Combined Energy Systems for Obtaining Energy from Renewable Sources Used in Isolated Areas

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Abstract: *The paper presents some aspects of obtaining energy from renewable sources, especially for remote areas, where we meet, usually, individual users or very limited groups of consumers. In the second part there are presented some solutions for combined systems that use renewable energies, which is a secure path to increase efficiency of their use and supply, throughout the day and even the year, the energy needed for consumption in remote areas.*

Keywords: *Renewable energy, capture technologies, power hydraulics, wind power, photovoltaic technology, hydrostatic transmission, fluid power transmission*

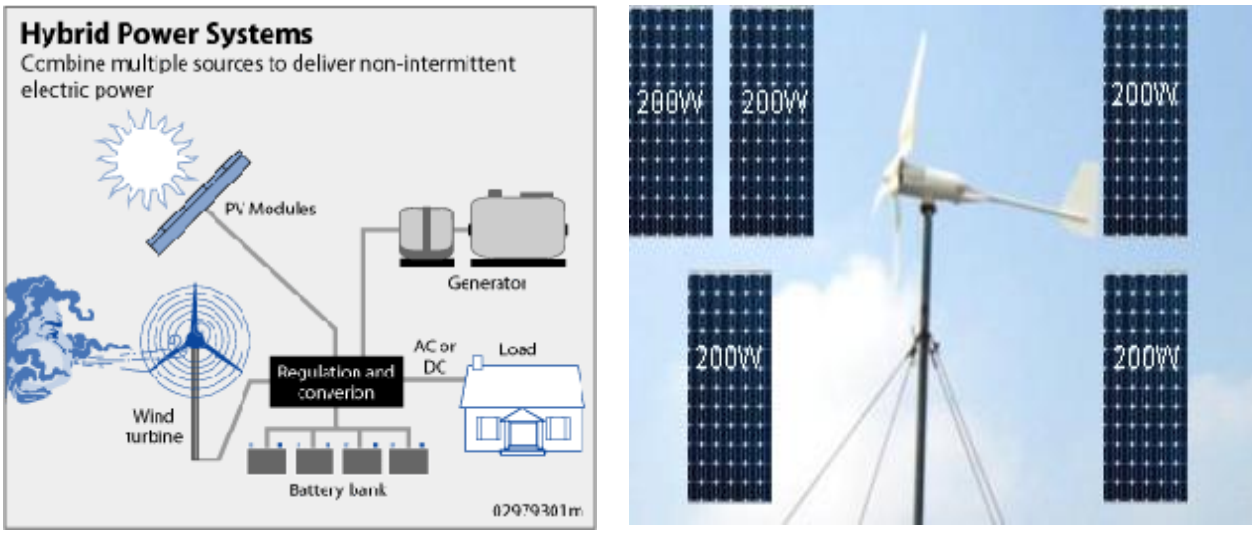
1. Introduction

European Union energy policy by 2020 is based on three core objectives: Sustainability, Competitiveness, Safety of energy supply.
Regarding the production energy from renewable sources, European Union **target** for 2030 is 27 % of total energy consumption, mandatory for the community block.
According to Romania's energy strategy over the period 2007 – 2020, the **general objective** of the strategy in the energy sector is represented by **meeting the energy needs,** both now, and in the medium and long term, by promoting the **production energy from renewable sources**, so the share of electricity produced from these sources in the total gross electricity consumption be 33% in 2010, 35 % in 2015, and 38 % in 2020, [1].
To implement this policy, there has been developed *Planul Naţional de Acţiune în Domeniul Energiei din Surse Regenerabile (PNAER) – 2010 / National Action Plan in the Field of Energy from Renewables – 2010,* which states that energy produced from renewable energy resources is "*clean*" energy, and their exploitation provides an alternative to energy produced from fossil fuels. An important role will be played by **measures to increase energy efficiency** in the public sector, which will have an important role at national level [2].
The concept of **energy efficiency** (or energy consumption optimization) has become, nowadays, one of the main concerns of humanity in the entire world.
Diversifying the energy sources is becoming **an economic and environmental imperative**. These alternative energies are renewable energies. The most popular renewable energy sources are: **solar** energy (direct, photovoltaic and thermal energy), **wind** energy (as a solar energy derivative), **hydraulic** energy (by using the potential and kinetic energy of the water), **geothermal, bio-energy,** etc.
Renewable energy sources can be used both as **centralized sources of energy** and, largely, **decentralized**. Decentralized sources are particularly advantageous, especially for **rural** consumers or those **in remote areas** [3].
Decentralized energy sources are particularly interesting for individuals or for small groups, especially if they are in remote areas.
The issue of choosing a particular **system of energy generation from renewable sources**, especially for natural persons, individuals, or for **consumers in remote areas**, is not a simple issue, as one needs to know very well the **requirements for power consumption**, on the one hand, and on the other hand the **technologies** that are addressed **must be well known** as well, including the thermal parameters, wind speeds, etc, which can result in energy availability, daily or seasonal, which is different for different areas, even if the equipment is the same.

