Conference Proceedings

EuroSun 2014

Aix-les-Bains (France), 16 – 19 September 2014

A method to guarantee the performance of solar cooling and heating systems

Amandine Le Denn[1], François Boudéhenn[2], Olivier Marc[3], Mihai Radulescu[4], Valentin Gavan[5], Edwige Gautier[6]

[1] Bureau d'étude TECSOL, Perpignan, France

[2] CEA LITEN INES, Le Bourget du Lac, France

[3] Laboratoire PIMENT, Université de La Réunion, France

[4] EDF R&D, Moret-sur-Loing, France

[5] GDF SUEZ, DRT CRIGEN Saint-Denis La Plaine, France

[6] Association ENERPLAN, La Ciotat, France

Abstract

As the French project MeGaPICS *Method towards the performance guarantee of solar cooling and heating installations* ends after 4 years of work, the output of the project are presented. The project dealt with improving the performances and the quality of solar cooling, heating and domestic hot water preparation installations. The main outputs are guidelines to help professionals to handle correctly a SHC project (from the design to the monitoring and maintenance phase) and a simple presizing tool, validated with several methods. The project outputs are available in French and for some in English in the webpage http://www.solaire-collectif.fr/index.php?pid=31.

Key-words: solar cooling and heating, guideline, presizing tool, performance indicators, guarantee, performances.

1. Introduction

The use of solar thermal energy for space cooling and air-conditioning is still not a widespread solution; it has to face to technical and financial barriers. Some key actions have been identified to enlarge the development of this application:

- additionally to the cooling production, the solar thermal has to be used all year long, for example for heating or for domestic hot water (DHW) production;
- the solar system must have good performances during its whole lifespan with very few breakdowns.

Since thirty years, several French and European R&D projects meant to increase the knowledge about solar cooling systems. Some project like ABCLIMSOL, SOLERA and SOLARCOMBI+ dealt with small scale and package sorption chiller solar cooling systems (SHC), while a French project called ORASOL proposed a comparison between several technologies and SHC systems and the ODIRSOL project proposed a TNRSYS-based software for sorption SHC installation. At the international level, the IEA SHC program Task n°48 named « Quality and support measures for solar air conditioning » confirmed the importance of the topic of increasing the quality of SHC installations.

In this framework, a new French project was set up in 2010, called "MeGaPICS" (Method towards the performance guarantee of solar cooling and heating installations). It was coordinated by the engineering company TECSOL. The partners were EDF R&D, GDF SUEZ, the laboratory PIMENT from the University of La Réunion, the CEA LITEN at the National Institute of Solar Energy (INES) and the French solar professional association ENERPLAN. The project began in January 2010 and lasted 48 month. The whole

doi:10.18086/eurosun.2014.07.17 Available at http://proceedings.ises.org

project cost was about 1200 k€ and it was granted by the French National Research Agency (ANR) with 560 k€.

The project consortium worked to establish a basis in order to go to a future guarantee of performance for SHC plants by:

- upgrading the knowledge of the system operating conditions,
- developing a simple and reliable method to evaluate and to plan the performances of the installations,
- creating best practices to design, to size, to operate, to maintain and to monitor SHC installations.

The MeGaPICS project focused on the solar cooling installation with sorption chillers producing chilled water (between 5 and 11°C) by converting solar heat at medium temperature (65 to 95°C). Indeed, the sorption units represent over 70% of all systems fed by solar thermal energy installed worldwide. As shown in Table 1, in 2013, about 13 manufacturers offered indirect single stage absorption or adsorption chillers with cooling capacities lower than 200 kW meant for small and medium scale markets.

