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# OPTIMAL OPERATION OF A TRIGENERATION SYSTEM DESIGNED TO SUPPLY AN ELECTRICITY, HEATING AND COOLING CONSUMER

BY

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**Abstract.** Residential, commercial and industrial consumers generally need different forms of energy provided by separate production facilities. Until recently, these installations are, in most cases, analyzed and operated separately. Combining the production of different forms of energy can bring some benefits, which is an opportunity to improve the operation of the system. Therefore, some systems of distributed production with multiple energy carriers can be developed, intended to supply consumers with different types of energy, which operate optimized according to certain criteria such as energy efficiency, fuel cost, emissions, security, availability, etc. This paper aims to present the optimization of the operation of a distributed generation plant intended to supply a complex consumer with electricity, cooling and heating. This type of installation, which can be considered as an energy hub, is capable of simultaneously managing the generation and consumption of electricity supplied from or to the grid, centralized heating and/or hot water and air conditioning or refrigeration installations. The authors present the results of an optimization study for an energy hub with two input components (electricity and natural gas) and three output components (electricity, heating and cooling).

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**Keywords:** energy hubş distributed generationş power plantş renewable energy sources.

## 1. Introduction

Distributed generation (DG) of different forms of energy (electricity, heating, refrigeration, etc.) has grown significantly in recent years with the development of the energy market. Some technologies of distributed generation were imposed on the market due to an increased cost-efficiency ratio, while others penetrated the market as a result of the support offered by the state, as technologies of the future, being friendly to the environment. Therefore, the problem of developing distributed systems for the production of various forms of energy, which meet the energy requirements of consumers, arises, but at the same time, it is also pursued to optimize their functioning according to different criteria such as energy efficiency, cost, emissions, security, availability, as well as other parameters (Geidl *et al*., 2007).

Depending on the energy needs of the consumers, the natural resources in the area where they are started, as well as the prices of the primary energies available in that area, various distributed generation solutions (schemes) can be designed (Hopulele *et al*., 2016). Also, different methods can be used to optimize the functioning of the component elements of the systems of distributed generation of the different forms of energy so that the cost generated by the primary energies consumed to satisfy the energy need to the consumer is minimal. One of the optimization methods is the use of genetic algorithms, described in (Hopulele *et al*., 2019). Lately, there have been more and more specialized software designed to optimize the energy supply of consumers.

## 2. Installation Description

We consider ensuring the supply of energy in a residential area consisting of 35 houses, a kindergarten, a school, a grocery store and a restaurant, which has daily electricity, cooling and heating consumption for certain characteristic months, such as shown in Fig. 1. The electric load profile is typical for residential consumers, with two peak periods and two valley periods, the electricity consumption is approximately constant during a calendar year with a slight increase during the winter months and somewhat lower in the summer. Heat demand is high in the winter months as all the areas in that neighbourhood have to be heated and much lower in the summer months, as the heat is being used only for domestic hot water. Cold consumption is low in cold months, as it is only necessary for a cold room of the grocery store and high in summer to keep a cool environment in the residential areas.

This energy requirement can be covered by a trigeneration system that can be seen as an energy hub (Geidl *et al*., 2007), which has primary energy sources such as electricity and fuel (natural gas) at the entry ports, and the energies required by the consumer: electric, refrigeration and thermal at the output ports (Fig. 2). Electricity can be produced by a cogeneration plant, with renewable energy sources - RES (photovoltaic panels and wind turbines), or can be taken directly from the local distribution network, heat can only be produced by burning the fuel in the CHP plant, and the cold can be produced in two ways: from electric power with a compression chiller or thermal energy with an absorption chiller.

In order to obtain an optimal solution for the operation of this installation so as to cover the consumer's energy needs with minimum costs, one of the most popular specialized software for optimization in the field of renewable energy, namely HOMER PRO (The Hybrid Optimization Model for Electricity Renewable) was used. HOMER PRO is a complex application that models and simulates various distributed production facilities, initially developed by the National Renewable Energy Laboratory and improved by HOMER ENERGY (HOMER).

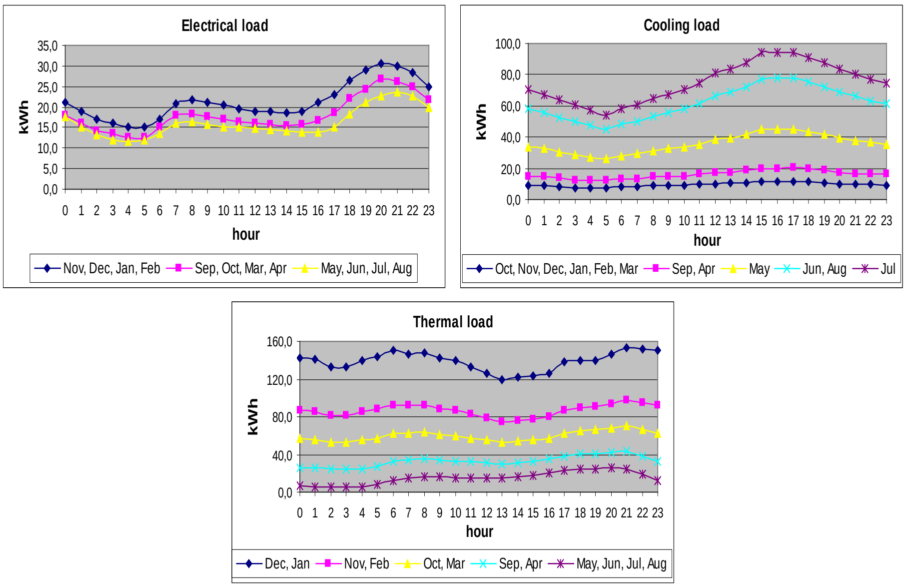



Fig. 1 − Power, cooling and heating demand for consumer.

This software has a library containing different distributed production equipment whose characteristics can be defined, which can be interconnected by means of conversion plants of different forms of energy, in order to find an optimum solution to supply consumers (Fig. 2). Depending on the needs of consumers, HOMER provides a solution for optimum economic operation of the considered equipment.

