Adriacold

"Diffusion of Cooling and Refreshing Technologies using the Solar Energy Resource in the Adriatic Regions"

Project Code: 2°ord./0030/1

Case Studies Report on Feasibility Studies Regarding Relevant Economic, Technical and Environmental Aspects

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1. Introduction

The ADRIACOLD project aims to promote and spread the use of alternative energy for cooling, on the territories of the Adriatic basin, in order to gain an increasing independence from fossil fuels. A very important issue of the project is to carry on the studies and the dissemination in the Adriatic region of solar cooling technology.

Case studies will be focused on the most relevant technologies and users, in order to highlight those cases more satisfactory and those applications where the implementation of solar cooling system is particularly convenient. The diffusion of the solar cooling system will be done by means of technical, economic, energy and environmental knowledge. Moreover the feasibility studies will highlight the need for technical or technological improvements, necessary to achieve satisfactory levels and standards. The ultimate goal of the feasibility studies is to ensure a large diffusion of this system in all those similar European areas.

This report is prepared in cooperation with ADRIACOLD partners who have participated in preparation of national case studies for selected buildings. In total 10 case studies were created: four in Croatia and two in Italy, Slovenia and Bosnia and Herzegovina. This report is prepared according to results obtained in these ten case studies.

The beneficiaries of this WP are the stakeholders of each participant region such as local authorities, enterprises, professionals and technicians and more in general people who are potentially interested in adopting such technologies.

Case studies report consisting in:

- Economic analysis: payback period, net present value, internal rate of return
- Energetic analysis: energy saved or obtained, energy balance
- Environmental analysis: reduction of GHG (Green Houses Gas) and other benefits

2. Case study description

The focus of the Adriacold studies was to examine feasibility of exploiting solar energy through a number of studies in different locations and various types of building (e.g. hotel, school, hospital, elderly home, winery and wellness centre) in the Adriatic region. Selected technology for these studies is LiBr Absorption unit with solar collectors. The case studies from Bosnia and Herzegovina, Slovenia, Italy and Croatia were included in this report. Case studies and their codes are given in the table below.

Study	Code
Case Study Croatia - Hotel Berulia	CRO_01
Case Study Croatia - Hotel Maestral	CRO_02
Case Study Croatia - Hotel Marina	CRO_03
Case Study Croatia - Elementary School Ivan Gundulić	CRO_04
Case Study Slovenia - Elderly Home Podsabotin	SLO_01
Case Study Slovenia - Izola Hospital	SLO_02
Case Study Italy - Wellness Centre Nadir-Putignano	IT_01
Case Study Italy - Winery Santa Margherita	IT_02
Case Study Bosnia and Herzegovina - Hotel Aćimović	BiH_01
Case Study Bosnia and Herzegovina - Hotel Zepter	BiH_02

Different location and types of building yielded different results. Aspects observed in these studies are economic viability, energy savings and reduction of CO_2 emission through decreased consumption of fossil fuels. The building uses different systems for cooling or heating e.g. HVAC systems, fuel oil boilers, conventional radiators and air conditioners. Also, different conditions are met at locations from condition of building to energy requirements. In the pages below an overall view will be shown for all of the studies.

Case Study Croatia - Hotel Berulia (CRO_01):

Bluesun hotel Berulia, has been chosen for prefeasibility study. Hotel is located in the municipality of Brela, Croatia. Location of hotel Berulia is shown in the Figure 1. Total area of the hotel is 15773 m^2. The hotel currently uses an HVAC system with compressor water chiller for cooling and cold water supply and central heating system for heating and hot water supply. Heat energy is produced in a boiler with installed capacity of 480 kW. The boiler is using extra light fuel oil.

Figure 1: Hotel Beruila

Case study Croatia - Hotel Maestral (CRO_02):

Bluesun hotel Maestral, is also located in the municipality of Brela, Croatia. Location and surrounding area of the hotel Maestral is shown on Figure 2. Total area of the hotel is 5557 m^2. The hotel currently uses an HVAC system with compressor water chiller for cooling and cold water supply. Water chiller unit has maximum electric power of 51 kW. It also has a central system for heating and hot water supply. Heat energy is produced for two more hotels: Marina and Soline and it is produced by two 1600 kW boilers. These boilers are using extra light fuel oil.

Figure 2: Hotel Maestral

Case study Croatia - Hotel Marina (CRO_03):

The hotel Marina, is third hotel from Bluesun Group located in the municipality of Brela, Croatia. Location of hotel Marina is shown in the Figure 3. Total area of the hotel is 12 845 m^2. The hotel currently uses an HVAC system with two compressor water chillers for cooling and cold water supply. Each water chiller unit has maximum cooling capacity of 270 kW. Bluesun hotel Marina does not have an internal system for heat production. Heat energy for hotel Marina is produced in two 1 600 kW boilers located in hotel Maestral.

Figure 3: Hotel Marina

Case study Croatia – Elementary School Ivan Gundulić (CRO_04):

Elementary school Ivan Gundulić, is located in the city of Dubrovnik, Croatia. Elementary school Ivan Gundulić is shown in the Figure 4. Total area of the school is 2819 m^2. The school currently uses air conditioners for cooling and heating. The air conditioners have a COP of 3.2 and a power input of around 1.6 kW. Total number of air conditioners in the school is 57. The school also has a central system for heating and hot water supply. Heat energy is produced in boiler which use extra light fuel oil. From the beginning of September 2014 the school uses only electrical energy to cover heating and cooling needs.

Figure 4: Elementary school Ivan Gundulić

<u>Case study Slovenia - Elderly Home Podsabotin (SLO_01):</u>

Elderly home Podsabotin, chosen for prefeasibility study, is located in the Podsabotin, Nova Gorica, Slovenia. Total area is 4100 m^2. One main feature of the building is very high consumption of domestic hot water (elderly people care). The rooms and most of the common areas in the winter period are heated with fan coils, other rooms are heated via radiators. During the summer, the rooms are cooled through the same fan coil system. Heat energy is produced in a central boiler plant. The boiler has a maximum capacity of 235 kW and uses oil. The nominal cooling capacity of the refrigeration unit is 130 kW.

<u>Case study Slovenia – Izola Hospital (SLO_02):</u>

General hospital Izola, chosen for second Slovenian prefeasibility study, is located in the city of Izola, Slovenia. The hospital is shown in the Figure 5. The total area of the hospital is 25500 m^2. A primary system for covering cooling and heating needs is two reversible heat pumps. For domestic hot water overheating and as a backup for space heating there are two boilers installed. DHW is preheated with a solar thermal system. A field of 250 m^2 flat plate solar collectors is installed on the roof of the building.

Figure 5: Hospital of Izola

Case study Italy - Wellness Centre Nadir-Putignano (IT_01):

Sport centre, chosen for the prefeasibility study, is located in the city of Putignano, Italy. This sports centre has high energy requirements for cooling and heating therefore it was reasonable to investigate into the possibility of implementing solar cooling system. The building is complex of multiple floors, features a swimming pool, gym, beauty salon, sauna, restaurant and two soccer fields. The system of cooling and heating of the premises is composed by a set of unit heaters with dual function distributed in the centre wellness.

Case study Italy - Winery Santa Margherita (IT_02):

Winery, chosen for second Italian prefeasibility study, is located in the city of Portogruaro, Italy. This building also has high energy requirements for heating and cooling. Total area of building is approximately 5000 m^2. The system of cooling and heating of the premises is composed by a set of unit heaters with dual function distributed in the local building.

<u>Case study Bosnia and Herzegovina - Hotel Aćimović (BiH_01):</u>

Hotel Aćimović, is located in the city of Trebinje, Bosnia and Herzegovina. The hotel is shown in the Figure 6. Total area of the hotel is 1400 m^2. For cooling and heating of the hotel is used cooling generator in version of heat pump air-water with cooling capacity of 65 kW and heating capacity of 71.7 kW. Two bivalent boilers (multiple heating modes) are installed for preparation of hot sanitary water. Two 10,5 kW electro heaters are installed in each boiler in case that heat exchangers in boilers are not able to produce enough heat energy. Solar collectors (flat plate), with a total area of 12 m^2, are placed on the roof of the object. Heating of hot sanitary water is automated and executed by determined priorities of heating sources (solar collectors - boilers - electro heater).

Figure 6: Hotel Aćimović

Case study Bosnia and Herzegovina - Hotel Zepter (BiH_02):

Hotel Zepter, is located in the municipality of the Kozarska Dubica, Bosnia and Herzegovina. The hotel is shown in the Figure 7. For cooling and heating of the hotel are used two cooling generators in version of heat pump air-water with cooling capacity of 202 kW and heating capacity of 234 kW. Four bivalent boilers (multiple heating modes) are installed for preparation of hot sanitary water. Solar collectors (flat plate) are placed on the roof of the hotel with total area of 27.6 m^2. Heating of hot sanitary water is automated and executed by determined priorities of heating sources (solar collectors - boilers - electro heater).

