues and situations encountered in the renewable energy industry. Other course goals are to provide students with the experience of talking about the materials and to keep the discussion on the topics purely technical, avoiding emotional encounters which are often found when discussing renewable energy and its impact on the environment.

Keywords and Phases: renewable energy, course development, undergraduate

Introduction

Renewable energy has become a critical component in addressing the environmental challenges that come with climate change. As the nations of the world strive to meet ambitious sustainability goals there is the need for professionals with the necessary understanding of renewable energy technologies. Higher education institutions provide the education to prepare students to learn and contribute to the evolving landscape. It becomes necessary to maintain a high level of education and adjust the curriculum to best educate students to become the next generation of professionals working to improve renewable energy.

This study focuses on the redesign and revamping of an undergraduate course through an independent study project aimed at improving the renewable energy content to meet the changes and modern era of renewable energy. Topics include solar power, wind power, hydroelectric power, geothermal power, biomass energy, and marine power. Each topic was systematically updated to provide students with a broad yet detailed understanding of the field. The revised curriculum incorporates scaffolded learning in conjunction with multimedia resources, interactive activities, and guest speakers to enhance student engagement and learning.

By revamping the materials presented to students through bridging the gaps between theories and practical applications, this study aims to contribute to the growing body of literature on renewable energy education and serves as a model for integrating new materials into existing coursework. The findings show the importance of teaching methods in equipping the future generation of engineers and scientists.

Literature Review

The selection of instructional methods is crucial in the revamping of course content, particularly when integrating scaffolding learning and student-centered approaches. Scaffolding learning is a pedagogical strategy that builds upon students' prior knowledge, gradually increasing complexity to enhance understanding. This method is akin to the process of learning to walk, as described by Taber, where children first master balance before progressing to the more intricate aspects of walking, such as coordinating their limbs and maintaining momentum [5]. This analogy illustrates how scaffolded learning can be effectively implemented in educational settings, allowing students to construct knowledge incrementally and with support. In the context of modern education, the integration of technology into scaffolded learning presents both opportunities and challenges. Kim and Hannafin emphasize the necessity of combining scaffolded learning with technology-enhanced environments, highlighting various forms of enhanced learning and identifying potential issues where scaffolding can be effectively applied [1], [9].

This synergy between technology and scaffolding not only enriches the learning experience but also addresses diverse learning needs, making education more accessible and engaging for students. Moreover, the importance of a student-centered approach in higher education cannot be overstated. Hannafin and Land argue that such an approach accommodates the varied educational backgrounds of students, allowing them to learn in ways that resonate with their individual experiences [3]. This method mitigates the common student frustration of uncertainty regarding their learning needs, which is often exacerbated in traditional instructional settings.

By placing students at the center of the learning process, educators can foster an environment where learners take ownership of their education, thereby enhancing engagement and comprehension. The necessity for tailored educational content, particularly in fields like renewable energy, is underscored by Shehzad et al., who advocate for the development of curricula that reflect current knowledge and practices in renewable energy [2].

This involves creating educational materials that are not only informative but also adaptable to various educational levels. The integration of up-to-date resources, including internet-based information and textbooks, is essential for constructing a relevant and effective curriculum that meets the needs of diverse learners. In summary, the combination of scaffolded learning and student-centered approaches, particularly within technology-enhanced environments, offers a robust framework for effective education. This approach not only builds upon students' existing knowledge but also empowers them to engage actively in their learning journey. As educational paradigms continue to evolve, the emphasis on personalized, relevant, and engaging instructional methods will be pivotal in preparing students for the complexities of the modern world.

Methodology

This methodology's purpose is to demonstrate the techniques and methods used to develop the revamped course materials rather than discuss an experiment. A detailed description of what is done follows:

Selection of Topics

In the initial weeks of the semester, we focused on traditional energy production methods and created an online discussion board for students to engage with. This platform aims to understand student interests, particularly in renewable energy topics.

Key themes that emerged from the discussions included comparisons of different power generation methods, nuclear energy, and battery technologies. Students explored how these technologies work and how they can differ based on location.

The insights gathered from the discussion board informed the development of our course materials. As we prepared for the second half of the semester, we aligned these topics with the planned sections of the course, which include: an introduction to renewable energy, solar energy, wind energy, hydroelectric power, geothermal energy, biomass, and marine energy.

Each of these topics will follow the established course format, where the first class of the week consists of a discussion led by the professor, and the second class allows for student presentations.

Renewable Technology Discussion

The weekly discussions contain the bulk of the content revamp where the existing materials were supplemented, adjusted, and updated to current knowledge of each subject. The discussion was guided by a page on the course website, the use of this page allows students to follow along in class, synchronously online, or on a different day. This structure provides the opportunity to use the methods that best support their learning experiences in the course. The website page follows the structure of scaffolded learning on a smaller scale in comparison to the class as a whole. The discussion includes various forms of media including images, videos, GIFs, other websites, and interactive tools. Each one of these media formats was specifically chosen or created to add variation in the presentation of the materials to benefit the students' understanding depending on how they learn.

The general format starts with the basic principles of the technology including the physical phenomenon that allows the technology to function. Following this would be a timeline for the development and usage of these technologies providing the students with the opportunity to learn about how long each technology has existed and the sheer number of improvements that have been made. The next section will come back to the technical aspects of how the technology works and the different components of it. For example, the solar discussion page has information on the function of solar panels and the various types of solar cells and their respective differences. This format was utilized again for concentrated solar power discussing the differences in each technology that harnesses the sun's thermal energy. The next subsection includes real-life examples of the systems and technologies found through the authors' experiences. Rounding out the discussion are links to more advanced materials, such as textbook sections and deep dives into each of the calculations and considerations in the design and construction.

