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# Cogeneration of energy in solar systems - a study case, Kosovo

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**ABSTRACT**

Nowadays the main goal of sustainable energy supply is the use of renewable energy sources and, in addition, the increased efficiency of the energy used. One possibility of using renewable energies is the use of solar energy through photovoltaic panels. Taking into account the meteorological characteristics of the country in which the study takes place, it appears that the use of photovoltaic panels will be available most of the time during the year. We applied a model of hybrid solar collectors for maintaining the cell temperature near 25°C by introducing a flat plate cover integrated with solar cells. This method represents a way to increase the efficiency of the solar collector. This will enable the production of electricity from the part of the photovoltaic panel incorporated into the solar collector, in which the water temperature will increase, and this heat from the water is due to the effect of sunlight and as a result of cooling the part of the photovoltaic panel. This represents an increase in the efficiency of the system and the main purpose of our analysis.



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## 1. INTRODUCTION

Energy is the most valuable resource and foundation of civilization. It is also our heritage for future generations. Preserving this resource for the future requires a thorough understanding of energy resources, optimal operation, and sustainable usage. Application of new capacity generated by renewable energy sources, new management systems, advanced technologies and improving productivity can contribute to economic growth [1].

By adding the alternative sources, one can overcome the scheduled power cut too [2]. A photovoltaic/thermal hybrid solar system (PVT – system) is a combination for photovoltaic (PV) and solar thermal components/systems which produce both electricity and heat from one integrated component or system [3]. On average, the direct solar radiation illuminating the earth's surface, which consists of a flux of photons covering a spectrum of energies from infrared to ultraviolet, delivers 1.6 to 2.8 MWh annually for each square meter of the earth's surface. At the outer shell of the terrestrial atmosphere, the intensity of solar radiation called the solar constant, is taken on average as ISC =1,353 to 1,367 W/m2, with a fluctuation of about 7% annually. Through photo thermal solar radiation conversion, there is a process of conversion of solar radiation (which carries photonic energy) into high-temperature heat followed by conversion of the heat into mechanical energy (or shaft work). Today's technological word fully depends on electricity, but the availability of electric source is low. The deficiency of electricity becomes the breaking point for emerging countries. The first reported study on a flat plate PV/T was presented by Wolf in 1976. The micro grid's energetic performance is directly affected by the solar radiation and the ambient temperature available at the installation site. The deregulated electrical power market tries to make the full utilization of the electric network with high economical benefits and also maintains the security of the power system [4-7]. Because the mechanical energy may be converted into electrical energy, figure thermal solar radiation conversion can be viewed as a means to generate either mechanical or electrical power. Photovoltaic solar radiation conversion results in the direct production of electric energy from solar energy using the photoelectric effect. It is important to have a theoretical model for converting solar radiation into work (electricity) and for determining the efficiency of this process. In our case, there is a power to a load in an isolated site, in order to study the proposed system based on climatic conditions [8]. The key problem of analyzing such a system is due to the lack of proper organization of the energy sector in the country under review. Over 95% of the generated energy is from coal-fired power plants, and now it has begun incorporating renewable technologies, generating energy from photovoltaic panels as well as solar panels (Figure 1).

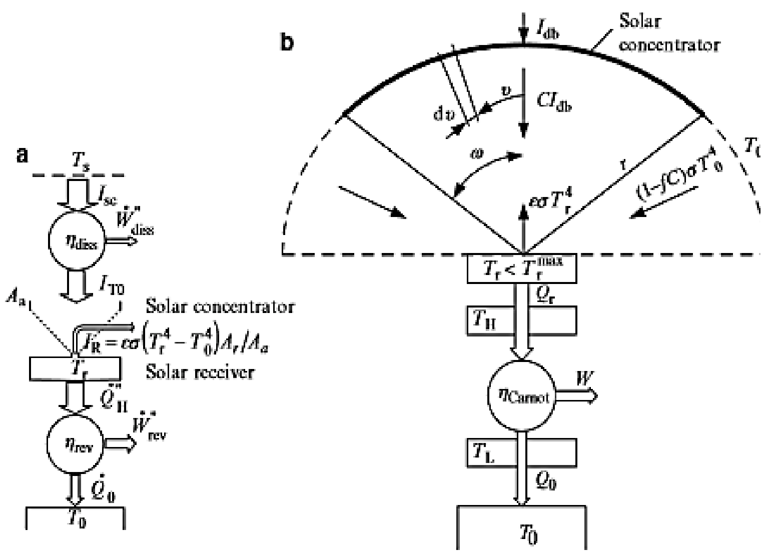



Figure 1: Thermodynamic models for photothermal solar radiation conversion into work. (a)Model for exergy of insolation; (b) model accounting for solar concentration and heat transfer

