Exploring the Applications of Building Information Modeling in Informal Settlements: Texas *Colonias*

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INTRODUCTION

Informal settlements are one of the major global challenges that developing countries face because of deplorable living conditions with lack of decent infrastructure, adequate living space and access to basic facilities and services, and direct effects on resident's satisfaction and quality of life (UN-Habitat 2003; 2009). Monitoring and evaluating the interventions are among the major steps to follow to be successful in upgrading informal settlements and improving residents' living conditions (UN-Habitat 2008). However, there is no common planning framework or method for monitoring these settlements and upgrading them to an acceptable quality; each country has a diversity of strategies for upgrading informal settlements (Abbott 2002a).

Colonias are the substandard housing developments in the United States located north of the U.S.-Mexico border from Texas to California. Government responses to the *colonias* show similar characteristics with approaches in other parts of the world. In the *colonias*, the improvements and expansions of houses are often performed by residents as 'self-help interventions' (Ward and Carew 2001; Ward et al. 2011; Giusti and Estevez 2011). According to Giusti and Estevez (2011), common upgrading interventions on houses in the *colonias* are installation of air conditioning systems and improvements to roof and floor materials. As these informal settlements have been upgraded over time, their impacts upon energy consumption are often very high as a result of the lack of precautions and practices to provide for sustainable use of energy (UN-Habitat 2008).

Conventional modeling of informal settlements uses Geographical Information Systems (GIS) maps and databases. Available GIS maps and databases developed for monitoring and evaluating the changes in the *colonias* are limited to infrastructure, health and quality of life indicators of the residents. Therefore, existing databases and maps have two challenges: (1) they lack in comprehensive information on design patterns, materials, construction, and parameters of individual informal houses and (2) they lack in information on informal settlements growth and upgrading patterns including their potential impacts upon energy consumption as well as improvements in living conditions to increase resident satisfaction.

The aim of this study is to devise a method, Parametric Building Information Modeling of informal settlements, to measure the impact of self-help upgraded houses on both energy use and cost of house. This method has been tested by four *colonia* houses by performing energy analysis, solar analysis and cost estimating using BIM automated tools (Yenerim, Clayton and Mills 2011). Hence, our research question is that 'can the use of BIM support these kinds of analyses in settlement scale'. The expected outcome will help develop advice for *colonia* residents on how to upgrade their houses and enable government officials to track the changes in houses.

BIM tool Autodesk® Revit® 2011 has been used to model four *colonia* houses and to generate cost schedules, and Autodesk® Project Vasari was being used to perform energy, solar and wind analyses of these houses.

We hypothesize that our method will be reasonably fast and accurate at modeling home value and energy consumption, analysis of results of the method will lead to insights in more sustainable and energy-efficient solutions when implementing upgrades of homes, and combining BIM and GIS will increase the awareness and understanding of the settlements among planners and officials.

COLONIAS AND EXISTING GIS MAPS AND DATABASES

Colonia is originally a Spanish word which refers to "colony" (Oxford University 2011). The term *colonia* does not have a rigid definition in the U.S.; each agency has its own definition according to their role in improvements. For instance, Texas Secretary of State defines the terms as "a community or neighborhood" (SOS 2010), whereas according to the U.S. Department of Agriculture-Rural Development (USDA-RD 2011), it is "characterized as small communities with inadequate drinking water, poor sanitary waste disposal facilities, and substandard housing". U.S. Housing and Urban Development (HUD 2003), on the other hand, has its own definition as:

> any identifiable community in the U.S.-Mexico border regions of Arizona, California, New Mexico, and Texas that is determined to be a colonia on the basis of objective criteria, including lack of a potable water supply, inadequate sewage systems, and a shortage of decent, safe, and sanitary housing. The border region means the area within 150 miles of the U.S.-Mexico border excluding Metropolitan Statistical Areas with populations exceeding one million.

Colonias are located in four states: California, Arizona, New Mexico and Texas. Our study focused on the *colonias* in Texas due to several reasons. The *colonias* in Arizona and New Mexico are different from the ones in Texas in several ways. First, they are less in number, and older than Texas *colonias* (Donelson and Esparza 2010). Second, the use of traditional building methods, and sustainable building materials such as adobe, rammed earth, straw bales along with their insulating capabilities, have an impact on decreasing energy-consumption and reducing in cost of the houses (Donelson and Esparza 2010). Therefore, they are more affordable and sustainable than the *colonias* in Texas. Another reason is the availability of data; our college has been involved by providing services and performing research on the *colonias* in Texas for nearly twenty years.

