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[Arante, 7(8): August, 2018]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PHOTOVOLTAIC POWER SYSTEM DESIGN FOR CARAGA STATE UNIVERSITY CABADBARAN CAMPUS, AGUSAN DEL NORTE, PHILIPPINES

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DOI: 10.5281/zenodo.1401798

ABSTRACT

This study proposed a segmented photovoltaic power system design for Caraga State University Cabadbaran Campus (CSUCC), Agusan del Norte during the Academic Year 2017 – 2018. Descriptive – Evaluative method of research was employed with energy audit as the primary tool in assessing the recent situation on energy demand and other energy related aspects in the Campus. A survey on the presence of energy conservation initiatives was also undertaken to assess its effect on energy demand. Based on the result of the utility bill audit conducted, the electric bills showed the total electric power consumption of CSUCC for the entire year 2017 was 157,048 Kw/hr. and paid the total amount of P1, 339,782.79. On the conducted walk through audit on the potential loads, the total end use of Caraga State University Cabadbaran Campus (CSUCC) was 267,290 kilowatts. The Other Equipment and Devices (OED) were accounted for 58 percent of the total potential loads. About 33 percent were consumed by the Ventilation and Air-Conditioning units (VAC) while Lighting Fixtures (LF) were accounted for 9 percent of the overall potential loads. Observation of both the faculty and staff on the presence of energy conservation initiatives at CSUCC with 25 respondents in each group selected from the total population using purposive sampling technique disclosed that the average weighted mean of the faculty's observation was 1.62 with a verbal interpretation of Not Observed while the staff's observation had an average weighted mean of 1.58 also with a verbal interpretation of Not Observed. It showed that both faculty and staff were consistent in their observation that most of the listed energy conservation initiatives were not present or practiced at Caraga State University Cabadbaran Campus thus contributing to the steady increase in energy consumption. Findings of the study born out a conclusion that Caraga State University Cabadbaran Campus (CSUCC) generally doesn't have concrete energy conservation initiatives that would help curtail its rising consumption of electricity thus a Photovoltaic Power System is heavily recommended for adoption. It would also help sustain the operation of the frontline offices of the university especially during power interruptions.

KEYWORDS: Energy audit, Energy conservation initiatives, Photovoltaic power bank, Power system, segmented design, walk through audit.

I. INTRODUCTION

Energy is the ability to do work. Its resources include the sun, water, the wind, fossil fuels, and thermal. This word is essential to ordinary people as it delivers lighting and runs all of the domestic appliances. The fast-rising usage of domestic machines such as oven toasters, refrigerators, computers, washing machines, dryers, DVD players, and TV sets, has moved household dynamics from human dynamism to electrical dynamism. Buesing (1980, p.194) in his study explained that electricity will go on to be the most prevailing energy source among households for three reasons. First, it is the most universally available energy source now in the homes. Second, it is the uppermost grade and most flexible energy source available. Third, it is the easiest to produce from any number of upcoming energy resources. When Philippine President Rodrigo R. Duterte sworn into office in 2016, his administration would like to implement a multitude of projects for its splendid plans in Mindanao, Philippines. Once an ultimate peace covenant with the Moro Islamic Liberation Front is consummated, Mindanao will live up to its status as the Land of Promise. However, the current sequence of massive power disruptions is a symptom of the present predicament facing Mindanao. Electricity in large parts of the region has been cut off for hours due to the shutdown of power plants. The main cause of the interruption: the demand for power far surpasses the current source.

Caraga State University Cabadbaran Campus (CSUCC) which situates in one of the provinces of Mindanao is a government-run institution that suffers much due to this present predicament of power shortage. The alarming numbers of brownouts daily hamper the operation of the school especially its frontline services. Built on the idea that almost all frontline services interconnect with computers and networks and most of the clients' files are in databases, any power interruption would entail to paralyze the operation. Another concern also is the fast-rising cost of electricity these days that prompt managers and educational leaders to find ways to manage power consumption without jeopardizing the institutions overall operations.

