UNIVERSITIES AS MODELS OF SUSTAINABLE COMMUNITIES? AN ENERGY EFFICIENCY ASSESSMENT AT TEXAS STATE UNIVERSITY

By

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
AASHE	Association for the Advancement of Sustainability in Higher Education
AC	Alternative Current
ANN	Artificial Neural Network
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
AUPCC	American College and University Presidents' Climate Commitment
BRS	Building Rating System
BTU	British Thermal Unit
CAV	Constant Air Volume
CBECS	Commercial Building Electricity Consumption Survey
CFL	Compact Fluorescent Lamp
CFO	Cash Flow from Operating Activities
CREST	Cost of Renewable Energy Spreadsheet Tool
CSHEMA	Campus Safety and Health Environmental Management Association
DC	Direct Current
DCF	Discounted Cash Flow
DM	Demand Management
DOE	U.S. Department of Energy
EBITDA	Earnings before Interest, Taxes, Depreciation, and Amortization
EDF	Environmental Defense Fund
EGRID	Emission and Generation Recourses Integrated Database
EIA	U.S. Energy Information Administration
EMAS	European Eco-Management and Audit Scheme

EMS .... Energy Management System

EPA .... U.S. Environmental Protection Agency

ERCT .... Electric Reliability Council of Texas

ESR .... Environmental and Social Responsibility Index

EUI .... Electricity Utilization Index

FCF .... Free Cash Flow

FEDS .... Facility Energy Decision Screening

FLEX .... Federal Lighting Energy Expert

GHG .... Green House Gas

GSF .... Gross Square Feet

GW .... Giga Watt

HP .... Horse Power

HVAC .... Heating, Ventilation, and Air Conditioning

IAS .... International Accounting Standard

IPCC .... Intergovernmental Panel on Climate Change

IRR .... Internal Rate of Return

kWh .... Kilo Watt Hours

LCC .... Life Cycle Cost

LED .... Light Emitting Diodes

LEED .... Leadership in Energy and Environmental Design

LTSM .... Lighting Technology Screening Matrix

MCF .... Thousand Cubic Feet of Natural Gas

MMBtu .... Million British Thermal Unit

Mtoe .... Million Tons of Oil Equivalent

NEMA .... National Electronic Manufacturers Association

NPV .... Net Present Value

NREL ....National Renewable Energy Laboratory

PV .... Photovoltaic

RCI..Residential and Commercial Building and Industry

REC.. Renewable Energy Credit

REEP..Renewable and Energy Efficiency Planning

SECO ....Texas State Energy Conservation Office

SI .... International System of Units

SPP..Simple Payback Period

SVM... Support Vector Machines

TSUS.. Texas State University System

VFD...Variable Frequency Drive

WACC.. Weighted Average Cost of Capital

WCED...World Commission on Environment and Development

WEO ....World Energy Outlook

I. SUSTAINABILITY IN HIGHER EDUCATION

Introduction

As scientists continue to warm to the notion that the Earth is entering (or has already entered) an epoch characterized by human-induced changes to Earth surface conditions—i.e., the "Anthropocene" (Castree, N., 2016)—more and more attention is being paid to the ecological consequences of uninterrupted population growth, its associated economic activities, and human consumption patterns in an ever-industrializing world (Ralph, M and Stubbs, W., 2014). That being said, in addition to descriptive and explanatory accounts of anthropogenic changes occurring in the environment, researchers are increasingly setting their sights toward action and affecting behavioral change (e.g., McKenzie-Mohr, D., 2011). In other words, how can humans, and, perhaps more importantly, human settlements, function in more "sustainable" manners (e.g., Mazmanian, D., & Kraft, M., 2009)?

Given the prominent position of academia in the vast constellation of sustainability studies and sustainability science (e.g., Alshuwaikhat, H. M., & Abubakar, I., 2008; Elliott, H. & Wright, T., 2013), it is natural to want to look to universities—insofar as they often function as their own spatially-based communities (Norton, R., et al., 2007)—as models of (or keepers of knowledge about) sustainability in *practice* (e.g., Ralph, M., & Stubbs, W., 2014). Nevertheless, there is a long history of and literature on universities failing to actualize their own sustainability initiatives—from student-initiative campaigns against the sale of bottled water (Elliott, H., & Wright, T., 2013) to a variety of projects aimed at increasing energy efficiency on campuses (e.g., Maiorano, J., & Savan, B., 2013). Apart from typical justifications for implementation failure that include budget constraints and financial infeasibility (e.g., Elliott, H., & Wright, T., 2013), one of the main obstacles that consistently keeps universities from achieving their sustainability-related goals is a lack of enforcement. More precisely, universities tend to codify their sustainability-related goals in non-binding declarations that are voluntary, and therefore non-mandatory (Bekessy, S., Samson, K., & Clarkson, R., 2007). In that respect, failure to achieve a goal does not result in any sort of formal sanction. As such, universities are free to claim a commitment to sustainability in their public communications, without having to consistently and persistently demonstrate that commitment in practice. Consequently, non-binding declarations are sometimes referred to as nothing but "greenwash" (Bekessy et al., 2007), as they do not produce organizational behavioral change.

Situated on this backdrop, the present thesis will investigate energy efficiency at a large (~40,000 students) U.S. university—Texas State University—that has a strong public commitment to sustainability, particularly in the domain of energy consumption (Texas State University Plan, 2012-2017). What makes Texas State University such an interesting case to study is the fact that recent state legislation (Senate Bill 898, passed in 2011) mandates that all political subdivisions, state institutions of higher education, and other state agencies reduce their electricity consumption by five percent per year for ten years. Thus, "sustainability" at Texas State University is characterized [minimally] by both a nonbinding sustainability declaration, and a legislative directive to reduce energy consumption. For those reasons, assessing energy efficiency at Texas State University can plausibly reveal information about the extent to which this sort of coupled (i.e., nonbinding declaration plus legislative directive) set of sustainability commitments might be a relatively effective mix for practicing more "sustainable" energy consumption at a large institution of higher education in the United States. At the same time, such an assessment also has the potential to reveal whether implementation failures like those often experienced by universities with exclusively nonbinding declarations (e.g., Bekessy et al., 2007; Maiorano, J., & Savan, B., 2013) also occur at Texas State University. Under such circumstances, it may be possible to identify weaknesses in the existing legislative directive that would allow for non-attainment of sustainability-related goals. In either case, the energy assessment in this thesis must produce valuable insights into the nexus of sustainability practice [qua energy consumption] and rhetoric at a major public institution of higher education.

Background – sustainability in higher education

The Stockholm Declaration of 1972 marked the first direct reference to "sustainability in higher education." Namely, in recognizing the inseparability of humanity and the environment, the Stockholm Declaration suggested several ways of achieving environmental "sustainability" (Alshuwaikhat, H. M., & Abubakar, I., 2008), including the following statement:

> A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences. Through ignorance or indifference, we can do massive and irreversible harm to the earthly environment on which our life and well-being depend. Conversely, through fuller knowledge and wiser action, we

can achieve for ourselves and our posterity a better life in an environment more in keeping with human needs and hopes.

Stated another way, in the aggregate, the ability of humans to live more sustainable lives in more sustainable settlements depends on better education. Accordingly, at the Stockholm Conference, Education was recognized one of the most important factors in “fostering environmental protection and conservation” (Lozano, R., Ceulemans, K., Alonso-Almeida, M., Huisingh, D., Lozano, F. J., Waas, T., Hugé, J., 2015). Approximately twenty years later, the Talloires Declaration, drafted in 1990 with more than 500 signatories from more than 40 countries, became the first official statement supported by university administrators of a commitment to environmental sustainability in higher education (University Leaders for a Sustainable Future, 1990). The non-binding ten points from that declaration cover the education, research, involvement, and collaboration on environmental issues in higher education. The objectives of Talloires declaration demand a broad scale changes in universities rather than isolated implementation of plans (Bekessy et al., 2007). In the same year, the U.S. Environmental Protection Agency (EPA) financed a research group at Tufts University's Environmental Center known as Tufts CLEAN! (Cooperation, Learning, and Environmental Awareness Now!) in order to reduce the environmental impacts from the university's own operations (Creighton, S. H, 1998). The Tufts team studied important issues like food waste, transportation, energy efficiency, and procurement practices to develop recommendations for several departments (Creighton, S. H, 1998).

In another example, more than 680 universities signed the American College and University Presidents' Climate Commitment (AUPCC) agreement which invites participating institutions to reduce greenhouse gas emissions (Agdas, D., Srinivasan, R. S., Frost, K., & Masters, F. J., 2015, p. 16).

Among more recent attempts to introduce the sustainable environment in higher education, the U.S Environmental Protection Agency in an issue of *Enforcement Alert* states that "colleges and universities are required to comply with all applicable environmental requirements like their counterparts in the industry to create a safe haven for human health and environment" (EPA document:300-N-00-012). *Fundamental Change to Resource Conservation and Recovery Act (RCRA) regulation in higher education*, proposed by the Campus Safety and Health Environmental Management Association (CSHEMA) suggests one possible policy for meeting the EPA regulations which consisted of reinterpretation, exemption or changes to existing regulations (Savely, S. M., Carson, A. I., & Delclos, G. L., 2007).

The current that underlies all of the preceding examples is that "sustainability in higher education" is evidently a broader concept than simply incorporating "sustainability" into classroom curricula. More specifically, while there is a robust and valuable literature on "education for sustainability" (see, for example: Cortese, A., 1999; Junyent, M., & Ciurana, A., 2008; Sterling, S., 2010), institutions of higher education also have the power to *practice* sustainability. Practice adds an observable and authentic dimension to the ways in which universities educate students and the pubic on important environmental issues. Indeed, universities can serve as models and test cases for programs and practices that could be scaled to the level of a whole human settlement, such as a neighborhood, multi-site corporation, or even a municipality. As Alshuwaikhat, H. M., and Abubakar (2008) observe, “universities can be compared to complex buildings and even small cities.” Peter Viebahn, the author of *Osnabruck Environmental Management Model for Universities* states that 334 different universities in Germany with regard to their consumption of energy and materials are comparable to large commercial concerns as well (Viebahn, P., 2002). Creighton (1990) believes that universities and colleges' use of electricity, oil, natural gas, water, and chemicals is significant and can cover the largest use in the community where they are located.

Agdas et al. (2015) suggest that “University campuses [therefore] are an excellent study set to assess the design and enforcement of sustainability and energy efficiency policies” (Agdas, D. et al., P. 16). Furthermore, institutions like universities are examples of public sector buildings owners from whom is expected a commitment to the future well-being of the surrounding communities (Pullen, S., 2000) or as an example of special social responsibility (Viebahn, P., 2002).

It is possible to consider higher education facilities in the Commercial Buildings Electricity Consumption Survey (CBECS) published by the U.S. Energy Information Administration (EIA) where the data for expenditure and consumption in commercial buildings reflects (partially) the energy consumption of facilities in higher education as well. The EIA’s survey on consumption offers an established base line which will be used to compare Texas State University energy consumption to the national standard of energy usage based on different parameters such as square footage, year of construction and climate of region. Also, CBECS survey will be used to assign principal activity of buildings (Table 5) despite the fact that in some cases such as LBJ Center it cannot represent the exact activity of the buildings. This is because several buildings on campus have a mix combination of offices, classrooms, halls, conference rooms, and food services.

The issue of campus sustainability has been subject to intensified scrutiny by governmental agencies and university stakeholders (Alshuwaikhat, H. M., & Abubakar, I., 2008). Brian McCall, chancellor of the Texas State University System (TSUS), during the Board of Regents of TSUS held in August 19, 2011 states the crucial impact of an articulated plan on environmental issues:

> Our administrators are not the only ones who will be aware of the environmental impact of water usage, temperature controls, insulation, and greener construction going forward. Our environmental performance will be increasingly scrutinized by the media, the public at large and our students. And, well it should! Therefore, I ask that each university president develop a detailed, campus-specific plan of action to improve environmental efficiencies (Sustainable Stewardship, Actions to improve campus energy efficiency, Presented by Sheri Lara, Former Director of Utilities Operations at Texas State University).

A university that is eager to promote sustainability on its campus should have clear vision and the commitment to sustainability. In addition, according to Alshuwaikhat and Abubakar (2008) the university should establish an organizational structure providing resources to achieve the sustainability vision which is mentioned in other sustainability plans such as Energy Management System or ISO 14001[1] as well.

However, just as environmental issues are complex and multidimensional, approaches to reduce the consumption of resources must be multifaceted and multiscalar. Not surprisingly, such complex strategies are passed over by most universities in favor of simpler tactics (Alshuwaikhat, H. M., & Abubakar, I., 2008). Furthermore, building energy efficiency is a complicated process influenced by various operational and design characteristics (Agdas et al., 2015). Despite these difficulties some researchers have tried to give a definition to the sustainability in higher education. Velazquez et al. (2006) state:

> A higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or a global level, the minimization of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles (Velazquez, L., Munguia, N., Platt, A., & Taddei, J., 2006).

Alshuwaikhat, H. M., and Abubakar (2008), offer their definition of sustainable campus as:

[1] ISO 14001 (1996) is a standard which enables organizations to develop policy and objectives taking into account legislative requirements and information about significant environmental impacts. This standard has been revised in 2004 and 2015.

> A healthy campus environment, with a prosperous economy through energy and resource conservation, waste reduction and an efficient environmental management promoting equity and social justice in its affairs and export these values at community, national and global levels (Alshuwaikhat, H. M., & Abubakar, I., 2008).

The conception of sustainability is subject to many different and conflicting interpretations (Weaver, R., 2015), which might not correspond to the social and political values (Portney, K. E., 2015). Perhaps the most common definition of sustainability comes from the World Commission on Environment and Development, when in 1987 states that “the need of present should not compromise the ability of future generation to meet their own needs” (WCED 1987:39). As stated by Portney (2015), this definition “provides a convenient point of departure for a broad understanding of this fairly abstract concept” (Portney, K. E., 2015, p.4). On the other hand, the economic aspect of sustainability has been always the inseparable part of any definition. Daly and Cobb (1989) are among those researchers who challenged the concept of economic growth based on human-built capital (Norton, B. G., 2005). Daly and Cobb in *For the Common Good* (1989), suggest the concept of “natural capital” which should be accessible for the future generation; an interpretation in harmony with the WCED definition and used to compare strong and weak sense of sustainability by Daly and Cobb (Norton, 2005). The skeptics have questioned whether it is possible to achieve sustainability with a significant positive economic growth. Jack Harich has a similar approach asking the same question: “how can we properly couple the ecological and economic systems, by finding and implementing the right policies to keep environmental impact at a sustainable level?" (Harich, J, 2010, p. 36). Kent E. Portney might have an answer to this question: He highlights the 8 years of Obama administration as an exception when policies regulated the carbon emissions under the Clean Air Act and Energy Efficiency and Conservation Block grant program (Portney, K. E., 2015). The 44th President of the United States provides an answer to the question regarding the relation between sustainability and economic growth in his latest intervention published in Science magazine:

> The United States is showing that GHG mitigation need not conflict with economic growth. Rather, it can boost efficiency, productivity, and innovation. Since 2008, the United States has experienced the first sustained period of rapid GHG emissions reductions and simultaneous economic growth on record (Obama, B., 2017).

Sustainability plans in higher education

As of 2011, there were more than 30 sustainability programs in higher education signed by over 1400 universities worldwide (Grindsted, T. S., 2011). Despite implementation difficulties, the declarations have influenced universities' decision making processes in different ways (Clarke, A., & Kouri, R., 2009). Clarke and Kouri state that the sustainability declarations in higher education are important because they form the basis for the formulation of individual sustainability policies at universities (Grindsted, T. S., 2011).

The Association for the Advancement of Sustainability in Higher Education (AASHE) website revealed that the best operational practices in energy efficiency are consistent across universities (Agdas, D., et al., 2015). These practices include temperature set-points for Heating, Ventilation and Air Conditioning **(**HVAC) systems, multiple/individual zones for controls, assigning individual responsibilities for saving energy, etc. Leadership in Energy and Environmental Design (LEED) as a rating system certification appears to be the most prominent design related guideline; although, according to Agdas et al. (2015) "the certification guidelines are not necessarily devised to serve this purpose" (Agdas, D., et al., 2015, p. 16).