In the *colonias*, the improvements and expansions on houses have been performed by the residents themselves as 'self-help interventions' (Bredenoord, van Lindert, and Smets 2010; Ward et al. 2011; Joshi and Sohail Khan 2010; Klaufus 2010; Landman and Napier 2010; Sengupta 2010; Tunas and Peresthu 2010; Yap and De Wandeler 2010; Ward and Peters 2007; Smart 2003; Ward and Carew 2001; Skinner and Rodell 1983; Giusti and Estevez 2011; Alnsour and Meaton 2009; Magigi and Majani 2006). According to Texas legislation, monitoring *colonia's* infrastructure, health and quality of life indicators of the residents is required to improve their houses and environment (García 2003).

The impact of existing poor housing quality on environment and health of residents has been well established according to the literature. Previously developed GIS maps and databases are listed below:

First, to improve and clarify the boundaries of the *colonias*, U.S. Geological Survey (USGS), Office of the Attorney General of Texas (OAG), Secretary of State (SOS), Texas Water Development Board (TWDB) and U.S. Census Bureau in 2000 developed a geographic database of Texas *Colonias* (maps.oag.state. tx.us/colgeog/).

Second, in 2003, US Green Building Council (USGB) and U.S. Housing and Urban Development (HUD) cooperated in developing a database that provides information on infrastructure and geographical boundaries of the *colonias* in an upper scale: regional level. The aim of this database was to inform planners in regional scale and allow them to estimate funding to upgrade infrastructure of these settlements (Parcher and Humberson 2007; 2009).

According to Parcher and Humberson (2007; 2009), the problem of previous databases was that they were not able to provide data on individually for each *colonia* and this situation limited monitoring the health risk level in the *colonias*.

Third, in 2003, The Colonias Monitoring Program developed a GIS map that accommodates several data layers: "[1] transportation routes, [2] digital orthophoto quadrangles, [3] digital raster graphics of Landsat imagery, [4] colonia boundaries, [5] hydrography,[6] demographics, and [7] geographic names" (HUD2003). On the other hand, in order to clarify the boundaries of each *colonia*, together with TWDB and OAG, USGB incorporated with local government officials and extended this database by basically adding utilities, transportation, and specific district data called Economically Distressed Areas Program (EDAP) database (Parcher and Humberson 2007).

Most recently, in 2006, based upon this database, USGS generated The Colonia Health, Infrastructure, and Platting Status Tool (CHIPS). CHIPS dwells five datasets: (1) geographical information on each *colonia*, (2) plat information, (3) available infrastructure, (4) health care facilities, and (5) financial availability (Parcher and Humberson 2007).

To sum up, the available information through GIS covers social, economic and physical data on a broader scale and this database is used for broad-decision-making regarding the intervention (Abbott 2002a; 2002b; Lo and Yeung 2007; Sliuzas 2003a; Sliuzas 2003b; Olowu 2003; McCall 2003). The challenge is the lack of comprehensive information on design patterns, materials, construction, and parameters of individual informal houses.

BIM AS A NEWER TECHNOLOGY

This study proposes Building Information Modeling (BIM). BIM has its roots in the development of object-based parametric modeling started by 1980s. Object-based parametric modeling refers to the objects that are defined by parameters and rules set up by the designer to determine geometric and non-geometric features (Eastman et al. 2008). This property makes BIM differs from other conventional drawing tools such as; Computer Aided Design (CAD).

The concept of BIM was defined as "a modeling technology and associated set of processes to produce,

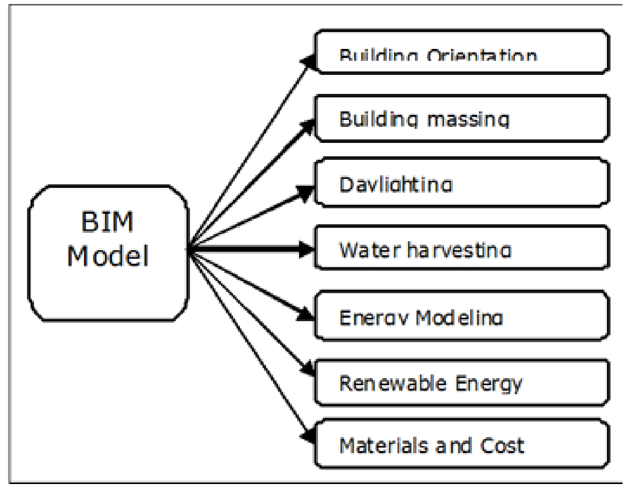

Figure 1. Possible analysis derived from BIM model (Adopted from Krygiel and Nies 2008)

