2018

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AP Research Academic Paper

Sample Student Responses and Scoring Commentary

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2018 AP Research Academic Paper Rubric **v1.0**

The response…

Score of 1 **Report on Existing Knowledge**	**Score of 2** **Report on Existing Knowledge with Simplistic Use of a Research Method**	**Score of 3** **Ineffectual Argument for a New Understanding**	**Score of 4** **Well-Supported, Articulate Argument Conveying a New Understanding**	**Score of 5** **Rich Analysis of a New Understanding Addressing a Gap in the Research Base**
• Presents an overly broad topic of inquiry.	• Presents a topic of inquiry with narrowing scope or focus, that is NOT carried through either in the method or in the overall line of reasoning.	• Carries the focus or scope of a topic of inquiry through the method AND overall line of reasoning, even though the focus or scope might still be narrowing.	• Focuses a topic of inquiry with clear and narrow parameters, which are addressed through the method and the conclusion.	• Focuses a topic of inquiry with clear and narrow parameters, which are addressed through the method and the conclusion.
• Situates a topic of inquiry within a single perspective derived from scholarly works **OR** through a variety of perspectives derived from mostly non-scholarly works.	• Situates a topic of inquiry within a single perspective derived from scholarly works **OR** through a variety of perspectives derived from mostly non-scholarly works.	• Situates a topic of inquiry within relevant scholarly works of varying perspectives, although connections to some works may be unclear.	• Explicitly connects a topic of inquiry to relevant scholarly works of varying perspectives **AND** logically explains how the topic of inquiry addresses a gap.	• Explicitly connects a topic of inquiry to relevant scholarly works of varying perspectives **AND** logically explains how the topic of inquiry addresses a gap.
• Describes a search and report process.	• Describes a nonreplicable research method **OR** provides an oversimplified description of a method, with questionable alignment to the purpose of the inquiry.	• Describes a reasonably replicable research method, with questionable alignment to the purpose of the inquiry.	• Logically defends the alignment of a detailed, replicable research method to the purpose of the inquiry.	• Logically defends the alignment of a detailed, replicable research method to the purpose of the inquiry.
• Summarizes or reports existing knowledge in the field of understanding pertaining to the topic of inquiry.	• Summarizes or reports existing knowledge in the field of understanding pertaining to the topic of inquiry.	• Conveys a new understanding or conclusion, with an underdeveloped line of reasoning **OR** insufficient evidence.	• Supports a new understanding or conclusion through a logically organized line of reasoning **AND** sufficient evidence. The limitations and/or implications, if present, of the new understanding or conclusion are oversimplified.	• Justifies a new understanding or conclusion through a logical progression of inquiry choices, sufficient evidence, explanation of the limitations of the conclusion, and an explanation of the implications to the community of practice.
• Generally communicates the student's ideas, although errors in grammar, discipline-specific style, and organization distract or confuse the reader.	• Generally communicates the student's ideas, although errors in grammar, discipline-specific style, and organization distract or confuse the reader.	• Competently communicates the student's ideas, although there may be some errors in grammar, discipline-specific style, and organization.	• Competently communicates the student's ideas, although there may be some errors in grammar, discipline-specific style, and organization.	• Enhances the communication of the student's ideas through organization, use of design elements, conventions of grammar, style, mechanics, and word precision, with few to no errors.
• Cites **AND/OR** attributes sources (in bibliography/works cited and/or in-text), with multiple errors and/or an inconsistent use of a discipline-specific style.	• Cites **AND/OR** attributes sources (in bibliography/works cited and/or in-text), with multiple errors and/or an inconsistent use of a discipline-specific style.	• Cites **AND** attributes sources, using a discipline-specific style (in both bibliography/works cited AND in-text), with few errors or inconsistencies.	• Cites **AND** attributes sources, with a consistent use of an appropriate discipline-specific style (in both bibliography/works cited AND in-text), with few to no errors.	• Cites **AND** attributes sources, with a consistent use of an appropriate discipline-specific style (in both bibliography/works cited AND in-text), with few to no errors.

AP® RESEARCH
2018 SCORING COMMENTARY

Academic Paper

Overview

This performance task was intended to assess students' ability to conduct scholarly and responsible research and articulate an evidence-based argument that clearly communicates the conclusion, solution, or answer to their stated research question. More specifically, this performance task was intended to assess students' ability to:

- Generate a focused research question that is situated within or connected to a larger scholarly context or community;
- Explore relationships between and among multiple works representing multiple perspectives within the scholarly literature related to the topic of inquiry;
- Articulate what approach, method, or process they have chosen to use to address their research question, why they have chosen that approach to answering their question, and how they employed it;
- Develop and present their own argument, conclusion, or new understanding while acknowledging its limitations and discussing implications;
- Support their conclusion through the compilation, use, and synthesis of relevant and significant evidence generated by their research;
- Use organizational and design elements to effectively convey the paper's message;
- Consistently and accurately cite, attribute, and integrate the knowledge and work of others, while distinguishing between the student's voice and that of others;
- Generate a paper in which word choice and syntax enhance communication by adhering to established conventions of grammar, usage, and mechanics.

The Second Sun: Determining and Simulating the most effective Solar Energy System for the United Arab Emirates' Next Solar Plant

AP Capstone Research 2018

Word Count: 4254

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INTRODUCTION

Fossil fuels such as oil and coal have been dominating the energy generating landscape since the industrial revolution. These non-renewable energy sources not only come in finite quantities, but also damage the natural environment through the release of chemicals that disrupt natural environmental processes. Carbon dioxide and other greenhouse gases have caused environmental damage and pollution, which has prompted the global society to move towards more sustainable energy sources, with solar energy being amongst the most popular.

