# SOLAR ENERGY - DESIGN ELEMENT

Budimir S. Sudimac, Andjela N. Dubljevic

University of Belgrade, Faculty of Architecture, Bulevar Kralja Aleksandra 73/II, Belgrade, Serbia

**Abstract**

*The main focus of this study is the theoretical examination of the possibilities of applying technological, functional, aesthetic and energy resources in elements of urban design. Designed solutions are treated as part of the overall optimization of architectural elements and urban space, in which technological development enables the use of certain energy potentials of elements of urban design. The paper presents student hypothetical design models of urban architectural elements with integrated photovoltaic modules. The analytical procedure was applied in the analysis of student work in a seminar of the first year of master studies at the Faculty of Architecture. The aim is to improve students' awareness of the need for proper handling of energy and the possibility of integration with other architectural elements. The research and the results have enabled further work on the sustainable development of architectural elements with a focus on the use of solar energy by promoting the modern design approach.*

**Key words:** *PV module, teaching, solar energy, urban design*

## 1. INTRODUCTION

The objective of teaching the subject of Urban Oasis at the Faculty of Architecture is the analysis and design of architectural elements that contribute to the increasing the use of solar energy as a renewable energy source. Working with students includes designing elements which would greatly influence the comfort of people residing in different climatic environments. Students examine the potential of the forms and technology of solar elements as an answer to the challenges of sustainable world.

The subject Urban Oasis is part of the secondary theoretical module of master studies and primarily aims the achievement of theoretical knowledge. In the final project students express acquired theoretical knowledge through their vision and thoughts on the design of urban architectural forms, including solar systems in their design (Fig. 1). Their work considers and explores the adaptability of solar energy use in the design of urban architecture elements. Based on the dynamic balance between the needs and requirements of the users of technology, students develop systems and strategies of hypothetical integration of photovoltaic modules in order to generate electricity from solar energy.

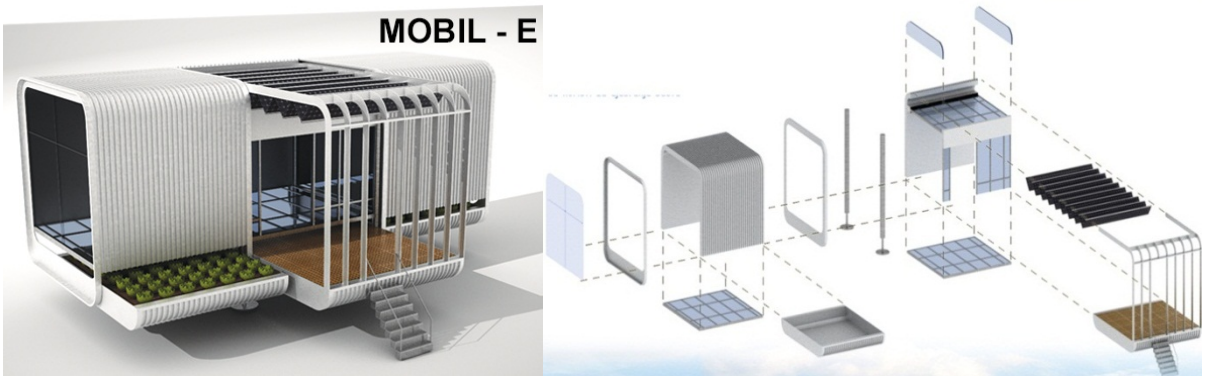



Figure 1: Mobil-E – student Aleksandar Andric, project of prefabricated mobile house designed for different locations which produces electricity using solar energy

## 2. METHODOLOGY AND TEACHING

Working with students in the course of Urban Oasis is an attempt to find a new approach for the realization of architectural projects which include elements of energy efficiency, sustainability and modern urban design by using appropriate scientific methods. The methods are based on previous analyzes of the urban individual's need for new forms of renewable energy and realizing opportunities for active use of solar potential in designing architectural elements. Students acquire basic knowledge on sustainable development, energy efficiency and solar energy as new elements in the design process. Lectures serve as inspiration for the design, in order to give students a theoretical framework, by focusing on the aesthetic aspects of solar energy use. Training is done through theoretical lectures, case studies and guest lectures. Examples of theory and practice are critically processed.

