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GREEN MOTEL COMPLEX: SOLAR ARCHITECTURE WITH INTEGRATED RENEWABLE ENERGY SYSTEMS AND ENERGY EFFICIENCY

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The main futures of advanced green motel complex design with low energy consumption are discussed. The solar energy audit of a local place, solar architecture design with thermal insulation, energy efficient loads, BIPV, active thermal system for water heating and smart energy management are presented. The design of active solar systems was done by Valentin Energy Software. The green motel complex is designed according the main principals of a passive solar architecture. The share of a green energy in the indoor energy mix is discussed.

Keywords: renewable energy, passive solar architecture, thermal insulation, photovoltaic system, active thermal system, energy efficiency, energy mix.

Introduction

The new mobile infrastructure is creating now in Bulgaria including long distance highways, petrol stations and motels. The future tendency of people mobility is oriented to use low petrol consumption cars with hybrid engine, alternative fuels as bio-fuels and advanced tourist "green service" as an accommodation in the new type motel complexes. The design of this infrastructure includes "green" motels with requirements to designers to apply advanced vision for passive solar architecture, thermal isolation and windows, energy efficient loads, integrated renewable energy systems and management of indoor energy mix.

The solar architecture basics is based on the main principals as orientation of the building, insulation, natural light and ventilation, Sun protection, interior improvement, energy saving glass, plasters, colors and integration into the building structure renewable energy systems as photovoltaic and thermal systems [1-3]. The new type green buildings need energy supply from renewable energy systems and these kinds of demonstration RE systems are designed and installed in Solar Energy Centre, South-West University, Bulgaria [4] and Department of Physical Engineering, Karaganda State University, Kazakhstan [5] under research and demonstration projects. The two types of PV systems as grid connected and stand alone are studied for high quality electricity supply of homes in the urban and isolated areas. The combined PV & active thermal systems [6] are studied for real applications to support green architecture concept for advanced buildings. The new vision on applications of building integrated photovoltaic (BIPV) energy saving systems with grid tie inverters [7], application of energy efficient loads and intelligent management of indoor energy mix [8] is addressing now to low energy consumption green buildings.

The gal of the paper is to present advanced design of a green motel complex as a pat of a new mobile infrastructure. The main tasks are: (i) design of motel accordance the principles of passive solar architecture, (ii) applying the energy efficiency to the loads, (iii) integration of RE systems as PV and Thermal into the building structure and (iv) intelligent management of indoor energy mix.

Results and Discussion

Design of a green motel complex. The schematic vision of the green motel complex is presented in Fig. 1 and standard house disposition in Fig. 2.

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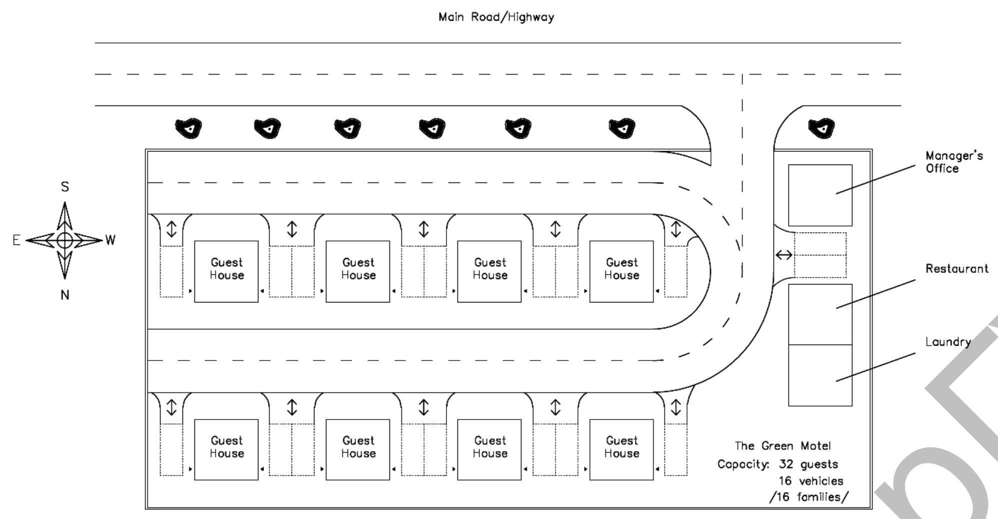