communicate, and analyze building models" (Eastman et al. 2008) and "an instance of populated data model of buildings that contains multi-disciplinary data specific to a particular building [through its life-cycle.]" (Bazjanac 2007) (Figure 1).

Application of BIM tool in the informal settlement context is significant in three ways. First, it allows documenting and collecting large amounts of data on both existing and newly designed individual houses. The National Building Information Modeling Simulation (NBIMS) committee configures BIM as folded in eight data sets: (1) designer data, (2) legal data, (3) geospatial data, (4) financial data, (5) specifier data, (6) environmentalist data, (7) sustainers data, and (8) owner/ occupier data (Eastman et al. 2008; Bazjanac 2007). In other words, BIM tool provides not only three dimensional visual models but also extensive information on individual houses.

Second, BIM provides a platform that helps in making decisions through integrating accessibility, sustainability, site design, environmental systems and structural elements. By referring to embedded detailed information on design patterns, elements, costs and carbon emission of the buildings, BIM can allow stakeholders better comprehend the development process and communicate with each other (Eastman et al. 2008; Krygiel and Nies 2008).

Finally, through establishing communication between stakeholders, it allows for more intelligent decision making for design improvements.

To sum up, integrating BIM tool in informal settlements development and monitoring process can play a crucial role in triggering more comprehensive thinking in architecture through considering accessibility, sustainability in terms of energy efficiency and material choice, site design, environmental systems and structural systems while improving quality of life and residents' satisfaction.

METHODOLOGY

This study tests a method called parametric building information modeling of informal settlements, on whether energy and cost components of houses can be represented in support of planning and forecasting. This paper draws on a test case of twelve houses with five additional small shacks in the *colonias* in Larga Vista, Webb County, Texas by utilizing BIM technology. The selection of the Larga Vista community was based on many reasons such as; (1) offering variety of houses: trailer/ mobile homes, manufactured houses, and self helped houses, (2) having adequate information on plans, materials and construction styles, (3) having running water and AC systems and household demographics and (4) existing the growing pattern of houses in time (Reimers Arias 2009).

The investigation of this study were threefold: (1) creating BIM models from masses of an informal community by utilizing BIM tool Autodesk® Revit® 2011, (2) generating cost schedule takeoffs by utilizing Autodesk® Revit® 2011 Schedules and Quantity Takeoffs tool, and (3) performing energy, solar and wind analysis by using Autodesk® Project Vasari 2.0.

1. Visualization: Creating BIM models

To achieve task 1, we referred to two sources: (1) aerial and street view images from Google Earth™ and (2) aerial images spanning between 28 years and GIS maps (Reimers-Arias 2009). They aided us gather information on (a) footprints, (b) number of storey, (c) materials, and (d) location of windows and doors of the houses (Figure 2).

Since Autodesk® Project Vasari requires mass objects to generate energy, solar and wind analyses; first, we created three dimensional masses of the houses. This was followed up by developing a

Figure 2. Aerial and street view images of Larga Vista (Google Earth™ 2011) and the BIM of houses

library of objects frequently used in the *colonia* houses and adding cost parameters for enabling quantity takeoffs for houses' cost estimates. As a final step, we assigned components for each house.

2. Capital: Generating Quantity Takeoffs Cost Estimations

The purpose of generating cost analyses of informal houses was to inform both residents and the experts from different constituencies such as municipal government, city service providers, state and federal agencies, lenders, and insurance companies about (1) equity of residents' investments and (2) the replacement cost of their houses.

We used Schedules and Quantity Takeoffs tool embedded in the Autodesk® Revit® 2011 and created ten schedules for each house: (1) Site, (2) Foundation, (3) Floor, (4) Roof, (5) Interior/ Exterior Wall, (6) Doors, (7) Windows, (8) Specialties, (9) Mechanical, (10) Electrical. In order to generate both equity cost and salvage cost of the houses, we input material, installation and total cost for each component. We adopted costs per square foot and each component from a recent data source, RSMeans Residential Cost Data (2011).