Due to these facts, an alternative means to address these problems is being conceptualized by the researcher. There is a pressing need to do an Energy Audit for the purpose of assessing the school's energy demand to find ways to manage them. A Photovoltaic Power System is also being thought to address the problem of power interruption if implemented by the CSUCC administration. This power system will give the institution a clean alternative source of power that can help sustain its operation even during power failure.

II. MATERIALS AND METHODS

Design

This study used descriptive – evaluative method of research which employed the process of energy audit as the primary tool in assessing the recent situation on energy demand and other energy-related aspects at Caraga State University Cabadbaran Campus. It also looked into documents filed in the office and also conducted interviews to validate the data gathered. Furthermore, a walk through audit was also employed with actual inspection on the different electrical equipment for the sole purpose of cross-checking the data. A survey on the presence of energy conservation initiatives was also undertaken to assess its effect on energy demand. It was also evaluative in the since that investigation process was benchmarked based on industry standards of an energy audit.

Instrument

In conducting the energy audit, a checklist was adapted from the Carbon Trust Company of United Kingdom which is one of the tools in data gathering. It was partially modified to suit the needs of the study. The checklist is used as guide in gathering information about energy demand that serves as inputs for the design process of the proposed photovoltaic power system. A walk through audit was also being employed to gather additional information together with an unstructured interview to verify the gathered data.

The study also adapts a portion of the questionnaire from the study of Duaso (2004) on Energy Management Realization of Cebu Institute of Technology. Modifications were made to suit the needs of this study as several questions were transformed, and incorporate several new questions to determine the presence of Energy Conservation Initiatives at CSUCC.

Data Gathering Procedure

1. Preliminary. Permission was secured to conduct an energy audit and administer the questionnaire from the Campus Director's Office of Caraga State University Cabadbaran Campus (CSUCC) through a letter request.
2. Questionnaire Administration. Survey was conducted by administering the questionnaire to the respondents. Prime users of power consuming equipment and facilities were chosen as samples and were made to answer the questionnaire on the presence of energy conservation initiatives at CSUCC.
3. Actual Energy Audit. The conduct of the actual energy audit at CSUCC was in two phases: The first phase deals with the review of the monthly electric bills retrieved from the state auditor's office and from the office of the Power Grid supplier in the area for the past twelve months. The purpose is to inspect and analyze the power consumption trend of CSUCC. The second phase is the conduct of a walk through audit. Inventory of equipment, gadgets, and lightings to determine the installed electrical demand in a particular building was done. It includes data like the kind of lighting used, total wattage and the number of hours used, height of ceilings etc. It was also reinforced by interview to the occupants, in-charge, and prime users of the equipment and facilities to validate the gathered data. The nameplate rating of electric motors and other energy consuming devices was utilized in determining the installed power capacity. The total installed power capacity was calculated as the sum of the kilowatt load of lighting units, ventilation and air-conditioning units, and other electrical units.

ISSN: 2277-9655
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CODEN: IJESS7

III. RESULTS AND DISCUSSION

Caraga State University Cabadbaran Campus (CSUCC) is in between Aglipay St. and S. Curato St. and in front of T. Curato Avenue, Brgy. 11, the City of Cabadbaran in Agusan del Norte. It has 21 campus buildings, big and small, situated within the 80,000 – square meters lot that covered a total gross area of 12,952.55 – square meters. The present electrical system of the campus has only one service entrance where an electric power source is supplied by Agusan del Norte Electric Cooperative (ANECO) as the local utility company.

Results of Energy Audit

An energy audit was conducted to determine the energy demand of Caraga State University Cabadbaran Campus. The results serve as inputs for the design of the proposed photovoltaic power system. The audit conducted was per building because the design would be segmented in nature so that the implementation would be in a phase by phase mode considering the huge amount that would be involved and the required land area for the installation of the solar panels if it is implemented as a whole.