The main systems / technologies for the **use of clean energies** are: **solar** systems (thermal and photovoltaic), **wind** systems / power plants, or **mixed or hybrid systems**, which combines two or more sources of renewables in order to increase energy efficiency and availability.
This is because, apart the clear benefits of renewable sources of energy, they also have downsides, which mainly consist of fluctuation, intermittence, of the basic parameters (temperature, wind speed), their variation both during the day and throughout the year.
From theoretical analysis and practice of **experts in renewable energies**, the use of **combined or hybrid systems** has **clear advantages** compared to the single ones, especially for **remote areas.** Of course, combined or hybrid systems also have the disadvantage of high upfront investment costs [4].

2. Combined systems practiced worldwide

The combined systems provide the opportunity to have energy throughout the day, irrespective of whether one of the sources is unavailable, being possible for another one to be operative and produce energy.
The combined systems which use **the energy of running water** or **geothermal energy** provide nearly **incessantly the energy required**, but such systems are **very expensive**, especially for individual users in remote areas.
Nonetheless, in the world there are many successful attempts to use combined or hybrid systems, confirming the superiority of this type of system in using the renewable sources of energy.
There are already companies that offer **kits for photovoltaic and wind hybrid systems** for **generation of electricity from renewable sources**, which work by using both photovoltaic panels and a wind turbine. Such photovoltaic and wind power hybrid kits are recommended for providing the necessary power in a tourist accommodation facility, housing, hostel, school or medical facility. The photovoltaic and wind power hybrid kits also include inverters, charge controllers and solar accumulators to store electricity which is beyond the consumption needs. The photovoltaic and wind power hybrid kits are also ideal to be used in irrigation systems on agricultural land [5].
In the following, **some examples** are given **of the diagrams of combined or hybrid systems** that use renewable energy to achieve continuous energy.
A **hybrid system** for electricity generation integrates **several energy sources** and it can feed consumers without interruptions, even if one source does not work any longer. The most used hybrid systems are the solar-wind ones, which combine photovoltaic panels and wind generators.



a) Schematic diagram

b) Photovoltaic panels and wind power plant

Fig. 1. Combined system of three types of energy: solar, wind and chemical energy [6].

A combined/ hybrid system of three energy sources, consisting of photovoltaic panels and wind generators, is shown in figure 1 a and b, composed of: photovoltaic panels, wind generator, generator with internal combustion engine, charge controller, inverter and electric accumulators. The advantage of such a system is using multiple sources for electricity production, working both day and night [6], [7].
As solar energy is fluctuating, and the generation capacity of the diesel genesets is limited to a certain range, it is often a viable option to include battery storage in order to optimize solar's contribution to the overall generation of the hybrid system.
Hybrid renewable energy systems (HRES) are becoming popular as stand-alone power systems for providing electricity in remote areas due to advances in renewable energy technologies and subsequent rise in prices of petroleum products.
Other solar hybrids include **solar-wind systems**. The **combination** of **wind** and **solar** has the advantage that the two sources complement each other because the peak operating times for each system occur at different times of the day and year. The power generation of such a **hybrid system** is more constant and fluctuates less than each of the two component subsystems.
The next figures 2 a,b,c and d present some combined/hybrid systems developed worldwide [6].

a) Typical wind and solar hybrid system

b) Hybrid on Žirje, Croatia

c) Hybrid in Leh, India

d) Small wind and solar hybrid system

Fig. 2. Some combined/hybrid systems developed worldwide [6]