The materials chosen for these sections come from various sources. The National Renewable Energy Laboratory, the U.S. Energy Information Administration, research papers, and companies that work on these technologies were selected to provide the information. The variation in the sources provides several perspectives, information, opinions, and methods of instruction.

Student Continent Presentations

The students were divided into groups of four, with each group selecting a different continent to focus on. Each week, they would give presentations lasting 10 to 15 minutes that covered the form of power generation relevant to their assigned continent. These discussions aimed to enhance understanding of the topic and provide technical background on the technologies and their applications. Working collaboratively, the students would use the information gathered to conduct research and present the current state of power generation technology in their respective continents.

The presentations were required to include:

- Summary Statistics
    - Total generation (MW), largest installations, comparison to other energy sources
    - Generation potential
    - Future outlook (planned increase or decrease in generation)
- Political/Legislative Discussion
    - Are there major barriers/aids to the renewable?
    - International cooperation
- Fun facts
    - Anything and everything worth sharing about the continent

The presentations allowed the students to think about the technologies in a different format and learn about the differences in how different parts of the world go about working with power generation.

Assignments

In the process of revamping the course assignments, a deliberate approach was taken to retain the foundational structure of previous semesters while simultaneously updating specific components to align with the revised course materials. This strategy was implemented to ensure continuity in learning while also enhancing the educational experience to reflect current advancements and understanding in the field of renewable energy, particularly wind energy. The assignment that underwent the most significant transformation was the wind energy assignment. This decision was motivated by the increasing importance of technical knowledge in the renewable energy sector, as well as the need for students to engage with real-world applications of theoretical concepts. The updates aimed to deepen students' understanding of wind turbine functionality and the broader implications of wind energy as a sustainable resource. The following are sections of the assignment with details supporting what was done to encourage engagement with the material:

1. Calculation of Potential Energy Output: The first question required students to calculate the potential energy output of a wind turbine of their choosing, utilizing publicly available datasheets and selecting a location for their analysis. This task was designed to familiarize students with the practical aspects of wind energy generation. By engaging with real data, students learn to interpret technical specifications and understand the variables influencing energy output, such as wind speed and turbine efficiency. This exercise not only reinforces theoretical knowledge but also cultivates critical thinking and analytical skills, as students must evaluate various factors impacting energy production.

2. Annual Energy Production and Household Power Calculation: The second question built upon the students' previous calculations by asking them to determine the annual energy production of the selected turbine and how many average U.S. households it could power for one year. This question was included to bridge the gap between technical calculations and their societal implications. By contextualizing energy production in terms of household consumption, students can appreciate the real-world impact of renewable energy solutions. This approach encourages them to think critically about energy distribution and the potential for wind energy to contribute to energy independence and sustainability.

3. Wind Turbine Replacement for Coal-Fired Electricity: The final question tasked students with calculating the number of wind turbines required to replace a specified amount of coal-fired electricity. This question was intentionally designed to prompt students to consider the broader energy landscape and the challenges associated with transitioning from fossil fuels to renewable energy sources. By engaging in this question, students are encouraged to analyze the environmental, economic, and logistical factors involved in energy production. This critical examination fosters a deeper understanding of the benefits and challenges of implementing wind power, thereby equipping students with the knowledge necessary to advocate for sustainable energy solutions in their future careers.

Updates to the wind energy assignment were carefully crafted to enhance students' technical knowledge while simultaneously fostering critical thinking about the implications of renewable energy. By retaining the core structure of previous assignments and integrating contemporary issues and data, the course aims to provide a comprehensive educational experience that prepares students for the complexities of the renewable energy sector. This approach not only aligns with current educational standards but also empowers students to become informed advocates for sustainable practices in their professional lives.

The other assignments for the renewable energy half of the course follow a similar layout with calculations and considerations of implementation of each technology. Biomass and marine energy did not have assignments associated with them to provide additional time to complete the feasibility study.

Feasibility Study

The feasibility study serves as the semester project for the course, engaging students in a comprehensive and practical exploration of new energy sources or improvements to the current infrastructure of a large Midwest university. The project is structured to mirror real-world problem-solving and project management processes, providing students with valuable hands-on experience.

Initially, the same groups that worked on the continent presentation were tasked with identifying potential solutions for enhancing the university's energy infrastructure. Each group proposes a potential solution, which could range from integrating renewable energy sources like solar or wind power to optimizing existing systems for greater efficiency.

Following the proposal stage, students conduct thorough market research. This involves analyzing the university's current energy usage and infrastructure, as well as investigating similar solutions implemented at other universities. This research phase is crucial as it provides the necessary data and insights to refine their initial proposals. Students must consider various factors, including the scalability of the solution, potential environmental impact, and the feasibility of implementation within the university's specific context.

Once the research is complete, the proposed solutions are reviewed and adjusted based on the findings. This iterative process ensures that the solutions are not only innovative but also grounded in practical reality. Students then evaluate their refined proposals through detailed calculations, assessing the financial, technical, and political viability of their solutions. This includes cost-benefit analyses, technical feasibility studies, and considerations of regulatory and policy implications.

An essential component of the project is developing a realistic project timeline. Students must outline the steps required to implement their solution, including key milestones, resource allocation, and potential challenges. This timeline helps to demonstrate the practicality of their proposal and provides a clear roadmap for implementation.

The project culminates in a formal presentation during the last week of the semester. Each group presents its findings and proposed solutions to the class, the professor, and a power plant engineer. This presentation not only allows students to showcase their work but also provides an opportunity for feedback from industry professionals, further enhancing the learning experience. Through this comprehensive project, students gain a deeper understanding of the complexities involved in energy infrastructure projects and develop critical skills in research, analysis, and project management.

