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Sustainable University: Towards the energy transition through photovoltaic electricity generation and energy efficiency

Universidad Sustentable: Hacia la transición energética mediante generación de energía eléctrica fotovoltaica y eficiencia energética

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Abstract

The Higher Education Institutions have the challenge for becoming in sustainables universities. Nowadays, it has been implemented many policies and actions in order to innovate in strategic areas. The main goal is integrating social responsible and this means acting as a leader in the social context. The environmental and energy areas have become the keystone to impulse substantial changes. Concern to electricity, the University of Colima has increased its consume in 3% per year, this has impacted in the payments to the electric utility in 9%. Consume of energy has been divided in four groups of users. Air conditioners represent 50%, lighting 20%, electronic devices 20% and services 10%. This project focuses in replacing inefficient air conditioners and lighting systems, this will impact on reducing 13% of the total amount of energy consumed by the university. Besides, this project takes into account to generate electricity by using five Photovoltaic Interconnected Systems. These changes will reduce the consume 13% of the total amount of energy. The Photovoltaic Interconnected Systems will have a capacity of 2.3 MWp distributed in five campus of the university. These PV Interconnected Systems will produce 34.61% of the total electricity demanded by the university. This project will avoid emitting 3,968 Ton CO_2 to the atmosphere.

Energy Efficiency, Renewable Energy, Sustainable University

Resumen

Las Instituciones de Educación Superior tienen el reto de converstirse en universidades sustentable. Recientemente, se han implementado varias políticas y acciones con el fin de innovar en áreas estrategicas. El objetivo principal integrar la responsabilidad social y esto significa actuar como líder en el contexto social. Las áreas de energía y medio ambiente se han convertido en la base para impulsar cambios sustanciales. En materia energética, la Universidad de Colima ha incrementado su consumo en un 3% cada año, esto ha impactado significativamente en los pagos por facturación en 9%. El consumo de energía se ha clasificado en cuatro grupos de usuarios. Aire acondicionado representa 50%, iluminación 20%, dispositivos electrónicos 20% y equipos de servicios generales 10%. Este proyecto se enfoca en el reemplazo de sistemas ineficiencientes de aire acondicionado e iluminación. Esto impactará en una reducción del 13% del consumo total de la energía eléctrica consumida en la universidad. Además, este proyecto considera la generación de energía eléctrica mediante cinco sistemas fotovoltaicos interconectados. Los sistemas en conjunto tendrán una capacidad de 2.3 MWp y serán distribuidos en cinco campus de la universidad. Estos sistemas fotovoltaicos interconectados producirán 34.61% de la energía total demandada por la institución. Se evitarán la emisión de 3,968 Toneladas de CO2 a la atmosfera.

Eficiencia Energética, Energías Renovables, Universidad Sustentable

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Introduction

The possibility of generating electrical energy for self-consumption and delivery of surpluses to the electricity supplier company in Mexico, has caused several companies to begin to consider investing in the development of energy projects to increase their competitiveness (PND, 2013). The main reason lies in the increase in the costs of fossil fuels necessary to satisfy consumers' demand for electricity. With increases in electricity costs for the HM rate of 18.49% during the period from January to September 2016, the operating conditions for the companies contracted in said rate represent an additional expense to satisfy the committed production (Federal Commission of Electricity, 2016).

In Mexico at the end of 2014, professors from Higher Education Institutions oriented to projects and academic activities on Renewable Energies and Energy Efficiency were summoned to participate in the Applied Leadership Program in Renewable Energies and Energy Efficiency (SENER, 2014), (Sectorial Energy Program, 2012) and (National Energy Strategy, 2013).

This program was taught by Harvard Professors, coordinated by the Center for Health and Environment of the Harvard University School of Public Health, as well as by the InTrust Global Investments organization, in alliance with the Ministry of Energy, the Autonomous Universities State and Federal Technological Institutes. With this program it was sought to implement a "democratizing" model of access to knowledge and effective development of renewable projects in Mexico, optimizing public and private resources, and giving effective access to Mexican Universities, so that they are allies and convenors of the application. true of the energy transition in Mexico.