3. Energy: Performing Energy and Solar Analyses

The aim of conducting energy and solar analyses was (a) to monitor the change according to the intervention over time and (b) to develop guidelines on precautions and practices to provide for sustainable use of energy.

We utilized Autodesk® Project Vasari 2.0 to conduct both energy and solar analyses of a group of houses. This cluster dwells three types of houses: (1) mobile/trailer, (2) self helped with shacks, (3) manufactured homes. Since each individual type of house in the cluster has different materials and construction standards, they were analyzed separately in terms of their energy consumption. However, solar analysis was conducted to the whole cluster.

FINDINGS AND DISCUSSION

The initial motivation of this study was to push the limits of BIM tool by utilizing it to model a cluster of houses in Larga Vista *colonias.* In recognition of BIM parametric modeling has capability in quantity takeoffs cost estimations and energy analyses of masses in building scale, we tested an option to model a cluster of informal houses and generate analyses.

1. Visualization: Creating BIM models

As mentioned above, this cluster of houses consists of three types: (a) trailer/ mobile, (b) self-helped, and (c) manufactured homes (Figure 3). The components such as roof, floor, wall, windows, and doors for each type have different materials and construction techniques. Therefore, we standardized the various materials used for each type of house by referring to secondary resources (Reimers 2009) and created the library. This might one of the limitations of the results.

It was found that creating visual models by utilizing BIM is quick and easy to perform. After developing our libraries consisting of components that have been frequently used in the *colonia* houses' construction, the process of modeling houses by utilizing BIM tool became routinized (Figure 4).

2. Cost Analysis

BIM tool has the ability of counting each component and performing material and cost takeoffs on entire buildings models in a fast and accurate way by integrating two and three dimensional data (Autodesk website). It was found that BIM tool were superior to cluster of buildings and has capability of counting and examining cost estimates for each house at the same time. The output of this process dwells: (1) quantity of each different type of components, (2) material cost, (3) installation costs, (4) total cost of each building separately, and together as a cluster (Table 01 and 02).

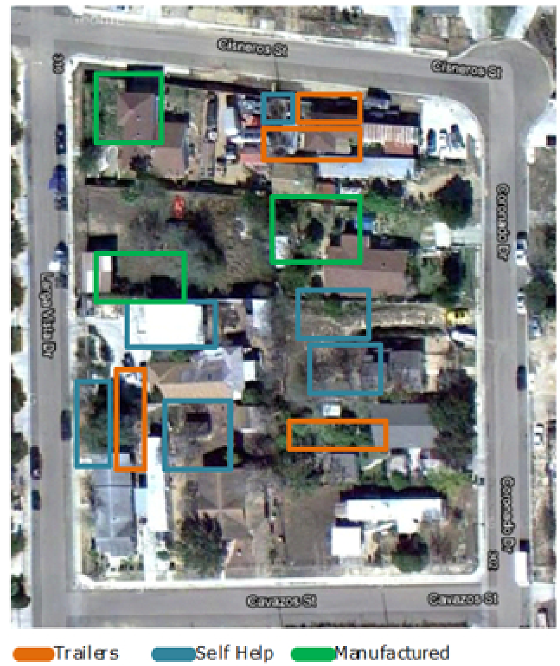

Figure 3. BIM of houses (Adopted from Google Earth™ 2011)

Figure 4. BIMs of houses

Table 1: Replacement and Equity cost of informal houses

HOUSES				T VALUE	HOUSE
NO	TYPE	SF	STOREY		
1	Trailer	1,484	1	27,748.85	59,141.14
2-A	Self-Help	1,381	1	42,955.68	83,058.99
2-B	Self-Help	1,651	1	32,961.04	66,062.77
3	Self-Help	1,372	1,5	49,843.43	91,573.65
4	Self-Help	1,866	1	55,968.72	105,628.76
5-A	Self-Help	619	1	18,918.77	40,823.72
5-B	Trailer	645	1	12,053.26	35,029.63
5-C	Trailer	1,022	1	17,615.23	36,105.09
6	Self-Help	525	1	16,310.99	35,283.28
7	Manufacture	1,743	1,5	47,647.21	78,938.00
8	Manufacture	1,231	1	43,430.67	67,702.62
9-A	Self-Help	1,683	1	50,070.09	88,976.44
9-B	Self-Help	258	1	8,354.05	23,231.20
9-C	Self-Help	177	1	5,224.59	19,225.76
10	Self-Help	1,414	1	45,002.15	86,693.38
11	Trailer	856	1	17,106.21	36,918.77
12	Self-Help	683	1	37021.881	71135.13

The findings showed that utilizing BIM in informal settlement context would be beneficial for calculating equity and replacement costs of houses. They also demonstrated that BIM tool with accurate input data can be used to develop a database that helps to proper improvement techniques. Residents could also refer to this database while applying to mortgage.