## 2. PHOTOVOLTAIC-THERMAL SYSTEMS

If exposed to a low solar concentration ratio, the temperature of a PV panel increases, as mentioned above. In this case, the PV cell efficiency decreases, but the overall panel efficiency increases. There is a limit to the operating temperature of the PC cells, which, depending on the construction, is in the range of about 60 to 100°C. Lowering the PV panel temperature is a means of increasing efficiency. If cooling is applied with the help of a heat transfer fluid to a PV panel, its temperature can be maintained between 40 and 80°C (depending on the solar radiation intensity and on whether concentration systems are applied) [9]. The heat recovered from PV panel cooling is thus a good level of temperature to be used in a multitude of applications. Consequently, PV/T (photovoltaic–thermal) systems make sense for both increasing the efficiency of power generation and increasing the efficiency of solar resource utilization. Water, glycol–water, and air are typical heat transfer fluids used in PV/T systems. Hot water can be used for energy generation, space heating, sanitary water heating, greenhouse heating, solar drying, solar stills, and other purposes [10]. When water is used as the cooling medium, arrangements can be made to combine PV technology with a flat plate solar thermal collector. Thus, water at its lower temperature can flow underneath a PV panel so that, through heat transfer, it cools the panel and improves its efficiency. Water is preheated in this way and then passed through flat plate solar thermal collectors for further heating. The diagram of a system as such, used for space and water heating in a residence, as suggested in Figure 2 [11]. The energy and exergy efficiency of the cogeneration system is usually defined as useful electricity and heat generated, expressed in energy or exergy units, respectively, over the consumed solar resource (again in energy exergy units). It is also possible to define the energy efficiency of the cogeneration system considering that the electricity is a more valuable product than the heat [12].

By dividing this heat into the total solar energy used we obtain:

$$n_{cog} = \frac{Q_e + Q_{th}}{I_{TO}} \tag{1}$$

Solar energy is available worldwide and can play a key role in facilitating energy independence and resilience at the regional, national, local and household level low- and medium-temperature, solar-thermal technologies can generate heat for many diverse residential, commercial and process heating applications, which can form natural distributed energy provision systems with high reliability [13]. The renewable energy sector employs 9.5 million people worldwide, of which 3.7 million are in the solar sector (including photovoltaic PV, solar heating, and cooling). Small- scale thermal and stand-alone applications create opportunities for local economic development in a much-localized value chain covering design, manufacture, installation, and maintenance. In addition, solar systems are insulated from the instabilities of oil price fluctuations, conflicts, and financial uncertainty. A PV-T module increases the longevity of the PV cells as these are operated at lower temperatures, especially in applications such as swimming pools, hotels, heat pumps, and underfloor heating, which require a large amount of low-temperature heat. This benefit arises from the fact the solar cells in PV-T collectors suffer lower temperature stresses, which are known to give rise to major causes for PV system failures due to cell breakage, encapsulation discoloration, and delamination. Moreover, PV-T systems enable 'self-consumption' – the generation and use of electricity on site. Self-consumption is the cheapest way to generate energy with renewables and reduce the stress on the local grid at the same time. PV-T systems can be integrated with heat pumps or cooling systems and the electricity generated in excess could be stored [14].