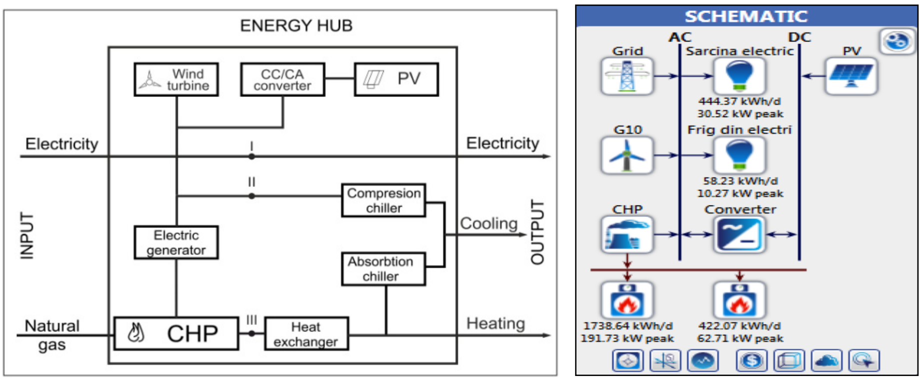



Fig. 2 − Energy hub corresponding the distributed production system implemented in HOMER.

Since the HOMER database does not contain heat exchangers or chillers, so this software does not model the cold component, the cold produced from electricity was considered as an electrical charge and thermal heat produced as a heat load. The consumer loads taken into account in this case are those determined in the MATLAB program using the genetic algorithms in points I, II and III of Fig. 2. These consumer loads, the mathematical model used to determine them, as well as the energy balance of the installation are presented in detail in (Hopulele *et al.*, 2019).

An analysis period of 25 years was considered, the investment of the distributed production system being considered for 4000 lei / kW installed, investment that includes the costs with the CHP installation (including the generator), the related installations and the network connection costs. The maintenance and repairs costs taken into account are 0.01 lei / hour for each installed kW of the installation, which means 87.6 lei / kW installed annually.

The installation of 0 ÷ 5 10 kW G10 turbines, which produce electricity directly at alternating current, with an investment and replacement cost of 35,000 lei each, was considered, the operating cost of a turbine being 400 lei annually, the curve of power characteristic of such a turbine can be seen in Fig. 3.

The power range of the installed photovoltaic panels was considered to be from 10 to 10 kW from 0 to 50 KW, their investment being 6600 lei / kw installed and the annual maintenance and repair costs of 50 lei / kW installed. Due to the fact that they generate electricity in direct current, an inverter is needed, whose power range is considered the same as that of the solar panels, its investment according to its power is shown in Table 1, the maintenance costs are zero.

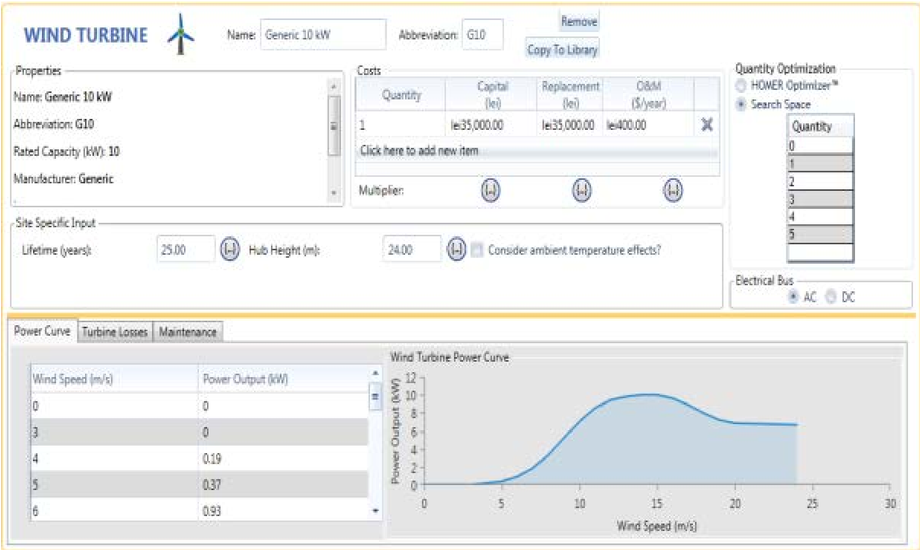



Fig. 3 − Wind turbine power curve.

**Table 1**
*Capital for DC / AC Converter*

| P [kW] | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|
| Capital [lei] | 8570 | 13830 | 19090 | 24350 | 29610 |

The lifetime of all the equipment in the plant is considered to be 219,000 hours, that is, exactly 25 years. If this would be shorter than the analysis time, its replacement costs should be taken into account, and if it were higher, at the end of the analysis period there would still be a certain material value in the plant that was not used and which can to be used later until the end of the service life of the installation (salvage).

The price of natural gas was considered 0.1270 lei / kWh, the price of electricity exchanged with the grid being 0.5058 lei / kWh for purchase and 0.3035 lei / kWh for sale.

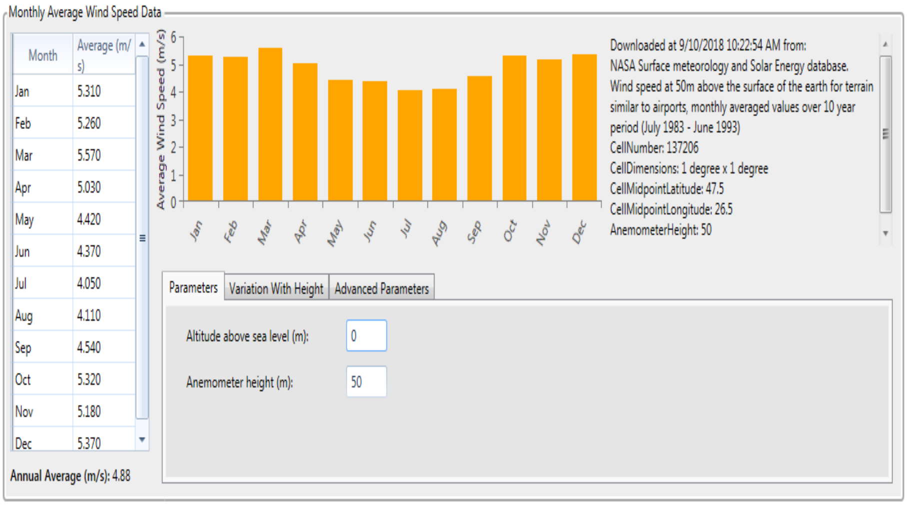
In order to see how it influences the use of renewable energy sources as well as their geographical location, how the distributed generation system works, as well as the total costs of its implementation and operation, simulations were performed in three distinct situations:

– The distributed production system works without RES;

– The distributed production system works with RES, which is located in the NE area of Romania, near Suceava;

– The distributed production system works with RES, which is located in the SE area of Romania, in Dobrogea.