Figure 7: Hotel Zepter

3. Brief technology information

Key parameter for using solar cooling technology is solar insulation. In the Figure 9 solar irradiance for each country is shown. To be able to dimension the solar cooling system first was necessary to calculate or estimate, from obtained data, required annual energy demand for cooling and heating. Figure 8 show calculated annual energy demand for each study.

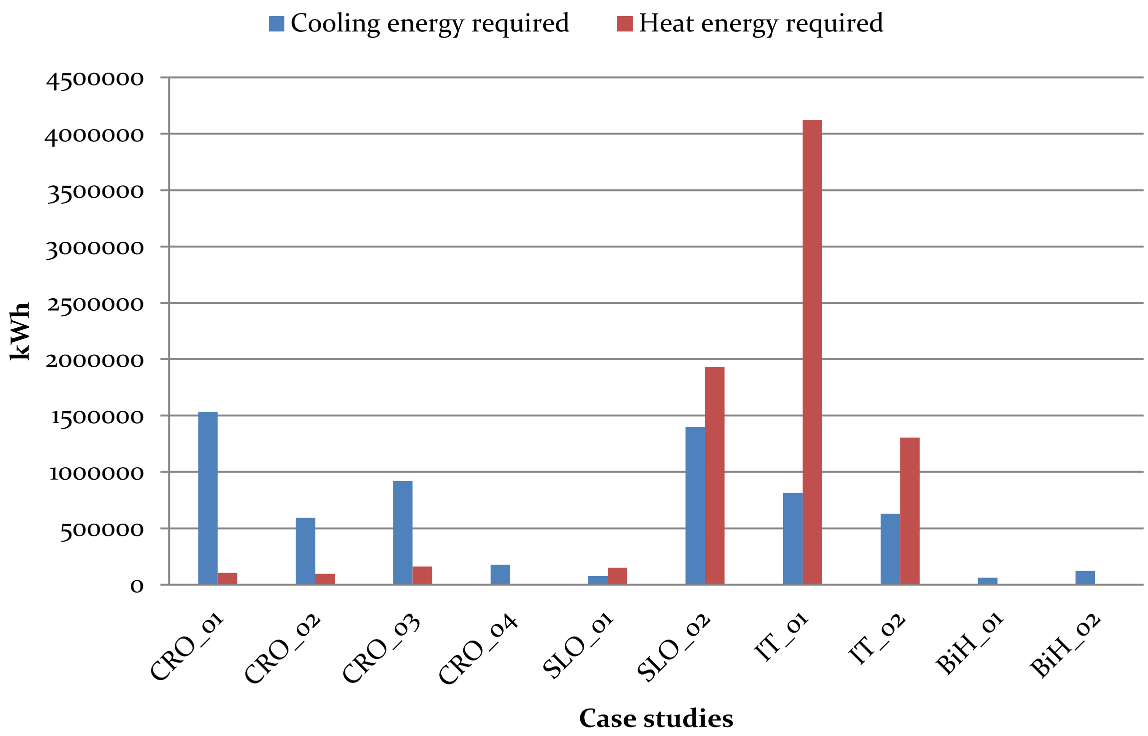

Figure 8: Annual energy demand in analysed case studies

Term "solar cooling" refers to all types of systems using solar energy. Solar cooling can be passive, through PV modules and air conditioners, or active, directly applying radiated solar energy through thermal collectors and thermally driven cooling devices. Nowadays, passive systems are widely used. Principle of operation is very simple. PV modules produce electricity depending on radiated solar energy. So produced electricity is then used to power the cooling device, for example air conditioner (Figure 10).

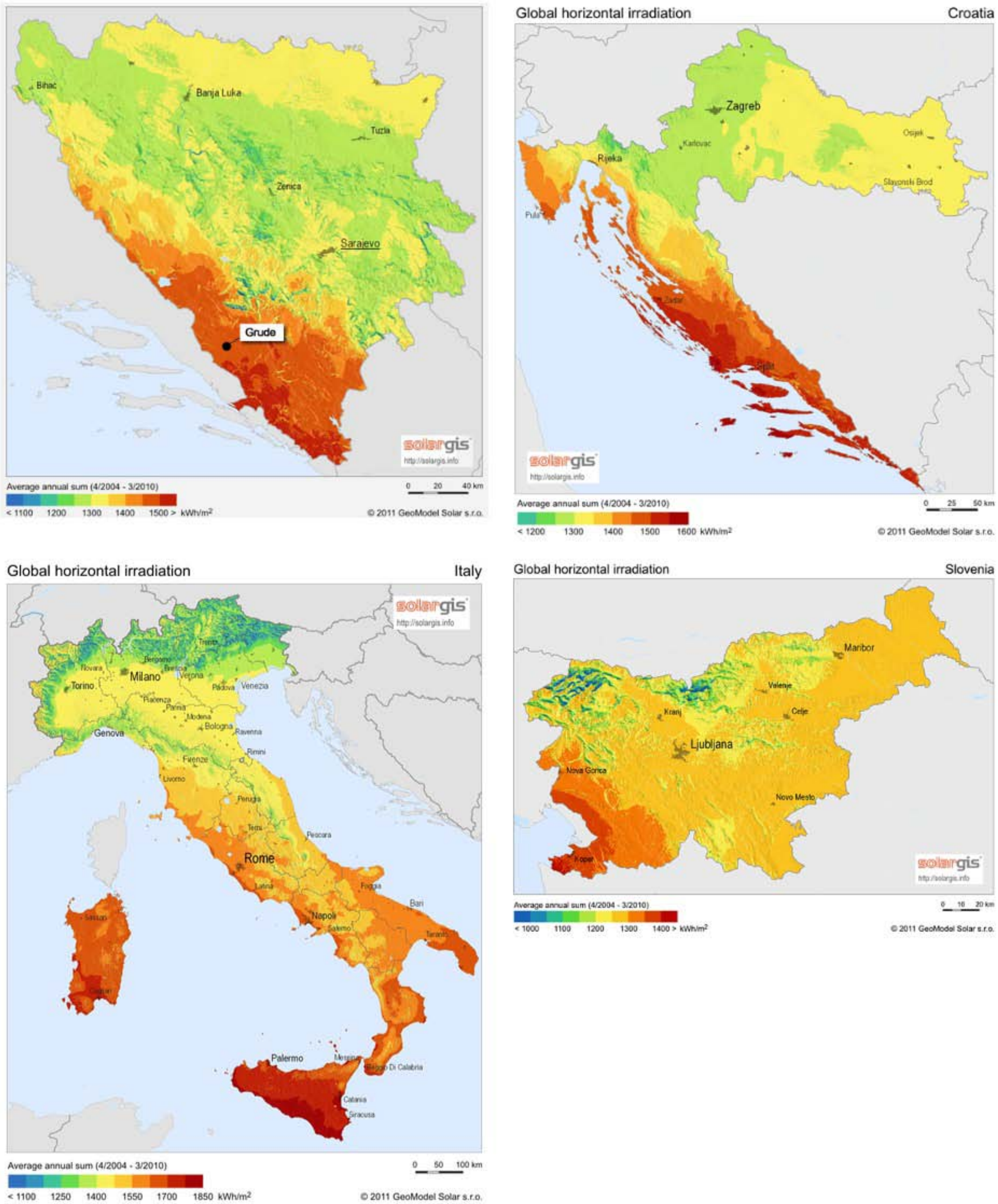

Figure 9: Solar irradiation in analysed countries

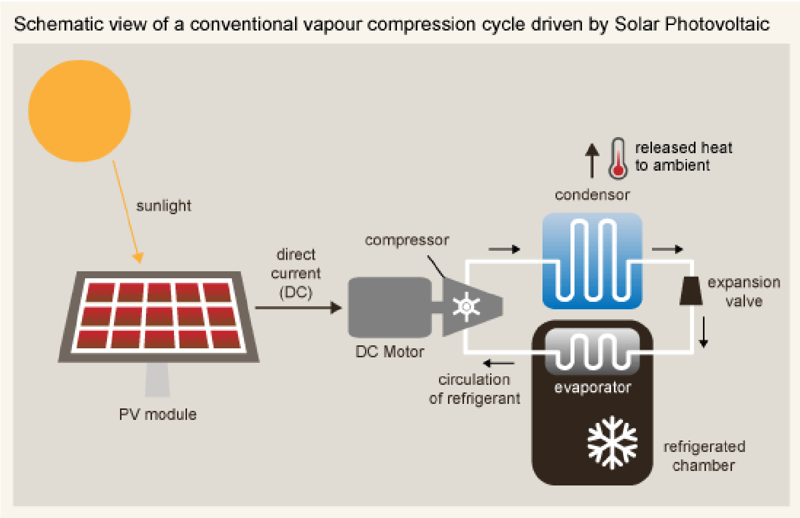

Figure 10: PV module and air condition system[1]

While passive systems are nowadays widely used, some active systems are quite a new technology. The basic principle of operation of such systems is based on the fact that the heat from the sun collected through solar collectors is used for evaporating respectively separation of the cooling medium from a mixture of adsorbent and the cooling medium that are under the pressure. Subsequent condensation of the so formed vapour leads to the same cooling effect as in the conventional mechanical cooling systems. Solar cooling system comprises solar collectors, heat buffer storage, air conditioning subsystem and backup system (Figure 11).