As an emerging university, Universitas Indonesia (UI), developed an online green ranking tool for world universities, based on environmental indicators (Suwartha, N., & Sari, R. F., 2013). The UI ranking program is the prototype to make a global ranking of universities' sustainable behavior (Grindsted, T. S., 2011). The UI GreenMetrics Ranking, launched in 2010, is designed to be suitable for universities in both developed and developing countries but some important indicators and criteria might not be addressed properly (Suwartha, N., & Sari, R. F., 2013). The UI GreenMetrics Ranking tried also to introduce the carbon footprint to the ranking process, providing universities with a more significant approach in combating the global warming. In 2013, 301 universities from 61 countries participated in the study, a 40 % increase form 2012.

Table 1. The 2013 ranking of UI GreenMetrics with the best 3 ranked universities.

University	Score
University of Nottingham (UK)	7,521
University College Cork National University of Ireland	7,328
Northeastern University (USA)	7,170

Three sustainability approaches have been highlighted by Alshuwaikhat, H. M., and Abubakar (2008): (1) Green building initiative, (2) ISO 14001 and (3) European Eco-Management and Audit Scheme (EMAS). The green building initiative aims to enable a series of projects to reduce the production of waste and hazardous materials, reduce level of energy consumption and promotes the energy efficient design (Alshuwaikhat, H. M., and Abubakar, 2008). ISO 14001 standard applies a regular auditing in addition of implementing environmental goals, policies, and responsibilities (Alshuwaikhat, H. M., and Abubakar, 2008). EMAS developed in 1993 catches the attention especially in the German-speaking countries (Steger, U. 2000). This sustainable approach with a declining rate of adoption, appears more demanding, more difficult to implement, and must correspond to environmental declarations which has been highlighted as a weakness (Alshuwaikhat, H. M., and Abubakar, 2008; Steger, U. 2000). Also, EMAS is the base of Osnabruck model which will be discussed in the next pages. In addition, several energy improvement programs exist to promote the energy efficiency. The most famous, *Energy Star*, is created by EPA. The adoption of Leadership in Energy & Environmental Design (LEED) is the most famous certification for energy savings even though it is not necessarily a design criterion, but benchmarks for building design and operation compared to other baselines such as CBECS for performance of buildings. According to

Agdas et al. (2015) “LEED rating system is the most widely accepted and adopted Building Rating System (BRS) in the U.S. with a total of over 44,000 registered and certified buildings since 2001” (p. 16). However, the research has shown that the mean Electricity Utilization Index (EUI) of the LEED buildings was significantly larger (331.20 kBtu/sf/yr) than non-LEED buildings (222.70 kBtu/sf/yr) even though the median EUI were comparable (EUI_{LEED}= 172.64 and $EUI_{non\text{-}LEED}$= 178.16) (Agdas, D., et al., 2015, p. 16).

Energy Management System (EMS), another sustainable approach, reflects some standardized points of ISO 14001 highlighted in the study of Savely et al. (2007), known as 16 Environmental Elements which can be used as a check list to have a complete control on environmental matters inside a higher education institution:

- An environmental policy,
- The Identification of environmental activities that may affect the environment,
- The development of environmental programs with objectives and targets,
- The use of procedure to identify legal requirements applicable to environmental issues,
- Assigning responsibilities for environmental matters to specific individuals,
- Reporting environmental performance issues to top management on a routine basis,
- Training individuals whose actions may have an impact on the environment,

- Maintaining documentation regarding internal and external communications about environmental matters,
- Creating a system to ensure that personnel are working with the most current version of environmental procedures,
- Having environmental emergency preparedness and response procedures in place,
- Monitoring and measuring operations that could have an environmental impact,
- Having procedures in place to correct any environmental non-conformances,
- Having procedures in place to manage and store environmental records,
- Conducting routine internal audits of the environmental program,
- Conducting routine third party audits of the environmental program, and
- Holding a periodic review of the environmental program by upper institutional management (Savely et al., 2007).

The Osnabruck environmental management model for universities is based on the Environmental Management and Auditing Scheme Directive of the European Union. This model corresponds in many aspects (except six points) to the standardizations of ISO 14001 (Savely et al., 2007). The Osnabruck model was created on ten different blocks of buildings and measures and provided the University of Osnabruck with a scheme to follow for the final introduction and continuation of an environmental model applicable to all universities (Viebahn, P., 2002).

Zhao, H., and Magoulès, F. (2012) provide a review on prediction applications on building's energy consumption: One of the approaches in assessing the energy efficiency is the statistical regression model. This approach simply correlates the energy consumption or energy index with the influencing variables (Zhao, H & Magoulès, F., 2012). Several characteristics of statistical approach are highlighted by Zhao, H., and Magoulès, F (2012):

> The first is to predict the energy usage over simplified variables such as one or several weather parameters. The second is to predict some useful energy index. The third one is to estimate important parameters of energy usage, such as total heat loss coefficient, total heat capacity and gain factor, which are useful in analyzing thermal behavior of building or sub-level systems.

Also, there are several artificial intelligence methods in the application of building energy consumption such as Artificial Neural Network (ANNs) and Support Vector Machines (SVMs) (Zhao, H., & Magoulès, F., 2012). In the past twenty years, researchers have applied ANNs to analyze various types of building energy consumption in a variety of conditions, such as heating/cooling load, electricity consumption, sub-level components operation and optimization, estimation of usage parameters (Zhao, H., & Magoulès, F., 2012).

The prediction of building energy consumption has attracted much attention from the research community (Zhao, H., & Magoulès, F., 2012) despite the fact that a large number of calculations are needed to evaluate the building energy system, from sub-system level, covered in Pullen (2000) to building level and even regional or national level.

The prediction of energy consumption can contribute to draw the base line of an energy efficiency assessment. If there is no intention to use an energy consumption prediction tool, researchers can provide their baseline comparing surveys such as CBECS to the actual energy consumption of a building where the level of inaccuracy increases with higher square footage and building main activity, especially where buildings such as LBJ center at Texas State University are subject to a multiple use.

Another important study conducted by Dixon and McMordie (1995) was prepared for the U.S. Department of Energy (DOE) in order to facilitate energy-efficiency improvements at federal facilities. Dixon and McMordie reviewed eight different assessment methods for energy efficiency in buildings comparing the scope, strength, and limitations of eight different tools:

- Renewables and Energy Efficiency Planning (REEP)
- Facility Energy Decision Screening (FEDS)-Level 1
- Facility Energy Decision Screening (FEDS)-Level 2
- Systems Engineering and Management Corporation (Systems Corp.) Manual Audit
- XenCAPTM
- Federal Lighting Energy Expert (FLEX)
- Lighting Technology Screening Matrix (LTSM)
- Green Lights Program.

To improve the energy efficiency in the university environment, some recommended renovation-related activities include: Lighting system upgrades, window film installation to minimize the absorption of heat, occupancy sensors to turning on/off the lighting system or other automated systems, optimization of parking garage, office equipment power management, and improving occupant behavior (Kozman, T. A., Aulds, B. N., & Lee, J., 2011). However, the study of Kozman et al. (2011) is limited to consider solutions that have a rapid simple payback period (SPP) of about one year or less:

$$\text{SPP} = \text{cost to make the change / energy cost savings per year} \qquad (1)$$

While the energy efficiency assessment for Texas State University that occurs in this research will be based on a financial approach—for reasons discussed below—the necessity to become more involved in environmental issues should not be exclusively conducted by financial arguments. This is because universities make a significant contribution to the development of the society, and have a special social responsibility about the sustainable protection of the environment and the use of resources (Viebahn, P., 2002). That is why even a gradual change in universities might not be considered as an appropriate response, given the role of universities in society (Bekessy et al., 2007).

Other studies may consider exclusively the material which has been used to construct a building like the study of Pullen (2000) where *embodied energy* becomes a factor which shows the energy consumed by all the processes associated with the production of a building, from the mining and processing of natural resources to manufacturing, transport, and product delivery (Costanza, R. 1980). Per Suwartha, N., & Sari, R. F. (2013) only a few institutions have measured their effort and rated the university's performance. Green League 2007 is one of the examples which shows the environmental performance of Britain's universities including the percentage of energy purchased from renewable sources, percentage of waste recycled, and CO_2 emissions for each institution (Green League, 2007). The other example is given by Environmental and Social Responsibility (ESR) index.

Building energy performance

Zhao and Magoulès (2012) identified numerous factors related to the building energy performance:

> The energy behavior of a building is influenced by many factors, such as weather conditions, especially the dry-bulb temperature, the building construction and thermal property of the physical materials used, the occupancy and their behavior, sub-level components such as lighting, HVAC systems, their performance and schedules (Zhao, H., and Magoulès, F. 2012).

In Europe, buildings account for 40% of total energy use and 36% of total CO_2 emission (Zhao, H., & Magoulès, F. 2012). Therefore, prediction of energy use in commercial buildings becomes significant and one of the indicators of energy performance to improve environmental impact. Buildings were estimated to be responsible for 35% to 45% of the global annual energy consumption in 2010 (Boza-Kiss, B., Moles-Grueso, S., & Urge-Vorsatz, D., 2013).

The green building definition varies from one university to another and from one region to another based on many factors like climate and primary use. This definition generally includes plans to decrease production of waste and hazardous material, reduce level of energy consumption and promotes the energy efficient buildings (Alshuwaikhat, H. M., & Abubakar, I., 2008). The green building concept also promotes the use of local materials in order to avoid the transportation costs and pollution (Alshuwaikhat, H. M., & Abubakar, I., 2008). Another concept which brought the topic of energy efficiency into the attention was the adoption of Building Rating System (BRS) with their promise on improved energy efficiency (Agdas et al., 2015).

Prior to studying the factor of building and how it can affect the energy efficiency assessment we need to establish a baseline for current conditions of buildings in higher education. *State of Facilities in Higher Education* report (2014), published by *Sightlines,* documents two major trends regarding the construction of new space in higher education system, termed as *waves of construction*. There were three waves of construction in the United States: In order of importance, the 1960-70s building boom occurred when almost 40% of current university spaces was constructed in an era with high demand for universities which caused the low quality in mechanical systems that managed building environmental conditions. Therefore, many of these spaces, even if renovated, will not meet today's needs and standards. The second wave consists of buildings constructed after 1995 to now known as *Millennial Expansion* with 30% of all buildings in national scale. The pre-war era is the first wave in chronological order of construction.

II. SUSTAINABILITY PARAMETERS FOR ENERGY ASSESSMENT

There are several parameters or sustainability criteria used to calculate the environmental impact of a facility, such as greenhouse gas emissions, energy consumption, resource depletion, land degradation, and financial implications (Pullen, S, 2000). Regarding the role of universities, Viebahn states that the environmental pollution occurs in all parts of facilities inside any university from laboratories to administration offices. A significant reduction on pollution can be achieved by a "systematic implementation of organizational and technical measures" (Viebahn, P, 2002).

Per Pérez-Lombard et al. (2008) the growing world energy use is at the center of attention especially with its implications over supply difficulties, unstable prices, and heavy environmental impacts such as global warming (Pérez-Lombard, L., Ortiz, J., & Pout, C., 2008). The data on energy consumption trends produced by International Energy Agency shows that during the two decades (1984–2004) primary energy usage has grown by 49% and CO_2 emissions by 43%, with an average annual increase of 2% and 1.8% respectively (Pérez-Lombard et al., 2008). In an updated information published by International Energy Agency there will be 30% of increase in energy demand, mostly from developing countries (World Energy Outlook, 2016). Also, according to the 2016 World Energy Outlook there will be a 50% of growth in demand for natural gas overtaking coal in the global energy mix as well.

Signs of change in global energy have multiplied in the 12 months since the publication of World Energy Outlook in 2014(WEO, 2015). The impact of climate change has been underlined in a white paper called *Energy Efficiency: A Tool for Climate Change Adaptation*:

> Climate change is already making the United States hotter, and much greater temperature increases are expected in the coming decades. Along with increasing temperatures, precipitation patterns are shifting, extreme weather events such as storms and droughts are increasing, and sea levels are rising (Goldman, S., Ungar, L., Capanna, S., & Simchak, T., 2012).

The question is whether the climate change can impact the use of energy and vice versa. In a simplistic point of view, hotter summers and colder winters cause higher energy demand especially with increased peak electricity consumption for air conditioning. Even the water supply can be affected by weather condition since it is the main material used in cooling systems (Goldman et al., 2012). Richard S.J. Tol states that "one cannot have cheap energy without carbon dioxide emission" (Tol, R. S. J., 2009, p. 29). On the other hand, per the U.S. Energy Information Administration (EIA) only in 2015 about 67% of the electricity generated was from fossil fuels such as coal, natural gas, and petroleum. In the same year emissions of carbon dioxide (CO_2) by the U.S. electric power sector were 1,925 million metric tons, or about 37% of the total U.S. energy-related CO_2 emissions of 5,271 million metric tons (EIA, 2015). Globally, the emissions of carbon dioxide have increased by almost 50% since 1990 and emissions grew more quickly between 2000 and 2010 than in each of the three previous decades (Sustainable Development Goals, United Nation). The sources of greenhouse gas emissions can be found everywhere, from homes to big industrial companies. The American electric-power sector is the largest source of GHG emissions in the United

States economy (Obama, B., 2017). The former President of the United State in his recent article, *The Irreversible Momentum of Clean Energy*, states that the total energy consumption in 2015 was 2.5% lower than it was in 2008 with the economy 10% larger (Obama, B., 2017). According to *Enerdata*, the amount of reduction reaches 3.5% comparing the same range of time reflected in figure 1. The total energy consumption in the United States drops from 2278 Mtoe[2] to 2196 Mtoe (Global Energy Statistical Yearbook, 2016). This amount of reduction in energy consumption would have a significant drop in pollutants production. This information proves that the government of the United States has shown its commitment to a sustainable reduction of GHG emissions simultaneous with an economic growth in the past 8 years when "CO_2 emissions from the energy sector fell by 9.5% from 2008 to 2015, while the economy grew by more than 10%" (Obama, B., 2017, p.1). Nevertheless, climate change caused basically by growing rates of energy production and consumption do not respect national borders and affect people and environment everywhere. Hence, the environmental commitment of only one country or a few of them is not sufficient to reduce the fast environmental degradation. To overcome this drawback, the Paris Agreement with more than 110 cosigner countries representing more than 75% of global emissions is a serious promise to reduce emissions globally (Obama, B., 2017). However, per the International Energy Agency even if nations are abiding by Paris Agreement[3] pledges, energy sector CO_2 emissions are not on track for a 2 °C reduction as a target scenario and to achieve this goal the energy sector

[2] Million tonnes of oil equivalent

[3] Paris Agreement on climate change has entered into force in November 2016. As mentioned in 2016 World Energy Outlook, this agreement is about energy consumption since different sources (included in the literature review) show the main cause of degrading conditions on climate change are driven from a high-energy consumption.

"must be carbon-neutral by 2100" (World Energy Outlook, 2016). The path to 2°C is achievable only if policies aim to accelerate further low carbon technologies and energy efficiency must be applied in all sectors.

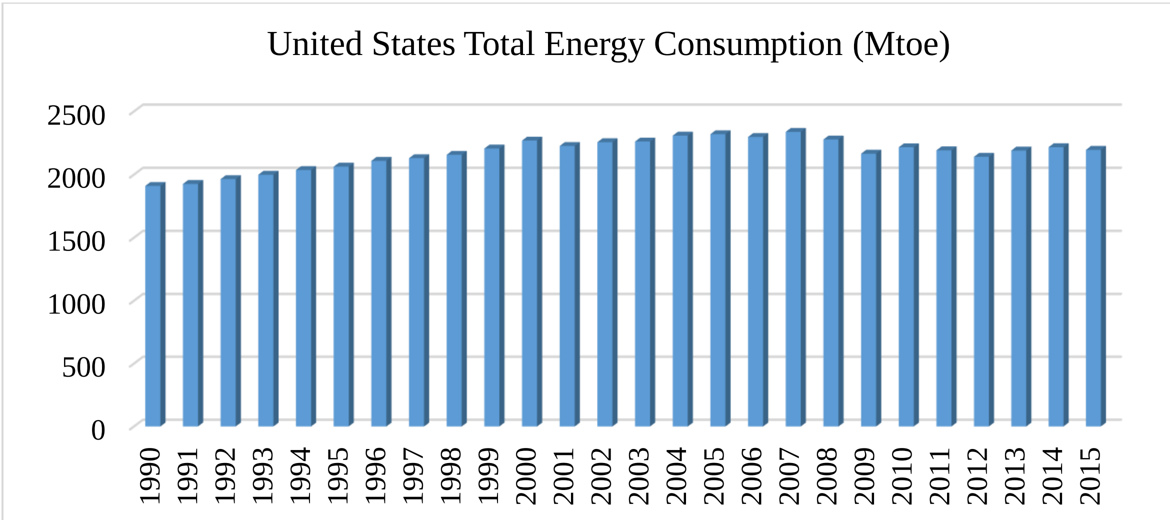


Figure 1. United States total energy consumption (Mtoe), Data Source: *Enerdata*

Table 2. CO_2 emissions from U.S. electric power sector by source, 2015. Source: EIA

Source	Million metric tons	Share of total
Coal	1,364	71%
Natural gas	530	28%
Petroleum	24	1%
Other	7	<1%
Total	1, 925	100%

In addition, the latest World Energy Outlook states that:

> Policy preferences for lower carbon energy options are reinforced by trends in costs, as oil and gas gradually become more expensive to extract while the costs of renewables and of more efficient end-use technologies continue to fall (WEO, 2015).