Guest Speakers

Guest speakers are brought into the class throughout the semester to discuss real-world examples of the different power generation technologies. For the renewable half of the class, there were two guest speakers. The first guest speaker came in to talk to the class about the levelized cost of electricity and the social, political, and ethical impacts that come from variations in the cost of electricity and power consumption. The presentation focused on hospitals and health care and how they are affected by these variations, especially with and without backup power systems. The second guest speaker was an engineer for a battery recycling company. Their presentation focused on the ways that batteries are recycled and what can be done with the recovered materials. Part of the presentation included information about utilizing old electric and hybrid vehicle batteries to create battery backup systems for parts of the electrical grid. The other method of recycling involves disassembling the batteries to recover the valuable materials that can be reused to create new batteries.

Results and Discussion

The course format, content, and continuous feedback received from students have been instrumental in shaping a positive and enriching learning experience. The semester-long feasibility study project, which involves identifying and proposing new energy sources or improvements to the current infrastructure of a large Midwest university, has been particularly well-received. This project not only provides students with practical, hands-on experience but also mirrors real-world problem-solving and project management processes, making it highly relevant to their future careers.

Students have expressed appreciation for the structured approach of the course, which begins with traditional and then renewable power generation, overlayed with proposal development, followed by market research, solution refinement, and detailed evaluations. This step-by-step intertwined process ensures that students are thoroughly engaged and able to apply theoretical knowledge to practical scenarios. The inclusion of a realistic project timeline and the final presentation to the class, professor, and a power plant engineer further enhance the learning experience by providing opportunities for feedback and professional insights. The input provided by students via the survey follows.

Course Feedback

At the end of the semester, an anonymous optional survey was conducted allowing the students to provide feedback on the updated course materials. Out of the 20 students in the course, 13 completed the survey. The students who completed the survey were primarily seniors, and everyone who filled out the survey was a student in Mechanical Engineering Technology. This aligns with expectations as the course is an upper-level elective class in the Mechanical Engineering Technology department. The following figures show the feedback given regarding the updated course materials.

Table 1. Familiarity with the Concept of Renewable Energy

Q4 - After the second half of this course, how familiar would you say you are with the concept of renewable energy?	Percentage	Count
Extremely familiar	8%	1
Moderately familiar	31%	4
Very familiar	62%	8

A course focused on power generation aims to help students learn about various topics and develop an understanding of the materials. As shown in Table 1, the students who completed the survey reported feeling moderately to extremely familiar with the concepts of renewable energy.

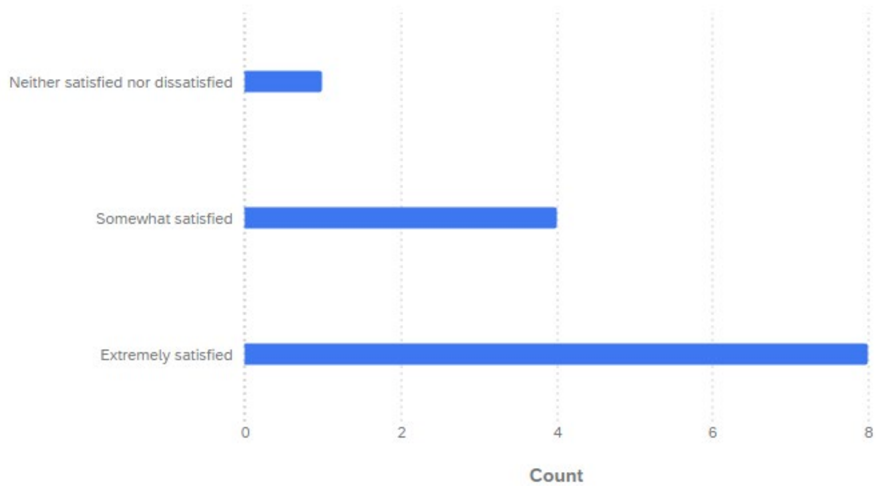


Figure 1. Course Content Satisfaction Level

The next objective of the survey was to assess students' satisfaction with the course content on renewable energy. This question served multiple purposes, including evaluating the quality of the materials gathered and presented, as well as understanding the students' opinions about them. Overall, the responses indicate that the students enjoyed the course materials.

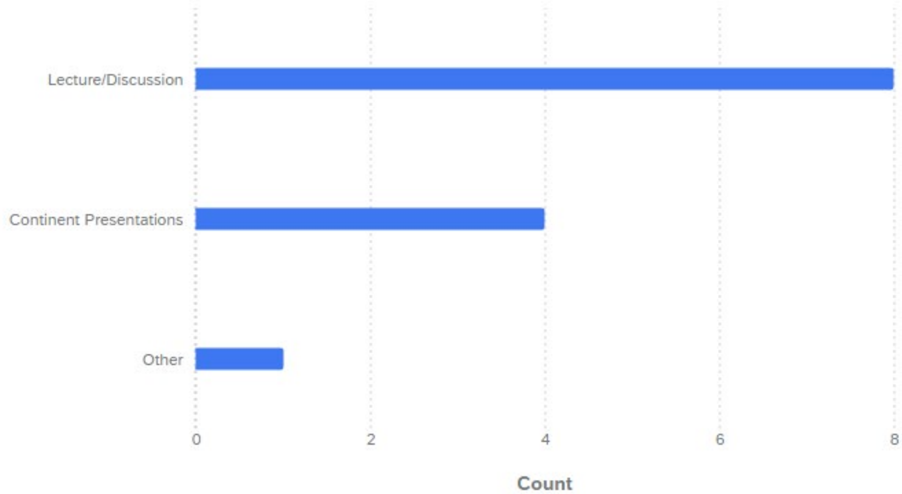


Figure 2. Most Effective Aspects of the Course

The survey assessed which aspects of the course provided students with the most effective education on the topics covered. The majority of respondents indicated that the lectures and discussions were the most effective in helping them understand the material. The continent presentations also demonstrated effectiveness in this regard. Interestingly, one respondent who selected "Other" in the free response section expressed that they found the continent presentations to be the most beneficial for their learning. Notably, neither the feasibility study nor the guest speakers received any selections from the respondents.

