MAIA-TAQA

MAIA-TAQA - Mobilizing new Areas of Investments And Together Aiming to increase Quality of life for All

Report on the Aqaba pilot project definition

WP3 Development of sustainable services in the MED area (pilot cases)

Output 3.1 Detailed design of the pilot project

WP leader: QUIPO

Responsible partner: Centre for Renewable Energy Sources and Saving - CRES

Date	Version	Comment
4/2/2020	1st	-

Contents

Abbreviations

AREC	Arab Renewable Energy Commission
ASCAME	Association of the Mediterranean Chambers of Commerce and Industry
CRES	Centre for Renewable Energy Sources and Saving
EBHE	Greek Solar Industry Association
ESTIF	European Solar Thermal Industry Federation
JOCC	Jordan Chamber of Commerce
NE	North-East
RE	Resource efficiency
RES	Renewable Energy Sources
SE	South-East
ST	Solar Thermal
SW	South-West

Abstract/summary

This report was elaborated in the framework of *Output 3.1 “Detailed design of the pilot project”* of the MAIA-TAQA project. The objective of this output was to identify the resource efficiency service to be piloted in Jordan and to specify the technical details of the pilot project in terms of beneficiary, location, technology and sizing. The effort was led by the Centre for Renewable Energy Sources and Saving, which cooperated with the Jordan Chamber of Commerce, MAIA-TAQA partner in Jordan, towards the definition of the pilot project. The partners followed a carefully designed methodology that included a desktop research, a series of roundtable discussions with important stakeholders, an onsite technical visit, and the employment of dedicated software for the elaboration of a feasible solution from a technical and economic point of view, taking into account end user requirements and project budget restrictions. The proposed solution is a solar thermal cooling system with a nominal capacity of 35 kW that will cover 50% of the cooling demand of the Aqaba Chamber of Commerce building in Aqaba.

1 Aqaba pilot project definition

1.1 Pilot Project Table Fact Sheet

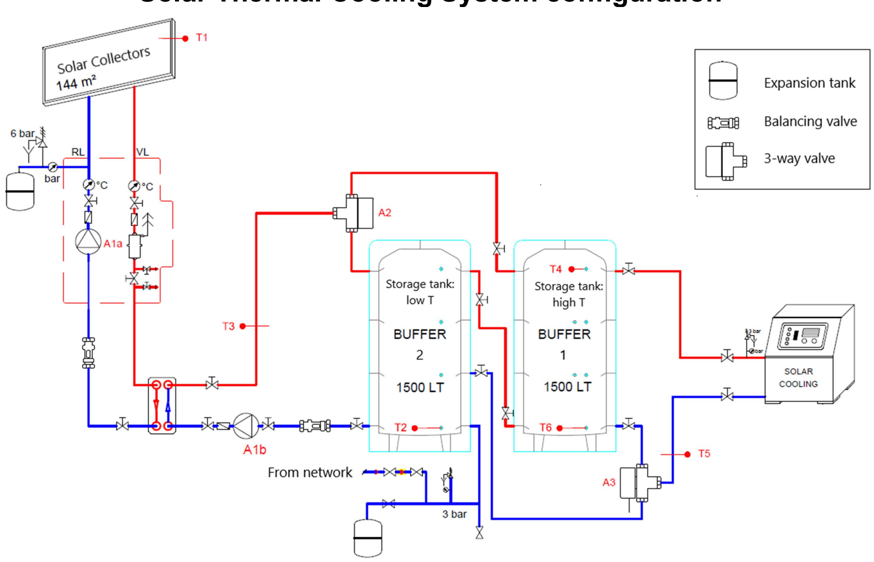
Pilot Project title: MAIA-TAQA Solar Thermal Cooling System in Aqaba

Resource efficiency technology: Solar thermal cooling system

Building: "Aqaba chamber of commerce", Jordan

Description of the Building / Site / Owner	**Technical Characteristics**
Owner: Aqaba Chamber of Commerce Location: Aqaba, Jordan Type of building: Office building Cooling area: Basement, ground floor and three floors of 450 m^2 each	***Solar Thermal Cooling System*** Solar collector type: Selective flat plate Solar collector aperture area: 144 m^2 Solar Cooling technology: Closed cycle Cooling system's type: Solar sorption (ab- or adsorption) chiller Nominal cooling capacity: 35 kW
General Description of the system The 1s pilot project in Jordan will be the implementation of a solar thermal cooling system at the office building of "Aqaba chamber of commerce" in Jordan. The solar thermal cooling system will be coupled with the existing central cooled water system and it will cover part of the cooling load of the building. The solar system will cover about 50% of the building's cooling energy demand.	***Configuration*** Heat storage: 3 m^3 (2 x 1500lt) Existing cooling system: Air cooled water chillers N° units: 2 Nominal cooling capacity 344 kW (2x172kW)

Solar Thermal Cooling System configuration



1.2 Methodology of the Aqaba pilot project definition

The methodology followed for the definition of the pilot project in Aqaba included the following phases:

- Pre-evaluation of the Resource efficiency (RE) service, pilot building and local market
- On-site technical visit
- Elaboration data and pilot project definition
- Simulation of the proposed pilot system

1.3 Pre-evaluation of the RE service and building and local market

During the pre-evaluation phase, the RE technologies with high perspectives in the area were examined through a desk analysis. The analysis focused in Solar Thermal (ST) technologies, since - according MAIA-TAQA project framework - ST energy is one of the target technologies to be applied in Jordan pilot project. For this reason, the ST market in Jordan was studied. According to the International Energy Agency (IEA), the total ST installed capacity in operation in Jordan by the end of 2017 for low and medium temperature applications is 882 MW_{th}, corresponding to 1,260,506 m^2 of solar collective area[1]. The main ST applications in the building sector are domestic hot water production, ST heating and ST cooling.

For the MAIA-TAQA pilot project in Jordan, the ST technologies with innovative features which could be applied in the pilot project were examined. Such a technology is ST cooling. ST cooling technology is based on the use of thermal energy generated by solar radiation, in order to feed/drive a cooling device, namely ST chiller. ST cooling systems can be classified into “closed systems” which have ST chillers providing cold water for the air conditioning of a building and “open systems” (air), based on the technology of evaporative cooling and dehumidification. The main components of a typical “closed” ST cooling system are:

- Solar field
- ST ab- or adsorption chiller
- Thermal storage
- Secondary hydraulic equipment: cooling tower, pumps, heat exchangers, piping, valves and connection with the auxiliary heating source
- Control system and (optional) remote monitoring.

Worldwide, the installed ST cooling systems has been growing rapidly from around 60 systems in 2004, to more than 1800 systems by the end of 2018 (IEA-SHC, 2019[2]). In the MED-countries, as according to IRENA[3], ST cooling is an important market since these countries are characterized by high cooling demand and high solar irradiation. In these countries, the rapid growth in the use of air conditioning units for cooling is creating peak loads to the grid. ST cooling technology is an

[1] Solar heat worldwide: Global Market Development and Trends in 2018 – Detailed Market Figures 2017. Weiss, W., Spörk-Dür, M., IEA Solar Heating and Cooling Programme (2019)
[2] IEA Solar heating and cooling programme (2019) Solar heat worldwide https://www.iea-shc.org/solar-heat-worldwide
[3] IEA-ETSAP and IRENA (2015) Technology Brief R12 www.irena.org/Publications

innovative technology, which can provide an effective solution to reduce those peak loads, since its efficient operation coincides with the highest cooling demand of a building.

Despite the substantial potential of solar energy to generate cooling especially in the MED countries, the current deployment level is low. One of the reasons for this, is the lack of experience and expertise on the implementation of this innovative technology, which is expected to be ameliorated through the implementation of the proposed pilot project.

The result of the desk analysis and the primary selection of ST cooling, as RE service in Jordan pilot project, was presented and discussed with important key actors in the Renewable Energy Sources (RES) field during the events indicated in Table 1. Key interviews were made during these events. The outcome of the discussions and interviews verified the choice of ST cooling as the RE service for the pilot project in Jordan.

Table 1: Events where the RE services to be applied in Jordan pilot project were discussed

#	Event	Date	Place
1	General Assembly of the Greek Solar Industry Association (GA of EBHE) (see Picture 1)	2nd of July 2019	Holiday Inn hotel, Athens, Greece
2	MAIA-TAQA internal meeting between CRES and EBHE (Chairman of Solar Heat Europe-ESTIF and Vice President of EBHE)	24th of September 2019	CRES premises, Pikermi, Greece
3	MAIA-TAQA Kick-off meeting – Round table discussion among CRES, JOCC, Arab Renewable Energy Commission - AREC, EBHE, ASCAME (see Picture 2)	2nd of October 2019	CRES premises, Pikermi, Greece

Picture 1: Presentation of MAIA-TAQA project in the GA of EBHE on the 2nd of July 2019

Picture 2: Round-table discussion on the pilot project in Jordan during the kick-off meeting of the project on the 2nd of September 2019

In parallel, there was a research for selecting the proper building where the ST pilot project in Jordan would be applied. The criteria taken into account were that the building should be located in an eligible area, the ownership of the building (owned by JOCC) and the existing system to be compatible with ST technology system without major renovation of the building.

The first examined building was the building of “Jordan chamber of commerce – JOCC” in Amman (see Picture 3). A questionnaire was created by CRES and filled in by JOCC, containing information about the building specifications, its uses and the installed energy systems (see Annex 1). Also, shading issues and the possibility to combine the existing installed cooling or HVAC energy system with a ST system were examined.

Picture 3: Building of “Jordan chamber of commerce – JOCC” in Amman, Jordan

The outcome of the analysis of the collected inputs showed that this building is not appropriate for the installation of a ST system for the following reasons:

- The roof is shaded by surrounding walls on the South-East (SE) and South-West (SW) sides. These walls, which were estimated at 4-5 meters, expected to cause shading problems as regards the installation of a solar collector field on the roof.
- The existing cooling system (15 outdoor split-system air conditioning units with total capacity 65.5 RT) is an air-conditioning system, which is not easily coupled with a ST

system, as it circulates a refrigerant and not water. In case of installing a ST system in this building, a new network of piping system should be installed, which would circulate water in fan-coil units.

The second building that was examined was the office building of “Aqaba chamber of commerce” (see Picture 4). Data collection and analysis for this building was also made, through exchange of e-mails, teleconferences, questionnaire (see Annex 1) and videos of the building. This building was found suitable for installing a ST system, after examining shading issues and the possibility of combining the existing installed cooling system with a ST system. The installed cooling system is central cooled water system, with two air cooled water chillers installed at the roof of the building. The existing central piping network system could be also used for the ST cooling system. The ST chiller could be connected in parallel or in series with the existing chillers. Besides, there is available space on the roof of the building without significant shadings for the ST collectors’ field implementation.

Picture 4: Building of “Aqaba chamber of commerce”

The exact location of the building in the city of Aqaba in Jordan is shown in Picture 5

Picture 5: Location of "Aqaba chamber of commerce" building

The meteorological data for the city of Aqaba in Jordan is shown in Table 2. This weather data reveals high solar potential (high irradiation), high cooling demand and no heating demand in the winter, which makes the implementation of a ST cooling system an appropriate selection. In Figure 1 the average outdoor temperature is illustrated.

Table 2: Meteorological data for Aqaba [4]

	Symbol	Unit	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Normal direct irradiation	B_n	kWh/m²	2,701	174	164	237	215	224	288	292	267	234	223	200	184
Minimum value (Power)		W/m²	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum value (Power)		W/m²	1,023	1,002	968	990	942	928	960	1,016	931	975	1,023	1,003	987
Diffuse irradiation, annual sum	D_h	kWh/m²	543	34.1	39.5	42.2	60.7	74.6	46.9	50.5	50.3	46.7	42.1	28	27
Minimum value (Power)		W/m²	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum value (Power)		W/m²	420	319	340	318	413	420	281	336	304	361	332	318	282
Global irradiation, annual sum	G_h	kWh/m²	2,196	115	129	191	207	230	249	252	233	194	162	125	110
Minimum value (Power)		W/m²	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum value (Power)		W/m²	1,127	726	813	937	982	1,052	1,068	1,127	1,015	966	912	761	672
Air humidity	H_{rel}	%	37.2	47.5	43.5	37	32.9	28.5	27.2	27.4	31.4	38.3	42.2	43.1	48
Minimum value		%	10.1	21.1	18.4	16.9	11	10.1	12.2	12	13.5	19.3	17.4	21.4	20.4
Maximum value		%	85.9	85.9	83.2	85.2	70.2	65.2	58.2	61	65.4	78.1	79.2	82.2	82.9
Long wavelength irradiation	L_h	kWh/m²	2,961	225	206	236	237	255	253	271	278	266	268	236	231
Minimum value (Power)		W/m²	261	262	261	275	270	288	318	326	338	334	309	290	264
Maximum value (Power)		W/m²	414	374	393	370	411	386	395	406	414	409	402	366	352
Outdoor temperature 24-h-mean	T_{amb24}	°C	26.1	15.8	17.6	21.6	25.5	29.7	32.8	35.1	34.6	31.7	28.4	22.4	17.7
Minimum value		°C	10.9	10.9	12.4	15.6	20.2	23	29.3	31.8	31.9	28.8	23.1	17.3	12.9
Maximum value		°C	39	20.6	24.2	28.6	32.4	35	37.4	39	37.7	36.5	32.7	28.1	23.2
Wind speed	V_{wnd}	m/s	4.6	3.6	3.7	4.4	4.6	4.9	5.4	4.6	5.3	5.5	4.8	4.4	3.7
Minimum value		m/s	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.1	0.2	0.3	0.2	0.2	0.1
Maximum value		m/s	15.1	11.3	12.1	12.8	13.7	13.6	14.3	13.8	14.9	15.1	14.1	13.4	12.2
Average outdoor temperature	T_{amb}	°C	26.1	15.9	17.7	21.7	25.4	29.9	32.8	35.2	34.6	31.6	28.3	22.3	17.6
Minimum value		**°C**	5.7	5.7	7.2	10	14.1	18.9	22.7	26.1	25.8	23.6	18.3	12	7
Maximum value		**°C**	44.9	26	30.2	34.8	38.4	41.4	43.5	44.9	43	41.2	38.3	33.8	29.3