The objective of the Program was to professionalize academics from various regions of the country, mainly in the development of renewable energy and energy efficiency projects and to promote specific projects in the field. Also, related to adaptations on climate change applications and mitigation of the same.

Upon completion of this program, a Certificate of Completion in Applied Leadership in Renewable Energy and Energy Efficiency was awarded and certified by the Center for Health and Environment at the Harvard School of Public Health (Certificate of Completion. Center). of Health and the Global Environment, School of Public Health, Harvard).

As a result of the participation of professors in this national training program on energy, professors from the universities of Colima and Veracruzana began a working collaboration on energy efficiency and renewable energies to demonstrate the social, energy and environmental impact that can provide Public Education Institutions in the development of society. The project corresponds to the University of Colima, in which an energy diagnosis and a feasibility study for the use of solar energy through Interconnected Photovoltaic Systems were prepared.

Current operational situation

The University of Colima is under an HM rate contract with the Federal Electricity Commission. In 2014, the university invoiced a total of $ 30'629,308.39 for this concept, which represented an increase of 9.09% compared to 2013. Regarding electricity consumption, this was 13'940,989 kWh and presented an increase of 2.86 % compared to 2013. The growth rate is positive to date and has remained so for the last 10 years. This article shows two main goals: the first is the generation of electrical energy in the five university campuses distributed throughout the state, contributing to 30.11% of current consumption. The second goal was to integrate technology to move towards energy efficiency in the air conditioning and lighting systems, the energy saving for this case is 13.01% of the total consumption.

As a whole, the Renewable Energy and Energy Efficiency generation project will reduce electricity consumption and will depend on the supplying company with 65.39% of current consumption, the rest will be generated with renewable energy.

The hourly HM rate in medium voltage is based on categorizing energy consumption in three schedules: base, intermediate and peak; the tip being the one with the highest cost per kWh.

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In addition, the rate includes the measurement of the maximum demand in the three schedules and by means of a simple calculation a billable demand is obtained, which is used to determine the cost for this concept. Finally, the measurement includes the monitoring of reactive energy in kVArh, which makes it possible to identify the degree of use of the energy consumed by the company, also known as the power factor. If this value is within the 90-100% range, then the consumer receives a bonus, otherwise a penalty. The description of the HM rate allows us to point out two very important things that companies contracted under this rate can take advantage of by having generation from a renewable source.

Power generation will be installed on the five campuses of the University of Colima and will have the following capacities: 1) Manzanillo Campus: 400 kWp, 2) Tecomán Campus: 300 kWp, 3) Colima Campus: 800 kWp, 4) Coquimatlán Campus: 500 kWp and 5) Villa de Alvarez Campus: 300 kWp. Figures 1 - 5 present the location of each of the interconnected photovoltaic systems in Manzanillo, Tecóman, Colima, Coquimatlón and Villa de Alvarez, respectively.

The distribution of electricity generation in the five campuses is due to the fact that the University of Colima provides care throughout the state of Colima, in addition to the fact that the state is rich in solar potential with a daily average of 5.4 kWh / m2 / day (GIS et al, 2009). The replacement of air conditioning and lighting equipment operating inefficiently was determined after having made an energy and environmental diagnosis throughout the institution, concluding that more than 75 percent of the lighting equipment installed did not meet the energy efficiency conditions. in non-residential real estate and lighting levels in work centers NOM-007-ENER-2014 and NOM-025-STPS-2008, respectively. In the case of air conditioning equipment, they represented 50% of the institution's total energy consumption and were 12 years old on average. With this information, an energy, operational and economic impact study was carried out for the replacement of these inefficient equipment for this project.