In the local context of the study area for this project (see the next chapter), the southern part of the United States produced significant portion of the nation's fossil fuels in 2007 and the region rich in petroleum and fossil fuels supplied 48% of the nation's energy resources in the same year. The South accounted for 43% of the nation's total energy consumption in 2006 (Brown, M. A., Gumerman, E., Sun, X., Baek, Y., Wang, J., Cortes, R., & Soumonni, D., 2010).

It might be possible to reduce the fossil fuel consumption by reducing the electricity usage through a more appropriate energy usage. Energy is the central challenge the world is facing today. According to the Sustainable Development Goals (2015), a sustainable and modern energy should be affordable for all and sustainable energy is opportunity and can transform lives, economies and the planet.

The surge of interest in energy efficiency measures pushed policymakers to ask how much wasted energy can be eliminated by expanding investments in cost-effective technologies and practices (Brown, M. A. et al., 2010). Even though the study of Brown et al. is focused on residential and commercial buildings and industry (RCI), it is still meaningful in case of higher education. As mentioned in previous paragraphs campuses can be considered like small cities containing plants for distributing energy and buildings with high rate of energy consumption comparable with commercial buildings.

Brown et al (2010) summarized their findings on energy efficiency in the southern United States as such:

1. Aggressive energy-efficiency initiatives in the South could prevent energy consumption in the RCI sectors from growing over the next twenty years and in absence of such initiatives, energy consumption in these three sectors is forecast to grow by approximately 16% between 2010 and 2030.

2. Fewer new power plants would be needed with a commitment to energy efficiency. The nine policies (illustrated in Brown et al. (2010)) can avoid the need to construct 49 GW of new plants to meet a growing electricity demand from the RCI sectors.

3. Increased investments in cost-effective energy efficiency would generate jobs and cut utility bills. The cost/benefit ratios for the modeled policies range from 4.6 to 0.3, with only two showing costs greater than benefits. When the value of saved CO_2 is included, only one policy is not cost effective.

4. Energy efficiency would result in significant water savings since water is the main material used in cooling systems.

There has been an emphasis on energy consumption as one of the principal parameters for assessing environmental performance of a facility highlighted by activities of the Australian Greenhouse Office (1999), the Australian Building Energy Council, the Australian Building Codes Board (1999) and the proposal to incorporate minimum energy efficiency requirements in the building codes (Pullen, 2000).

According to *Sightlines' The State of Sustainability in Higher Education* report (2015) a significant number of universities mobilized to offer leadership in climate change contributing to Carbon Commitment featuring the carbon management hierarchy to tackle best practices in reducing greenhouse gases emissions. Intergovernmental Panel on Climate Change (IPCC) in its 2014 report emphasizes the role of reduction in building energy use which lowers greenhouse gas emissions and reduces the global warming trends. The first point in the Summary for Policymakers included in the final report of IPCC 2014 states that:

> Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural system.

Based on previous paragraphs it is essential to apply a significant energy reduction in campuses to enhance the environmental commitment of universities. improving energy efficiency is the key to reducing GHG emissions (Saidur, R., 2010). One of the ways to attain the more-efficient use of final energy in an industry is to determine the amount of energy used and energy losses (Saidur, R., 2010) which will be covered in the next chapters through different types of energy efficiency plans.

Enrollment, space, and energy

There are several facts highlighted by *Sightlines* report (2015) regarding the relationship between space and enrollment. Texas and Utah are two states with a continuous increase in high school enrollment caused by migration and immigration. Public campuses in Texas are often overcrowded. The enrollment has increased by 8%

between 2007 and 2011 and "since 2011 enrollment has flattened out and by 2013 and 2014 the rate of growth was in decline". However, the average of space for each student or member has continued to grow; since 2007 campuses have increased the average space by 10%, but now only have 7% more students (The state of facilities in higher education, Sightlines report, 2015).

Texas State University in the past 18 years has recorded a steady growth in the numbers of students and enrollment. According to the Texas State University Office of Institutional Research, the quantity of enrollments for the fall semester increased from 27,485 in 2006 to 38,808 in 2016. Registering a gradual growth in the university enrollment does not necessarily mean a higher level of energy consumption. But, continued and significant growth together with infrastructure modifications and new constructions with a 5.7% net increase in gross square feet during the past four years demand an extensive energy conservation and information plan to achieve energy savings opportunity.

Due to the dramatic global environmental state, many universities around the world have decided to subscribe to different sustainable development plans regardless to the number of their members. The University of Osnabruck with 14000 members in 2002 is an example of environmental commitment by assuming a special social responsibility providing a road map to the future decision makers (Viebahn, P., 2002).

Sightlines provides another useful fact by looking at the amount of space per student over time. Public and private universities have gradually added more space per student from 2007 to 2014. Public campuses have 350 gross square feet/student; private campuses have 600 gross square feet per student. However, "the bottom line is that campuses are getting less dense; overall, they have more space for their students than ever before".

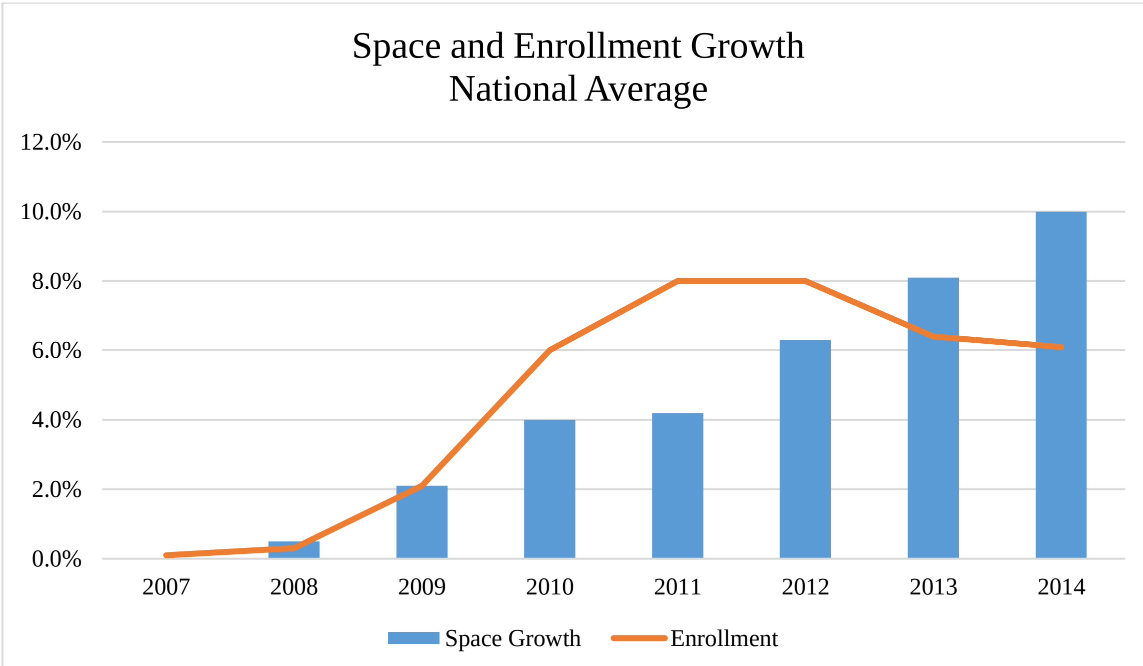


Figure 2. Space and enrollment growth national average. Source: Sightlines *State of Facilities in Higher Education* report, 2015.

Studies have shown that many institutions are re-evaluating their campus space through financial analysis with an eye towards creating greater efficiencies and cost savings (Sightlines, State of Facilities in Higher Education report, 2015). One example is the University of Maine System. In a January 3, 2014 report, the system noted that "the current multi-year financial analysis indicates the University of Maine System has more space than it can afford to sustain and annual facility assessments have documented that the facility portfolio continues to age and grow more costly". Because of this evaluation, the System has adopted policies to reduce the total square footage of their campuses (Sightlines *State of Facilities in Higher Education* report 2015).

Saving money

Large institutions like universities, as well as most businesses, agree that reducing emissions in addition to the significant improvement of environment “can boost bottom lines, cut costs for consumers, and deliver returns for shareholders” (Obama, B., 2017). Following these details, the Obama Presidential administration introduced energy efficiency standards that are projected to cut more than 10.4 billion tons of carbon pollution over the next 15 years in the United States (Obama, B., 2017).

This policy development aligns with the concept of rational use of energy which aims at reducing energy use and corresponds to the optimum use of all limited economic resources (Saidur, R., 2010). The consumption of energy covers a great portion of budget spending in university environment. At Texas State University, a huge portion of cost is driven from electricity. The CoGeneration Power and Chiller Plant which is in charge with providing energy for more than 80 facilities (Table 7) has consumed 62,269,842 kWh (212,527 MMBtu[4]) of electricity in the billing period between April 2015 and April 2016 which covers more than 75% of the cost for energy (Figure4). In financial terms, this means $5,146,463.39 with an average cost of $0.0826/kWh. This is while electricity covers only 36.5% of use percentage and natural gas consumption constitutes 63.5% of total use percentage with an average price of $4.3749/MCF[5] (Figure 3 and 4).

[4] Million British Thermal Unit
[5] Thousand Cubic feet of Natural Gas

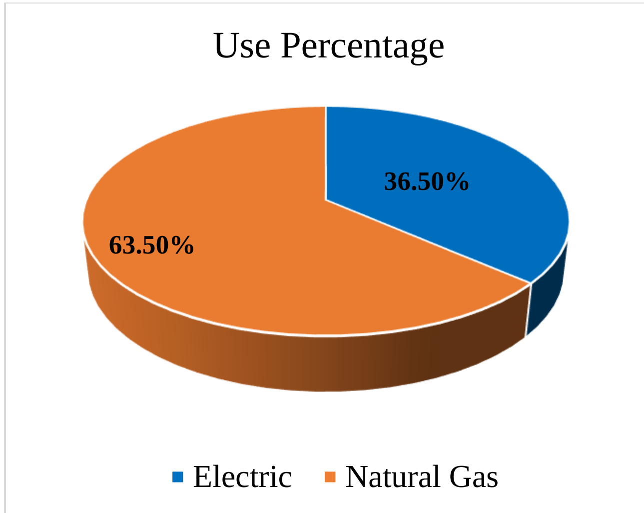


Figure 3. Use percentage of energy at Central Plant (CoGeneration Plant)

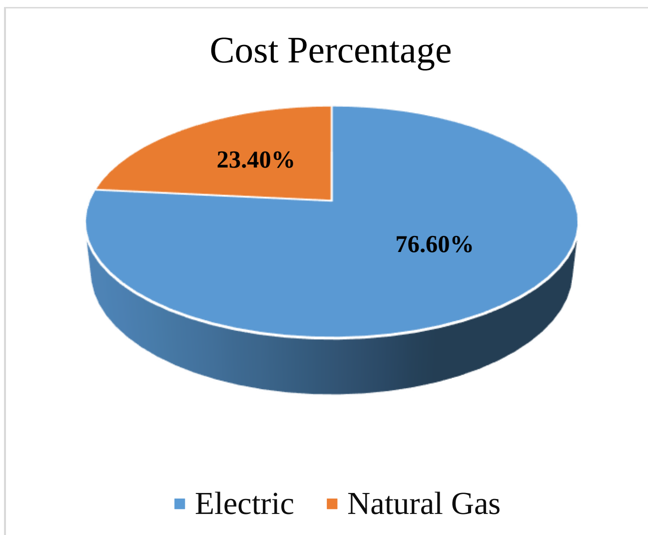


Figure 4. Cost percentage of energy at Central Plant (CoGeneration Plant)

The predominance of electricity consumption (and cost) is verifiable in other universities besides the proportion, year of construction, and other factors. The city West campus of the University of South Australia on North Terrace, Adelaide is another example provided by the study of Pullen (2000) where eight buildings over four levels with a floor area of approximately 30,000m^2 rely their primary source of energy on electricity with a very small amount of reticulated gas (Pullen,S, 2000). The annual averages were converted to primary energy by means of factors of 1.22 for gas and 3.12 for electricity (Dept. of Mines & Energy, 1994) (Pullen, S, 2000).

Many universities are spending more than needed on energy. According to Kozman et al. (2011) this fact has also been observed at the University of Louisiana at Lafayette where cutting back on energy usage was a practical way of saving the university money (Kozman et al., 2011). Per Viebahn if the University of Osnabruck were to reduce its energy consumption by just 20% it could save 500,000 Demand Management (DM) in energy costs every year.

The U.S. Energy Information Administration (EIA) states that in 2015 about 67% of the electricity generated was from fossil fuels such as coal, natural gas, and petroleum. All these types of fuels are directly correlated to the greenhouse gas emissions. The World Energy Outlook in 2015 states that the price of oil and gas production are increasing since operators must move to smaller, more remote or more challenging reservoirs. World Energy Outlook (2015) states that:

> By contrast, cost reductions are the norm for more efficient equipment and appliances, as well as for wind power and solar PV, where technology gains are proceeding apace and there are plentiful suitable sites for their deployment (WEO, 2015).

It is recognizable that energy efficiency projects can save money but as stated by former President of the United States "it also has the potential to create jobs that pay well" (Obama, B., 2017). 2.2 million Americans are employed in design, installation, and manufacture of energy-efficiency products and services compared to 1.1 million Americans employed in the production of fossil fuels used to produce electric power (Obama, B., 2017).

In conclusion, it is important to remember that environmental protection and commitment should be the responsibility of all university members, as part of the society, whilst at work or in the classrooms and when travelling to and from the University (Guidelines for Environmental Protection for the University of Osnabruck). Also, Creighton (1998) states that the biggest lesson from Tufts CLEAN! is that the elimination of negative impacts of universities on environment would not be possible without the personal involvement of staff (Creighton, S. H, 1998).

Summary

After reviewing what has been done in case of energy efficiency with a relative focus on the United States, it is noticeable that some of approaches have been considered and included in the previous energy efficiency plans at Texas State University. The most recent is offered by EEA, Consulting Engineers report (2012) which consisted of finding energy saving opportunity in the selected buildings at Texas State University with a higher energy consumption.

In energy efficiency assessment at Texas State University, the most recent opportunities have been carefully planned to update the possibilities of reducing energy consumption with a more articulated financial approach including factors like net present value (NPV), internal rate of returns (IRR), annual annuity and CO_2 reduction projection and the relative cost saving for each project.

III. IMPLEMENTATION CHALLENGES

Most scientists concur that organizations, industries and governments must adapt sustainable practices to prevent further degradation of the environment (Ralph, M and Stubbs, W., 2014). Although universities are recognized for their important role in societal changes, in the main they have not been successful in achieving institutional scale “sustainable” changes (Ralph, M and Stubbs, W., 2014).

One potential reason for this outcome is that many sustainability-related initiatives in higher education are established within non-binding declarations. Crucially, signing a declaration and participating in sustainable partnerships will not lead necessarily to a successful environmental commitment (Lozano et al., 2015; Bekessy et al., 2007; Wright, 2004). Royal Melbourne Institute of Technology (RMIT) University is one of the examples of failure to achieve progress despite being a leader in signing declarations and developing policy (Bekessy et al., 2007). The barriers to integrate sustainability into universities are mainly internal (Ralph, M and Stubbs, W., 2014). Financial limitations are one of the most known reasons for not including sustainability in universities master plans. Particularly, long term savings of projects are not accounted in budget modeling (Ralph, M and Stubbs, W., 2014). Hence, the energy efficiency assessment at Texas State University is focused on demonstrating the potential long term savings included in each project.