The research done in this study aims to help design the next most effective solar energy plant that can be the solution to many of the problems that non-renewable energy creates in the United Arab Emirates (UAE). Due to its almost year-round susceptibility to the sun's rays, the UAE is the ideal environment for solar energy plants.

LITERATURE REVIEW

Research Question

Shams 2: Through Which Solar Power System Could the UAE Create the Most Effective Solar Farm?

United Arab Emirates's Energy Summary

The United Arab Emirates (UAE) is a nation that discovered natural resources of oil and gas over half a century ago. This development allowed for rapid industrial growth that resulted in the UAE becoming a leading nation in the hydrocarbon energy industry. (1) As the fifth largest producer of oil in the Organization of the Petroleum Exporting Countries (OPEC), the UAE has been relying solely on fossil fuel based energy production since the beginning of its energy endeavors. According to their released 2016 reports, the UAE government has seen a dramatic rise in the energy production. From 77.9 TeraWatt hours (TWh) consumed in 2008 to 105.4 TWh in 2013, (2) the UAE has shown an increase in energy consumption of 35.3%.

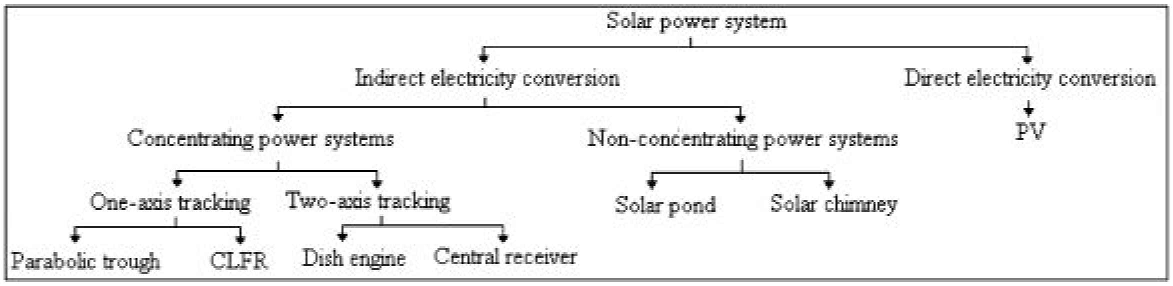
In the same report, Mr. Bilal Hassan, a lead engineer for the UAE Ministry of Energy, described how the United Arab Emirates is looking to replace much of that energy generation from fossil based fuels to renewable energy. He stated that "in order to meet energy demand while balancing environmental considerations, renewable energy must play an important role, solar energy being one of the most promising sources", (3) showing that the UAE is focused on creating a more sustainable future primarily through solar energy. It is evident that with their Shams 1 solar plant that they are on their way to a cleaner future through renewable energy. As stated in the introduction, the immediate goal for the UAE is to have 30% of its electricity be generated from local solar energy initiatives, and a plan for a second solar energy system has already been developed, for which 14.2 billion dirhams ($3.866 billion as of March 2018). (3)

The Shams 1 Initiative

The Shams 1 initiative is a Concentrated Solar Plant (CSP) located in the capital city of Abu Dhabi at the coordinates of 23º34' and on the longitude of 53º42'. (4) It spans 2.5 km^2, and was inaugurated in 2013. It has the installed capacity of 100 MegaWatts (MW) which, according to Masdar (the parent company of Shams) powers 20,000 homes in Abu Dhabi (the UAE's capital city). (4) The full project cost $600 million (the largest financing for a Concentrated Solar Plant yet), (4) and from *Abu Dhabi Distribution Co.* (the electricity authority of Abu Dhabi), the charge per home for 1 kiloWatt hour (kWh) of energy costs 26.8 fils (assuming one is an expatriate consuming energy under the recommended daily usage) per kWh. This means that 20,000 will provide the UAE with 5,360 dhs in one hour, and 128,640 dhs per day. From this, it can be calculated that the amount of time it would take to earn back all of the cost for the plant, which is roughly 4,666 days, or 12 years and 9 months. This, however, is just a baseline calculation considering there are other variables (such as the UAE's local *Emiratis* only having to pay 6.7 fils for energy, and there being an overuse charge charge which is 7.5 *fils* for *Emiratis* and 30.5 *fils* for expatriates), but it is a good estimation considering there are only 551,535 nationals, compared to the 2,356,638 non-nationals, and the lack of exact data to determine how much energy each of those 20,000 house holds utilize. (5)

Understanding Solar Power Systems

Solar power systems (SPSs) are the amalgamation of hardware and processes that convert energy released by the sun in the form of heat and light to electrical energy that can be directed into the grid. The authors of the scholarly journal *Toward clean environment: evaluation of solar electric power* *technologies using fuzzy logic* separate the types of solar power systems using a flow chart that categorizes every single type of solar power system (Figure 1).



*CLFR = Compact Linear Fresnel Reflector

Figure 1: Flow Chart showing the breakdown of the different solar power systems (6)

SPSs are separated into two types of conversion. Direct electricity conversion is the system that allows for heat to be absorbed by a panel and then converted to energy. (6, 7) Conversely, Indirect electricity conversion is the system that contains a reflective surface - a heliostat - which directs energy to an absorbing surface (which varies based on the system). (8)

The sub-branches of indirect electricity systems highlight the method of which electricity is transferred from one surface to another. Concentrating power systems utilize heliostats that reflect power in a manner that focuses energy into a central area. For example, parabolic troughs utilize the properties of a parabola in that the heliostat is curved around a central point (the focus) so that all light that falls onto it is reflected into a pipe located at the focus (Figure 2). The single axis tracking system focuses only on the sun, so the only movement necessary is for the sun to stay in exactly the same position as the Earth rotates about it. In contrast, dual tracking systems require the system to track the sun and where the sun's rays are being reflected too. For example, the solar tower systems (figure 3) requires the sun to reflect heat from the sun to a heliostat and then to a central location that absorbs the heat. This requires the heliostat to be angled in relation to both the sun and the central absorbing system which requires adjustment of the whole system. (6)

