

Comparative analysis of performance indicators for photovoltaic panels and cogeneration generators

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Abstract. The energy perspective of the near future relies on the use of natural gas and renewable energy resources and for the distant future hydrogen energy is shaping up. In order to provide the correct information necessary for a high-performance option in the case of the availability of photovoltaic panels or cogeneration generators, this paper addresses energy performance and environmental impact in the case of the two systems based on different primary energy resources. The comparison method is based on the calculation of energy balance elements and the results obtained are used to calculate quantitative and qualitative performance indicators. Based on the obtained indicators, the level of response to the requirements of a sustainable energy is verified, for the analyzed variants.

1. Introduction

Solar energy, one of the renewable energy resources, is in the attention of electricity users, due to the following advantages: major quantitative availability, low impact on the environment, throughout the life cycle, adequate facilities and technologies for recovery, operational safety and low risk of accident. Photovoltaic systems are flexible offering a major advantage for decentralized energy production. While harnessing photovoltaic solar energy is a significant component of the energy transition and environmentally friendly, help reduce consumption of fossil fuels that emit greenhouse gases and it alleviate bad climate change.

In terms of energy based on conventional sources, cogeneration is a variant of superior recovery of conventional fuel. In a cogeneration system, a heat engine (steam / gas turbine, internal combustion engine) drives an electric generator that supplies electricity and the heat dissipated (steam, flue gases and / or coolants) is recovered and produced technological steam or heating agents. The use of cogeneration / trigeneration in the energy

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industry and in industrial objectives equipped with energy generators, is a variant of operationalization of the notion of sustainable energy, responding to the three postulates of sustainability - ecological responsibility, economic efficiency, social solidarity. Cogeneration has many advantages in different fields such as environment (natural capital), economy (built capital), social and society (human and social capital). Cogeneration is part of the concept of circular economy, representing an example of responsible production and consumption.

2. Energy performance of a photovoltaic panel system

The forms of renewable energy, partially capitalized in the current stage, are grouped in two categories:

- flows;
- funds.

The category of flows includes: solar irradiation on the Earth's surface, wind, water flows, waves and planetary energy (geothermal, tide).

Biomass is a form of gain re of energy and solar is and is taken as funds - reserves.

The capitalization efficiency of the different energy sources is presented in figure 1.

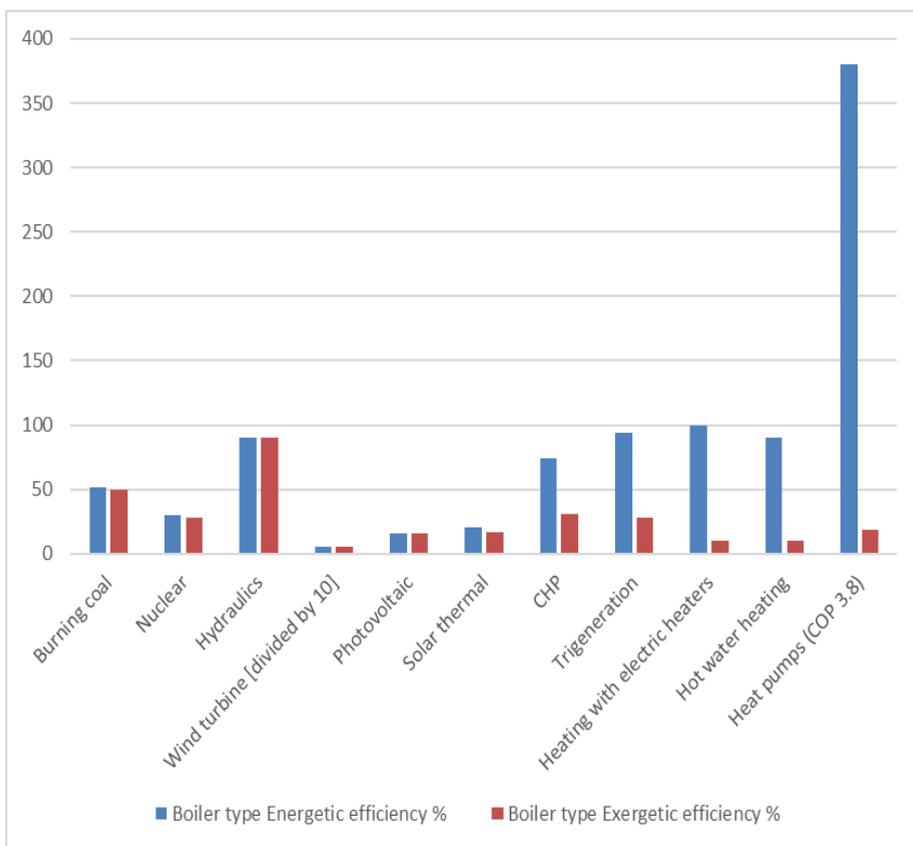


Fig.1. Graphic representation of the efficiency of capitalization of different energy sources [%]

The specific cost of the different energy resources is evaluated according to the data in figure 2.