[4] Source: Meteonorm database

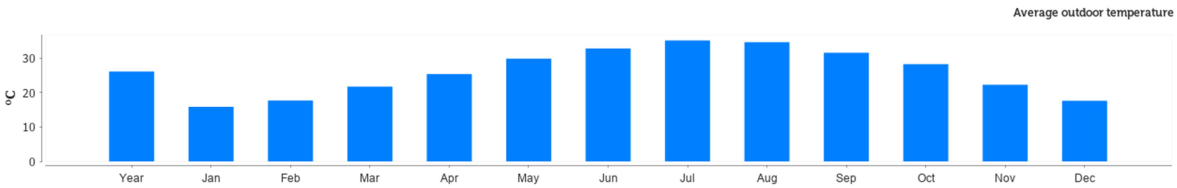
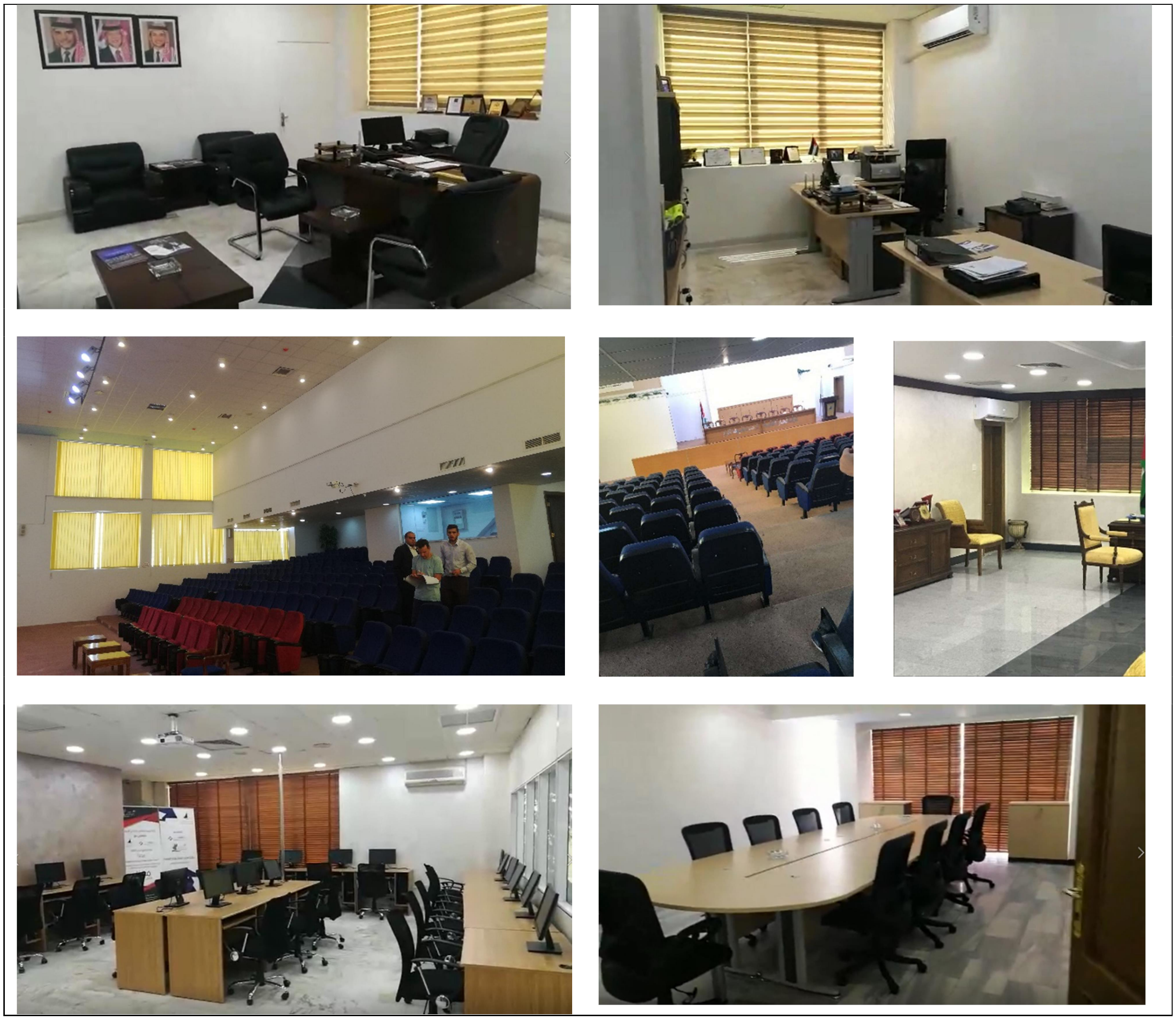


Figure 1: Average outdoor temperature in Aqaba city in Jordan

Regarding the general description of the “Aqaba chamber of commerce” building, it is an office building, with 21 working employees. The daily working hours are from 8:00 am to 3:00 pm (7 hours /day) and the weekly working days are from Sunday to Thursday (5 days /week). The building consists of a two-level basement, a ground floor and three floors. In the basement there are meeting rooms with computers, which are used for trainings. For events and conferences the auditoriums in the ground floor are used. The offices are mainly located in the 2^{nd} floor. The 3^{rd} floor is mainly used for meetings. The surface per floor is 450 m^2. The building also includes an open parking area of 1000 m^2, on the North-East (NE) side of the building. The type of use per level is given in Table 3.

Table 3: “Aqaba chamber of commerce” building uses per level

Level	Use	
	Type	**N°**
Basement	Public space	1
	office room	1
	meeting room	3
Ground floor	Public space	1
	Office room	2
	Auditorium	2
1^{st} floor	Public space	1
	Office room	4
2^{nd} floor	Public space	2
	Corridor	1
	Office room	7
	Meeting room	1
3^{rd} floor	Public space	2
	Corridor	1
	Office room	3
	Meeting room	1



Picture 6: Photos of indicative type of rooms of the building

The electricity consumption data, from electricity bills, for the period January 2017 till July 2019 are given in

Table 4 and Figure 2. In

Table 4, it is shown that the cost of electricity for the building is high. Specifically, the average electricity cost for the given period was 0.24 JD/ kWh. The two main consumers of the building are the cooling and the lighting systems. In Figure 2, it is illustrated that there are peaks in the electricity consumption during the months with high cooling demands. The variations in the diagram are related to the use of the building. As abovementioned, except for the use of the offices by the 21 employees of the building, the use of the rest of the building (auditoriums, meeting rooms for seminars, etc.) is occasional and not periodically. The building is underused most of the days of the year.

Table 4: Electricity consumption data from January 2017 to July 2019.

Year	2017		2018		2019	
Month	**kWh**	**JD**	**kWh**	**JD**	**kWh**	**JD**
Jan	3,600	809	3,300	771	7,492	1,798
Feb	5,250	1,233	3,750	900	4,050	965
Mar	3,750	848	4,800	1,189	3,150	724
Apr	8,550	2,018	9,600	2,514	3,300	764
May	27,000	6,823	17,400	4,651	4,200	1,005
Jun	29,550	7,478	1,950	431	5,700	1,405
Jul	15,450	3,871	12,300	3,340	2,850	644
Aug	9,750	2,390	12,300	3,340		
Sept	6,300	1,503	9,000	2,394		
Oct	9,150	2,218	8,100	2,143		
Nov	4,650	1,097	6,300	1,616		
Dec	3,450	784	4,650	1,134		

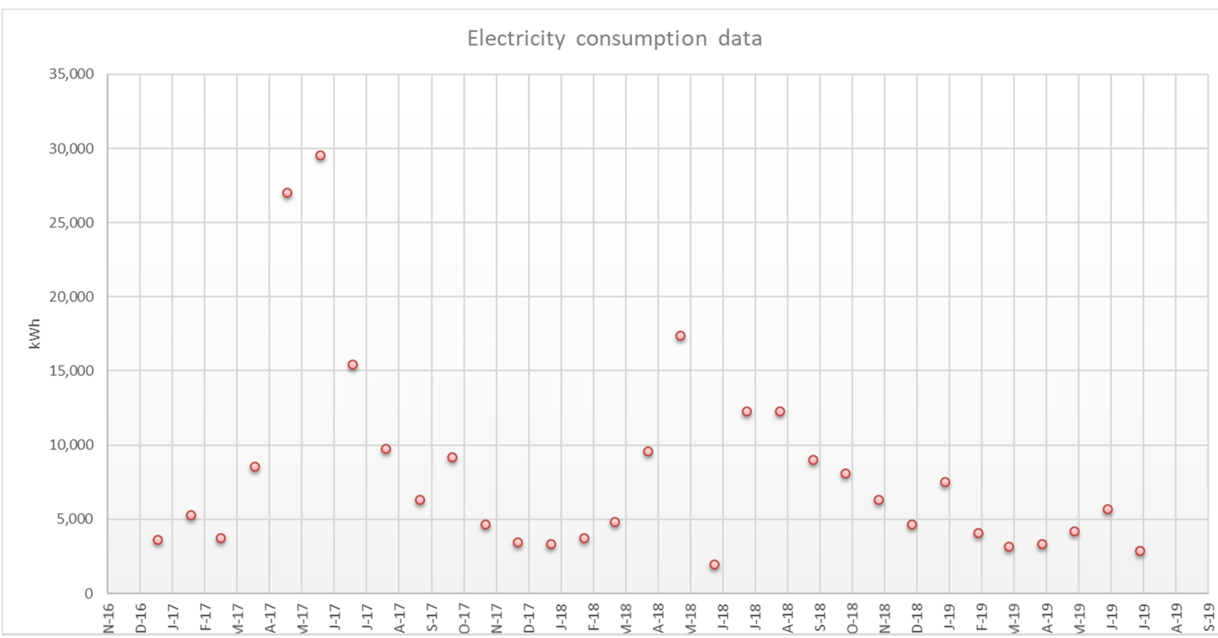


Figure 2: “Aqaba chamber of commerce” building’s electrical consumption data for the period January 2017 to July 2019

The pre-evaluation phase concluded that the 1st pilot project in Jordan will be implemented at the “Aqaba chamber of commerce” building in Jordan and the technology that will be applied will be ST cooling.

1.4 On-site technical visit

After the pre-evaluation of the pilot project, an on-site visit at the selected building of “Aqaba chamber of commerce” in Jordan was organised. The objective of the visit was to examine the compatibility of the building for the installation of a ST cooling system and to collect further necessary input for the pre-design of the ST cooling system.

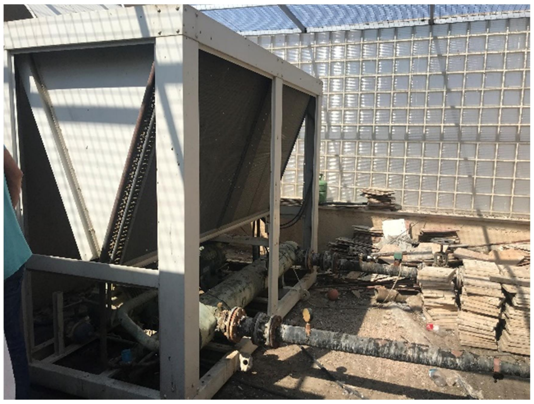
CRES team carried out the technical visit at the building of the “Aqaba chamber of commerce” building on the 10th and the 11th of October 2019. Personnel from the Arab Renewable Energy Commission – AREC, that officially supports technically JOCC, accompanied CRES team during the visit.

The on-site visit started with a meeting and discussion with the responsible for the building. The available documentation was collected, which included architectural and lighting drawings of the building. Then a walk-through inspection of the building was made, where the existing installed energy systems and equipment were identified and recorded. Emphasis was given to the cooling system of the building. Also, the air condition split units and the lighting system were recorded. Then electricity measurements were made. The findings of the technical visit were analyzed.

The existing main energy system for covering the cooling needs of the building is a central cooled water system. Two air cooled water chillers with reciprocating compressors, are installed at the roof of the building. The cooling capacity of each chiller is 49 RT and the total cooling capacity of both chillers is 98 RT. The chillers are connected with a central piping network system (with estimated flow rate 5.5 m^3/hr) distributing cooled water to the floors. The terminal units of the network system are 46 fan coil units (RAC system), installed in the ceiling of the floors (see Picture 8). There is also one Air Handling Unit (AHU) in the building, used for providing fresh air in the auditorium (see Picture 9). The main characteristic of the existing chillers and pictures of the existing central cooling system are given in Picture 7, Picture 8 and Picture 9.

Table 5: Existing chillers’ specifications

Chiller specifications	
Company	Petra
Model	APX 50-2D
Quantity	2
Refrigerant	R-22
Compressor type	Reciprocating
Inlet water temperature	12.7 ^{o}C
Outlet water temperature	7.22 ^{o}C
Cooling capacity	49.0 RT
Water flow rate	26.7 m^3/h
Number of condenser fans	2
Condenser fan type	Propeller
Number of rows	4
Fins/inch	12

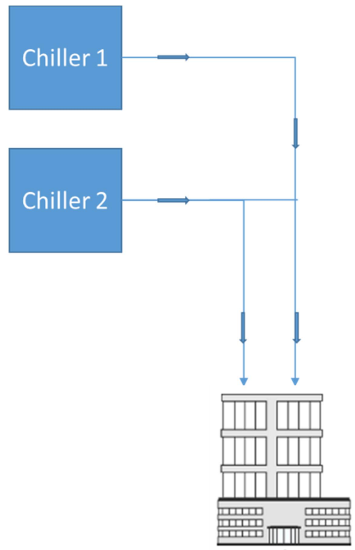



Picture 7: Existing chillers on the roof of the building


Picture 8: Fan coil units in the roof of the floors

Picture 9: Air handling unit for the auditorium of the building

For understanding the operation of the existing cooling system, the technical drawings and the distribution network of the central cooling system were requested by CRES. Despite the efforts of the Jordanian partners, these drawings could not be tracked down during the realization of this report. The technical documentation with the specifications of the installed equipment was collected and analysed. Based on the inspection and discussion with the users of the building during the on-site visit, it was concluded that each of the two chillers serve two different parts of the building (certain floors) and they do not cooperate. The first chiller covers the cooling demand of the basement and the ground floor and the second chiller is connected to the three floors. Besides, when needed – for example in case one of the two chillers is out of order – one chiller can serve the needs of the whole building (see Picture 10).