3. Energy: Performing Energy and Solar Analyses

By utilizing Autodesk® Project Vasari 2.0, we assigned type of windows, walls, floor, roof materials and construction standards, and HVAC systems to each individual houses grouped under trailer/mobile, self helped with small shacks and manufactured houses and run energy analyses separately. For energy analysis, it was found that the factors that have an impact on the output data from this technology can be listed as such: (1) orientation, (2) self-shading, (3) building shading, (4) square footage, (5) number of storey, (6) percentage of glazing on the surface, (7) materials and construction standards, and (8) type of HVAC system used in houses.

The output of the program includes several categories of data (Table 03). The findings demonstrate life cycle energy use, life cycle energy cost, renewable energy potentials, annual carbon emission, annual energy use, annual energy cost, cost of fuel, cost of electricity, monthly fuel consumption and monthly electricity consumption. Therefore, if the input data is accurate, this technology would provide a very comprehensive data on energy consumption and possible renewable energy technologies to save energy. It would also allow modifying the interventions to more sustainable solutions.

We performed solar analyses of the whole community according to fall, winter, spring and summer periods (Figure 5). The visual output of the analysis demonstrates self and building shading. The findings can be used for decision support on making houses more sustainable through deciding on the location and size of windows, shading elements, and photovoltaic systems.

CONCLUSION

In this study, we explored the capabilities of BIM tool in settlement scale and in informal settlement context. We are finding that BIM have a potential to increase the level of understanding on informal settlements growth patterns through visualizing houses in three dimensions, and providing data on the capital and energy consumption of the houses.

The utility of three dimensional models with embedded capital and energy data to improve communication between experts and public may support the interaction involvement at various stages

Table 2: Cost analyses of informal houses

HOUSES				SITE	FOUNDATION	FLOOR		ROOF	
NO	TYPE	SF	NO OF STOREY	INSTALLATION (TOTAL)	TOTAL	MATERIAL	TOTAL	MATERIAL	TOTAL
1	Trailer	1484	1	1,196.56	68.26	3,960.00	9136.00	5,06300	10,127.00
2A	Self-Help	1381	1	1,160.53	6,905.00	4,599.00	8162.00	10,03000	23,468.00
2B	Self-Help	1651	1	1,165.63	8,255.00	5,498.00	9758.00	3,46500	8,104.00
3	Self-Help	1372	1,5	1,150.36	6,860.00	4,571.00	8114.00	9,79700	22,912.00
4	Self-Help	1866	1	2,108.58	9,330.00	6,215.00	11031.00	13,44400	31,444.00
5A	Self-Help	619	1	699.47	3,095.00	2,060.00	3657.00	3,60000	8,888.00
5B	Trailer	645	1	911.80	29.67	2,678.00	6388.00	1,52700	3,053.00
5C	Trailer	1022	1	858.48	47.01	1,749.00	3104.00	3,06600	6,132.00
6	Self-Help	525	1	593.25	2,625.00	2,037.00	3616.00	2,98000	7,356.00
7	Manufacture	1743	1,5	1,464.12	80.18	5,804.00	10301.00	9,55700	23,591.00
8	Manufacture	1683	1	1,391.03	6,115.00	4,098.00	7273.00	7,48200	17,500.00
9A	Self-Help	258	1	1,191.79	8,415.00	5,604.00	9946.00	8,94200	22,073.00
9B	Self-Help	177	1	291.54	1,200.00	721.00	1527.00	1,99000	4,665.00
9C	Self-Help	1123	1	200.01	885.00	499.00	1046.00	1,45700	3,408.00
10	Self-Help	1414	1	1,268.99	5,665.00	4,592.00	8321.00	14,04300	32,844.00
11	Trailer	856	1	319.04	38.38	2,348.00	5352.00	3,21000	6,489.00
12	Self-Help	683	1	71.79	3,415.00	1,848.00	4106.00	12,00000	28,089.00

