Combine Desalination - Cooling Plant in Nisyros Island Utilizing Geothermal Energy

CHRISTOPHER J. KORONEOS[1], APOSTOLOS L. POLYZAKIS[2], DIMITRIOS C. ROVAS[1]
[1]Laboratory of Heat Transfer and Environmental Engineering
Aristotle University of Thessaloniki
Box 483, 54124, Thessaloniki
GREECE

[2]West Macedonia District
ZEP 50100, Kozani
GREECE

Abstract: - The geothermal energy that is stored in the earth is so vast that could supply all the energy needed by humanity. The difficulty in tapping this energy lies in its diffusivity. The geothermal energy in regions close to volcanoes is close to the surface and easy to use economically. The main objective of this work is to utilize the existing geothermal potential of the Greek island of Nisyros located in the south-eastern part of the Aegean Sea for desalination of seawater. The exploitation of the geothermal brine will be done in a way that the cooling load of the island, in the summer months, will be completely covered from the geothermal energy. The technologies for the exploitation of geothermal energy are the Multi Flash Desalination (MFD) and the Single effect absorption chiller. The exploitation of the geothermal hot water sources located in the island combined with an effective desalination technology can eliminate energy use from hydrocarbons, minimize the environmental impact and reduce dramatically the cost of fresh water. This work is to determine and demonstrate the feasibility of a combine geothermal-driven desalination - cooling plant to provide high quality potable water in sufficient quantity at affordable cost, while protecting the fragile island environment.

Key-Words: - Clean Energy; Multi Flash Desalination; Geothermal Energy; Space Cooling;

1 Introduction

Nowadays most of the energy used is generated by conventional fuels. Almost 50% of the electricity generation is produced from the coal combustion followed by natural gas, nuclear power and oil. In the next decades it is estimated that fossils will remain the main providers of the power plants. Although there will be a decrease of the nuclear share from 19 to 12% , the natural gas share in electricity production will be increase significantly from 19% in 2001 to 30% in 2025 [1]. Not only do fossil fuels have a limited duration of life but their combustion has negative environmental impacts, with the CO_2 emissions to be dominating. The fossil fuels emissions are 7200 million metric tones carbon equivalent, and there is an increasing tense. It is estimated that in 2025 the emissions will surpass the 9000 metric million tones carbon equivalent [2]. Reducing the fossil fuel consumed while supplying the energy demand is a difficult task. Renewable energy sources are among others the most promising future potential.

The energy demand issue in islands that are geographically distributed and incapable of central management has a specific nature due to small capacity energy production schemes that are most applicable. The fragile environment of the islands requires the application of energy production technologies and resource management schemes, which are ecologically rational. Their schemes must be adjusted to the specified areas concerned with their specific resources. Their environmental impact must be minimised. The fact that the islands today are depended on imported fuels, further development must be achieved in the context of technological flexibility. Furthermore, it is obvious that advances must be made in the direction of renewable energy sources in order to equalise the energy balance of theses isolated regions.

The Mediterranean areas are among the regions of the world where fresh/ potable water sources are very limited and the demand for potable water is expected to increase in the coming years. The demand for water is increasing due to several factors. There is a continuous development of the tourist industry, a demographic grown and the increased per capita consumption, extension of the water distribution networks, increased irrigation and industrial development. Tunisia, Algeria, the scattering islands of the Mediterranean Sea or isolated areas around Mediterranean and the Middle East countries have a great potential of brackish water. Seawater or brackish water desalination appears as a promising technique for potable water production.

Over the past decade, the number of desalination plants and their total capacity has almost doubled. Currently, the production capacity exceeds 32 10^6 m^3/d, and the number of plants has increased to more than 15,000 units. During the, 1996–2002 period the desalination capacity in Spain has doubled. As a result, Spain became the leading producer in Europe, with more than 30% share of the installed desalination capacity in the continent. Currently, the desalination capacity in Spain is approaching 1.5 10^6 m^3/d. Another example is found in Saudi Arabia, where the production capacity stands at 5 10^6 m^3/d and is expected to double its capacity by the year 2020. Similar scenarios are also found in other countries, Oman, Kuwait and the United Arab Emirates, [1].