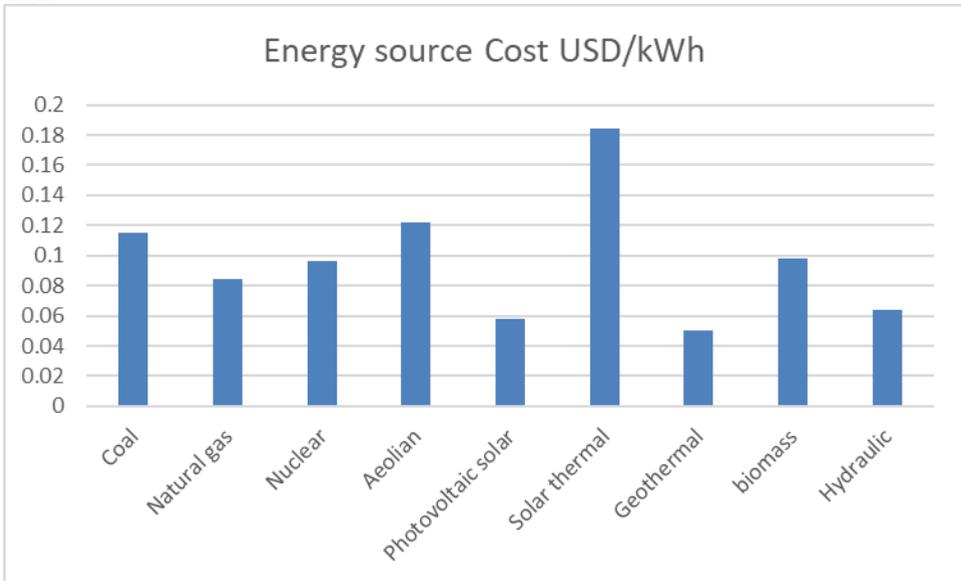


Fig.2. The graphical representation of cost IU specific energy different

A common indicator for evaluating energy sources is the rate of return on energy (EROI). The energy return rate is calculated as the ratio between the potential energy of an energy resource and the energy consumed to extract the respective energy resource.

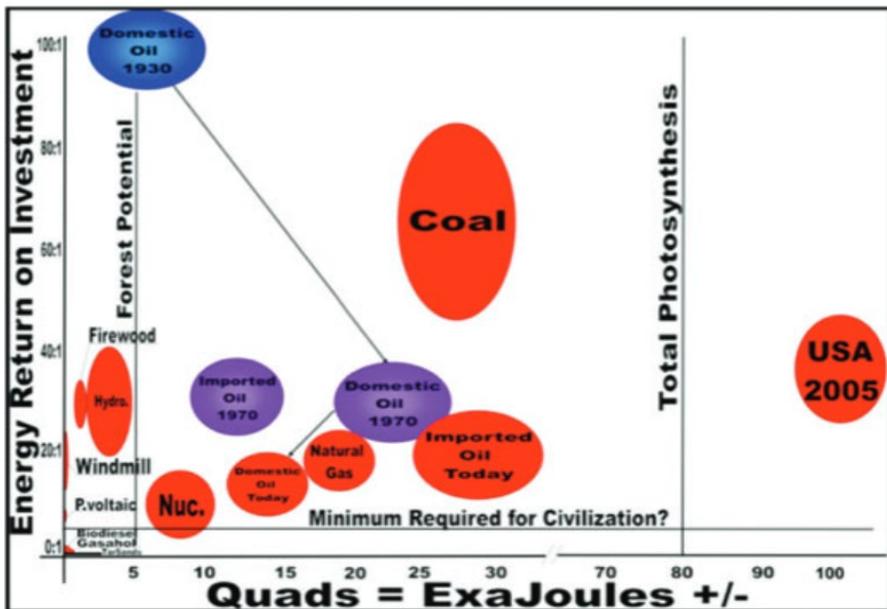


Fig.3. Energy return rate (EROI) for exploitable energy resources (Source: Murphy & Hall 2010)

In order to perform the comparative analysis proposed in the title of the paper, we chose the data from the project of a photovoltaic park, for which we prepared an energy balance. Based on the primary data from the chapters with technical specifications of the project, using the methodology from the works [4], [5], we calculated the elements of the real hourly energy balance , presented in table 1.

Table 1. Summary table real energy balance schedule photovoltaic panel 255 kW

INPUT ENERGY			OUTPUT ENERGY		
Name	kWh	%	Name	kWh	%
Solar energy	16 27.00	10 0	Useful energy	140. 41	8. 63
			Total useful energy	140. 41	8. 63
			Losses due to photovoltaic effect	137 2	8 4.32
			Inverter losses	10.4 2	0. 64
			Losses depending on temperature (degree of ventilation)	31.2 5	1. 92
			Cable losses	4.17	0. 26
			Incline losses	45.8 3	2. 82
			Low radiation losses	18.7 5	1. 15
			Losses due to dust / snow deposits	4.17	0. 26
			Total energy lost	148 6.59	9 1.37
TOTAL	16 27.00	10 0	TOTAL	162 7.00	1 00

Based on the technical characteristics of the panel prospectus, the energy performance indicators are:

- theoretical efficiency - 15.67%
- real efficiency (calculated in the balance sheet) - 8.63%
- the surface occupied by the panels - 12650 sqm
- energy density on the surface - 0.158 kWh / sqm
- investment costs - 1250 Eu / kW
- energy return rate - 9.8 kWh produced / kWh consumed

3. Energy performance of a diesel engine cogeneration system

The principle of cogeneration. In a cogeneration system, a heat engine (steam / gas turbine, internal combustion engine) drives an electric generator that supplies electricity and the heat dissipated (steam, flue gases and / or coolants) is recovered and produced technological steam or heating agents.

