Article

Enhancing Green Building Rating of a School under the Hot Climate of UAE; Renewable Energy Application and System Integration

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Abstract: Similar to many fast growing countries, the United Arab Emirates (UAE) witnessed fast population and urbanization growth. The building sector accounts for a major share of its electricity consumption, reaching up to 70%. To encourage sustainable development and reduce energy consumption and emissions, the government introduced a sustainability initiative called “Etidama”, which employs the use of the Pearl Building Rating System (PBRs). Government buildings, which constitute 20% of the built environment, aim to lead the way, and are therefore required to attain a high level of achievement, based on their PBRs ranking (minimum of two out of five pearls). Schools, led by Abu Dhabi Educational Council (ADEC), are governmental buildings and aim to attain a higher level of achievement (three out of five pearls). The ADEC plans to build one hundred schools to be built by 2020, through its Future Schools Program. Over half of the schools have been completed, but only 20% reached the targeted rating (of three out of five pearls). The Renewable Energy (RE) application in the UAE is minimal, although it represents 25% of the local rating code. The objective of this paper is to explore the sustainable performance of one representative school that did not reach the desired green rating level, with the objective to assess opportunities for an enhanced performance. This is done through testing the performance and the application of three RE systems comprising of photovoltaics (PV) array, an absorption cooling system and a geothermal cooling system through Transient Systems Simulation (TRNSYS) software. Cumulatively, implementation of these options results in RE potentially contributing to 19% of the school’s annual energy consumption, enhancing the school’s performance by up to 14 additional credit points, and reaching the target level of achievement (a three pearl rating). Furthermore, system integration of RE into the existing school were also considered. Results indicate the significant potential of integrating RE systems in future schools in hot climatic contexts, for an improved energy performance.

Keywords: building energy performance; green building rating system; photovoltaic; solar absorption chiller; geothermal; schools; UAE; TRNSYS

1. Introduction

Fast growing economies often share common traits in terms of population growth and rapid urbanization, resulting in high energy demand and significant carbon emissions. Abu Dhabi, the capital of the United Arab Emirates (UAE), has similarly experienced a sharp increase in energy demand, leaping from 25,423 GWh in 2005 to 62,248 GWh in 2015. This drove similar increases in generation capacity, as indicated in Figure 1 [1]. The surge in energy consumption, positions the UAE as one of the world’s largest energy consumers per capita, with the building sector accounting for almost 70% of its total electrical energy consumption [2]. The primary electricity loads in the UAE are, by far,

cooling demand, then lighting, refrigeration and other appliance loads. In Abu Dhabi, the residential electricity load distribution is 47% for cooling (but can exceed 60% during the summer peak), 7% for lighting, 3% for refrigeration and 35% for other appliance loads [3]. The UAE's extreme hot climate, and subsequently high cooling demand, generated a challenging environment for energy conservation and environmental sustainability of buildings [4].

Figure 1. Total electricity power production in the Abu Dhabi emirate [1].

In line with worldwide initiatives to implement energy efficiency strategies in buildings, the UAE government introduced in 2008 a stringent sustainability code, named “Estidama” [5]. Followed in 2010 by the development of a green building rating system, named the Pearl Building Rating System (PBRs). The latter aligns with the principles of international green building rating systems, aiming to promote the development of sustainable buildings. The code compliance is governed by the PBRs, ranging from one to five pearls, ranking the level of achievements across seven categories. Similarly to most green rating system, PBRs is comparable with Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) rating systems. It rates buildings based on six categories: (1) Integrated Development Process (10 credit points), (2) Natural Systems (14 credit points), (3) Livable Communities (35 credit points), (4) Precious Water (37 credit points), (5) Resourceful Energy (42 credit points), and (6) Stewarding Materials (19 credit points)]. The first level of a building attainment requires meeting all mandatory credits and would gain one pearl, while if it achieves 60 additional credits it will reach the second level of attainment (or two pearls). Reaching 85 credits will achieve the third level or three pearls, while 115 credits translates to four pearls, and 140 credits qualifies for five pearls, which is the maximum number of pearls. The PBRs has a manual with specific guidelines on the methodology and calculation equations that are used to validate each system in order to achieve the credits [6].