A wind-hydro system generates electric energy combining wind turbines and pumped storage. The combination has been the subject of long-term discussion, and an experimental plant, which also tested wind turbines, was implemented by Nova Scotia Power at its Wreck Cove hydro electric power site in the late 1970s, but was decommissioned within ten years [6].
Biomass-wind-fuel cell hybrid system. For example, let us consider a load of 100% power supply and there is no renewable system to fulfill this need, so two or more renewable energy systems can be combined. For example, 60% from a biomass system, 20% from wind system and the remainder from fuel cells. Thus combining all these renewable energy systems may provide 100% of the power and energy requirements for the load, such as a home or business [6].

Suntech Green Energy hybrid systems make optimal use of sunlight and wind speeds - the two main resources readily available in the South Asian sub-continent. When the solar resource is low during the monsoon, the wind is quite strong and vice versa. The resultant hybrid system thus offers an optimal solution at a substantially lower cost. It is ideal for electrification of **remote villages** in India [8].

a) Schematic diagram b) Actual placing of the combined system

Fig. 3. Suntech Green Energy hybrid systems

In figure 4, for a Hybrid Renewable Energy System, there is presented the diagram of economical optimization of wind and solar based hybrid production systems [8].
A ***Hybrid energy*** system usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply.
An example of a hybrid energy system is a **Solar photovoltaic** array of panels, and even **Solar Heat collectors**, coupled with a **Wind Turbine**. Such a system is shown in figure 5 [9].

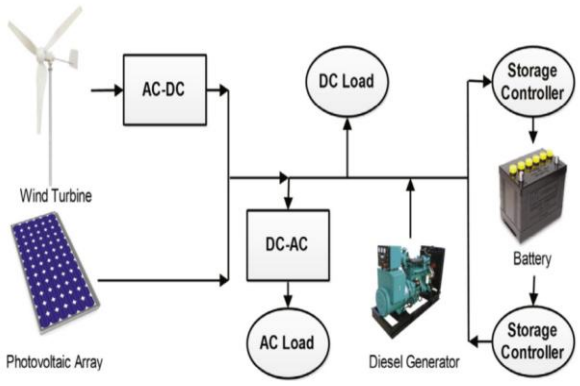


Fig. 4. Diagram of a triple source combined system

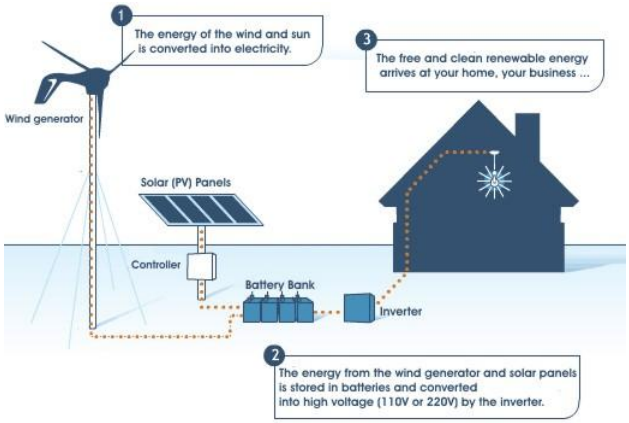


Fig. 5. Solar Heat collectors**,** coupled with a Wind Turbine

This would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output.
The **combination** also **works efficiently with greater energy output** during the day with the Solar panels & collectors, with wind turbine generated energy at night [9].
Figure 6 presents a Hybrid system that uses wind and solar system to support and power a street light; it is an independent system which does not need power supply from the grid (all the power comes from renewable energy: wind & sunshine).
The Hybrid renewable system below, figure 7, is one that again provides electricity from a Wind generator and Solar panels from the sun during the day, and continues to be supported by the Wind energy generator source, coupled with energy stored in batteries at night.

The Hybrid renewable energy system presented in figure 7 may also include a Solar thermal Hot water system that has collected the sun's radiation during the day to heat and store hot water in the boiler for use at night, for a personal home.

Fig. 6. Wind and solar combined system to support and power a street light

Fig. 7. Wind and solar combined system for a personal home

Hybrid energy systems oftentimes yield greater economic and environmental returns than wind, solar, hydro or biomass generation stand-alone systems by themselves [9].