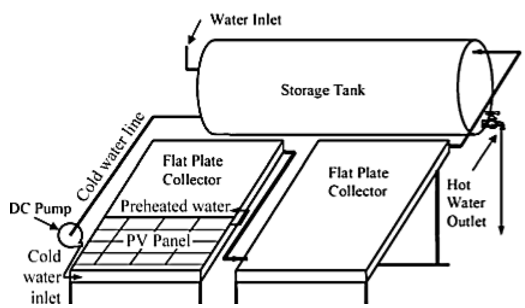



Figure 2: Hot water production with PV/T systems

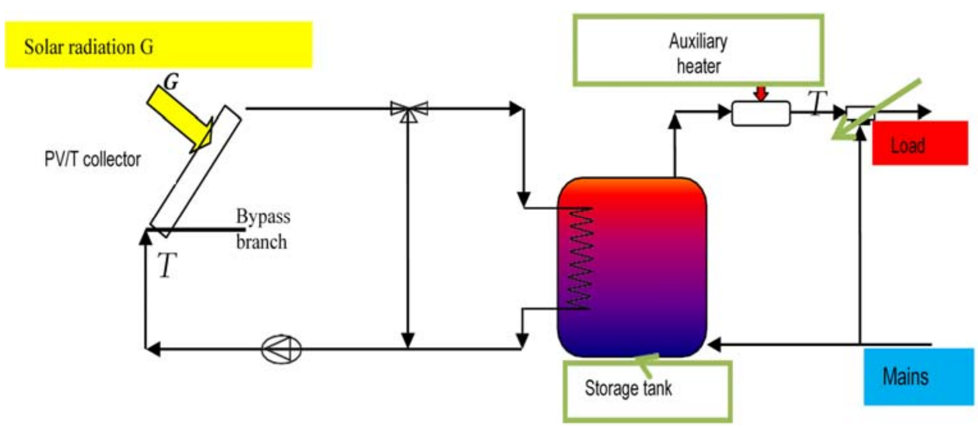



Figure 3. Schematic diagram of PV-Thermal system

Agency (IEA) Task indicates a potential cost reduction of roughly 10% for PV-T installations compared to the combination of separate systems with market development. Hybrid photovoltaic and thermal (PVT) collectors combine photovoltaic (PV) cells and solar thermal components and enable the simultaneous conversion of solar energy into heat as well as into electricity [15], which is the integrated thermal store, or in the ground to be reutilized by ground-source heat pumps. Careful planning of energy use (demand-side management) may also be important in the effective operation of the system. Estimates conducted in the framework of the International Energy can see in Figure 3. As well as the details of the hybrid collector given in figure 4 in which you can see, besides the photovoltaic mirror, the pipes in which cold water is introduced by means of the pump, and then by the heat received from the sun is sent to the heat shifter which for the secondary cycle presents the boiler [16].

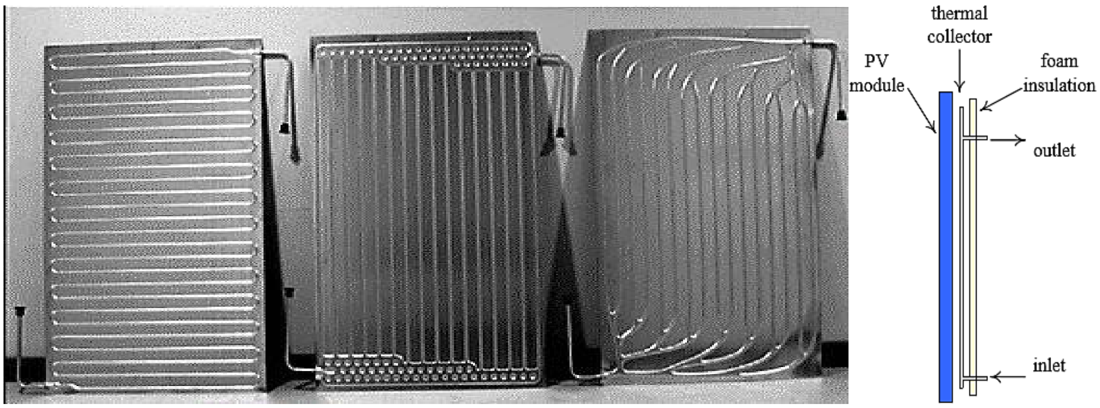



Figure 4. PV-T panel components

### 2.1. Thermal Part

An energy balance indicates the distribution of the incident solar energy into the useful energy gain, thermal losses, while optical losses describe the thermal performance of a solar collector [17]. In the steady state, the thermal energy loss from the collector to the surroundings by conduction, convection, and infrared radiation could be represented as the product of the heat transfer coefficient UL times the difference between the mean absorber plate temperature $T_{pm}$ and the ambient temperature $T_a$ . The useful energy output of a collector with area Ac is equal to the difference between the absorbed solar radiation and the thermal loss [18] and it is given in equation 2 as:

$$Q_u = A_c[(\tau.\alpha)_e.S - U_L.\left(T_{pm} - T_a\right)] \tag{2}$$

### 2.2.1.Hottel-Whillier-Bliss equation

The mean temperature of the absorber plate is difficult to calculate or measure since it is a function of the collector design, the incident solar radiation, and the entering fluid conditions. For the purpose of the system design, it is convenient to relate the performance of the solar collector to the temperature of the heat transfer fluid, as the plate temperature is usually not known. Here, two efficiency factors of the collector, $F_R$ and, F', are introduced by Hottel- Whillier-Bliss (eq. 3) to allow the use of either the mean or inlet fluid temperature in the collector [19]:

$$Q_u = A_c.F'[(\tau.\alpha)_e.S - U_L.\left(T_{pm} - T_a\right)] \tag{3}$$
$$Q_u = A_c.F_R[(\tau.\alpha)_e.S - U_L.\left(T_{pm} - T_a\right)] \tag{4}$$