Fig.1.Solar design of green motel complex

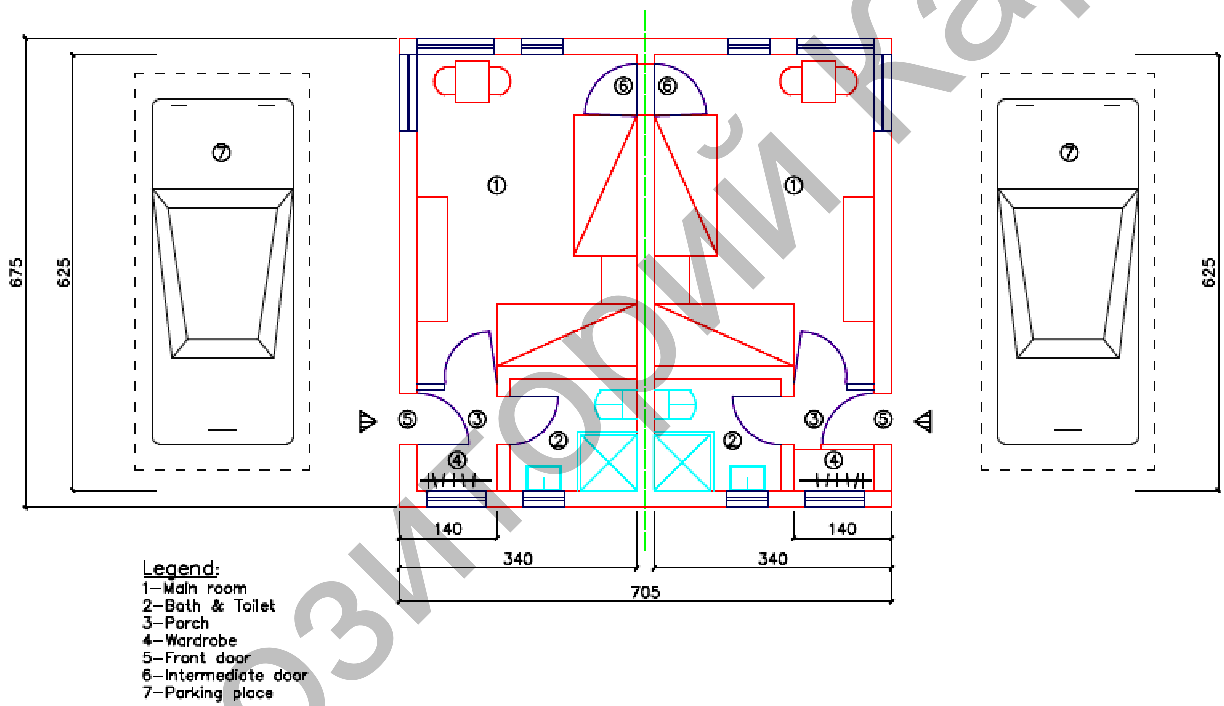

Fig.2.Standard House disposition

The green motel complex is designed according the main principals of a passive solar architecture. This complex consist 8 guest houses, 18 parking places, restaurant, laundry and manager's office. The guest house buildings are oriented east-west along its long side and the larger part of the façade has southern orientation. The living rooms as bedrooms are occupied the south part of the house and bathrooms and WC are in the northern part. The roof design of the guest house according position of the Sun during the year is presented in Fig.3.

The East-façade with optimized 30^{o} inclination of the roof for direct integration of solar systems is shown on Fig.4

The South-façade with total roof tilted area 34.14 m² for solar integrated systems is presented in Fig. 5.

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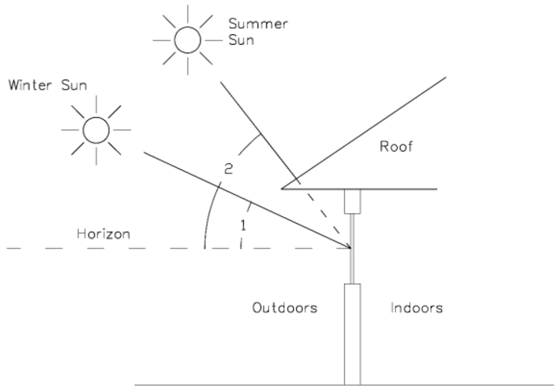