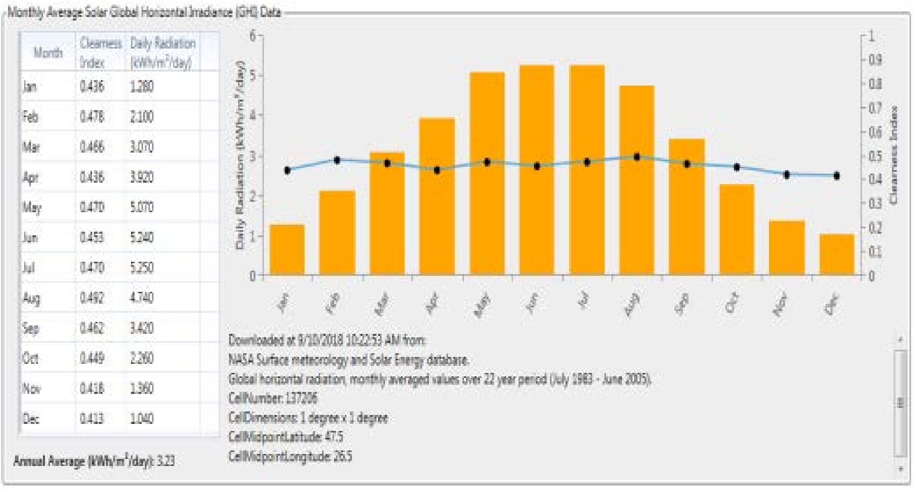
These geographical areas were selected because there are significant differences between them regarding the weather conditions. Statistical data on wind speed and solar irradiation were collected for each of the two geographic areas, the data source being the NASA Surface meteorology and Solar Energy database. The monthly average of the wind speed for the two geographical areas, analyzed over a period of 10 years, is shown in Fig. 4, and the monthly average of the irradiance, analyzed for a period of 22 years, can be seen in Fig. 5.



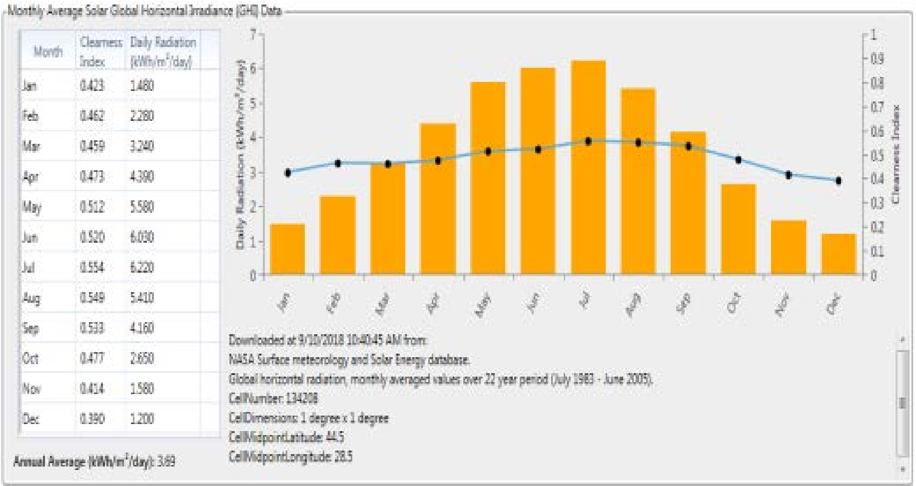

*a*) Near Suceava


*b*) In Dobrogea

Fig. 4 – Monthly average wind speed.




*a*) Near Suceava




*b*) In Dobrogea

Fig. 5 − Monthly average solar global horizontal irradiance.

## 3. Simulation Results

When running the HOMER PRO optimization software in case no renewable energy sources are used, there is a total cost for the implementation and operation of such a system for a 25-year period of 3.75 million lei (NPC - Net Present Cost, Fig. 6*a*), composed of 280,000 lei investment costs in the cogeneration plant - Capital, -345,829 operating and monitoring costs - O&M and 3,816,597 lei fuel costs - Fuel (Fig. 7*a*). The operating and monitoring costs include both the maintenance and repair costs of the CHP installation (153,300 lei) and the costs generated by the exchange of electricity with the network (-499,129 lei).

For the case when renewable energy sources are used, these being located on the outskirts of Suceava city, when running the optimization software it is found that the optimal solution contains besides the cogeneration plant only wind turbines. This can be seen by following the system architecture (Fig. 6*b*). Thus, the total investment and operating costs in this situation reach 3.68 million lei for the 25 years of operation, being composed of 455,000 lei investment costs in the cogeneration plant and wind turbines, -588,027 lei operating and monitoring costs and 3,816,597 lei fuel costs (Fig. 7*b*). If the photovoltaic panels were also introduced the total costs would increase to 3.69 million lei (Fig. 6*b*), due to the fact that the prices of the panels and converters are still high and the solar irradiation in this area does not have an average very high within a year.

The optimal solution for the location of the distributed system for the production of renewable energy in Dobrogea, being a much more meteorologically favorable area for RES contains, in addition to the CHP, photovoltaic panels and wind turbines (Fig. 6*c*). The total costs of implementing and operating the system for 25 years are reduced to 3.35 million lei, composed of 809,350 lei investment costs, -1,278,711 lei operating and monitoring costs and 3,816,597 lei fuel costs, these costs by components of the installations and by types of costs are shown in Fig. 7*c*.

| Architecture | Cost | | | | System | | | | CHP | Grid | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CHP (kW) | NPC (lei) | Operating cost (lei/yr) | Fuel cost (lei/yr) | O&M (lei/yr) | Elec Prod (kWh/yr) | Therm Prod (kWh/yr) | Elec Cons (kWh/yr) | Therm Cons (kWh/yr) | Fuel ($m^3$) | Energy Purchased (kWh) | Energy Sold (kWh) |
| 70.0 | lei3.75M | lei138,831 | lei152,664 | -lei13,833 | 251,725 | 788,657 | 251,725 | 788,657 | 116,094 | 1,495 | 68,274 |