Utility Bill Audit

Table 1. Summary of CSUCC Electric Bills for CY 2017

Month	Power Consumption (Kw/hr.)	Amount Paid
January	8,624	P 74,696.10
February	12,464	111,799.52
March	11,724	104,157.86
April	10,888	82,728.16
May	11,912	107,028.18
June	14,200	124,628.02
July	14,912	126,336.02
August	13,796	118,906.50
September	15,944	132,739.25
October	17,332	137,802.46
November	13,948	120,489.61
December	11,304	98,471.11
Total	**157,048**	**P 1,339,782.79**

Table 1 shows the electric power consumption of CSUCC and its corresponding amount paid for each month during the calendar year 2017. For the entire year, the total power consumption is 157,048 Kw/hr. It paid the total amount of P1,339,782.79. The documents from the Agusan del Norte Electric Cooperative (ANECO) and from the office of the Commission on Audit (COA) CSU Cabadbaran Campus provided this data.

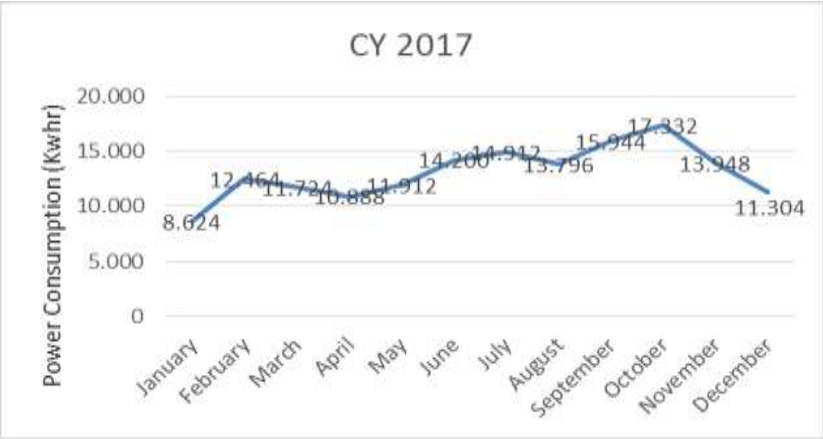

Chart 1. Monthly Power Consumption in Kwhr/month of CSUCC

Based on the Chart above, October had the highest energy consumption of 17,332 kW/hr. It is because of the construction and installation of new equipment for the engineering's new automation room and the installation of additional air-conditioning units in various offices. The consumption was at its smallest at 8,624 kW/hr. on the

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first month of the year where campus activities were minimal as occupants were coming back from Christmas vacation and laboratory activities in the shops where huge energy consuming equipment are located were at a minimum level as classes' starts anew.

Walk-Through Audit

The total end use of CSUCC buildings based on the conducted walk-through audit on potential loads classified into three categories: The Ventilation and Air-Conditioning Units (VAC), Lighting Fixtures (LF), and Other Equipment and Devices (OED) is 267,290 kilowatts.

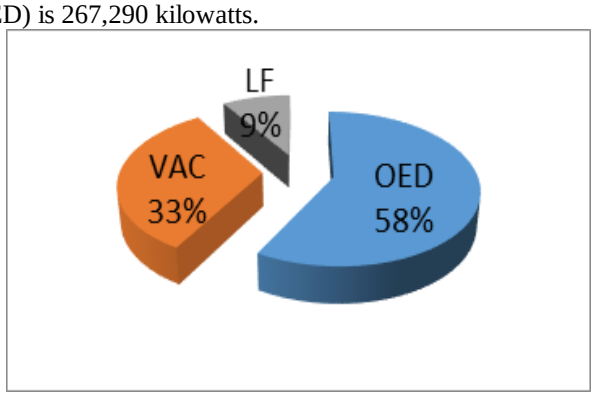

Chart 2. Distribution of Potential Loads at CSUCC

The pie chart indicates that the highest category of loads is the Other Equipment and Devices (OED). It's about 58 percent of the total potential loads. These loads are composed of electric arc welding machines, induction motors and other huge equipment. Water Dispensers, Freezers and refrigerators, Computers and small appliances also form part of the OED. The Ventilation and Air-Conditioning (VAC) only represents 33 percent of the total potential loads while the smallest is the Lighting Fixtures (LF) which is about nine (9) percent of the total potential loads.