Fig.3. The roof and position of the Sun during winter and summer days

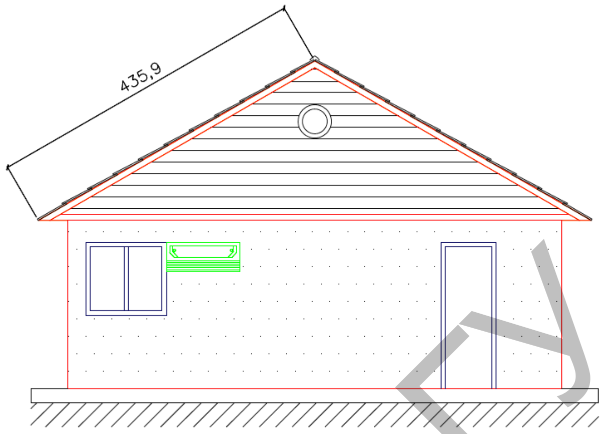

Fig. 4 East-façade with 30^{o} inclination of the roof

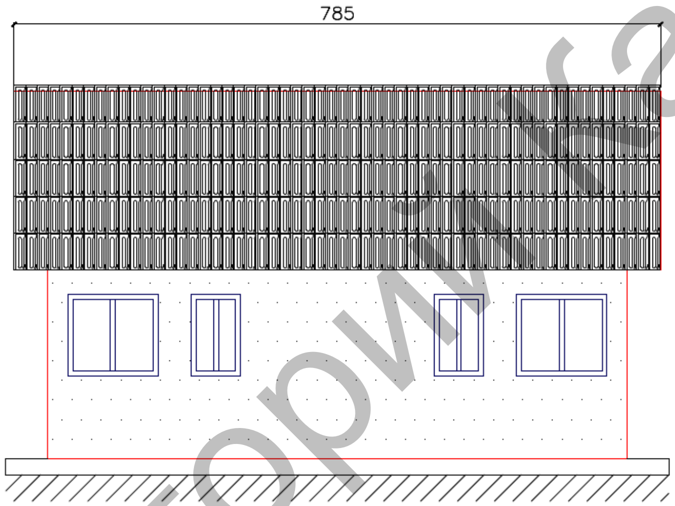

Fig.5.South-façade of a guest house and a roof tilted area for integrated solar systems

Insulation of the guest house. The PC program Baumit Thermo [9] for computer simulation of a head transfer between insulation layers covering the walls and the roof was applied. The Baumit Star system insulation materials are used for a façade area 63.48 m^2 and for a total area 158.65 m^2 included façade, roof and floor. The heating of a guest house near Yambol, Bulgaria is providing by electricity for 2520 hrs annual heating period. The input parameters for PC simulation are internal temperature + 23 ^{o}C, minimal external temperature for the region – 14 ^{o}C and the external average temperature for the heating period +5.1 ^{o}C. The energy used without Baumit insulation system for 63.50 m^2 walls is 4287.9 kWh and for a total aria 158.65 m^2 it is 10713.3 kWh. The energy saving effect of Baumit Star insulation depending from width of the panel is presented in Table 1.

Table 1 - Energy saving effect of Baumit Star systems depending from EPS panel width

Thermal insulation width of ERS panel, [cm]	8	10	12
Energy used with Baumit system, 63.5 m^2, [kWh]	877.8	732.9	629.1
Energy used without Baumit system, 158.65 m^2, [kWh]	2193.3	1831.2	1571.7

The energy saving effect increase with increasing the width of EPS panel as fallow: 8 cm EPS panel reduce energy consumption 4.8 times, 10 cm EPS panel reduce energy consumption 5.8 times and 12 cm EPS panel reduce energy consumption 6.8 times.

The temperature profile across the wall with 12 cm width EPS panel is shown in Fig. 6