NO	WALL		DOOR		WINDOW		SPECIALTIES		MECHANICAL		ELECTRICAL	
	MATERIAL	TOTAL	MATERIAL	TOTAL	MATERIAL	TOTAL	MATERIAL	TOTAL	MATERIAL	TOTAL	MATERIAL	TOTAL
1	3,779.00	13118.00	1606.28	3,491.99	4,086.35	5,480.93	2,746.40	3,769.36	5194.00	9,586.64	1,246.56	3,116.40
2A	3,130.00	13181.00	1570.54	3,488.12	6,128.87	8,030.85	3,397.26	4,697.78	5910.68	10,467.98	1,284.3	3,217.78
2B	1,499.00	13214.00	955.52	2,079.52	625.35	844.83	4,061.46	5,580.38	7066.28	12,514.58	1,535.4	3,846.88
3	4,258.00	12649.00	1570.54	3,488.12	12,283.65	17,886.29	3,375.12	4,637.36	5872.16	10,399.76	1,275.5	3,196.76
4	4,788.00	14456.00	1875.30	4,095.17	6,004.20	8,364.87	4,590.36	6,307.08	7986.48	14,144.28	1,735.3	4,347.78
5A	2,352.00	11396.00	1219.04	2,668.20	1,865.00	2,193.54	1,522.74	2,098.22	2649.32	4,692.02	575.67	1,442.27
5B	1,385.00	12757.00	1619.04	4,097.62	822.00	1,003.04	1,193.25	1,638.30	2257.50	4,166.70	541.80	1,354.50
5C	3,580.00	9611.00	1565.04	3,413.62	1,282.00	1,594.78	1,880.70	2,595.88	3577.00	6,602.12	858.48	2,146.20
6	1,711.00	8934.00	1570.54	3,488.12	1,360.70	1,753.66	1,291.50	1,774.50	2247.00	3,979.50	488.35	1,223.25
7	2,085.00	8575.00	3141.08	6,886.24	6,190.78	8,723.16	3,224.55	4,427.22	6100.50	11,259.78	1,464.12	3,660.30
8	9,880.00	8575.00	1570.54	3,488.12	4,808.36	7,020.48	3,028.26	4,160.78	5268.68	9,330.98	1,144.8	2,868.23
9A	4,750.00	8468.00	2789.58	6,096.32	6,660.90	9,709.26	4,140.18	5,688.54	7203.24	12,757.14	1,565.9	3,921.39
9B	968.00	9583.00	609.52	1,412.47	796.67	1,043.37	636.68	872.04	1104.24	1,955.64	239.94	601.14
9C	685.00	10589.00	346.00	765.42	-	-	416.42	598.26	757.56	1,341.66	164.61	412.41
10	4,605.00	11516.00	1570.54	3,488.12	6,004.20	8,775.60	2,762.58	3,795.74	4806.44	8,512.34	1,044.9	2,616.59
11	3,438.00	10856.00	955.52	2,079.52	1,911.67	2,462.23	1,588.60	2,174.24	2996.00	5,529.76	719.08	1,797.60
12	4,798.00	9971.00	2174.56	4,787.72	7,946.71	10,987.55	1,680.18	2,308.54	2923.24	5,177.14	635.9	1,591.39