Through practical work on the project, students gain knowledge on the complex aspects of architectural structures and the elements of solar components. By analyzing various concepts, they will study the possibilities of designing integrative systems as integral parts of element structure. Exploration enables working on the sustainable development of urban elements, with an emphasis on the use of solar energy and the promotion of modern design approach. Through their research, students spatially and programmatically redefine the relationship between architecture and the use of solar energy. Students design architectural elements and study flexibility and adaptability of implemented technological solutions. Teachers and assistants are tasked to formulate research subjects together with students. The methodological process applied is that of linear education.

## 3. THEORETICAL ARGUMENT

The seminar profiles the field of action and intriguingly poses critical questions: Has the word "urban" become synonymous with abandoned, alienated, uncomfortable and unhealthy? Is it possible to establish an urban space with a natural ecological balance and create a better and healthier place for human? How modern technology encourages and enhances natural processes and puts them at the service of the urban community?

Considering these and many other topical issues related to energy-efficient construction and modern concepts of sustainability in architecture, the seminar tries to interest students and encourage research in these increasingly important areas of training architects. Avoiding some dull and outdated teaching methods, teachers try to convey the ideas of the seminars in a modern, multimedial and unconventional pedagogical manner.

Theoretical analysis is focused on the familiarization with the modern and traditional ways of using solar energy, natural and manmade impacts as well as the basics of forming complexes and functional systematization. The formal, technological, functional and aesthetic possibilities of using solar energy as a resource in the design of urban elements is examined and explored (Fig. 2).

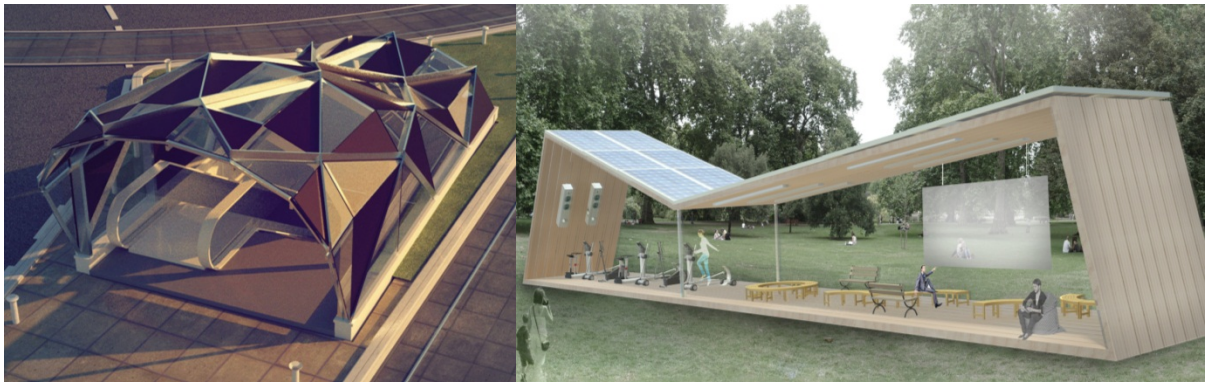


Figure 2: Implementation of solar systems on different elements of urban space, Project of Underground Eco Entrance - student Mina Milovanovic and Project of Self Sustainable Gym – student Katarina Petrovic

The integration of solar systems in the design process is a part of the overall energy optimization of the architectural object or area within which technological development enables the use of current and future natural resources in the architecture of buildings of the 21st century.

The methods of learning for the need for renewable energy are the basis of relations between energy efficiency and the needs of people. By developing awareness among students on the necessity of application of solar technology in architectural buildings, students acquire basic knowledge on proper decision-making in the design process. In the theoretical part, a connection between the case studies, experiments, architectural practices and architectural design is found.

The use of elements of solar energy in the architecture of the 21st century has opened up new design opportunities and created challenges for the designers, with the aim of increasing energy efficiency in buildings. The necessity of using renewable energy sources leads to a new analysis of factors influencing the design process, energy efficiency, ecology and comfort. It is essential that in the process of education, students get familiar with the methodology of manner of design. Students should be enabled to create their own criteria, which they apply in the design process. The basis of the methodology is the relationship between architecture and integrated elements for converting solar energy into electricity.