Picture 10 Schematic network connection of the chillers with the building

As abovementioned, for covering the cooling loads, besides the existing chillers, there is also a number of air-conditioning split-units installed in the building. The users of the building activate them on demand, when they feel that the cooling needs are not covered by the central cooling system. The main specifications of the split units are given in Table 6. The majority of the split units, manufactured by the company "Sharp" (14 out of 17) were new and recently installed. In Table 7 the distribution of the split units in each floor is given. In Picture 6 - where indicative type of rooms is presented - certain split units can be seen.

Table 6: Air-conditioning split-units specifications

	Air-conditioning split-units		
Company	SHARP (new model)	SHARP (old model)	CHICO
Cooling capacity	6.7 kW	6.7 kW	6.6 kW
Electrical capacity	1.875 kWe	2.84 kWe	2.3 kWe
COP	3.57	2.36	2.87
Quantity	14	3	7

Table 7: Air-conditioning split-units distribution per level

Total number of units	**SHARP (new)**	**SHARP (old)**	**CHIGO**	**Total**
3rd Floor	0	0	0	0
2nd Floor	12	0	0	12
1st Floor	0	2	2	4
Ground Floor	2	0	0	2
Basements	0	1	5	6
Total	14	3	7	24

In order to estimate the energy loads of the building, the rest of the building equipment contributing to energy consumption were identified and recorded. In Table 8 and Table 9, the type of the lighting systems and the distribution of them in each level are given. Also, the lamps that were in use during the on-site visit were identified and recorded, in order to calculate the actual energy loads of building.

Table 8: Lighting system specifications

	Lighting system specification		
Type	Linear Fluorescent (4 x 18 W)	Compact fluorescent lamp (CFL)	Spot
Power	72 W	26 W	50 W
Quantity	267	36	100

Table 9: Lighting system distribution

Total number of units	**Linear Fluorescent**	**CFL**	**Spot**	**Total**
3rd Floor	80	9	0	89
2nd Floor	101	8	0	109
1st Floor	15	14	65	94
Ground Floor	26	0	30	56
Basements	45	5	5	55
Total	267	36	100	403

During the on-site visit, electricity measurements were also made in the inspected building. CRES team recorded and analysed building's electricity consumption data for a typical working day (Thursday, 10th of October 2019) and a typical public holiday (Friday 11th of October 2019). During the working hours of the measurements, most of the spilt-units in offices with people working in them, were in use. Specifically, all the split units in the 2nd floor were in use, while the ones in the basement were closed. At the rest of the floors half of split-units were open. The total electric power of the lightings in operation during the working hours of the measurements was 10 kW, while the power for the no-operational lights was 15 kW.

For the measurements, a power analyser was fixed into the Low voltage main switchboard of the building (see Picture 11). The ultimate goal was to estimate the daily and weekly electricity consumption profile of the building and to estimate the cooling loads. The recorded data are illustrated in Figure 3. The recorded data reveals that during the evening of the10th of October one of the two chillers of the building were left in operation mode. The building was fully operative early in the morning (9:00-12:00pm). After midday (12:00pm-3:30pm) the building energy load was decreasing, as the people working in the building were leaving their offices, after switching off the equipment that they were using (spilt units, lighting, pc, etc).

Picture 11: Photos from monitoring works

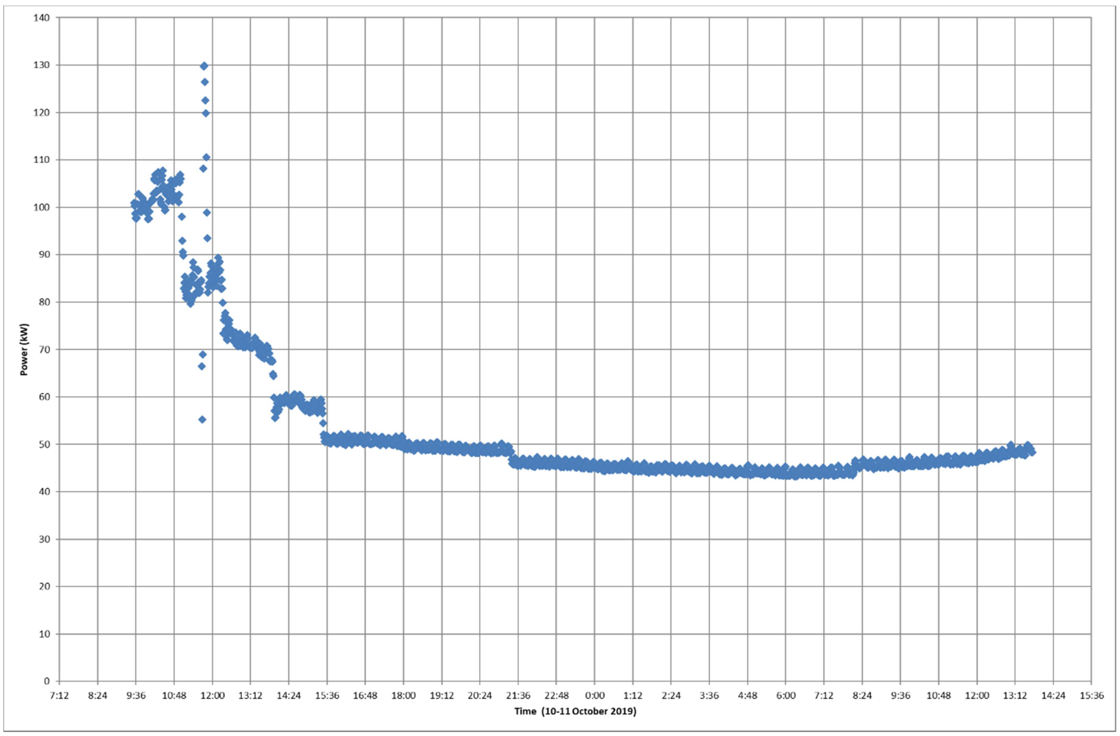


Figure 3: Electricity consumption data monitored in “Aqaba chamber of commerce” building (10-11 October 2019)

In Figure 4 the indoor and outdoor temperature, as monitored with appropriate equipment, is illustrated. The monitored outdoor temperature is within the given range of temperature for the month October in Aqaba according to the weather data presented in Chapter 1.3 (see Table 2). The indoor temperature was monitored with a thermometer placed in the second floor of the building.

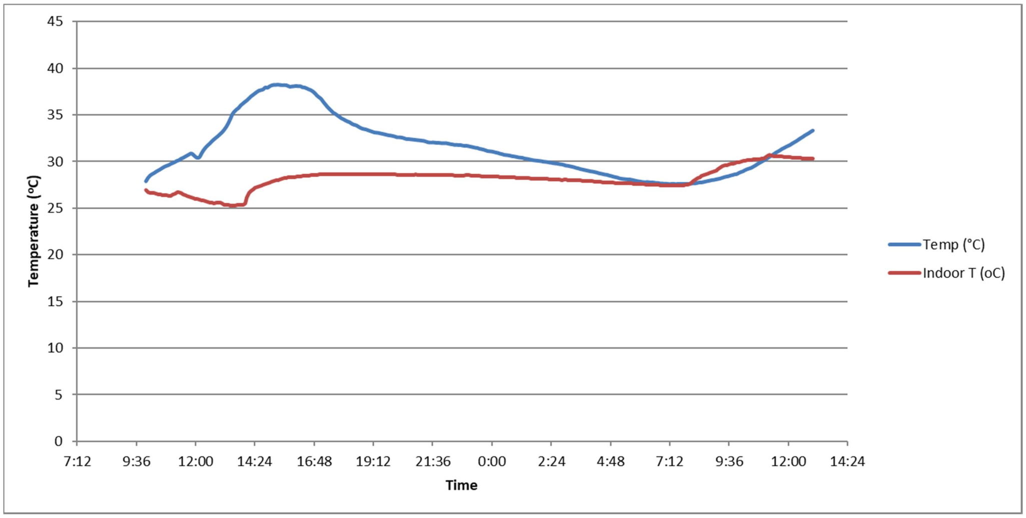


Figure 4: Indoor and outdoor temperature, as monitored, during the on-site visit in “Aqaba chamber of commerce” building (10-11 October 2019)

The recorded data of the existing equipment of the building were analysed and used as input in a building simulation program in order to calculate the design cooling loads of the building. The result of the analyses is summarized in

Table 10. Comparing the total cooling load (99.5 RT) with the existing capacity of the installed chillers (98 RT) it is shown that the existing system is at the limit of covering the building needs. Taking into account the decreased efficiency of the existing twenty-year old chillers, it is estimated that the existing system hardly covers the whole cooling demand of the building. The installation of a ST cooling system, with a small cooling capacity, is expected to improve the operation of the cooling system of the building.

Table 10: Calculated design cooling loads of the building

Level	Type	Persons (designed)	Cooling load	
			kW	RT
1st Basement	Office room B.1	5	5.31	1.51
	Public space B.1	0	8.96	2.55
	Meeting room B.1	20	6.15	1.75
	Meeting room B.2	20	12.15	3.45
	Meeting room B.3	20	8.88	2.53
Ground floor	Office room G.1	5	7.16	2.04
	Office room G.2	1	4.14	1.18
	Public space G.1	1	4.23	1.20
	Auditorium G.1	50	21.47	6.11
	Auditorium G.2	200	81.03	23.04
1st floor	Office room 1.1	5	8.42	2.39
	Office room 1.2	1	4.87	1.39
	Office room 1.3	10	4.90	1.39
	Office room 1.4	2	7.02	2.00
	Public space 1.1	1	7.44	2.12
2nd floor	Office room 2.1	2	4.40	1.25
	Office room 2.2	1	1.72	0.49
	Office room 2.3	1	1.18	0.33
	Office room 2.4	5	6.20	1.76
	Office room 2.5	2	5.54	1.58
	Office room 2.6	4	15.17	4.31
	Office room 2.7	2	7.43	2.11
	Meeting room 2.1	40	18.73	5.33
	Corridor 2.1	0	3.99	1.14
	Public space 2.1	3	2.11	0.60
	Public space 2.2	1	9.80	2.79
3rd floor	Office room 3.1	5	20.98	5.96
	Office room 3.2	1	4.50	1.28
	Office room 3.3	2	7.00	1.99
	Meeting room 3.1	45	32.59	9.27
	Corridor 3.1	0	5.64	1.60
	Public space 3.1	2	3.73	1.06
	Public space 3.2	1	7.07	2.01
Total cooling load			**349.92**	**99.50**

An important part of the on-site visit was to identify suitable space for the ST system equipment, to examine shading issues and to find ways to couple the ST system with the existing cooling system. To this end, the roof of the building was thoroughly inspected. The inspection resulted in the conclusion that the most suitable place for the solar collector field is the roof of the building (see Picture 12). The roof of the building is covered with tiles, which will be taken into account for choosing the appropriate bases for the solar collectors' field.

Picture 12: Available place for the solar collector field on the roof of the building (SW and NE sides of the roof)

Analytic measurements of the existing available space in the roof were recorded. These data were used for the simulation of the ST system, given in the next chapter. The recorded measurements resulted in the drawing given in Figure 5. The most suitable side of the roof for the solar collectors is the SW side of it, where currently two containers are installed. These containers will be removed, in order to maximize the available space for the solar collectors. Certain collectors will also be installed in the NE side of the roof, after taking into account the shading by the wall of the top floor in the internal part of the building. Other available space for solar collector fields, such as the parking area of the building, was rejected because of the expected increase of cost of the ST system and because of the expected complexity of the ST system. Furthermore, the ST cooling system will be coupled with the existing electric chillers, which are installed also in the roof of the building.

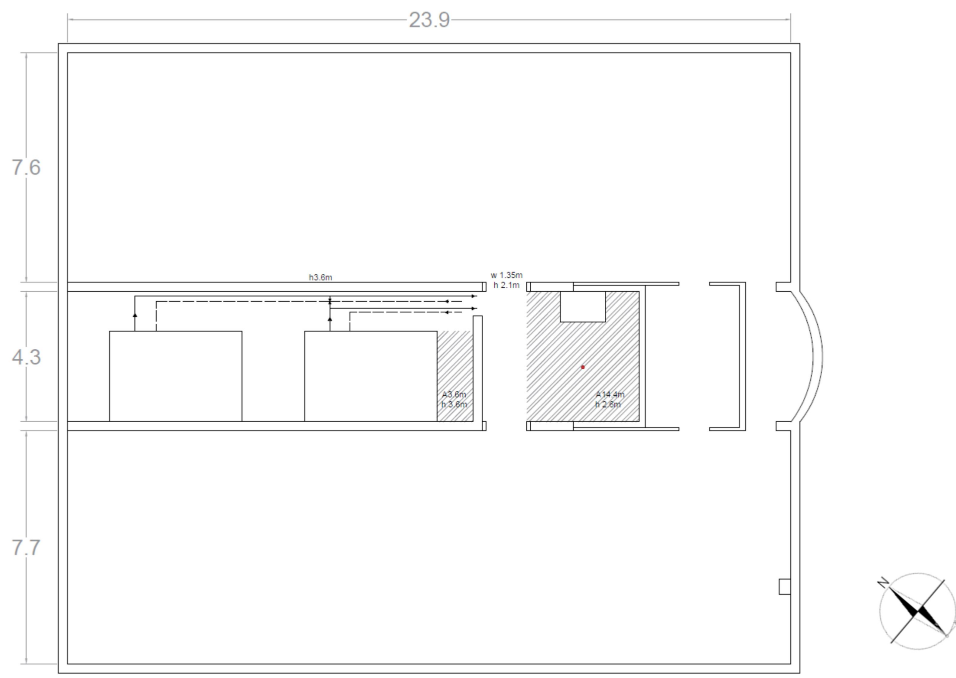


Figure 5: Layout of the roof of the building as measured during the on-site visit

Appropriate place for the rest of the ST system equipment (ST chiller, hot water tank, heat exchanger, etc) was also examined during the on-site visit. This place, is proposed to be the room on the top floor on the roof of the building, where the collectors will be installed (see Picture 13). The geometric characteristics of the selected ST system equipment should take into account their location in the existing room of the building (room height 3.21m, door width: 1.46m, door height 2.1m).