Tab. 1: Single stage sorption chiller manufacturers (Boudéhenn F. & Al. 2013)

Country	Manufacturer	Model	Technology	Working pair	P [kW]	COP_{th} [-]
Austria	PINK	PC19	aBsorption	NH_3/H_2O	19.0	0.63
China	JIANGSU HUINENG	RXZ-11	aBsorption	H_2O/LiBr	10.0	0.70
		RXZ-23			23.0	0.70
		RXZ-35			35.0	0.70
		RXZ-58			58.0	0.70
		RXZ-115			115.0	0.70
		RXZ-175			175.0	0.70
Germany	AGO	Congelo 50		NH_3/H_2O	50.0	0.51
		Congelo 100			100.0	0.51
		Congelo 150			150.0	0.51
	EAW	Wegracal SE 15		H_2O/LiBr	15.0	0.71
		Wegracal SE 30			30.0	0.75
		Wegracal SE 50			54.0	0.75
		Wegracal SE 80			83.0	0.75
		Wegracal SE 150			150.0	0.75
		Wegracal SE 200			200.0	0.75
	INVENSOR	LTC 10 plus	aDsorption	H_2O/Zeolite	10.0	0.60
		HTC 18 plus			18.0	0.52
	SORTECH	ACS 08		H_2O/Silica Gel	8.0	0.60
		ACS 15			15.0	0.60
India	THERMAX	LT 1	aBSorption	H_2O/LiBr	35.0	0.78
		LT 2			70.0	0.78
		LT 3			105.0	0.78
		LT 5			171.0	0.78
Japan	MAYEKAWA	ADR-Noa Z3515	aDsorption	H_2O/Zeolite	105.0	nr
Japan	MITSUBISHI PLASTICS	AHP10	aDsorption	H_2O/Zeolite	10.0	0.45
		AQSOA-Z3515			88.0	
		AQSOA-Z3525			175.0	
Japan	SAKURA	SHL003	aBsorption	H_2O/LiBr	10.5	0.72
		SHL005			17.6	0.71
		SHL008			28.1	0.72
		SHL010			35.2	0.71
		SHL030			105.0	0.80
		SHL040			141.0	0.80
		SHL050			176.0	0.80
Japan	YAZAKI	WFC SC 5			17.6	0.70
		WFC SC 10			35.2	0.70
		WFC SC 20			70.3	0.70
		WFC SC 30			105.6	0.70
		WFC SC 50			175.8	0.70
South Korea	CENTURY Corporation	AR-D30L2			98.0	nr
		AR-D40L2			130.0	nr
		AR-D50L2			165.0	nr
		AR-D60L2			193.0	nr
United States	HIJC	ADCM1-060	aDsorption	H_2O/Silica Gel	185.0	0.70

This paper firstly presents the methodology used in the MeGaPICS project. Secondly, it explains the main output and presents the available documents like guidelines for professionals. In a third part, it finally more deeply describes the PISTACHE software, a tool to pre-design and evaluate sorption SHC system performances, and its validation process.

2. Specific objectives and methodology of the MeGaPICS project

The specific objectives of the MeGaPICS project were to create some engineering tools required to upgrade the quality of the SCH installations in the field of pre-design, design and installation phases and during their operation period. The goals are to increase the global and annual performances of the system and to be able to guarantee it in the future.

The main topics addressed in the MeGaPICS project were the following:

- the simplification of the theoretical simulation of the solar cooling systems,
- the standardization of the hydraulic scheme, the system performance indicators and the sorption chiller performances,
- the definition of the minimum levels of quality for the installation using min. and max. target values of the performance indicators,
- the edition of best practices for design and sizing, project planning, monitoring, exploitation and maintenance.

Additionally to a large bibliography of project results on the SHC topic, the partners based their work on their own knowledge and professional experiences of designing and operating solar, HVAC and solar heating and cooling installations. It was also decided to base an important part of the work and to run validation process thanks to the feed-back of existing SHC installation. The following existing SHC installations have been monitored and used during the project, all of them are also described in fact-sheet available on the website of the project (see §2) :

- « SOLERA » at the CEA LITEN INES in Chambery, France: a solar cooling and heating packaged installation for offices, in operation since March 2009, with a 4.5kW absorption chiller, a 30m² flat-plate collector field and ground heat exchanger (Chèze & Al., 2011).
- « RAFSOL » at IUT in Saint Pierre, France: a solar cooling installation for classroom, in operation since March 2008, with a 30kW absorption chiller a 90 m² double-glazed flat-plate collector field and an open wet cooling tower (Praene & Al. 2011).
- « SOLACLIM » at the CNRS-PROMES center in Perpignan, France: a solar cooling and heating installation for offices, in operation since July 2008, with a 7.5 kW adsorption chiller, a 25m² double-glazed flat-plate collector field and an adiabatic dry-cooler (Siré & Al. 2011).
- « SONNENKRAFT » at the General Solar Systems France Company head office at Haguenau, France: a solar cooling and heating installation for offices, in operation since July 2009, with a 17.5kW absorption chiller, two flat-plate collector field of 54m² and 62m² and a drycooler.

