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Integration of Renewable Energy Technologies in University Campuses: a Case Study

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Abstract. Renewable energy technologies are becoming widely integrated into energy generation systems around the world. While the majority of such technologies are integrated at a large scale in the form of wind and solar farms, there is a need for their incorporation into the built environment. A university campus is an ideal place for testing and understanding how renewable energy technologies can be integrated at a building site scale. Nazarbayev University in Nur-Sultan, Kazakhstan, is a research intense institution which is set to lead the sustainability-related research in the region. The campus is populated with a number of technologies such as a passive house, wind turbines, and photovoltaic solar panels of different capacities and configuration. The review of the technologies and assessment of their operation allowed the study to understand the nature of pioneering technologies that can be integrated in the climate conditions of the locality and how such solutions can help to increase the awareness and popularize renewable energy through education and research.

1. Introduction

Energy is a fundamental resource to sustain life on Earth. It supplies cities with light, empowers vehicles, cools or heats the buildings, and has many other applications. Over the centuries, the global population has been relying on energy to advance technological development which simultaneously became a reason for environmental degradation [1-3]. Global warming caused by excessive discharge of greenhouse gas emissions into the atmosphere and depletion of energy resources pose a great threat to the future of the planet. In recent decades, scientists and governments started to search for alternative clean energy sources to meet the growing energy demand and reduce the impacts on global climate [4-7]. At present, the renewable energy output is only a small fraction of all produced energy globally, and it is particularly small in the case of developing countries such as Kazakhstan [8-11]. Therefore, any attempt to integrate renewable energy sources both at a large and a small scale should be based on detailed studies, analysis of lessons learned and investigation of further multiplication possibilities.

A university campus is a suitable environment where sustainability measures and renewable energy technologies can be implemented and studied. This is particularly true due to the availability of



researchers, students, and technicians who have time and resources to conduct time-consuming investigations on the efficiency and practicability of renewable energy technologies [2-3]. University campuses with their technological parks and polygons tend to be used as demonstration sites both for students and visitors from outside the campus ranging from government representatives to business owners. This provides an opportunity to raise awareness among various stakeholders who can potentially be engaged in similar projects outside the campus [12-13]. Physical viewing of wind turbines, solar panels and solar water heaters by various stakeholders, and where students are actually engaged with technologies, tend to be more impactful and educational compared to mere theoretical knowledge. Thus, installing renewable energy technologies in university campuses allows increasing the awareness among stakeholders and allows testing their integration in the city scale since a university campus can be considered as a model of a typical urban area. Therefore, a university campus is an ideal place to encourage the promotion of energy sustainability and the integration of renewable energy technologies [2-3]. Many educational institutions around the globe have already integrated renewable energy technologies on their campuses. For example, in the University of Minnesota Morris 70% of daily electricity usage on campus is coming from renewable sources. They have two wind turbine towers with a total generation capacity of more than 20 million kWh of electricity per annum, 20 kW Solar PV Microgrid that powers one of the residence halls and biomass gasification facilities that extracts fossil fuels from local corn and cobs biomass [14]. Colorado State University installed 6.7MW capacity solar PV panels during 2009-2015. Arizona State University installed 24.1 MW on-site and 28.8 MW off-site solar PV panels. University of California campuses are home to 36 MW capacity solar PV panels with more than 52 million kWh electricity [15].

Chinese university Shenyang has taken serious steps in becoming a sustainable university by means of installation of a ground heat pump, recycling of greywater, implementing effective waste management and sustainability-oriented education, and launched many on-going projects on environmental protection [16]. The University of Kansas took green initiatives and installed an energy system that has 36 solar PV panels which produce 7.4 kWh energy and a wind turbine that generates 400 kW per month [17]. The Savona university campus located in Italy meets campus thermal energy demands by installing 28kW cogeneration gas turbines, two 400kW boilers which are fed by natural gas, biomass gasifier connected with an internal combustion engine, 100kW gas turbine microgrid, 250kW diesel engine charged with turbo. Some other initiatives have smart polygeneration microgrid (SPM) that includes wind turbines, PV solar panels, electrical battery storage, two recharge stations for electric vehicles, etc. [18]. University of Cape Town located in South Africa has created a Green Campus Plan and undertook measures such as abatement of carbon emission, conservation of water, and waste recycling system [19]. Kalinga Institute of Social Sciences (KISS) located in India undertook massive sustainable infrastructure initiatives to diminish the carbon footprint of more than 30000 students and faculty members. KISS installed 870KWp Solar PV system on campus that meets 100 percent energy demand and is considered as the largest roof installation amid Indian universities, rooftop solar water heating installation, biogas plant with 1000 kg capacity per day, rainwater harvesting system, etc. [20].

2. Review of renewable energy technologies at Nazarbayev University campus

2.1. Passive house

One of the main components of the University's renewable energy polygon is a traditionally shaped "Yurt" building which is built according to the standards of a passive house (Figure 1). It is an energy-efficient autonomous building with a unique round shape, designed in the form of a traditional nomadic house, that has integrated state-of-the-art energy-efficient and renewable energy technologies. The building is powered by solar, wind, and geothermal energy with automated control of the system.