*a*) The distributed generation system works without RES

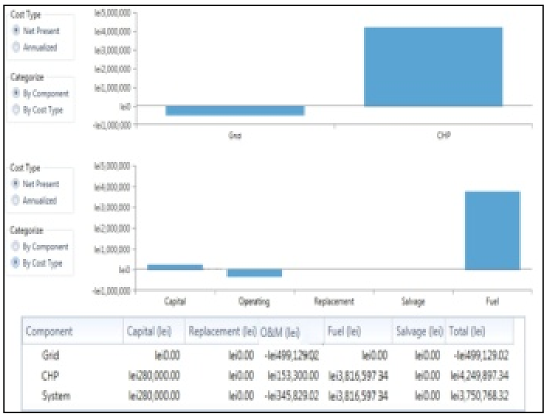
| Architecture | | | | Cost | | | | System | | | | CHP | PV | | G10 | | | Converter | | Grid | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PV (kW) | G10 | CHP (kW) | Converter (kW) | NPC (lei) | Operating cost (lei/yr) | Fuel cost (lei/yr) | O&M (lei/yr) | Elec Prod (kWh/yr) | Therm Prod (kWh/yr) | Elec Cons (kWh/yr) | Therm Cons (kWh/yr) | Fuel ($m^3$) | Capital Cost (lei) | Production (kWh/yr) | Capital Cost (lei) | Production (kWh/yr) | O&M Cost (lei) | Rectifier Mean Output (kW) | Inverter Mean Output (kW) | Energy Purchased (kWh) | Energy Sold (kWh) |
| | 5 | 70.0 | | lei3.68M | lei129,104 | lei152,664 | -lei23,522 | 289,348 | 788,657 | 289,348 | 788,657 | 116,094 | | | 175,000 | 38,157 | 2,000 | | | 962 | 105,898 |
| 10.0 | 5 | 70.0 | 10.0 | lei3.69M | lei126,350 | lei152,664 | -lei26,276 | 300,598 | 788,657 | 300,034 | 788,657 | 116,094 | 66,000 | 11,271 | 175,000 | 38,157 | 2,000 | 0 | 1.22 | 941 | 116,584 |
| | | 70.0 | | lei3.75M | lei138,793 | lei152,664 | -lei13,833 | 251,725 | 788,657 | 251,725 | 788,657 | 116,094 | | | | | | | | 1,495 | 68,274 |
| 10.0 | | 70.0 | 10.0 | lei3.76M | lei136,028 | lei152,664 | -lei16,598 | 262,923 | 788,657 | 262,360 | 788,657 | 116,094 | 66,000 | 11,271 | | | | 0 | 1.22 | 1,423 | 78,910 |

*b*) The distributed generation system works with RES near Suceava

| Architecture | | | | Cost | | | | System | | | | CHP | PV | | G10 | | | Converter | | Grid | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PV (kW) | G10 | CHP (kW) | Converter (kW) | NPC (lei) | Operating cost (lei/yr) | Fuel cost (lei/yr) | O&M (lei/yr) | Elec Prod (kWh/yr) | Therm Prod (kWh/yr) | Elec Cons (kWh/yr) | Therm Cons (kWh/yr) | Fuel ($m^3$) | Capital Cost (lei) | Production (kWh/yr) | Capital Cost (lei) | Production (kWh/yr) | O&M Cost (lei) | Rectifier Mean Output (kW) | Inverter Mean Output (kW) | Energy Purchased (kWh) | Energy Sold (kWh) |
| 50.0 | 5 | 70.0 | 40.0 | lei3.35M | lei101,515 | lei152,664 | -lei51,148 | 391,530 | 788,657 | 388,250 | 788,657 | 116,094 | 330,000 | 61,913 | 175,000 | 78,643 | 2,000 | 0 | 6.69 | 744 | 204,800 |
| | 5 | 70.0 | | lei3.38M | lei116,814 | lei152,664 | -lei35,850 | 329,633 | 788,657 | 329,633 | 788,657 | 116,094 | | | 175,000 | 78,643 | 2,000 | | | 761 | 146,183 |
| 50.0 | | 70.0 | 40.0 | lei3.72M | lei123,521 | lei152,664 | -lei29,143 | 313,565 | 788,657 | 310,285 | 788,657 | 116,094 | 330,000 | 61,913 | | | | 0 | 6.69 | 1,422 | 126,835 |
| | | 70.0 | | lei3.75M | lei138,831 | lei152,664 | -lei13,833 | 251,725 | 788,657 | 251,725 | 788,657 | 116,094 | | | | | | | | 1,495 | 68,274 |

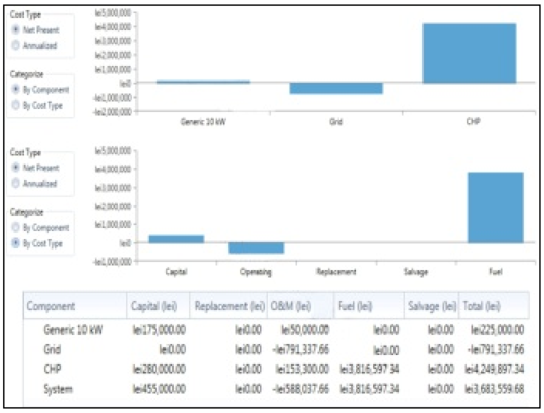
*c*) The distributed generation system works with RES in Dobrogea

Fig. 6 − Optimization results.




| Component | Capital (lei) | Replacement (lei) | O&M (lei) | Fuel (lei) | Salvage (lei) | Total (lei) |
|---|---|---|---|---|---|---|
| Grid | lei0.00 | lei0.00 | -lei499,129.02 | lei0.00 | lei0.00 | -lei499,129.02 |
| CHP | lei280,000.00 | lei0.00 | lei153,300.00 | lei3,816,597.34 | lei0.00 | lei4,249,897.34 |
| System | lei280,000.00 | lei0.00 | -lei345,829.02 | lei3,816,597.34 | lei0.00 | lei3,750,768.32 |

a) DG without RES




| Component | Capital (lei) | Replacement (lei) | O&M (lei) | Fuel (lei) | Salvage (lei) | Total (lei) |
|---|---|---|---|---|---|---|
| Generic 10 kW | lei175,000.00 | lei0.00 | lei50,000.00 | lei0.00 | lei0.00 | lei225,000.00 |
| Grid | lei0.00 | lei0.00 | -lei791,337.66 | lei0.00 | lei0.00 | -lei791,337.66 |
| CHP | lei280,000.00 | lei0.00 | lei153,300.00 | lei3,816,597.34 | lei0.00 | lei4,249,897.34 |
| System | lei455,000.00 | lei0.00 | -lei588,037.66 | lei3,816,597.34 | lei0.00 | lei3,683,559.68 |