### 2.2.2. Incidence Angle Modifier

As shown in equation (4), the coefficient of incidence angle modifier is approximated as the ratio between transmittance – absorptance coefficient of collectors and the coefficient itself at normal incidence:

$$K_{\tau\alpha} = \frac{(\tau\alpha)}{(\tau\alpha)_n} \tag{5}$$

where $\tau$- the transmittance of the cover system at the esired angle and α = the angular absorptance of the absorber plate. ASHRAE 93-97 recommends that Kτα should be experimentally determined based on Eq. (5) by positioning a collector in the indoor testing (with θ=0, 30, 45, and 60 degrees). Moreover, in the outdoor testing, the pairs of the test symmetrical to the solar noon should be conducted, when the angles of the beam incidence are approximately 30º, 45º and 60º. On the other hand, EN 12195 also recommends determining Kτα, for both indoor and outdoor tests. A solar simulator should be used under indoor test, while in the outdoor test a movable test rack could be used, in which the orientation of the collector could be arbitrarily adjusted. In general, the effective transmittance-absorbance coefficient ετα for ordinary glass can be approximated by [20] by (6) equation:

$$(\tau\alpha)_e = (\tau\alpha) + (1-\tau\alpha).\frac{U_t}{U_{c-\alpha}} \quad (6)$$

$$(\tau\alpha)_e \cong 1.02(\tau\alpha) \quad (7)$$

And for the collectors with negligible absorption covers, it can be approximated by from the expression in the equation (8):

$$(\tau\alpha)_e \cong 1.01(\tau\alpha) \quad (7)$$

Furthermore, Klein (1979) proposed an empirical equation for the heat loss from the top for the mean plate temperatures in the range of ambient and 250°C. It can be described as:

$$U_t = \left[\frac{N}{\frac{C}{T_{pm}}.\left[\frac{(T_{pm}-T_a}{(N+f)}\right]} + \frac{1}{h_w}\right]^{-1} + \frac{\sigma.(T_{pm}+T_a).(T_{pm}^2+T_a^2)}{(\varepsilon_p+0.00591.N.h_w)^{-1} + \frac{2.N+f-1+0.133.\varepsilon_p}{\varepsilon_g}} \quad (8)$$

Where:
N = number of glass covers
β = collector tilt (degrees)
$\varepsilon_g$ = emittance of glass (0.88)
$\varepsilon_p$ = emittance of plate (0.88)

$$f = (1 + 0.089 \cdot h_w - 0.1166 \cdot h_w \cdot \varepsilon_p) \cdot (0 + 0.07866 \cdot N)$$

$$C = 520(1 - 0.000051 \cdot \beta^2) \ for\ 0° < \beta < 70°. For\ 70° < \beta < 90°\ use\ \beta = 70$$

$$e = 0.430 \cdot \left(1 - \frac{100}{T_{pm}}\right)$$

$T_a$= ambient temperature (K)
$T_{pm}$ = mean plate temperature (K)
$h_w$ = wind heat transfer coefficient $W/m^2 \cdot C$
Wind coefficient $h_w$ given by McAdams in 1954:

$$h_w = 5.7 + 3.8 \cdot w \quad (10)$$

where 0 < w < 5m/s
For flat plates, Lloyd and Moran give the following equation:

$$\begin{cases} 0.76 \cdot Re^{\frac{1}{4}} & for\ 10^4 < Ra < 10^7 \\ 0.15 \cdot Re^{\frac{1}{3}} & for\ 10^7 < Ra < 10^{10} \end{cases}$$

$$\mathrm{Re} = \frac{2 \cdot \dot{m}}{w \cdot \mu} \quad (11)$$

The heat losses through the edges of collectors could be approximated by comparing the edge loss-coefficient-area product (UA) edge and the collector area (Ac):

$$U_e = \frac{(U \cdot A)_{edge}}{A_C} \quad (12)$$

While the energy loss through the bottom of the collector due to the insulation could be presented by the following equation [15]:

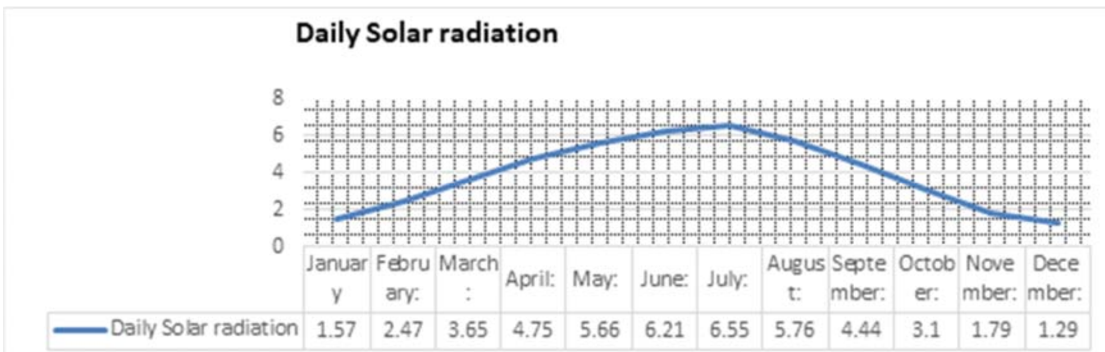
$$U_b = \frac{k}{L} \quad (13)$$

Thus

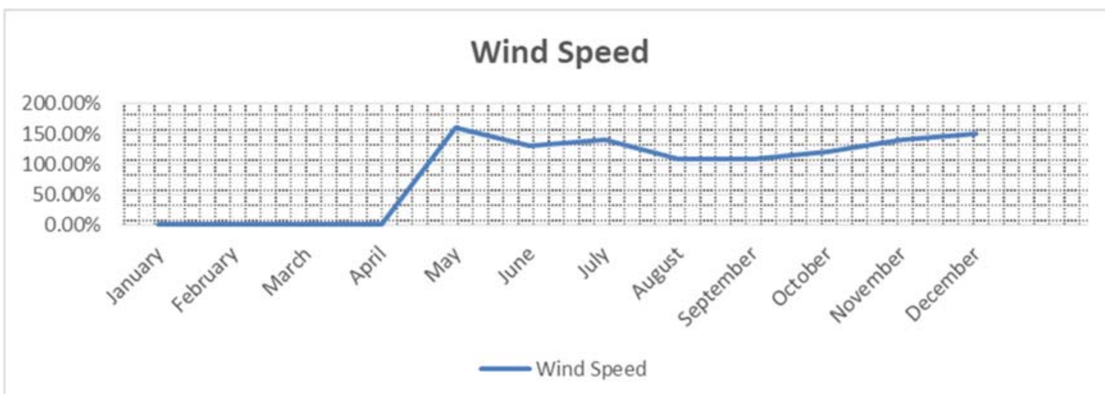
$$U_L = U_b + U_e + U_t \quad (14)$$

## 3. ASSUMPTIONS IN MODEL

The glazing is 2-substrate, the material from which the photovoltaic panel is built is monocrystalline silicon. The part of the collector consists of copper pipes that are placed between the insulation layer and the photovoltaic panel glass [22]. Suppose that the surface of the photovoltaic and photovoltaic panels involved in that is 2 m2, length 2m and width 1m, we also assume that the layer of the photovoltaic panel is 2 double glazing. The hybrid panel is placed at the angle of 30˚. To carry out the analysis in question, they receive an air temperature of 25 °C. To calculate the wind coefficient around the solar collector will be based on data from the NASA institute as shown in Figure 5:




(a)




(b)

Figure 5: Daily solar radiation and wind speed for Kosovo given by Nasa Station a, b) [5]

## 4. RESULTS AND ANALYSIS

Bearing in mind that Kosovo as the country's most recent country declared as an independent country has long been underdeveloped, and now as a place of traction has the elementary problems of the energy sector as a key element for the development of the industry. From the earlier analyses of the PV / T systems we mainly have the systems that generate electricity from the photovoltaic panels and thermal energy as sanitary water, we have analyzed that because our country has good geographic position, which ensures for a while during solar radiation then it was worth analyzing the electricity generation system by heating the water to high temperatures, which serves as a source for the production of electricity through the Rankin cycle. During the process of analyzing this paper, we assume that the outdoor ambient temperature is 25°C and some approximations have also been made, which in certain cases are mentioned (Figure 6). If we assume that the water temperature in the outlet from the collector is about 250℃ which will then be used for either electricity generation or heating then the manufacturer's characteristics for such types of the hybrid collector.

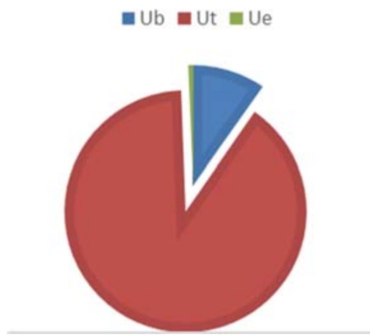



Figure 6: Schematic diagram of heat losses in a flat plate solar collector for an experimental case.