Figure 1 Campus Manzanillo, 400 kWp

Figure 2 Tecóman Campus, 300 kWp

Figure 3 Campus Colima, 800 kWp

Figure 4 Campus Coquimatlón, 500 kWp

ISSN 2523-6997

Figure 5 Villa de Alvarez Campus, 300 kWp

In order to simulate the effect of replacing inefficient equipment and take into account load changes, a program was developed capable of evaluating the impact of energy and demand on the HM tariff over time and determining billing costs.

The Federal Electricity Commission provided historical consumption profiles every 15 minutes for the last five years. The photovoltaic generation profiles were obtained by monitoring small-scale interconnected photovoltaic systems that the institution itself has and where their history is every 5 minutes and for more than 2 years.

Tables I to V show the impact on billing before and after carrying out the energy efficiency project and the use of solar energy through the installation of interconnected photovoltaic systems.

Photovoltaic + Energy Efficiency			Manzanillo
	Billing in MX pesos		
Month	Current	Proposed	Saved
January	168,116.67	63,406.64	104,710.03
February	222,255.18	112,209.25	110,045.93
March	221,862.17	114,804.31	107,057.86
April	152,668.42	36,766.32	115,902.10
May	248,906.23	134,825.21	114,081.02
June	250,352.26	136,080.53	114,271.72
July	180,597.26	64,508.08	116,089.18
August	259,421.00	143,081.94	116,339.06
September	226,838.29	113,655.23	113,183.05
October	124,991.97	16,759.82	108,232.15
November	203,523.88	98,484.12	105,039.76
December	152,856.40	48,480.35	104,376.05
Total	2,412,389.72	1,083,061.81	1,329,327.91

Table 1 Impact on the billing of the Mazanillo campus by the 400 kWp interconnected photovoltaic system

Photovoltaic + Energy Efficiency			Tecoman
	Billing in MX pesos		
Month	Current	Proposed	Saved
January	218,686.52	115,917.89	102,768.63
February	252,210.21	147,572.47	104,637.74
March	252,935.43	152,890.48	100,044.94
April	168,397.18	66,513.93	101,883.25
May	265,491.83	166,000.97	99,490.86
June	244,373.99	142,817.87	101,556.12
July	226,160.28	123,873.97	102,286.31
August	262,119.88	157,524.65	104,595.23
September	229,890.09	125,762.58	104,127.52
October	114,548.73	14,013.23	100,535.50
November	223,434.26	125,656.46	97,777.79
December	189,318.91	92,154.65	97,164.26
Total	2,647,567.30	1,430,699.15	1,216,868.15

Table 2 Impact on the billing of the Tecomán campus by the 300 kWp interconnected photovoltaic system

Photovoltaic + Energy Efficiency			Colima
	Billing in MX pesos		
Month	Current	Proposed	Saved
January	851,034.97	591,872.10	259,162.87
February	996,972.00	732,810.24	264,161.76
March	1,094,744.66	833,488.09	261,256.57
April	697,262.74	429,752.40	267,510.35
May	1,027,564.42	766,121.90	261,442.52
June	1,001,697.98	737,502.42	264,195.56
July	817,589.69	550,454.45	267,135.24
August	1,104,548.60	831,440.91	273,107.68
September	991,726.12	724,126.56	267,599.56
October	507,091.92	245,455.93	261,635.99
November	956,087.28	705,334.74	250,752.54
December	757,500.36	518,062.86	239,437.50
Total	10,803,820.75	7,666,422.62	3,137,398.13

Table 3 Impact on the turnover of the Colima campus by the 800 kWp interconnected photovoltaic system

Photovoltaic + Energy Efficiency			Coquimatlán
	Billing in MX pesos		
Month	Current	Proposed	Saved
January	229,341.56	95,586.65	133,754.91
February	274,778.57	137,595.61	137,182.96
March	295,093.52	162,438.26	132,655.25
April	186,535.08	51,271.31	135,263.78
May	281,325.45	151,595.77	129,729.69
June	279,411.78	149,328.30	130,083.47
July	224,590.59	90,234.47	134,356.11
August	320,786.10	185,165.91	135,620.19
September	294,725.02	161,282.57	133,442.45
October	144,052.90	16,146.04	127,906.86
November	271,711.83	143,519.77	128,192.06
December	227,564.27	99,098.78	128,465.49
Total	3,029,916.68	1,443,263.45	1,586,653.23