Table 2. Scale of Confidence of Explaining each Renewable Energy Topic

	Average	Minimum	Maximum	Count
Solar	4.31	3.00	5.00	13
Wind	4.54	3.00	5.00	13
Hydro	4.23	3.00	5.00	13
Geothermal	3.77	2.00	5.00	13
Biomass	3.15	2.00	5.00	13
Marine	2.92	1.00	5.00	13

The results of the survey question regarding respondents' confidence in explaining how each renewable energy source works show a correlation with both the amount of information provided and the timing of the survey. Solar, wind, and hydroelectric power are the most widely used forms of renewable energy [4]. The lower average scores for geothermal, biomass, and marine energy can be attributed to the limited materials available for each technology and the timing of the survey release. The survey was initially distributed during a week when biomass energy was featured, while marine energy had not yet been discussed.

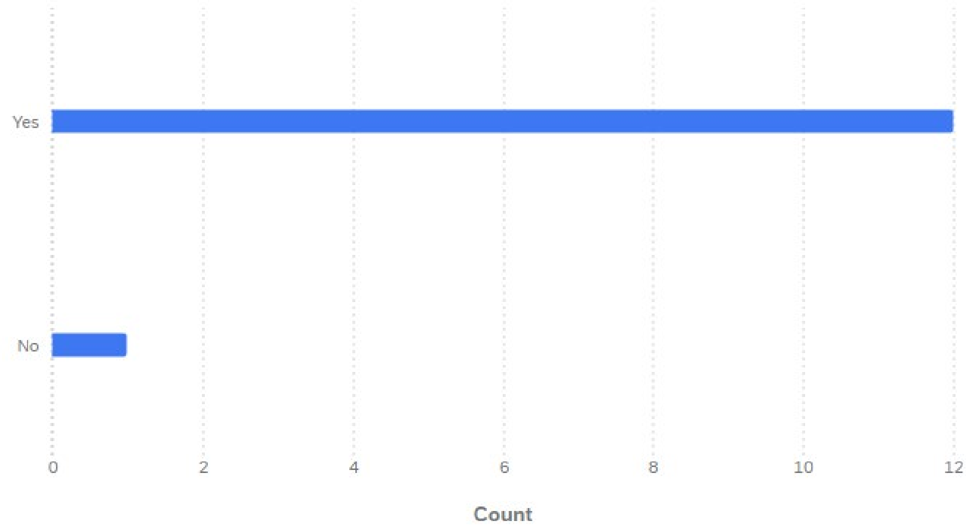


Figure 3. Comprehensive Material Coverage

The majority of survey respondents indicated that the course material thoroughly covered each subject and was sufficient for their learning. However, one respondent who answered "No" to this question mentioned in the comments section that they would have liked more information on current innovations and challenges. The primary goal of collecting this feedback for the content revamp is to enhance the overall understanding of each subject. This specific feedback can also be used to further improve the course material in the future.

Course Format

The course was taught using a hybrid format, combining both online and in-person instruction, which differs from standard teaching methods. This approach allows students who are sick or unwell to participate by attending online. For those who prefer to be present in person, that option is also available. This combination of online and in-person classes offers students a level of flexibility that is often lacking in other courses.

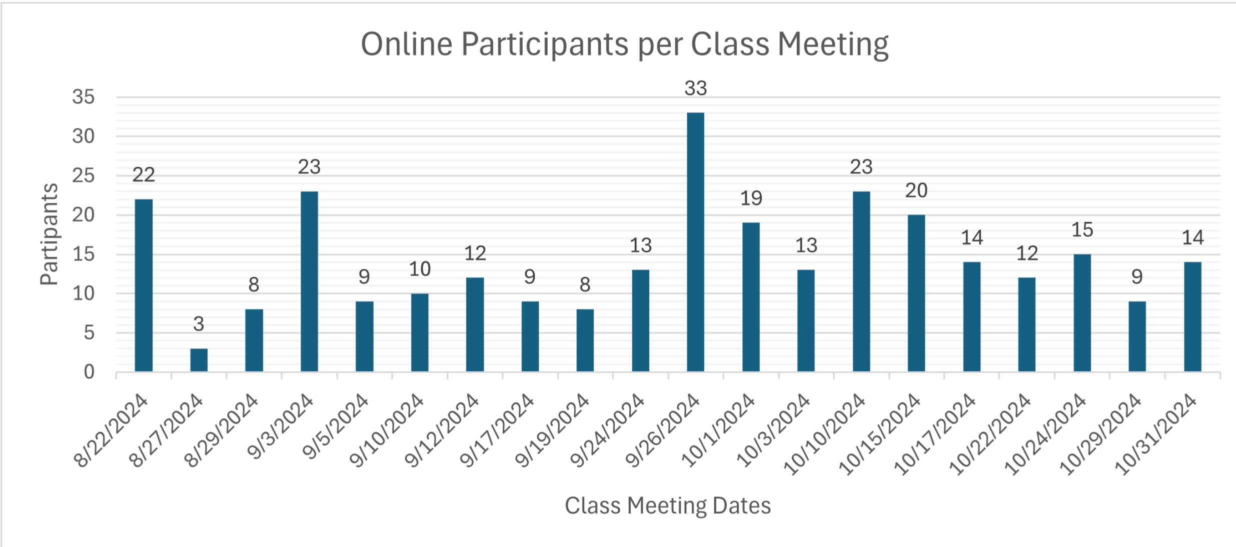


Figure 4. Online Participation per Class Meeting Throughout the Semester (until Oct)

This semester, the total number of students, instructors, and teaching assistants was 22. The days when attendance exceeded 22 participants coincided with the presence of guest speakers, with the exception of September 26th. On that date, the number of participants was significantly higher than expected due to technical errors in the online meeting software and students joining the class using multiple devices. Throughout this section of the semester, the average number of online participants accounted for more than half of the total attendance, resulting in an overall average of 13.47 participants (excluding the outlier of 33 participants). As the semester progressed, the class transitioned to a fully online format to streamline the logistics of the feasibility study presentations.