The Precious Water and Renewable Energy categories are the dominant categories, comprising of the highest number of credit points. Twenty five percent of each of these categories represents a response to the context: characterized by scarcity of water and the extreme harsh climate that requires a substantial amount of cooling. The UAE has one of the highest sun exposure rates in the world, giving it a high potential for renewable energy development [7]. The application of RE in the UAE has been minimal and needs to be reinforced more in buildings in order to overcome the current energy challenges. Renewable energy makes up less than 0.1% of the UAE's total final energy consumption, which is unsustainable due to global current energy consumption challenges [8]. The UAE's RE energy base was non-existent in 2008. Since then, approximately 150 megawatt (MW) of solar panels have been installed, and over 300 additional MW have been announced. A further 100 MW of solar photovoltaic (PV) in Dubai, and 53 MW of waste-to-energy in Sharjah, was constructed. Nevertheless, in the context of other Gulf Cooperation Countries (GCC), the UAE has maintained the lead in total contracted capacity and project scale [9]. Early RE feasibility studies for Gulf countries directed their attention to greenhouse gas emissions as a driver [10,11]. Sustainability and the use of RE is prominent in the

strategic plans of the country, in terms of targets that will need to be achieved through RE contribution to the overall energy sector. Despite the overall intents, there is still a significant gap in the integration of RE which creates an opportunity for its integration within buildings in the UAE.

The government-sector buildings account for 20% of the building stock. Therefore, there is focus to adopt energy efficient practices in order to curb energy consumption, as well as establishing better building practices [12]. Governmental buildings aim to lead the way, and are therefore required to achieve at least two pearls [6] by adopting energy efficiency measures and integrating RE systems. Among all public buildings, school buildings have a major social and energy responsibility on account of their educational purpose. Educational facilities are a vital field to implement the sustainability practices and energy efficiency programs. Many countries are developing sustainable regulations and policies for schools building. In order to achieve several national energy efficiency targets, the local governments support all possible and effective initiatives to augment the benefits and the sustainable practices [13,14]. Therefore, the Abu Dhabi Educational Council (ADEC), a governmental entity, envisaged a promising 10-year strategic plan (2010–2020) named the “Future Schools Program”. This program seeks to construct 100 new schools with a minimum rating of two pearls (60 out of 140 points), and a strongly targeted higher goal of three pearls (85 out of 140 points) [15,16]. To date, 53 schools have been completed that meet the mandatory two pearl requirement. However, only 20% of these schools have reached the desired target of three pearls. This research aims to uncover the viability of enhancing the green rating performance of school buildings, through renewable energy integration. This research explores the performance of one recently built school under the hot climate of the UAE, which did not reach the desired rating (3 pearls), to serve as a model for the 100 planned schools that are built, or due to be completed by 2020. The aim of this paper is to explore the sustainable performance of one representative school in the context of the UAE’s hot climate, with the objective to assess opportunities for an enhanced performance.

2. Analysis of the School Green Rating System Performance

A review of green rating achievements of a newly built school prototype was carried out based on the design files and data from the educational council (Figure 2). The school was selected based on its green rating level of achievement (two pearls). The data included architectural drawings, design strategy, and technical specifications. The simulated data of the school performance including building loads, electricity consumption, operational schedules, and used systems. The documentation review revealed that the school already achieved most credits related to passive building envelope components, such as insulation, roof, and glazing systems; and active systems such as LED lighting, sensors, controls, and water efficiency.

Figure 2. External view of the school [17].

The design strategies implemented in the school were based on the local PBRS green rating requirements. A detailed review of the school's two pearl rating revealed that it achieved 81 credit—only 4 points short of achieving the desired level of attainment (three pearls). The analysis revealed that the highest number of unachieved credits (up to 70%) were within the Resourceful Energy category, despite this being the most weighted PBRS category. The RE credit distribution comprises of 6 sub-categories, by which 25 credit points were not achieved. The main reasons for this, as indicated in the submission files, were due to the in the lack of expertise offered in the field, therefore this school provides a good opportunity for the investigation of the energy performance enhancement of the building.