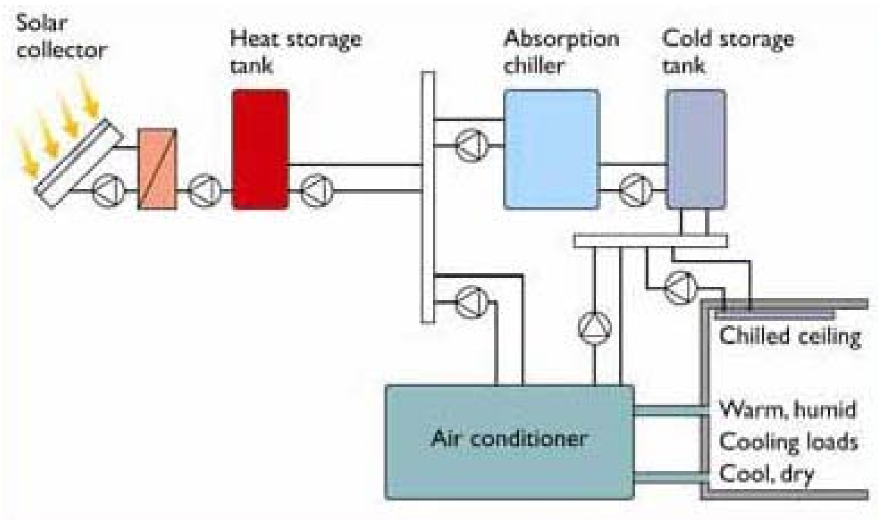

Figure 11: Active solar cooling system[2]

[1] www.aboutyourrefrigeration.blogspot.com/2014/03/refrigeration-solar-absorption.html
[2] EECM (Energy Efficiency Competence Master) site, www.eecm.eu/?page_id=118

The main advantage of solar cooling is that the cooling demand corresponds with the highest solar radiation and in some places the heating demand can be satisfied using solar collectors (Figure 12).

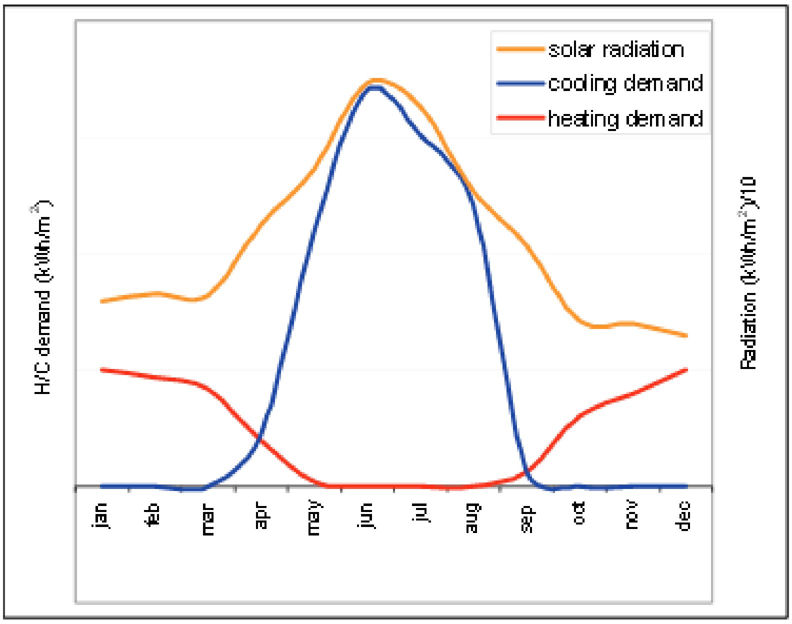

Figure 12: Comparison of cooling and heating demand with solar radiation[3]

Despite the fact that this systems still need electricity for powering some components solar cooling technology is considered as renewable source of energy and they can achieve large energy savings. Solar cooling technology for residential appliance is a mature technology and widely used but on large scale there are still problems with lack of practical knowledge and experience among builders and planers and high capital costs.

It is estimated that nowadays space heating and cooling and hot water supply make the half of global energy consumption in buildings. Most of this energy demand is still met by burning fossil fuels that are related to CO_2 emission. Solar cooling technology can play key role in meeting this growing energy demand and strict regulations regarding to CO_2 emission. Major barrier for wide application of solar cooling include the high investment cost and insufficient knowledge and experience.

[3] Marco Beccali, Pietro Finocchiaro, Bettina Nocke , "Solar Heating and Cooling of Buildings" , Italy, April 2008., www.brita-in-pubs.eu/bit/uk/03viewer/retrofit_measures/pdf/FINAL_11_SolarCooling_Marco_01_4_08b.pdf

4. Technical aspects of a solar cooling plant

Here will be shortly elaborated technical data for proposed solar cooling plants in each case study. Collector area (absorber) and chiller power for each case study and each scenario is given in the figures below. Also, different scenarios were discussed and analysed in ADRIACOLD case studies:

- **Scenario 1** is designed to cover basic and peak loads
- **Scenario 2** is designed only to cover basic load.

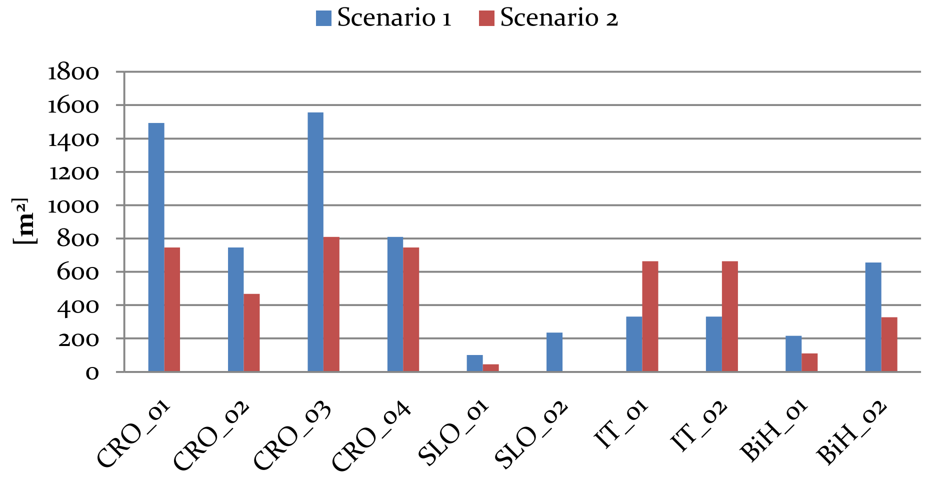

Figure 13: Collector area (absorber) in analysed case studies

Figure 13 and Figure 14 shows that collector area and chiller power are proportional to energy demand shown in Figure 8. As it can be seen the highest chiller power considered in case studies was around 450 kW while lowest chiller power considered was around 20 kW.

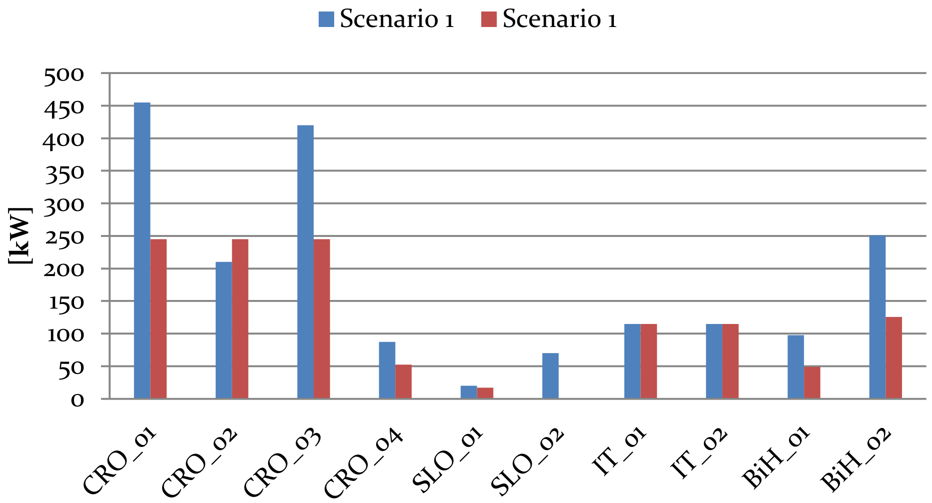

Figure 14: Chiller power in analysed case studies

The highest collector area was around 1600 m^2 and lowest area was around 100 m^2. Furthermore, different types of solar collectors were used. Figure 15 and Figure 16 shows percentage of two types of solar collectors used.