Table 3. Comfortability of Switching to Fully Online Course

Q10 - Were you comfortable switching over to a fully online class near the end of the semester?	Percentage	Count
Yes	100%	13

This question confirmed that the students in the course were comfortable transitioning to being fully online for the end of the semester, according to another question in the survey which asked for the students' opinions on having the flexibility to come to class in-person or online. As shown in Table 3 several students stated that they appreciated the flexible options and allowed them to still participate while taking care of their health. Other students stated that they preferred to be in person for the quality of the discussion, but they understood the benefit and convenience of the hybrid class format.

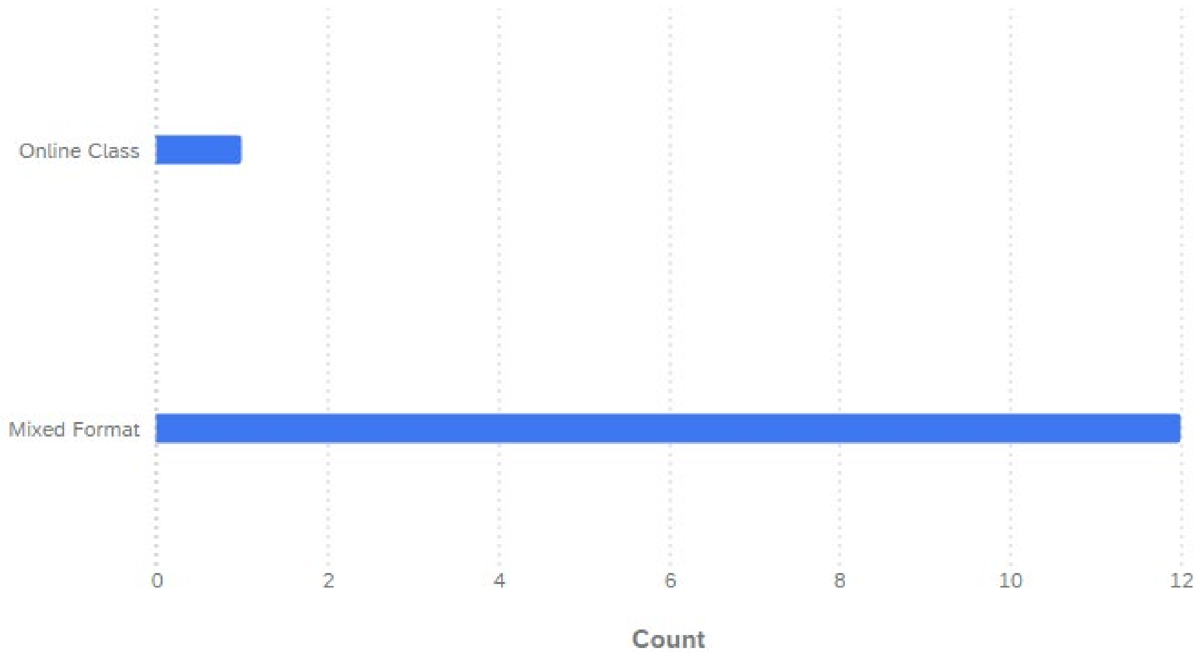


Figure 5. Preference of Class Format

Most of the students who responded to the survey stated that they preferred the mixed format of the class, and one student would have preferred to have done the entire course online as shown in Figure 5.

Conclusion and Future Work

The importance of creating a comprehensive set of multimedia resources to update a course focused on renewable energy cannot be overstated. Renewable energy is a constantly changing and adapting area of study that, when done correctly, can reduce the carbon footprint we have as a species. It takes scientists and engineers to have the education and experience to develop these technologies further to achieve greater efficiencies, reduce environmental impacts, and find better ways to produce clean energy. Using scaffolded learning in conjunction with student-centered learning helps to achieve this goal of educating students so that they can become the scientists and engineers needed to improve renewable energy generation.

As time progresses and technologies continue to change, it is important to adapt the course materials further to fit the growing field. The future work for projects such as this includes further updates to the course materials collected. Additionally, the assignments in the class can be changed and adapted to better support the lectures and discussions such that the students in the course can learn the materials and become the best engineers and scientists they can be. This work can be carried out in future semesters; this course is being taught, and receiving more feedback from the students will continue to create the best course possible.