Chart 3. Summary of the Total Electrical Energy Consumption in KWH/Day at Peak of CSUCC

Chart 3 shows the summary of the estimated electrical energy consumption at peak per building at Caraga State University Cabadbaran Campus (CSUCC) based on the walk-through audit. The 2-Storey College Building had the highest expected power consumption of 540.88 kilowatt-hours while the lowest expected power consumption belongs to the New LHS Building with 2.83 kilowatt-hours. This two (2) classrooms New LHS Building is not yet finished that's why it is not also furnished with other electrical consuming equipment and devices thus contributing to its low energy consumption. The Administration Building, Science Building, U-Shaped Building, Automotive Building, Electronics Building, Food Tech Building, Culture and Arts Building, Electrical Building 1, Electrical Building 2, Civil Tech/Wood Building, Guest House, Bleacher, Gymnasium, and Motor Pool had a total estimated energy consumption of 322.41; 194.11; 105.57; 66.35; 70.45; 80.79; 35.51; 22.64; 77.52; 19.52; 86.10; 13.35; 13.68, and 54.92 kilowatt-hours per day respectively. All in all the Caraga State University

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Cabadbaran Campus (CSUCC) had a total estimated energy consumption of 1,706.63 kilowatt-hours per day at peak.

Table 2. Estimated Energy Demand in Kwh/Day of the top five energy consuming buildings at CSUCC

AREA	ELECTRICAL SYSTEM			TOTAL
	(VAC)	(LF)	(OED)	(Kwh)
ADMINISTRATION BLDG.	171.61	31.67	119.13	**322.41**
2 STOREY BUILDING	147.27	16.41	377.20	**540.88**
SCIENCE BUILDING	114.16	15.18	64.77	**194.11**
U-SHAPED BUILDING	51.89	15.30	38.38	**105.57**
GUEST HOUSE/HOSTEL	83.42	2.68	0.00	**86.10**

Table 2 discloses that the top five (5) energy consuming buildings at CSUCC based on their expected energy demand per day at peak are the Admin Bldg., 2-Storey Bldg., Science Bldg., U-Shaped and Guest House.

Energy Conservation Initiatives Observed by Faculty and Staff

n = 25

Table 3. Faculty Observation on the Presence of Energy Conservation Initiatives at CSUCC

Energy Conservation Initiatives	3	2	1	TW	X	QD
The School promulgated Energy Conservation Policy	5	3	17	38	1.52	NO
The School has an updated Energy Conservation Manual	2	4	19	33	1.32	NO
The School conducts Energy Conservation Symposium	2	4	19	33	1.32	NO
Employees participate in Energy Conservation Program	3	16	6	47	1.88	PO
School allocates budget for Energy Conservation related activities	3	5	17	36	1.44	NO
Management supports researches related to energy conservation	2	2	21	31	1.24	NO
The School has created an Energy Audit Team	0	1	24	26	1.04	NO
The School conducts Energy Audit regularly	0	2	23	27	1.08	NO
Energy conservation posters are strategically posted inside school premises	0	1	24	26	1.04	NO
Lights and other electric consuming devices are turned off when not in use	18	5	2	66	2.64	FO
All equipment are maintained regularly	10	15	0	60	2.40	FO
The School prioritized the purchase of equipment with Energy Efficiency Rating	3	16	6	47	1.88	PO
Employees awareness on energy conservation and its environmental impact is evident	2	10	13	39	1.56	NO
The school is replacing busted lights with high energy saving one like LEDs	5	15	5	50	2.00	PO
The school is replacing desktop computers with laptops for energy conservation purposes	1	7	17	34	1.36	NO
Ventilations and Air-conditioning units are turned off on cool rainy weather.	8	16	1	57	2.28	PO
AVERAGE WEIGHTED MEAN				**1.62**		
INTERPRETATION				**NOT OBSERVED**		

Legend: FO – Fully Observed PO – Partially Observed NO – Not Observed

Table 3 indicates the observation of the faculty on the presence of energy conservation initiatives at CSUCC with 25 respondents. The Table reveals that 10 out of the 16 listed energy conservation initiatives are Not Observed by the respondents. Four (4) were Partially Observed and two (2) were Fully Observed. Analysis of the findings further revealed that the average weighted mean of the faculty's observation on the presence of energy conservation initiatives was 1.62 with a verbal interpretation of Not Observed. It means that most of the listed energy conservation initiatives were not present or either practiced at CSUCC as observed by the faculty in their respective work area thus contributing to the steady increase in energy consumption. Without these initiatives, the institution is seen to be a major cause of the energy shortage in Mindanao. These findings further imply that there