The selection of systems that have generated solar structure, structural characteristics, architectural details and aesthetics of buildings are parts of student projects. Solar panels are part of an integrative architectural representation and the basis for identifying and resolving architectural aesthetic dilemmas, as well as the energy potential of architectural objects. Student projects analyze architectural elements that contribute to the reduction of extreme natural impacts on the comfort of people residing in different climatic environments with the presentation of technical, structural and architectural design potential of solar energy. The theoretical work with students includes the use of different design tools and software with the help of which certain aspects of the use of solar collectors are analyzed. In this way, we can easily determine the efficiency of the proposed solution.

## 4. WORKSHOP

The thematic framework of student projects is related to the exploration of the solar potential as an element of urban design, by treating it as part of the entire process of energy optimization of the architectural form. Technological development and the development of awareness for the use of solar energy enable the use of these resources in the realization of architectural elements. A result of this are the student projects, which can be implemented in any environment, as well as a completely new approach in the use of PV modules as integral parts of design solutions.



Figure 3: Energy Field – student Milica Andjelic

The main goal of project Energy Field is to enable lighting for parks without conventional energy sources. Element are shaped like plant and designed to move and follow the Sun in order to collect enough energy during the day to provide lighting at the night time (Fig. 3).



Figure 4: Solar Tree – student Konstantin Brasovan

By exploring the basic human need for energy, students observe architectural elements as a training ground for completely new possibilities in architecture, design and technology. Some students found inspiration for their design in the nature and made concepts for open spaces in modern cities. Reinterpretation of natural shapes of tree and flower led to projects Solar Tree and Eco Flower which could be applied on various public spaces (Fig. 4 and 5).

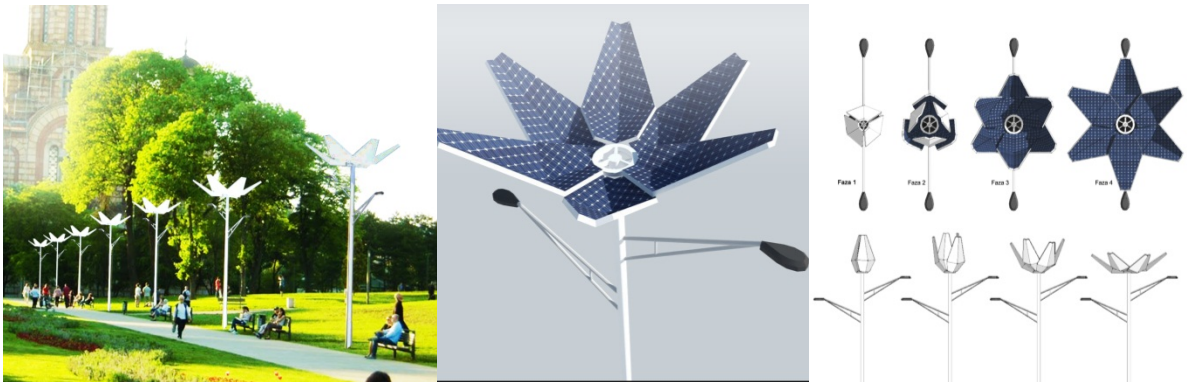


Figure 5: Eco Flower – student Aleksandar Djordjevic

Students offer a unique concept of using solar energy in their innovative projects and solutions. They try to apply available technical solutions, with an emphasis on increasing the aesthetic quality of proposed solutions. Students sometimes aim to even improve existing elements of urban design which could contribute to their appearance and serviceability (Fig. 6).