This scenario provides a promising potential to explore the use of renewable energy generation. A review of Abu Dhabi's climatic data revealed that the weather remains predominantly hot and humid, with peak summer temperatures reaching 48 °C and a relative humidity of 90% [18]. Extreme weather such as this requires extensive air conditioning, which may contribute up to 75% of a building's energy use [19].

This research explores alternative cooling systems that require less energy input, with the goal of substantially decreasing energy consumption. Solar radiation is plentiful in the UAE, and free to use. Additionally, preliminary assessments have shown a substantial temperature difference of up to 20 °C between the ground temperature (23 °C) and ambient temperature (48 °C) in the peak summer months, favoring geothermal cooling system [20]. Weather data revealed a yearly solar radiation is 2370 kWh/m², i.e., 6.5 kWh/m² per day [21], which favored the choice of an absorption cooling system, and photovoltaic energy generation. Geothermal cooling system have also been found promising to deliver the effective cooling required [21].

The contextual characteristics of the promising renewable energy systems for integration into the selected school building are summarized in Table 1 [22].

The energy produced by the aforementioned systems is compared to the school's baseline energy demand (Table 2), to determine the energy savings and perform the calculation. The predicted energy savings are then converted into credits earned, based on the PBRS guidelines. The cooling system performance is compared with the demand in peak months (May–August) in order to determine the reductions achieved in peak-period cooling capacity and energy use.

Table 1. Renewable energy systems selection in harsh climate.

System/Criteria	Advantages	Limitations	Performance	Payback Period versus Life Span
Photovoltaic system [23]	Annual solar radiation of 2285 kWh/m ² , expected energy of 850 kW year/m ²).	Dust results in radiation reduction on panel. High temperature results in power losses.	Electrical energy production of 322 kWh/m ² -year [24,25].	Pay-back period: 3–5 years [26] based on unsubsidized tariffs. Lifespan: 25–30 years.
Solar absorption cooling system [27,28]	Annual solar radiation of 182,800 kWh/m ² .	High initial cost. Dust on collectors results in radiation reduction. High temperature results in power losses.	A cooling energy production of 1059 kWh/m ² -year.	Average payback period: 4–10 years. Lifespan: 25–35 years.
Geothermal cooling system [20,29]	Ground temperature is used to modulate interior temperature (difference up to 20 °C during summer)	High initial cost. Land required to install the loop. Lower temperature gradient in moderate seasons.	Cooling energy delivered by 46 kWh/year-m length of borehole [30].	Average payback period: 7–10 years according to the system size. Life span: up to 50 years.

Table 2. Baseline energy consumption data for the school building [17].

System	Peak Capacity (kW)	Annual Energy Consumption (MWh)
Space cooling (peak months)	360.5	777.6
Heat rejection	49.4	151
Space heating	79.7	0.066
Pumping energy	42.8	105.7
Interior Fans	304.6	276.9
Interior Lighting	188.3	410
Service Water Heating	200.0	231.8
Receptacle/Process	167.5	252
Equipment		
Total	1392.9	2206

3. Methodology

A transient simulation model is developed using Transient Systems Simulation (TRNSYS) software, employing Typical Meteorological Year (TMY) weather data for Abu Dhabi to predict energy performance for the proposed renewable energy systems [31]. TRNSYS simulation program has been widely used in literature, and has been proven as an effective program for simulating geothermal systems [32–34], absorption cooling [35–37] and photovoltaic systems [38–40]. A dynamic model that couples the solar cooling system with the building was developed in TRNSYS to assess its performance in an office building in Tunisia [41]. The model predicted a primary energy savings up to 82.3% compared to a classic air conditioning system, resulting in a CO₂ emissions savings of 2947 kg [41]. In another study, a solar powered absorption cycle was modeled in TRNSYS, employing evacuated tube collectors coupled with a 10 kW ammonia–water absorption chiller. The results showed a cost and energy saving of up to 24.5% and 35.3%, respectively [42]. A desiccant cooling system and geothermal heat pump used together in a solar hybrid desiccant air conditioning system were tested using TRNSYS software in Shanghai. Under typical weather condition, the solar driven desiccant cooling unit achieved an average cooling capacity of 70 kW, contributing up to 31.4% of the cooling capacity of the system [43]. A TRNSYS model has been developed to simulate both winter and summer period. Results showed that using these systems reduced the payback from 14 years to 1.2 years, with the Primary Energy Savings of about 90% [44].

