CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 3

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Heiselberg, P. K. (Ed.) (2016). *CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 3*. Department of Civil Engineering, Aalborg University.

The Application of Combined Renewable Energy Systems in Smart Buildings

František Vranay[1], Clayton Stone[2], Marek Kusnir[3], Daniela Kaposztasova[4]

[1-4] *Faculty of Civil Engineering, Technical University of Kosice,*

Vysokoskolska 4, Kosice 042 00, Slovakia

[1.] *frantisek.vranay@tuke.sk*

[2.] *clayton.stone@tuke.sk*

[3.] *marek.kusnir@tuke.sk*

[4.] *daniela.kaposztasova@tuke.sk*

Abstract

Sustainable building technologies, designed to create an indoor environment that uses fewer resources and generates less waste, can also be used to retrofit existing buildings to be more efficient in terms of energy and water. This paper deals with renewable energy sources based on current technology system environments made of advanced materials with the use of modern terminal and distribution elements for smart buildings within smart cities. The synergy between these technologies in a specially made full-scale experimental laboratory aims to achieve a zero-net-energy balance and provide experimental data on energy storage, optimization and occupant behaviour. It proposes the application of computer and telematics tools with automation organized systems and passive bioclimatic strategies, to achieve a socio-technical management of smart buildings that are energy efficient and environmentally sustainable.

Keywords – envelope; heat storage; smart building; sustainable development

1. Introduction

The centre for researching the effectiveness of integrating combined systems of renewable energy sources was initiated, by the Technical University of Kosice with the support of European Regional Development Fund and the Slovak Ministry of Education, in 2014. To approach the significant reductions in building energy use proposed by Directive 2010/31/EU Article 9, which requires that: "*Member States shall ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings; and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings"*, [1] well-integrated building designs will be required. Successful energy efficient design begins with load reduction and continues with integrated design incorporating multiple advanced building systems. A nearly zero-energy building is defined in Article 2 of the EPBD as: "*a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*" [1].

2. Project Objectives and Significance to Industry

Develop, assess and validate innovation components that will reduce energy use in buildings while improving occupant comfort. By building on recent research and technological innovations in several fields, the project will create and demonstrate the feasibility of combined renewable energy systems and operational practices. The new control paradigm should be transposable to existing buildings as well as new designs, and aims to economically achieve a substantial reduction in energy use and carbon footprint. These innovations will support building energy performance design targets, and advance codes and standards toward deep energy efficiency and demonstrate the practical application of a combined set of renewable energy systems. In the final phase a demonstration and commercialization plan will be created to guide initiatives to take project technologies into the European market.

3. Research Approach

The project aims to accelerate the adoption of new building control technologies that are far more occupant responsive and energy efficient than current practice by implementing the strategy illustrated in Figure 1, overleaf [2]. The team will use diverse climate conditions and building control systems at the laboratory as a test bed. Eleven forms of combined renewable energy sources will provide a constant supply of energy to the consumer model situated in a climate chamber and the output and efficiency of each source will be monitored year round to determine which combination can be most efficiently harnessed for the given climate. Energy derived from the renewable sources will be used to produce various forms of work. The entire system is over dimensioned so that there will always be excess energy which will be accumulated in two 1000 litre short term storage tanks and three larger long term storage tanks with a capacity of 150 000 litres, Figure 2. The total annual thermal capacity of the permanent storage tanks is 290 GJ or 87 MW/h. The peak performances of the individual renewable sources of energy are presented in Table 1. Manipulation of these energy resources will be accessible via a cloud computing network so that registered institutions may conduct experiments for their desired climatic conditions remotely.