Picture 13: Potential place for solar thermal equipment installation

For ensuring the suitability of the water to be used in the ST cooling system, a quantity of water circulating in the public Aqaba' network was collected during the technical visit and taken for chemical analysis. The results of the analysis shown that the water in Aqaba city is suitable for the ST system implementation and for choosing a water cooling tower – instead of an air-cooled system - in the ST cooling system (see Annex 2).

The analysis of the findings during the on-site visit showed that the existing central cooling system, with certain piping modifications, can be coupled with a ST cooling system. However, the inspection of the existing central cooling system has shown that it didn't seem to work efficiently. This could be due to a variety of reasons (e.g. low performance of the existing chillers, low performance of the air-handling units and/or fan-coil units, incorrect dimensioning of the terminal units etc.) that it could not ascertained definitively during the brief on-site visit of CRES team. For this reason the users of the building regularly use the air-conditioning split-units for their cooling needs. Some of the problems, identified during the on-site visit are:

- Air from fan coils at 3rd floor was not satisfactorily cold, even though thermostats were set to 10^{o}C
- Most of the time only 1 compressor – from the two available - was in operation, even though the 3rd floor was not cold enough
- Building users complain that the central cooling system is not enough. That's why they have installed air-conditioning split units.

The outcome of the inspection of the existing cooling systems was presented to Jordanian partners and necessary actions were taken. Among them was the inspection of the system by the company that had provided the chillers and that has an ongoing service contract with ACC. Among other, the inspection has shown that there was a failure in the second compressor of the chiller covering the cooling needs of the 3rd floor of the building. This problem was fixed during the inspection.

However, before applying the new ST cooling system, a detailed engineering inspection of the existing cooling system should be carried out. Moreover, it is proposed that the two existing water distribution networks -one for each existing chiller- (see Picture 14) should be connected. This can be applied by using a water distribution collector, which will be connected with all the two existing chillers. The proposed connection of the ST system with the existing cooling system is described in Chapter “*1.5 Technical description of the pilot project*”.

Picture 14: Existing water distribution network of the two installed chillers

Concluding, the main outcomes of the on-site technical visit in the building of “Aqaba chamber of commerce” in Jordan are:

- The “Aqaba chamber of commerce” building is suitable for installation of a ST cooling system
- The most suitable place for installing the ST cooling system is the roof of the building
- The existing cooling system, with certain piping modifications, can be coupled with a ST cooling system
- During the on-site visit the existing central cooling system did not seem to work satisfactorily. This is probably the main reason why the users of the building often deem it necessary to use the air-conditioning split-units on a regular basis.
- In order to make sure the effectiveness of the coupling of the existing cooling system with the new ST cooling system, it is very important that the functionality and efficiency of the existing cooling system should be ascertained. For this, before applying the new ST system, a detailed engineering inspection of the existing cooling system should be carried out.
- The two existing water distribution networks -one for each of the existing chillers- should be connected.

1.5 Technical description of the pilot project

The outcomes of the pre-evaluation phase and the on-site technical visit, were used for the selection of the system for the pilot project in Aqaba. CRES examined several system configurations and made the energy simulations for each of them, using the simulation software "Polysun – Designer", version 11.2. The alternative ST systems and their configurations were also discussed with EBHE. The outcome of this procedure resulted in the definition of the ST cooling system for the 1st pilot project in Jordan. The proposed system is described in the following paragraphs. The energy simulation of the proposed system and the main results of the simulation are given in paragraph "*1.6 Simulation results of the pilot system*".

1.5.1 Description of the system

The first pilot project in Jordan will be a ST cooling system, which will be coupled to the existing cooling system, and it will contribute to cover part of the cooling loads of the building of "Aqaba chamber of commerce" in the city of Aqaba, in Jordan.

The proposed ST cooling system, shown in Figure 6, consists of the following main components:

A. Solar flat plate collectors (~ 150 m^2)
B. Thermal energy storage tanks (2 x 1500 lt)
C. ST chiller (~ 35kW)
D. Secondary hydraulic equipment (cooling tower, pumps, heat exchangers, piping, valves and connection with the auxiliary heating source, etc.)
E. Control system

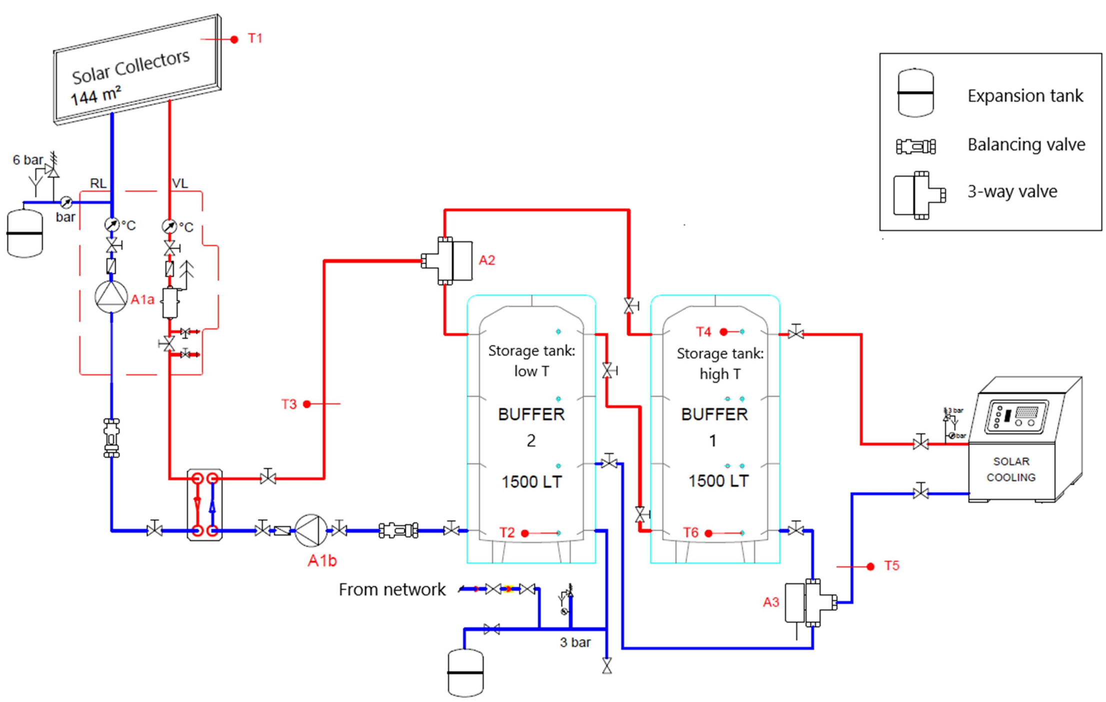


Figure 6: MAIA-TAQA 1st pilot project ST cooling system configuration

The ST cooling system will have the first priority to cover the building cooling loads, during summer and throughout all season. The solar collectors of the system, will be installed on the roof of the building, as shown in Figure 7 and they will be grouped into solar collector fields.

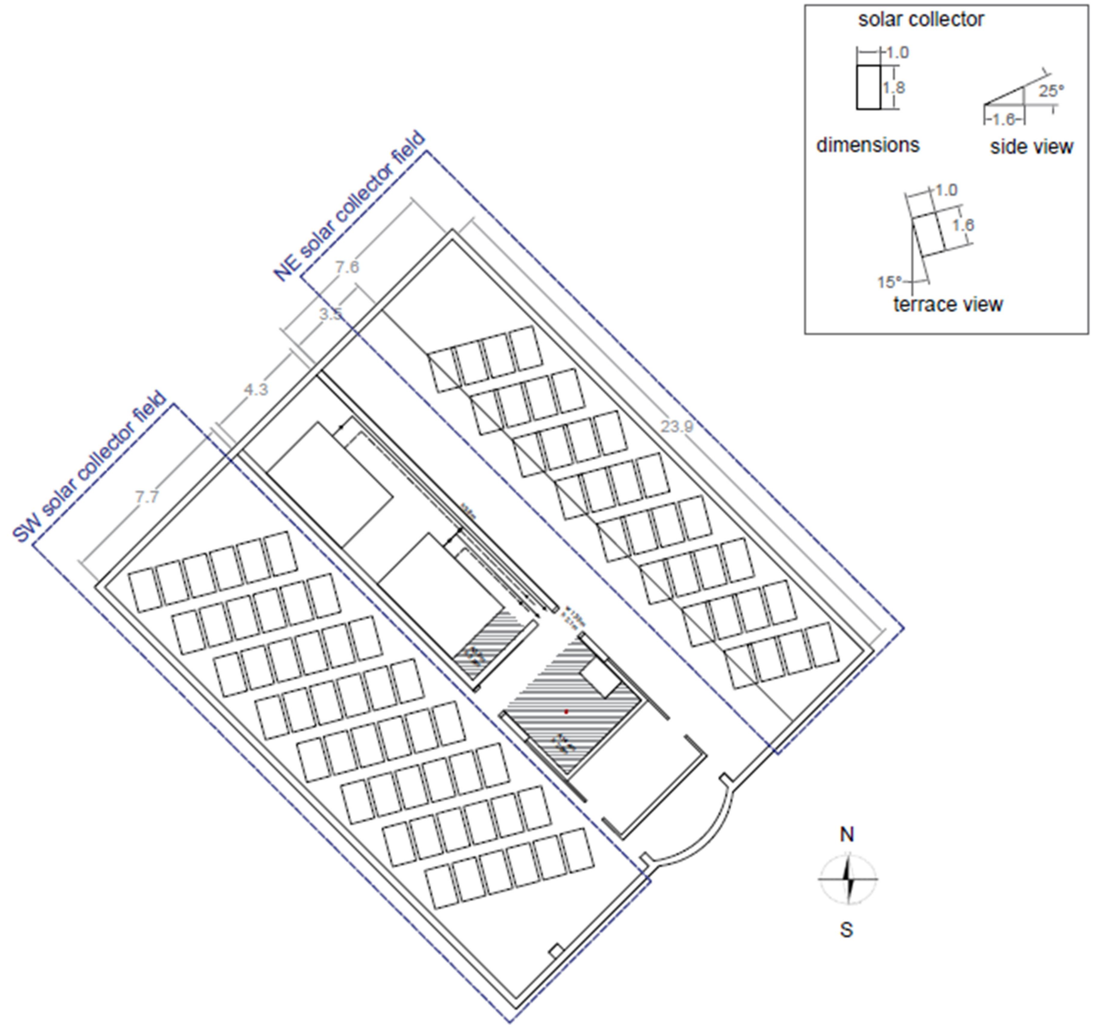


Figure 7: Indicative solar field layout on the roof of the building

In the primary circuit, the solar energy retrieved by the collectors will be transferred to an external heat exchanger through a heat transfer fluid of water-glycol mixture. The captured heat at the external heat exchanger will be transferred to the thermal storage tanks of the system. Two energy storage tanks (buffers) - instead of one - were selected in the configuration of the system due to the limited available room space. The connection of the two storage tanks in the proposed configuration ensures that the required stratification is achieved, as illustrated in the simulation of the system (see Annex 3). The water flow direction to each storage tank will be defined by proper control of two 3-way valves, (A2 and A3, “on-off” type). The first storage tank (buffer 1) will store water at high temperatures and it will be connected with the solar chiller. The second storage tank (buffer 2) will store water at medium temperatures.

The heat driven from the first storage tank (buffer 1) to the solar chiller will be used to generate the solar chiller in order to provide chilled water to the building. A cooling tower will be connected to the solar chiller in order to reject the waste heat during the cooling process.

The hydraulic system includes piping, pumping elements and thermal insulation, designed to transfer the thermal energy to storage and to the point of use. The main circuits of the proposed ST circulation-hydraulic ST system are:

- the primary circuit, connecting the solar collectors with an external heat exchanger, using as heat transfer fluid a water-glycol mixture
- the hot water circuit connecting the external heat exchanger with the heat storage tanks
- the hot water (heat medium) circuit, connecting the heat storage tanks with the solar chiller
- the cooling water circuit, connecting the solar chiller with the cooling tower and
- the chilled-water circuit, connecting the ST chiller with the existing electrical chillers of the building

An important component of the ST system is the control system. This system will ensure the proper and efficient operation of the ST systems. It will include components such as temperature sensors, flow meters, flow controllers, Programmable Logic Controller-PLC with local and remote control and various automations, which adjust inputs and outputs and optimize system functions.

The main operation scenarios of the system follows.

In case of high solar radiation, when T3>T4, there are two options:

- when T5>T6, the operation mode is given in Figure 8.