Bekessy et al. have stated in different cases that the support of university leaders is essential to achieve sustainability even though this commitment has failed to be materialized in most universities (Bekessy et al., 2007). The authors of *The failure of* *non-binding declarations to achieve university sustainability* argue that “while small-scale action by interest groups is valuable, it is not in itself sufficient to lead to the adoption of sustainability in mainstream business of the university” (Bekessy et al., 2007, p.302). On the other hand, “signing key declarations is a concrete demonstration of commitment from universities and an excellent vehicle to create publicity for the move” (Bekessy et al., 2007). In 2007, 12 years after the initiation of sustainability program at RMIT it has been clear that the university was not able to meet adequately its commitment towards sustainability (Bekessy et al., 2007). It is a clear evidence of inefficiency of isolated implementation of projects despite the adequate attention they receive individually.

The non-binding declarations usually fail to force repercussions after failure in implementation of sustainability plans. One of the other applied program at RMIT was Greening RMIT (1998-2004) based “on the premise that institutional change for sustainability requires direct cultural change” (Bekessy et al., 2007, p.309). The effectiveness of this program in creating a “systemic change” was limited in the opinion of Bekessy et al. (2007) and led to the closure of the organization. This is where the problem of “proper coupling” presented in Jack Harich paper (2010) can be introduced: The author of *Change resistance as the crux of the environmental sustainability problem* states:

> Proper coupling occurs when the behavior of one system affects the behavior of other systems in a desirable manner, using the appropriate feedback loops, so the systems work together in harmony in accordance with design objectives. For example, if you never got hungry you would

> starve to death. You would be improperly coupled to the world around you. In the environmental sustainability problem, the human system has become improperly coupled to the greater system it lives within: the environment (Harich, J, 2010).

Harich reviews some of the suggested proper coupling since 60th to recent years: Garrett Hardin in *The Tragedy of The Commons* (1968) discussing the privatization, polluter pays, and regulation, Ostrom (1990), introducing the eight design principles for community-based resources management, The U.S National Research Council in *The Drama of the Common* (2002) with the significance associated to the word “institutions”, and IPCC report in 2007 by suggesting climate policies. In all these cases “proper coupling is seen as the problem to solve” while considering the problem from another perspective can lead to another paradigm which is change resistance as the real problem to solve (Harich, J, 2010). For universities to address sustainability, there is a need to connect research, administrative practices, and education (Ralph, M and Stubbs, W., 2014). The integration of sustainability demands “a third wave of sustainability” focusing on teaching and learning (Wals, A. E., & Blewitt, J., 2010). Ralph and Stubbs suggest 5 characteristics for an integrated sustainability plan in universities:

- Leadership and vision that expresses commitment to, and promotes, sustainability;
- Incorporation of the concepts and practices of sustainability into the teaching and research of all academic disciplines;

- An emphasis on fostering the inter-and trans-disciplinary teaching and research needed to provide solutions to sustainability challenges;
- Recognition of the ecological footprint of the institution, together with sustainable policies and practices in operations, support and services that minimize this footprint
- Engaging in community outreach that enhances environmental sustainability (Ralph, M., and Stubbs, W., 2014).

Leadership and engagement of the university could replace funding policies in the qualitative research conducted by Ralph and Stubbs (2014). Furthermore, the latter study shows that a clear leadership is needed in prioritizing interdisciplinary collaboration to provide skills and knowledge to which is critical to the success of integrating environmental sustainability (Ralph, M., and Stubbs, W., 2014).

Top down and ground up approach

Research suggests that a ground up approach, marked by the absence of strong administration, is not necessarily the end of sustainability in universities (Bekessy et al., 2007). However, Bekessy et al. argue that the problem of sustainability cannot be addressed through a “club of interested members”:

> relying on small-scale “club” activities establishing demonstrations and raising awareness is unlikely to lead to permanent, systemic change. The evidence of RMIT’s engagement with sustainability shows that even when successful pilot studies are conducted, these initiatives may do little

> to affect the mainstream practices of a university unless certain conditions exist (Bekessy et al., 2007, p.313).

Despite the growing rate of integration of sustainability education at universities it is questionable whether changes have been occurred simultaneously (Elliot, H., Wright, T., 2013). Possible barriers to achieve campus sustainability were summarized by Elliot and Wright (2013) as “misunderstanding or lack of shared vision, a lack of sustainability champion, a lack of financial resources or competing priorities” while “attitudes and cultural models can negatively impact campus sustainability” (Elliot, H., Wright, T., 2013 p. 2-4).

Another barrier relates to the high rate of specialization among academics, which lead to the lack of collaboration between different disciplines (Ralph, M., and Stubbs, W., 2014). Multidisciplinary approach is not still very common in most universities which was detected in Australian and English universities (Ralph, M., and Stubbs, W., 2014). Furthermore, academic staff “saw having to integrate environmental sustainability as a threat to their academic freedom, and as not relevant to their discipline (Ralph, M., and Stubbs, W., 2014) supporting previous studies (Noonan and Thomas 2004; Nicolaides 2006; Hopkinson et al. 2008; Justice et al. 2009). As shown in Ralph and Stubbs study, a high degree of integration of environmental sustainability demands coordination among all university activities from sustainability research through a sustainability institute to the university government commitment.

IV. STUDY AREA AND STUDY CONTEXT

As stated above, one university that has shown a strong public commitment to sustainability is Texas State University (Texas State University Plan 2012-2017; see "Mission and Goals"). Furthermore, the State of Texas Senate Bill 898 mandates that certain political subdivisions and institutions—including Texas State University—reduce electrical consumption throughout the university by at least 5% each year for 10 years, beginning September 1, 2011 (Figure 5). Participant entities must submit annual reports to the Texas State Energy Conservation Office (SECO) regarding their progress and efforts to meet the 5% goal to reduce electrical consumption. Crucially, however, SB 898 states that any "political subdivision, institutions of higher education or state agency that does not attain the goals established "must provide justification" in their report to SECO. The burden is on the entity to establish that non-attainment occurred after all cost-effective measures were taken (SB 898 [emphasis added]). For the purpose of this thesis, the foregoing clause has at least one crucial implications. Above all, it provides a mechanism for institutions (e.g., Texas State University) to avoid compliance with the legislatively mandated energy reduction *without penalty*. That is, institutions need not meet the mandated 5% per annum reduction in electrical consumption if they offer evidence that further action toward such ends would create cost burdens.

With that in mind, recent technical reports show that Texas State University has been decreasing its energy consumption by retrofitting buildings, upgrading equipment, and constructing new buildings based on LEED criteria (Table 5) (Texas State University, Fiscal Year 2016 Energy Conservation Accomplishments for Senate Bill 898 report, 2016). Moreover, the University did attain the legislatively mandated 5%

reduction in electrical consumption for the first four years following passage of SB 898—from 2012 to 2015. However, in the most recent fiscal year, 2016, natural gas consumption increased by 3.1%, even though the University's total square footage footprint decreased from 7,763,457 to 7,719,991 (equal to -0.5%) (Table 4). The increase of gas consumption is mainly caused by the need of producing more steam used for heating and distributing hot water in cold days. The decrease in square footage was the result of several demolitions of old buildings and dorms around campus. CoGeneration Center increased its kWh consumption by 6.8% from 2015 to 2016 (Figure 7). This percentage is significant since it includes almost 4 million kWh of increase based on the previous year (2015).

A potential weakness of the Senate Bill is given by its limitation on electrical consumption. Gas consumption constitutes a significant portion of usage at Texas State University by 63.5% as the total consumption of Central Plant in 2015. With that in mind, the Senate Bill 898 is a response to a required energy efficiency program which might be better to address other sources of energy consumption such as natural gas and water.

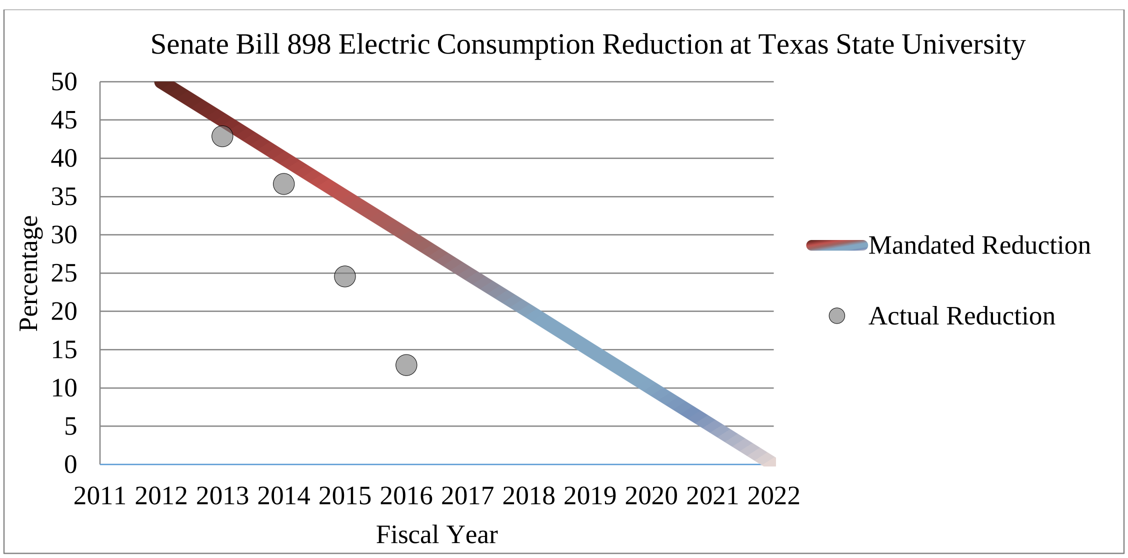


Figure 5. Senate Bill 898 Goals

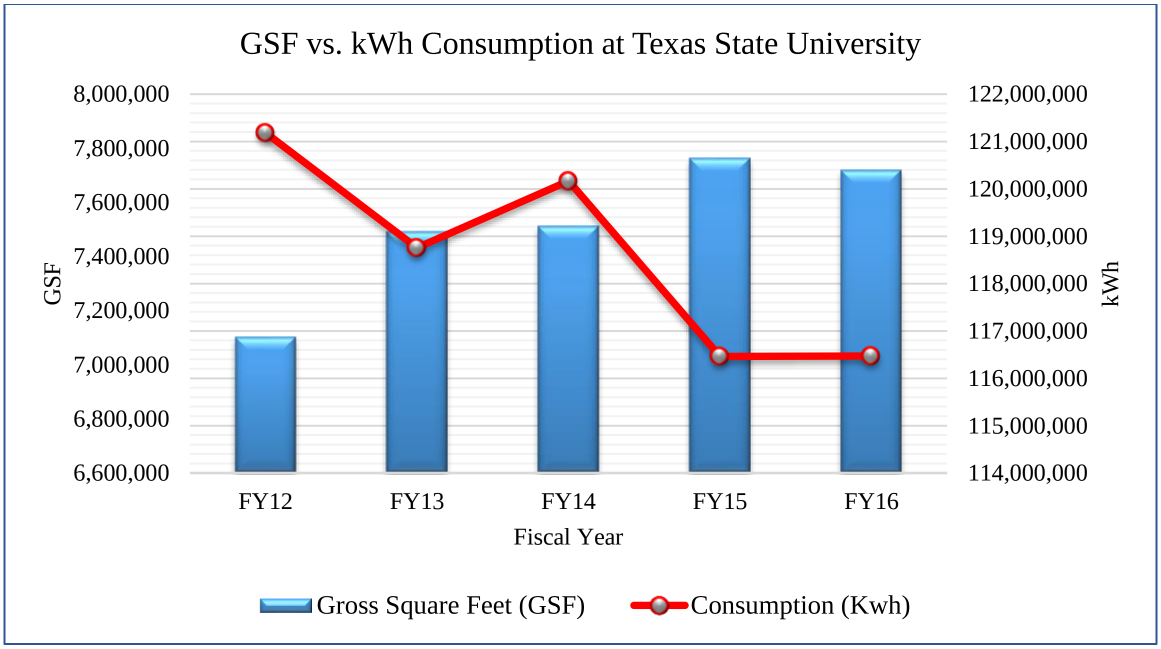


Figure 6. GSF vs. kWh consumption at Texas State University

Table 3. Electric consumption based on fiscal year and savings at Texas State University

	Gross Square Feet (GSF)	Consumption (kWh)	Consumption Per Sq.ft (EUI)	Percentage Savings
FY12	7,102,422	121,184,231	17.062	Base Year
FY13	7,493,405	118,753,429	15.848	**-7.119**
FY14	7,513,016	120,167,425	15.995	**-6.258**
FY15	7,763,457	116,461,145	15.001	**-12.080**
FY16	7,719,991	116,468,027	15.087	**-11.580**

Table 4. Gas consumption based on fiscal year and savings at Texas State University

	Square Feet	Consumption (MCF)	Consumption (BTU)	Consumption MCF/ Sq.ft	Consumption BTUs/ Sq.ft	% Saving
FY12	7,102,422	397,994	405,953,880,000	0.056	57,157	Base Year
FY13	7,493,405	355,812	362,928,240,000	0.047	48,433	**-15.263**
FY14	7,513,016	388,788	396,563,760,000	0.052	52,784	**-7.652**
FY15	7,763,457	411,137	419,360,026,519	0.053	54,017	**-5.494**
FY16	7,719,991	424,003	432,482,630,414	0.055	56,021	**-1.987**

Total electricity consumed by 13 facilities selected for this study (Table 5) reaches 80,180,457 kWh in 2015 which is equivalent to the energy consumed by 7,334 homes[6]. One of these facilities, Central Plant (CoGeneration), is in charge with providing energy (cooling, heating) for 84 buildings (Table 7). Hence, it is appropriate to look at the year of construction of those buildings since the literature on energy consumption suggests that the year of construction is one of the important factors in energy efficiency assessment (Table 5 and Figure 8). Texas State University contains 457 acres in the main San Marcos campus (20.5 million square feet) and 266 main buildings with 7.6 million GSF in different places. Electricity consumption constitutes 76% of all energy cost on campus and the remaining 24% belongs to the natural gas[7]. The primary building activity (classroom, labs, residential, office, and health care) has been considered in the process of sampling in order to select a significant variety of buildings and determine the baseline of Energy Utilization Index

[6] This is based on the average annual electricity usage of a US single-family home equal to 10,932 kWh determined by the 2014 Average Monthly Bill-Residential EIA Data.

[7] According to the EnergyCAP (application used for reading energy consumption), the consumption period at Texas State University is based on readings from April 2015 to April 2016.

(EUI)[8]. This approach will provide the possibility of conducting a comparison between the Commercial Buildings Energy Consumption Survey (CBECS 2012)[9] and actual energy consumption of each building. The entire square footage of buildings surveyed totals approximately 1,777,000. Seven of these buildings are used for educational purposes and cover 959,743 square feet. Table 5 shows some characteristics of the building sample.

[8] The Energy Utilization Index determines the amount of energy used based on a square foot.

[9] Commercial Buildings Energy Consumption Survey is provided by U.S Energy Information Administration. This is a national sample survey that collects information on energy usage including consumption and expenditures. Tables C21 and C14 have been used to determine the baseline of electricity consumption at Texas State University.