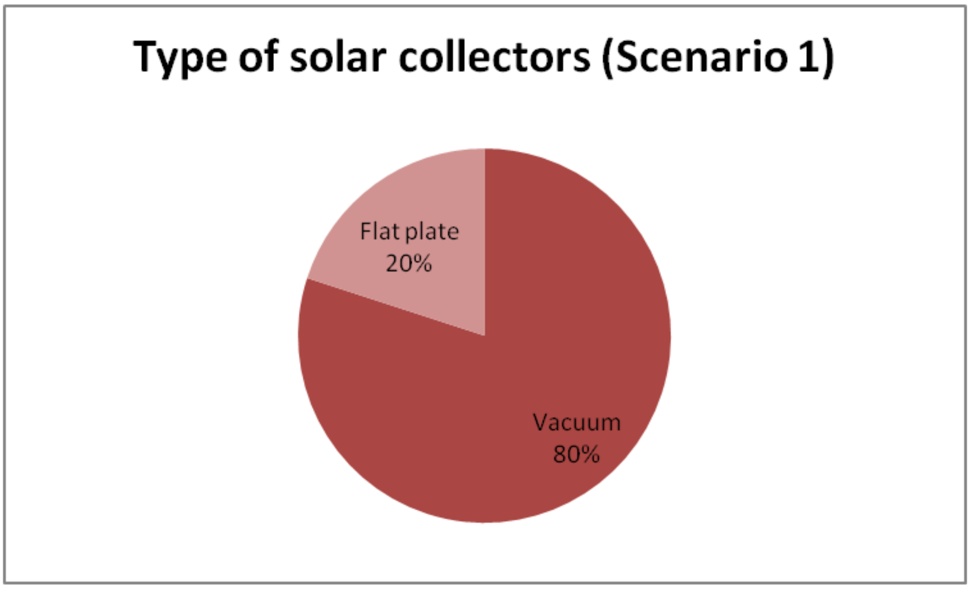

Figure 15: Type of solar collectors used in Scenario 1

The most represented type of solar collectors in scenarios 1 and 2 were vacuum collectors, but two case studies in scenario 1 were analysed with flat collectors.

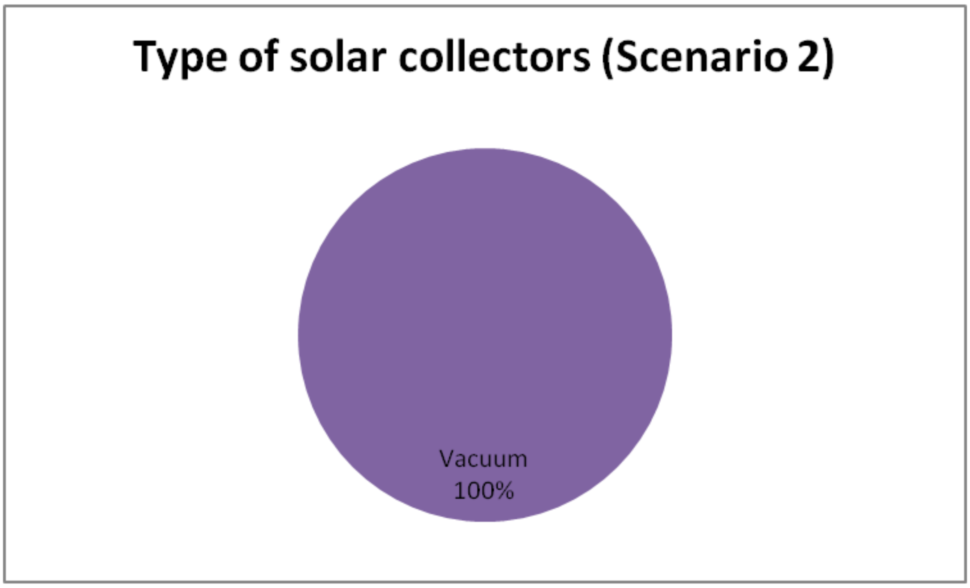

Figure 16: Type of solar collectors used in Scenario 2

5. Economic analysis

Short comparison of economic viability of each case study will be presented. Figure 17 shows the total investment while Figure 18 and Figure 19 show cost of two main components of solar cooling system, solar collector and absorption unit in analysed case studies. In the case of Italian case studies *Scenario 1* has smaller area of solar collectors and because of this *Scenario 2* is more expensive compared to other scenarios analysed in ADRIACOLD project.

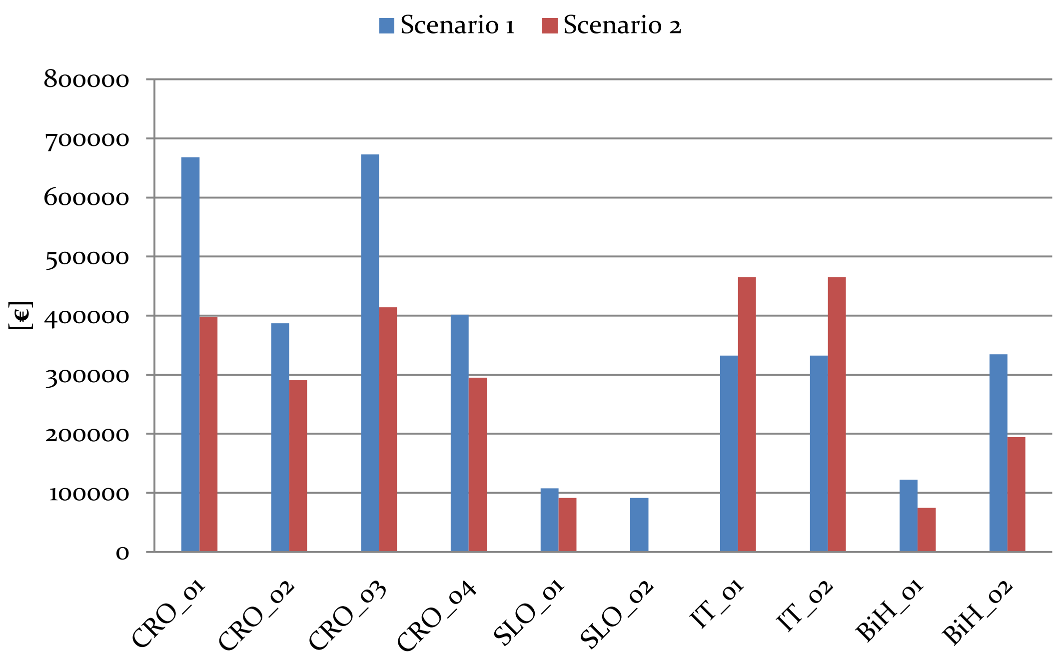

Figure 17: Total investment in analysed case studies

Figure 17 show that the most expensive case study is case study CRO_03. Scenario 1 is more expensive than scenario 2 because Scenario 1 is designed to cover base and peak energy needs while scenario 2 is designed to only cover base energy needs. Figure 18 and Figure 19 show that approximately 65 % of total investment is costs of solar collectors and absorption unit.