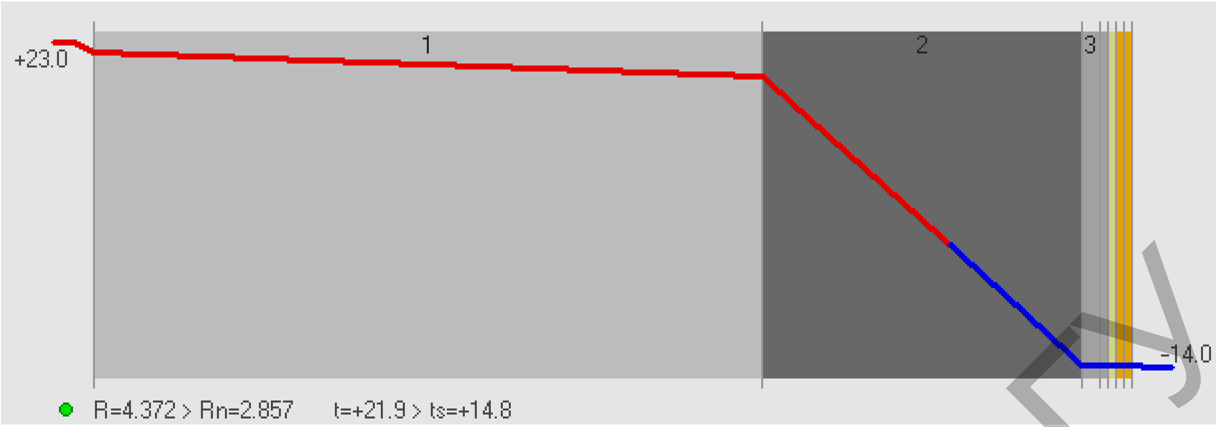

Fig.6. Temperature profile across the wall with 12 cm width EPS insulation plate

The actual thermal resistance is R = 4.372 m^2 $^oC/W$ and a normative thermal resistance is Rn = 2.857 m^2 $^oC/W$. The temperature of the inner surface of the workpiece is t = +21.9 ^oC and a condensation temperature of the inner surface is ts = +14.8 ^oC.

1 - Masonry ordinary solid bricks of lime-sand solution;
2 – StarTerm insulation EPS plate;
3 – StarKontakt adhesive putty mixture;
4 – StarTeks fiberglass mesh;
5 – UniPraimer universal primer;
6 – Pasty plaster.

For the energy saving effect of a Guest House are selected Baumit Star isolation system with 12 cm width EPS panels and PVC windows with 1.4 –1.8 W/m^2K solar K-glass.

The facades are insulated with the Baumit Star system 12 cm width.

The roofing elements are provided by TONDACH Bulgaria Ltd. and they are used to attach PV panels to the roofing tiles with ventilation under the panels and ladders access to PV aria.

Energy Efficiency Loads. The standard house appliances are shown in Fig. 6. The most important thing is the usage of utensils of a higher energy class (A+, A++) which consume less energy. The amount of energy used for water heating is reduced because of the thermal system and the air-conditioning system is greatly facilitated by the thermal insulation.

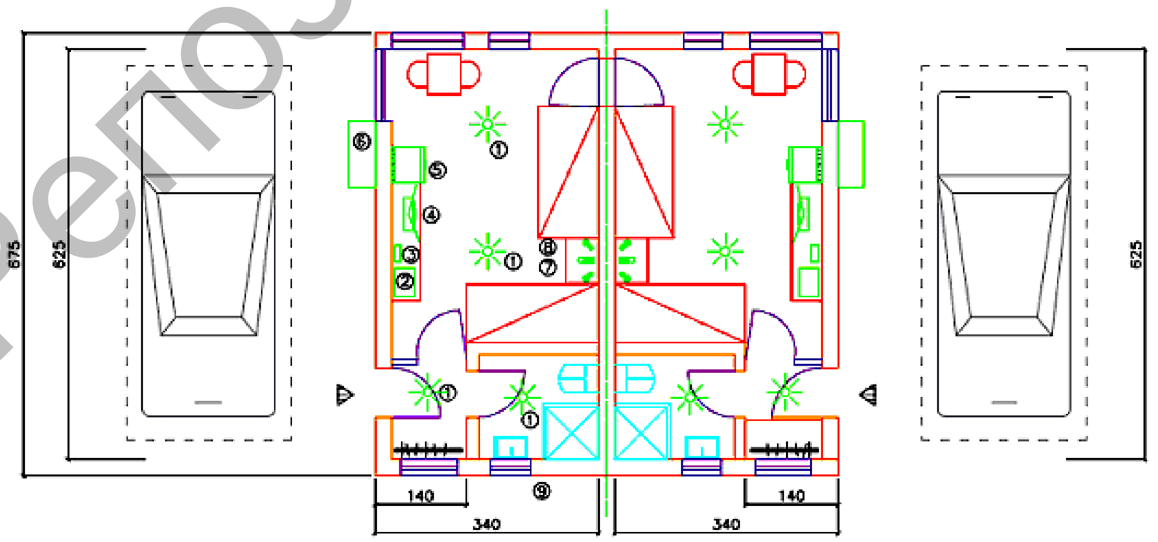

Fig.7. Location of standard household appliances

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The locations of high energy efficiency standard house appliances inside a guest house are presented in Fig. 7