Table 5. Sample buildings with annual energy consumption

Building Name	Year of Construction/Renovation	Principal Building Activity/CBECS Category	Sq. Ft	kW/hr 2014-2015
Alkek Library	1990/2003/2016	Education	313,581	3,154,484
JC Kellam	1969/1973	Office	209,521	1,842,136
LBJ Student Center	1978/1997	Mix	221,001	2,171,532
Jowers Center	1978/1996	Education	144,516	1,685,760
McCoy Hall	2006	Education	127,370	691,518
Evans Liberal Arts	1938	Education	111,179	689,123
Student Health Center	2004	Health Care	26,361	239,140
Roy F. Mitte	2003	Education	152,449	3,339,883
San Jacinto Hall	2004	Residential	138,543	865,159
Student Rec Center	1994	-	163,337	684,039
Supple Science	1991	Education	110,648	174,000
Central Plant	1961/1987	Industrial	46,626	62,269,842
East Chiller Plant	1969	Industrial	12,020	2,373,841

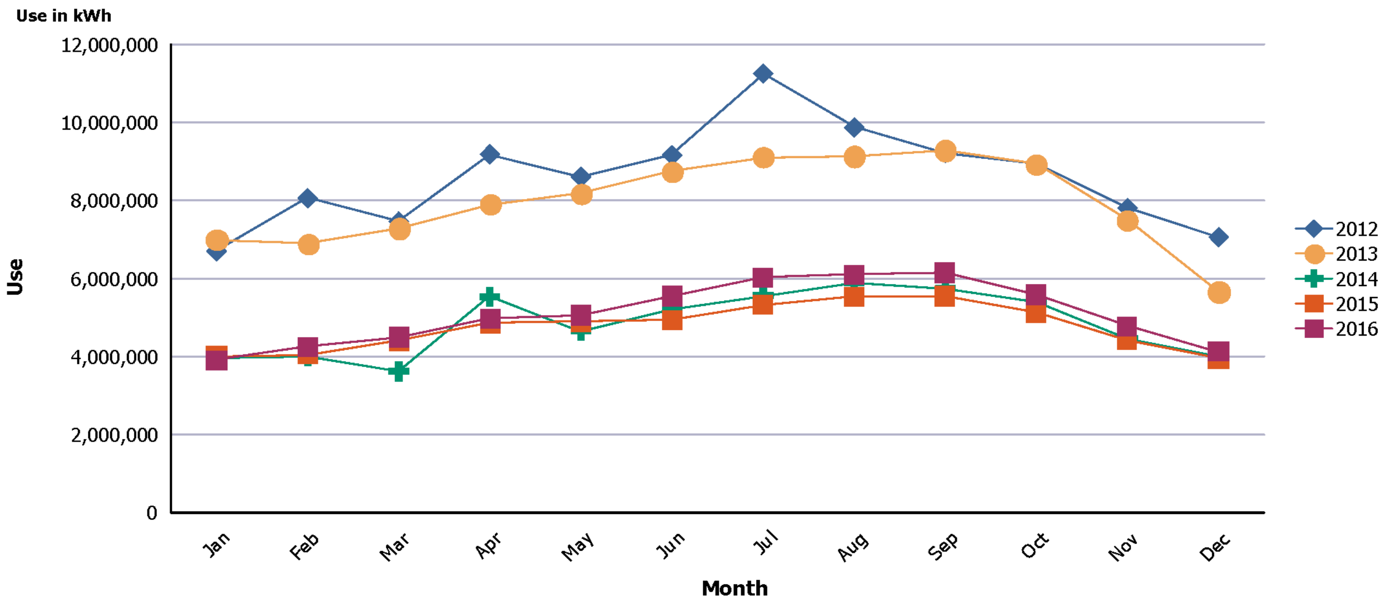
An Electricity Utilization Index (EUI) comparison is calculated based on Energy Information Administration survey of 2012 (released in May 2016). The numbers for CBECS EUI come from table C21-Electricity Consumption and Conditional Energy Intensity by Building Size, retrieved from Commercial Buildings Energy Consumption Survey of 2012 (CBECS). Based on table C21, most Texas State University sample buildings are showing a good EUI, indicating a relatively contained electrical consumption. However, CBECS numbers are calculated based on units with more than 100,000 square feet. Therefore, the result is more accurate for buildings falling in this range of size such as Evans Liberal Arts and Supple Science.

Table C14 form CBECS contains units with more than 100,000 Sq/ft which is more accurate for calculating the energy consumption of bigger buildings. However, this table does not include the factor of Principal Building Activity. Further research is needed to improve the accuracy of the calculations for Public Use Micro Data of CBECS. Moreover, it is necessary to find a method to calculate the energy consumption in buildings with a mix combination of offices, classrooms, halls, conference rooms, and food services (such as LBJ Student Center) since CBECS does not include a category for these buildings. A summary of electricity consumption is presented in table 6. It is important to consider the difference between EUI provided in table 2 and 3 where there is no reference to the main activity of buildings and table 6 where the main activity has been considered even though the size conflicts with the accuracy.

Table 6. Sample building baseline comparison between CBECS EUI and actual EUI

Building Name	Electricity Cost (2014-2015)	% of Total Electricity Consumed Based on the Sample Size	EUI(kW/hr)	CBECS EUI Based on Square Feet (table C14 of CBECS)	CBECS's EUI by Building Size and Activity (Table C21)	CBECS's EUI by the Year of Construction (Table C21)
Alkek Library	$252,358.72	3.93%	10	17	10,8	17,8
JC Kellam	$147,370.88	2.30%	9	17	19,4	16,4
LBJ Student Center	$173,722.56	2.71%	10	17	NA	NA
Jowers Center	$134,860.80	2.10%	12	15	10,8	18,1
McCoy Hall	$55,321.44	0.86%	5	15	10,8	18,5
Evans Liberal Arts	$55,129.84	0.86%	6	15	10,8	13,1
Student Health Center	$19,131.20	0.30%	9	11	24,1	12,4
Roy F. Mitte	$267,190.64	4.17%	22	15	10,8	16,2
San Jacinto Hall	$69,212.72	1.08%	6	15	15	18,5
Student Rec Center	$54,723.12	0.85%	4	15	20	17,8
Supple Science	$13,920.00	0.22%	2	15	10,8	17,8
Central Plant	$4,981,587.36	77.66%	1,336*	12	NA	NA
East Chiller Plant	$189,907.28	2.96%	197.49*	11.7	17.1	12.6

*Not significant since it belongs to industrial section



Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
2012	6,701,404	8,058,308	7,467,330	9,185,795	8,602,727	9,162,222	11,256,120	9,868,913	9,214,294	8,927,633	7,806,675	7,062,119	103,313,540
2013	6,987,488	6,895,869	7,287,094	7,901,913	8,178,075	8,742,618	9,106,397	9,134,432	9,280,644	8,936,697	7,493,469	5,658,150	95,602,846
2014	3,955,200	4,013,232	3,624,605	5,534,218	4,658,620	5,225,251	5,564,755	5,902,071	5,745,245	5,389,344	4,453,584	4,010,573	58,076,698
2015	4,017,955	4,056,547	4,416,691	4,862,564	4,887,830	4,936,330	5,336,140	5,532,365	5,548,636	5,136,460	4,432,992	3,953,808	57,118,318
2016	3,915,754	4,259,021	4,493,606	4,974,336	5,058,730	5,551,142	6,032,688	6,106,176	6,147,965	5,584,454	4,786,272	4,124,736	61,034,880
Totals	25,577,801	27,282,977	27,289,326	32,458,826	31,385,982	33,617,563	37,296,100	36,543,957	35,936,784	33,974,588	28,972,992	24,809,386	375,146,282

Figure 7. CoGeneration Plant kWh usage. Source: EnergyCap application

Table 7. Facilities on CoGeneration (Central Plant) meters at Texas State University

Name	Year	GSF	Name	Year	GSF
OLD MAIN	1902	38,880	FAMILY AND CONSUMER SCIENCES	1968	54,223
LAMPASAS	1912	24,886	EAST CHILLER PLANT	1969	12,02
PSYCHOLOGY	1018	39,142	JC KELLAM ADMINISTRATION	1969	209,521
CENTENNIAL HALL	1926	106,964	CHILD DEVELOPMENT CENTER	1970	15,294
HINES ACADEMIC CENTER	1938	33,336	COLORADO	1970	5,280
EVANS LIBERAL ARTS	1939	109,905	THEATRE CENTER	1970	57,932
FLOWERS HALL	1939	82,637	AQUA SPORTS CENTER	1971	25,573
BERETTA HALL	1946	22,868	THE TOWER	1971	103,203
BRAZOS	1951	10,534	THE TOWE PARKING GARAGE	1971	117,438
BROGDON HALL	1951	30,388	AGRICULTURE	1972	63,579
COMMONS HALL	1951	44,541	DERRICK HALL	1972	89,904
HORNSBY HALL	1951	13,650	MEDINA	1974	2,455
TAYLOR-MURPHY HISTORY	1951	27,574	ACADEMIC SERVICES BUILDING NORTH	1977	33,991
CANYON HALL	1952	10,013	ACADEMIC SERVICES BUILDING SOUTH	1977	46,302
BEXAR HALL	1955	45,390	COLLEGE OF EDUCATION	1977	91,173
HILL HOUSE	1956	5,537	SABINAL	1977	12,320
LAUREL HALL	1956	31,682	MATH COMPUTER SCIENCE	1982	39,960
MUSIC	1956	74,048	FREEMAN AQUATIC BIOLOGY	1983	29,400
RETAMA HALL	1956	31,682	CHEMISTRY	1985	51,000
BURLESON HALL	1958	13,521	BLANCO HALL	1987	193,155
SMITH HALL 1	1958	9,456	BLANCO PARKING GARAGE	1987	89,743
SMITH HALL 2	1958	10,357	COGENERATION PLANT (CENTRAL PLANT	1987	45,531
SMITH HALL 3	1958	9,456	HARRIS DINING HALL	1987	49,000
PECOS	1959	10,800	ALKEK LIBRARY	1990	313,581
PEDERNALES	1959	5,163	ALKEK PARKING GARAGE	1990	79,802
TRINITY	1959	11,165	JEROME & CATHERINE SUPPLE SCIENCE	1991	107,526
ARNOLD HALL A 1962	1962	11,484	HEALTH PROFESSIONS	1992	92,463
ARNOLD HALL ADMINISTRATION	1962	6,221	STUDENT RECREATION CENTER	1994	163,337
ARNOLD HALL B	1962	14,184	LBJ PARKING GARAGE	1997	184,477
ARNOLD HALL C	1962	11,820	LBJ CENTER	1997	221,001
LANTANA HALL	1962	53,926	PLEASANT STREET PARKING GARAGE	1998	113,300
NUECES	1962	38,220	SAN MARCOS HALL	2002	119,024
ELLIOT HALL A	1963	15,510	SAN MARCOS HALL PARKING GARAGE	2002	127,000
ELLIOT HALL ADMINISTARTON	1963	7,180	JOANN COLE MITTE	2003	122,334
ELLIOT HALL B	1963	14,603	ROY F. MITTE	2003	152,449
BUTLER HALL	1965	49,687	SAN JACINTO HALL	2004	138,543
JONES DINING COMPLEX	1965	42,533	STUDENT HEALTH CENTER	2004	26,361
COLLEGE INN	1966	77,381	WOODS STREET PARKING GARAGE	2004	152,112
PRESIDENT'S HOUSE	1966	5,448	EMMETT & MIRIAM MCCOY HALL	2005	127,370
JACKSON HALL	1967	93,171	WEST CAMPUS STORAGE BUILDING	2007	1,100
JACKSON MECHANICAL BUILDING	1967	2,079	MATHEWS STREET PARKING GARAGE	2010	325,008
STERRY HALL	1967	89,862	UNDERGRADUATE ACADEMIC CENTER	2012	130,455

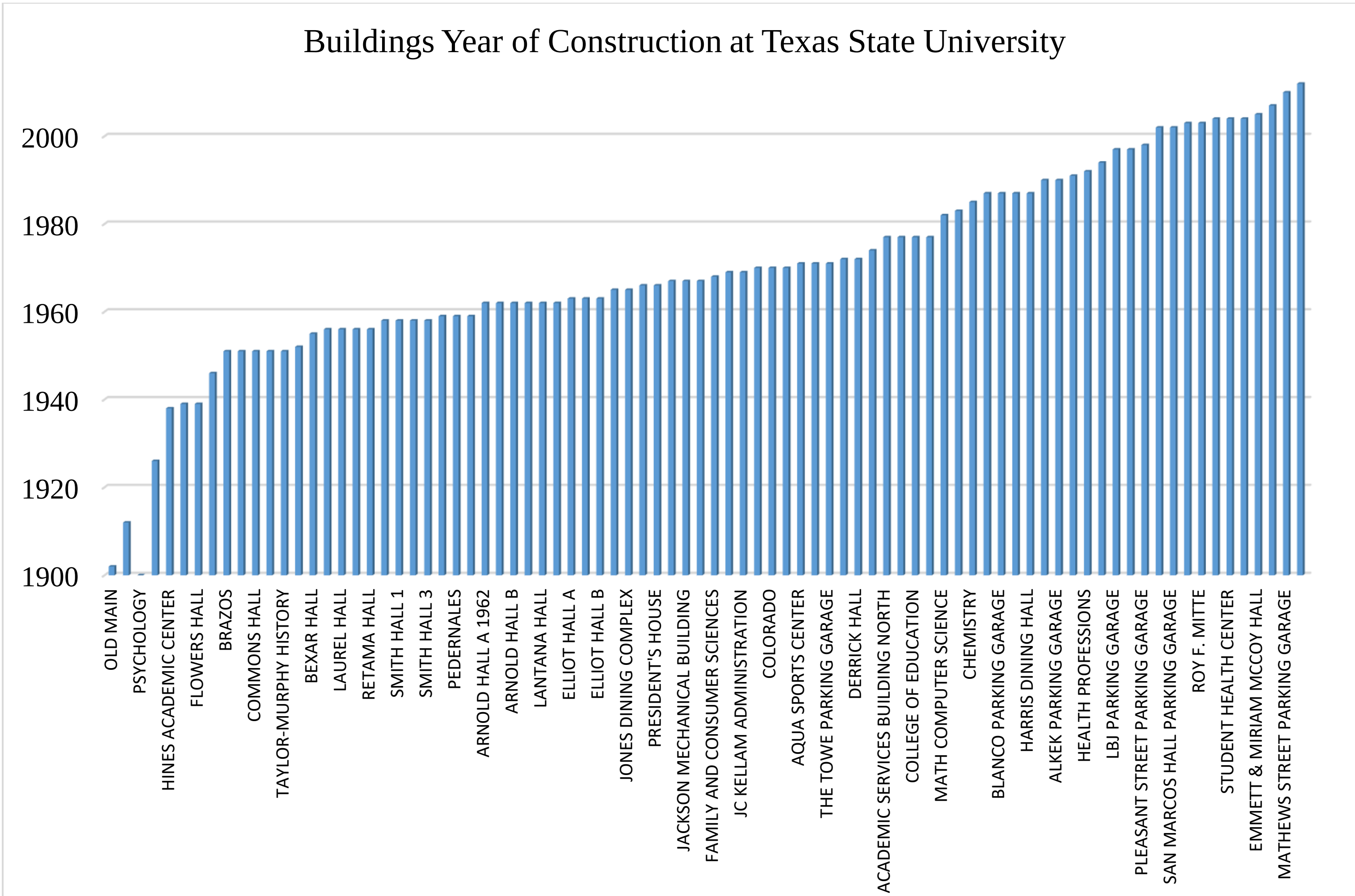


Figure 8. Year of construction range at Texas State University

V. METHODOLOGY

As noted above, the sample for the energy assessment in this study includes thirteen buildings across the Texas State University main campus that have a higher than average level of electricity consumption and energy cost (Table 5). Eight out of these thirteen buildings have been inspected for energy consumption by *EEA Consulting Engineers* with respective estimated cost in 2012 (Table 8). The intent of 2012 energy audit conducted by EEA was to identify potential energy conservation (Energy Audit Implementation Summary, 2012).

Table 8. Selected buildings by EEA for energy audit with respective cost in 2012

Building Name	Estimated Cost
Alkek Library	$139,657
Evans Liberal Arts	$311,762
Health Center	$49,745
J.C Kellam Administration	$98,945
Supple Science	56,371
Roy F. Mitte	$273,818
Jowers Center	332,866
McCoy Hall	$57,378

Cash flow, free cash flow, and discounted cash flow

Although there are many barriers to achieve a more sustainable university, the use of positive and demonstrable financial savings can encourage decision makers to overcome difficulties (Elliot, H., Wright, T., 2013). The energy efficiency assessment at

Texas State University is based on a financial-economic approach. A financial analysis aims to provide the information needed to propose the best options in order to reduce the energy consumption. This method must determine the level of attractiveness of investing in a new technology like replacing compact fluorescent lamps (CFL) with light emitting diodes (LED) in terms of money savings in a yearly basis (simple payback) or longer period like more than 20 years in the case of solar panel installation (cash flow model).