3. Innovative solutions for combined systems

Out below, we will present some new, innovative concepts / diagrams of achieving combined systems that use renewable energies. Figure 8 presents a diagram for use of solar thermal energy system on a **river pontoon**, intended to reduce, to a large extent, the conventional fuel consumption in the existant **power motor-generator**, with which it is **operating in a combined system**.

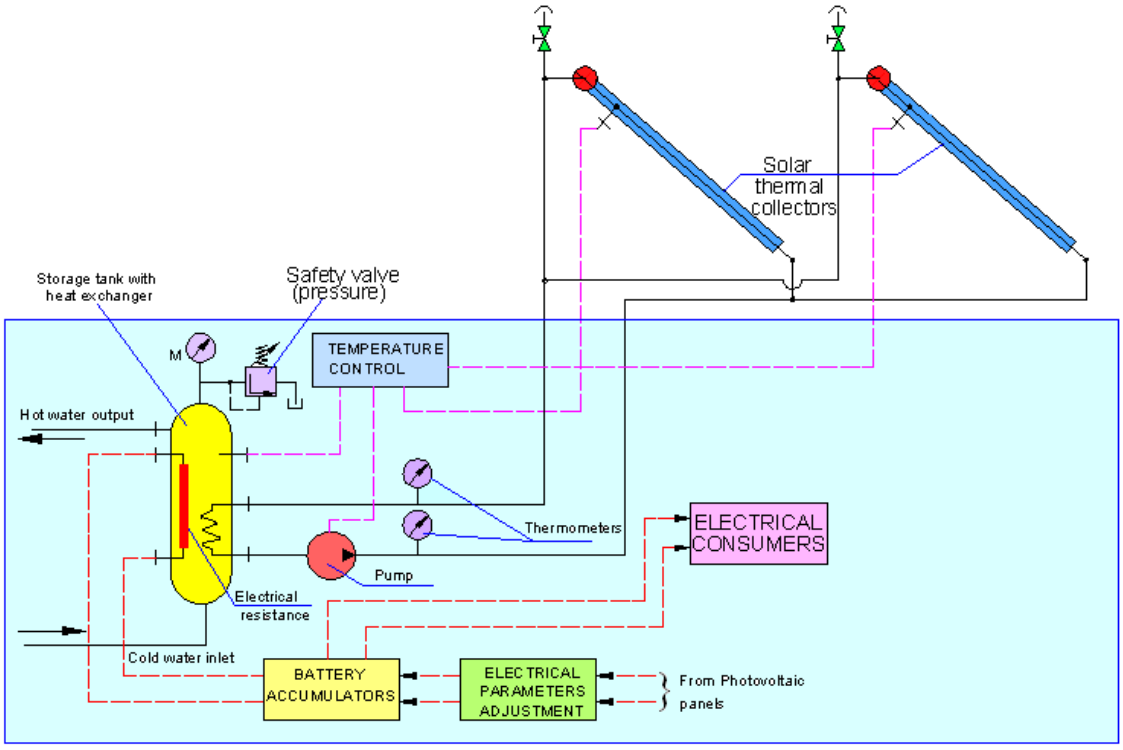


Fig. 8. Diagram/Concept of a combined system of solar energy and power from the motor-generator

Figure 9 presents a concept/diagram of a combined system for energy production from two renewable energy sources, namely: thermal and electrical energy, both from the sun. Thermal energy is produced by using solar thermal panels, flat or vacuum tube panels, while electrical power is supplied by photovoltaic panels / collectors, which operate on the photoelectric phenomenon. For domestic water heating, solar thermal panels contribute directly, and also electricity generated by photovoltaic panels, which, after adjustment of the parameters to the storage system consisting of a battery of electric accumulators, is conveyed to an electrical resistance installed inside the container / tank of hot water. Also from the battery of electric accumulators other electrical consumers (light bulbs, air conditioning, radio, TV set, etc.) are supplied as well.