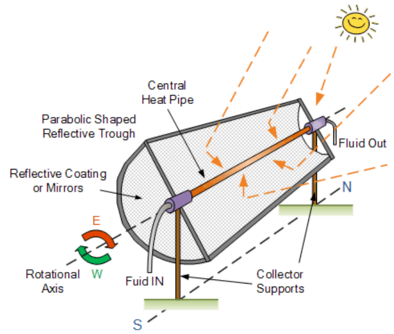


Figure 2: Diagram depicting the shape of a Parabolic Trough heliostat and absorbing pipe reflecting and absorbing sunlight (9)

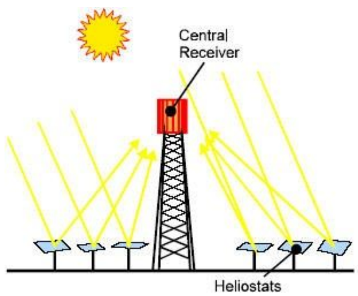


Figure 3: Solar power tower reflecting light from the sun to a central receiver using a dual tracking system (10)

Non-concentrating systems, on the other hand, do not focus the energy but absorb it by means of a fluid with a large surface area and transfer the heat to a collector or generator. (10, 11) Solar chimneys, for example, utilize a vast surface area to trap hot air inside of a chimney shaped dome (figure 4) which then pushes a vertical turbine at the base of the chimney to convert solar energy to kinetic energy. (6) The large area of air under the transparent dome acts as the carrier, making it an indirect, non-concentrating system.

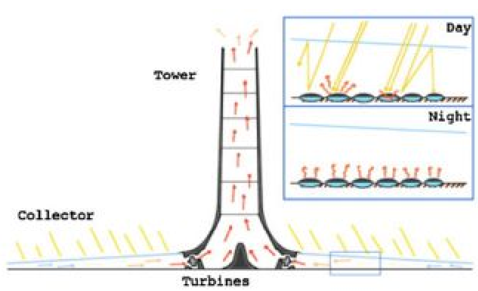


Figure 4: Solar chimney absorbing light (yellow arrows) through transparent glass and turning turbines. The air is then filtered out through the chimney to make way for cooler air that is ready to absorb heat. (6)

By using this system of organization for each of the different SPS, The researcher can determine what would be the best system for the UAE to use for its next solar farm. By sorting these systems into the various categories, the researcher will be able to better analyse the system they determine to be the ideal one for the United Arab Emirates.

RESEARCH METHODOLOGY

The purpose of this study was to determine the best system for the United Arab Emirates through a detailed analysis of the ideal Solar Power System and through an evaluation of the main components of the aforementioned system. The researcher utilized a grounded theory research methodology to evaluate a multitude of sources to simulate an ideal SPS (Appendix) in the United arab Emirates.

The first stage of research was based on discovering the ideal SPS from a scholarly journal that evaluated all of the different types of SPSs through the use of 'fuzzy logic'. (6) Fuzzy logic is a concept that allows for a quantitative observation of both qualitative and quantitative raw data. The data is processed into a decimal system that ranges from 0 to 1 and the ranges can go from one decimal place (least accurate) to 3 decimal places (most accurate) in this journal. (6, 12) The journal splits the evaluation into costs and benefits, so a higher score for benefits is ideal (a score of 1 for power means the system is very efficient) and a lower score for costs is ideal (a score of 0.10 out of 0.5 for water usage is also considered efficient). Furthermore, fuzzy logic uses parameter importance to determine how important each component is based on the overall relevance to the system. For example, temperature may not be as important as the amount of power generated. The researcher will be re-evaluating the parameter importance to allow for specification to the United Arab Emirates. It evaluates 14 benefits and 8 costs, including and defined as:

Table 1: Benefits

Term	Definition	Original Parameter Importance	Revised Parameter Importance
Power	Plant's Installed capacity or size (MW)	1	No Change (NC)
Annual Efficiency	Annual solar to electrical energy conversion efficiency	0.71	0.8
Thermal Efficiency	Efficiency of heat absorbance and transfer	0.71	NC
Peak Efficiency	Maximum solar to electrical energy conversion efficiency	0.5	NC
Availability	Availability of resources	1.0	NC
Annual CF	Annual Capacity Factor	0.5	NC
Storage h	Number of hours heat is storable after absorbance	0.5	NC
Maturity	Popularity or development of system	1.0	0.8
T	Temperature	0.71	NC
Safety	General Safety of farm	0.43	NC
Concentration Ratio (CR)	Area of reflector panel in relation to area of receiver	0.71	NC
Relative Weight	The average score of the system on a scale of 0 - 1	N/A*	N/A
Normalized Relative Weight	The weight of the system in relation to all other systems divided by the largest weight possible (to create a scale from 0 to 1)	N/A	N/A

Table 1: Costs

Term	Definition	Original Parameter Importance	Revised Parameter Importance
Hardware Cost	Cost of all the physical items used to create the solar farm	0.5	0.8
Electricity Cost	Cost of all the energy used to power the system (rotating panels, computer systems ect.)	0.5	NC
Water Usage	Cost of all the water being transferred through piping (assuming all heat transfer fluids are water (to create consistency)	0.5	NC
Land Usage	Cost of renting the land	0.4	0.1
Maintenance Cost	Cost of replacing old/malfunctioning parts	0.5	NC
Environment	Damage done to the environment	0.25	0.1
Relative Weight	The average score of the system on a scale of 0 - 1	N/A	N/A
Normalized Relative Weight	The weight of the system in relation to all other systems divided by the largest weight possible (to create a scale from 0 to 1)	N/A	N/A