The PV and absorption cooling systems are based on size of roof area available to install the PV panels and thermal collectors. Three types of PV systems, namely polycrystalline silicon, mono-crystalline silicon, and amorphous silicon, are preliminary assessed using the manufacturer's data sheets. The analysis revealed that mono-crystalline PV is the most suitable system. This is due to its high efficiency of up to 20% supporting building integration, and low temperature-based power loss coefficient (up to 0.38%), making it favorable in hot climates [45]. The geothermal heat exchanger is chosen based on the size of the land area available around the school to install the loop. The TRNSYS model of the three systems included several building parameters used for modeling. It included parameters for a building envelope, HVAC and plug loads.

4. Results and Discussion

4.1. Photovoltaic System Performance

The PV module is tested at various slopes and azimuth angles to represent different pitch angles and orientations during building integration, either driven by need or design choice. Figure 3 shows energy produced by PV integrated to building at pitch angles of 0° representing flat roof, 24° representing latitude pitch, 45° representing regular building pitch, and 90° representing building vertical facade.

Figure 3. Monthly energy produced per panel at various Photovoltaic (PV) slopes representative of different building integration schemes.

The highest variation in power output is observed at 0° , for which the power output is lowest in winter (December–January) and highest in summer (April–August). This trend can be attributed to the sun position, which moves near zenith up to 18° in summer and shifts away from zenith up to 30° in winter, inducing a substantial drop in output. In summer, the incident radiation is nearly normal to the plane of the PV panel at horizontally integrated panels (0°), while in winter the incident radiation is substantially off normal at the same inclinations. The PV panel produces consistently lower power at 90° fundamentally due to larger deviation of incident angle. At 24° , the energy produced remains higher during most of the months (apart from winter) due to lower solar angles. At 45° , the highest energy production is witnessed during winter, while a substantial decrease is observed in summer. All of these observations are in agreement with previous findings [46,47]. Architecturally, integrating PV at 0° offers ease of installation, as no additional cost is incurred for structural support, in contrast to sloped PV. However, at 0° slope the PV panel is prone to increased dust retention compared to the tilted PV, as dust particles on tilted panels can slide down off the panels under gravity.

These results reveal that energy production peaks at different panel slopes during different times of year, suggesting that the PV slope should be adjusted monthly, or at least seasonally, to enhanced energy production. The annual energy production for conventional fixed slopes compared to the monthly adjustable slopes is presented in Figure 4. It can be observed that the adjustable slope improves the power by 3% output compared to the optimal fixed sloped (24°).

Figure 4. Annual power production per panel (kWh) for different static slope angles, and an optimized adjustable slope design.

The optimum PV orientation is reported to be exactly southerly in the northern hemisphere, represented by 0° [48]; however, the energy loss incurred by deviating from the optimum orientation is not well known. The building configuration varies substantially depending on design demands, and architects are often compelled to select a sub-optimal azimuthal orientation in order to adhere to the building design, facilitate mobility, or maintain symmetry. In order to predict PV performance due to sub-optimal azimuth orientation, the energy produced from a PV panel with an azimuth angle varying from 90° to -90° (with an interval of 45°) is presented in Figure 5.

It can be observed that 0° yields the highest energy production, while declines of 24 kWh/m^2 at 45° (Southwest) and 45° (Southeast) and 65 kWh/m^2 at 90° (West) and -90° (East) are observed. In order to provide optimal PV power penetration for the school building, half of the available roof area is allocated to PV installation reserving the rest for PV shading and mobility requirements for maintenance. Thus, the total area covered by PV panels was found to be 555 m^2 that can house 342 PV panels. The PV array produces 209 MWh of energy, which makes up 10% of the total yearly energy consumption of the school in 2016.