b) DG with RES near Suceava


| Component | Capital (lei) | Replacement (lei) | O&M (lei) | Fuel (lei) | Salvage (lei) | Total (lei) |
|---|---|---|---|---|---|---|
| Generic 10 kW | lei175,000.00 | lei0.00 | lei50,000.00 | lei0.00 | lei0.00 | lei225,000.00 |
| Generic flat plate PV | lei330,000.00 | lei0.00 | lei62,500.00 | lei0.00 | lei0.00 | lei392,500.00 |
| Grid | lei0.00 | lei0.00 | -lei1,544,511.93 | lei0.00 | lei0.00 | -lei1,544,511.93 |
| CHP | lei280,000.00 | lei0.00 | lei153,300.00 | lei3,816,597.34 | lei0.00 | lei4,249,897.34 |
| System Converter | lei24,350.00 | lei0.00 | lei0.00 | lei0.00 | lei0.00 | lei24,350.00 |
| System | lei809,350.00 | lei0.00 | -lei1,278,711.93 | lei3,816,597.34 | lei0.00 | lei3,347,235.41 |

c) DG with RES in Dobrogea

Fig. 7 – Total costs by components and types of costs.

From these data, it appears that, regardless of whether or not renewable energy sources are used and regardless of where they are located, to cover the energy needs of the consumer the fuel costs remain unchanged, so fuel consumption is the same (Fig. 8), which means that the operation of the CHP system is the same in all 3 situations (Fig. 9). This is due to the fact that the thermal energy required by the consumer is completely covered only by the CHP plant and its operation mode is faithfully aiming to cover this need (Fig. 10*a*).

For the optimization solution without RES, the electricity generated by the CHP installation is 250,230 kWh / year and covers 99.4% of the electricity demand from the consumer (Fig. 10*b*), the remaining 0.6% being taken over from the grid at certain times of April, May and September, when the thermal energy requirement is low and electricity production does not cover consumption. Of the total electricity produced, 72.9% is consumed locally (183,450 kWh / year), the rest of 27.1% is delivered to the grid (68,274 kWh / year), generally in the colder months when the heat requirement is high and the production of electricity is higher than consumption. The electricity exchange with the grid is illustrated in Fig. 11*a*.

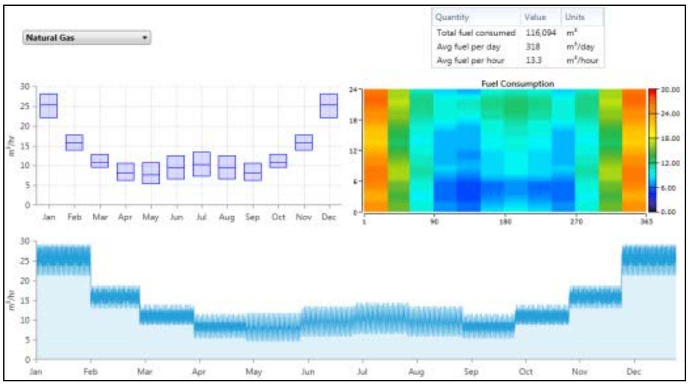



Fig. 8 − Natural gas consumption.

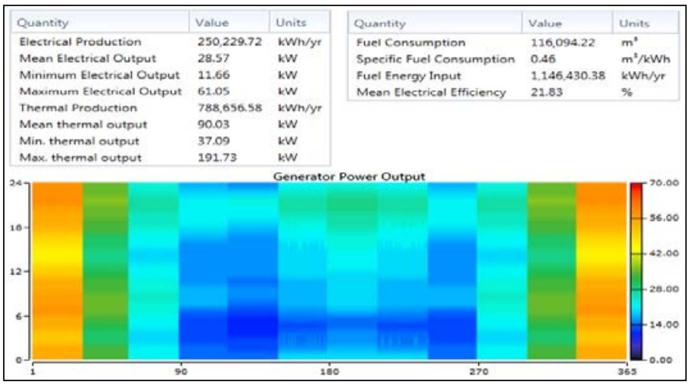
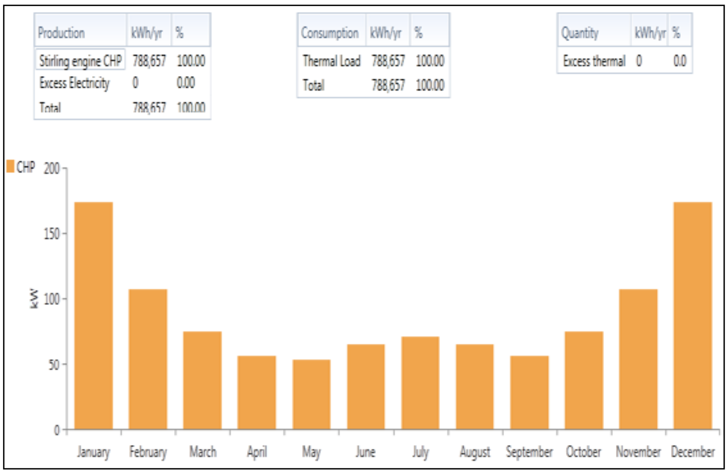


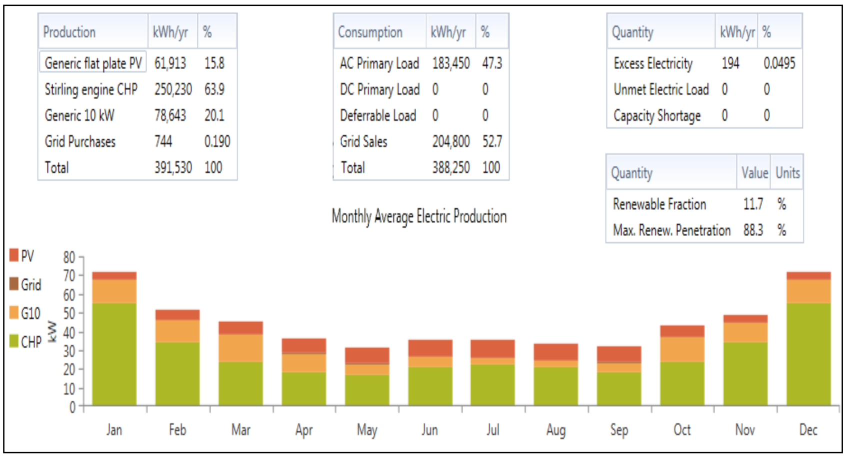

Fig. 9 − CHP activity.