All data collected from Source 6
* These values were considered not applicable because of their objective nature in that they are just comparisons of mass of the structure which has nothing to do with the quality of the farm, but they are good comparison standards

Fuzzy Standard Adjustments:

The following are reasons for why the researcher had altered the specific data values from the original fuzzy logic data set:

1. **Annual Efficiency:** Part of the conclusions of this study was to estimate the payback time of the solar farm so that the researcher could analyse whether or not the solar farm would be efficient in the long run for the UAE government. As annual efficiency is an essential part of that calculation, the researcher felt that it needed an increased value of importance.
2. **Maturity:** The researcher felt that the maturity of the system did not need to be valued as high as other standards of system evaluation due to the fact that the data collected on installed capacity and efficiency would matter more than how far the technology has developed since it had first been designed. In some cases, some technologies may have developed faster or later than others,

but objectively they could still be more powerful (as will be analyzed through our data of the fuzzy sources.

3. **Hardware Cost:** The United Arab Emirates may be a leading solar energy developer, but its resources are mostly imported from other regions. This led the researcher to consider that the cost of components may need to be increased to account for the increase of component pricing due to shipping and transport costs.
4. **Land Usage:** Considering that the UAE is a monarchical society, all land is owned by the presiding Sheikh of Abu Dhabi at the time, and considering the project will be government funded, the land would either be gifted or rented at a much cheaper price. Thus, it was necessary to greatly depreciate the parameter importance of the cost of land since this would not be a private venture. (13)

Once the researcher had completed his reevaluation of the fuzzy parameter importances, he began to compare all of the data to determine the overall costs in relation to the overall benefits of each system. He first multiplied each value for each parameter by the parameter importance to gain an accurate value for each data point. For example, if the value for some standard was 0.71, but its parameter importance was 0.5, then its Real Data Value (RDV) , the value of the specific score in relation to every single score of every standard, would be 0.355. This is essential because the next step was to sum all of the data points for cost and all of the data for benefits (independent from each other) to find the total benefits and cost for each SPS. This would then allow the researcher to quantitatively identify the system with the highest benefits and the lowest cost. This, however, could mean that one system has the highest benefits, but does not have the lowest cost, so the benefit will then divide the benefits by the cost to see which system has the most ideal ratio of benefits to cost and will then select the top choice of SPS.

After completing the evaluation of these systems through fuzzy logic, the researcher began the second phase of data collection which was to utilize scholarly journals and information on existing and similar solar energy systems (between the top two systems). These documents allow the researcher to find more variables in order to compare the top systems with and give a more in depth understanding of the systems and their differences. Furthermore, the real life comparison of the separate systems will allow the researcher to determine more of the architectural and economic variables of the plant that may affect the quality of the system including the cost and the size of the whole system.

DATA COLLECTION

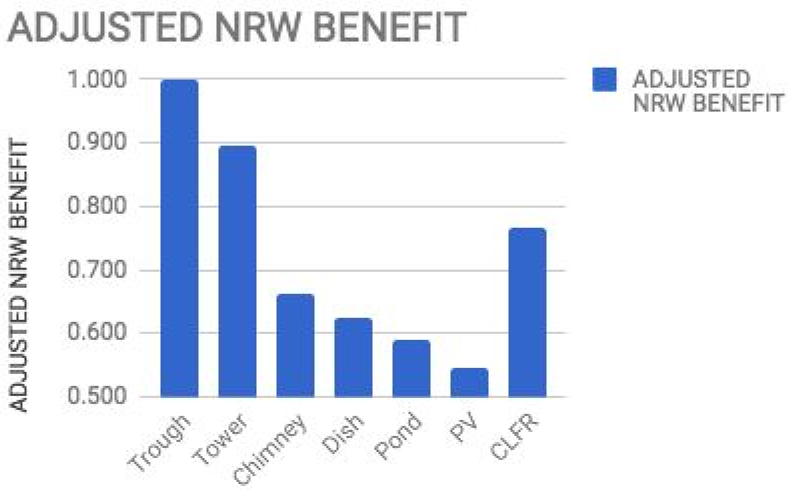


Figure 4

Figure 4 is the graphical representation of all of the average values of the Normalized Relative Weight once the researcher had modified the parameter importances and recalculated all values to factor in the new parameter importances. Once those were calculated, the values for each system were averaged to obtain the Relative Weight (RW) for benefit and then divided by the highest Relative Weight of all the systems to generate the Normalized RW (NRW) of them on a scale of 0.000 - 1.000 (See Appendix A). The same was done for the cost analysis (See Appendix B) (Figure 5).

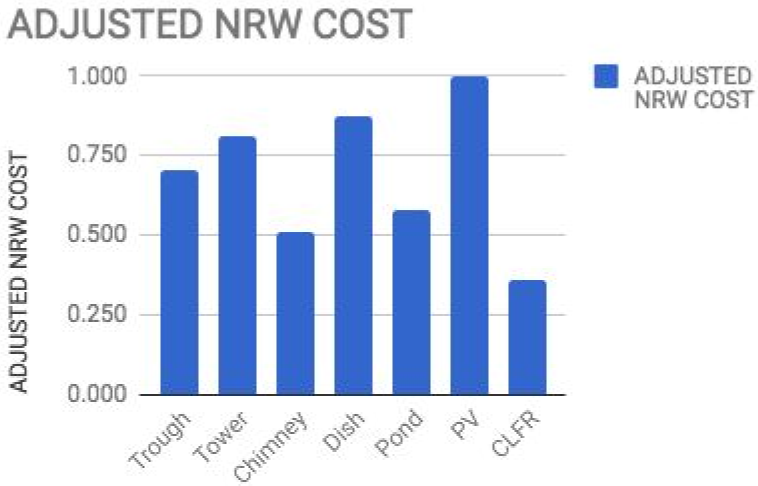


Figure 5

Finally, all the costs and benefits were compared by dividing the benefit by the cost to find the ratio (figure 6) (See Appendix C). If any of these B/C values were below 1, that meant that the costs outweigh the benefits so they were immediately disregarded.