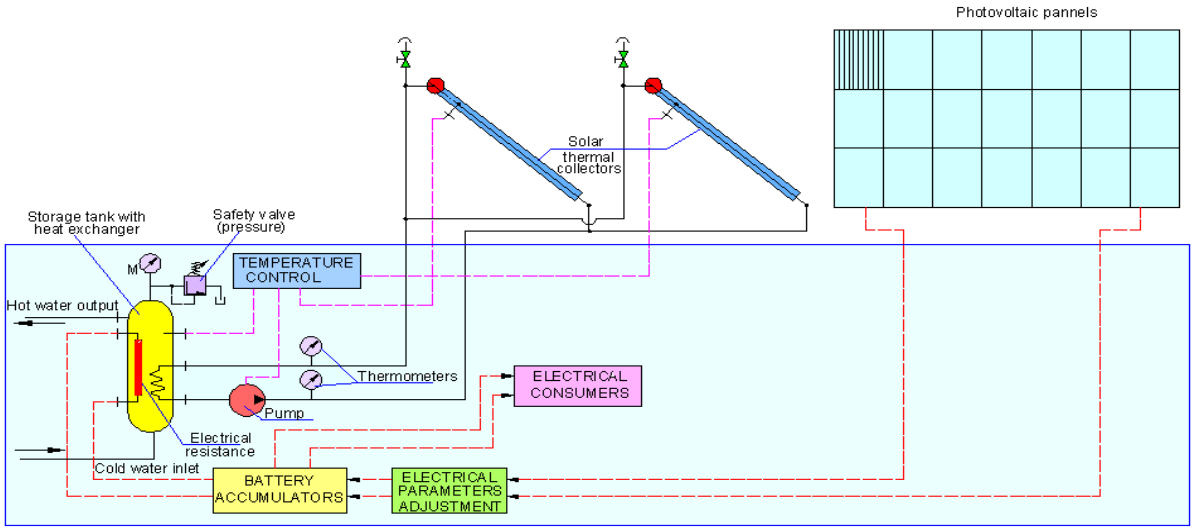


Fig. 9. Solar system combined diagram to obtain heat and electricity from photovoltaic panels

On the **hot water tank**, provided with cold water connections at the bottom and hot water connections at the top, there are installed a **safety valve** and **a manometer** indicating the working pressure, and on the input and output circuits of the **heat exchanger coil** there are provided **sensors and thermometers**, one for the lowest temperature, one for the highest. The system operates with **two circuits**, one for actual use and the other for heat transfer from heat panels / collectors to the water in the tank, by means of a **heat exchanger**, which can be located inside or outside the storage tank.

The fluid circulating through the heater coil releases the heat received from the collector to the cold water inside the heater, and there may be **water / propylene glycol mixture**, in a ratio **40/60** or **45/55**, based on the minimum temperature of the environment, during cold seasons the mixture 45/55 ensuring protection down to -26^{0}C. The fluid in the heat transfer circuit is circulated by means of a **centrifugal pump**, controlled by temperature control system / controller, ensuring the smooth functioning. The controller compares the temperatures provided by the two temperature sensors and activates the circulation pump as long as between the 2 points there is a temperature difference (adjustable) of more than 6...20 K°; when the temperature difference decreases below the set threshold, the pump is switched off and heat transfer ceases.

Another variant of a **combined system** for generation of **heat and electricity**, shown in figure 10, consists in **combination of one renewable energy source from the sun**, in order to **obtain thermal energy**, and a **wind micro/mini power plant**, intended to **supply electrical current** for one consumer or more, in **remote areas**, without the possibility to connect to the national electricity networks.

Figure 10 presents a concept/diagram of a combined system for energy production from **two renewable energy sources**, namely: **thermal** energy and **electrical** energy; the first comes directly from the sun, solar energy, and the second source exploits **wind energy**.

Thermal energy is obtained by using **solar thermal panels**, flat or vacuum tube panels, as in the first variant, while electrical energy is supplied by **a wind micro/mini power plant**.

This combined system requires a significant investment on the wind power plant.