Figure 1. Energy efficient “Yurt” building

Passive house design in the case of the “Yurt” building emphasizes harnessing energy from renewable sources. This is also done by optimizing the building design in a way that maximum solar radiation can be used to heat the building, wind to cool the buildings, vegetation to create shadow, and the temperature of the ground to heat and cool the building via a geothermal pump. It is reported that passive design measures allowed the “Yurt” building to perform 3.5 times energy-wise compared to buildings designed and built according to conventional standards [21]. One of the key building design elements that are deemed to create a passive house effect is the shape of the “Yurt” building’s roof which is made in the form of a dome. It is reported to be efficient against winds and snow loads, minimizes heat losses, and requires fewer materials and labor to build. It was reported that yurt-shaped buildings use 23-27 percent less energy during exploitation [21]. The main design specifications are presented in Table 1.

Table 1. Specifications of the “Yurt” building

Total area (sq.m)	115
Number of floors	2
Number of rooms	5
Building diameter (m)	10
Building height (m)	6
Foundation	Pile type
Utilities system	Power, water, drainage
Insulation	Polyurethane-based
Framework of the dome	Softwood lumber lined with sheets of OSB

2.2. Photovoltaic (PV) solar panels

PV solar panels (ZDNY-250C60) is a system with the total number of 15 PV connected solar panels (Figure 2). Each module has dimensions of 1650 x 992 x 45 mm and consists of 60 cells connected in series. One mono-crystalline cell’s dimension is 156 x 156mm. The weight of the PV solar module is 22.5 kg. The maximum power capacity of the module is 250 Watt and the whole system has a power capacity of 2.5 kW. The efficiency of cells in this model is 17.9%. The cells can operate in -40 to 85 degrees Celsius temperature range and have 47 degrees Celsius nominal operating temperature. Typically, on sunny days, the system produces 7.5-10.0 kW of energy per hour [22]. This energy goes through optimized three phase inverter (Suntellite ZDNY-TL), gets collected in the rechargeable batteries and after that used to supply the autonomous energy building (Yurt) [23].



Figure 2. PV solar panels connected to the “Yurt” building

2.3. Wind turbine

The wind turbine made of reinforced fiberglass (Figure 3). It has a maximum power output of 3 kW and has a rated power of 2.5 kW at a wind speed of 11 m/s. The maximum allowable wind speed for the system is 40 m/s with auto furl and dump load for over-speed protection. The operational temperature range is between -30°C and 60°C [24]. The machinery can generate 324 kWh per month at an average wind speed of 5.4 m/s. For the average wind speed of 4.45 m/s in Nur-Sultan, the turbine can produce 267kWh per month. This power is directly supplied to meet the energy demand of the “Yurt” building. The turbine consists of 3 blades with a diameter of 3.8m and it performs 450 rpm at 2.5kW power [24].



Figure 3. Wind turbines

3. Discussion and Conclusions

As described in the sections above, Nazarbayev University campus has a polygon with integrated renewable energy technologies. Although there is a wide number of technologies in place, this study considered only those which are connected to the “Yurt” building, an energy-efficient house that was designed and built according to passive house principles. The “Yurt” building is also designed with consideration of local traditional design elements pertinent to nomadic style. This design, including the rounded shape and a dome-shaped roof, proved to increase the energy efficiency by exploiting the wind and solar energy effectively. The “Yurt” building is connected to the network of 15 solar PV panels that produce 7.5-10.0 kW of energy per hour and a wind turbine that can produce 267kWh per month. The “Yurt” building itself reported being 3.5 times more energy efficient compared to standard houses built according to conventional construction norms. The energy produced by the integration of renewable energy and saved by the passive design contributes to the overall sustainability of the university campus. The passive house is a unique concept for Kazakhstan and can be considered as a breakthrough project which needs to be studied more carefully and replicated at a wider scale. The same can be stated regarding the wind turbine and solar PV panels. Existing wind turbines and solar panels supply energy to batteries and not to actual homes; so, it can be stated that the case study of “Yurt” building with the integrated renewable energy technologies can be considered as a pioneering

model of a smart grid. Careful examination and long-term assessment of such a grid should be carried out and replicated at a wider scale.

The future study should discuss all the renewable energy technologies installed at Nazarbayev University campus such as Concentrated Solar Power (CSP) plant - Sun Power (25 kW), PV solar panels (15 kW) integrated to the Technopark building, tilttable solar tracker (10 kW), geothermal pump (3 kW), and solar collectors (32 sq.m.). One of the limitations of the study can be related to the fact that the operational data on monthly energy generation over the past periods was not available for the analysis due to commercial privacy. Future research should also consider the cost-benefit analysis to understand the payback period of building a passive house and integrating various renewable energy technologies.

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