The disadvantage of the desalination is the high capital cost and only large capacity desalination plants are economically feasible. The energy requirements are provided by fossil fuels with serious impact to the environment. The Mediterranean region has a great renewable energy potential. Renewable energy, such as solar, wind and geothermal, can be utilized in small capacity desalination plants. The last decades several studies have been done to this direction. Most of them focus on the usage of solar energy through the routes of the photovoltaics and the solar stills, due to the high solar irradiation to the region.

Geothermal energy is also widely available in these countries. The geothermal water temperature varies between 80-110 ^oC to the upper layers of the surface to 325 ^oC for a depth of 700-1400m [3]. Studies shown that low temperature geothermal waters in the upper 100 m may be a reasonable energy source for desalination [4, 5].

A study for a proposed project for the island of Milos, located in Cyclades Islands in Greece, has shown that the high geothermal potential of the island can be utilized with the use of an organic rankine cycle (ORC) turbogenerator electricity production unit, with an installed capacity of 300 kW, coupled to a multi-effect water desalination unit with an installed water production capacity of 80 t/h. The unit combines geothermal energy with an absorption chiller driven by the hot water at 85 ^oC [3]. The study showed that the exploitation of the low enthalpy geothermal energy would help save the equivalent of 5000 TOE/y for a proposed plant capacity of 600-800 m^3/d of fresh water. Even in the case of limited geothermal energy, thermal desalination processes such as MED, thermal vapor compression (TVC), single-stage flash distillation (SF) and MSF can benefit greatly when coupled to geothermal sources by economizing considerable amounts of energy needed for preheating [8]. Membrane distillation (MD) is an emerging desalination technology, which can be driven by a thermal energy at low enthalpy (less than 363 K) as geothermal energy, and a fluidised bed crystalliser can ensure reduction of an important portion of hardness without significant loss of temperature [9].

On the other hand, the geothermal potential can be utilized in the space cooling and heating, as already it is been shown with the use of Ground Source Heat Pumps. Ground source heat pumps (GSHPs), often referred to as geothermal heat pumps (GHPs), are recognized to be outstanding heating, cooling and water heating systems. They provide high levels of comfort, offer significant reductions of electrical energy use and demand, have very low levels of maintenance requirements they are environmentally attractive and they are high efficient [02].

A GSHP utilizes the ground as a heat source in heating and a heat sink in cooling mode operation. In the heating mode, a GSHP absorbs heat from the ground and uses it to heat the house or building. In the cooling mode, heat is absorbed from the conditioned space and transferred to the earth through its ground heat exchanger. GSHPs are an efficient alternative to conventional methods of conditioning homes because they utilize the ground as an energy source or sink instead of using the ambient air. The ground is a thermally more stable heat exchange medium than air, essentially unlimited and always available. The GSHPs exchange heat with the ground, and maintain a high level of performance even in colder climates [03].

Another potential in space cooling is the absorption refrigeration cycle. The cycle usually utilizes the waste heat of a process, but it can well exploit the geothermal potential, even of middle and low enthalpy.

The early development of an absorption cycle dates back to the 1700's. It was known that ice could be produced by an evaporation of pure water from a vessel contained within an evacuated container in the presence of sulfuric acid. In 1810, ice could be made from water in a vessel, which was connected to another vessel containing sulfuric acid. In 1859, Ferdinand Caue introduced a novel machine using water/ammonia as the working fluid. This machine took out a US patent in 1860. Machines based on this patent were used to make ice and store food. It was used as a basic design in the early age of refrigeration development. In the 1950's, a system using lithium bromide/water as the working fluid was introduced for industrial applications. A few years later, a double-effect absorption system was introduced and has been used as an industrial standard for a high performance heat-operated refrigeration cycle [10].