The advantages of cogeneration. The use of cogeneration / trigeneration in the energy industry and in industrial objectives equipped with energy generators, is a variant of operationalization of the notion of sustainable energy, responding to the three postulates of sustainability - ecological responsibility, economic efficiency, social solidarity. Cogeneration has many advantages in different fields such as environment (natural capital), economy (built capital), social and society (human and social capital).

Energy balance for a cogeneration plant with diesel engine.

Since the photovoltaic panel system, chosen for the comparative analysis, has a power of 2 MW, we chose a group with cogeneration of the same power.

Table 2. Table summary balance actual energy zone group sets 2000 kWh_s

INPUT ENERGY			OUTPUT ENERGY		
Name	kWh	%	Name	kWh	%
Fuel gas energy	2752	100	Energia electrică utilă	1033	37.536
			Useful thermal energy	1345	48.874
			Total useful energy	2378	86.410
			Losses in the electric generator	37	1.344
			Losses by gases of combustion discharged	157	5.705
			Losses in water with potentially thermally reduced	104	3.779
			Loss by radiation in the generator	30.4	1.105
			Loss by radiation in the engine heat	45.6	1.657
			Total energy lost	374	13.590
TOTAL	2752	100	TOTAL	2752	100

Based on the technical characteristics of the generator set leaflet, the energy performance indicators are:

- real efficiency (calculated in the balance sheet) - 86.41 %
- the area occupied by the group - 2500 sqm
- energy density on the surface - 0.8 kWh / sqm
- investment costs - 800 Eu / kW
- energy return rate - 14 kWh produced / kWh consumed
- environmental footprint - CO₂ ton / MWh
- unit fuel cost - 0.37 l / m³.

4. Calculation of a synergistic performance indicator

In order to provide an indicator capable of synthetically expressing the energy, economic and ecological performances, we resorted to the aggregation of the specific performances of the photovoltaic system and of the specific performances afferent to the cogeneration system.

In order to establish a tie-breaking criterion, we resorted to a scoring system, through which we scored the positive effects on the interval 6 ÷ 10, and the negative ones on the interval 1 ÷ 5.

The aggregation of the effects is done with the help of the radar diagram (fig.4).
 The points awarded are centralized in table 3.

Table 3. Comparative value generator set – photovoltaic system

	efficiency	ecological footprint	fuel cost	specific investment	eroi	occupied area	energy density
generator set	8	5	5	7	8	9	10
photovoltaic system	4	10	10	6	4	4	3

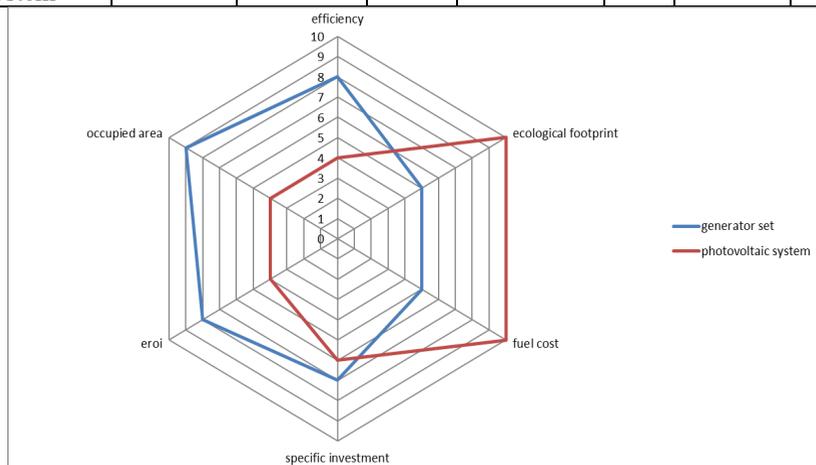


Fig. 4. Performance diagram for the cogeneration system and the photovoltaic system

Relating the surfaces related to the two systems to the total (ideal) surface, we obtain:

- aggregate system indicator with cogeneration $I_{SCG} = 0.473$;

- aggregate indicator photovoltaic system $I_{SPH} = 0.443$

From the point of view of the aggregate performance indicator, the two systems are almost equal. The photovoltaic system is more efficient for the ecological footprint and the cost of fuel. The cogeneration system is more efficient in the area of efficiency, energy return rate and occupied area.

5. Conclusions

The comparative analysis highlights the perspectives of the photovoltaic systems in the conditions of the environmental restrictions and of the continuous modernization of the equipment for transformation of solar energy.

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