"There are many ways to define cash flow and free cash flow resulting in problems of consistency and comparability" (Mills, J., Bible, L., & Mason, R., 2002, p.37). Most companies and institutions produce the annual *Statement of Cash Flows.* The authors of *Defining free cash flow* (2002) state that since there is no consensus on a unique definition of cash flow and free cash flow, then there is a need to reach this consensus. This becomes important from the time when many analysts and investors use this criterion to assess the attractiveness of investments (Mills, J. et al., 2002). Here, two of these definitions are mentioned from Mills, J et al. (2002): In the equation (3) EBITDA stands for Earnings before interest, taxes, depreciation, and amortization.

$$\text{Cash Flow} = \text{Net Profit} + \text{Depreciation} \tag{2}$$

$$\text{Cash Flow} = (\text{EBITDA}) \tag{3}$$

Also, the authors of *Defining free cash flow* provided an extensive table of definitions for cash flow taken from different sources:

Table 9. Cash flow definition in different sources. Source: Mills, J., Bible, L., & Mason, R., 2002

Station Casino	EBITDA plus operating leases
Accounting for Dummies	Net income plus depreciation, plus or minus changes in short-term operating assets and liabilities
Barron's Accounting Handbook	Net income plus non-cash charges (such as depreciation) plus or minus changes in accounts receivable, inventory, repaid expenses, accounts payable, and accrued liabilities
Financial Accounting: An Introduction to Concepts, Methods, and Uses	Net income plus depreciation, depletion, and amortization
Handbook of Common Stocks	Net income plus non-cash depreciation charges less preferred dividends
Standard and poor's Stock Report	Net income (before extraordinary items and discontinued operations and after preferred dividends) plus depreciation, depletion, and amortization
Forbes Magazine	Net income after taxes but before interest depreciation and rental expense
Harry Domash's Winning Investing	Net income after taxes minus preferred dividends and general partner distributions plus depreciation, depletion, and amortization
Investorama	Net income after taxes plus non-cash charges
Money Magazine	Net income before depreciation, amortization and non-cash charges

Cash flow in the first place is the measure of ability to produce money from an investment. But there are many factors to be subtracted from or added to the investment and this is why we can have different definitions. EBITDA, one of the common definitions for cash flow has several shortcomings. First of all, it ignores many non-cash adjustments and the need to fund working capital changes (Mills, J. et al., 2002).

Free cash flow represents the available cash after meeting all current commitments. The lack of a unique definition applies to FCF as well. Some analysts argue that FCF should represent the availability of cash after subtracting the operations expenses (Mills, J. et al., 2002). Based on International Accounting Standard (IAS 7) (1992) “dividends and mandatory debt payments should not be subtracted to arrive at FCF” (Mills et al., 2002 p.39). There are different definitions for FCF as well. These definitions are presented by Mill, J. et al. (2002) in table 10.

Table 10. Definitions of Free Cash Flow (FCF) according to different sources

Bell Canada	CFO minus investing activities minus dividends
Coca-Cola	CFO less business reinvestments
Gerdau Steel	EBITDA minus debt service cost, minus income taxes incurred and actually paid, minus capital expenditures incurred
Money Magazine	Operating income minus capital expenditures minus change in working capital
Forbes Magazine	Net income plus depreciation and amortization plus or minus working capital adjustments, minus maintenance capital expenditures
Harry Domash's Winning Investing	CFO minus cash paid for property and equipment minus dividends
The Motley Fool	Net income plus depreciation and amortization minus change in working capital plus or minus cash outlay for taxes
Valueline	Net income plus depreciation minus dividends, minus capital expenditures, minus required debt repayments, minus any other scheduled cash outlays
InvestorLinks	Operating cash flow (net income plus, amortization and depreciation) minus capital expenditures minus dividends
Advisors Inner Circle Fund	Net income plus depreciation and amortization minus capital expenditures
Financial Management, Theory and Practice	CFO minus gross investment in operating capital
Financial Accounting: An Introduction to Concepts, Methods, and Users	CFO plus interest expense plus income tax expense

The cash flow model may differ based on the type of analysis (e.g., after tax cash flows, before-tax cash flows, incremental cash flows, etc.). Since Texas State University is part of a public sector governed by Texas State, there is no tax rate included and in all parts of the calculation the value 0 has been considered for tax rate.

A cash flow model can be thought in terms of three different activities performed by a company (Short, W., et al., 2005): (1) operating, (2) investing, and (3) financing. Cash flows from operating activities include all revenues captured, minus operating and maintenance expenses. Cash flows from investments is given by capital expenditure minus expenses and financing cash flows include repayment of debt. The specific type of cash flow studied in this research is a discounted-investing cash flow model (DCF).

Actual cash flows observed in the market are called current dollar cash flows representing the actual number of dollars required in the year the cost is incurred (Short, W., et al., 2005). Constant dollar cash flows stand as F_n. Cash flow in current dollars in year *m* is F_m. In this approach Where *n* stands for base year and *e* stands for a constant inflation we have:

$$F_n = \frac{F_m}{(1+e)^{m-n}} \tag{4}$$

DCF analysis discounts the future cash flows to the expenses to assess the attractiveness of an investment. The basic assumption in DCF is that the value of DCF should be positive and higher than the initial investment discounted to the expenses (6):

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots \frac{CF_n}{(1+r)^n} \tag{5}$$

$$NPV(i, N) = \sum_{t=0}^{n} \frac{CF}{(1+r)^t} - \text{investment} \tag{6}$$

Time value is another important factor which assumes that the value of money possessed today is higher than the value of money made in the next year. This is because the money earned today can be invested as soon as possible to make interest.

$$\mathrm{FV} = \mathrm{PV}\left(1 + \left(\frac{\mathrm{i}}{\mathrm{n}}\right)\right)\hat{}(\mathrm{n} * \mathrm{t}) \tag{7}$$

FV = Future value of money

PV = Present value of money

i = interest rate

n = number of compounding periods per year

t = number of years

The discount rate acts as a measure of time value and central to calculate the present value. Also, the discount rates are often used to account for the risk inherent in an investment (Short, W., et al., 2005). When it comes to assessing the future value of investments, it is common to use the weighted average cost of capital (WACC) as the discount rate (Investopedia). In the case of Texas State University, the discount rate has been fixed for 5% in all projects which is very common in higher education systems. According to Short et al. “real discount rates and dollars cash flows exclude inflation” and nominal discount rates include inflationary effects and they can be calculated by following formula: (Short, W., et al., 2005).

$$(1 + \mathrm{d_n}) = (1 + \mathrm{d_r})(1 + \mathrm{e}) \tag{8}$$

$$d_n = [(1 + d_r)(1 + e)] - 1$$

$$d_r = [(1 + d_n) / (1 + e)] - 1$$

Where:

d_n = nominal discount rate

d_r = discount rate in the absence of inflation(real)

e = inflation rate

The financial analysis is one of the possible ways to answer the crucial question regarding whether failure of universities to meet their commitments on sustainable measures can be blamed on lack of financial resources.

The Internal Rate of Return is another parameter used in this study which basically is given by the rate at which the NPV will be zero (no loss and no profit). IRR should be always greater than Discount rate.

$$0 = \mathrm{N\rho v} = \sum_{n=0}^{N} [F_n \div (1 + d)^n] \tag{9}$$

Where:

NPV = net present value of the capital investment

F_n = cash flows received at time n

d = rate that equates the present value of positive and negative cash flows when used as a discount rate.

As mentioned by Short et al. (2005) “there is no absolute standard as to which costs are included in operation and maintenance costs.” O&M costs can be broken into these following categories:

- Costs during the operation

- Variable O&M costs
- Fixed costs

Energy costs are typically variable costs and labor costs are frequently fixed O&M costs and they tend to increase since the system gets older and more maintenance is required (Short, W., et al., 2005).

Greenhouse gas calculation

In this study, the calculation of emission driven by electricity consumption is based on Scope 2 method. The Scope 2 represents a "policy-neutral, collaborative solution guided by GHG Protocol principles" (GHG Protocol Scope 2 Guidance, 2014). There are two methods included in Scope 2: (1) Location-based method which reflects the average emission intensity of grids[10], calculated by the emission factor provided by the distributer of electricity which in Texas is ERCOT[11] and (2) Market-based method which calculates the emission from electricity distributed from a third party (company). The emission factors in the second method are provided by contract which includes attributes about the energy generation. The new GHG Protocol states that companies shall report both location-based and the market-based method for Scope 2 GHG emissions. The calculation of market-based GHG emission is dependent on the possibility of obtaining market base emission factor. Since it was not possible to gather this information, the first method (location base) has been chosen to calculate the emissions at Texas State University which basically is given from the saved kWh multiplied by the emission factors. Emission factors are fundamental to create and control inventories of GHG emissions and eventually for air quality management. EPA has a specific definition for emission factor:

> An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity

[10] (Emission) & Generation Resources Integrated Database (eGRID)

[11] Electric Reliability Council of Texas

associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average) (from www.EPA.gov retrievable in https://goo.gl/9kI9BS).

Hence, the general equation for emission calculation is:

$$E = A * EF * (1 - ER / 100) \quad (10)$$

Where:

E = emissions

A = activity rate

EF = emission factor

ER = overall emission reduction efficiency

The emission factors for location based calculation are provided by the electricity emission factors on EPA web portal (https://goo.gl/gP8Idw) where table 6 provides the needed factor for CO_2, CH_4, and $N2_O$. The ERCT (ERCOT ALL) emissions are shown in the table 11.

Table 11. Electricity emission factors in Texas

	Total Output Emission Factors			Non-Baseload Emission Factors		
eGRID Subregion	**CO_2 (lb CO_2/MWh)**	**CH_4 (lb CH_4 MWh)**	**N_2O (lb N_2O /MWh)**	**CO_2 (lb C_2/MWh)**	**CH_4 (lb CH_4 MWh)**	**N_2O (lb N_2O /MWh)**
ERCT (ERCOT ALL)	1,143.04	0.0167	0.01233	1,280.59	0.02153	0.01071

So, we have:

$$\text{Scope 2 Emission} = \text{Electricity Consumption (MWh)} * \text{Emission Factor} \quad (11)$$

Lighting system replacement

Recommended illuminance for indoor

Linear fluorescent lighting is the main detected lighting system in many of the surveyed buildings at Texas State University. The T8 bulb with 32 Watts of electricity consumption is the most used type of lamp in the observed areas. Therefore, replacement of T8 bulbs and high pressure sodium with Light Emitting Diodes (LED) is strongly recommended for all the buildings. In the total 1,777,155 square feet of area considered in this study, more than 959,000 sq/ft are dedicated to educational purposes. The majority of lighting systems in these buildings are linear fluorescent systems using T8 bulbs and 32 Watts of electricity consumption. Each fixture contains often two bulbs and in some cases with three lamps such as the area dedicated to food services at LBJ Center. LEDs can provide the same amount of Lumens needed with lower electricity consumption and their expected life in average equals 50,000 hours.

Illuminance is referred as a unit of measurement for the amount of light measured in a plane surface. Illuminance is measured in foot candles (ftcd, fc,fcd) or lux (metric system) in international system of units (SI). A foot candle is equal to one lumen of light per square foot and one lux is one lumen per square meter. The outdoor light level is approximately 1,000. There has been a rapid change in recommended illuminance levels since the 1930s (Mills and Borg, 1999). The needed amount of lumens varies based on the main activity of the space used for lighting, the proximity to the window during the day and the physical properties of the building and office. However, illumination can be calculated as:

$$I = L_I C_u L_{Lf} \,/\, A_I \tag{12}$$

Where:

I = illumination (lux, lumen/m^2)

L_l = lumens per lamp (lumen)

C_u = coefficient of utilization

L_{LF} = light loss factor

Al = area per lamp (m^2)

The assumptions for different usage of space is delivered by the table 12 provided by Environmental Defense Fund. There are different on-line calculators to calculate the needed amount of lumen and many of them reaches the average lumen represented in the last column of Table 12.

Table 12. Average needed lumen for indoor activity (EDF)

Illumination Required (lumen/m2)		
Activity	**Illumination** ***(lux, lumen/m²)***	**Average Lumen**
Public areas with dark surroundings	20 - 50	40
Simple orientation for short visits	50 - 100	75
Working areas where visual tasks are only occasionally performed	100 - 150	125
Warehouses, Homes, Theaters, Archives	150	150
Easy Office Work, Classes	250	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500	500
Supermarkets, Mechanical Workshops, Office Landscapes	750	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000	1000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000	1750
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000	2250
Performance of very prolonged and exacting visual tasks	5000 - 10000	7500
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000	15000

The next important step consists of calculation of fixture number which is given by the next formula:

$$F = L^{*}S_{f} \,/\, MF * UF * L_{f} \qquad (13)$$

Where:

F = required number of fixtures

L = required Lux

S_f = Square feet (converted to square meter in calculations)

MF = maintenance factor

UF = utilization factor

L_f = lumen per fixture (lumen per watt * each fixture watt)

Assumptions and factors

Different studies have considered upgraded lighting system to assess the electricity savings in residential and commercial sections (Mahila et al., 2005; Mahila et al., 2011; Franconi, E., & Rubinstein, F., 1992). "Electricity savings over time is significant enough to not only pay for the new lighting, but also produce return on the investment" (Mahlia, T. M. I., Said, M. F. M., Masjuki, H. H., & Tamjis, M. R., 2005). Normally, each square foot needs 50 lumens for desks and task lighting (Table 12). The Alkek Library building requires almost 7,283,2500 lumens. When accounting for the building's square footage, this means 550 Lumens on average for each square meter. We use the unit Square Meter because the formula is based on this unit of area. An 18 Watts LED bulb can provide sufficient light for four Square Meters. These calculations are based on the fact that LEDs can be installed on linear fluorescent's fixtures. However, it is possible to calculate the cost of new fixtures for LEDs bulbs and ballast as well. If the variable fixture is included in the analysis, the payback period will extend over three years. The ballast price has been introduced to the formula with an average price of $10.00. The assumption is that there is no need to remodel the distance between each fixture.

Table 13 shows all the assumptions and factors needed to run the calculation in Alkek Library. One challenge to consider in this project is represented by the number of bulbs to be delamped and recycled. The current bulbs can be replaced gradually at the end of their lifespan but the expected life of current linear fluorescents bulbs is unknown and will cause a quite variable workflow for the implementation. This problem marks the slow process of energy saving in the case of the gradual removal process. Therefore, there is a need to find a way to dispose the large number of linear fluorescents bulbs installed prior to purchasing LEDs.

Table 13. Factors and assumptions for lighting system (Alkek Library)

Building Details	
Type of Building	Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories
Building Area (sq. meter)	29,133
Type of Lamp	Linear fluorescent system
Power Consumption (Watts)	32
Number of Lamps per Fixture	2
Recommended Number of Fixtures	4848
Annual Operating Time	
Hours of Operation (Hrs./Day)	15
Operating Days per Year	350
Current Lighting	
Light Location	Indoor
Type of Existing Light Technology	T8
Power Consumption (Watts)	32
Total Number of Fixtures	4848
Number of T8 per Fixture	2
Total Number of T8	9696
Proposed Lighting	
Type of Proposed Light Technology	LED
Equivalent Watts of LED	18
Expected Life of LED (Hours)	50000
Actual Useful Life (Years)	10
Savings and Cost Economics	
Number of LED Installed	4247
Number of Lamp Delamped	5,449
Cost of LED	$10.00
Installation Charges ($/ LED)	$0.30
Fixture	No
Ballasts	Yes
Number of LED per Ballast	1
Total Number of Ballasts	4247
Cost of Ballast ($/Ballast)	$10.00
Rebate	
Rebate by kWh ($/kWh)	
Rebate by LED Installed ($/ LED)	
Rebate by T8 Removed ($/Delamped)	
Annual Savings	
Energy Savings per LED ($)	$5.88
Demand Savings per LED ($)	

Table.13 Continued

Project Cash Flow											
Years	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment:											
Capital Outlay	86214										
Savings:											
Energy Savings		99189	100181	101183	102195	103216	104249	105291	106344	107407	108482
Demand Savings		0	0	0	0	0	0	0	0	0	0
Depreciation		8621	8621	8621	8621	8621	8621	8621	8621	8621	8621
Operating Expenses/Savings											
Operating Income		90568	91559	92561	93573	94595	95627	96670	97723	98786	99860
Taxes		0	0	0	0	0	0	0	0	0	0
Net Income		90568	91559	92561	93573	94595	95627	96670	97723	98786	99860
Cash Flows:											
Free Cash Flow	(86214)	99189	100181	101183	102195	103216	104249	105291	106344	107407	108482
Cumulative Cash Flow	(86214)	12975	113156	214338	316533	419749	523998	629289	735633	843041	951522
NPV	$711,905										
IRR	116%										
Payback Period	0.87										
Profitability Ratio	9.26										
Equivalent Annual Annuity	$92,194.92										

Solar panel installation

Much of the recent literature on the “Anthropocene” epoch of history implicates a need to curb large-scale fossil fuel consumption all over the world (e.g., Castree, N., 2016). “Among renewable energy sources, solar energy is the most promising due to its tremendous potential” (Gençer, E., & Agrawal, R., 2016). Indeed, only 1 hour of solar radiation is comparable to the annual global energy consumption (Lewis, N. S., & Nocera, D. G., 2006). Solar power has received a remarkable attention and growth in recent years. Tax incentives[12] have a remarkable role in this process and projections show that solar PV industry continues to experience a significant cost reduction (Comello, S., & Reichelstein, S., 2015).