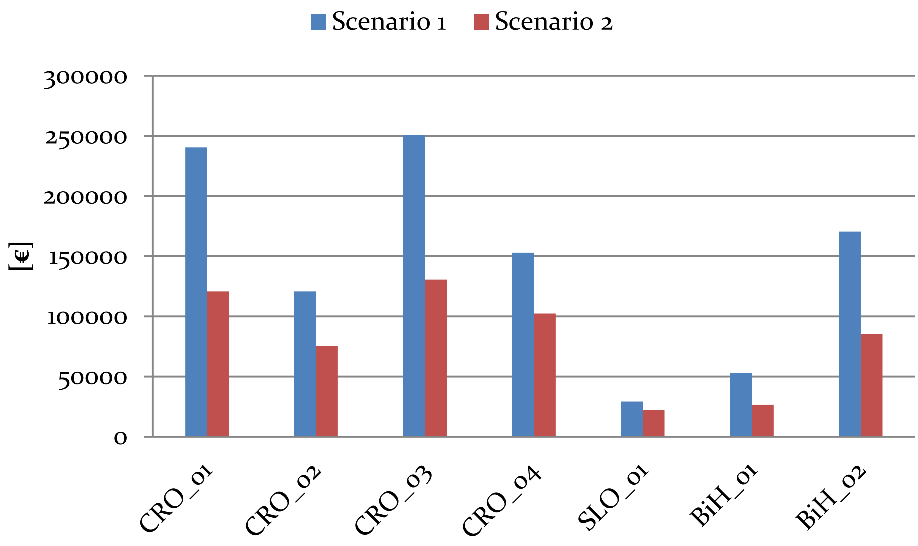

Figure 18: Cost of solar collector in analysed case studies

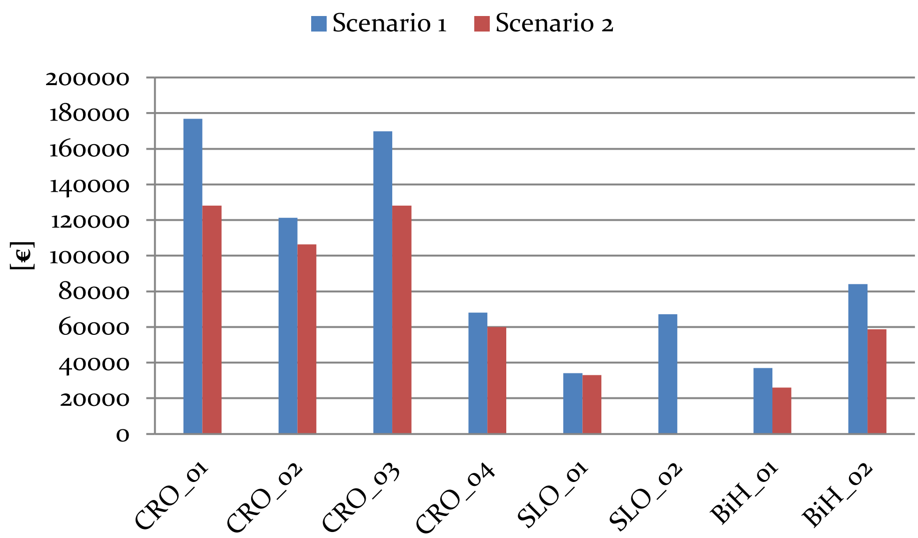

Figure 19: Cost of absorption unit in analysed case studies

Clearer picture of cost of each component is given in Figure 20 and Figure 21. Cost of solar collectors varies from country in which case study was considered but it can be seen that for majority of cases cost of solar collectors is nearly the same for scenario 1 and scenario 2. A little different situation is with absorption unit. It can be seen that cost of absorption unit is bigger in scenario 2 than in scenario 1. This is due to absorption unit is more expensive, in €/kW for smaller installation powers.

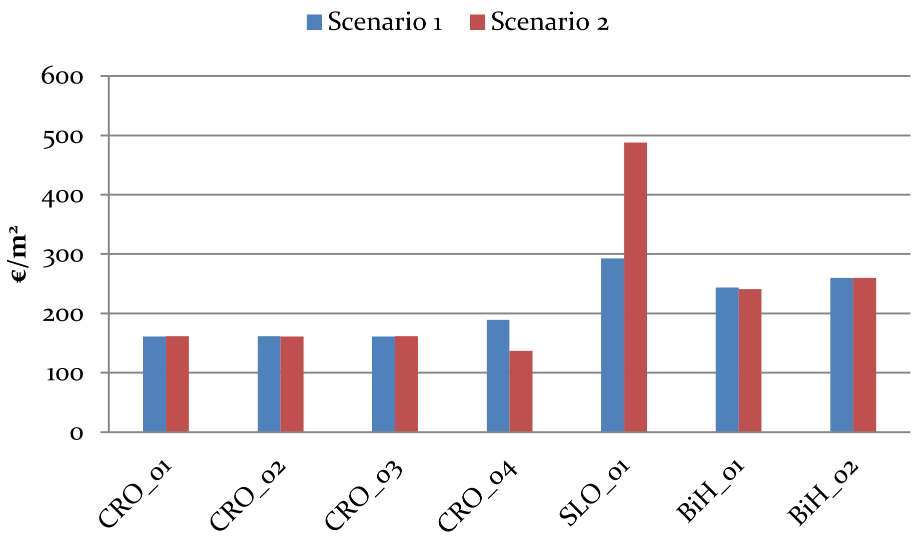

Figure 20: Solar collector cost in analysed case studies

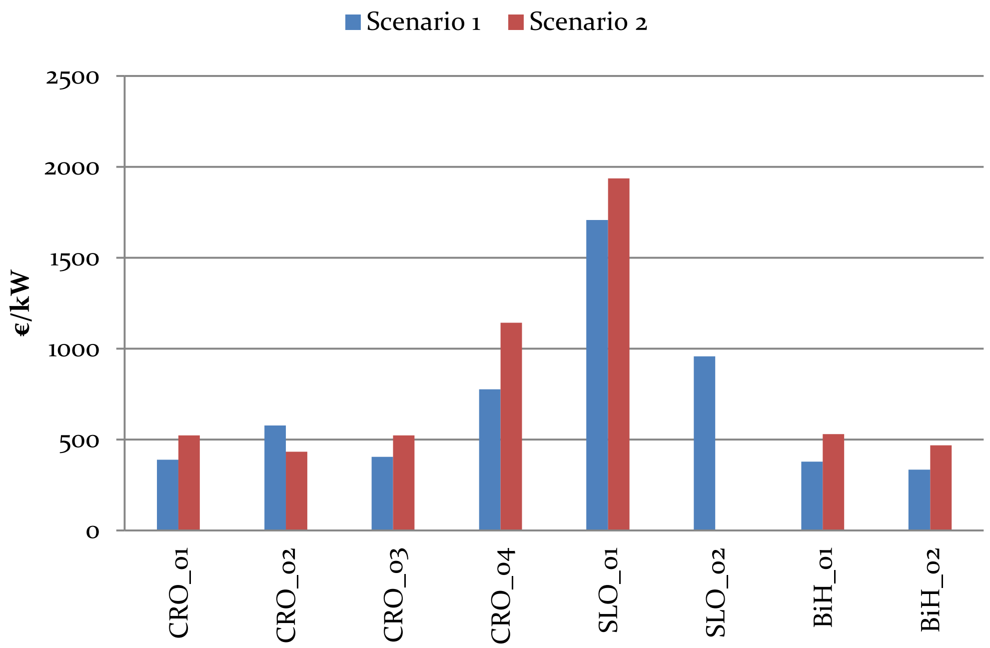

Figure 21: Absorption unit cost in analysed case studies

A little better picture of the costs of each case study is shown in Figure 22. Here is cost expressed per kW of absorption unit. Total cost is inversely proportional to the needed power of absorption unit. Most expensive cases (in €/kW) are cases SlO_01 and CRO_04 because there is a relatively small power of absorption unit while in the other hand, cases CRO_01, CRO_02, CRO_03, SLO_02, BiH_01 and BiH_02 are relatively cheap because of the higher power of absorption unit needed which is also related to energy demand shown in Figure 8.

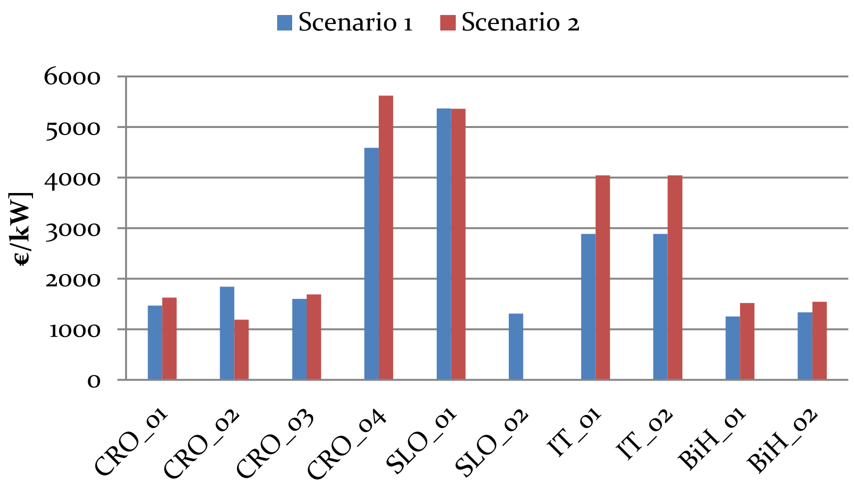

Figure 22: Total cost in analysed case studies

Next, with given costs, economic viability was calculated. Figure 23 and Figure 24 show Internal Rate of Return (IRR) for each study and scenario in case of 100%, 75% and 50% private investment while rest of funding is obtained from public funds. Figure 23 shows that every case except case studies CRO_04, BiH_01 and BiH_02 are feasible with 50% co-funding. The same thing is with scenario 2. For case study IT_01 and IT_02 IRR wasn't calculated. Every case study with 100% private investment is not feasible. This is due to the high cost of solar cooling technology.