ISSN: 2277-9655
Impact Factor: 5.164
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is a need for CSUCC management to implement and practiced various energy conservation initiatives to curtail the increasing energy demand of the school.

n = 25

Table 4. Staff Observation on the Presence of Energy Conservation Initiatives at CSUCC

Energy Conservation Initiatives	**3**	**2**	**1**	**TW**	**X**	**QR**
The School promulgated Energy Conservation Policy	3	8	14	39	1.56	NO
The School has an updated Energy Conservation Manual	0	8	17	33	1.32	NO
The School conducts Energy Conservation Symposium	0	3	22	28	1.12	NO
Employees participate in Energy Conservation Program	0	6	19	31	1.24	NO
School allocates budget for Energy Conservation related activities	1	5	19	32	1.28	NO
Employees are encourage by the management to do research related to energy conservation	1	5	19	32	1.28	NO
The School has created an Energy Audit Team	0	3	22	28	1.12	NO
The School conducts Energy Audit regularly	2	2	21	31	1.24	NO
Energy conservation posters are strategically posted inside school premises	0	3	22	28	1.12	NO
Lights and other electric consuming devices are turned off when not in use	17	8	0	67	2.68	FO
All equipment are maintained regularly	10	15	0	60	2.40	FO
The School prioritized the purchase of equipment with Energy Efficiency Rating (EER)	3	20	2	51	2.04	PO
Employees are aware of the benefits gained from energy conservation and its environmental impact	3	11	11	42	1.68	PO
The school is replacing busted lights with high energy saving one like LEDs	4	10	11	43	1.72	PO
The school is replacing desktop computers with laptops for energy conservation purposes	2	7	16	36	1.44	NO
Ventilations and Air-conditioning units are turned off on cool rainy weather.	2	23	0	52	2.08	PO
AVERAGE WEIGHTED MEAN			**1.58**			
INTERPRETATION			**NOT OBSERVED**			

Legend: FO – Fully Observed PO – Partially Observed NO – Not Observed

Table 4 specifies the responses of the staff on their observation on the presence of energy conservation initiatives at CSUCC. Only two (2) of the listed 16 items on energy conservation initiatives were **Fully Observed,** which is identical to what the faculty observed while four (4) items were also **Partially Observed**. Out of the16 listed items, the staff did not observe the presence of the 10 remaining items on energy conservation. It means that the school does not have these initiatives that are vital on their energy conservation efforts. The average weighted mean of **1.58** with a verbal interpretation of **Not Observed** further support these findings. It means the overall effort of the school for energy conservation lacks intensity. Without these initiatives, the school's energy consumption will continue to rise. These findings further imply that the CSUCC management should put emphasis on energy conservation related activities and efforts to help address the problems brought by the power shortage of Mindanao. Realignment of priorities is very vital for the success of this noble cause.

Technical Design of the Proposed Photovoltaic Power System

The Administration building was chosen by the researcher as the first priority due to the fact that most of the frontline offices are situated there. During the design process of the power system, the researcher gave exact attention to the required energy demand, and specification of the necessary Photovoltaic (PV) system components. The researcher also paid attention to the installation requirements (i.e. area and solar exposure), and was watchful of the fiscal aspect of the entire project. The researcher prepared two designs of the proposed Photovoltaic Power System for the Administration Building. The first design is a Stand Alone Type of system while the second design is for a Grid-Tied Type of System. These designs will be used as benchmark designs for other buildings within the campus. Presented here is a sample design of an Off Grid or Stand Alone type of system for Lighting Fixtures