References

[1] Anggraeni, N. (2021). Improving the quality of education through the application of students centered learning: a theoretical review. Eduvest - Journal of Universal Studies, 1(7), 603-607. https://doi.org/10.59188/eduvest.v1i7.99

[2] D, V. and M, K. (2015). Teaching and learning methodology in medical education: an analysis - in gsl medical college, rajahmundry, a. p .. Journal of Evolution of Medical and Dental Sciences, 4(72), 12557-12565. https://doi.org/10.14260/jemds/2015/1808

[3] Gaffney, T. (2022). Examining the impact of a student-centered learning and assessment strategy on engagement among nursing students. Journal of Quality in Health Care & Economics, 5(4), 1-4. https://doi.org/10.23880/jqhe-16000293

[4] Gupta, A. (2020, January 6). *The world's most used renewable power sources*. Power Technology. https://www.power-technology.com/features/featurethe-worlds-most-used-renewable-power-sources-4160168/?cf-view

[5] Güven, G. and Çakir, N. (2019). The relation between teachers' attitudes towards renewable energy sources and critical thinking dispositions. Journal of Baltic Science Education, 18(5), 717-731. https://doi.org/10.33225/jbse/19.18.717

[6] Hannafin, M.J., Land, S.M. Technology and student-centered learning in higher education: Issues and practices. *J. Comput. High. Educ.* **12**, 3–30 (2000). https://doi.org/10.1007/BF03032712

[7] Hodge, B.K. (2017) Alternative Energy Systems and Applications. 2nd Edition, John Wiley & Sons, New York.

[8] Kandpal, T. C., & Broman, L. (2014). Renewable energy education: A global status review. *Renewable and Sustainable Energy Reviews*, *34*, 300–324. https://doi.org/10.1016/j.rser.2014.02.039

[9] Kim, M. C., & Hannafin, M. J. (2010). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers & Education*, *56*(2), 403–417. https://doi.org/10.1016/j.compedu.2010.08.024

[1] Shehzad, S., Afzal, J., & Anwar, G. (2023). Significance of 'Renewable Energy Education' in Curriculum of Students. *Academy of Education and Social Sciences Review*, *3*(3), 361–373. https://doi.org/10.48112/aessr.v3i3.603

[11] Taber, K. S. (2018). Scaffolding learning: principles for effective teaching and the design of classroom resources. In M. Abend (Ed.), Effective Teaching and Learning: Perspectives, strategies and implementation (pp. 1-43). New York: Nova Science Publishers.

Appendix

An example of the content and materials gathered and created for the course follows below slightly reformatted to best fit the formatting of the paper. The contents presented here are reduced from what was given to the students to best highlight the varies aspects discussed above.

Basic Details and Physical Phenomenon from Solar Discussion

Sunlight is a form of electromagnetic radiation, including ultraviolet (UV), visible, and infrared (IR) light. This electromagnetic radiation is made up of elementary particles called photons. Photons exhibit wave-particle duality, as defined by Albert Einstein. The wavelength of different light is dependent on the energy of the photons.

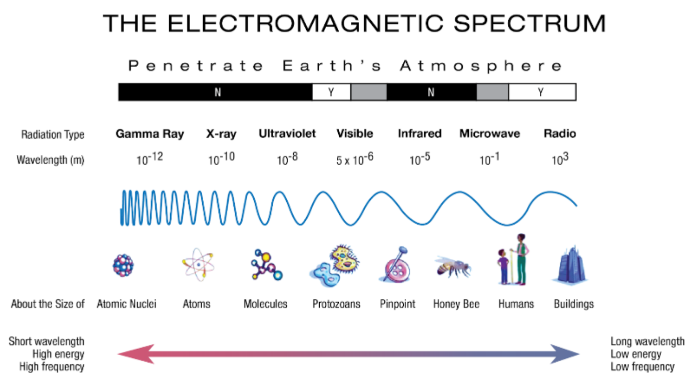
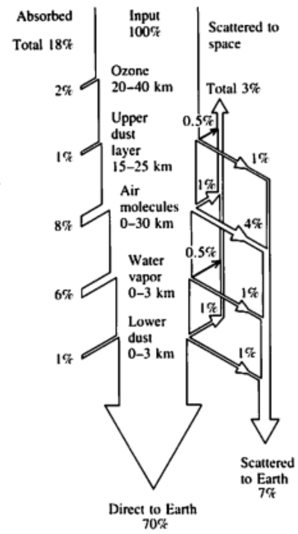


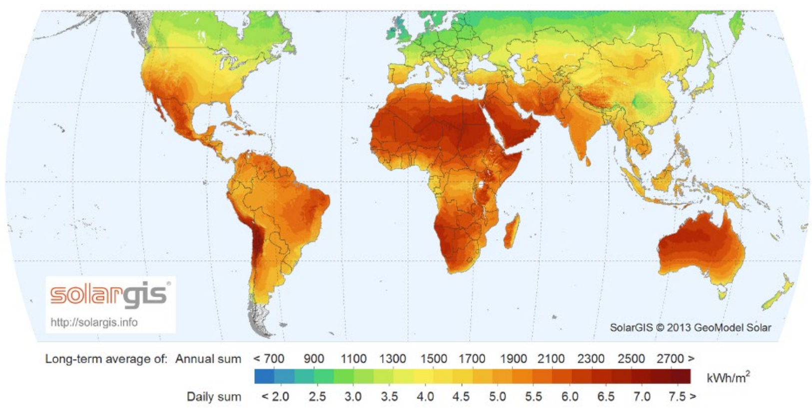
Image Credit: NASA

Another property of photons is that they can be absorbed by matter, this property is what allows solar power systems to capture and use sunlight to generate heat and electricity. Photovoltaic (PV) solar panels absorb visible light to generate electricity via the photovoltaic effect. The photovoltaic effect is the generation of voltage and current inside materials upon being stuck by light. Solar thermal systems absorb sunlight to be used as heat, this heat can be used to generate electricity via traditional methods or be used itself.

Sunlight or solar radiation incident on Earth is highly dependent on atmospheric conditions, weather, season, time of day, and geographic location. The radiation is absorbed into gasses and particles, reflected out of our atmosphere, and scattered away from surfaces.