Figure 5. Total annual power production (kWh) for different PV panel azimuth angles for at latitude angle of 24° .

4.2. Solar Absorption Chiller Performance

The absorption cooling system is designed to deliver 10% (36 kW) of the building peak cooling capacity of 360 kW. Considering the typical UAE peak solar radiation intensity of 1 kW/m^2 [21] and absorption cooling system efficiency of 40%, [49,50] a typical thermal collector of 3 m^2 area can produce 1.2 kW of cooling power. Thus, an absorption cooling system comprising of 30 collectors covering 90 m^2 of roof area would be required to generate 36 kW of cooling power. The proposed absorption system is simulated with varying concentration ratios (i.e., the aperture area: receiver surface area ratio) and inlet fluid flow rate to achieve the desired fluid temperature of 200°C at the collector outlet deemed safe for building integration [51].

The results show that as the concentration ratio increases from 5 to 25, the temperature of the fluid at collector outlet increases from 150°C to 580°C and the energy delivered increases from 2258 kWh to 58,600 kWh. The optimal temperature of 200°C [51], is achieved at a concentration ratio of 10 delivering 24,500 kWh (Figure 6a).

The water flow rate through the solar collector affects its useful thermal energy gain and, consequently, the amount of cooling produced. Optimal system operation therefore depends on achieving a balance between the temperature of the collector and the useful energy production. Simulations are conducted in sequential order, maintaining a collector temperature above 200°C through the use of optimal flow rates. A collector temperature of 618°C (much higher than optimal 200°C) is achieved at 2 kg/h and produces 10.56 kWh of useful energy. With increasing flow rate, the peak collector

temperature decreased, while paradoxically the useful energy gain increased. A collector temperature of 200 °C is achieved at a flow rate of 8 kg/h, producing 12.11 kWh of useful energy (Figure 6b).

The proposed absorption cooling system consists of a thermal collector array, covering a net area of 90 m², and employs Fresnel lenses to achieve the concentration ratio of 10, and a water circuitry system to maintain a flow rate of 8 kg/h per collector. The system produced 150,505 kWh/year of cooling energy, which is equivalent to 19.35% of the annual cooling energy consumption and 7.2% of the total annual energy consumption of the school.

Figure 6. Energy and collector outlet temperature produced by the simulated absorption cooling system under various concentration ratios (a) and fluid flow rates (b) in 2016.

4.3. Geothermal System Performance

The geothermal cooling system is preliminarily assessed by comparing the ground temperature at a depth of 5 m to the minimum and maximum air temperatures in Abu Dhabi, as shown in Figure 7. This analysis reveals that the yearly ground temperature fluctuates between 24 °C and 26 °C, which offers huge potential as an ambient heat sink, as peak summer air temperature measures up to 48 °C.

Figure 7. Peak ambient air temperature and ground temperature at a depth of 5 m.

The parametric influences on the geothermal system are studied to optimize the system energy output (Table 3).

The geothermal system output is monitored in terms of inlet and outlet fluid temperatures, fluid-to-ground heat transfer rate, and the amount of energy delivered representing the cooling produced. The simulation results of nine consecutive representative days in the peak summer month of July are expressed as outlet fluid temperature and energy produced.

The pipe length of the horizontal heat exchanger (2000 m) is calculated based on the available land area. The effect of fluid flow rate is evaluated from 400 kg/h to 4400 kg/h in increments of 400 kg/h. The results show that the energy delivered increases with increasing flow rate up to 2800 kg/h, delivering 22 MWh of cooling energy during peak months (Figure 8).

Table 3. Parameters and values pertaining to the geothermal system.