ISSN: 2277-9655
Impact Factor: 5.164
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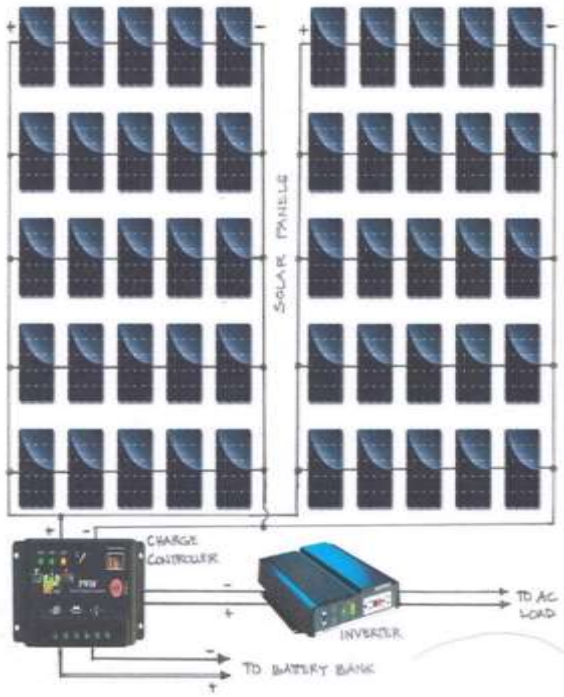
based on the energy audit results of the Administration Building having an estimated demand of **31.67** kilowatt-hours per day at peak. Based on these data, design computations were done, and the results were the following:

For Lighting Loads of 31.67 kilowatt-hours/day at peak

Items	Quantity	Wiring Configuration/Specifications
PV Modules 250 Wp	50 pcs.	5 in series and 10 in parallel
Deep Cycle Battery @ 200 Ah	60 pcs.	5 in series and 12 in parallel
Charge Controller	1 unit	60 – 90 VDC, 76 Amperes
Inverter	1 unit	Input : 60 – 90 VDC Control Capacity: 4,948 watts Surge Capacity: 15,832 watts

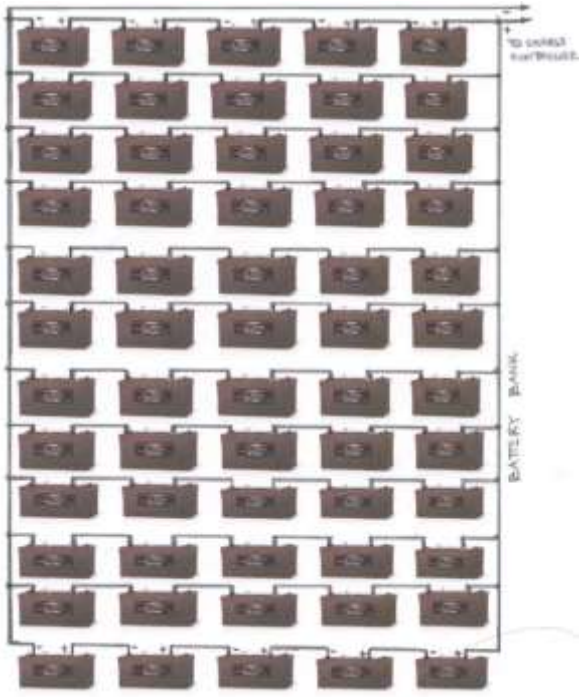
The power system is stand-alone type and will be roof mounted. The required area for PV Panels is 100 m^2.

Figure 1



Pictorial Diagram of Solar Panel Array, Charge Controller and Inverter

Figure 2



Pictorial Diagram of Power Bank

IV. CONCLUSION

Based on the findings on the survey conducted about the presence of energy conservation initiatives, it can be concluded that Caraga State University Cabadbaran Campus (CSUCC) doesn't have a concrete energy conservation program that would curtail its rising consumption of electricity. It is therefore necessary to create and implement a concrete energy conservation program to reduce energy consumption. In addition, the proposed Photovoltaic Power System is also recommended for implementation in order to sustain the frontline service of the school especially during power interruptions.

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CITE AN ARTICLE

Arante, R. B., Dr. (2018). PHOTOVOLTAIC POWER SYSTEM DESIGN FOR CARAGA STATE UNIVERSITY CABADBARAN CAMPUS, AGUSAN DEL NORTE, PHILIPPINES. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 7*(8), 500-507.