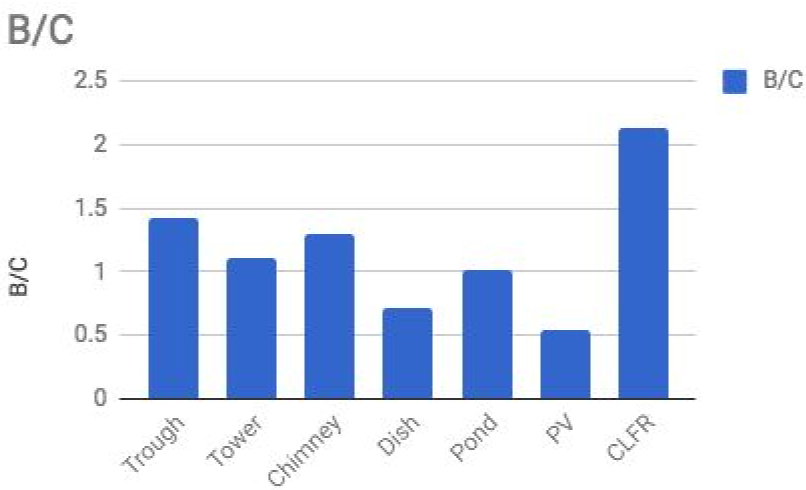


Figure 6

RESULTS

Comparing Systems

The Compact Linear Fresnel Reflector (CLFR) solar system is a single axis, concentrating system that converts energy indirectly. This means it contains both reflector and absorbing units, but only needs to track one object (the sun) and position its reflectors in relation to the object. The parabolic trough is also a single axis, indirect conversion, concentrating solar system and therefore operates in much the same way. The differences between them lay in their design, as the parabolic trough utilizez curved reflectors that reflect light into a single focusing tube. This absorbing tube lays above the reflectors and contains the heat transfer fluid (HTF) that act as the transportation system for the solar energy which is converted through a generator.

The CLFR solar system is similar in that it concentrates heat energy from curved (or straight) reflectors onto absorbing pipes, but these pipes are positioned much higher up and usually allow for multiple rows of heliostats to reflect into a singular (or usually 2) transfer pipes. Figure 7 and 8 show a Parabolic Trough (PT) system and a CLFR system respectively.

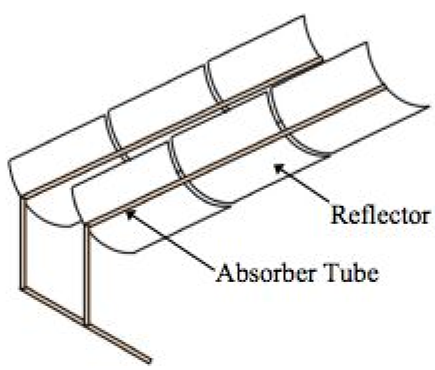


Figure 7: Source 14

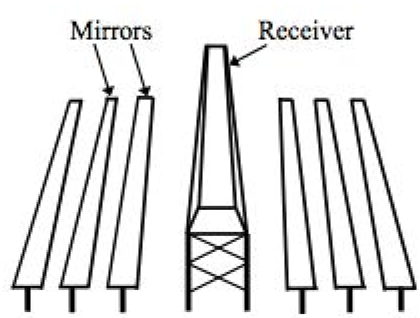


Figure 8: Source 14

According to the scholarly journal authored by Nishith B. Desai - an Energy Systems Engineer from the Indian Institute of Technology, Bombay, and colleagues - and Professor Bandyopadhyay - of the same institute - which evaluated both systems, it was noted that the major difference and disadvantage that the Linear Fresnel reflectors have is their limited optical efficiency (the amount of energy that can be reflected to the absorbing panels) and steam efficiency. (14) One advantage that PT systems have (as a product of 20 years of further development over the Fresnel Reflector systems) is that they can utilize multiple heat transfer methods (known as cycles) to achieve heat transfer, whereas CLFR systems are limited to only steam based cycles, which severely limits their installed capacity because of the actual boiling point of water being lower than those of molten salt or oil. (14) Furthermore, Desai highlights that in their most latest forms, PT technology is at least two - four percent more efficient than CLFR, and even though both have a relatively low capital cost, the risk for implementing the latter is much lower when considering the rapid improvement of technology being made with Fresnel Reflectors in comparison to PT collectors. (14)

Operational System Analysis

Currently, the CLFR plant with the largest capacity is the Rajasthan Sun Technique Energy Pvt. Ltd Power Plant in Rajasthan, India. It has an alleged installed capacity of 125 MegaWatts (MW), according to the Reliance Power Co. (the owners of the plant), and covers an area of 340 hectares (ha). It has an expected power generation of 280,000 MegaWatt hours per year (MWh/yr), and cost approximately $351 million as of 2014 (converted from Rupees). (15)

In comparison, the Solnova power plant is a parabolic trough based system that is comprised of 3 separate units (Solnova 1, 3, and 4). Independently, each of the 3 units cover 115 ha, they generates an estimated 113,520 MWh/yr, have an installed capacity of 150 MW, and all together cost approximately $527,743,000 as of 2007 (the first year of operation). (16, 17, 18, 19)

From the data above, it can be seen that the CFLR plant generates less energy at almost the same area (340 ha < three 115 or 345 ha). The PT plants generate a combined 341,000 MWh/yr of energy which is almost 80,000 MHh/yr greater than the CFLR, and even though the PT system was built 7 years earlier than the system in Rajasthan it still generates more energy, but at a higher accounting cost (by almost $175 million.