*a*) Heat generation


*b*) Electricity generation (DG without RES)


*c*) Electricity generation (DG with RES near Suceava)



| Production | kWh/yr | % |
|---|---|---|
| Generic flat plate PV | 61,913 | 15.8 |
| Stirling engine CHP | 250,230 | 63.9 |
| Generic 10 kW | 78,643 | 20.1 |
| Grid Purchases | 744 | 0.190 |
| Total | 391,530 | 100 |

| Consumption | kWh/yr | % |
|---|---|---|
| AC Primary Load | 183,450 | 47.3 |
| DC Primary Load | 0 | 0 |
| Deferrable Load | 0 | 0 |
| Grid Sales | 204,800 | 52.7 |
| Total | 388,250 | 100 |

| Quantity | kWh/yr | % |
|---|---|---|
| Excess Electricity | 194 | 0.0495 |
| Unmet Electric Load | 0 | 0 |
| Capacity Shortage | 0 | 0 |

| Quantity | Value | Units |
|---|---|---|
| Renewable Fraction | 11.7 | % |
| Max. Renew. Penetration | 88.3 | % |



*d*) Electricity generation (DG with RES in Dobrogea)

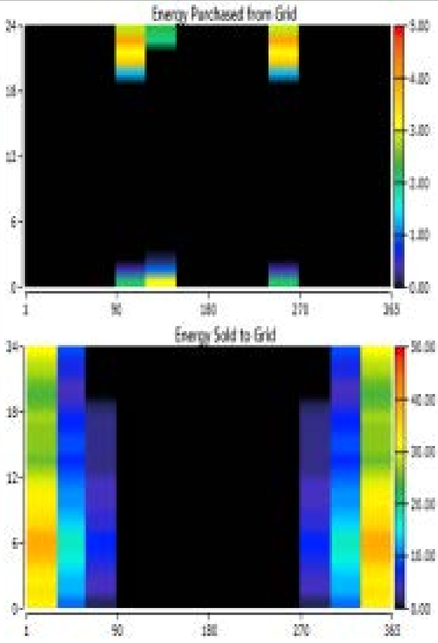
Fig. 10 − Monthly average of electricity and heat production.

For the distributed generation solution located near Suceava which includes RES, the electricity produced by the CHP plant is the same, but in addition to this, electricity is produced by the wind turbines (Fig. 10*c*). It is noted that the supply of electricity from the grid over a year has decreased from 1495 kWh / year (~ 0.6%) to 962 kWh / year (0.332%) due to the fact that some of this contribution is supplemented by electricity produced by wind turbines. This supply of electricity from the grid is not fully covered by wind turbines because there are moments of calm. This time the electricity transferred to the grid is 105,898 kWh / year, representing about 36.5% of the total electricity produced, which brings a financial benefit of 31,653 lei annually, the electricity exchange with the network being presented in Fig. 11*b*.

If the production system distributed with RES is located in Dobrogea, in addition to the electricity generated by the CHP plant (same as in the previous cases) and the wind turbines (double compared to the one produced in Suceava with the same number of turbines) the energy produced by the photovoltaic panels also appears (Fig. 10*d*). It reduces the amount of electricity taken from the grid to 744 kWh / year (approx. 0.19%), but it does not reach zero, because this energy is taken over at night, when the photovoltaic panels do not produce electricity. The electricity delivered to the grid is much higher this time, reaching the value of 204,800 kWh / year, which represents about 52.7% of the total electricity produced and brings a profit of 61,780 lei annually (Fig. 11*c*).

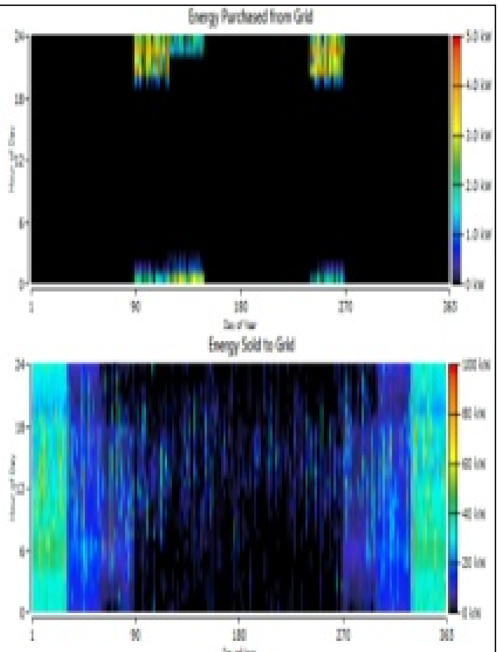
The operation mode of the wind turbines for the two geographical areas where they are located can be seen in Figs. 12*a*,*b*, and the operation of the photovoltaic panels and the DC / AC converter that are located only in Dobrogea is illustrated in Figs. 12*c*,*d*.

| Month | Energy Purchased (kWh) | Energy Sold (kWh) | Net Energy Purchased (kWh) | Energy Charge (lei) |
|---|---|---|---|---|
| January | 0 | 23,715 | -23,715 | -lei7,197.59 |
| February | 0 | 7,367 | -7,367 | -lei2,235.86 |
| March | 0 | 2,779 | -2,779 | -lei843.43 |
| April | 575 | 0 | 575 | lei290.96 |
| May | 303 | 1 | 302 | lei152.98 |
| June | 15 | 6 | 9 | lei5.86 |
| July | 10 | 12 | -2 | lei1.56 |
| August | 16 | 6 | 9 | lei6.05 |
| September | 575 | 0 | 575 | lei290.96 |
| October | 0 | 2,779 | -2,779 | -lei843.41 |
| November | 0 | 7,893 | -7,893 | -lei2,395.58 |
| December | 0 | 23,716 | -23,716 | -lei7,197.68 |
| Annual | 1,495 | 68,274 | -66,779 | -lei19,965.16 |