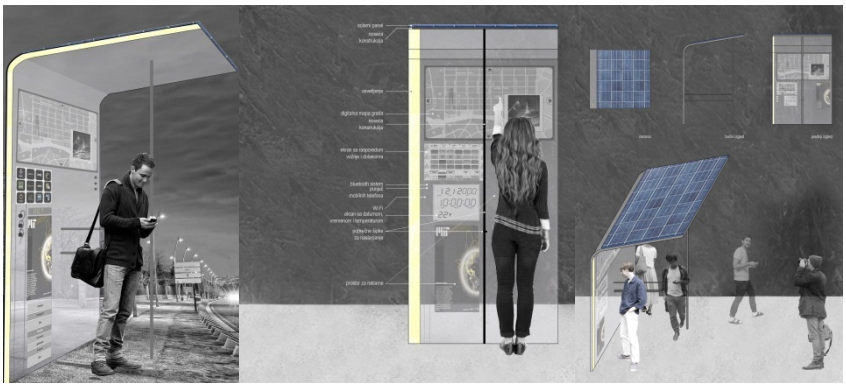


Figure 6: Solar Stop – student Jovana Dimitrijevic

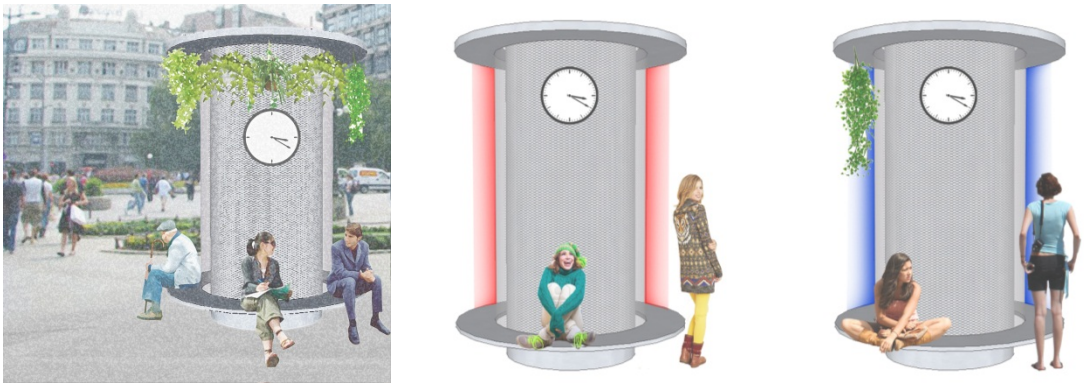


Figure 7: Urban cooler/heater - student Nikolina Vranic

Using elements with integrated photovoltaic modules students tried to create different urban spaces and meeting points (Fig. 7 and 8). The designing of these elements, using the system for converting solar energy into electricity aims to enhance the architectural thought. Research into new ways of using solar energy and the establishment of urban and architectural models for solving various problems of urban environment are the main goals of student projects.

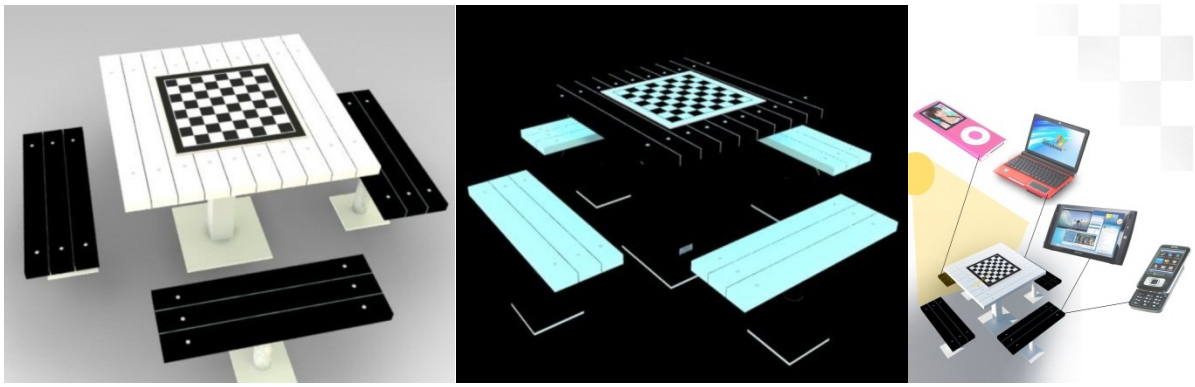


Figure 8: Solar Chess – student Milica Kovacevic

The main goal of practical work is the exploration of sustainable systems and the establishment of new urban and architectural model for solving the energy problems of aesthetic and modern cities (Fig. 9). Practical design work aim is that students critically observe, improve and explore architectural

adaptability and the design potential of PV modules. Students explore the symbiosis of technology and the natural environment by creating a new architectural discourse.