The solar panel installation at Texas State University has been studied only for a few buildings with a significant flat and even roof. Many of the roofs on Texas State University’s campus have no shadow area and can absorb sunlight for the entire day and panels can point toward the south without any obstacles (best direction). On the other hand, in some cases the roof would not support the additional weight of the panels such as the case of the Central Plant where it is not possible to install additional weight. Usable roofs should be able to support the addition of 5-6 pounds per square foot to avoid substantial construction costs. Furthermore, the average cost of electricity purchased from the local utility is $0.08 per kWh while producing electricity through solar panels costs more. The criteria of converting Direct Current (DC) (produced by panels) to Alternating

[12] The Solar Investment Tax Credit (ITC) is one of the federal policies to support the deployment of solar energy.

Current (AC) has been applied to the calculations. It is necessary to bear in mind that the installation can be a grid-connected system to benefit from Renewable Energy Credit[13] (REC) in the case of excess in electricity production. However, Texas State University does not benefit from any type of rebate (common in other projects) and realization of on-site energy production is currently implausible. The installation of photovoltaic panels depends on many factors. The calculation is based on the Cost of Renewable Energy Spreadsheet Tool (CREST) version 1.4; this is an economic cash flow model created on behalf of the partnership between major energy organization in the U.S[14]. This project has been measured for five buildings. Realizing an on-site electricity production system is the most expensive among all the energy efficiency measures with a $7,434,000 initial investment and the average payback period is 8.5 years. These factors might affect negatively the enthusiasm towards the realization of renewable energy plants. Tariff escalation rate is the projected increase or decrease in the cost of renewable energy in future over the duration of project. It can be between 2 to 5 percent. The generation capacity has been calculated using PV Watts calculator[15], an on-line toolkit provided by National Renewable Energy Laboratory (NREL). It is necessary to bear in mind that the roof tilt and sun azimuth cannot be automatically determined from the aerial imagery and consequently the estimated system capacity may not reflect what is actually possible. The

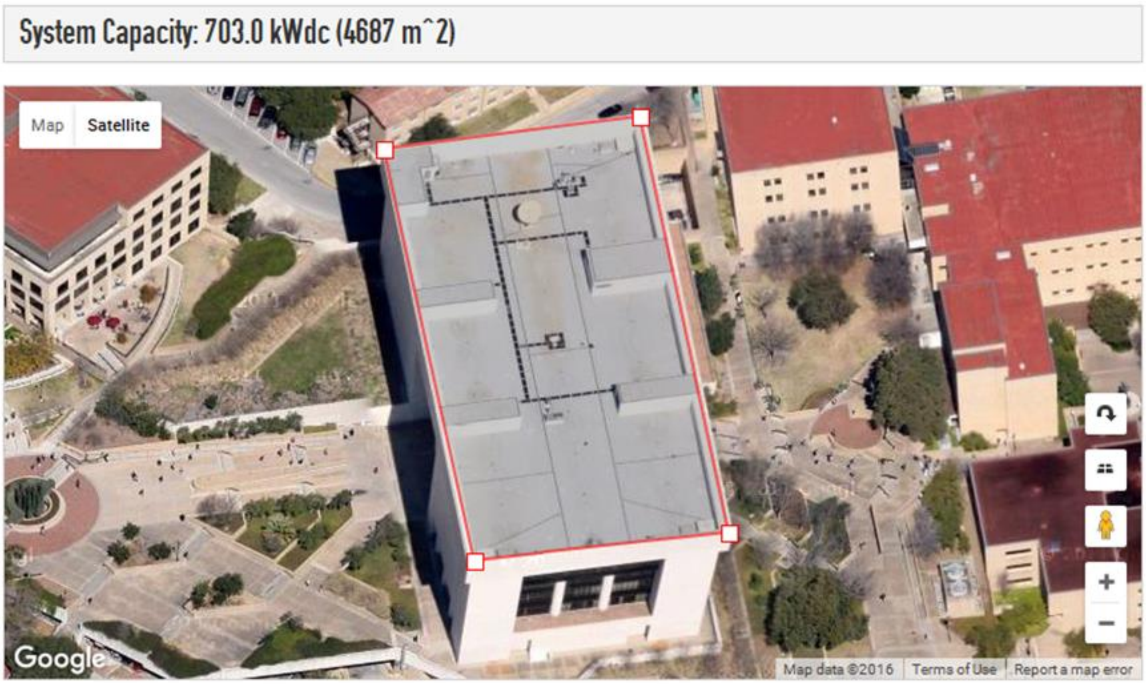
[13] Renewable Energy Credit can be sold or purchased in compliance or voluntary markets.

[14] National Renewable Energy Laboratory (NREL), the U.S. Department of Energy (DOE) Solar Energy Technologies Program (SETP), and the National Association of Regulatory Utility Commissions (NARUC). The model was developed by Sustainable Energy Advantage (SEA) under the direction of NREL.

[15] http://www.pvwatts.nrel.gov

solar PV capacity factor is taken form EIA[16]. Capacity factor is the percentage of actual energy produced after removing all the losses. The percentage degradation of production is due to natural aging of mechanical components and it can be between 0 to 2 percent.

Illustration 1. Alkek Library Capacity calculation with PV Watt on-line toolkit



The system capacity in kW of direct current per square meter ($kW(DC)/m^2$) has been used as input for other calculations.

[16] https://www.eia.gov/electricity/data/eia860/

Table 14. Factors and assumptions for solar panel installation (Alkek Library)

Renewable Energy Cost	
Recommended Minimum Cost of Energy(¢/kWh)	14.75
Cost of Energy (¢/kWh)	16
Cost-Based Tariff Escalation Rate (%)	2.0
Production Capacity	
Generation Capacity (kW_{DC})	703
Net Capacity Factor (State Average)	Texas
Capacity Factor (%)	16.2
Production (kWh)	995082
Annual Degradation Factor (%)	2.0
Project Useful Life (Years)	20
Installation and O&M Expenses	
Total Installed Cost ($/$Watt_{DC}$)	$2.50
Fixed O&M Expense ($/$kW_{DC}$Yr)	$20.00
Variable O&M Expense (¢/kWh)	0.00
Inflation Rate (%)	2.0
Financing	
Debt (%)	50
Cost of Debt (%)	3
Term (Years)	15
Tax Rate (%)	0
Equity (%)	50
Cost of Equity (%)	10
Project Discount Rate - WACC (%)	6.50
Debt	$878,000
Equity	$878,000
Rebate and Tax Incentives	
Rebate Type	Cost Based
Type of Incentive	Investment Tax Credit
ITC or Cash Grant Amount (%)	30
ITC or Cash Grant Amount	$527,250
Performance Based Incentive Rate (¢/kWh)	
Performance Tax Credit Duration (Years)	

Table 14. Continued

Project Valuation											
Years	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Capital Outlay	1757500										
Production:											
Energy Production (kWh)		995082	955279	917068	880385	845169	811363	778908	747752	717842	689128
Project Revenue:											
Revenue from Tariff ($)		159213	155901	152659	149483	146374	143330	140348	137429	134571	131772
Rebate/Incentive ($)											
Total Revenue		**159213**	**155901**	**152659**	**149483**	**146374**	**143330**	**140348**	**137429**	**134571**	**131772**
Project Expense:											
Fixed O&M Expense		14060	14341	14628	14921	15219	15523	15834	16151	16474	16803
Variable O&M Expense											
Total Expense		**14060**	**14341**	**14628**	**14921**	**15219**	**15523**	**15834**	**16151**	**16474**	**16803**
EBITDA (Operating Income)		145153	141560	138031	134563	131155	127806	124514	121279	118097	114969
Depreciation		61513	61513	61513	61513	61513	61513	61513	61513	61513	61513
Taxable Income		83641	80048	76518	73050	69643	66294	63002	59766	56585	53456
Taxes											
Net Income		**83641**	**80048**	**76518**	**73050**	**69643**	**66294**	**63002**	**59766**	**56585**	**53456**
Tax Credit											
Cash Grant/Investment Tax Credit		527250									
Performance Tax Credit											
Total Tax Credit		**527250**									
Cash Flows:											
Free Cash Flow	**(1757500)**	**672403**	**141560**	**138031**	**134563**	**131155**	**127806**	**124514**	**121279**	**118097**	**114969**
Cumulative Cash Flow	(1757500)		943537	805506	670943	539788	411982	287467	166189	48092	66877
NPV	$66,635										
IRR	7%										
Payback Period	9.42										
Profitability Ratio	1.04										
Equivalent Annual Annuity	$6,048										

Motors

Most motors installed around the Texas State University campus exceed 90 percent of the National Electrical Manufacturers Association (NEMA) nominal efficiency at full-load capacity, which means a reasonably good performance. As a matter of fact, the amount of kW saved by replacing motors is not a big number compared to the other projects, which confirms the good performance of the motors. However, most of motors are in the second half of their expected life and are frequently replaced rather than fixed due to the cost and the evidence that rewinding may reduce the motor's efficiency (Jordan, H.E, 2013).

"A motors efficiency tends to decrease dramatically below about 50% load" (Fact Sheet, Motor Challenge, Determining Electric Motor Load and Efficiency. *US-DOE Program).* If the energy efficiency motor is still in a serviceable condition, there is no need to change the motors. The Department of Energy (DOE) indicates that even the best rewinding causes a loss of efficiency of the motor and motors with less than 70 HP should not be rewound but replaced. The high volume of motor duty cycle is an important factor in the process of retrofitting. The Texas State University HVAC system is running 24/7 with lower demand during the night. That means a faster depreciation and a lower rate of lifespan for motors that run fans, pumps and chillers. When existing motors meet the end of usability, they should be replaced with high efficiency models.

The nameplate of motor includes factors needed to apply the energy efficiency calculation. In cases where it was not possible to read the factors, the vendor or producer were contacted to obtain information. The NEMA definition of energy efficiency is given by the ratio of its useful power output to its total power input, shown in percentage (Fact

Sheet, Motor Challenge. Determining Electric Motor Load and Efficiency. *US-DOE Program)*:

$$\eta = \frac{0.7457 * \mathrm{hp} * \mathrm{Load}}{\rho_i} \tag{14}$$

Where:

η = Efficiency as operated in %

hp = Nameplate horsepower

Load = Output power as % of rated power

ρ_i = Three-Phase power in kW

Power factor is calculated by:

$$\mathrm{PF} = (\mathrm{Volt}*\mathrm{Current}*1.732)/((\mathrm{HP})*0.7457*1000) \tag{15}$$

Table 15 shows factors and assumptions used in calculations for replacing motor at Texas State University.

Table 15. Factors and assumptions for replacing motors at Alkek Library

Motor Details (Nameplate)	
Type of Standard Motor *(optional)*	NEMA B-DP
Size of Motor (hp)	25
Enclosure Type	TEFC
Frequency (Hz) *(optional)*	60
Synchronous Speed (RPM)	1800
Full-Load Speed (RPM)	1770
Full-Load Amperage	98
Full-Load Power Factor *(optional)*	87
Full-Load Efficiency (%) *If mentioned enter the nameplate efficiency*	90
Annual Operating Time	
Hours of Operation (Hrs./Day)	20
Operating Days per Year	340
Measured Parameters	
Actual Current (Amps)	*98*
No-Load Current (Amps)	*57*
Actual Voltage (V)	*230*
Power Factor (P.F)	*87.00*
Horsepower Required (hp)	*25.0*
Energy Efficiency (%)	*0.5*
Proposed Energy Efficiency Measures	
Energy Efficiency Measure	Replacement of Same Size Standard Motor with EE Motor
Size of Energy Efficient Motor (hp)	25
Enclosure Type	TEFC
Percent Loading (%) (**Should be close to 75%**)	*NA*
Efficiency (%) of EE (NEMA Premium) Motor	93.6
Expected Life (Hours)	100000
Actual Useful Life (Years)	15
Savings and Installation Charges	
Number of Motors Installed	2
Cost of Motor	$3,000.00
Installation Charges ($/Motor)	$200.00
Rebate	
Rebate ($/kWh)	
Rebate ($/Motor)	
Annual Energy Savings per Motor ($)	$325.05
Annual Demand Savings per Motor ($) *(Assume 75 percent Loading)*	$0.00

Variable frequency drive installation

One of the best ways to meet energy efficiency measures is to apply variable frequency drives on the motors with constant speed induction. The output flow in case of fans and pumps changes in accordance with seasonal change and hours of operation of the buildings. Several buildings in Texas State University have HVAC system with constant air volume (CAV). This means that the air handlers provide the same amount of air, regardless of cooling and heating load in the space. The installation of VFD is proposed for centrifugal fans and pumps (Central Plant has already applied VFDs for pumps) with a higher level of electricity consumption but this technology can be used all over the campus. VFD can be applied in two levels: first, at thermal plants where the needed flow rate is produced and secondly in HVAC systems inside each building in order to optimize the output of components. Moreover, installation of VFDs for HVAC system has been done in 10 buildings prior to this study which means a lower load on electricity and chilled water supply at the Central Plant. Figure 9 compares the power consumption between fans with VFDs and fans without it.

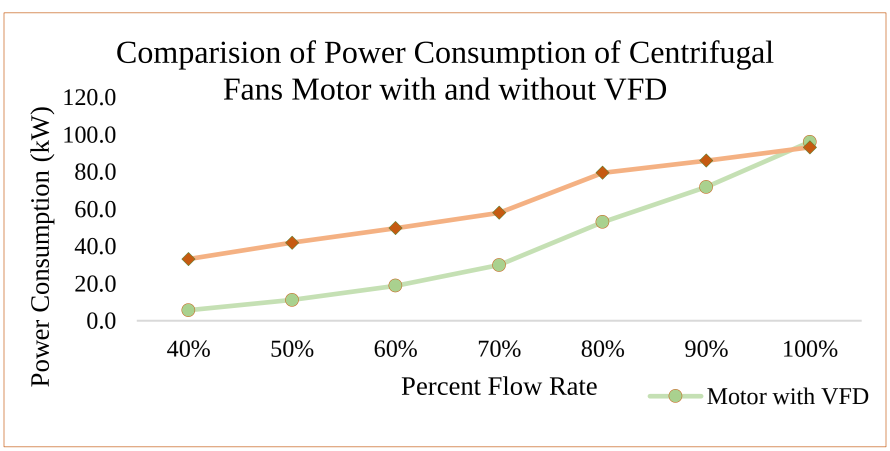


Figure 9. Comparison of power consumption in fans

Table 16. Factors and assumptions for installing VFDs at Alkek Library

Motor Details (Nameplate)							
Type of Standard Motor *(optional)*	Centrifugal Fan						
Size of Motor (hp)	150						
Enclosure Type	TEFC						
Frequency (Hz) *(optional)*	60						
Synchronous Speed (RPM)	1200						
Full-Load Speed (RPM)	1170						
Full-Load Amperage *(optional)*	240						
Full-Load Power Factor *(optional)*							
Full-Load Efficiency (%) *If mentioned enter the nameplate efficiency*	93.3						
Annual Operating Time							
Hours of Operation (Hrs./Day)	24						
Operating Days per Year	350						
Load (Nameplate) and VFD Details							
Type of Load	Centrifugal Fans						
Designed Flow Rate (CFM)	16.77						
Rated Power Consumption (hp)	100						
Type of VFD *(optional)*	Centrifugal Fans						
VFD Rating (hp)	100						
Full Load Efficiency of VFD	97.0						
Actual Useful Life (Years)	7						
Motor Load Type	Variable Torque Load						
Affinity Law Factor (Exponent)	2						
Motor Loading @ Rated Load (%)	66.7						
Motor Power Consumption	79.9						
Measured Parameters							
Duty Cycle (Hrs./Day)	7	6	4	3	2	1	1
Average Loading Percent	100%	90%	80%	70%	60%	50%	40%
Load Power Consumption (hp)	100	90	80	70	60	50	40
Average Flow Rate (CFM)	17	15	13	12	10	8	7
Motor Loading (%)	67	60	53	47	40	33	27
Motor Efficiency % ***(Refer Figure 9)***	80	78	75	90	90	89	90
Efficiency of VFD (%)	97	97	96	95	95	94	94
Motor Input Power Consumption with VFD	96.1	71.8	53.0	29.9	18.8	11.1	5.6
Motor Power Consumption without VFD	93.2	86.0	79.5	58.0	49.7	41.9	33.1
Percent Hours of Operation/Day (%)	29	25	17	13	8	4	4
Power Savings (kW)	-0.8	3.5	4.4	3.5	2.6	1.3	1.1
Savings and Installation Charges							
Number of VFD Installed	6						
Cost of VFD	$10,000.00						
Installation Charges ($/VFD)	$500.00						
Annual Energy Savings per VFD ($)	$10,507.92						

Pump replacement

In many cases at Texas State University, pumps currently have a negative Life Cycle Cost (LCC) due to the depreciation and imminent end of life expectancy. According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), regardless of the fact that pumps have been under a scheduled maintenance plan, they are at the end of their lifespan of 15 to 20 years. Using more efficient pumps during the replacement process will be an important step in reducing energy consumption. The combination of new energy efficiency pumps with VFD will improve energy efficiency in two ways. It reduces chilled water pumping energy in each building and reduces chilled water pumping at the Central Plant. Furthermore, it improves building Delta T[17], keeping it above 15F° of difference and improving efficiency at the Central Plant.