Table 03: Energy Analysis Results

	TRAILER/MOBILE HOM	SELF HELPED HOMES	MANUFACTURED HOMES
Building Performance Factors			
Number of Houses	4	15	3
Floor Area (m2)	3,272	5,483	9,200
Exterior Wall Area (m2)	6,484	6,925	13,879
External Window Ratio	0.09	0.10	0.09
Electrical Cost ($/Kwh)	0.13	0.13	0.13
Fuel Cost ($/Therm)	1.05	1.05	1.05
Energy Use Intensity (EUI)			
Electricty EUI (KkWh/sm/yr)	14	16	15
Fuel EUI (MJ/sm/yr)	3	3	7
Total EUI (Mj/sm/yr)	49	57	57
Life Cycle Energy Use/Cost(30 yrs)			
Life Cycle Electricity Use (kWh)	1,325,610	2,598,672	4,155,654
Life Cycle Fuel Use (MJ)	3,108	5,573	21,087
Life Cycle Energy Cost ($)	79,957	156,496	256,052
Renewable Energy Potential: Roof Mounted PV Systems (kWh/yr)			
Low Efficiency (5%)	36,433	43,075	92,989
Medium Efficieny (10%)	72,866	86,150	185,979
High Efficiency (15%)	109,299	129,226	278,968
Renewable Energy Potential:Single 15' Wind Turbine Potential (kW	1,813	1,813	1,813
Annual Carbon Emmisions (metric tons/yr)			
Electricity Consumption	31	62	95
Fuel Consumption	0	1	4
Roof PV Potential (high Efficiency)	-78	-92	-195
Single 15' Wind Turbine Potential	-1	-1	-1
Net CO2	-48	-30	-97
Annual Energy Use:			
Electricity (kWh)	44,187	86,622	138,521
Fuel (MJ)	103	185	702
Annual Energy Cost	5,871	11,491	18,799
Electricity ($)	5,762	11,296	18,063
Fuel ($)	109	195	736
Energy Use: FUEL	103	185	702
HVAC (MJ)	-	-	410
DHW (MJ)	103	183	292
Energy Cost: FUEL	108	194	735
HVAC ($)	-	-	430
DHW ($)	108	194	305
Energy Use: Electricity		86,621	138,521
HVAC (kWh)	30,500	61,931	95,530
Ligthing (kWh)	6,950	11,650	20,157
Misc Equipment (kWh)	6,736	13,040	22,834
Energy Cost: Electricity	44,186	11,294	18,062
HVAC ($)	3,977	8,075	12,457
Ligthing ($)	906	1,519	2,628
Misc Equipment ($)	878	1,700	2,977
Monthly Fuel Consumption (Therms)			
Jan	10.00	18.00	145.00
Feb	9.30	16.00	130.00
Mar	10.00	18.50	30.00
Apr	9.30	16.50	35.00
May	8.80	15.50	30.00
Jun	7.90	14.80	25.00
Jul	7.50	13.50	25.00
Aug	7.60	14.00	25.00
Sep	7.60	13.50	25.00
Oct	7.60	14.00	25.00
Nov	7.80	15.50	55.00
Dec	9.00	18	175.00
TOTAL	102	188	725
Monthly Electricity Consumption (kWh)			
Jan	3,500	5,800	9,000
Feb	3,250	5,500	8,200
Mar	3,000	6,100	10,500
Apr	3,000	6,250	10,500
May	3,750	7,800	12,500
Jun	4,250	9,000	14,000
Jul	4,300	9,100	14,100
Aug	4,600	9,200	14,300
Sep	3,500	7,800	12,500
Oct	3,650	7,900	12,750
Nov	3,100	5,800	9,500
Dec	4,200	6,300	9,000
TOTAL	44,100	86,550	136,850

of informal settlement interventions on materials, construction standards, architectural and community layout of houses, and HVAC systems. This interaction between public and experts may result in more sustainable and energy renewable solutions.

The opportunity exists for follow-up research to answer remaining important questions regarding the capability of BIM technology on monitoring landscape change, energy consumption and capital in the *colonias* focusing on time laps.

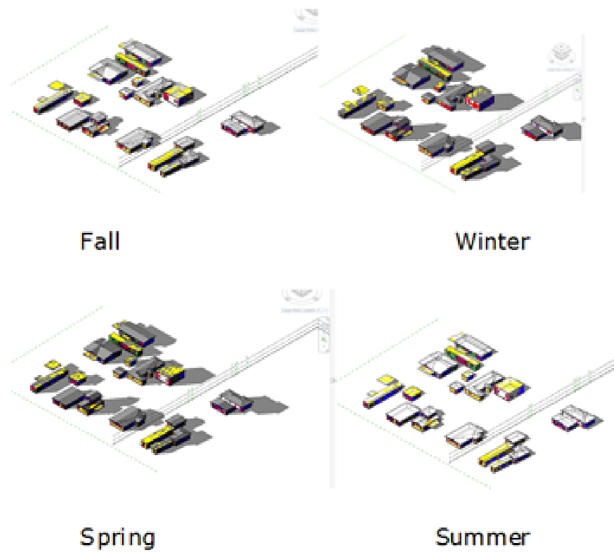

Figure 5. Solar analyses of the community

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