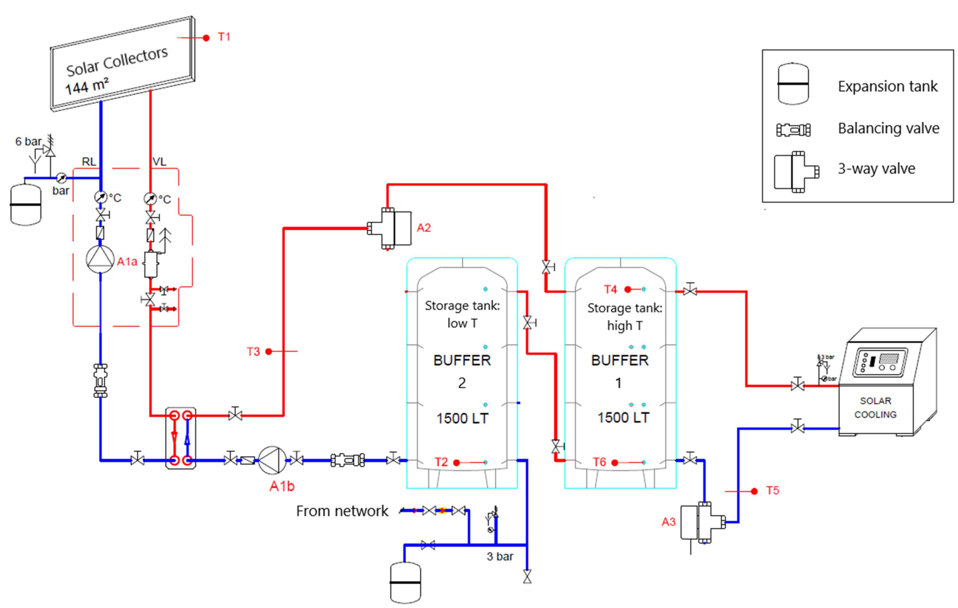


Figure 8: Operation mode in case of high solar radiation (T3>T4 and T5>T6)

- when T5<T6 the operation mode is given in Figure 9.

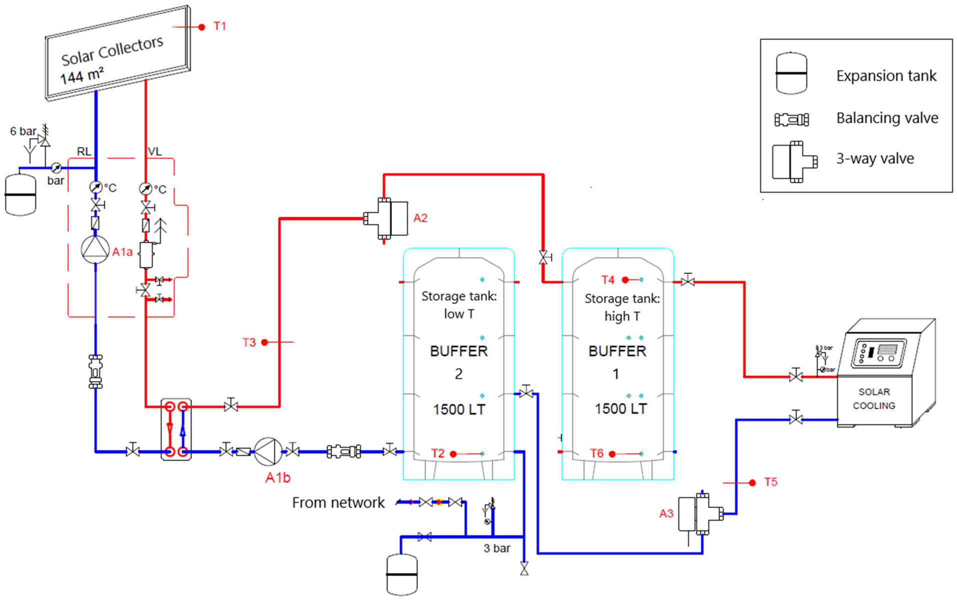


Figure 9: Operation mode in case of high solar radiation (T3>T4 and T5<T6)

In case of low solar radiation, when T3<T4 and T4>95°C, the operation modes are given in Figure 10. According to the water temperature T5 in relation with T6, the water coming from the building, will be directed either to the storage tank of low or high temperatures (when T5>T6, directed to buffer 1 and when T5<T6, directed to buffer 2).

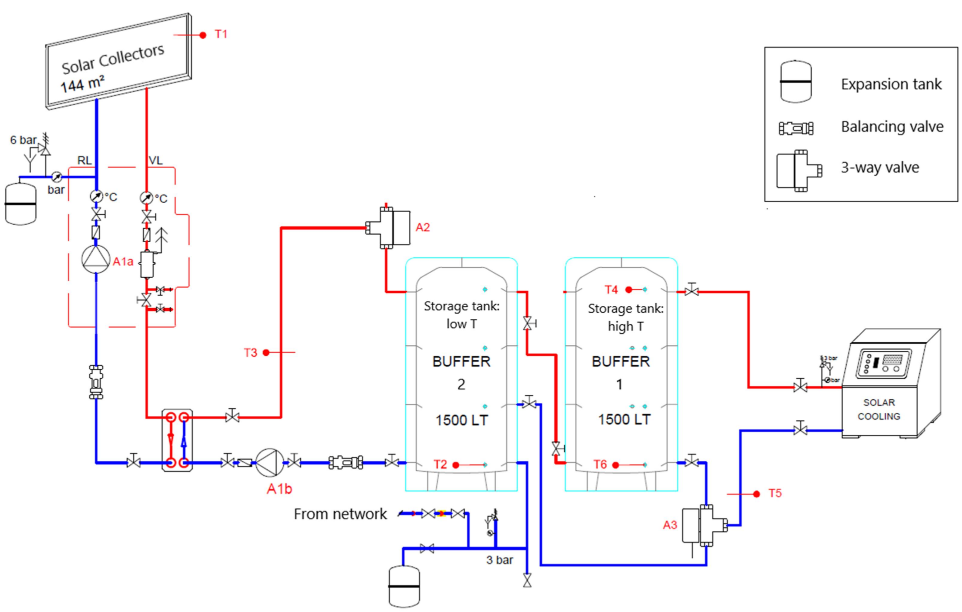


Figure 10: Operation mode in case of low solar radiation (T3<T4)

The operation of the system during winter will be separately described (see chapter “*1.5.4 Protection of the ST system*”), since there is only cooling demand in the building throughout the year.

1.5.2 Connection of the ST system with the existing system

The ST chiller and the conventional existing electric chillers will be connected in series. The scheme of the proposed connection of the ST system with the existing cooling system is illustrated in Figure 11. In this figure, the main operation mode, as well the supportive operation modes are given.

According the main operation mode, the achieved energy by the ST chiller will be transfer to a cold storage tank through an internal heat exchanger. The input of the cold storage tank will be the water coming out of the building and the output of the storage tank will be directed to the distributor/collector connected to the existing chillers. The other two operation modes, indicated in Figure 11, are supportive operation modes, installed in case of maintenance or malefaction.

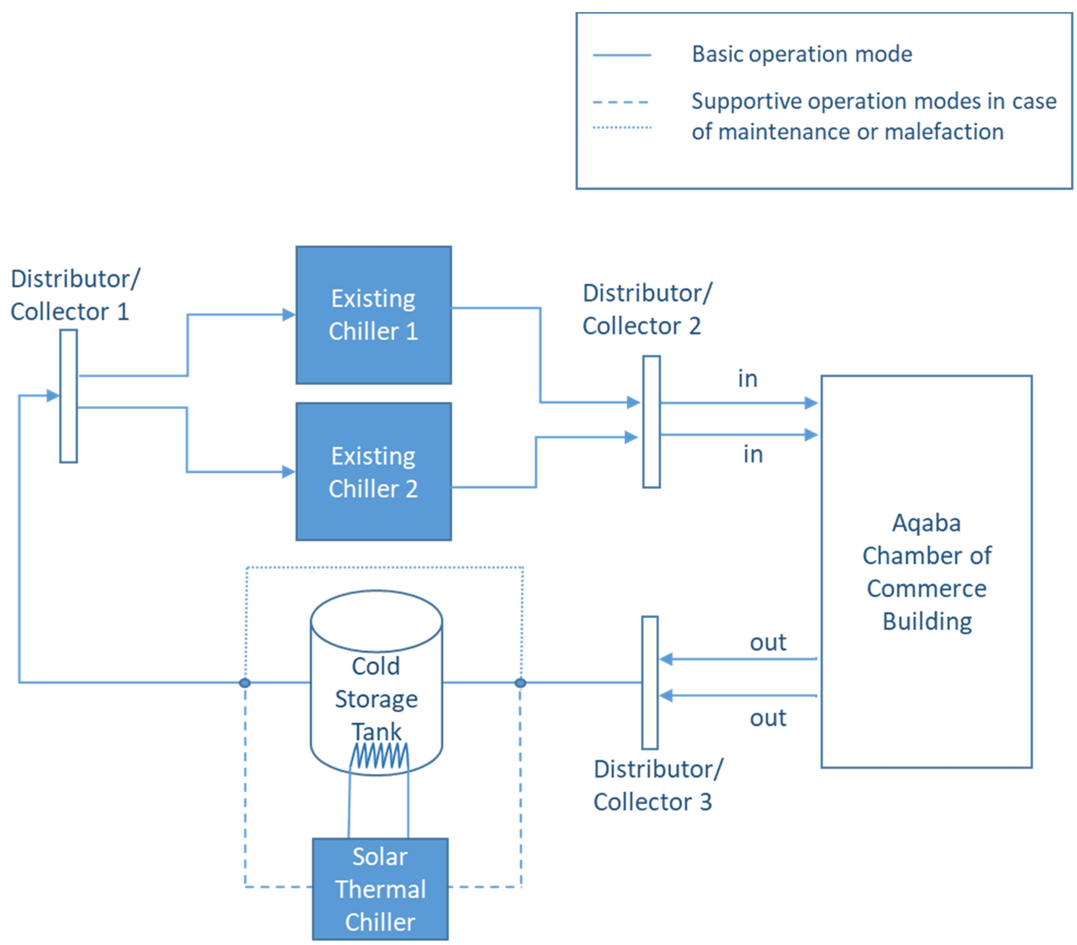


Figure 11: Scheme of ST system connection with the existing conventional cooling system

1.5.3 Technical specifications

The technical specifications for each of the main components of the system are given in the next paragraphs. Also, all the system components should:

- be suitable for use in solar systems ("Solar" type)
- withstand the high temperatures of the circuit
- have the appropriate certifications in accordance with Jordanian legislation and Standards
- have CE marking certification
- be accompanied by Technical Manuals
- be accompanied by warranty. The minimum warranty for each part of the system is set to 1 year, unless otherwise specified in the following paragraphs

In accordance with article 10 par. 3 of Regulation (EU) No 236/2014, purchase of supplies must be in line with the restrictive measures on trade established and regularly updated by the European Union. A list of restrictive measures (sanctions) in force can be found at https://www.sanctionsmap.eu/#/main?search=%7B%22value%22:%22%22,%22searchType%22:%7B%7D%7D. The map allows to verify if there are particular restrictions which may be relevant for the rule of origin (importing of products). In particular, if there are any embargoes on goods from the list of countries marked in the map. In all cases, the rules of nationality and origin set forth in Articles 8 and 9 of the Reg. 236/2014 shall also apply. No restrictions may be applied to the nationality of the contractors and for all supplies purchased under a procurement contract or in accordance with a grant agreement for purchases below 100.000€ (articles 8 and 9 of Regulation (EU) No 236/2014).

1.5.3.1 Solar Collectors

The main technical specifications of the solar collectors to be installed in the pilot project in Jordan are:***Total aperture area:*** ~150 m^2

- ***Collector type:*** Flat Plate
- ***Heat Transfer Medium:*** Water
- ***Absorber surface treatment:*** Solar Selective coating
- ***Maximum temperature of operation:*** up 200 ^{o}C
- ***Maximum operating pressure:*** 10 bar
- ***Cover type:*** low secured iron tempered glass
- ***Thermal isolation, back:*** at least 40 mm (material rockwool)
- ***Thermal isolation, sides:*** at least 20 mm (material glasswool)
- ***Instantaneous efficiency n_G:*** at least 0.75, measured according to standards EN 12975-1+A1:2010[5] and EN ISO 9806:2017[6] for conditions ΔT=30K, G=800W/m^2.
- ***Solar certification:*** Solar Key mark with valid test report (optional)
- ***Test report:*** Valid Test Report “Determination of thermal performance of glazed liquid heating solar collectors” according to standards EN 12975-1+A1:2010 /EN ISO 9806:2017 from an accredited institution
- ***Guarantee:*** at least 5 years

[5] EN 12975-1+A1:2010: "Thermal solar systems and components – Solar Collectors".
[6] EN ISO 9806: 2017 "Test methods for solar collectors ".

Solar collectors field layout

The solar collectors will be installed at the roof of the building in two separate collector fields. An indicative layout of the two solar collector fields for a solar collector with dimensions 1 m x 1.8 m is given in Figure 7.

Indicative SW solar collector field specifications

Orientation (E=+90°, S=0°, W=-90°): + 15 °
No of arrays: 8
No of solar collector per series: 6
Distance between two consecutive collectors: 0.2 m
Distance between arrays: 0.5 m
Tilt angle: 25

Indicative NE solar collector field specifications

Orientation (E=+90°, S=0°, W=-90°): + 15 °
No of arrays: 8
No of solar collector per series: 4
Distance between two consecutive collectors: 0.2 m
Distance between arrays: 0.5 m
Vertical distance of each array from the NE wall (of 3.6m height): 2.5 m
Tilt angle: 25

Connection of solar collectors

Two piping networks should be installed on the roof of the building, one for each solar collector field (SW and NE). The collectors in each array of the two solar collector fields (SW and NE) should be connected in series, according to the two connection types given in Figure 12 and Figure 13.