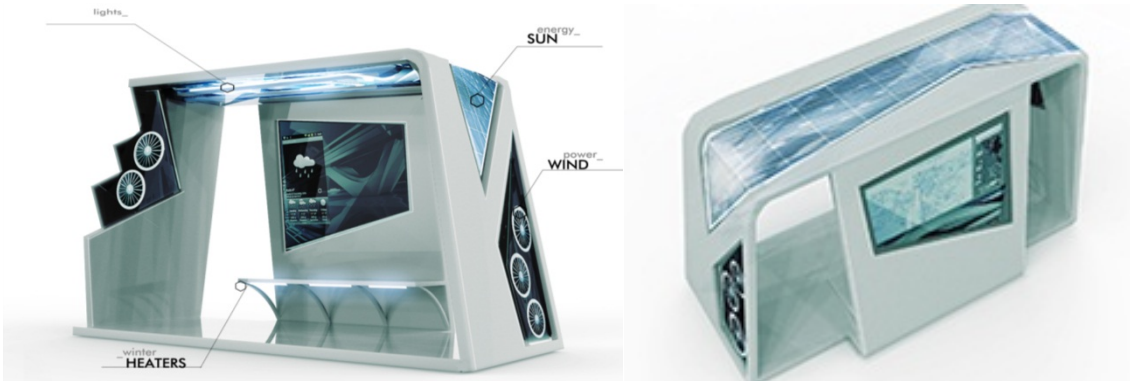



Figure 9: Cyber Stop – student Petra Nikolic

The integration of PV modules in projects is hypothetical and tries to discover new opportunities for the use of these elements, in order to provide energy from alternative sources. Solutions represent specific innovations in the design when it comes to the application of PV systems.

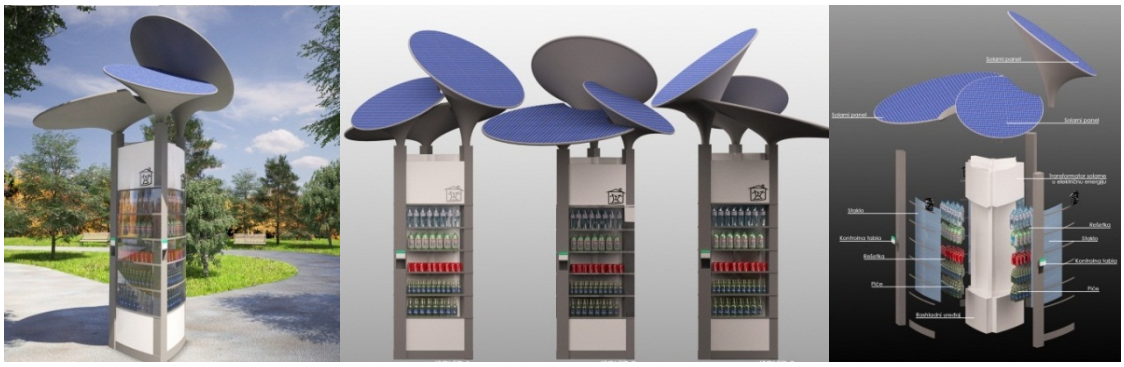


Figure 10: Solar Fridge – student Lazar Ciric

In projects students conceptually implement the acquired theoretical knowledge of passive and active solar system and strategies in the design elements of the urban structure. Besides thinking of elements of urban design students are also trying to find solutions for different furniture elements, equipment and gadgets (Fig. 10, 11 and 12).

