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The EPFL campus in Lausanne: new energy strategies for 2050

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Abstract

The increase of the urban population and the climate change are issues that scientists and stakeholders are facing nowadays; in this optic a sustainable design should address buildings, and all the physical phenomena that interact with them, from the urban to the district scale. The Swiss Federal Institute of Technology in Lausanne (EPFL) located in Switzerland is now facing this problematic, and its sustainable strategy "Energy Concept 2015-2045" aims to reduce the energy demand per person by 30%, and the CO_2 emissions by 50% in 2035. The university campus is growing -the energy reference area has increased by 25% from 2001, and is expected to continue in the next years- and the actual district heating system (two heat pumps with a combined heat and power facility installed in the early 70s) is facing peak power limitations nowadays. Looking for an answer for this issue, a new concept called Energy Hub is sought for the campus: an intelligent unit able to stock and redistribute energy with different carriers. This paper presents the pre-requisite for a potential energy hub on the site of the EPFL campus in Lausanne: the validation of a dynamic heating energy demand model (correlation factor R^2=0.89 compared to monitoring) and a BiPV power plant model for the solar electricity produced on the EPFL buildings roofs (correlation factor R^2=0.93 compared to monitoring). Finally, two hypothetical refurbishment of the site, according to the Swiss Minergie and Minergie-P labels, are proposed; they reduce the heating demand of buildings by 38% and 44% respectively. Refurbishments are analysed using actual weather data (average data from the last ten years), as well as future scenarios for 2050, showing the impact of climate change on the building thermal behaviour.

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Keywords: climate change; district energy modelling; energy hub

1. Introduction

The increase of world population, mostly in urban environment, and climate change are problems that scientist and politics are facing nowadays, and oblige them to rethink our way of living introducing new technologies and land policies to reduce our energy footprint [1] [2] [3]. The Ecole Polytechnique Fédérale de Lausanne (EPFL) is one of

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the largest universities in Switzerland, and hosts around 15.000 people (including students and professional) each day. According to Energy Strategy for 2050 (Swiss federal energy policy), EPFL is working to define the "Energy Concept 2015-2045", a strategic report that aims to reduce the energy demand per person by 30% of final energy and 25% of primary energy in 2035, to increase the percentage of electricity coming from renewable energy and to reduce by 50% CO_2 emission by 2035 [4]. The campus is heated by renewable energy (56% by district heating system using lake water and 18% Swiss hydroelectric), but as the energy reference area has increased by 25% from 2001, and is expected to increase in the next years, the actual district heating system (two heat pump combined with heat and power facility) is facing limitation [5]. With the goal of reducing the energy demand of the site, the EPFL is part of an innovative project called IDEAS4cities that tends to develop an Energy Hub: an intelligent unit able to collect, store and redistribute energy from different energy carriers, according to the need of buildings [6] [7] [8].
This paper presents the first approach to create an energy hub on the site of the EPFL: the validation of the energy model of the site and the optimisation of the energy demand by refurbishment. The energy demand for heating and the electricity produced by the BiPV power plant are analysed with the software CitySim -an urban energy modelling able to analyse the energy demand of buildings at the urban scale [9]- and validated with on-site monitoring [10]. Finally the existing model and refurbishment scenarios (according to Minergie and Minergie-P Swiss standards) are analysed for three scenarios for 2050 (2050-B1, 2050-A1B and 2050-A2), showing the impact of climate change on the energy demand of the site, and proposing an optimal strategy for the future development of the campus.

2. Methodology

EPFL campus is located near the city of Lausanne, the capital of Vaud Canton, in Switzerland (46.53 N, 6.56 E); the university is near the Geneva Lake, at 400 meters above the sea level. The university is composed by more than 50 buildings, interconnected with a pedestrian circuit. The climate in Lausanne is temperate by the Geneva Lake, however presenting cold winters and warm summers. A typical meteorological year (TMY) climate file is created with the software Meteonorm [11] using average radiation data for the period 1991-2010 and average temperature for the period 2000-2009. The highest temperature during the summer is 30°C, and the lowest temperature is -9.5°C during the month of January. The relative humidity is comfortable during the year; the total precipitations are 1,142 mm per year and showing by snow during the winter time.

2.1. Heating demand and BiPV production

The university was built in two main phases, which characterize the geometry and materials of buildings: first phase in 1972-1984 and second one in 1980-2002 [12]; later buildings were added to the site such as the Rolex Learning Centre and Swiss Tech Convention Centre. Buildings' envelopes are defined according to the period of construction: buildings built in the same period are part of a homogenous architectural plan and present the same physical characteristics, summarized by their U-value in Table 1.

Table 1 Envelope of the buildings, defined according to their period of construction

Construction phase	U-value Roof ($W \cdot m^{-2} \cdot K^{-1}$)	U-value Wall ($W \cdot m^{-2} \cdot K^{-1}$)	U-value Floor ($W \cdot m^{-2} \cdot K^{-1}$)
First Phase (1972-1984)	0.33	0.33	0.56
Second Phase (1980-2002)	0.31	0.38	0.56
Minergie Building (since 2002)	0.16	0.16	0.16

The geometry of the campus is based on an existing 3D model [13], and the occupancy profile is defined according to SIA 2024/2006 [14]: the number of occupants and their presence is based on the liveable surface of the building and its function (office, restaurant, classroom and dormitory). A different profile is applied during the Christmas holidays, when the university has a limited number of occupants. The Swiss Tech Convention Centre and the adjacent residences are analysed without occupants, because they were inaugurated in 2014 and consequently no monitored data are available yet.
The EPFL campus is heated by a central heat pump, that uses the water from the Geneva Lake: the water is pumped