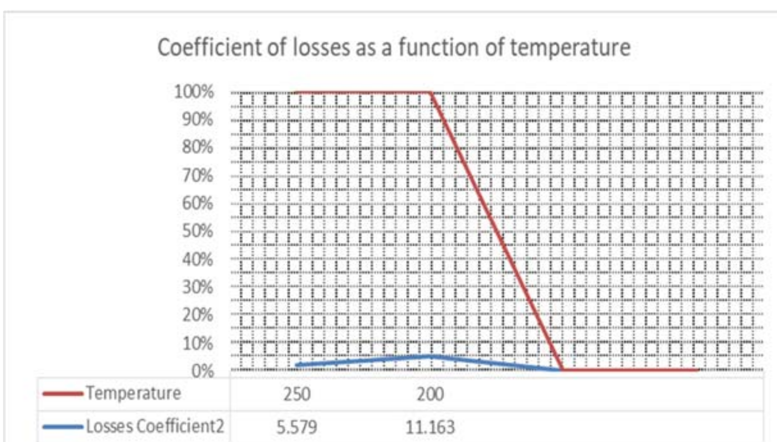
### 4.1. Temperature distributions in flat-plate collectors

The energy transferred to the fluid will heat the fluid, causing a temperature gradient to exist in the direction of flow. Since in any region of the collector, the general temperature level is governed by the local temperature level of the fluid. Determine the collector top loss coefficient for a single glass cover with the following specifications (Figure 7):

- The thickness of this hybrid collector 0.055m
- Plate emittance 0.88
- Ambient temperature 25℃
- Mean plate temperature 250℃
- Collector tilt 30˚
- Wind heat transfer coefficient 11.4 W/m2◦C

Analyzing the case for different types of materials used in the collector, as well as for the relationship between global temperature and global radiation, we will get the results as in Figure 8 where it can be seen that the highest efficiency can be achieved in the case of using a better material such as the case of low iron glass, T=0.9, and e=0.88, and the lowest efficiency will be achieved with the use of the material

ITO/Low Iron Glass/AR, T=0.86, e=0.20:

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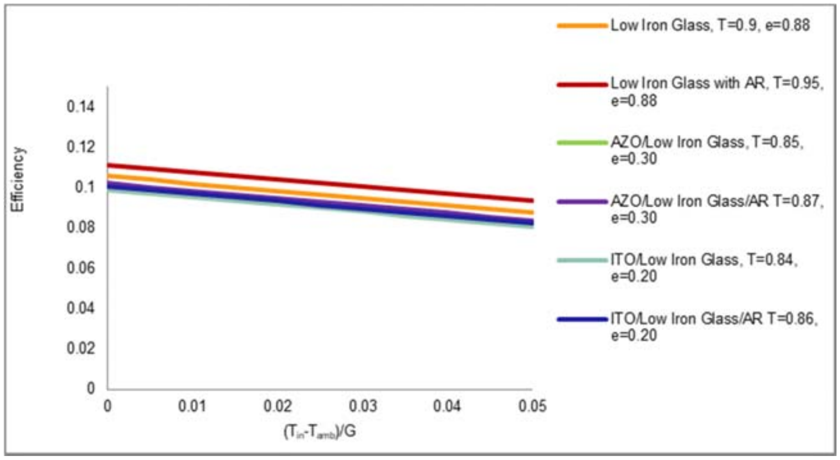



(b)

Figure 7. a) Coefficient of losses as a function of temperature, b) solar collector efficiency changes for different types of material used

The smelting has an important role in increasing the efficiency of the solar hybrid panel, and for this reason, the case of a double-glazed and double-glazed collector is analyzed, taking into account the ratio between the temperature at the entrance of the collector and the temperature environment to global radiation in that country. With the change of irradiation and other specifications of the module, the output varies [23]. From the graphic representation of such cases can be seen the increase of collector efficiency on how to achieve it.

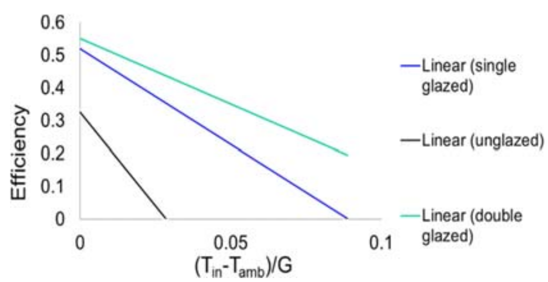
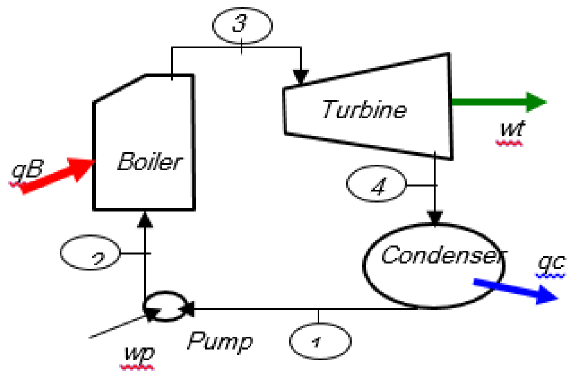



Figure 8: Efficiency difference for unglazed, single glazed and double glazed.