The main proposed measure consists of replacing of oversized standard pump with energy efficiency pumps. Factors to apply calculations are provided by the nameplate. In the case of nonexistence, the vendor or producer was contacted to obtain needed information. The calculation of efficiency is similar to the calculation of efficiency in motors and VFDs and other parameters for flow rate are retrievable through charts provided by vendors. Total head[18] in feet is often provided by the plot of total head vs. flow. However, it is possible to calculate total head by:

$$H_T = H_d - h_s \tag{16}$$

[17] Delta T is given by the difference in temperature before and after a cooling coil in HVAC system.

[18] Total head is given by the maximum height (pressure) a liquid (water) should be delivered.

where:

H_T = Total head

H_d = Suction head

h_s = Discharge head

Pump hydraulic power is calculated as:

$$P_{h(hp)} = P_{h(kW)} / 0.746 \quad (17)$$

where:

$P_{h\ (hp)}$ = hydraulic horsepower (hp)

$P_{h\ (kW)}$ = hydraulic power (kW)

Table 17. Factors and assumptions for pumps at Alkek Library

Pump and Motor Details (Nameplate)	
Type of Pump *(optional)*	Centrifugal
Designed Flow Rate (GPM)	1200
Designed Head (Ft)	50
Rated Speed (RPM)	3485
Designed Efficiency (%)	90.2
Designed Impeller Diameter (inches)	15
Rated Power Consumption (hp)	15
Type of Standard Motor *(optional)*	NEMA
Size of Motor (hp)	25
Enclosure Type	TEFC
Frequency (Hz) *(optional)*	60
Synchronous Speed (RPM)	3600
Full-Load Speed (RPM)	3500
Full-Load Amperage *(optional)*	98.8
Full-Load Power Factor *(optional)*	87
Full-Load Efficiency (%) *If mentioned enter the nameplate efficiency*	88.6

Annual Operating Time	
Hours of Operation (Hrs./Day)	20
Operating Days per Year	340

Measured Parameters	
Operating Flow Rate (GPM)	1000
Absorbed Power Consumption (kW) *(System Power Consumption (motor + pump)*	120.0
Static Suction Head (Zs) (Ft)	50
Static Discharge Head (Z_D) (Ft)	100
Pump Suction Pressure (Ps) (psig)	60
Pump Discharge Pressure (P_D) (psig)	60
Suction Pipe Diameter (in)	15
Discharge Pipe Diameter (in)	8
Specific Gravity of Fluid *(for water SG = 1)*	1
Total Head (Ft)	51
Motor Loading (%)	570
Motor Efficiency % ***(Refer Chart)***	93
Pump Hydraulic Power Output (hp)	12.8
Pump Efficiency (%)	8.5

Table 17. Continued

Proposed Energy Efficiency Measures		
Energy Efficiency Measure	Replacement of Oversized Standard Pump with EE Pump	
Designed Flow Rate (GPM)	2000	
Designed Head (Ft)	100	
Designed BEP Efficiency (%)	90	
Absorbed Power Consumption (kW)	45.0	
Trimming Factor ***(Shall not be less than 80 percent)***	*80*	
Impeller Diameter (inches)	*0.0*	*Refers to Pump Characteristics Curve*
Flow Rate (GPM)	*0*	
Total Head (Ft)	*0*	
Absorbed Power Consumption (kW)	*0.0*	
Actual Useful Life (Years)	10	

Savings and Installation Charges	
Number of Pump Replaced/Retrofit	2
Cost of Pump/Retrofitting	$3,000.00
Installation Charges ($/Pump)	$500.00
Rebate	
Rebate ($/kWh)	
Rebate ($/Pump)	
Annual Energy Savings ($)	40802.20
Annual Demand Savings ($)	0.00

VI. RESULTS

Several energy efficiency projects were analyzed to determine the potential reduction in energy consumption (kWh), CO_2 emissions, and associated cost savings. A summary table of recommended projects is shown in Table 18. The total electricity cost of sample equals $6,414,436.56. These identified projects, once implemented, can save 17% on annual energy costs for Texas State University. Replacement of current lighting system has the largest carbon dioxide reduction and the most attractive NPV. The shortest payback period belongs to the pump replacement and the biggest annual kWh savings is represented by the replacement of lighting system.

Table 18. Summary of all projects

Project	NPV of cost savings	Up Front Investment	Annual Cost Savings ($)	Annual kWh savings	CO2 reduction (metric tons/yr)	Payback average (yrs)
Replacement of Lighting system with LED	$5,201,804	$1,916,199	$739,775	9247195	$5,387.00	1.19
Replacement of Motors	$71,320	$46,616	$15,152.56	189407	$111.00	5.56
VFD	$816,867	$161,750	$138,519	1734141	$831.00	1.95
Pump Replacement	$2,529,808	$115,300	$337,655	4220693	$2,459.00	0.99
Solar Panel Installation	$1,495,143	$7,434,000		5,027,783 **(kW production)**	$2,926.81	8.5
TOTALS	**$13,217,848**	**$12,173,865**	**$1,231,102**	**15,391,436**	**$12,561.81**	**21.93**

Table 19. Summary of Lighting system replacement project

Name of the Building	Annual kWh saved	NPV	Annual Cost Savings	CO2 reduction (metric tons)	Payback (year)	Investment
Jowers Center	550,800	$367,867	$44,064	321	0.70	$35,000
Central Plant (office)	11,691	$5,172	$935	7	2.19	$2,050
Health Center	380,880	$205,080	$30,470	222	1.38	$42,550
Rec Center	1,326,000	$724,603	$106,080	772	1.28	$137,500
Alkek library	1,227,587	$711,905	$98,207	715	0.87	$1,227,587
Central Plant (Industrial)	170,382	$56,725	$13,631	99	1.08	$14,820
Evans Liberal Art	414,000	$228,163	$33,120	241	1.22	$41,000
JCK	991,440	$554,675	$79,315	578	1.12	$89,910
LBJ	2,154,065	$1,262,939	$172,325	1255	0.79	$137,532
McCoy Hall	453,600	$242,409	$36,288	264	1.43	$52,500
Roy Mitte	480,000	$265,823	$38,400	280	1.19	$46,250
San Jacinto	755,550	$397,733	$60,444	440	0.86	$52,500
Supple Science	331,200	$178,331	$26,496	193	1.38	$37,000
Totals	**9,247,195**	**$5,201,425**	**$739,776**	**5387.00**	**15.49**	**$1,916,199**
Average					**1.19**	**$147,400**

Table 20. Summary of solar panel installation project

Name of the Building	Annual kWh production	NPV	Annual Cost Savings	CO2 reduction (metric tons)	Payback (year)	Investment
Central Plant	299,940	$131,066	Not applicable	174.0	8.72	$423,800
Jowers Center	1,656,111	$369,661	Not applicable	964.0	9.05	$2,340,000
Alkek Library	934,217	$62,560	Not applicable	544.0	9.42	$1,650,000
LBJ Center	1,124,032	$370,072	Not applicable	654.8	8.07	$1,588,200
Mathews Garage	1,013,483	$561,784	Not applicable	590.0	7.17	$1,432,000
			Not applicable			
Totals	**5,027,783**	**$1,495,143**	Not applicable	**2926.81**	**42.43**	**$7,434,000**
Average					**8.5**	**$1,486,800**

Table 21. Summary of pump replacement project

Name of the Building	Annual kWh saved	NPV	Annual Cost Savings	CO2 reduction (metric tons)	Payback (year)	Investment
Central Plant	3,053,871	$1,808,995	$244,309.68	1779.00	0.32	$77,500
Alkek Library	1,020,055	$656,192	$81,604	594.00	0.08	$7,000
LBJ Center	146,767	$64,621	$11,741	86.00	2.58	$30,800
Totals	**4,220,693**	**$2,529,808**	**$337,655**	**2459.00**	**2.98**	**$115,300**
Average					**0.99**	

Table 22. Summary of motor replacement project

Name of the Building	Annual kWh saved	NPV	Annual Cost Savings	CO2 reduction (metric tons)	Payback (year)	Investment
Central Plant	160,667	$67,250	$12,853	94.00	2.49	$32,000
Alkek Library	8,126	-$1,117*	$650	5.00	9.35	$6,400
LBJ Center	20,614	$5,187	$1,649	12.00	4.84	$8,216
Totals	**189,407**	**$71,320**	**$15,153**	**111.00**	**16.68**	**$46,616**
Average					**5.56**	

Note: *The only negative value for NPV among all the projects

Table 23. Summary of VFD installation

Name of the Building	Annual kWh saved	NPV	Annual Cost Savings	CO2 reduction (metric tons)	Payback (year)	Investment
Central Plant	413,530	$212,954	$33,080	241	1.26	$42,500
Central Plant Condenser Water Pump VFD	140,000	$74,912	$11,000		1.34	$15,000
Alkek Library	788,094	$315,969	$63,042	459	0.99	$63,000
LBJ	224,420	$124,908	$17,952	131	1.16	$21,000
East Plant	28,396	$3,212	$2,271		6.47	$15,250
East Plant Condenser Water Pump VFD	138,293	$84,912	$11,174		0.45	$5,000
Totals	**1,732,733**	**$816,867**	**$138,519**	**831**	**11.67**	**$161,750**
Average					**1.95**	

VII. DISCUSSION

There are promising paths towards decreasing electricity consumption at Texas State University; however, to take these paths likely requires going against business as usual. For instance, while several buildings have recently been retrofitted or upgraded with energy efficient equipment, and new buildings are being constructed according to the LEED criteria—compared to 2015, total energy consumption failed to experience a significant reduction. More precisely, due to a reduction on reportable gross square footage from 2015 to 2016, a relatively small reduction can be expected on total electricity consumption. Nevertheless, this expectation was not borne out in the preceding analysis. Moreover, the projections show an increase of electricity utilization index (EUI) due to the increase of enrollment and growing rate of square feet in the new constructed buildings. All these facts point to a likely increase of energy consumption on electricity, gas, and water.

It would be a challenging assignment to keep the electricity consumption at a flat rate (if not increased) given the 2015 and 2016 consumption when the electricity usage did not decrease despite the square footage dropped by more than 40,000 square feet. On the other hand, several buildings in the base year (2012) were not included for usage reading. This fact led to the creation of a base line with assumptions which eventually decreased the accuracy of calculations for the total amount of kWh saved. It is more appropriate to establish the base year on 2013 with a more significant amount of square footage. In addition, there is a need to calculate the coefficient of growth in number of student and another coefficient for added space to the total square feet to better understand the future energy consumption.

In terms of adhering to declarations or environmental commitments, the Senate Bill 898 is exclusively focused on electricity consumption while achieving sustainability goals on energy clearly demand a broader development including renewable, affordable, and modern sources of energy mentioned in the UN Sustainable Development Goals (2015). The Senate Bill applies to political subdivision, institute of higher education and state agency facility which are located in the 41 non-attainment or near non-attainment counties in Texas (SB 898). Texas State University is in Hays county, one of the 41 non-attainment or near non-attainment counties in Texas (Clean Air Act Amendments, 1970-1977). Considering the non-satisfactory air quality in Hays county it is strongly recommended to take the energy efficiency measurements in action, bringing the university beyond the binding bill and presenting a good example of social responsibility. Also, there is a need to study the gas consumption since the average rate of consumption is increased from the second year (2013) along the next 3 years within base line range (Figure 10).

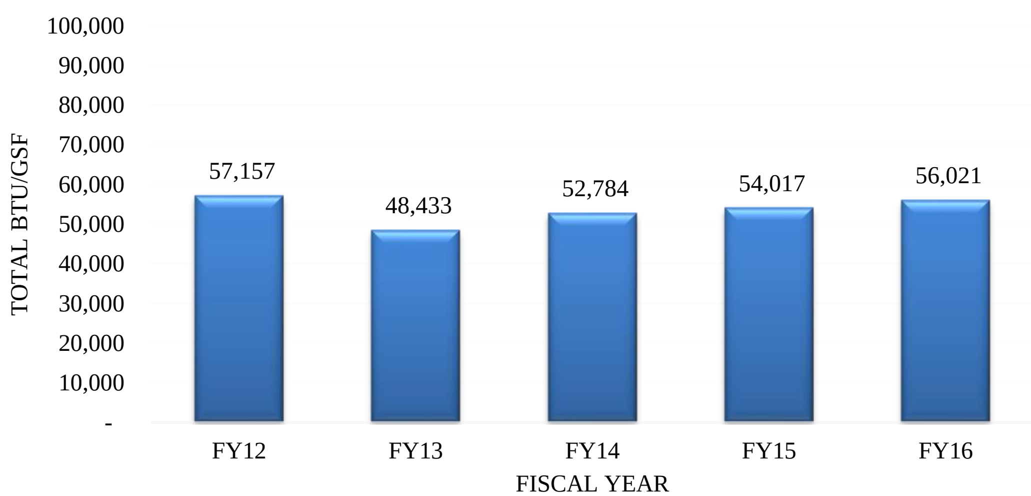


Figure 10. Natural gas consumption comparison at Texas State University

Texas is not only rich in petroleum. Studies showed that Texas can produce 20% of total U.S solar power (Lopez, et al., 2012). Currently, the city of San Marcos does offer rebate for implementation of renewable energy (installation of solar panels) for single family homes. This support comes from a federal policy consisting of 30 percent tax credit for residential and commercial solar projects where there is no direct reference to universities. As mentioned in previous chapters, universities can be considered as commercial units since their energy consumption fits the commercial and industrial sections in many aspects.

There are many cost-effective projects that can be immediately taken in action. The replacement of lighting system is one of the best choices in terms of quick payback and a relative small investment for individual units except Alkek Library. Even when there is a need to invest more money, the payback period can show a very short time to recoup the investment. This case has been proven in several projects like the case of Alkek Library where replacing T8 bulbs demands more than $1 million of initial investment. This amount of money can be returned to the university budget in 0.87 year. However, the replacement of lighting system has been applied only at the first floor due to the need of reconstructions.

As mentioned before the resistance to change can lead to an institutional inertia. In order to change this approach there is a need to institutionalization of sustainability at Texas State University. Such entity should go beyond establishment of norms and conventions connecting researchers, university administration, and education.

VIII. CONCLUSION

During recent years, universities across the U.S. and globally have made public declarations regarding their commitments to sustainability. One large public university, Texas State University, has been committed to improve the energy consumption across the campus. This study used the Discounted Cash Flow model and the related positive and significant Net Present Value to assess energy efficiency at Texas State University main campus. The two goals of saving money and improving the environmental condition (avoided CO_2) form a “proper coupling” (Jack Harich 2010).

Like many large public institutions of higher education, Texas State University is facing a constant growth of student population which creates an upward demand on gross square feet and energy consumption. Undertaking feasible energy efficiency measures is essential for the sustainable growth of the university. However, these measures can be expensive and not easy to implement in many cases. This study used a sample size of 13 buildings with the highest energy expenditure on campus. The only project applied to all the buildings was the replacement of lighting system. The average payback period is relatively short for many individual projects, especially in case of lighting system and pump replacement. The ratio of payback compared to the invested money can be considered as another proper coupling to overcome the difficulties in financial terms because cumulative cash flow will be increased along the years after the implementation of proposed project.

The positive outcomes of this study indicate that extrapolating the results to all university buildings with 7,719,991 gross square feet will increase savings, reduce emissions, and constitute a sound financial investment. Based on the limitations of this study, it is recommended that future studies repeat the experience with a larger sample size and in different university campuses with the same characteristics. Assessing energy consumption and efficiency in light of the growing student and surrounding population will continue to be a necessary step to reach the sustainable development of Texas State University, now and in the future.

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