Hu and White - Solar Cell From Basics to Advanced Systems 1983, p. 21



Solar insolation data is publicly available through Typical Meteorological Year (TMY) data.

This can be used to calculate estimates of solar panel power output. One source for this information: Photovoltaic Geographical Information System
A deeper dive into solar motion and atmospheric effects summarized: Sunlight and the Motion of the Sun

Explanation of Technologies from Solar Discussion

Each of these sections include lists of the various technology types used and their specifications, for brevity those lists have been excluded to focus on the flow of the class discussion.

Photovoltaic (PV) Systems: Photovoltaics and Electricity

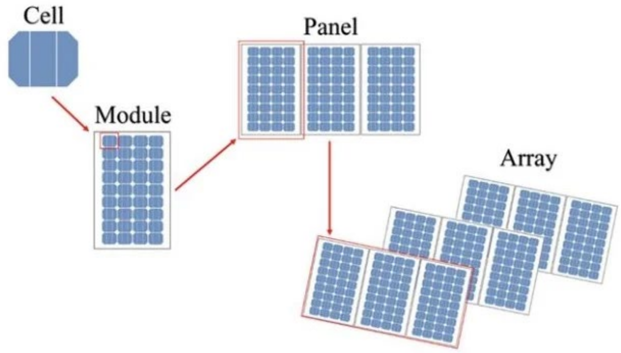


Image credit: Photovoltaic/Thermal (PV/T) Systems - Springer

Photovoltaic solar cells are built using two types of semiconductors (p-type and n-type) joined together to form a p-n junction (p-n junction - Wikipedia). P-type and n-type semiconductors are created by doping, the process of adding "impurities" to create positive and negative types. When photons hit the solar cell, they are absorbed by the semiconductor, and the electrons are "knocked loose" from their atoms. The electrons move from the valence band to the conduction band (band gap) creating electron-hole pairs. The electric field generated inside the semiconductor causes one side to have an excess of electrons and the other to have an excess of holes. When connected to a load or circuit the electrons will flow (creating a current). If a circuit is not connected the electrons will eventually return to equilibrium.

Concentrated Solar Power (CSP): Solar Thermal Power Plants

Concentrated solar power systems follow a similar approach to traditional power systems such as coal and natural gas. Each method uses heat to generate steam to spin a turbine to produce electricity. Concentrated solar power differs from traditional methods as it does not use fuels for heat but mirrors and lenses to focus sunlight. CSP systems have concentration ratios associated with them, these indicate the amount of solar flux on the receiver compared to the ambient flux from the Sun.

<u>Advanced Materials</u>

At the end of each discussion, a series of applicable chapters from Alternative Energy Systems and Applications, 2nd Edition [7]. These chapters were supplied to the students for their understanding and to be used as supplemental information to support their learning in another format. Students could also use the information from these chapters to aid the homework assignments and their continent presentations.

<u>Multimedia Resources from Solar Discussion</u>

Various forms of media were gathered for the students to aid in their understanding of the materials as everyone learns differently. Some examples of those resources are included below.

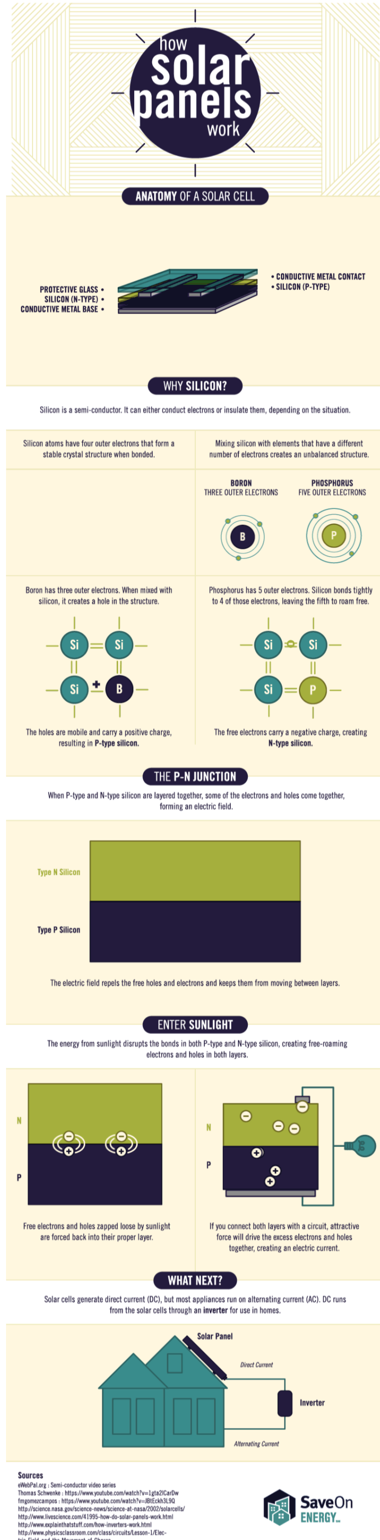
Videos:

The Engineering Mindset: Generate Electricity – How Solar Panels Work! (2023)
https://youtu.be/Yxt72aDjFgY

U.S. Department of Energy: Energy 101: Concentrating Solar Power (2010)
https://youtu.be/rO5rUqeCFY4?si=lxIq2j9uIdIHD9eu

Unbox Engineering: World's Largest Concentrated Solar Thermal Plant in California's Desert (2021)
https://youtu.be/A7wUrakeQfY?si=Q2YmkT14GRuwVEN0

Graphical Interchange Format (GIFs)