Nowadays, this technology is used in Europe, but is more common in the USA and Japan, where much has been done to improve its performance. Absorption chillers use heat as primary energy to produce cold, instead of mechanical rotation work for compression chillers. They can use the heat of steam, hot water or direct gas combustion, depending on technologies. There are various possibilities of use. They can be integrated in a steam, hot water or gas district network

2 Cooling and Fresh Water Production System

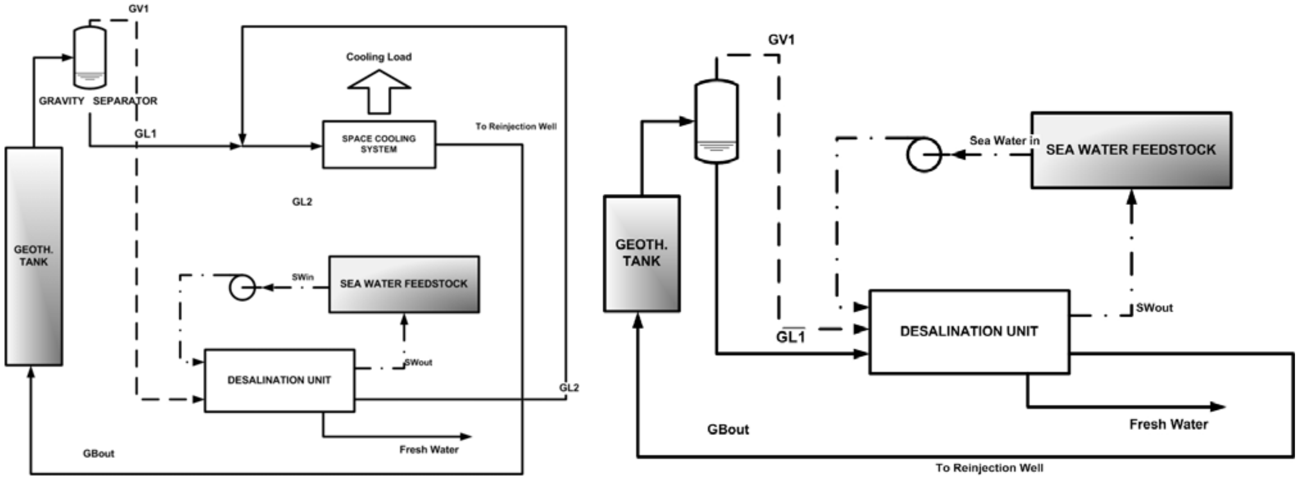
In the present study, the geothermal potential of the Nisyros Island, located in Dodecanese, Greece, will be investigated.

Nisysros is a volcanic island with high enthalpy geothermal streams. Nisyros is extended in 41km^2 and the islands population is 800 during the winter and almost doubles in summer months reaching up 1200 persons. The average fresh water use is about 200lt/person/day. That is to say the production rate of potable water should be 6.12m^3/day, to cover the annual needs. The weather data for the Nisyros Island are presented in Table 1. The basic assumptions made, are that the sea water temperature is stable during the year and equal to the average air temperature, that is to say 19.1^{0}C.

The geothermal brine from the drilling that is going to be exploited is a high enthalpy vapour water mixture of 12t/h flow. It is found at a pressure of 10bar and a temperature of 187 ^{0}C. The geothermal brine after the gravity separator is split into a superheated geothermal vapour stream of 9.3t/h flow and 192^{0}C, and a geothermal liquid stream of 2.7t/h and 180^{0}C. During the summer months (June to September), the geothermal steam will be utilized in a 20 stage Multi Flash Desalination (M.F.D.) system to produce fresh water while the geothermal liquid and the waste heat from the Multi Flash Desalination plant, will be utilized in a way to cover the cooling needs of the island (case I). The rest of the year the total flow (liquid and steam) will be used to produce potable water (case II). In case II the production of fresh water will overcome the requirement. The additional potable water could be stored in tanks and used later when needed. A schematic representation of the system under study, both cases, is presented in Fig. 1