DISCUSSION

Choosing the System

From all of the data presented, the researcher has evaluated that the best Solar Power System for the United Arab Emirates to implement is the Parabolic Trough solar system.

From the fuzzy logic data set, the researcher performed an in-depth analysis of all of the different aspects of each solar system, and came to the conclusion that the top two systems of that evaluation were the Concentrated Linear Fresnel Reflecting system and the Parabolic Trough system. These two were both connected by exactly the same branches on the flowchart diagram (figure 1) which meant that they were both single-axis tracking, concentrating, indirectly converting solar energy systems. This also meant that the designs that fit these categories are the most effective in solar energy generation.

In the first section of our results section the researcher compared the two systems and described them in more detail than the flow chart could provide. By evaluating the limitations of both systems the researcher learned that the CLFR system could only utilize steam based heat energy transfer and that due to the PT system's popularity and existence for a longer period of time, they have been developed further, making PT systems the best candidate for the UAE's new solar system.

Finally, to compare both the systems in a non-simulated situation - to give a third and final perspective on which system would be the most effective - the researcher evaluated two systems of similar size (in hectares) and installed capacity (in MW). The researcher further learned that the PT systems generated more electricity yearly, but were considerably more expensive. However, this cost may be due to the gap in development, as the PT system was seven years older than the CLFR system. The PT system was chosen by the researcher as the most effective because it was the highest scoring system for fuzzy logic benefits, its limitations were fewer than the CFLR system, and it was more well developed.

Meeting the UAE's Goals

Currently, the largest solar farm that utilizes PT technology is the Solar Energy Generating Systems (SEGS) in the Mojave Desert, California. It is a collection of 9 units that each have the installed capacity of 80 MW, and each has the ability to generate 2,725 kWh/m^2/yr or 1.265 tWh/yr per plant. (20)

From the UAE's released electricity consumption history, it can be said that as of 2013 the UAE consumes at least 105.4 tWh of energy. 30% of this figure would be 31.62 tWh, which would need 25 independent solar energy generating units to supplement. Considering that the 80 MW unit utilizes 483,960 m^2 of area, the UAE would theoretically need 12,099,000 m^2 to construct this farm, (20) which is equivalent to 0.014% of the total area of the United Arab Emirates (the total area being 83.6 billion m^2). (21) From a UN Food and Agriculture Organization, the total uninhabited area of the uae is equivalent to 5.9 billion m^2, (21) which is approximately 7.05% of the total area of of the UAE.

In terms of land usage this is feasible, but the cost of the system is a heavy determinant of the feasibility. The International Renewable Energy Agency (IRENA) released a cost analysis on the different types of solar systems as of 2010, which stated that a parabolic trough system with a "storage capacity of 7.5 hours estimated to cost […] USD 7 280/kW". If our system had an installed capacity of 80 MW or 80,000 kW, the cost of one system would be $582.4 million, which would allow us to create 24 plants. This would also mean that the revenue collected by the operational units (depending on the cost of electricity) could be fed back into the production of the last unit, making the creation of 25 units feasible.

From the current owners of the SEGS, Nextera Energy, the researcher found that the production for each unit began a year after the previous and was completed after four years of construction. Allowing for two years of planning from now, if the plants commissioned building, it would have ten years to finish all of the units, or 6 to begin the construction of all of them. If five units were constructed for the first three, four for the next two, and two in the last year, the UAE would be able to meet their goal of 30% renewable energy in 2030.

Limitations

The two biggest limitations to this paper as a whole was the accumulation of too many variables that could not be assessed in any of the 3 standards of comparison, and the limited access to information and knowledge that would make the paper more accurate. It is first evident through the parameters of importance in the fuzzy logic phaze of data collection that there was a limited access to data. The researcher was unable to fully modify all the specific parameters that were set in the original data set to fit the UAE's specifications because justification for each parameter was not provided so the researcher chose to carefully change only a few and instead manipulate given data to re-evaluate the Solar Power Systems.

Considering the fuzzy logic standards, the real life systems, and the design of each system, the researcher was unable to accurately give consistent measures for each systems positive and negative attributes due to the sheer number of variables present in the study. The researcher had to eliminate several systems early on to create a 'funneling' process that brought seven systems down to two and then finally the best one. This made it easier for the researcher to determine a system for the UAE, but did not give the other systems a chance to be qualitatively examines, thus the researcher would suggest any further research to go in the direction of qualitative research and evaluation for all of the various SPS.

Finally, the project of a 25 unit Parabolic Trough Solar Power System could exist given the current conditions and calculated values for the land usage, plant cost, and build time. These values were either calculated or obtained from what limited public information the researcher had access to, but the calculations themselves are accurate. The researcher would suggest that if this research were to be taken further, it be in the direction of a more accurate analysis of each standard, with less weight on fuzzy standards (due to their consideration of too many variables) and more emphasis on the direct comparison of both the quantitative and qualitative data on each of the various solar powered systems.

CONCLUSION

The purpose of this research paper was to identify and simulate the implementation of a Solar Power System that could provide the UAE with the most energy while still taking into consideration other factors that may affect the quality of the system. By assessing SPS's benefiting factors such as the Annual CF and Maturity, while also weighing them against cost factors such as Environmental impacts and Electrical cost the researcher was able to compare seven different systems across 20 or so standards to calculate the more effective system (or systems) through a fuzzy logic data set. This helped us eliminate several of the candidates for UAE's ideal SPS, but to choose the most ideal one required more qualitative analysis. By evaluating the design aspects of the top two contenders and the real system comparison of the two helped the researcher select the final candidate for the system: the solar trough.