Legend:

1 – Internal illumination
2 – Laptop
3 – Router
4 – TV
5 - MiniBar
6 – Air conditioner
7 – Night lamp telephone
8 - Telephone
9 – Water heater

The energy consumption of proposed appliances is shown in Table.2.

Table 2 - Household appliances in a standard room in the Guest house

		Consumer	Number	Power		Day time	Night time	Day Energy	Night Energy	Total Energy
№	Brand			W	kW	h	h	kWh	kWh	kWh
1	Cree LED bulb	LED bulb	4	9.5	0.01	1.5	4	0.057	0.152	0.209
2	various	Laptop/PC	1	100	0.1	6	6	0.6	0.6	1.2
3	WRT610	Router	1	18	0.02	12	12	0.216	0.216	0.432
4	Philips 196V3LAB	TV	1	13.5	0.01	2	4	0.027	0.054	0.081
5	DM 50 D	MiniBar	1	16	0.02	12	12	0.192	0.192	0.384
6	Mitsubishi Electric MSZ-SF25VE	Air-conditioner	1	900	0.13	6	6	0.798	0.798	1.596
7	Cree LED bulb	Night Lamp	2	9.5	0.01	0	4	0	0.076	0.076
8	various	Telephone	1	9.5	0.01	12	12	0.114	0.114	0.228
9	Thermal system**	Water-Heater	1	1800	0.72	2	2	1.44	1.44	2.88
*Baumit thermal insulation reduces the amount of energy needed for heating/cooling by 6,815 times									summary:	**7.086**
** The thermal system reduces the amount of energy needed by 60%										kWh/day

The loads are using 3.44 kWh/day energy and 3.642 kWh/night energy for 24 hrs.

According the proposed model 63.1% energy from the all 24 hrs consumption is using for water and air heating. The energy for water heating is 40.6 % from total energy consumption and can be reduced till 16.2 % by application of active solar system. The air heating by air-conditioner is 22.5 % from total energy consumption of a gust house and half of this energy can be covered by green energy from roof installed PV system.

Building Integrated Solar Systems. The solar systems as an active thermal system and a grid-connected PV generator installed on the roof are right decision to reduce energy supply of a guest house from utility grid.

The climatic conditions and a solar energy audit of the place for a green motel complex are recommended to be discussed first before to apply solar technologies.

The designed green motel complex is situated in the region of the town Yambol which belongs to the Eastern-Bulgarian climatic region as a part of the European continental zone according the climatic register [10]. The solar activity is 1223 hrs and during 1550 – 1660 hrs the average air temperature is + 10 ^{o}C. The total solar radiation is 5600 MJ/m^2. The average temperature during the year is shown in Table 3. The region has a mild winter, a hot summer with annual temperature 12 ^{o}C and a low frequency of wind velocity lower than 1 m/s.

Table 3 - Average month temperature in ^{o}C during the year

F	J	M	A	M	J	J	A	S	O	N	D	ann.
2.5	0.2	5.6	11.3	16.4	20.3	23.2	22.6	18.5	13	7.8	2.8	12

The places of PV and thermal panels on the roof of a guest house are shown on Fig. 8

The optimised roof aria for solar systems integration is suitable for six PV modules and one thermal panel for solar energy supply to one room of guest house.

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The grid-connected 1.4 kWp PV generator with six c-Si PV modules is a suitable for roof integration. The on-line Internet simulation of solar electricity generation was done by PVGIS software and PVGIS-CMSAF data base [11] for location 42°32'59'' North, 26°31'11'' East and elevation 148 m a.s.l. The results are presented in Table 4.