Table 1 – Weather Data of Nisyros Island

NISYROS	**BAROMETRIC PRESSURE**	**AVERAGE AIR TEMPERATURE**	**ABSOLUTE MAXIMUM AIR TEMPERATURE**	**ABSOLUTE MINIMUM AIR TEMPERATURE**	**HOURS OF SUNLIGHT**	**RELATIVE HUMIDITY**	**AVERAGE**
MONTH	**mmhg**	**^{o}C**	**^{o}C**	**^{o}C**	**h**	**%**	**CLOUDINESS**
							(scale of 8)
1	1,015.7	11.9	22	-4	135.7	70.1	4.3
2	1,014.8	12.1	22	-2.2	142.0	69.1	4.2
3	1,013.4	13.6	27.4	0.2	206.0	68.7	3.9
4	1,012	16.6	30.6	5.2	246.7	66.5	3.5
5	1,011.7	20.5	34.8	5	314.5	64.4	2.9
6	1,009.8	24.7	37.4	12.6	355.5	58.5	1.1
7	1,006.9	26.9	40	14.6	387.1	57.6	0.3
8	1,007.5	27.1	42	17	373.3	59.9	0.3
9	1,011.4	24.6	36.6	10.6	313.6	61.4	0.8
10	1,014.7	20.8	33.2	7.2	239.6	67.5	2.4
11	1,016.4	16.5	28.4	2.4	184.4	71.4	3.5
12	1,015.8	13.4	22.4	1.2	142.1	72.4	4.2
AVER		**19.1**			**3,041**	**65.6**	



Case I Case II

Figure 1 – Cooling and Fresh Water production co-generation unit

3 The desalination system

The twenty stage flash desalination unit is represented in Fig. 2. The system consists of 20 condensers (preheaters) (C1 to C20) where the vapour from the flashes condenses and heats the sea water, twenty flashes and nineteen secondary flashes (SF) where the condensed freshwater expands, in order to gain more heat for the condenser/ preheater. The seawater temperature, after the pump, is at 20 ^{0}C and pressure 5 bar and need to be heated up to 150 ^{0}C before it enters the first flash.

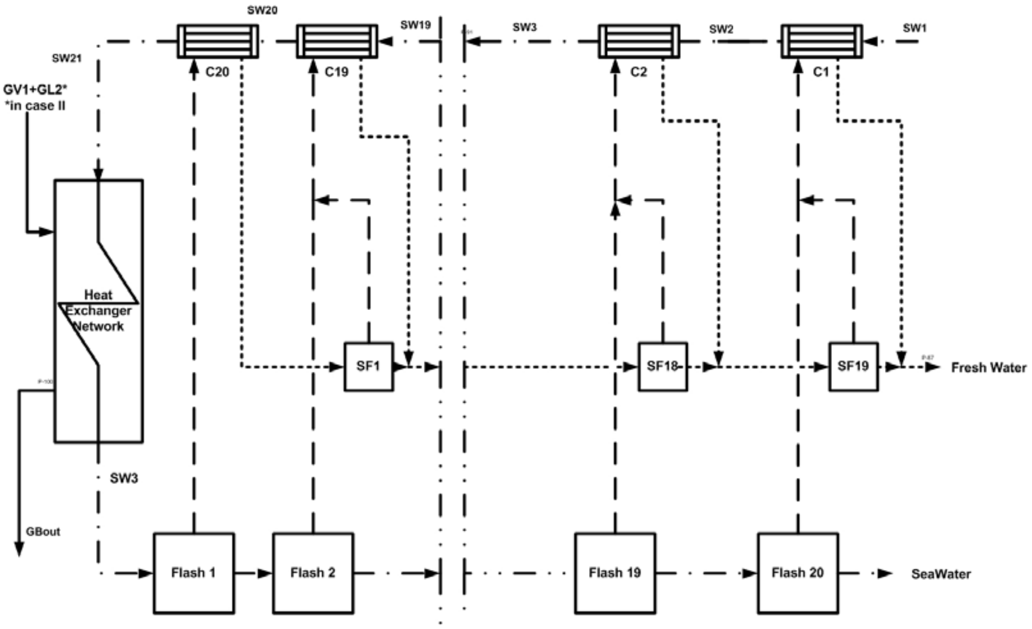


Figure 2 – Twenty stage flash desalination system

The seawater exits the condenser No 20 at 74^0C and proceeds through the heat exchanger network where it exits at 150^0C and 5bar. The geothermal vapour condenses in heat exchanger No1 and the afterwards it is cooled to 145^0C. The waste flow (145^0C and 10bar) is then utilized in the space cooling system together with the geothermal liquid. The mixture of the condensed and cooled geothermal vapour and the geothermal liquid is a 12ton/h flow of 153^0C and 10bar.