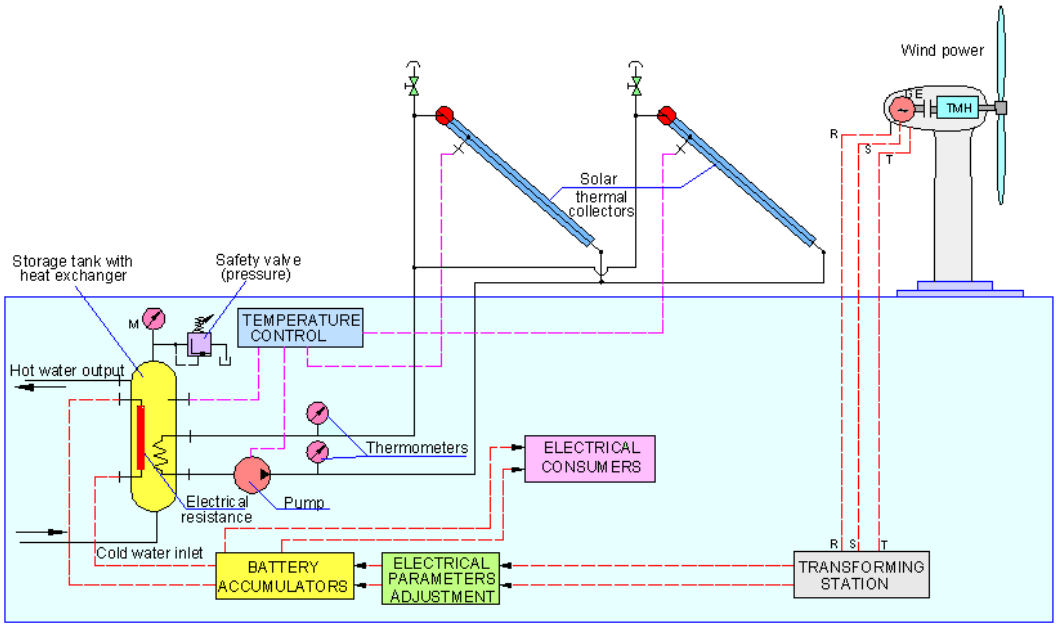


Fig. 10. Combined system for obtaining heat and electricity

Electricity provided by the wind power plant is first converted and then adjusted to the required parameters so that to be possible to **store it in the battery of electric accumulators**.
From the electric accumulators, the current can be used by **usual electrical consumers** or by **heating resistance** installed into the hot water tank, if appropriate.
As for the rest, structure and operation of the combined energy production system are similar.
The system shown in figure 11, below, is similar to that shown in the previous figure, but it integrates **3 energy supply systems**, being further provided with a connection to a **wind micro/mini power plant**, which also has fluctuating functioning, as the wind blows, at higher or lower speeds.

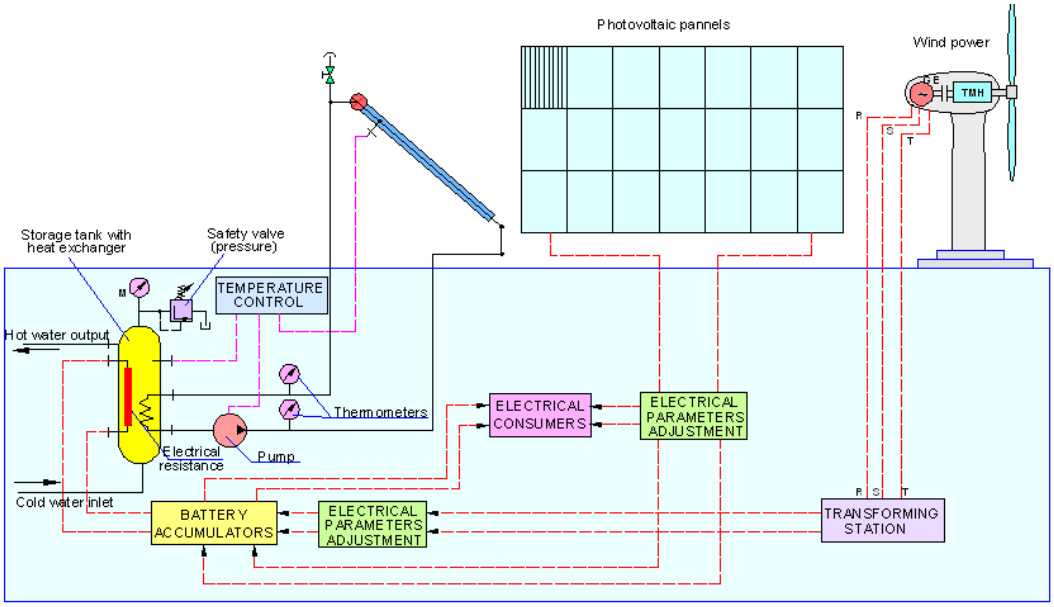


Fig. 11. Solar system combined diagram to obtain heat and electricity from photovoltaic panels and wind power

Combining the **three types of energy** offers increased security to have available at any time of day, the energy needed for a **consumer located in remote areas**.
If alternating, the electric current supplied by the wind power plant is first converted and then adjusted to the required parameters so that to be possible to **store it in the battery of electric accumulators**.