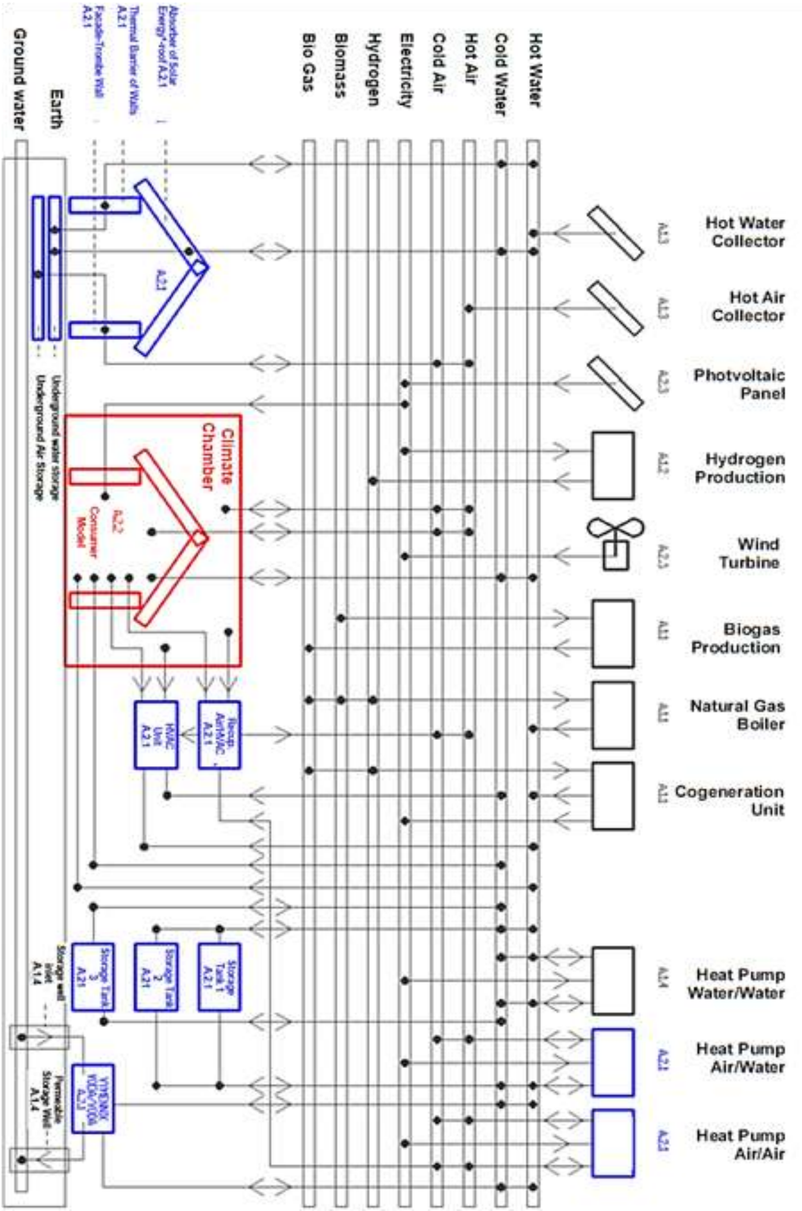

Fig. 1 Schematic depicting the symbiosis between renewable energy sources [2]

Fig. 2 Left: Insulated long-term heat storage tanks under construction with operating temperature between 15-85 ° C; Right: Short-term heat and coolth stored in 1,000 litre tanks

Table 1. Peak design output of the renewable energy sources [3]

Source	Heat [kW]	Electricity [kW]
Solar Collector 128m^2	**90**	**0**
Hot Air Collector	**3**	**0**
Photovoltaic	**0**	**5**
Hydrogen	**3**	**3**
Wind turbine	**0**	**1.5**
Bio gas	**90**	**0**
Natural gas	**25**	**0**
cogeneration	**37**	**30**
Heat pump water/water	**43**	**0**
Heat pump air/water	**15**	**0**
Heat pump air/air	**3.5**	**0**
Total	**312.5**	**39.5**

4. The Consumer Model

The specially built 55 m^2 passive house passive-house consumer model is situated in what shall be a full sized laboratory climate chamber. The materials for the walls were selected as a source of heat sink for diurnal fluctuations of temperature. The typology of the building is near symmetrical so that the performance may be compared when different heating elements are used. The building envelope features triple glazing in the windows and doors and 250 mm of mineral wool insulation in the walls. The internal floor is raised above the ground level and is ventilated. The floor and flat roof are both insulated with 400 mm of thermal insulation. Figures 3 and 4 depict views and details of the consumer model.

Fig. 3 The consumer model showing the heat pumps for the climate chamber (not-shown) (Photograph by Grul, R.)

External shading devices can be adjusted by smart control systems, HVAC is solved using radiant wall, floor and ceiling systems, traditional hot water radiaters, fan coils and split AC systems and a recuperation system that also humidifies or dehumidifies fresh air. The HVAC system must respond to a variety of conditions inside and outside the building (including weather, time of day, different heating zones in a building and occupancy), while simultaneously optimizing its operations and related energy usage.