The expansion ratio in a single flash is expressed as

$$y = \frac{h_0 - h^{'}}{h^{"} - h^{'}} \tag{1}$$

and the produced steam

$$M_{steam} = y * Min = \frac{h_0 - h^{'}}{h^{"} - h^{'}} * Min \tag{2}$$

where Min the mass of the inlet flow

In the second flash the steam production equals to

$$\begin{aligned} M^2_{STEAM} &= y * (Min - M^1_{STEAM}) = \\ &= \frac{h_0 - h^{'}}{h^{"} - h^{'}} * (Min - M^1_{STEAM}) \end{aligned} \tag{3}$$

and so goes on.

The steam flows pass through the condensers in order, to produce fresh potable water (steam condensate) and to preheat the sea water flow. The “specific consumption” in a multi-stage flash desalination system can be expressed as [11]

$$\begin{aligned} d_H &= \frac{D_H}{D} = \\ &\frac{c(t_F - t_F^* + N - \vartheta_e)}{(c_{H1}t_{H1} - c_{H2}t_{H2})(N+1)\left[1 - (1 - c\frac{t_F - t_F^* + \vartheta_e}{(n+1)r_m})^N\right]} \end{aligned} \tag{4}$$

where

D_H is the flow of the heat source

D is the flow of the produced steam

c the specific heat of the water taken 4.19kJ/kgK [11]

t_F the temperature of the seawater before enters the first flash

t_F^* the of the seawater before it enters the first condenser

N the number of the flashes

θe the temperature difference of the preheat exchangers (varies between 3 and 5 ^{0}C)
c_H the specific heat of the heat source
t_H the temperature of the heat source
r_m the medium latent heat
The latent heat temperature for a stage is [11]:

$$t_n = \frac{(N+1-n)t_F + n(t_F^* + \vartheta_e)}{N+1} \qquad (5)$$

The condensation is expressed as [9]:

$$\frac{\xi_a}{\xi_e} = (1 - c\frac{t_F - t_F^* - \vartheta_e}{(N+1)r_m})^N \qquad (6)$$

Where
ξa is the content in salt before the flash system
ξe is the content in salt after the flash system.
The produced steam at the system can be expressed as [9]

$$\frac{D}{F} = 1 - \frac{\xi_a}{\xi_e} = (1 - c\frac{t_F - t_F^* - \vartheta_e}{(N+1)r_m})^N \qquad (7)$$

Where
F is the seawater flow.

4 The Space Cooling System

All the power plants are using coal, natural gas, oil or biomass, as burning fuel in order to produce power. In all cases, large amounts heat is produced. On the other hand, most of industrial process uses a lot of thermal energy by burning fossil fuel to produce steam or heat. Waste Heat is rejected to the surrounding as waste. This waste heat can be converted to useful refrigeration by using a heat operated refrigeration system, such as an *absorption refrigeration cycle*.

Electricity purchased from utility companies for conventional vapour compression refrigerators can be reduced. The use of heat-operated refrigeration systems help to reduce problems related to global environmental, such as the so-called greenhouse effect from CO_2 emission from the combustion of fossil fuel in utility power plants.

Gas absorption systems feature several *advantages* over conventional vapour compression electric systems:

- Lower operating costs (operating with waste heat).
- No ozone-damaging refrigerants (no use of CFCs or HCFCs).
- No need for extra electric power (no overcharge of the existing electric power network, especially during the peak hours).
- Lower-pressure systems with no large rotating components.
- Low maintenance.
- Safer operation.
- High reliability.
- Smaller total space requirements compared to an electric chiller with separate boiler.
- Long lifetime, (25-30 years, compare to the 10-15 years of the vapour compression systems).
- Silent operation. Except for two hermetically sealed pumps, absorption chillers do not have any moving parts. They run more quietly (there are few vibrations) than compression chillers. This difference could be significant in office buildings, hotels or hospitals.
- Potential financial support from National Government, EU, etc.