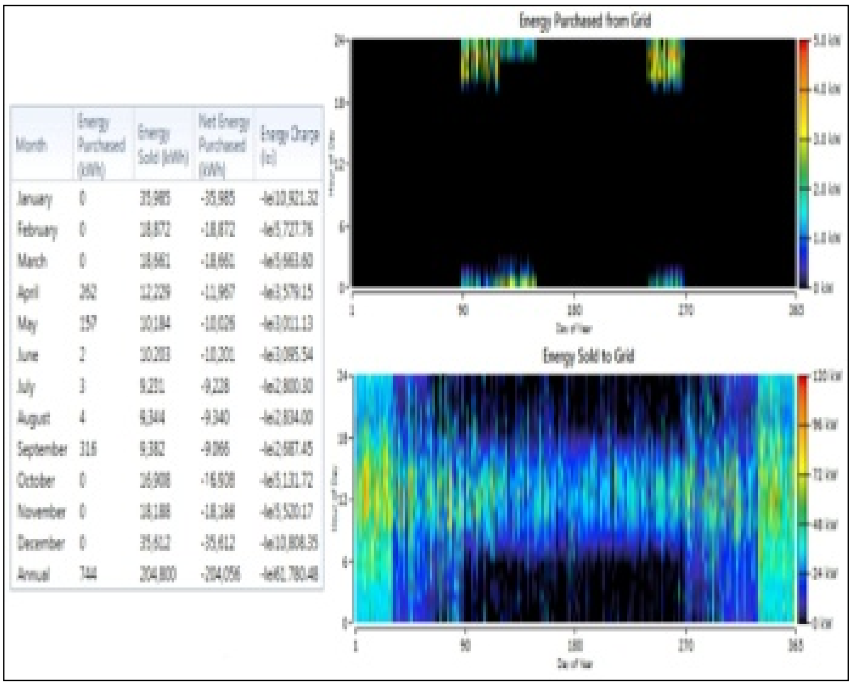



*a*) DG without RES

| Month | Energy Purchased (kWh) | Energy Sold (kWh) | Net Energy Purchased (kWh) | Energy Charge (lei) |
|---|---|---|---|---|
| January | 0 | 27,941 | -27,941 | -lei8,479.95 |
| February | 0 | 11,053 | -11,053 | -lei3,354.46 |
| March | 0 | 7,722 | -7,722 | -lei2,343.50 |
| April | 364 | 3,170 | -2,806 | -lei777.82 |
| May | 201 | 2,042 | -1,841 | -lei518.09 |
| June | 7 | 1,988 | -1,982 | -lei600.03 |
| July | 5 | 1,488 | -1,483 | -lei452.00 |
| August | 8 | 1,604 | -1,596 | -lei482.83 |
| September | 377 | 2,116 | -1,740 | -lei451.81 |
| October | 0 | 7,018 | -7,018 | -lei2,129.86 |
| November | 0 | 11,643 | -11,613 | -lei3,533.60 |
| December | 0 | 28,104 | -28,104 | -lei8,529.55 |
| Annual | 962 | 105,898 | -104,936 | -lei31,653.51 |




*b*) DG with RES near Suceava

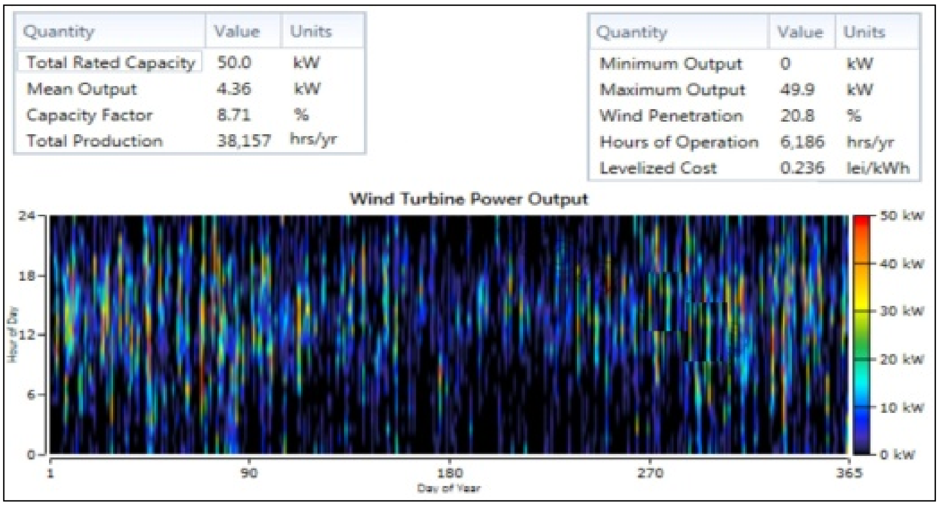


| Month | Energy Purchased (kWh) | Energy Sold (kWh) | Net Energy Purchased (kWh) | Energy Charge (lei) |
|---|---|---|---|---|
| January | 0 | 35,985 | -35,985 | -lei10,921.32 |
| February | 0 | 18,872 | -18,872 | -lei5,727.76 |
| March | 0 | 18,661 | -18,661 | -lei5,663.60 |
| April | 262 | 12,229 | -11,967 | -lei3,579.15 |
| May | 157 | 10,184 | -10,026 | -lei3,011.13 |
| June | 2 | 10,203 | -10,201 | -lei3,095.54 |
| July | 3 | 9,231 | -9,228 | -lei2,800.30 |
| August | 4 | 9,344 | -9,340 | -lei2,834.00 |
| September | 316 | 9,382 | -9,066 | -lei2,687.45 |
| October | 0 | 16,908 | -16,908 | -lei5,131.72 |
| November | 0 | 18,188 | -18,188 | -lei5,520.17 |
| December | 0 | 35,612 | -35,612 | -lei10,808.35 |
| Annual | 744 | 204,800 | -204,056 | -lei61,780.48 |



*c*) DG with RES in Dobrogea

Fig. 11 − Energy exchange with the grid.