Some other results of installation from IEA SHC program Task 38 monitoring activity presented by Sparber & Al. 2009, were also used anonymously for the validation process.

Using the model of a SHC installation developed within the ORASOL project and O. Marc Doctor Thesis (Marc 2010) and presented by Pons & Al. 2012, the simulation work consisted in defining and quantifying the influence of key-factors on the performances of SHC systems. The sensitivity studies laid a solid scientific basis for the project and placed emphasis on the most important parameters that should be taken into account during the sizing process.

3. Output and available documents

Several tools and support documents have been developed during the project. Professionals can use it as pedagogic kit or to assist the design SHC systems; this measure should enable an increased reliability of the future SHC installations. The following tools are available:

- 4 guidelines to design and to pre-size medium and large scale SHC installations, to plan and to commission SHC projects, to operate, maintain and monitor installations,
- a simple calculation tool called PISTACHE to evaluate the performance of existing or planned SHC installations. Numerical as well as experimental methods were used in order to validate this tool, which can be used as a pre-sizing tool. It is available free of charge in French and English languages,
- a table to easily calculate the quality and the performance indicators of a SHC installation. The table is based on monthly energy balance as presented by Nowag & Al. 2012,
- standardized schemes for different architectures or configurations, targeting packaged and medium/large scale SHC installations,
- several fact sheets on existing SHC plants complete with technical and performance data.

In addition to these public available results, internal work was done. The theoretical modelization of an absorption chiller coupled with solar thermal collectors has been presented in the O. Marc Doctor Thesis (Marc 2010). In MeGaPICS, PIMENT laboratory re-used and simplified the models so as to drive sensitivities studies. Those studies lead to emphasis the most influent parameters on the main SHC installation performance, and were presented in several scientific publications (Letexier et Al. 2012, Semmari et Al. 2014). It was the basis used to develop a simple pre-design tool and to write pre-design and sizing best practice guideline.

To complete the theoretical approach, CEA LITEN INES began the development of a methodology so as to standardize the performance characterization of small scale and packaged solar cooling systems in semi-virtual test bench. This should be a first step for an international normalization of the test method for this application.

2.1. Standardized hydraulic schemes

As presented in Table 2, the hydraulic scheme were classified according the purpose or utilization of the solar energy as for space cooling, space heating, domestic hot water (n°1 to 5) and the presence of a back-up directly connected to the system. Two big configurations were identified: handmade systems for collective and medium and large scale application (n°A and B) and pre-fabricated, packaged systems for small scale applications (n°C and D). Twelve schemes were drawn to illustrate the energy flux and the component, as shown in Figure 1a and 1b.

Tab. 2: Example of existing installation and their configuration scheme

N°	Space Cooling	Space heating	DHW preparation	Hot back-up	Cold back-up	Example of existing installation
A1	✓	×	×	×	×	RAFSOL (FR), GICB Banyuls (FR)
A2	✓	✓	×	×	×	SOLACLIM (FR)
A3	✓	✓	×	✓	×	MACLAS (FR), SONNENKRAFT (FR)
A4	✓	×	✓	✓	×	VENELLES (FR)
A5	✓	✓	✓	✓	×	GIVAUDAN (FR)
B1	✓	✓	×	×	✓	DIREN (FR), Port Louis (FR), Kristal (FR)
B2	✓	✓	×	×	✓	Saint Maxime (FR)
B3	✓	✓	×	✓	✓	ISTAB (FR), CSTB (FR), UMSICHT (DE)
B4	✓	×	✓	✓	✓	
B5	✓	✓	✓	✓	✓	CRES (FR), ZAE Bayern (DE)
C	✓	✓	✓	×	×	SOLERA (FR)
D	✓	✓	✓	✓	✓	