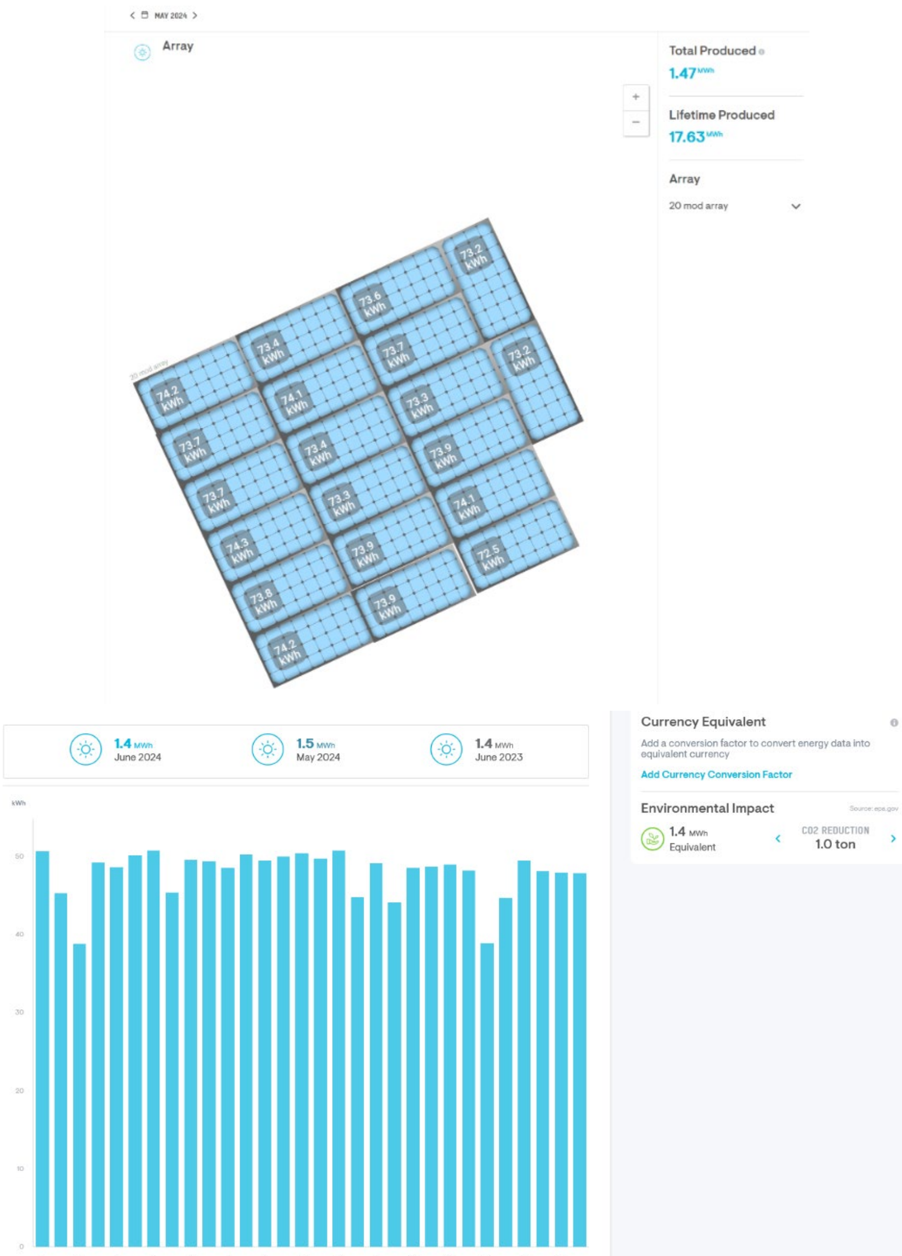


Source: SaveOn Energy

Real-Life Examples

Off-grid solar panel in Ontario, Canada

Solar panels with a passive solar tracker in Texas, U.S.

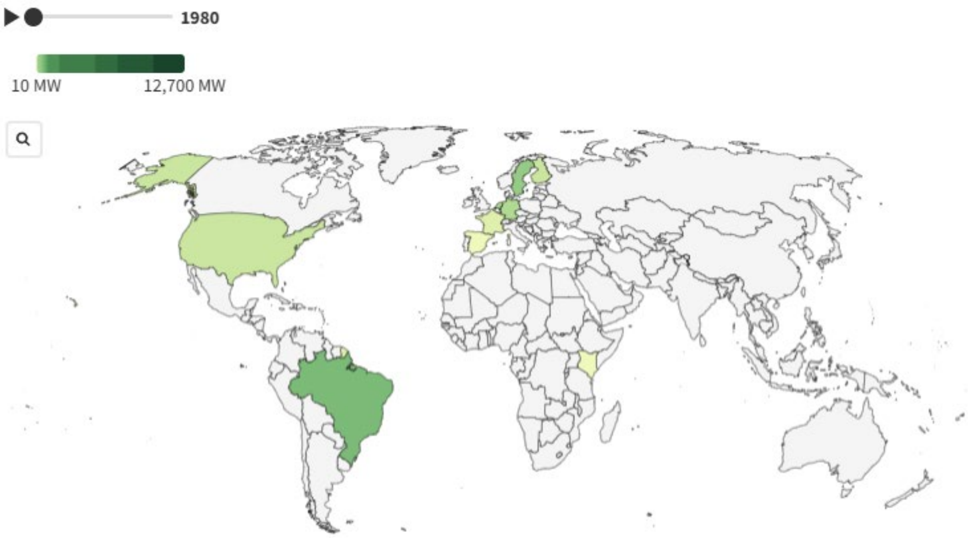


Power output from home array in California, U.S.

Embedded Interactives (from Biomass Discussion)

Generating capacity of bioenergy power plants, 1980-2022

Only those units with a reported start date are included. This power plant survey was published in January 2023



Source: Global Bioenergy Power Tracker, Global Energy Monitor, January 2023 release
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