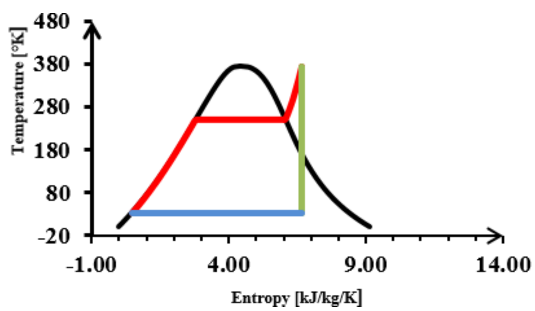
From Figure 10) it can be seen that in the case of the glazing of the collector, the difference is very small in terms of efficiency between the single-glazed and double-glazed collector, and as far as the case of the collector's case is concerned Double glazing is much larger than those with single glazing, so for practical cases it would be a better technical solution to use a single-glazed collector. Although power loss minimization has been studied extensively, this aspect is still attracted the numerous research interests [24].

### 4.2. Rankine cycle calculations

The researchers are always interested in working in this field, particularly with the massive incorporation of renewable energy into the power system [25, 26]. The analyzed solar collector has also been carried out by the ranking cycle so that many different clarifications are provided in each phase. work of the pump Given that we have a hybrid system in which photovoltaic panels and solar collectors are incorporated, then we can assume that the work that the pump spends to carry out the Rankine cycle can be taken to be entirely covered by solar panels in the hybrid system (Figure 9).




(a)




(b)

Figure 9: a) Rankin's scheme implementation, b) T-s diagram of the Rankine cycle, without taking into account the work of the pump

## 5. EFFICIENCY OF HYBRID SYSTEM

To calculate the hybrid system efficiency we use the formula as below:

$$Efficiency = EFF_{ref} \cdot \left(1 + Temp_{Co} \cdot (T_{ref} - T_{cell})\right) \tag{15}$$

$$T_{cell} = T_{OA} + \left( Solar_{insolation} \cdot \frac{T_{Op} - T_{ref}}{\mathrm{Re}\ f_{insolation}} \right) \cdot (1 - EFF_{ref}) \tag{16}$$

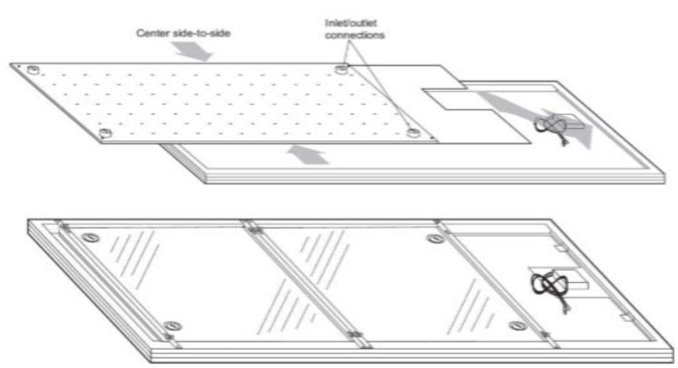
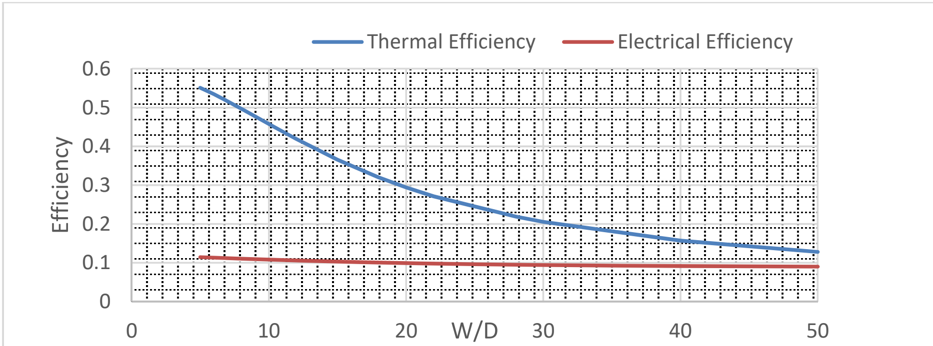
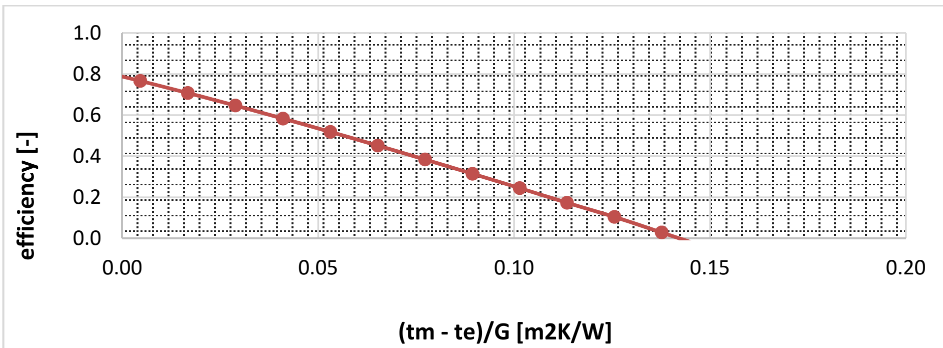