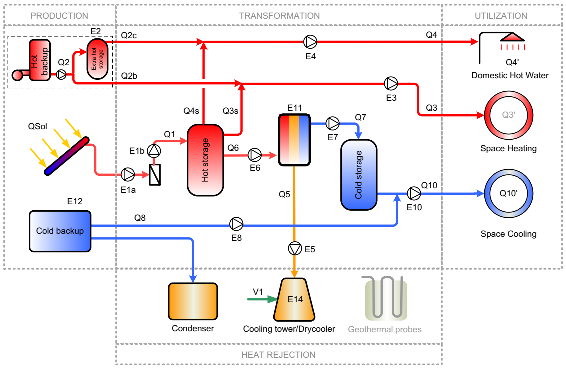

Fig. 1a: Scheme "B5"

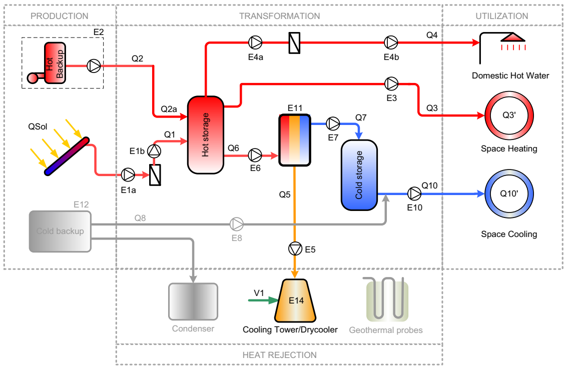

Fig. 1b: Scheme "C "

for use in space cooling, space heating and DHW production

2.2. Performance indicators

At a very early stage of the project, a list of several performance indicators were set-up, using the work done in Task38 [13] and according the MeGaPICS standardized hydraulic scheme. Those indicators are calculated according the thermal energies of the system (Qi) defined in Table 3 list, the electrical consumption of auxiliaries (Ei) and the water consumption.

Tab. 3: List of thermal energies according the standardized MeGaPICS scheme

Label	Description	Unit
Qsol	Total irradiation on the collector input surface	kWh
Q1	Solar thermal heat energy supplied to the hot storage tank	kWh
Q2	Total thermal heat energy supplied by the hot back-up	kWh
Q2a	Back-up thermal heat energy supplied for storage	kWh
Q2b	Back-up thermal heat energy supplied to the building (heating)	kWh
Q2c	Back-up thermal heat energy supplied to the building (domestic hot water)	kWh
Q3s	Solar thermal heat energy supplied for heating	kWh
Q3	Solar thermal heat energy supplied to the building for heating	kWh
Q3'	Heating requirements	kWh
Q4s	Solar thermal heat energy supplied for domestic hot water production	kWh
Q4	Thermal energy supplied for domestic hot water	kWh
Q4'	Domestic hot water requirements	kWh
Q5	Thermal heat energy rejected by the ab/adsorption machine	kWh
Q6	Thermal heat energy supplied to the sorption machine	kWh
Q7	Thermal cooling energy supplied by the evaporator	kWh
Q8	Thermal cooling energy supplied by the cold back-up	kWh
Q10	Thermal cooling energy supplied to the building	kWh
Q10'	Cooling or air-conditioning requirements of the building	kWh

The performance indicators are calculated over long period (season or year) as presented by Nowag & Al. 2012. Moreover, some target values have been defined for each selected indicators so as to define a zone of "good operating" conditions (Nowag & Al. 2012). The following list is an extract of the most used performance indicators:

- **Thermal efficiency indicators** : hot storage efficiency (η_{stc}), cold storage efficiency (η_{stf}), sorption chiller coefficient of performance (COP_{th}),
- **Solar performance indicators** : net solar productivity in kWh/m².year (PSU), electricity efficiency of the system ($COP_{elec\ sol}$), collector efficiency (R_{capt}) and solar system efficiency (R_{sol}),
- **Environmental impact indicators**: specific water consumption (CE_{spe}).