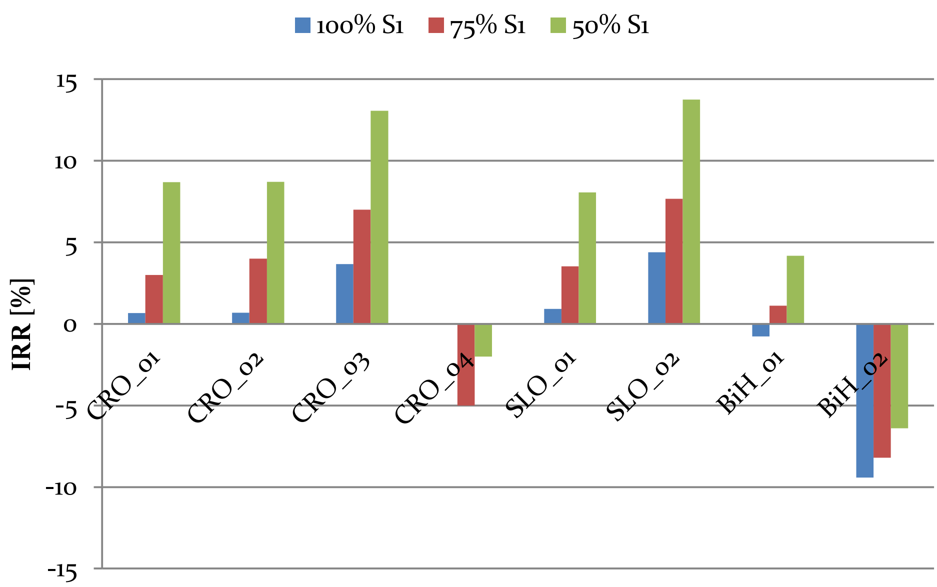

Figure 23: IRR in Scenario 1 of analysed case studies

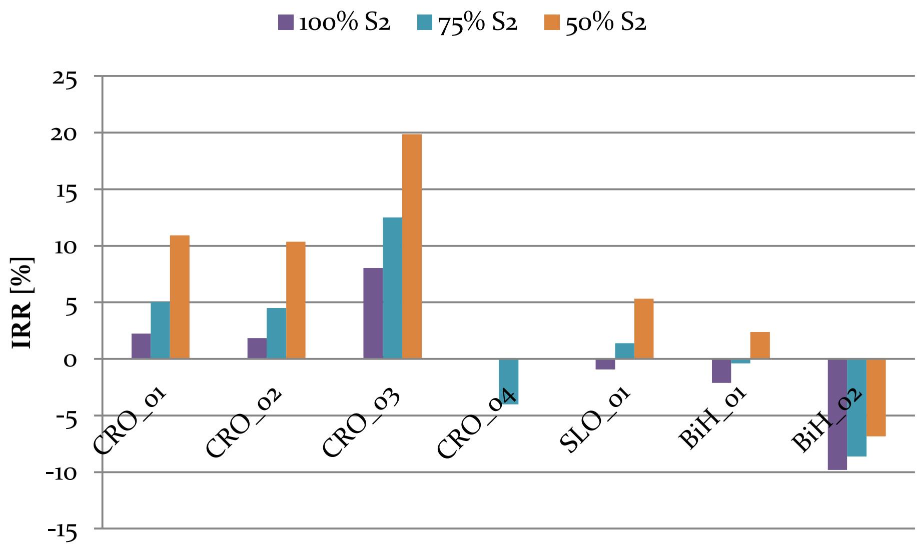

Figure 24: IRR in Scenario 2 of analysed case studies

Net present value (NPV) is shown in Figure 25 and Figure 26. In these Figures we can see that case studies IT_01 and IT_02 are feasible in case of both scenarios. A case study was considered economically viable if it had an IRR of 7%.

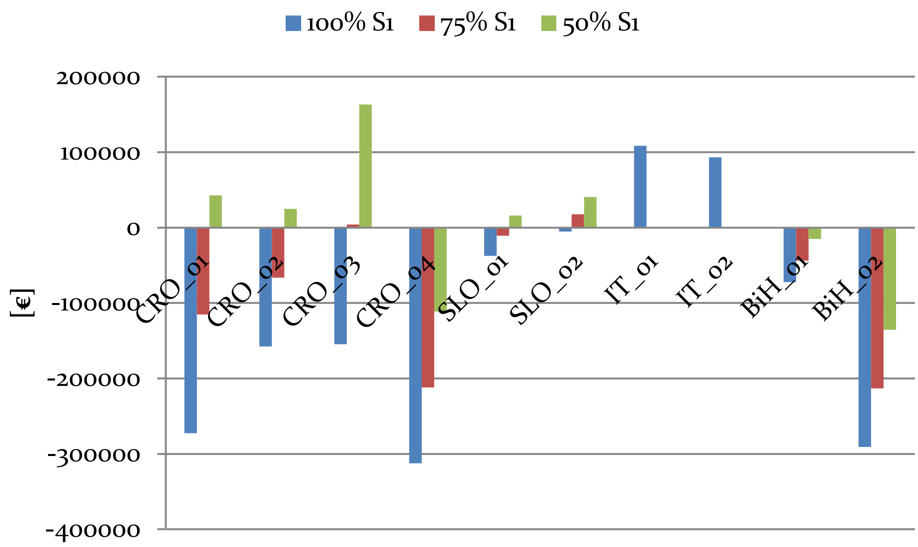

Figure 25: NPV in Scenario 1 of analysed case studies

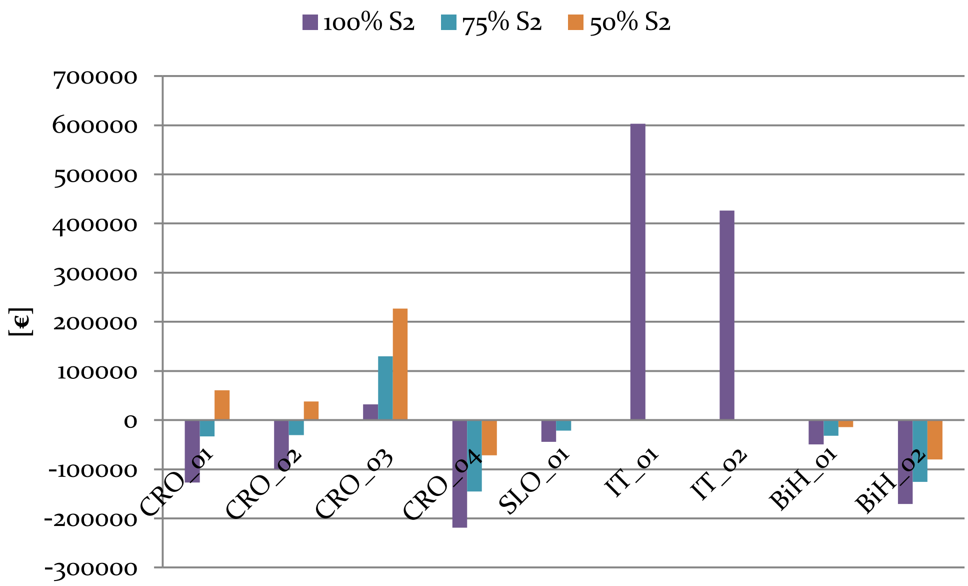

Figure 26: NPV in Scenario 2 of analysed case studies

Last payback period (PP) was calculated and shown in Figure 27 and Figure 28. The payback period is relatively small in every case study except case studies CRO_04, BiH_01 and BiH_02. This is also related to energy demand and the type of energy resource used. Most of buildings in studies, which are proven to be viable with co-funding from other resources, were using fuel oil to cover some of energy demand.