Figure 10: Thermal panel incorporated into a traditional panel




(a)




(b)

Figure 11: a) The difference between thermal and electrical efficiency given by hybrid collector (PV&T), b) thermal efficiency for a hybrid collector for different temperature report

A numerical model of the collector is used to study in more detail the effect of the module design parameters on its thermal and electrical efficiencies and to evaluate the temperature locally on the solar cell. This study assesses the effect of two design parameters: the collector glazing and the tube spacing (*W*/*D* ratio).

## 6. CONCLUSIONS

Photovoltaic Plants (PV) are fast growing to satisfy electrical power demand. Different maximum power point tracking techniques (MPPT) are used to maximize PV systems generated power. Another one of methods is using this system also called cogeneration system. Solar-based renewable systems capable of delivering domestic hot water, space heating and/or cooling, and electricity have a significant potential to contribute to Kosovo and European targetsof:

1. A 20% reduction of greenhouse gas emissions; and
2. An increase in the proportion of final energy generation from renewable sources to 20% by 2020, while at the same time decreasing the primary energy consumption in the building sector.

The photovoltaic-thermal hybrid system has a device that can provide the same time. The system performance depends on the PV operating temperature and for lower values of it, higher levels of electricity and heat can be obtained. Hybrid photovoltaic-thermal (PV/T) modules generate heat and electricity simultaneously in one module. The basic idea of the concept is to utilize more of the solar radiation by also harvesting the waste heat that is generated in photovoltaic (PV) modules. The above-made analysis is made when the water in this collector is heated up to steam and serves for the production of electricity, expanding into the turbine and by virtue of that, the generation of electricity in such a form is presented with small efficiency making it the most suitable form of operation together with a thermal pump or the use of this system for heating only buildings or for producing sanitary hot water. From those analyzes we can see how a more reliable system for the operation of a solar hybrid collector will be its operation that will enable the production of electricity through the photovoltaic cells, and the solar collector part will be such that it will allow water heating only for sanitary needs or for any heating needs of any building. Heat loss from the top of the hybrid panel is the biggest losses of a till system, followed by heat losses due to insulation at the bottom of this collector. During a wide range of power imbalance conditions, the change in negative sequence voltage and currents are examined for islanding detection. A hybrid PV/Thermal (PV/T) system is designed to provide both a thermal output and an electrical output with the following advantages over separate (side-by-side) PV and thermal systems:

- Combined generation of electricity from a common area, also leading to a more aesthetically pleasing solution that provides greater architectural uniformity than separate PV and solar thermal systems with a different appearance
- Higher PV conversion efficiency and electrical output due to the cooling effect of the circulating fluid
- Reduced installation costs (and cost per unit energy) due to the fact that only one system has to be installed. Additionally, because the prices of PV panels are different year-by-year and depend on the types of PV cells, the payback year should be investigated in future work.
- Various PV/T collector designs (Figure 11) are available depending on the application. The sheet-and-tube collector water-type design, or PVT/T, operating under forced circulation has been found to perform with high thermal efficiency in cold climates and is an easily adaptable PV/T configuration.
- In Kosovo, the use of such hybrid panels would be more efficient if they are used for sanitary water heating and not for heating the building due to the very high temperatures reached.

As the new technology proposed for future research would be the use of technologies that work with nanofluids because only in such cases would be possible the efficient transmission of energy by enabling maximum utilization of such technology and faster energy independence.

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