The application of the calculation method of the performance indicators to some monitoring data of some existing installation permits to compare them easily to their target values as shown in Figure 2. A calculation sheet is available on the MeGaPICS website for professional who wants to use this methodology.

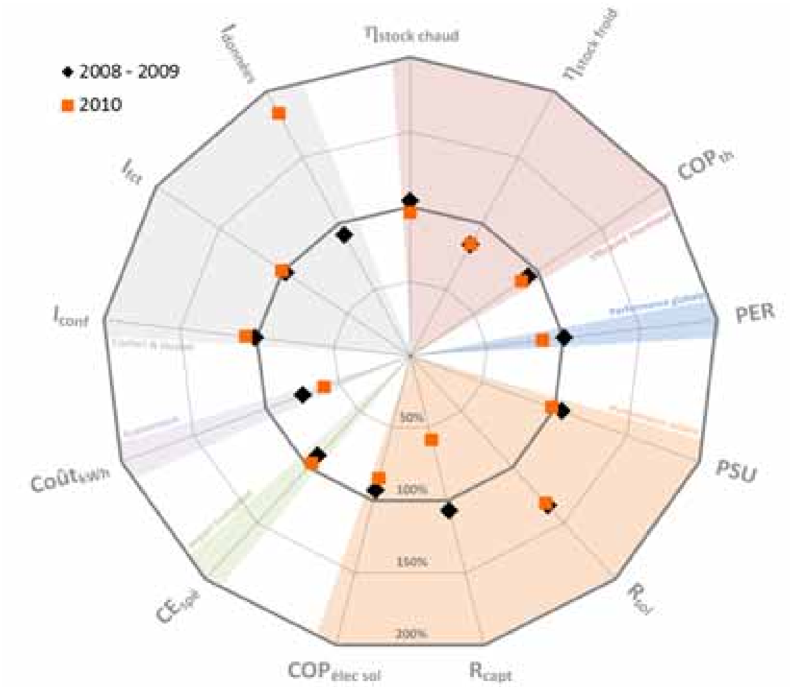

Fig. 2: Performance indicators and target values of the RAFSOL installation

2.3. Best practice guidelines

Best practice guidelines are important element to upgrade the quality. Several guidelines have been made available to the public; they can be used by professionals during the various steps of a SHC project.

Firstly, the main design and sizing rules like the selection of the hydraulic scheme, the calculation of the chiller capacity and the collector area, have been summarized in a guideline. This guide, only available in French, deals with handmade collective solar installation. It also presents the pre-design and sizing process for handmade calculations. A software is then necessary to evaluate the yearly solar production and the global performances of the installations. PISTACHE (Cf. §3) can be used for this purpose.

Secondly, a guideline for project planning was written. It is available in French, in the html format and gathers some model of documents which can be used during the whole process like documents for the call for tender, commissioning check-list, … Moreover, some technical specifications are summarized in factsheet detailed for each component: sorption chiller, heat rejection systems, principles of the control system, distribution equipment, back-up. Two other factsheet presents the characteristics of project in tropical and humid climate for one, the other provide a list of the standard applicable in France for the SHC project (in 2011).

Because the monitoring aspects are crucial to generate a guarantee of solar results, this topic has been treated in a specific guideline. The objective is to define a basic monitoring with a limited cost compared to the whole cost of the installation but with an adequate level of accuracy. The accuracy of the monitoring system not only depends on the measurement components ones, but also on their installation; it also has to be consistent with the treatment and the required information. Some specifications are then summarized in the guideline for telemonitoring. This public report, available in French but also translated in English and transmitted to IEA SHC Task 48, then provides some specifications about the measurement and monitoring equipment and their installation. It also presents the different standardized schemes (Cf. §2.1), the performance indicator calculation formulas and their target values (Cf. §2.2). In addition, some advices are given concerning the daily analysis of the SHC system, so as to perform a guarantee of "good operation".

Finally, a guideline of prescription to operate and maintain the SHC installation was developed by GDF SUEZ ; it addresses to the users of SHC installation, to O&M companies and to the technical in charge of maintenance of such systems. It consists in a list of maintenance actions, to prevent or to cure the main problems they can face. The document focuses on the action to make for each component of the installation (solar collector field, heat exchanger, storage and buffer tank, sorption chiller, heat rejection system, …). It is available in French.