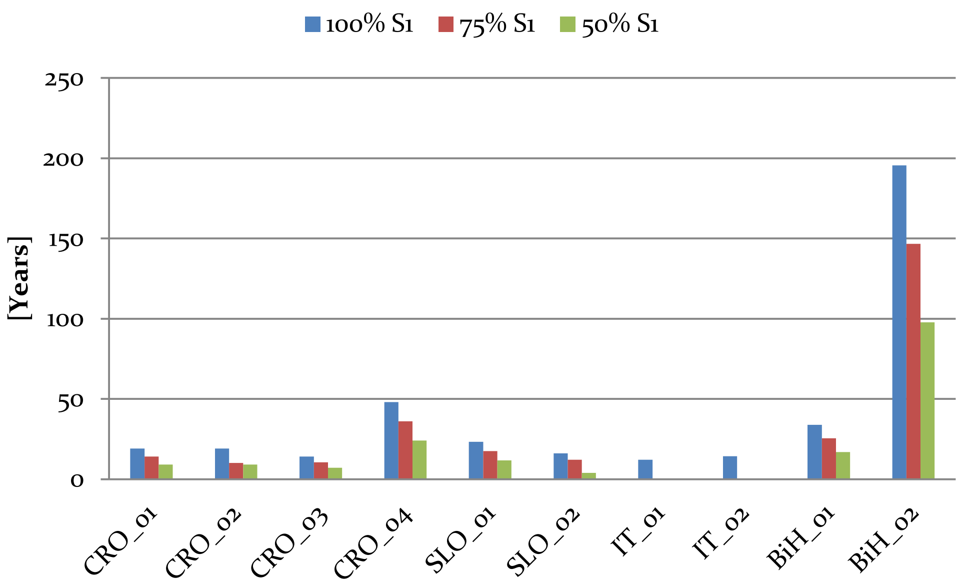

Figure 27: Payback Period in Scenario 1 of analysed case studies

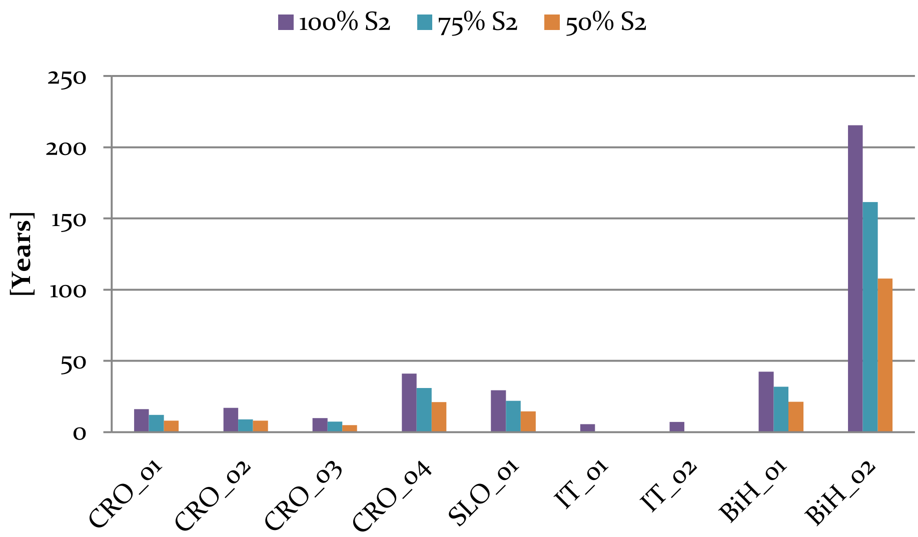

Figure 28: Payback Period in Scenario 2 of analysed case studies

From short and general economic analysis of each case study presented in the figures above, it can be concluded that almost every case study is not viable with 100% private investment. Relatively expensive solar cooling system is the most influential factor. In addition energy demand and type of energy resource used are also of big importance. It is recommended to continue investigating into the possibilities of implementing solar cooling technology as it could lower price of equipment and enable its installing into almost every building and location. This could result in more energy and CO_2 saving. As will be shown below, even this economically unprofitable case studies are achieving substantial amount energy and CO_2 saving.

6. Environmental analysis

Environmental impact of the solar cooling plant was studied regarding CO_2 emission and achieved energy savings due to decreased usage of fossil fuels. Figure 29 shows achieved energy savings in scenario 1 and scenario 2. It is shown that total energy saving is also related to energy demand. The higher energy demand of building is, the more energy will be saved as in case studies CRO_01, CRO_02 and CRO_03.

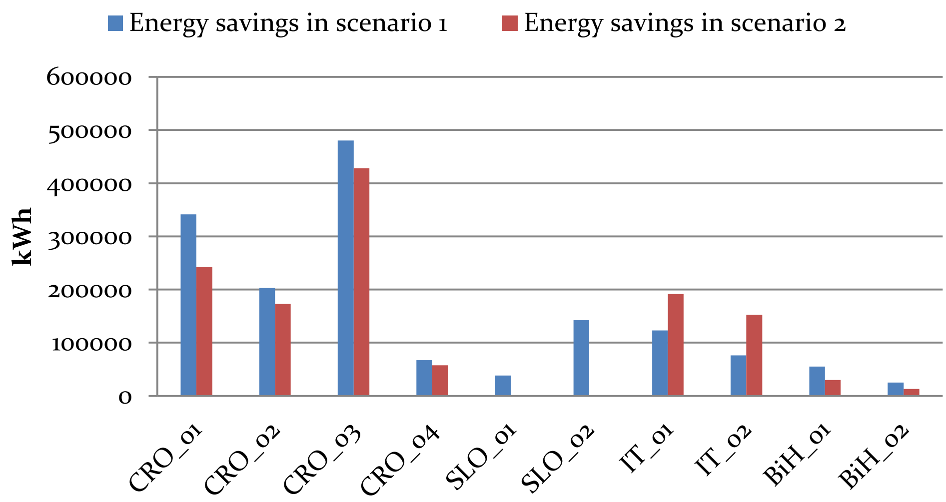

Figure 29: Total energy saving in ADRIACOLD case studies

Figure 30 and Figure 31 show total energy saved in scenario 1 and scenario 2 but with amount of electric energy saved and amount of fossil fuel energy saved.

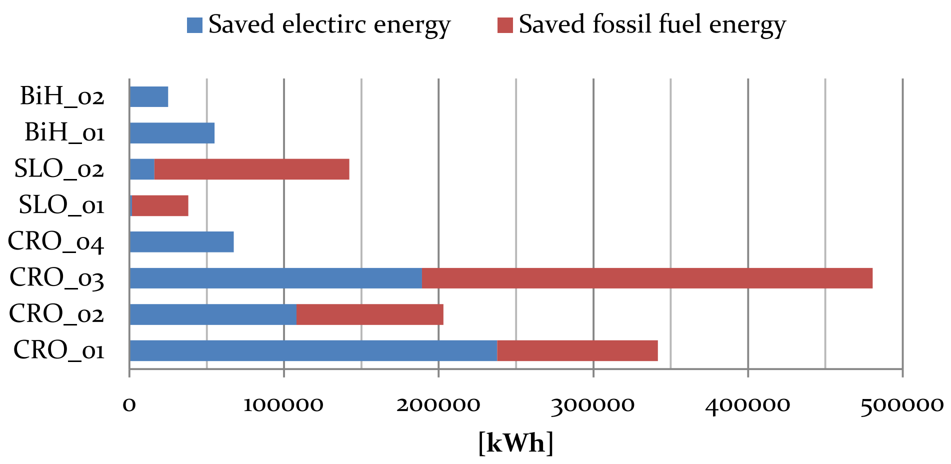

Figure 30: Energy savings in scenario 1 of analysed case studies

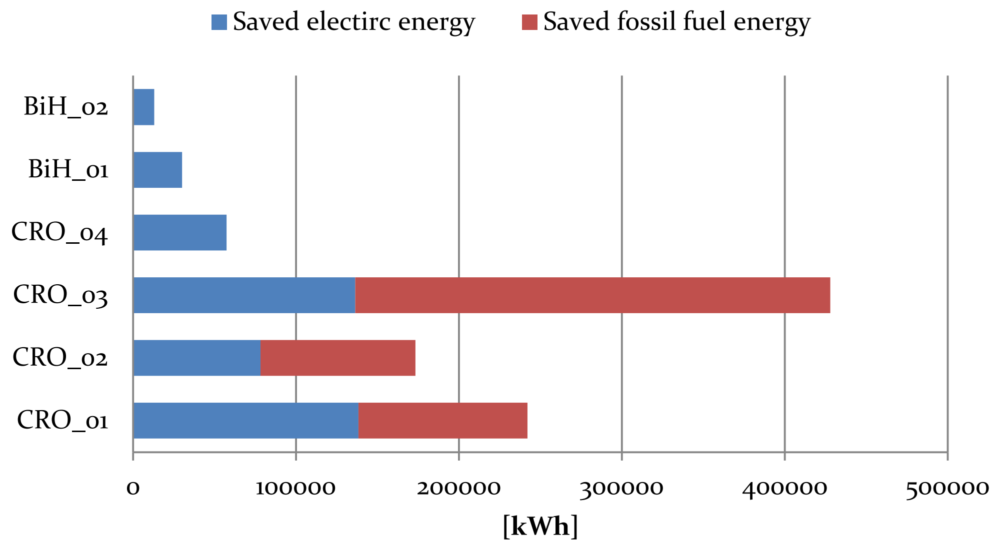

Figure 31: Energy savings in scenario 2 of analysed case studies

In some cases scenario 2 does not exist, like in case study SLO_01 and in some cases fossil fuel energy saving was not achieved because fossil fuel wasn't used (e.g. case study CRO_04, BiH_01 and BiH_02). For case studies IT_01 and IT_02 only total energy saving was given. Figure 32 shows CO_2 emission in kg of CO_2 per kWh energy used. For Croatia CO_2 emission for electricity and fossil fuel are nearly the same. In Italy this value of nearly 0.7 presents CO_2 emission per kWh of total energy used. In case studies in B&H only electric energy saving was achieved so there was no need to obtain value of CO_2 emission for fossil fuel. In case studies in Slovenia are the biggest differences between CO_2 emission for electricity and for fossil fuel.