Table 4 Impact on the billing of the Coquimatlán campus by the 500 kWp interconnected photovoltaic system

ISSN 2523-6997

Photovoltaic + Energy Efficiency			VdeA
	Billing in MX pesos		
Month	Current	Proposed	Saved
January	126,239.24	43,813.79	82,425.45
February	171,792.26	88,540.19	83,252.07
March	189,882.67	108,938.62	80,944.05
April	116,300.24	30,914.61	85,385.63
May	174,191.65	89,361.73	84,829.92
June	146,703.47	61,705.84	84,997.62
July	94,953.52	7,044.83	87,908.70
August	185,657.94	96,239.73	89,418.22
September	175,108.82	87,904.74	87,204.08
October	96,121.00	14,226.17	81,894.83
November	158,836.13	80,075.23	78,760.90
December	109,565.22	33,728.44	75,836.78
Total	1,745,352.17	742,493.92	1,002,858.26

Table 5 Impact on the billing of the Villa de Alvarez campus by the 400 kWp interconnected photovoltaic system

The evaluation of the simple internal rate of return considering the generation of electrical energy through photovoltaic systems from 300 to 800 kWp and the energy efficiency in the air conditioning and lighting systems are shown in tables VI to X. It is observed that the total amounts invested for the campus range between $ 9, 436,995 and $ 25, 165,320 Mexican pesos. While the internal rates of return are with ranges of 8.02 and 9.91 years. These values correspond to a useful life of photovoltaic systems of 30 years and a replacement of air conditioning and lighting equipment every 12 years. It is planned to replace these last systems at the end of their useful life and with the savings achieved during the 2.09 years of life, to replace these systems with equal or greater efficiency found in the market.

Campus Manzanillo	
Investment description	Amount ($)
Photovoltaic system 400 kWp	11,022,660.00
Samsung Inverter Air Conditioner	1,040,000.00
LED lighting and T5 Magg	520,000.00
Total	12,582,660.00
Annual savings	1,329,327.91
IRR (years)	9.47

Table 6 Economic balance of the 400 kWp interconnected photovoltaic system for the Manzanillo campus

Campus Tecoman	
Investment description	Amount ($)
Photovoltaic system 400 kWp	8,266,995.00
Samsung Inverter Air Conditioner	780,000.00
LED lighting and T5 Magg	390,000.00
Total	9,436,995.00
Annual savings	1,216,868.15
IRR (years)	7.76

Table 7 Economic balance of the 300 kWp interconnected photovoltaic system for the Tecomán campus

Campus Colima	
Investment description	Amount ($)
Photovoltaic system 400 kWp	22,045,320.00
Samsung Inverter Air Conditioner	2,080,000.00
LED lighting and T5 Magg	1,040,000.00
Total	25,165,320.00
Annual savings	3,137,398.13
IRR (years)	8.02

Table 8 Economic balance of the 800 kWp interconnected photovoltaic system for the Colima campus

Campus Coquimatlán	
Investment description	Amount ($)
Photovoltaic system 400 kWp	13,778,325.00
Samsung Inverter Air Conditioner	1,300,000.00
LED lighting and T5 Magg	650,000.00
Total	15,728,325.00
Annual savings	1,586,653.23
IRR (years)	9.91

Table 9 Economic balance of the 500 kWp interconnected photovoltaic system for the Coquimatlán campus

Campus Villa de Alvarez	
Investment description	Amount ($)
Photovoltaic system 400 kWp	8,266,995.00
Samsung Inverter Air Conditioner	780,000.00
LED lighting and T5 Magg	390,000.00
Total	9,436,995.00
Annual savings	1,002,858.26
IRR (years)	9.41