Parameters	Values
Fluid Flow rate	400–4400 kg/h in increments of 400 kg/h
Pipe Length	200–2800 m in increments of 200 m
Pipe Diameter	1 inch, 1.25 inches, 1.5 inches, 2 inches
Pipe Material	Aluminum, Copper, Polyethylene
Pipe Depth	3 m, 4 m, 5 m, 6 m, 7 m
Pipe Spacing	0.25 m, 0.5 m, 0.75 m, 1 m

Figure 8. Delivered energy for various pipe flow rates.

The performance of three heat-exchanger materials (i.e., aluminum, copper, and polyethylene) are compared in terms of the amount of heat removed as shown in Figure 9a. Aluminum has a thermal conductivity of 237 W/m·K, copper has a thermal conductivity of 401 W/m·K, and polyethylene has a thermal conductivity of 0.33 W/m·K. The delivered energy range of variation is between 22,100 MWh to 22,400 MWh, showing a negligible variation. However, polyethylene pipe is expected to last longer due to its higher resistance to corrosion. Thus, polyethylene is used as the heat exchanger material for further simulations. The effect of pipe depth on delivered energy is determined for depths ranging from 3 m to 7 m, in increments of 1 m [52]. The results in Figure 9b show an increase in delivered energy with increasing pipe depth up to 5 m producing up to 39 MWh cooling energy. The effect of heat exchanger loop spacing on the delivered energy is determined ranging from 0.25 m to 1 m, shown in Figure 9c. The energy delivered increases with increasing inter-loop spacing, reaching 39 MWh at 1 m spacing. Finally, the effect of pipe diameter is determined ranging from 0.75 inch to 2 inches, as shown in Figure 9d. The results indicate that the energy delivered increases with increasing pipe diameter, reaching 22 MWh at a 2-inch diameter.

The optimal arrangement reduced the leaving air temperature by 12 °C, thus resulting in a 5.8% reduction in annual cooling energy, and a 2.8% reduction in annual energy consumption.

The temperature is not expected to increase by the geothermal loop, since the earth has infinite thermal mass, so the heat will eventually dissipate into the earth. Thus, it is least likely that the temperature of the earth will rise. Additionally, the spacing between pipes is 1 m; therefore, the temperature will spread between the pipes. Moreover, the heat exchanger has minimal effect on the earth temperature compared to the solar radiation, which is much higher than the earth temperature. Ground temperature below a particular depth remains relatively constant throughout the year; due to the high thermal inertia of the soil [53]. At a sufficient depth, the ground temperature is always lower than the outside air in summer. When Ground Source Heat Pump (GSHP) is used, the temperature difference between the outside air and the ground is utilized to dump heat into the ground during summer to provide cooling. Our findings are in line with a research done in similar climates as the UAE, in which a mathematical model was developed and validated experimentally coupling the Solar Cooling System (SCS) with a Geothermal Heat Exchanger (GHX) in California, USA [52]. The results show that a 12.30 kW cooling capacity SCS would be necessary to satisfy the maximum cooling load requirement during the summer. Additionally, between 10 and 23% of the energy demand was met by the systems [52].

Recently, some buildings started integrating geothermal system in the UAE as a pre-cooling system, and are reported to be effective [54]. In particular, Sheikh Zayed Learning Center, a museum in Al Ain city, UAE, integrated geothermal system and was able to achieve a five pearls, based on the PBRS system, and was certified a LEED platinum rating [54].

Figure 9. The parametric influence of pipe material (a) pipe depth (b) pipe spacing (c) and pipe diameter (d) on the delivered energy.

5. Credit Enhancement Verification of the Local Green Rating System

In order to verify the result of the study with the local PBRS rating system, an analysis has been done to calculate the contribution of the studied systems to the overall credits achieved.

The number of RE-1 credits achieved through the integration of the renewable energy systems, discussed in Section 4, are calculated by applying Equation (1) which comes from Estidama manual:

$$RE - 1 = \frac{100 \times 2,088,493.2 \left(\frac{\text{kWh}}{\text{yrh}} \right) - 1,684,467.2 \left(\frac{\text{kWh}}{\text{yrh}} \right)}{2,088,493.2 \left(\frac{\text{kWh}}{\text{yrh}} \right)} = 19.35\% \quad (1)$$

The proposed systems reduce building energy consumption by 19.35%, earning 4 additional credits points, and thus achieving all of the 5 credits allocated to the RE category in the PBRS.