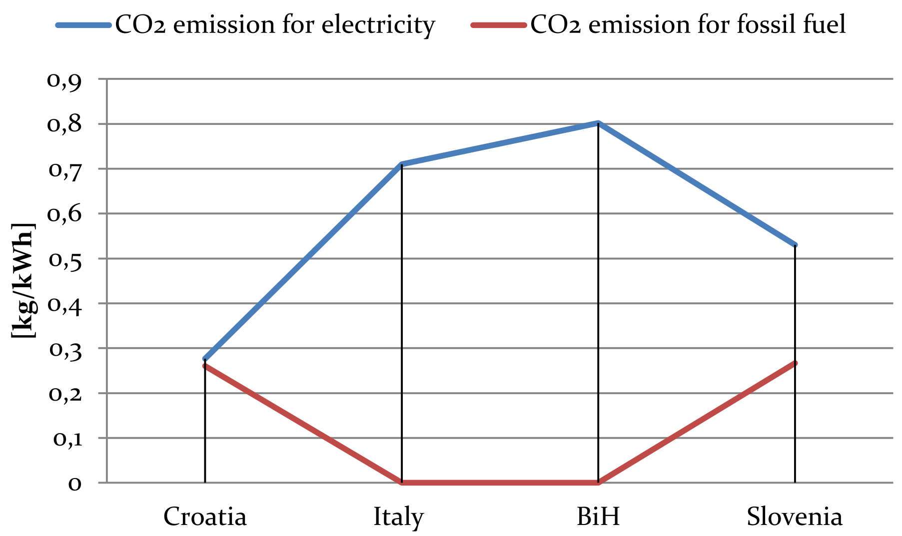

Figure 32: CO_2 emission

Finally, total CO_2 emission is shown in Figure 33. Case studies IT_01, in case of scenario 2, and case study CRO_03, in case of scenario 1, will achieve the highest CO_2 saving. Buildings in case studies, that were using fuel oil to cover some of energy demand, are achieving greatest CO_2 savings.

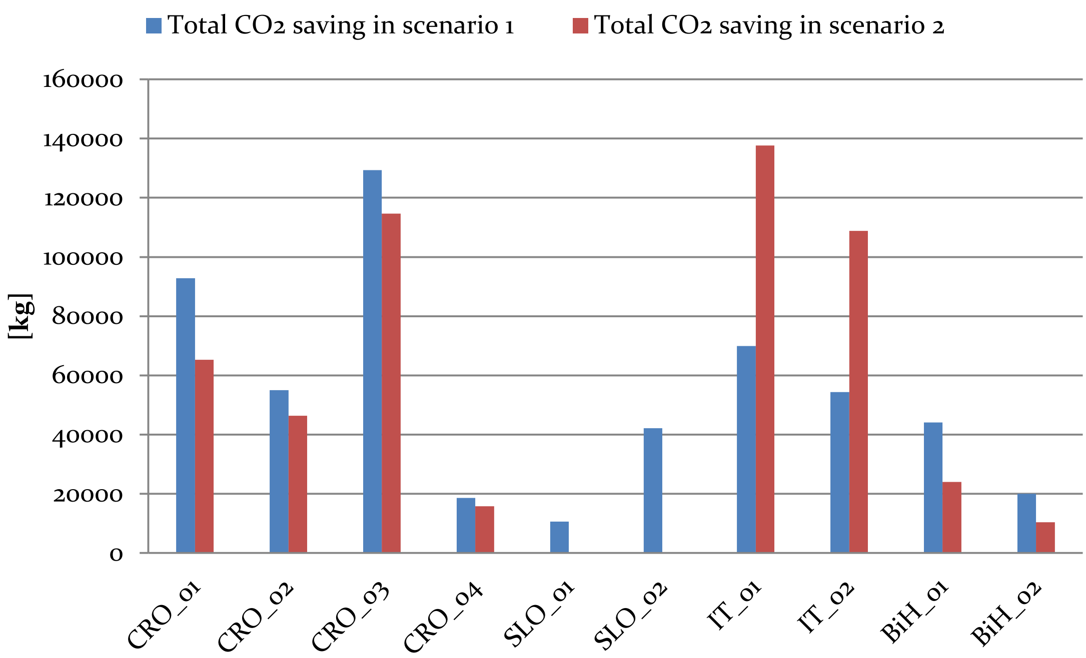

Figure 33: Total CO2 saving in ADRIACOLD case studies

7. Conclusion

At the end of each case study SWOT analysis is presented. Here will be shortly elaborated general SWOT analysis.

SWOT analysis	
Strengths	**Weaknesses**
• positive environmental impact • reducing electricity consumption • increased share of renewable energy sources • compatibility with existing systems • low operating costs	• high investment • need additional hot/cold storage buffer • dependence on the availability of solar radiation • need additional cooling/heating system
Opportunities	**Threats**
• expected increase of electricity price • expected decrease in prices of solar cooling equipment and technologies • expected growth of fossil fuels prices • European fund support project with renewable energy sources	• owners of buildings should make first step and invest in these systems • competitiveness of traditional technologies which are capable to cover peak load • profitability of investment in existing buildings with existing conventional cooling systems • low electricity price is not stimulating for energy efficiency investment

This SWOT analysis is just a short review of detailed SWOT analysis given in each case study. This analysis gives common strengths, opportunities, weaknesses and threats. Reduced CO_2 emission and electricity consumption are good strengths which could lead to detailed analysis of each case study to provide detailed and more accurate data since this were only prefeasibility studies. If showed that these locations could be feasible it would lead to increased interest in investment in solar cooling technology in other regions and cities with good insulation. Currently, only high investment could be a big problem since solar cooling technology is quite a new technology. Of course growth of prices, both electricity and fossil fuels could be motivating factor for new investors.

With increased research and development of solar cooling technology, it would be normally to expect a decrease of solar cooling equipment and technology. With still relatively low electricity and fossil fuel prices owners of buildings need to make the first step. Most of these building have conventional cooling and heating systems which are covering theirs demand.

From short elaboration of these case studies we can give some general recommendations for choosing buildings to implement solar cooling technology. Occupation of a building does matter. Buildings like hospitals, wellness centres and hotels generally have higher energy demands which are good for implementing this type of technology because it would achieve larger energy savings. Also related to this, energy resources currently used for heating and cooling also have a large impact on energy savings and viability of solar cooling technology. It is clear that buildings which use fuel oil for heating and hot water supply will have faster payback period, than building that uses only electricity to cover all of their energy demand. Buildings in case studies number 9 and 10 only use electric energy to cover all of their energy demands and it can be seen that their payback period is very long while buildings in case studies number 1 and 2, uses both fuel oil and electricity and their payback period is smaller and energy savings are larger. Also there it can be seen that, even if it is the same type of building (hotel) they achieved different energy saving due to energy resources used and number of people stayed in a hotel in their work period. Also an important factor for choosing into implementing solar cooling technology is solar insulation as shown in Figure 9. Places with high insulation should have priority.

Annex: Template for prefeasibility studies

Adriacold

"Diffusion of Cooling and Refreshing Technologies using the Solar Energy Resource in the Adriatic Regions"

Project Code: 2°ord./0030/1

Common methodology for pre-feasibility study of new solar cooling/heating system in selected building – general guidelines

Work Package:	
Action:	
Deliverable due date *(as in the AF):*	
Responsible partner:	
Editors:	
Deliverable code (if applicable only):	
First Created:	
Last Updated:	
Version:	

Table of Contents

1. Introduction

In this chapter, basic information about the project and locations is provided.

Furthermore, socio-economic context, as well as clear objective is provided. Discussion should consist of the links between national and EU legislative and the objectives.

Key points of national legislative are detected and project scope and objectives are shown to fulfil national legislative.

2. Solar thermal collectors

In this chapter, information about the technology is given in more detail, with graphic display of key features and statistics.

3. Solar cooling system

In this chapter, the idea of solar cooling system is presented in more detail, with appropriate graphic displays and explanations of system features and the ways it can be implemented.

4. Conditions on the site

This chapter gives full information about the site (hotel or hospital or some other public building) which will be further investigated in this study. Pros and cons about the site conditions are detected and being discussed.

4.1 Location

Description of the location, with key information regarding climate conditions, or some other important factors is presented. Road connections, public transport, as well as other important factors are being discussed.

4.2 Building

Technical features of the building that can make use of new heating/cooling system.

4.3 Heating/cooling system

Description of present solution for building's heating and cooling demands. Heat losses/gains are presented. Thermal comfort is being discussed.

4.4 SHW system

Description of present solution for building's SHW demands.

4.5 Energy consumption

Types of fuel or energy forms that are being used by the building's systems at present are being listed and evaluated.

4.6 Final consumption calculations

Total amount of energy that is being consumed by the building at present is provided.

5. Possible solutions

In this chapter, possible new solutions are being presented in some detail. Pros and cons of each study are presented.

5.1 Scenario 1

5.2 Scenario 2

5.3 Scenario 3

6. Financial analysis

In this chapter, financial details of proposed solutions are being discussed in some detail and different scenarios are being evaluated.

6.1 Scenario 1

6.1.1 Feasibility

Discussion about feasibility of proposed solution is held.

6.1.2 Sensitivity analysis

Discussion in some detail about influence of changes a few key factors on the feasibility of the proposed solution.

6.2 Scenario 2

6.2.1 Feasibility

Feasibility of proposed solution is discussed.

6.2.2 Sensitivity analysis

Discussion in some detail about influence of changes a few key factors on the feasibility of the proposed solution.

6.3 Scenario 3

6.3.1 Feasibility

Feasibility of proposed solution is discussed.

6.3.2 Sensitivity analysis

Discussion in some detail about influence of changes a few key factors on the feasibility of the proposed solution.

7. SWOT analysis

8. Conclusion

9. References