All water-cooled absorption systems on the market today, use *water as the refrigerant* and *a lithium bromide solution as the absorbent material* and they used for medium and large scale applications (3-2,500RTs or 10-9,000kW), while the COP_R is between 0.6 and 1,3. A typical air-cooled absorption chiller uses *ammonia as the refrigerant and water as the absorbent material* and they used for rather small applications (3-30RTs or 10-100kW), while the COP_R is between 0.6 and 0.7. [10],[12],[13],[14]

However, gas absorption systems have three important *disadvantages* [10],[12]

Low COP_R, the usual range for absorption chillers is 0.6-1.3 depending to the technology used, instead of the 3.5-5.5 of the vapour compression systems.

- In cases where there is no waste heat available, absorption chillers cost more to operate than electric chillers. They also cost about 50% more to purchase
- Water consumption in cooling tower.

4.1 The single-effect LiBr/Water absorption cycle flow description

The absorption working fluid used is LiBr/Water because it is one of the best choices found among hundreds of working fluids that have been considered. The fundamentals of operation of an absorption cycle using aqueous lithium bromide as the working fluid are discussed in this section. To keep the discussion simple, only the most basic cycle is considered.

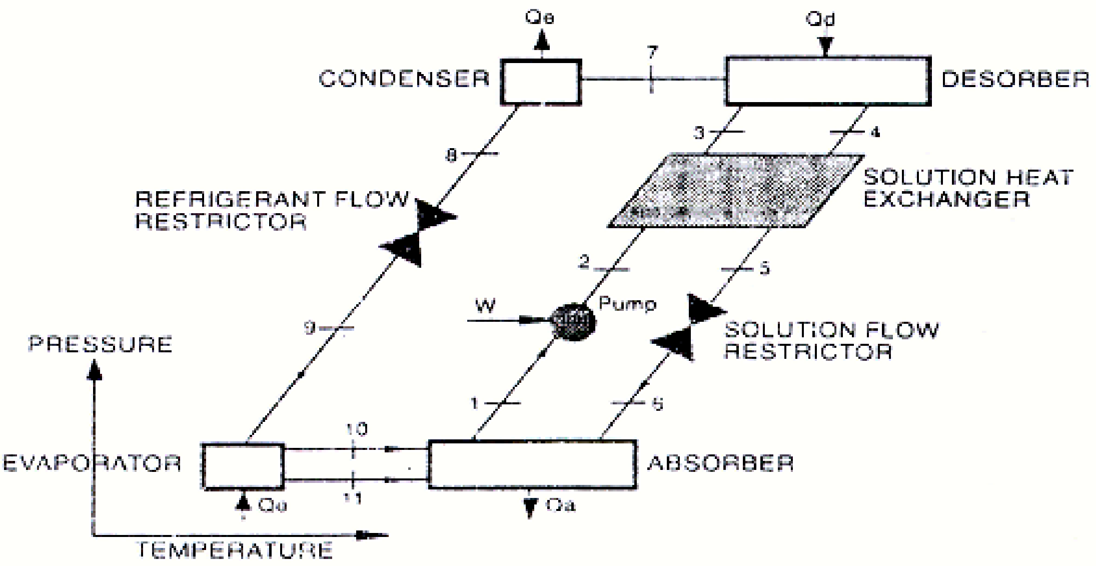


Figure 3. Single-effect LiBr/Water absorption cycle

A block diagram of a single-effect machine is provided as Fig. 3. The diagram is formatted as if it were superimposed on a *Duhring plot* [8] of the working fluid. Thus, the positions of the components indicate the relative temperature, pressure and mass fraction. The cycle has five main components as shown in figure 3: the *generator (sometimes called desorber), the condenser, the evaporator, the absorber*, and the *solution heat exchanger.*

Starting with state point **4** at the generator exit, the stream consists of absorbent-refrigerant solution, which flows to the absorber via the heat exchanger. From points **6** to **1**, the solution absorbs refrigerant vapour (**10**) from the evaporator and rejects heat, to the environment. The solution rich in refrigerant (**1**) flows via the heat exchanger to the generator (**3**). In the generator thermal energy is added and refrigerant (**7**) boils off the solution. The refrigerant vapour (**7**) flows to the condenser, where heat is rejected as the refrigerant condenses. The condensed liquid (**8**) flows through a flow restrictor to the evaporator. In the evaporator the heat from the load evaporates the refrigerant, which then flows (**10**) to the absorber. A portion of the refrigerant leaving the evaporator leaves as liquid spillover (**11**). The thermodynamic state of every point is summarized in table 2