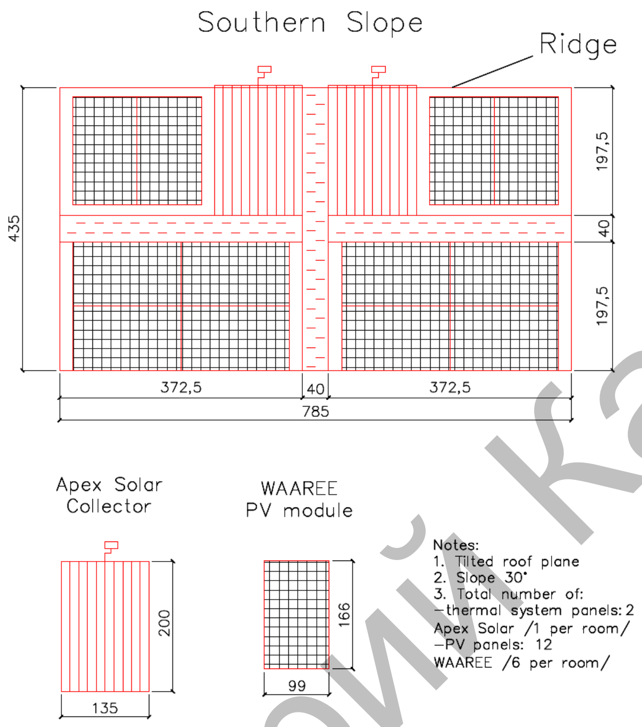

Fig.8. Solar roof of a guest house with integrated PV and thermal systems

Table 4 - PVGIS estimates of solar electricity generation

	Fixed system: inclination=30 deg., orientation=0 deg.			
Month	Ed	Em	Hd	Hm
Jan	2.23	69.2	2.07	64.3
Feb	3.30	92.3	3.12	87.3
Mar	4.68	145	4.63	143
Apr	5.22	156	5.37	161
May	5.92	184	6.22	193
Jun	5.99	180	6.44	193
Jul	6.33	196	6.82	211
Aug	6.21	192	6.76	209
Sep	5.31	159	5.63	169
Oct	4.14	128	4.18	130
Nov	2.87	86.2	2.75	82.5
Dec	2.04	63.3	1.89	58.6
Year	4.53	138	4.66	142
Total for year		1650		1700

Ed: Average daily electricity production from the given system (kWh)

Em: Average monthly electricity production from the given system (kWh)

Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

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The proposed 1.4 kWp grid-connected PV generator is for electricity supply of one room of a guest house.

The PV generator on the roof can be realized by two different ways: (i) a grid-connected PV generator with one inverter and (ii) a grid-connected PV generator with three grid-tie inverters.

The design of a grid-connected PV generator is done by Sunny Design software [12]. The 1.4 kWp PV generator consist six PV modules and one Sunny Boy 1300TL-10 inverter with 90.6 % effectiveness. This system is design to use all the time six PV modules. The total surface of PV generator is 10 m^2 and yearly energy yield is 1534 kWh.

The grid-connected PV generator can be realised by three 500 W grid tie inverters. Every inverter is connected with two PV modules. This design of PV generator is more flexible concerning the management of load electricity consumption. When a load is low 33% of installed PV can be used by indoor intelligent energy management.

Design of active solar thermal system. The design of active solar systems was done by Valentin Energy Software [13].

The input data in this software for two persons to use warm water at 40 ^{o}C are 4 m^2 solar panel with 30^o inclination installed direct on the roof and 100 l boiler. The calculated irradiation is 5.219 kWh/a, system yield 1.000 kWh/a, 79% solar fraction and 263 kg/a CO2 saving. This active solar thermal system can reduce 60% electricity energy consumption for heating the water.

Energy Mix

The Green Motel Complex has energy supply from outdoor utility energy mix and outdoor energy mix from active thermal solar and PV systems integrated into the roof structure. The deal of RES energy in outdoor energy mix of Bulgaria for 2012 is 16.3 %. The potential of RES components in outdoor energy mix are 34% solid biomass, 29% hydropower, 9% solar energy, 8% liquid bio-fuels, 7% geothermal energy, 7% wind energy and 6 % biogas. The outdoor electricity supply from energy mix is monitoring by electronic E-meter of Green Motel Complex. The indoor energy mix is realized by energy from thermal solar system, PV generator and electricity from outdoor energy mix. The management of outdoor energy is from energy politic of the government and the indoor energy mix is managing from Green Energy Complex. The indoor energy mix in Guest house depends from (i) construction - passive solar architecture, (ii) isolation - thermal isolation, windows and glass, (iii) energy efficient loads and (iii) RES energy supply by solar systems. The management of indoor energy mix is key part of design of Green Motel Complex. The solar system smart, intelligent energy management from SMA [14] is monitoring Guest house power consumption at all times and it is showing where we can save energy. This system has automatic control features that take into account the specific needs of Guest house loads. The Sunny Home Manager is integrated part into the Guest house infra structure. This intelligent energy management system is providing Guest house to consume effectively green energy from solar systems, to minimize energy consumption from outdoor mix and to increase the deal of green energy into the indoor energy mix.