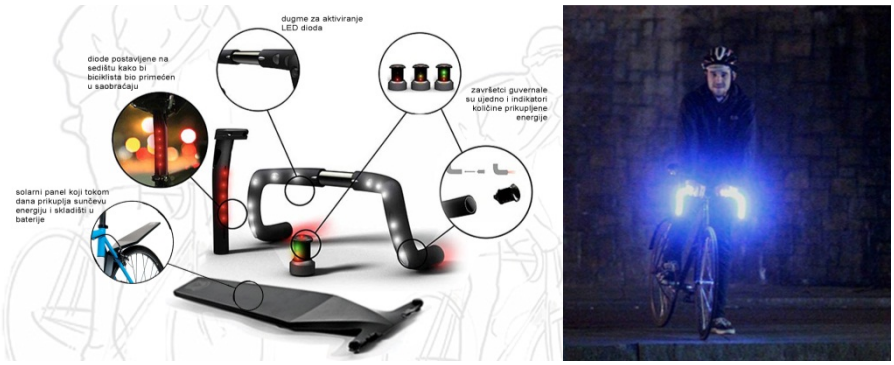



Figure 11: LED Bike – student Andrija Krcunovic

In individual cases, preoccupied with provocative design, students consciously ignore the basic principles of sustainable design. Student projects aim to demonstrate the seriousness and scientific justification of the approach to the topic of sustainable development, primarily the use of solar energy.

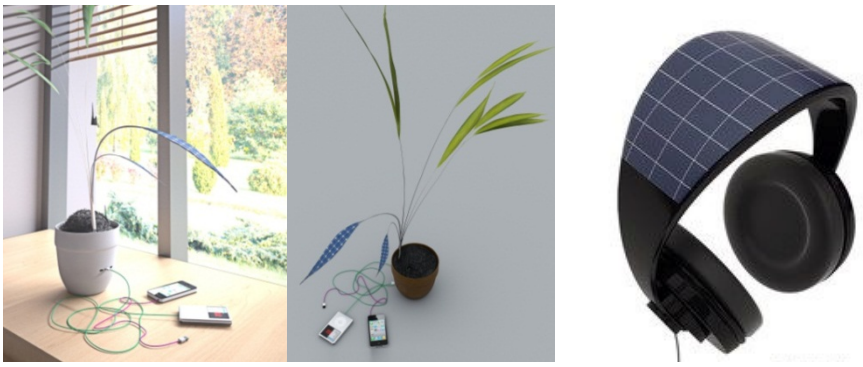


Figure 12: Green charger – student Aleksandar Copic and Solar Bluetooth Headphones – student Aleksandar Simonovic

In the practical part of the work with students there have been no measurements, due to the lack of proper equipment which unabled students to understand benefits of specific use of PV modules in the design, on the basis of data obtained by measuring.

## CONCLUSION

The technological development of civilization is gaining greater acceleration in ever shorter time intervals and goes to infinity in the form of an exponential function, so that the challenges of using solar energy are growing. Design challenges in the architecture of the new millennium impose a need to educate students in the direction of understanding solar system technology in the solving of design requirements. It is essential that final year students are able to understand the need for cooperation with other stakeholders in the design process, taking into account the overall designing process.

Teaching students the basic principles of solar energy requires the use of certain software in theoretical or practical work, in order to avoid the lengthy process of developing practical models and measurements. Consequently, project development and decision-making enable greater speed in the research process. However, the use of measuring equipment contributes significantly to examinations and reviews of hypothetical models. The course of Urban Oasis gives its focus to the design elements of the application of PV modules, while the technical solutions and guides of justification of these elements are only part of the analysis.

**REFERENCES**

Altomonte, S 2009, 'Environmental Education for Sustainable Architecture', *European Studies*, vol. 1, no. 2, pp.12-24.

Behling, S 2000, *Solar power the evolution of sustainable architecture*, Prestel, New York.

Castanheira, RG & Corbella OD 2010, 'Photovoltaic Panels: shade and energy on rooftops', paper presented at III Congresso Brasileiro de Energia Solar, Belém, 21-24 September.

Cole, RJ 1999, 'Environmental performance of buildings: Setting goals, offering guidance, and assessing progress', in CJ Kibert (ed.), *Reshaping the Built Environment: Ecology, Ethics & Economic*, Island Press, Washington D.C., pp. 279.

Cooper, I 1999, 'Which focus for building assessment methods: Environmental performance or sustainability?', *Building Research & Information*, vol. 27, no. 4/5, pp. 321-331.

Ding, GK 2008, 'Sustainable construction: The role of environmental assessment tools', *Journal of Environmental Management*, vol 86, pp. 451-464.