Table 2 - Thermodynamic state point summary

Point	State	Notes
1	Saturated liquid solution	Vapour quality set to 0 as assumption
2	Sub-cooled liquid solution	State calculated from pump model
3	Sub-cooled liquid solution	State calculated from solution heat exchanger model
4	Saturated liquid solution	Vapour quality set to 0 as assumption
5	Sub-cooled liquid solution	State calculated from solution heat exchanger model
6	Vapour-liquid solution state	Vapour flashes as liquid passes through expansion valve
7	Superheated water vapour	Assumed to have zero salt content
8	Saturated liquid water	Vapour quality set to 0 as assumption
9	Vapour-liquid water state	Vapour flashes as liquid passes through expansion valve
10	Saturated water vapour	Vapour quality set to 1.0 as assumption
11	Saturated liquid water	Vapour quality set to 0 as assumption

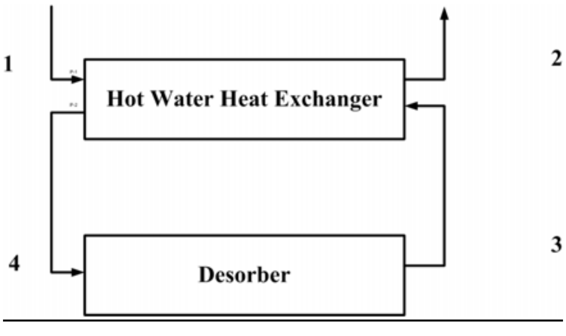
In general the *Coefficient of Performance of an absorption refrigeration system* is obtained from:

$$COP_{RA} = \frac{\text{cooling capacilty obtained at evaporator}}{\text{heat input for the generator + work input from the pump}}$$

An average of the coefficient of performance value is 4.0 and this one is going to be in the analysis follow.

As it has been mentioned in [10], the absorption cooling system is a very promising technology when waste heat is used as heating source of the absorption refrigeration cycle. From that point of view, the heat coming from a geothermal field could also be attractive. The mass flow of the hot water 12kgr/h, while its temperature 145^{o}C. In order to transfer heat from the water to the desorber of absorption chiller, the use of a heat exchanger is needed. That heat exchanger is called **e***xhaust gas heat exchanger*. (*Fig.4*)

Figure 4 - Heat transfer system from the hot water to the absorption chiller desorber [15]



The hot water heat exchanger is working with two streams. The “hot water stream” consist of HOT water coming from the exit of desalination system (point 1), getting through the hot water heat exchanger, and end up (point 2), either to the environment as waste heat water or to another heat exchanger where their *remaining heat can be used for others purposes (such as dry up), increasing further more the overall efficiency* of the installation. The “desorber stream” is closed cycle, circulating of water coming from the desorber (point 3), getting through the hot water heat exchanger, and coming out as superheated water (point 4) with temperatures between 105-130^{o}C. It is obvious that the second stream is under pressure to reassure that the water remains always in liquid face, and so keeping the hot water heat exchanger efficiency at relatively high level. Typical values of exhaust *hot water exchanger efficiency* (η_{EHE}) *is consider to be 0.8,* [10], while it is dependable on the manufacture technology and on the cleanness degree of the hot water stream internal paths.

The Cooling requirements of Nisyros Island are been shown in Table 3.

Table 3 - The Cooling requirements of Nisyros Island

MONTH:	**COOLING** $\mathbf{MW_e}$	**MWCooling** COPaverage=4	**Future 20%**	**Peak 10%**
1	0,0000	0,0000	0	0,0000
2	0,0100	0,0400	0,0480	0,0528
3	0,0375	0,1502	0,1802	0,1982
4	0,1253	0,5012	0,6015	0,6616
5	0,1499	0,5995	0,7194	0,7913
6	0,2101	0,8405	1,0086	1,1095
7	0,2896	1,1584	1,3901	1,5291
8	0,3338	1,3352	1,6022	1,7625
9	0,2227	0,8909	1,0691	1,1760
10	0,1613	0,6452	0,7743	0,8517
11	0,0112	0,0449	0,0539	0,0593
12	0,0000	0,0000	0,0000	0,0000