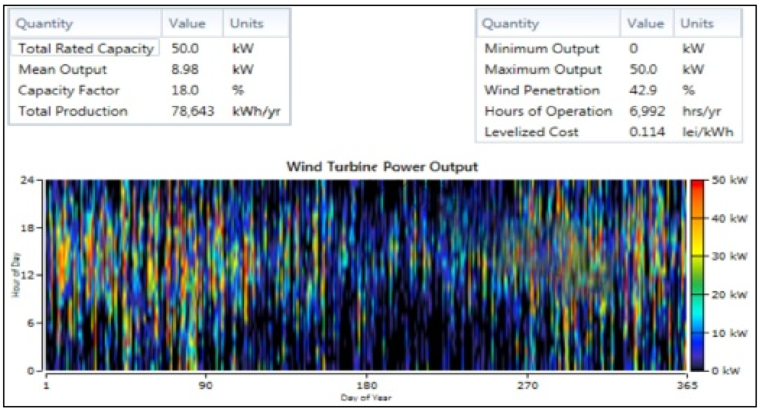


| Quantity | Value | Units |
|---|---|---|
| Total Rated Capacity | 50.0 | kW |
| Mean Output | 4.36 | kW |
| Capacity Factor | 8.71 | % |
| Total Production | 38,157 | hrs/yr |

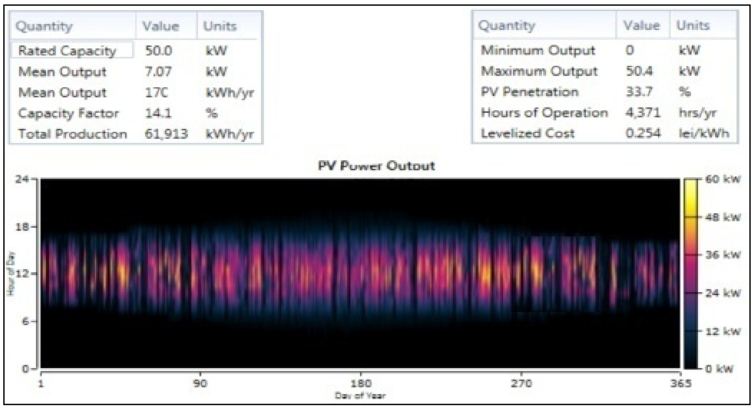
| Quantity | Value | Units |
|---|---|---|
| Minimum Output | 0 | kW |
| Maximum Output | 49.9 | kW |
| Wind Penetration | 20.8 | % |
| Hours of Operation | 6,186 | hrs/yr |
| Levelized Cost | 0.236 | lei/kWh |



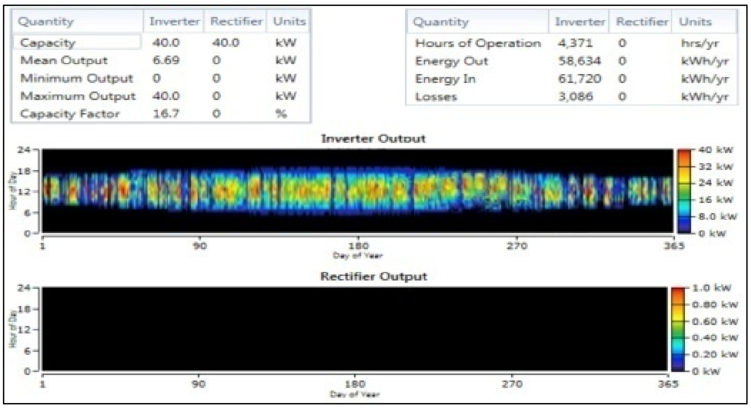
*a*) Wind turbine activity (near Suceava)




*b*) Wind turbine activity (in Dobrogea)




*c*) PV activity




*d*) Converter activity

Fig. 12 − RES activity.

## 3. Conclusions

Because the HOMER software does not model the cold component, the refrigerant load to the consumer was considered as an electrical load (for the cold produced by electricity) and a thermal load (for the cold produced by heat) these tasks were obtained by the genetic algorithms method and subsequently introduced as parameters by entering the HOMER software. Regardless of whether or not renewable energy sources are used and regardless of their geographical location, the CHP works in a similar way, due to the fact that there is no other heat source to cover the thermal needs of the consumer, the entire thermal load being produced by the CHP installation, its operation mode following the coverage of this thermal load.

With the use of renewable energy sources, a different operation is observed depending on the weather conditions in the geographical area in which they are located. In the area with less favourable weather conditions for the RES location (near Suceava), if 5 wind turbines of 10 kW each are fitted, a financial benefit of approximately 67,200 lei is obtained for a period of 25 years of operation of the distributed generation, compared to the case when RES is not used. In the Dobrogea area, if the weather conditions are more favourable to the location of the renewable energy sources, with the addition in the distributed production system of 5 wind turbines of 10 kW each and of photovoltaic panels of 50 kW, a more consistent financial benefit is obtained, about 403,500 lei for 25 years.

These financial benefits are due to the supply of electricity produced by renewable energy sources to the grid. Very little of the electricity produced by RES is consumed locally, by the considered consumer, this being done only between certain hours of April, May and September, when the thermal energy requirement is reduced and the electricity production of the CHP plant does not cover all consumption. Although RES is used, during this period of time there are certain time intervals when it is necessary and a supply of electricity from the grid, given that photovoltaic panels do not produce energy at night and the wind turbines do not generate moments of calm. This can be eliminated by the use of batteries, but the investment in such equipment is not fully justified, due to the fact that the electricity supply from the grid is only observed for short periods of time and for a reduced number of days during a year.

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*** HOMER Softwware: https://www.homerenergy.com/

## OPTIMIZAREA FUNCȚIONĂRII UNUI SISTEM DE TRIGENERARE DESTINAT ALIMENTĂRII UNUI CONSUMATOR DE ELECTRICITATE, FRIG ȘI CĂLDURĂ

(Rezumat)

În general, consumatorii rezidențiali, comerciali și industriali necesită diferite forme de energie furnizate de instalații de producere diferite. Până de curând, de cele mai multe ori, aceste instalații au fost analizate și operate separat. Combinarea producției diferitelor forme de energie poate aduce unele beneficii, ceea ce reprezintă o oportunitate de a îmbunătăți funcționarea sistemului. Prin urmare, pot fi dezvoltate unele sisteme de producere distribuită cu purtători multipli de energie, destinate să alimenteze consumatorii cu diferite forme de energie și care să funcționeze în mod optimizat conform anumitor criterii precum eficiența energetică, costul combustibilului, emisiile, securitatea, disponibilitatea etc. Această lucrare își propune să prezinte optimizarea funcționării unei instalații de generare distribuită destinată alimentării unui consumator complex cu energie electrică, frig și căldură, instalație care poate fi privită ca un hub de energie. Autorii prezintă rezultatele unui studiu de optimizare a funcționării unui astfel de hub de energie cu două porturi de intrare (electricitate și gaze naturale) și trei porturi de ieșire (electricitate, căldură și frig).