The *Estidama* PBRS also awards additional RE-5 credits for peak cooling capacity reductions as given in Equation (2). The annual average electrical load is calculated in Equation (3).

$$\text{Peak Reduction} = \frac{\text{Peak Load}}{\text{Average Electrical Load}} \quad (2)$$

$$\text{Annual Average Electrical Load} = \frac{\text{Cooling Load kWh}}{180 \text{ days} \times 24 \frac{\text{hr}}{\text{day}}} + \frac{\text{Other Loads kWh}}{180 \text{ days} \times 9 \frac{\text{hr}}{\text{day}}} \quad (3)$$

A system achieving a peak cooling load-to-average electrical load ratio of 1.8 or below qualifies for two additional credits. The proposed systems reduce the peak-cooling-to-average load ratio to 1.7, thus earning two additional credits. The school analyses in this article is already producing 5% of its energy through RE systems. Adding 19.3% energy generated from the proposed three systems would bring the total RE penetration to 24.3%, nearly reaching the ceiling of 25% allowed by the PBRS. This would lead to additional 14 credit points, increasing the school's current rating from 81 to 95 credit points: Thus enabling it to reach the desired three pearl rating (which requires a minimum of 85 credit points).

6. System Integration

The school building is being served by a central chiller as a cooling system. The geothermal and absorption chiller energy systems are designed to work together with the existing cooling system of the school. Solar thermal panels, used to heat water, would be used directly for heating water in the building during winter, and to pass the water to the absorption chiller, to cool the building during summer (Figure 9). During summer, the air coming from outside would be monitored as it passes through geothermal system, and is then cooled through the Air Handling Unit (AHU) before entering the building. At the same time, the hot water passes through the absorption chiller system to cool, and then passes through the AHU before being used. If hot water entered the absorption chiller, it will be cooled down but still will not be comfortable, thus, it would enter the chiller compressor to be chilled water, before passing through the AHU, ready to be used in the school. During winter, the air will go directly to the AHU and there will be no cooling demand, thus the thermal panels will be used to heat the water inside the building (Figure 10).

Figure 10. Renewable energy system integration.

7. Conclusions

This paper investigates opportunities of integrating renewable energy strategies to enhance the energy performance of governmental schools, under the harsh climate of the United Arab Emirates. Specifically, it aims to improve the local green building rating performance of a public schools in Abu Dhabi (UAE) by taking it from two pearls to three pearls. This is done through gaining credits in the PBRS' Resourceful Energy category, which represent one-fourth of the obtainable credits. This particular category has not been optimally integrated in the newly built public buildings, despite its potential.

The technical feasibility of renewable energy systems, namely photovoltaic, solar-powered absorption chiller and geothermal systems, were studied. The systems were evaluated using TRNSYS Simulation Software under UAE climatic conditions to test their performance. Relevant parameters and variables in each energy system were optimized in order to maximize energy savings, while remaining grounded in qualitative design terms, special requirement, and cost constraints. The geothermal system yields an annual cooling energy reduction of 5.8%, and a total energy reduction of 2.2%. The solar absorption cooling system results in 19.35% reduction in annual cooling energy use, and 7.2% reduction in total annual energy use. The photovoltaic system contributes 10% of the total energy consumption (or a 10% energy savings). The total energy savings from the combined three systems can reach 19.35%, which leads to an additional 14 PBRS credit points. The rating enhancement is found feasible in terms of energy, and special provisions involving photovoltaic, solar-powered absorption cooling, and geothermal renewable energy systems. Thus, integrating these systems will allow the school to improve its pearl rating from the current level of performance to the next i.e., from two pearls to the desired three pearls. Furthermore, this study considered the RE system integration into the existing cooling system of the school. The investigated solar systems hold an applicability enhancement potential that spans to most similar buildings under the same, or similar settings.

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