In column $MW_{cooling}$ are presented the present cooling requirements, while in the next two columns there is an assumption of a future 20% raise and an over 10% raise as a peak load. The exploitation of the geothermal brine is able two impute a 3.354MW of cooling load, thus, it is overcome the cooling needs, even when there will a total raise of 32%

5 Conclusions

The objective of this work was to investigate the potential of the geothermal energy in the Island of Nisyros and its ability to respond the requirements in cooling and fresh water production. The results were rather promising. The cooling load is by far overweighed, even when is arise of 32% (a 20% future raise and a 10% peak load raise) will occur. On the other hand, geothermal energy is able to provide the essential power in order to cover the fresh water needs of the island and produce almost 700m^3 per year, more potable water which will be stored and used when it is needed. Together, there is 1.4MWel saving, which was going to be used in the space cooling and a 2.4 to 3.7MW saving, if the MFD plant was operating with conventional fuels, resulting in low air emissions and capital savings.

In this work, two cases where examined. The exploitation of the geothermal energy though, is not that narrow. There are several variations of the system under study. The geothermal brine exits the presents co-generation system at 65^{0}C which could further utilized before it enters the re-injection wells. On the other hand, as a former study by the authors have shown [16], the steam can be used in electricity production and the waste heat could be used in desalination, space cooling or space heating.

Thus, geothermal energy could play a vital role in future development, especially in small islands and isolated areas where the replenishment is a difficult and high costly task.

References

[1] www.ce-int.org

[2] Thomas Ackermann: Means to Reduce CO2 - Emissions in the Chinese Electricity System, with Special Consideration to Wind Energy, *Renewable Energy* 16 (1999) 899-903

[3] http://www1.eere.energy.gov

[4] http://www.geothermal.org

[5] http://hotrock.anu.edu.au

[6] http://wwwphys.murdoch.edu.au/rise/reslab/resfiles/geo/text.html

[7] http://www.ucsusa.org/clean_energy/renewable_energy_basics/offmen-how-geothermal-energy-works.html

[8] Ingvar B. Fridleifsson: Status and potential role of geothermal energy in the world*, WREC* 1996

[9] Ingvar B. Fridleifsson: Geothermal energy for the benefit of the people*, Renewable and Sustainable Energy* Reviews 5 (2001) 299–312

[10] Polyzakis A. Technoeconomic Evaluation Of Trigeneraton Plant: Gas Turbine Performance, Absorption Cooling And District Heating, PhD Thesis, Cranfield University, 2007.

[11] B. A. Sotiropoulos; *Evaporators*, Sighroni Pedia 1996, Thessaloniki, ISBN:960-357-016-8 (In Greek)

[12] Herold E. K., *Absorption chillers and heat pumps, CRC Press,* 1996.

[13] Papaeftimiou B., *LiBr/water chilling system*, PhD Thesis, 2001.

[14] Papadopoulos A. M., *Perspectives of solar cooling in view of the developments in the air-condition sector, Renewable & sustainable energy reviews*, Elsevier, 2004.

[15] ASHRAE *Handbook, Fundamentals, Amer. Soc. Of Heating Refrigerating and Air-conditiong Engineers*, 1997.

[16] C.J. Koroneos, D.C. Rovas, Electricity from geothermal energy with the kalina cycle, *ICCEP 07*

[17] Miklos Arpasi: Geothermal development in Hungary—country update report 2000–2002, *Geothermics* 32 (2003) 371–377

[18] Neven Duic; Maria da Grac; ´E Carvalho: Increasing renewable energy sources in island energy supply: case study Porto Santo, *Renewable and Sustainable Energy Reviews* 8 (2004) 383–399

[19] Vladislovas Katinas; Antanas Markevicius: Promotional policy and perspectives of usage renewable en*ergy in Lithuania,* Energy Policy 34 (2006) 771–780

[20] Ramazan Kose: Geothermal energy potential for power generation Turkey: A case study in Simav, Kutahya, *Renewable and Sustainable Energy Reviews* 11 (2007) 497–511