The researcher then discussed the potential of solar trough farms in the UAE by estimating the amount of trough units, the time of construction, and the cost of construction to estimate whether the goals of the UAE could be met with current technology. With the limitations of a lack of available information and an accumulation of variables, the researcher was able to provide a rough method for the implementation of 25 units that would cost more than $500 million each and take 10 years to be fully operational. With the UAE's ambitious goals of being a leader in renewable energy, leaps in energy technology and funding into solar plants of such scale and magnitude are necessary for realizing the efforts to push to more renewable energy focused initiatives that can both utilize natural resources and eliminate the global necessity for natural gases, oil, and coal. Thus, making the UAE a pioneer in energy collection and renewable energy generation.

References

1. UAE State of Energy Reports 2017. Abu Dhabi (UAE): United Arab Emirates Ministry of Energy; 2017. 49 p.
2. UAE State of Energy Reports 2017. Abu Dhabi (UAE): United Arab Emirates Ministry of Energy; 2016. 30 p.
3. Dubai launches world's largest Concentrated Solar Power project. Abu Dhabi (UAE): Gulf News. 2017 Sept 16; 1 (Par. 1-4).
4. Location. Shams Power Company. Abu Dhabi (UAE): [Internet] [accessed 2018 Feb 2]. http://www.shamspower.ae/en/the-project/location/.
5. Abu Dhabi Emirate: Facts and Figures. Abu Dhabi (UAE): Abu Dhabi Digital Government; [accessed 2018 Mar 29]. https://www.abudhabi.ae/portal/public/en/abu-dhabi-emirate/abu-dhabi-emirate-facts-and-figures.
6. Badran O, Mamlook R, Abdulhadi E. Toward clean environment: Evaluation of solar electric power technologies using fuzzy logic. Clean Technologies and Environmental Policy 2012 04;14(2):357-67.
7. Knier G. How do Photovoltaics Work?. Science@NASA: NASA; 2008 Aug 6 [accessed 2018 Mar 29]. https://science.nasa.gov/science-news/science-at-nasa/2002/solarcells.
8. Bordry F. Power converters: definitions, classification and converter topologies. Geneva (CH). CERN; 24 - 30 p.
9. Parabolic Trough Reflector. Alternative Energy Tutorials: Home of alternative and renewable energy tutorials; 2010 [accessed Feb 13 2018]. http://www.alternative-energy-tutorials.com/solar-hot-water/parabolic-trough-reflector.html.

10. Tan AYK, Wong NH. Influences of ambient air speed and internal heat load on the performance of solar chimney in the tropics. Solar Energy; 2014 04. 102 - 116 p.
11. Akbarzadeh A, Johnson P, Singh R. Examining potential benefits of combining a chimney with a salinity gradient solar pond for production of power in salt affected areas. Solar Energy 2009 08;83(8):1345 1 p.
12. Cintula P, Fermüller CG, Noguera C. Fuzzy Logic. Stanford Encyclopedia of Philosophy. 2017 Jul 18 [accessed 2018 Mar 29]. https://plato.stanford.edu/entries/logic-fuzzy/.
13. Al-Muhairi, Butti Sultan Butti Ali. "The Position of Shari'a within the UAE Constitution and the Federal Supreme Court's Application of the Constitutional Clause concerning Shari'a". Arab Law Quarterly; 1996 Jan 1. 11 (3): 219–244 p.
14. Desai NB, Bandyopadhyay S. Line-focusing concentrating solar collector-based power plants: A review. Clean Technologies and Environmental Policy 2017 01;19(1): 12-29 p.
15. Puerto Errado 2 Thermosolar Power Plant. Concentrating Solar Power Projects - Puerto Errado 2 Thermosolar Power Plant. Concentrating Solar Power. NREL; 2013 Apr 26 [accessed 2018 Mar 29]. https://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=159.
16. Solnova 1. Concentrating Solar Power Projects: Solnova 1. Concentrating Solar Power. NREL; 2017 Mar 20 [accessed 2018 Mar 29]. https://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=21.
17. Solnova 3. Concentrating Solar Power Projects - Solnova 3. Concentrating Solar Power. NREL; 2017 Mar 20 [accessed 2018 Mar 29]. https://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=22.
18. Solnova 4. Concentrating Solar Power Projects: Solnova 4.Concentrating Solar Power. NREL; 2017 Mar 20 [accessed 2018 Mar 29]. https://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=25.

19. Solnova Solar Power Station, Sanlúcar la Mayor, Seville. Power-Technology.com; 2018 [accessed 2018 Mar 29]. https://www.power-technology.com/projects/solnova-solar-power-station/.

20. Solar Electric Generating Station VIII. Concentrating Solar Power Projects: Solar Electric Generating Station VIII. Concentrating Solar Power. NREL; 2015 Oct 1 [accessed 2018 Mar 29]. https://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=35.

21. United Arab Emirates: Geography, Climate, and Population. AQUASTAT Survey: Food and Agriculture Organization of the United Nations; 2016 [accessed 2018 Mar 29]. 1 - 6 p.

Appendix

Appendix A:

Benefits - Original Data:

	Power	Annual Efficiency	Thermal Efficiency	Peak Efficiency	Avaliability	Annual CF	Storage h
Parameter Importance	1.00	0.71	0.71	0.5	1.00	0.50	0.50
Trough	1.00	0.67	0.70	0.72	1.00	0.69	0.50
Tower	0.25	0.74	0.91	0.69	0.50	1.00	0.67
Chimney	0.50	0.10	0.21	0.10	0.70	1.00	1.00
Dish	0.13	1.00	1.00	1.00	0.60	0.31	0.00
Pond	0.01	0.10	0.24	0.97	0.80	1.00	1.00
PV	0.05	0.70	-	0.97	1.00	0.19	0.42
CLFR	0.44	0.48	0.70	0.69	0.90	0.70	0.50