If we assume that one room of guest house is occupied 24 hrs from travelers during the sunny day the total electricity consumption from high efficiency loads will be 7.086 kWh. The thermal energy saving by passive solar architecture, insulation and PVC windows with solar K-glass is 6.8 times less than total energy used for heating by air conditioner and it is 1.361 kWh/day. The active thermo system is saving about 60 % from electricity for water heating and it is 1.728 kWh/day. Integrated PV system is powering the guest house from 2 to 6.33 kWh/day green electricity depending from solar radiation. During the winter day more than 70% from electricity consumption of a guest house is saved and in summer days electricity consumption is covered during the sunny part of the day from green energy. The annual ecological effect from proposed two room guest house is till 2562 kg CO2 reduction of greenhouse gas emission [15].

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Conclusions

The vision of integration between solar architecture, renewable energy systems, energy efficiency loads and smart indoor energy management is presenting modern technological style innovated green energy application as green motel connected to advanced mobile style of life. The green motel is based on the basic principles of solar energy audit, technologies of passive solar design, heat transfer insulation, energy efficiency loads, thermal and BIPV systems with smart control of indoor energy mix. The results from this combination of advanced technologies are (i) attractive “green” vision of complex with comfort for occupants, (ii) energy saving from 70 to 100 % during the year from energy requested for standard living in guest house, (iii) sustainability by powering a house with green energy from Sun by renewable energy technologies and (iv) environmental effect by drastically reduction of CO2 greenhouse gas emission.

REFERENCES

1 Doerr T. *Passive Solar Simplified*, 1st Edition, 2012

2 Kaplanis S., Kaplani E. Renewable *Energy Systems: Theory, Innovations and Intelligent Applications (Renewable Energy Research Development and Policies),* Nova Science Pub Inc., 2013.

3 Stoev M., Stoilov A., Shtrakov St. Study on Combined Solar Systems. *Proceeding of the Int. Conf. “The Integration of Renewable Energy Systems into the Buildings structures”,* T.E.I. of Patra, Greece, 2005, pp. 205 – 211.

4 Stoev M. EC DEMO EPSILON project, No PL962045 INCO-COPERNICUS “Energy provision using solar systems in isolated locations”, 1996 – 2000.

5 Stoev M., Kussaiynov K., Shuyushbayeva N., Turdybekov K., Ahmadiev B. Study on energy efficiency of solar photovoltaic system. *Proceeding of the Int. Scientific-practical Conference “Qualified Education, Leading Scientific Green Economy – The Future of Planet”,* Almaty, 2014, pp. 313 – 316.

6 Stoev M. Realization of PV EU demonstration project in Bulgaria and creation of the new PV educational infrastructure. *2nd International Workshop on Teaching in Photovoltaics, IWTPV’04,* Prague, 2004, pp. 45-49.

7 J. Tao, V. Xue, Grid-Connected Micro Solar Inverter Implement Using a C2000MCU. *Texas Instruments Application Report, SPRABTO*, 2013, pp. 3-25.

8 Zhang D., Papageorgious L., Samsatli N., Shah N. Optimal Scheduling of Smart Homes Energy Consumption with Microgrid. *Proceeding of the 1st Int. Conf. on Smart Grids, Green Communications and IT Energy-aware Technologies*, 2011, pp.70-75.

9 Baumit Thermo software: http://www.baumit.bg/front_content.php?idcat=2372

10 http://www.stringmeteo.com/synop/bg_climate.php

11 http://re.jrc.ec.europa.eu/pvgis

12 http://www.sma.de/en/products/planning-software/sunny-design.html

13 http://www.valentin-software.com/en

14 http://www.sma.de/en/home-systems/solar-system-smart.html

15 http://www.sunearthtools.com/tools/CO2-emissions-calculator.php

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