Table 10 Economic balance of the 300 kWp interconnected photovoltaic system for the Villa de Alvarez campus

Technical considerations

The total energy produced is estimated at 4'197,500 kWh per year. The photovoltaic systems will be made up of 250Wp modules - Solartec, while the inverters will be Fronius. The systems will be mounted on aluminum structures and will be interconnected to the medium voltage distribution systems by means of a step-up transformer with the required capacity of 13.8 kV. 80% of the air conditioning units will be replaced by more efficient units with inverter technology. The adopatos luminaires for this Project will be with T5 and LED technology.

By concept of energy efficiency, both have contemplated a saving of 1,814,404 kWh per year. In summary, the entire project will reduce electricity consumption by the utility company by 43.12%.

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The University of Colima will reduce energy consumption by using efficient equipment by 13.01% for the first time in its history and will produce 34.61% of all energy consumed taking advantage of solar energy. The cost of these components is $ 4'823,353 USD and the return on investment is 8.75 years.

The useful life is 30 years and the University of Colima will reduce the unit cost of electrical energy from $ 0.1464 to $ 0.1134 USD for each kWh consumed. This represents 22.54 less than the current one.

Table XI shows the comprehensive economic benefits of the project, while Table XII indicates the final contribution of electricity generation at the University of Coima.

Investment description	Amount ($)
Photovoltaic system 400 kWp	63,380,295.00
Samsung Inverter Air Conditioner	5,980,000.00
LED lighting and T5 Magg	2,990,000.00
Total	72,350,295.00
Annual savings	8,273,105.68
Investment description	8.75

Table 11 List of economic benefits of the project

Stage	Energy Consumption (kWh)	Contribution (kWh)	
		CFE	Photovoltaic system
Current	13,940,989	13,940,989	0
	100.00%	100.00%	0.00%
Draft	12,126,586	7,929,086	4,197,500
	100.00%	65.39%	34.61%

Table 12 Comparison of total energy contributions

Comparison of total energy contributions

The environmental impact of generating electricity through photovoltaic systems in generating 4.1975 MWh and energy savings due to energy efficiency of 1.814404 MWh, will prevent the University of Colima from emitting 3,962 tons of CO2 into the atmosphere, these tons of CO2 are equivalent to filling 1,836 Olympic pools. The economic benefits to health for the photovoltaic systems total 2.3 MWp $ 239,304.45 USD / year. In addition to the reduction of particles in 862.71 Kg of PM2.5 / year by this intervention.

In economic terms, the Project itself represents a great opportunity as an investment strategy due to the savings generated each year. The Project requires an investment of $ 72,350,295.00 pesos and will have a saving of $ 8,273,105.68 pesos each year. The return on investment is 8.75 years with an internal rate of return of 10%

The social impact of this Project is to awaken awareness in the community and to contribute to renewable energies being increasingly positioned by society. The development of sustainable projects by Higher Education Institutions can contribute to the paradigm shift of citizens and society, while at the same time maintaining a healthy ecosystem for the development of society.

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Conclusions

The development of energy projects of high impact in Institutions of Public Education in a reality. Integrating renewable sources of energy as part of the social responsibility that these institutions have with society is a duty in the transition to a sustainable university.

With the start-up of the photovoltaic electricity generation project and energy efficiency in the air conditioning and lighting systems, there is a reduction in electricity consumption of 1,814,404 kWh, equivalent to 13.01% of current consumption. The total consumption of the university will be 12'126,586 kWh, of which 34.61% will be generated by the institution itself through the proposed photovoltaic system, the rest will be delivered by the Federal Electricity Commission.

There are economic needs for these institutions, so it is necessary that within the budget for the universities, budgetary allocations are generated for the adoption of renewable technologies. The development of sustainable projects by Higher Education Institutions can contribute to the paradigm shift of citizens and society, while at the same time maintaining a healthy ecosystem for the development of society.

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