	Maturity	T	Safety	CR	Relative Weight	Normalized Relative Weight
Parameter Importance	1.00	0.71	0.43	0.71	-	-
Trough	1.00	0.33	0.50	0.40	0.684	1.000
Tower	0.80	0.67	0.40	0.70	0.651	0.952
Chimney	0.30	0.06	0.45	1.00	0.399	0.583
Dish	0.20	0.10	0.60	0.10	0.564	0.825
Pond	0.20	0.08	1.00	0.10	0.380	0.556
PV	0.60	-	0.3	-	0.522	0.763
CLFR	0.30	0.33	0.70	0.40	0.546	0.798

Benefits - Recalculated Data Values:

	Power	Annual Efficiency	Thermal Efficiency	Peak Efficiency	Avaliability	Annual CF	Storage h
Parameter Importance	1.00	0.80	0.71	0.5	1.00	0.50	0.50
Trough	1.00	0.54	0.50	0.36	1.00	0.35	0.25
Tower	0.25	0.59	0.65	0.35	0.50	0.50	0.34
Chimney	0.50	0.08	0.15	0.05	0.70	0.50	0.50
Dish	0.13	0.80	0.71	0.50	0.60	0.16	0.00
Pond	0.01	0.08	0.17	0.49	0.80	0.50	0.50
PV	0.05	0.56	-	0.49	1.00	0.10	0.21
CLFR	0.44	0.38	0.50	0.35	0.90	0.35	0.25

	Maturity	T	Safety	CR	Relative Weight	Normalized Relative Weight
Parameter Importance	0.80	0.71	0.43	0.71	-	-
Trough	0.80	0.23	0.22	0.28	0.502	1.000
Tower	0.64	0.48	0.17	0.50	0.450	0.897
Chimney	0.24	0.04	0.19	0.71	0.333	0.664
Dish	0.16	0.07	0.26	0.07	0.314	0.626
Pond	0.16	0.06	0.43	0.07	0.297	0.591
PV	0.48	-	0.13	-	0.274	0.545
CLFR	0.24	0.23	0.30	0.28	0.384	0.765

Appendix B:

Costs - Original Values

	Hardware Cost	Electricity Cost	Water Usage	Land Usage	Maintenance Cost	Environmental Constraints	Relative Weight	Normalized Relative Weight
Parameter Importance	0.500	0.500	0.500	0.400	0.500	0.250	-	-
Trough	0.440	0.180	0.700	0.420	0.300	1.000	0.434	0.754
Tower	0.550	0.210	0.800	0.310	0.520	0.740	0.512	0.889
Chimney	0.530	0.150	0.100	0.900	0.520	0.000	0.402	0.698
Dish	1.000	0.500	0.100	0.300	0.520	0.600	0.487	0.845
Pond	0.290	0.180	1.000	1.000	0.200	0.000	0.432	0.750
PV	0.840	1.000	0.100	0.360	1.000	0.000	0.576	1.000
CLFR	0.350	0.110	0.300	0.200	0.100	0.300	0.247	0.429

Costs - Recalculated Data Values:

	Hardware Cost	Electricity Cost	Water Usage	Land Usage	Maintenance Cost	Environmental Constraints	Relative Weight	Normalized Relative Weight
Parameter Importance	0.800	0.500	0.500	0.100	0.500	0.250	-	-
Trough	0.352	0.090	0.350	0.042	0.150	0.250	0.206	0.702
Tower	0.440	0.105	0.400	0.031	0.260	0.185	0.237	0.808
Chimney	0.424	0.075	0.050	0.090	0.260	0.000	0.150	0.511
Dish	0.800	0.250	0.050	0.030	0.260	0.150	0.257	0.876
Pond	0.232	0.090	0.500	0.100	0.100	0.000	0.170	0.581
PV	0.672	0.500	0.050	0.036	0.500	0.000	0.293	1.000

CLFR	0.280	0.055	0.150	0.020	0.050	0.075	0.105	0.358

Appendix C:

Benefit/Cost Ratio:

	ADJUSTED NRW BENEFIT	ADJUSTED NRW COST	B/C	NORMALIZED B/C
Trough	1.000	0.702	1.424454737	0.667
Tower	0.897	0.808	1.109632534	0.520
Chimney	0.664	0.511	1.297957447	0.608
Dish	0.626	0.876	0.7142492603	0.335
Pond	0.591	0.581	1.016518449	0.476
PV	0.545	1.000	0.544911264	0.255
CLFR	0.765	0.358	2.135204464	1.000

AP® RESEARCH
2018 SCORING COMMENTARY

Academic Paper

Sample: E
Score: 3

The paper earned a score of 3 because it is an example of basic capital "R" research, which includes a narrowing research topic (page 8, paragraph 1: " ... what would be the best system for the UAE to use for its next solar farm"; also page 9, paragraph 1: "The purpose of the study was to determine the best system for the United Arab Emirates ..."), a solid survey of the literature (pages 4–7), it identifies its method (page 9, paragraph 1, as: "... a grounded theory research methodology" into which it incorporates: "... the use of 'fuzzy logic'" [paragraph 2]) and some sense of a coherent argument supported by original evidence leading to a new understanding provided in text and a series of tables (pages 10–14). The paper then discusses the results (pages 15–17) and reaches a new understanding on page 18, paragraph 1: "From all of the data presented, the researcher has evaluated that the best Solar Power System for the United Arab Emirates to implement is the Parabolic Trough solar system."

The paper did not earn a 2 because it describes a reasonably replicable method, conveys a new understanding, and communicates its ideas competently.

The paper did not earn a 4 because it does not fully explain and defend the use of grounded theory and fuzzy logic in a way that lends credibility to the student as researcher. Even though the paper implies a gap on page 3, paragraph 2, and page 8, paragraph 1, it does not provide enough information in its literature review to establish that this gap is verifiable.