2.4. SHC installation factsheets

Information factsheets were created about the installation used in the MeGaPICS project (Cf. §1). They aim to show case studies of design and sizing, and to give to professionals some references about key values like costs and performances. They are available in French in the website.

2.5. Website to download documents

The website was developed by ENERPLAN, a partner of the MeGaPICS project, as a page of a general French website about large scale and collective solar installation: http://ww.solaire–collectif.fr. The MeGaPICS project dedicated website is reachable through the subcategory *Froid solaire / MeGaPICS*. It makes available the various outputs of the project i.e the guidelines, factsheets as well as some references of some scientific publications and some information about the project itself and the partners. It aims to be a reference platform for French SHC projects.

4. PISTACHE software

The PISTACHE software has been developed as a tool to pre-size and evaluate the performances of solar installation for space cooling with sorption chiller, space heating and domestic hot water preparation. It can be used at an early stage of a solar cooling project, for feasibility study as well as to plan the performance of a realized installation. It is a simplified method which provides monthly and annual energy balance of a pre-defined configuration. The user has to provide a meteorological and load hourly data file, as well as basic information about the required installation. Some automatic pre-sizing functions can help him to select the main component characteristics.

The software has been wholly developed in the framework of the MeGaPICS project, by CEA LITEN INES and TECSOL. It is available since January 2013 for free in a French and English version by a simple demand using the following address: http://www.tecsol.fr/pistache. Up to now, more than 300 demands to download the software have been registered; most of them comes from French companies, but the interest is also rather high in the educational community as well as in the Maghreb countries.

4.1. Description of the tool

The user interface has been described by Le Denn & Al. 2013. It consists in 3 pages to filled-in in the appropriate order and 1 page of results:

1. General information and input file upload: the user will need to compile annual hourly data with the meteorological information of the selected site (horizontal global irradiation, outdoor temperature and relative humidity), the cooling and heating loads and the domestic hot water demand. The data must be provided in a text file with a specific extension name (*.mgp) which characteristics are detailed in the step by step help included in the software. The user also has to select the configuration of the installation between packaged and collective as defined in the MeGaPICS project (Cf. §2.1).
2. Simulation information and scheme selection: the user can select a scheme among the 12 scheme defined in MeGaPICS (Cf. §2.1) by defining the use of the solar installation (cooling + heating and/or DHW) and the presence of a hot and/or a cold back-up. It also provides some information about the operating conditions of the installation like the solar cooling period.
3. Component characteristic and sizing: as shown in Figure 3, each main component of the SHC installation has to be sized i.e the chiller, the solar collector field, the buffer and storage tanks, the heat rejection system and the hot and cold back-up. The sizing process is the same as defined in the MeGaPICS guideline for presizing (see §2.3). For each of them a pre-sizing functions and default values proposed values of the key parameters. The automatic calculation functions for the sorption chiller nominal capacity, collector area and storage tank volumes are presented by Le Denn & Al. 2013.

At the end of the step, the calculation can be launched, and the results are calculated. A summary of the whole installation and simulation parameters can be downloaded in a text file as an output.

4. Results: as shown in Figure 4, the monthly energy balance is presented in a table, also downloadable in a text file as an output. PISTACHE also calculates the main performances indicators and their target values as defined in the MeGaPICS project (Cf. §2.2). A short interpretation of the numerical results is

proposed, specifically to warn the user in case of oversizing.