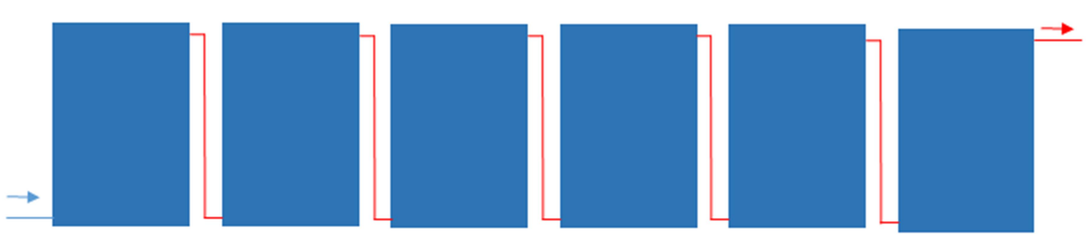


Figure 12 Connection type for solar collectors in the SW solar collector field (in series)

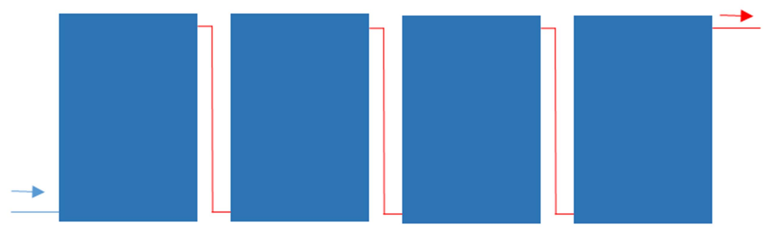


Figure 13 Connection type for solar collectors in the NE solar collector field (in series)

The arrays in each solar collector filed should be connected among them according to the "Tichelmann configuration" (or reverse return) in order to provide balanced flow rate to the solar collectors (see Figure 14).

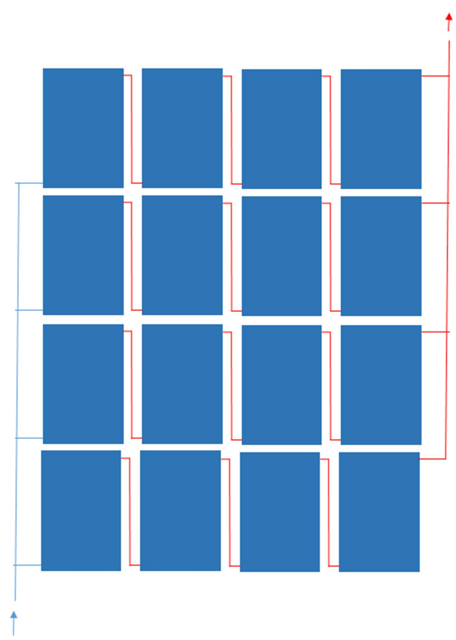


Figure 14 Tichelmann (reverse return) configuration connection for the two solar collector fields

1.5.3.2 Thermal storage tank

The main technical specifications for the thermal storage tank are:

- ***Type:*** Vertical storage tank (Buffer tank)
- ***Medium:*** water
- ***Water volume***: 2 tanks of ~1,500 lt each
- ***Material:*** Steel
- ***Maximum tank operating pressure:*** 6bar.

- ***Maximum tank operating temperature:*** 120 °C.
- ***Insulation:*** At least 100 mm thickness of polyurethane.
- ***Corrosion protection:*** Magnesium anode. The threshold should be controlled and replaced every 2 to 5 years.
- ***Warranty:*** 5 years

The ***geometric characteristics*** of the tanks should take into account their location in the existing room of the building (see Picture 13). The storage tanks should have such external dimensions, so that it can fit a door opening with width 1.46 m and height 2.1m. Also, it should be taken account that it will be installed in a room with height 3.21 m. Tank should be fitted with suitable holes at the top, middle and bottom of the tanks to provide the necessary sensors (e.g. temperature sensors).

1.5.3.3 External heat exchanger

The main technical specifications for the external heat exchanger are:

- ***Type:*** Plate heat exchanger
- ***Flow type:*** Counter-flow
- ***Nominal transfer capacity:*** 17,000 W/K
- ***Material:*** Suitable for the use of a mixture of glycol

1.5.3.4 *Solar Thermal Chiller*

The technical specification of the solar chiller are:

- ***Type:*** Closed loop ST sorption (ab- or adsorption) chiller
- ***Capacity:*** Approximately 35 kW
- ***COP_{th} :*** At least 0.6
- ***Hot water (heat medium) maximum inlet temperature (°C):*** 89°C
- ***Standards:*** It will be positively evaluated if the solar chiller performance is tested and certified according to an authorized standard (for example EN 12309-2, JIS B 8622, ANSI/AHRI 560, ANSI/ASHRAE 182, EN 15316-4-2, RAL-UZ 118[7])
- ***Manuals:*** Operation and installation manuals
- ***Warranty:*** 2 years

[7] http://www.estif.org/solarkeymarknew/images/downloads/QAiST/qaist%20d5.3%20tr5.3.3%20review%20of%20standards.pdf

1.5.3.5 Cooling tower

The Cooling tower will be connected to the solar chiller in order to reject the waste heat during the cooling process. The selection of a cooling tower should be made in order to reject the heat from the chiller at the local Wet Bulb summer design temperature. At non-standard operating conditions, the cooling tower must be sized for the new heat rejection requirements of the chiller (cooling capacity). The cooling tower capacity required for a single-effect absorption chiller is typically 200-250% the size of that which is required for conventional vapor compression systems. The risk of Legionella should be evaluated in the cooling tower and proper actions should be taken if needed.

1.5.3.6 Circulation - hydraulic ST system

The hydraulic ST system and its components should be suitable for the use of a mixture of glycol.

Manual isolation valves must be installed before and after the pump and the auxiliary accessories for the maintenance of the system.

Close type expansion tanks (with membrane) should be proper dimensioned and installed in the circulation system to protect ST system from excessive pressure.

ST circuit pipping specifications

The pipes of the ST circuit must comply with at least the following:

- ***Material of construction:*** Copper
- ***Operating pressure resistance:*** 6bar
- ***Resistance to fluid temperatures*** of 150 ° C
- ***Diameter:*** suitable for fluid velocity between 0.7m / s and 1m / s and pressure loss less than 300Pa/m.

Piping insulation

The insulation of the piping of the ST circuit must at least comply with the following:

- ***Resistance to operating temperatures*** of 150 ° C
- ***Thermal conductivity*** ≤0,040W / (m · K)

Thickness of piping and pipes insulation: selection according to the

- Table 11
- ***Insulation material:*** All piping should of be insulated with shaped aluminum foil to protect against humidity, UV radiation and rodents or birds.

Table 11: Minimum requirements of pipes isolation (source EN 12977-2:2012)

Flow rate in collector circuit l/h	External pipe diameter [a] mm	Pipe thickness mm	Thickness of one-layer insulation [b] mm
<90	10	1	20
90 to 140	12	1	20
140 to 235	15	1	20
235 to 405	18	1	20
405 to 565	22	1	20
565 to 880	28	1	30
880 to 1445	35	1,5	30
1445 to 1500	42	1,5	39
>1500	Such that the flow velocity is approximately 0,5 m/s	1,5	as the internal pipe diameter
NOTE Based on a thermal conductivity of (0,04 ± 0,01) W/(m x K) for temperature at 10°C.			
[a] Tolerance 1 mm. [b] Tolerance 2 mm.			

Pumps

The technical specifications of each pump of the ST circuit are:

- Type: water lubricated and water-cooled
- Low energy consumption with an energy efficiency index (EEI) of less than 0,27
- Capable of overcoming the pressure drop of the circuit materials at maximum operating flow

The minimum requirements required are:

- Temperature resistance at least: - 10°C to 110°C
- Operating pressure resistance at least: 10bar
- Controlled by frequency converter (inverter)
- The inverter should be equipped with a magnetic compatibility filter to prevent interference with the other systems in the building
- Degree of protection IP44, when fitted internally and IP55, when placed outdoors
- Covered with anti-corrosion coating
- Ability to be connect to a control system
- Guarantee: 2 years

3-way (triode) valves

The technical specifications for the 3-way valves are:

- ***Type:*** On-off
- ***Material of construction:*** Copper
- ***Operating pressure:*** 10bar
- ***Resistance to fluid temperatures:*** -10 το 150 ° C
- ***Diameter:*** suitable for the piping circuit to be adapted

1.5.4 Protection of the ST system

The ST system must be protected against damages caused by environmental conditions. In general, the most common damages are caused from frost or overheating.

For the protection of the system from frost –although the weather data analysis for the last years have shown that these conditions are rare in the city of Aqaba - a mixture of water with glycol should be used in the primary solar piping circuit. The percentage of glycol should be defined based on the extreme weather conditions of the area. The glycol should have the following specifications:

- Non-toxic
- Minimum boiling point: 200 ^{o}C
- Suitable for preventing thermal degradation at high temperatures (thermal cracking).
- Freeze protection at -10 °C.
- Adequate corrosion protection
- Be accompanied with a Safety data sheet In line with EU Regulation 453/2010

Provision should be made for the ST system in the event of stagnation, which may be caused by a malfunction of the pump while there is still incident radiation in the collectors, which overheats. This situation can occur due to technical failure of the system, power failure or simply due to lack of cooling load. During stagnation, the temperature of the collector may reach or even exceed 200ºC. The protection measures must be taken to protect the circuit, such as proper dimensioning of expansion tanks and safety valves and also operation of the primary solar circuit during the night of summer months.

Proper actions should be examined and evaluated for the operation of the ST system during winter. These may include actions such as empting the primary ST circuit, partly covering the solar collector field, operation of the system during the night, etc.

1.6 Simulation results of the pilot system

The proposed ST system - described in Chapter "*1.5 Technical description of the pilot project*" - was simulated with the simulation software "Polysun-Designer", version 11.2.

For the simulation of the ST system the following main assumption were made:

- The building characteristics (dimensions, number of floors, location, type of building, etc.) was insert as input in the software to calculate the cooling needs of the building. This was estimated to be ~ 150.000 kWh per year
- The building has only cooling needs and not heating
- The ST system will be activated all days of the week (not only the working days). In the no working days (Friday and Saturday) the ST system will transfer the achieved energy in the storage tanks
-

The detailed energy simulation report of the proposed system is given in Annex 3. In this chapter the main energy results from the simulation are presented.

In

Table 12, the main simulated annual ST system' values are presented. The total annual solar energy produced by the solar collectors (total annual field yield) is 131,103 kWh and the total annual cooling energy yield is 79,525 kWh. The annual electricity consumption for the operation of the ST system is 4,979 kWh.

Table 12 Overview of the main ST system values

Overview solar thermal energy (annual values)	
Collector area	160 m²
Total annual field yield	**131,103.1 kWh**
Collector field yield relating to gross area	819.4 kWh/m²/Year
Collector field yield relating to aperture area	910.4 kWh/m²/Year
Overview heat driven chiller (annual values)	
Seasonal performance factor - Cooling	0.75
Total cooling energy yield	**79,525 kWh**
Heat supplied by generator	106,030.7 kWh
System overview (annual values)	
Total fuel and/or electricity consumption of the system [Etot]	4,979 kWh
Total electricity consumption [Ecs]	4,979 kWh
Primary energy factor	0.12

The distribution of the ST energy to the system per month is given in Figure 15.

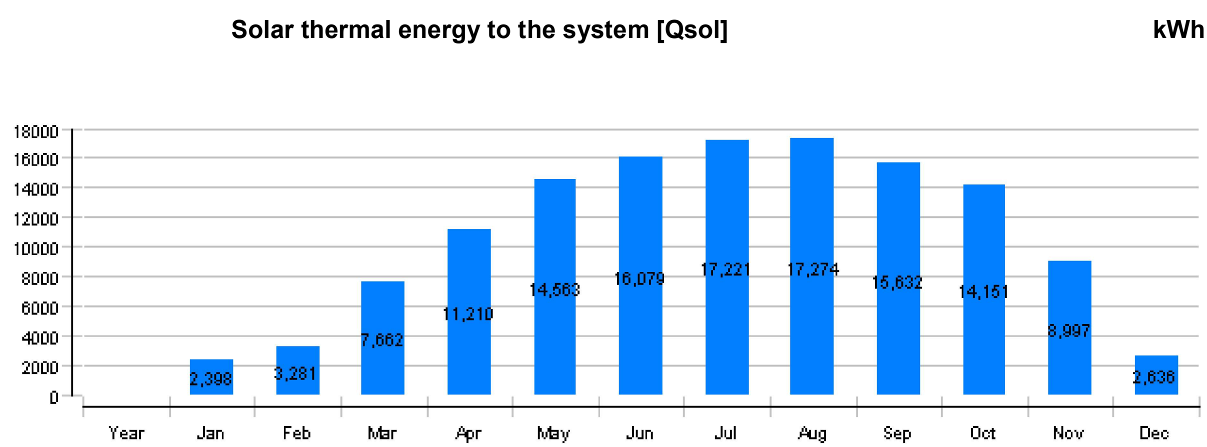


Figure 15 Simulated distribution of the solar thermal energy to the system per month

In Table 13, an overview of the main meteorological data for the location of the building (Aqaba city) are given.

Table 13 Meteorological data overview for the location of the building

Meteorological data-Overview	
Average outdoor temperature	26.1 °C
Global irradiation, annual sum	2,197 kWh/m²
Diffuse irradiation, annual sum	542 kWh/m²

The annual values for the main components of the ST system are given in Table 14. For the simulation, an absorption chiller of design cooling capacity of 35 kW was selected. The selected solar collectors were flat plate with a total aperture area of 144 m^2. The selected heat transfer fluid mixture in the solar loop was a propylene mixture of 30% concentration. The wet cooling tower selected was 90kW.