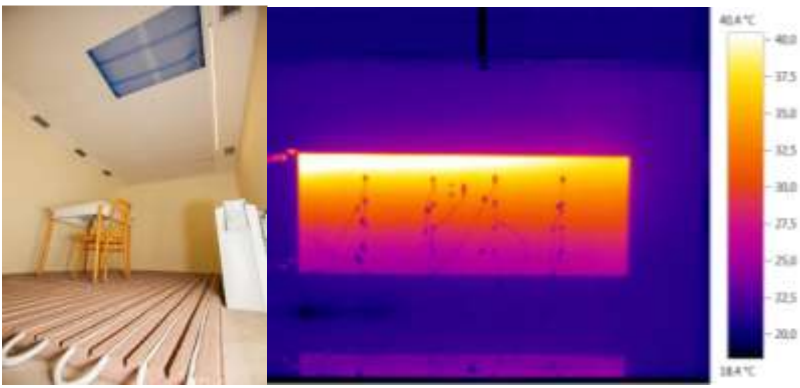

Fig. 4 Left: Floor/wall celing heating and cooling and fan coil; Right: hot water radiator experiment

Fig. 5 Split system with recuperation and humidity control

5. Smart Building Control and Climate Chamber

Smart building technology generally refers to the integration of four systems: a Building Automation System (BAS), a Telecommunications System (TS), an Office Automation System (OAS), and a Computer Aided Facility Management System (CAFMS) [4]. In smart building design, the building envelope constitutes the boundary, as opposed to the barrier, between the internal and external environments. The building envelope is therefore adjusts gains and losses to and from the interior either inherently, through static elements such as building mass or cohesively through automatic response or control. The climate chamber currently under construction, is designed to operate within a temperature range of -15 to 50 °C; a relative humidity range of 10 to 95 %; a wind speed of 0,1 to 15 m/s and atmospheric pressure range of 700 to 1085 hPa simulating an altitude range of below sea-level to approximately 3000 m above sea level. With modifications the chamber can function as a multi-zoned entity to emulate cardinal environments. As a result the consumer model is transposable to a range of climates to provide a comprehensive study of building performance using a single test subject. The multivalent laboratory will constantly monitor the building envelope, building environment, storage devices and service systems using temperature, pressure and heat sensors. Currently, the next evolutionary step is being considered with the concept of smart materials which can be separated into two groups: passive smart materials which only perceive changes in the environment and active smart materials which exhibit the properties of passive ones and additionally react to stimuli and have also the actuator.

Fig. 6 Floor plan depicting the consumer model situated inside the climate chamber with sensors and actuators

6. Conclusions

This model and its details are representative of the current state of the art trends in building construction. Special consideration was taken to reduce the effects of thermal bridges and maximize airtightness. The model is a ‘smart building’ designed to identify the number of occupants their location and level of activity via CO_2 consumption and motion sensors. The practical implications of the applied research and development of intelligent building service systems is the creation of a platform to research the efficiency and interoperability of components and renewable energy technologies which will be based on experimental analysis. It will involve:

(i). The management, distribution and consumption of multivalent sources used in the system, auxiliary pumps regulatory nodes etc,

(ii). The optimum use of energy produced in relation to its potential temperature, and researching principles of short and long term storage of energy [5],

(iii) Examining the principles of temperature stratification in the tank (soil characteristics, depth, the influence of humidity and temperature gradient at different timescales) [6],

(iv).In situ simulation and testing conditions of energy and process controls subjected to dynamic environmental conditions [6],

Acknowledgment

This work is supported by the Slovak Grant Agency for Science (Grant No. 1/0563/15).

References

[1] Concerted Action: Energy performance of buildings website (2014) http://www.epbd-ca.eu/themes/nearly-zero-energy
[2] F. Vranay, Z. Vranayova, D. Ocipova. In: Green energy and indoor technologies for smart buildings, Challenges, opportunities and solutions in structural engineering and construction, Pages 869-872 (2010)
[3] M. Kušnír, D. Košičanová, F. Vranay. In: The effective use of renewable energy sources and advanced technology of environment systems in public buildings, Applied Mechanics and Materials Volume 361-363, Pages 382-385 (2013)
[4] S. Vattano. In: Smart buildings for a sustainable development, Economics World, Vol. 2, No. 5, 310-324 (2014)
[5] R.Sekret, M. Turski.In: , Research on an adsorption cooling system supplied by solar energy Energy and Buildings, Volume: 51 Pages: 15-20 (2012)
[6] P. Fedorcak, D. Kosicanova, R. Nagy, R., et al., In: Solar cooling in Slovakia, 3rd International Conference on Civil Engineering, Architecture and Building Materials (CEABM 2013) Sustainable cities development and environmental, PTS 1-3 Book Series: Applied Mechanics and Materials, Volume: 361-363, Pages 286-290 (2013)