From the electric accumulators, the current can be used by **usual electrical consumers** or by **heating resistance** installed into the hot water tank, if appropriate.
As for the rest, structure and operation of the combined energy production system are similar.
As one can see from the above, developing new technologies for renewable energy storage, conversion and use is a major global activity, and consequently in our country, where the target is to meet the percentage set by the EU in use of renewable energy.

4. Conclusions

The paper has developed on the issue of using renewables at high energy efficiency, namely by means of combined energy production systems for remote areas.
As a synthetic conclusion, it can be said that the use of renewable energy is in full expansion and it includes all forms.
Therefore, the article presented a number of methods and technologies for combined systems, practiced worldwide, including in our country, some still being in a concept phase or experimental phase.
Finally, there are presented some new concepts for development of combined systems that use renewable energy, diagrams which will be the basis of several applied research activities to be developed in our institute.
Developing novel technologies and systems for capture, conversion, storage and reuse of renewable energies represents a new research direction within INOE 2000-IHP Institute [10], [11].

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References

[1] *** Strategia energetică a României pentru perioada 2007 - 2020 actualizată pentru perioada 2011 – 2020. În: http://www.minind.ro/energie/STRATEGIA_energetica_actualizata.pdf;
[2] *** Planul Naţional de Acţiune în Domeniul Energiei din Surse Regenerabile (PNAER) – 2010. In: http://www.minind.ro/pnaer/draft_PNAER_15_06_10.pdf;
[3] G. Mircea, Course: "Conversia neconvenţională a energiei electrice. Introducere",.In: http://mircea-gogu.ro/pdf/Curs%20Conversia%20neconventionala%20a%20energiei%20electrice/Introducere.pdf;
[4] *** E-SOLAR : De ce trebuie să ținem cont atunci când instalăm un sistem fotovoltaic sau/și eolian? In : http://www.esolar.ro/sfaturi-utile/ce-sistem-de-energie-alternativa-alegem-fotovoltaic-eolian-sau-unul-hibrid.html;
[5] *** E-SOLAR: Kituri hibride fotovoltaice si eoliene - Hybrid photovoltaic and wind kits. In: https://www.esolar.ro/tehnologie-solara-fotovoltaica/kituri-hibride-fotovoltaice-si-eoliene.html;
[6] ***Wikipedia. Solar hybrid power systems. In: https://en.wikipedia.org/wiki/Solar_hybrid_power_systems;
[7] *** Sisteme hibride – Hybrid systems. In: http://www.sunnyway-solar.ro/sisteme%20hibride.html;
[8] *** Suntech Green Energy hybrid systems. In: http://http://enarchgroup.com/ees/hybridenergy.php;
[9] *** Hybrid Energy.EcoPlanetenergy. In: http://www.ecoplanetenergy.com/all-about-eco-energy/overview/hybrid/;
[10] C. Cristescu, C. Dumitrescu, I. Ilie, L. Dumitrescu, "Increasing energy efficiency of the solar thermal panels through the use of hydraulic tracking systems", In: Proc. of International Multidisciplinary Scientific Geo-Conference SGEM-2014, 17 – 26 June, 2014, Albena Co., Bulgaria, Vol.: „Energy and clean technologies", pp. 291–298, ISBN 978-619-7105-15-5, ISSN 1314-2704, DOI: 10.5593/SGEM2014/B41/S17.038;
[11] C. Cristescu, C. Dumitrescu, R. Rădoi, G. Vrânceanu, C-tin Chirita, "Capturing and storage the energy recovered from hydraulic drive systems of mobile machinery and equipment", In: CD Proc. of 22nd International Conference on Hydraulics and Pneumatics HERVEX – 2016, November 9-11, 2016, Baile Govora, Romania, pp. 105-114, ISSN 1454 – 8003.