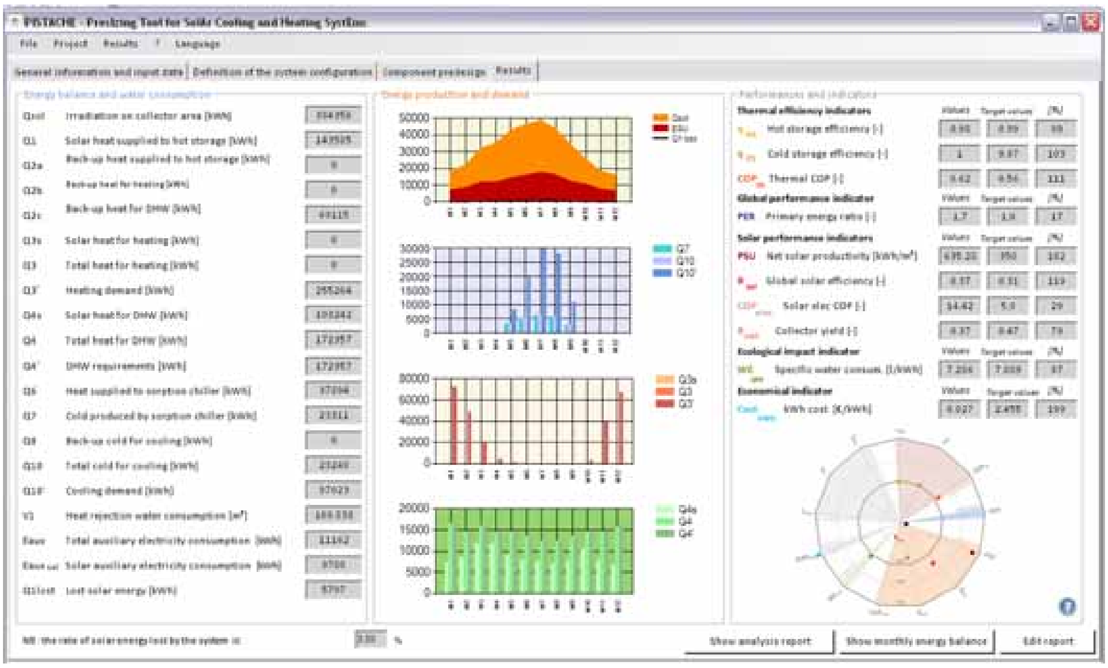

Fig. 4: Main result interface of PISTACHE

4.2. Validation of the tool

Several validations steps have been made on PISTACHE tool, they have been run on both the ALPHA and the BETA version of the software. The ALPHA version was the initial, non-encapsulated version of the tool and consisted in an Miceorsoft Excel version developed with the Visual Basic for Application language. The BETA version was created to encapsulate the tool, using Visual Basic.Net. It was controlled to get no differences between the two versions by comparing the results.

In the framework of the MeGaPICS project, general validation actions were operated so as to compare monthly and annual energy balance, as well as the main performance indicators, between the ALPHA version and the monitored installation listed in §1 of the present article, as described by Le Denn & Al. 2013.

Moreover, PIMENT laboratory of the University of La Reunion then proposed to do some more specific validation action, by identifying some internal parameters that influence the solar thermal production. The concerned parameters were coefficient of maximization and minimization on the thermal energy required at the hot inlet of the sorption chiller which defined its operating condition and coefficient to define the time heat loss constant of the hot and cold storage tank. The whole validation process was made by using the optimization program GenOpt, so as to reach the optimum set of PISTACHE parameters. Two configurations have been studied, using, for the identification, a first year of monitoring results of two related installations: RAFSOL for configuration A1 (solar cooling) and SONNENKRAFT for configuration A3 (solar cooling + heating). The values of the identified parameters were then introduced into PISTACHE source code, and the results compared to a second year of monitoring data. The difference obtained between the experiment (monitoring) and PISTACHE results are satisfying:

- 9 to 16 % on the yearly energy balance of RAFSOL (Q1, Q6 and Q7 as defined in Table 3),
- 3 to 10% on the yearly energy balance of SONNENKRAFT (Q1, Q6, Q7 and Q3 as defined in Table 3).

Finally, PIMENT laboratory also developed a numerical validation process, to compare PISTACHE to a numerical model developed with DELPHI only for configuration A1 (solar cooling). These models are presented in O. Marc Doctor Thesis (Cf. Marc 2010). Simulations were performed both with the PISTACHE tool and the DELPHI model for a whole year. The results show that 96% of the time, the error on the evaluation of COPth between DELPHI model and PISTACHE tool is lower than 20%. It can be concluded that PISTACHE tool has a coherent behavior towards another solar cooling simulation tool.