EDUCATE 2010, *State of the Art of Environmental Sustainability in Academic Curricula and Conditions for Registration*, viewed 10 March 2015, <http://www.educate-sustainability.eu/downloads/state-of-the-art>.

EDUCATE 2012, *Education for Sustainable Environmental Design*, viewed 10 March 2015, <http://www.educate-sustainability.eu/results-summary>.

Energy Commission 2011, *The Energy Commission Diamond Building*, viewed 10 March 2015, <http://www.st.gov.my>.

European Commission 2004, P*hotovoltaics-manual on technology, design and installation.* ALTENER.

Gonzalo, R & Habermann, K 2006, *Energy Efficient Architecture*, Birkhaeuser Publisher for Architecture, Berlin.

Hausladen, G 2006, *Clima skin*, Callwey, Munich.

Hegger, M, Fuchs, M, Sark, T & Zeumer, M 2008, *Energy Manual – Sustainable Architecture*, Birkhaeuser Verlag.

Herzog, T 1996, *Solar energy in architecture and urban planing*, Prestel, London.

Hilli, G & Reiche, K 1996, 'Potential der Photovoltaik auf Lärmschutzwänden an deutschen Verkehrswegen' paper presented at 11. Symposium Photovoltaische Solarenergie, Staffelstein, Germany.

Johannsen, K & Möser. M 2000, 'The Influence of the Sur- face of Small Barriers on the Sound Reduction Efficiency of Shroud-Barrier Combinations', *Proceedings of Seventh International Congress on Sound and Vibration*, pp. 2623–2630.

Jones, CJC & Thompson, DJ 1999, 'Application of Numerical Models to a System of Train- and Track-Mounted Acoustic Shields', *Proceedings of Sixth International Congress on Sound and Vibration*, pp 2661–2668.

Kaatz, E, Root, D & Bowen, P 2005, 'Broadening project participation through a modified building sustainability assessment', *Building Research & Information*, vol. 33, no. 5, pp. 441- 454.

Kastner, J & Wallis, B 2005, *Land art y arte medio ambiental*, Phaidon, London.

Klaus, D 1999, *Technologie des ökologischen bauens*, Birkhauser, Basel.

Koch-Nielsen, H 2007, *Stay Cool – A Design Guide for the Built Environment in Hot Climates*, Earthscan, London.

Krstic-Furundzic, A 2007, 'PV Integration in Design of New and Refurbishment of Existing Buildings: Educational Aspect', *JAAUBAS-Journal of the Association of Arab Universities for Basic and Applied Sciences*, vol 4., pp. 135-146.

Kwok, A & Grondzik, W 2011, *The Green Studio Handbook – Environmental Strategies for Schematic Design*, Elsevier Inc., Burlington.

Lutzkendorf, T & Lorenz, D 2006, 'Using an integrated performance approach in building assessment tools', *Building Research & Information*, vol. 34, no. 4, pp. 355.

Marinoski, DL, Salamoni IT & Rüther, R 2004, 'Preliminary design of a photovoltaic solar system: A case study of CREA-SC headquarters of the São Paulo', paper presented at I Conferência Latino-America de construção sustentável- X Encontro nacional de tecnologia do Ambiente Construído.

Ruegemer, J 2009, *Teaching Sustainable Strategies in Architecture: Learning from the Global Perspective*, Les Presses de l'Universite Laval, Quebec.

Rüther R & Montenegro AA 2001, 'Building-integrated, grid- conected photovoltaic installations in warm climates: choice of technologies', *Proceedings of* the 18th International Conference on Passive and Low Energy Architecture, Florianópolis: PLEA, pp. 243-248.

Rüther, R 2004, Photovoltaic solar buildings, UFSC/ LABSOLAR., pp 107.

Soebarto, VI & Ness, D 2010, 'Rethinking the adoption of green building rating systems in developing countries', paper presented at 11th International Conference on Sustainable Environmental Architecture (SENVAR), Surabaya, Indonesia, 14-16 October.

Van Uffelen, C 2009, *Ecological Architecture*, Berlin.

Widera, B 2011, 'Passive and Low Energy Architecture in Education of Contemporary Architecture', *PLEA 2011 Proceedings*, vol. 1., Louvain-la-Neuve, Belgium, 13-15 July, pp. 113-118.