5. Best practice and lessons learnt

Many lessons have been learnt from the project. Based on this experience, the paper will advise on best practices, such as:

- An optimal use of solar energy : the combination between cooling and domestic hot water production is, in most of the cases, the best option, both in energetic and financial aspect,
- A detailed monitoring of the installations is compulsory to evaluate if they operate correctly. The start-up, adjustment and control phases have to be dealt with carefully.
- A sensibility analysis carried out thanks to simulation tools concluded that a solar cooling installation with steady loads inside the building and a medium solar radiation will have best performances than an installation with a very good solar radiation but unstable loads inside the building. Moreover, it seems important not to oversize the cooling production so as not to degrade the performance of a system. Sometimes, a backup system has to be installed to ensure comfort conditions inside the building.

6. Acknowledgements

This work has been supported by the MeGaPICS project “Method towards the performance guarantee of solar cooling and heating installations” co-financed by the French National Research Agency (ANR) within the framework of the HABISOL program.

7. References

Boudéhenn F. & Al. 2013. IEA SHC Task 48: Quality Assurance and Support Measures for Solar Cooling, Market overview of available chillers compatible with solar thermal energy, Solar Newsletter January 2013

Chèze D., Boudéhenn F., Papillon P., Mugnier D., Nunez T., 2011. Solera demonstrator of small scale solar heating and cooling system in INES office building. 30th ISES Biennial Solar World Congress 2011.

Le denn A., Boudéhenn F., Mugnier D., Papillon P., 2013. A simple predesign tool for solar cooling, heating and domestic hot water production systems. Proceedings of BS 2013: 13th Conference of the International Building Performance Simulation Association

Letexier, B., O. Marc, J-P. Praene, F. Lucas, Sensitivity analysis of a solar cooling system. ASME, July 2-4, 2012, Nantes, FRANCE.

Marc, O., Étude expérimentale, modélisation et optimisation d'un procédé de rafraîchissement solaire à absorption couplé au bâtiment, Université de La Réunion, Décembre 2010, 191 p.

Nowag J., Boudéhenn F., Le denn A., Lucas F., Marc O., Radulescu M., Papillon,P., 2012. Calculation of performance indicators for solar cooling, heating and domestic hot water systems. Energy Procedia. 30, 937-946.

ORASOL « Optimisation des procédés de RAfraîchissement SOLaire », ANR PREBAT 2006 n° ANR-06-PBAT-0009. LPBS Université de la Réunion, CNRS-PROMES, CNRS-LIMSI, LOCIE Université de Savoie, LATEP Université de Pau, CEA INES, TECSOL, CIAT. Avril 2007 durée 49 mois.

ODIRSOL “Sizing Tool for Solar Cooling Installation”, contrat ADEME n°0405C0087. TECSOL, CSTB

Pons M., Anies G.,, Boudéhenn, F., Bourdoukan, P., Castaing-Lasvignottes, J., Evola, G., Le Denn, A., Le Pierrès, N., Marc, O.,, Mazet, N., Stitou, D., Lucas, F., 2012. Performance comparison of six solar-powered air-conditioners operated in five Places. Energy. 46, 471-483.

Praene J.P., Marc O., Lucas F., Miranville F., 2011. Simulation and experimental investigation of solar absorption cooling system in Reunion Island. Applied Energy. 88, 831–839.

Semmari, H., O. Marc, J-P. Praene, A. Le Denn, F. Boudéhenn, F. Lucas. Sensitivity analysis of the new sizing tool “PISTACHE” for solar heating, cooling and domestic hot water systems. Energy Procedia 48 (2014) 997 – 1006

Siré R. & Al., 2011. Solar Cooling, an intelligent option, report SOLAIR Increasing the Market Implementation of Solar Air-Conditioning Systems for Small and Medium Applications in Residential and Commercial Buildings, EIE/06/034/S12.446612

Sparber W., Thür A., Streicher W., Henning H.M. 2009. Monitoring procedure for solar heating and cooling systems. Presentation IEA SHC Task 38 Solar Iar-Conditioning and Refrigeration.