Table 14 Annual values for the main components of the ST system

Component overview (annual values)		
Absorption chiller	**single-effect, WFC-SC10, 35 kW**	
Seasonal performance factor - Cooling [ ]		0.75
Cooling energy yield	kWh	**79,525**
Collector	**Flat-plate, good quality**	
Total gross area	m²	160
Total aperture area	m²	144
Tilt angle (hor.=0°, vert.=90°)	°	25
Orientation (E=+90°, S=0°, W=-90°)	°	15
Collector field yield [Qsol]	kWh	**131,103**
Irradiation onto collector area [Esol]	kWh	347,892
Wet recooler CT	**Wet Cooling Tower**	
Rejected heat	kWh	230,243

In Table 15, the main building parameters and simulation results are presented. The annual cooling energy demand of Aqaba Chamber of Commerce office building is 146,510 kWh. The actual energy subtracted from the building (cooling effect) from the ST cooling system, including the heat losses, is 76,687.4kWh. So, the solar system can cover the 52.3% of the building's cooling energy demand.

Table 15 Overview of building simulation results

Building Air conditioned area	**Office building - Aqaba Chamber of Commerce**	
Heated/air-conditioned living area	m²	1,848
Cooling set point temperature	°C	26.5
Cooling energy demand [Qdem]	kWh	**146,510**
Fan coil	**Four-pipe system size 5**	
Net energy from/to heating/cooling modules	kWh	**-76,687.4**

The graphical evaluation of the collector field yield, the irradiation onto the collector area and the cooling energy yield is given in Figure 16.

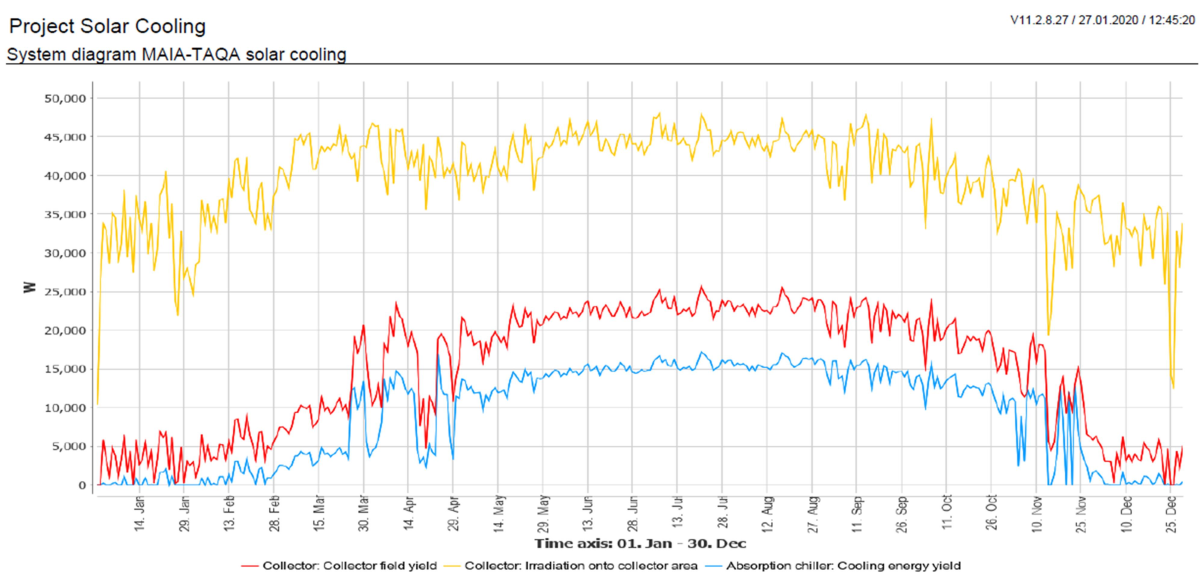


Figure 16 Graphical evaluation of the main ST values within a year

Annexes

Annex 1: Questionnaire for MAIA-TAQA pilot project in Aqaba

Annex 2: Aqaba water analysis results

Annex 3: MAIA-TAQA- Aqaba pilot project simulation results report

Questionnaire for MAIA-TAQA pilot project in Jordan

General Information			
Owner of the building:			
Address/city/country:			
Contact person/position:			
Tel /e-mail/ site:			
Sector:	Office building ☐ Other (please define) ☐ ____________		
Construction year/ Year of last renovation:		Employees/persons using the building:	

Existing energy building systems and equipment	
Systems for building **heating**:	**Boilers** ☐ Number of boilers____ For each boiler please define: • Capacity ________ • Model__________ • Year of construction_____ • Energy source: Oil ☐ LPG ☐ Other(please define) ☐____________ **Heat pumps** ☐ Number of heat pumps____ For each heat pump please define: • Capacity _____ • Model__________ • Type__________ • COP_________ • Year of construction_____ • Energy source: Electricity ☐ LPG ☐ Other(please define) ☐____________ **Other heating system (**please define) ☐_________ Please provide **a sort description of the system:** ______________________________
Systems for building **cooling**:	**Air condition split units** ☐ For each type of unit please define: • Capacity _____ • Model______ • Number of units___ • Year of construction_____ **Heat pump** ☐ Number of heat pumps____ For each heat pump please define: • Capacity _____

	• Model__________ • Type__________ • EER_________ • Year of construction_____ • Energy source: Electricity ☐ LPG ☐ Other(please define) ☐___________ **Chiller** ☐ Number of chillers____ For each chiller please define: • Capacity _______ • Model__________ • Type__________ • EER__________ • Year of construction_____ • Energy source: Electricity ☐ LPG ☐ Other(please define) ☐___________ **Other cooling system (**please define) ☐________ Please provide **a sort description of the system:** ___________________________
Systems for **hot water production**:	**Boilers** ☐ Number of boilers____ For each boiler please define: • Capacity _______ • Model_________ • Year of construction_____ • Energy source: Oil ☐ LPG ☐ Electricity ☐ Other(please define) ☐___________ **Heat pumps** ☐ Number of heat pumps____ For each heat pump please define: • Capacity _____ • Model__________ • Type__________ • Year of construction_____ • Energy source: Electricity ☐ LPG ☐ Other(please define) ☐___________ **Other(**please define) ☐______________________ Please provide **a sort description of the system:** ___________________________

Energy annual consumption for **heating**:	
Energy annual consumption for **cooling**:	
Energy annual consumption for **hot water production**:	
Please provide, if available, energy consumption bills – electricity, oil, etc. – for one year	
Water annual consumption (m^3/day):	
Operation hours per day/ Days per week:	
Total surface/number of floors:	
Surface per use, per floor (m^2) Please provide, if available, architectural and engineering designs	Offices:____ Warehouses:___ Parking:___ Common rooms:___, Other(please define):_________________
Building envelope characteristics (Insulation, openings energy class)	Insulation: _________ Openings (single glazed, double glazed, etc):______
MAIA-TAQA Solar Thermal (ST) system – additional required information	
Available space for solar storage tanks and other MAIA-TAQA sub-system (m^2). Please define and provide a simple drawing and photos.	
Height of the available space for solar storage tanks and other MAIA-TAQA sub-system (m)	
Available roof space for solar collectors (m^2). Please provide a simple drawing and photos.	
Please define possible obstacles on the roof and shading from other buildings.	

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ΕΚΘΕΣΗ ΔΟΚΙΜΩΝ

ΣΤΟΙΧΕΙΑ ΠΕΛΑΤΗ	
Εταιρεία :	**ΚΕΝΤΡΟ ΑΝΑΝΕΩΣΙΜΩΝ ΠΗΓΩΝ & ΕΞΟΙΚΟΝΟΜΙΣΗΣ ΕΝΕΡΓΕΙΑΣ (Κ.Α.Π.Ε.)**
Αρμόδιος /οι :	κ. Χριστόφορος Περάκης
Διεύθυνση :	Πικέρμι 190 09

ΣΤΟΙΧΕΙΑ ΔΟΚΙΜΙΟΥ /ΩΝ	
Περιγραφή δοκιμίου /ων :	ΝΕΡΟ
Κωδικός /οί δοκιμίου /ων :	181019-01
Ημερομηνία παραλαβής :	18-10-2019
Κατάσταση δοκιμίου /ων κατά την παραλαβή :	Κανονική
Ημερομηνία περάτωσης αναλύσεων :	05-11-2019
Αντικείμενο που υποβλήθηκε σε δοκιμή :	Το δοκίμιο ως έχει. Τα μέταλλα δίδονται επί του διηθημένου δείγματος εκτός αν αναγράφεται ο όρος «ολικό / ος» .
Δειγματοληψία :	Από τον πελάτη

ΕΠΙΣΗΜΑΝΣΗ ΔΟΚΙΜΙΟΥ /ΩΝ	
Κωδικός Δοκιμίου	Στοιχεία / Επισήμανση πελάτη
181019-01	Νερό

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Κωδικός Έκθεσης	181019-01
Ημ/νία : 05-11-19	

ΑΠΟΤΕΛΕΣΜΑΤΑ ΑΝΑΛΥΣΕΩΝ

Κωδικός δείγματος : 181019-01

Παράμετρος	Αναλυτική Μέθοδος	Αποτέλεσμα	LoQ	Όρια (*) Ποσίμου	Μονάδες
pH	SMEWW – 4500/H^+	**7,8**	---	6,5 – 9,5	---
Αγωγιμότητα (@ 20°C)	SMEWW – 2510	**382**	10	2.500	μS/cm
Χλωριούχα (Cl^-)	SMEWW – 4500 – Cl^-/B	**45**	5	250	mg/l
Αμμωνιακά (NH_4^+)	MERCK 1.14752	**<LoQ(0,04)**	0,05	0,5	mg/l
Θειικά* (SO_4^{-2})	SMEWW – 4500 – SO_4^{-2}/E	**18**	10	250	mg/l
Ασβέστιο (Ca^{+2})	In house based on ASTM D 511-14	**41,7**	0,2	(*)	mg/l
Μαγνήσιο (Mg^{+2})	In house based on ASTM D 511-14	**7,09**	1,0	(*)	mg/l
Νάτριο (Na^+)	In house based on ASTM D 4191-15 & ASTM D 3561-11	**23,4**	5	200	mg/l
Μαγγάνιο (Mn^{+2})	In house based on ISO 15586:2003	**MA**	2	50	μg/l
Σίδηρος* (Fe)	In house based on ISO 15586:2003	**<LoQ(8)**	10	200	μg/l
Ολικά Αιωρούμενα Στερεά (TSS)	SMEWW – 2540/D	**MA**	10	(*)	mg/l

Συντμήσεις: Μ. Α.: Μη Ανιχνεύσιμο — LoQ : Όριο Ποσοτικοποίησης
< LoQ : μικρότερο του Ορίου Ποσοτικοποίησης
SMEWW: Standard Methods For the Examination of Water and Wastewater

Σημειώσεις: 1. **(*)**: Όρια ποσίμου (παραμετρική τιμή) βάσει της Απόφασης με Αρ. Γ1(δ)/ ΓΠ οικ. 67322.
2. Για τις παραμέτρους που επισημαίνονται με αστερίσκο (*) δεν προβλέπεται ανώτατο όριο.

Ο Προϊστάμενος Εργαστηρίου

ΣΤΕΦ. Κ. ΑΝΔΡΕΟΥ
ΧΗΜΙΚΟΣ MSc

* Εκτός Πεδίου Διαπίστευσης

ACL ΑΝΔΡΕΟΥ Κ. Ι.Κ.Ε.
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Κωδικός Έκθεσης	181019-01
Ημ/νία : 05-11-19	Σελίδα 1 από 1
ΓΝΩΜΑΤΕΥΣΗ	

ΓΝΩΜΑΤΕΥΣΗ

- Το δείγμα πληροί τις προδιαγραφές του ποσίμου (Αρ. Απ. Γ1(δ)/ ΓΠ οικ. 67322) όσον αφορά τις παραμέτρους στις οποίες εξετάσθηκε.
- Δείγμα με χαμηλή γενικά σκληρότητα , δεν αναμένονται σοβαρά προβλήματα εναπόθεσης αλάτων στις συσκευές θέρμανσης του νερού (π.χ. πλυντήριο, θερμοσίφωνας).

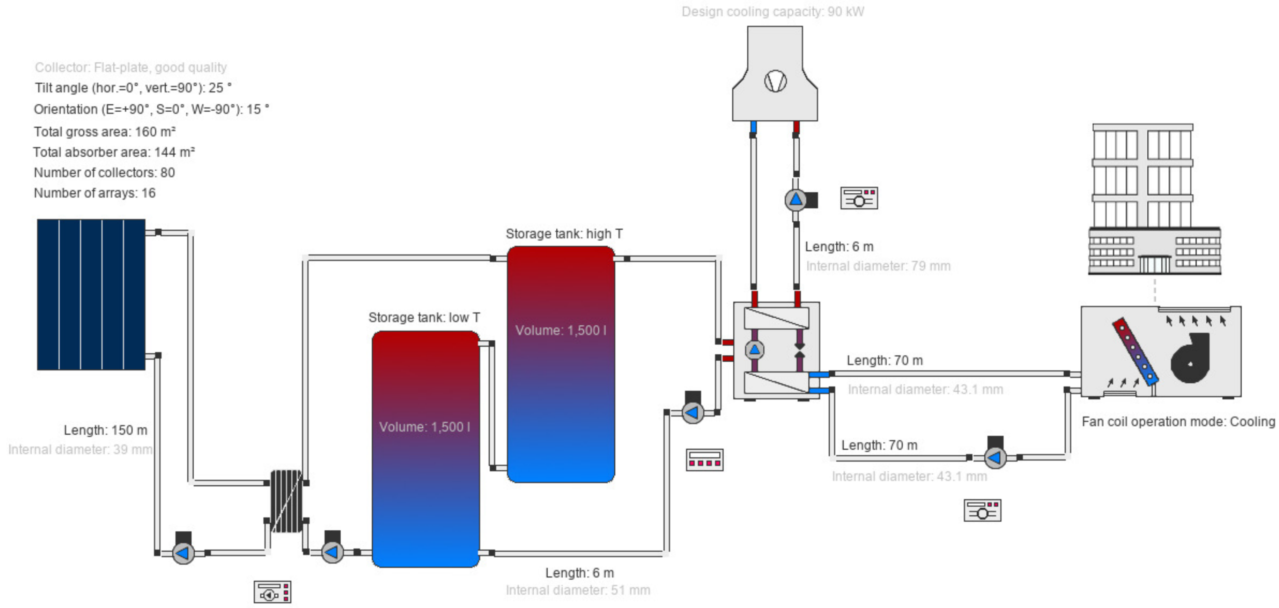
Ο Προϊστάμενος Εργαστηρίου

ΣΤΕΦ. Κ. ΑΝΔΡΕΟΥ
ΧΗΜΙΚΟΣ MSc

Professional Report

CENTRE FOR RENEWABLE ENERGY SOURCES AND SAVING

Solar Cooling **MAIA-TAQA solar cooling**



Location of the system

Aqaba
Longitude: 35.01°
Latitude: 29.536°
Elevation: 13 m

Map section

This report has been created by:

CRES Centre for Renewable Energy Sources and Saving
Marathonos av. 19klm
19009 Pikermi
0030 2106603300

Photograph of property

System overview (annual values)

Total fuel and/or electricity consumption of the system [Etot]	4,979 kWh
Total electricity consumption [Ecs]	4,979 kWh
Total energy consumption [Quse]	77,442 kWh
System performance [(Quse+Einv) / (Eaux+Epar)]	15.55
Primary energy factor	0.12

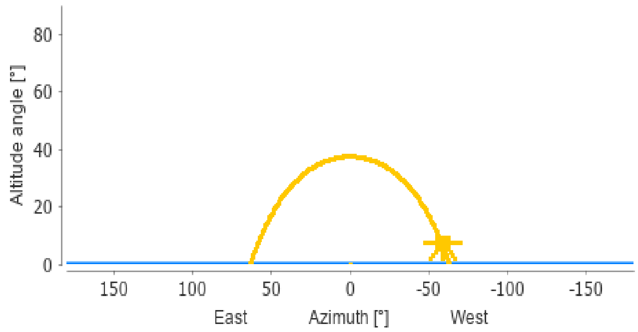
Overview solar thermal energy (annual values)

Collector gross area	160 m²
Total annual field yield	131,103.1 kWh
Collector field yield relating to gross area	819.4 kWh/m²/Year
Collector field yield relating to aperture area	910.4 kWh/m²/Year

Overview heat driven chiller (annual values)

Seasonal performance factor - Cooling	0.75
Total cooling energy yield	79,525 kWh
Heat supplied by generator	106,030.7 kWh

Horizon line



Meteorological data-Overview

Average outdoor temperature	26.1 °C
Global irradiation, annual sum	2,197 kWh/m²
Diffuse irradiation, annual sum	542 kWh/m²

Component overview (annual values)

Absorption chiller	**single-effect, WFC-SC10**	
Seasonal performance factor - Cooling [ ]		0.75
Cooling energy yield	kWh	79,525
Heat supplied by generator	kWh	106,031
Collector	**Flat-plate, good quality**	
Data Source		SPF
Number of collectors		80
Number of arrays		16
Total gross area	m²	160
Total aperture area	m²	144
Total absorber area	m²	144
Tilt angle (hor.=0°, vert.=90°)	°	25

Orientation (E=+90°, S=0°, W=-90°)	°	15
Collector field yield [Qsol]	kWh	131,103
Irradiation onto collector area [Esol]	kWh	347,892
Collector efficiency [Qsol / Esol]	%	37.7
Direct irradiation after IAM	kWh	253,522
Diffuse irradiation after IAM	kWh	77,730
Wet recooler CT	**Wet Cooling Tower**	
Rejected heat	kWh	230,243
Thermal efficiency [ ]	%	87.89
Building Air conditioned area	**Office building - Jordan Chamber of Commerce**	
Heated/air-conditioned living area	m²	1,848
Cooling setpoint temperature	°C	26.5
Cooling energy demand [Qdem]	kWh	146,510
Specific cooling energy demand [Qdem]	kWh/m²	79.3
Solar gain through windows	kWh	116,304
Total energy losses	kWh	59,917

Fan coil	**Four-pipe system size 5**	
Number of fan coils	-	46
Nominal cooling power	W	1,800
Nominal cooling water inlet temperature	°C	6
Nominal cooling water return temperature	°C	12
Net energy from/to heating/cooling modules	kWh	-76,687.4

External heat exchanger	**large**	
Transfer capacity	W/K	17,000

Pump solar loop	**Eco, medium**	
Circuit pressure drop	bar	1.452
Flow rate	l/h	5,760
Fuel and electricity consumption [Epar]	kWh	50.1

Pump hot water	**Eco, medium**	
Circuit pressure drop	bar	0.754
Flow rate	l/h	8,631
Fuel and electricity consumption [Epar]	kWh	29

Pump chilled water	**Eco, large**	
Circuit pressure drop	bar	1.393
Flow rate	l/h	8,631
Fuel and electricity consumption [Epar]	kWh	71.9

Pump cooling water	**Eco, large**	
Circuit pressure drop	bar	1.058
Flow rate	l/h	8,631
Fuel and electricity consumption [Epar]	kWh	71.9

Pump tank	**Eco, medium**	

Circuit pressure drop	bar	0.376
Flow rate	l/h	5,760
Fuel and electricity consumption [Epar]	kWh	50.1

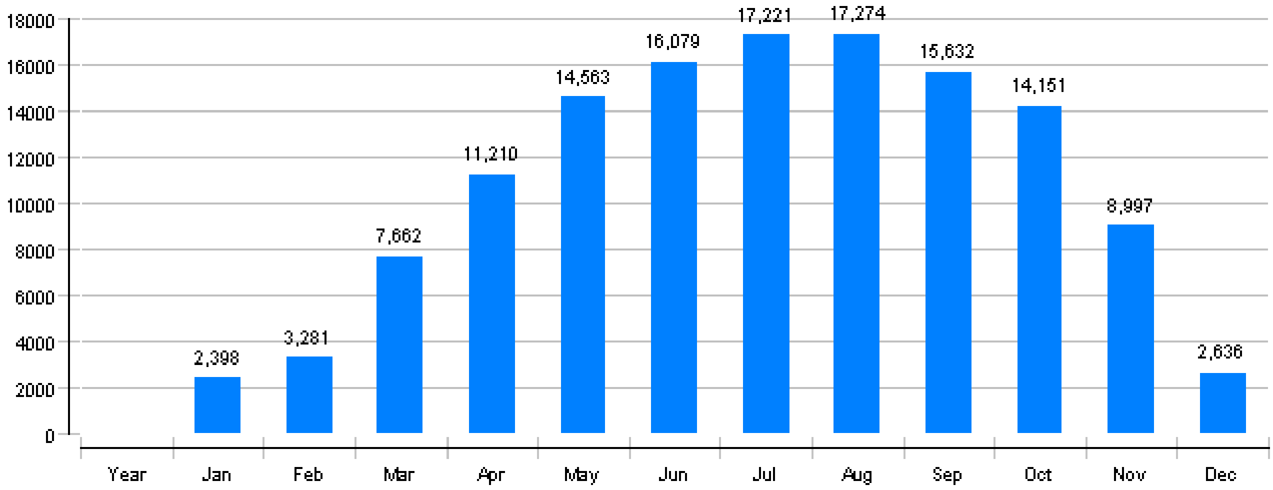
Storage tank high T	**1500l buffer**	
Volume	l	1,500
Height	m	2
Material		Steel
Insulation		Rigid PU foam
Thickness of insulation	mm	80
Heat loss [Qhl]	kWh	1,329
Connection losses	kWh	185

Storage tank low T	**1500l buffer**	
Volume	l	1,500
Height	m	2
Material		Steel
Insulation		Rigid PU foam
Thickness of insulation	mm	80
Heat loss [Qhl]	kWh	1,281
Connection losses	kWh	262

Loop

Solar loop		
Fluid mixture		Propylene mixture
Fluid concentration	%	30
Fluid domains volume	l	218.5
Pressure on top of the circuit	bar	4

Solar thermal energy to the system [Qsol] **kWh**



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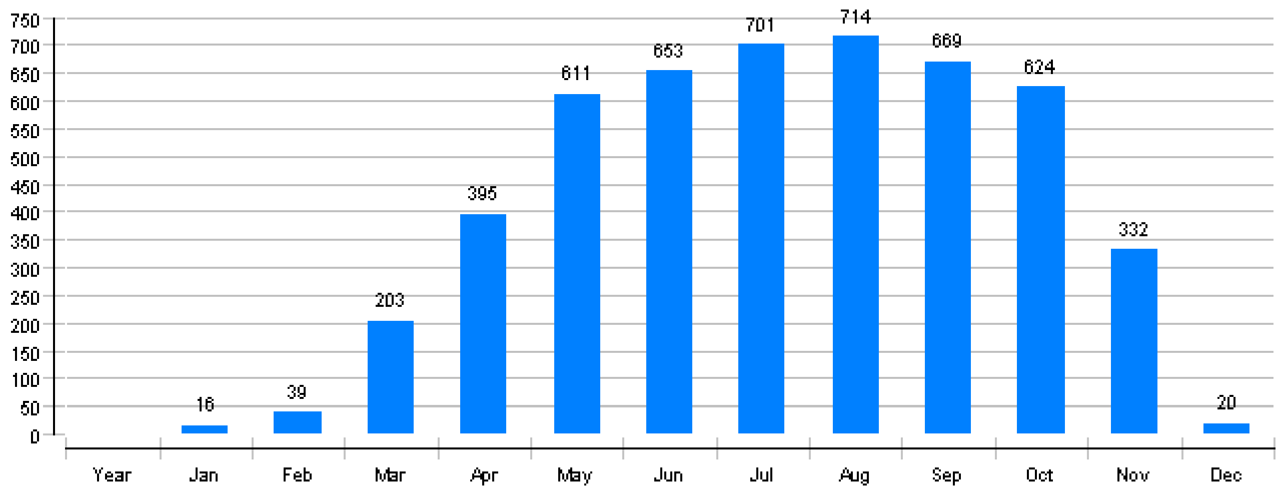
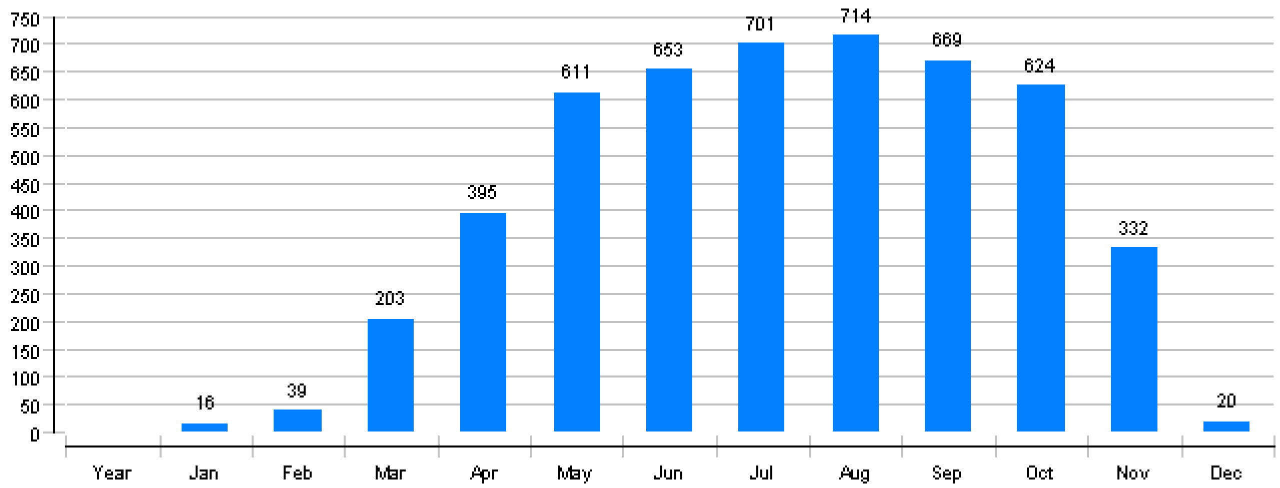
Total fuel and/or electricity consumption of the system [Etot] kWh



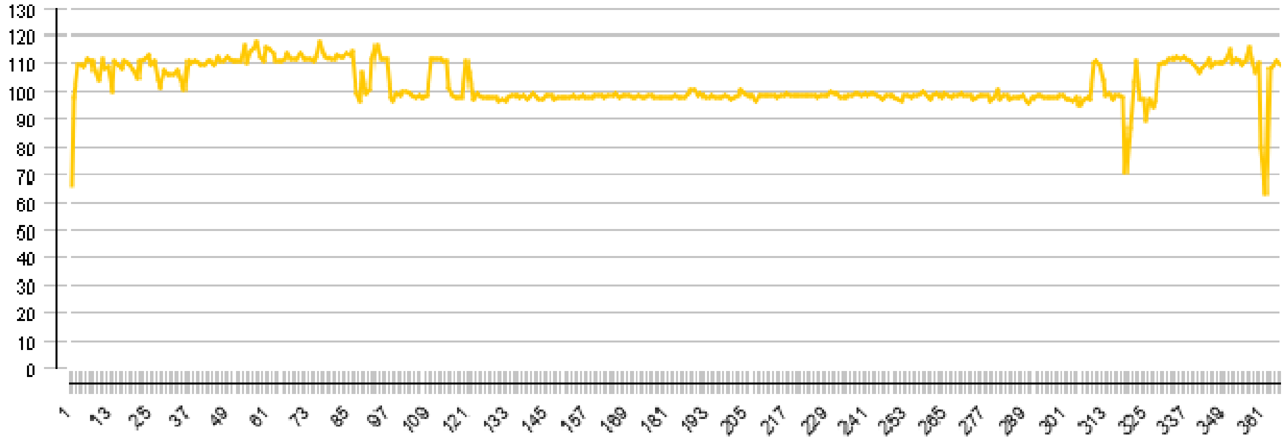
Total electricity consumption [Ecs] kWh



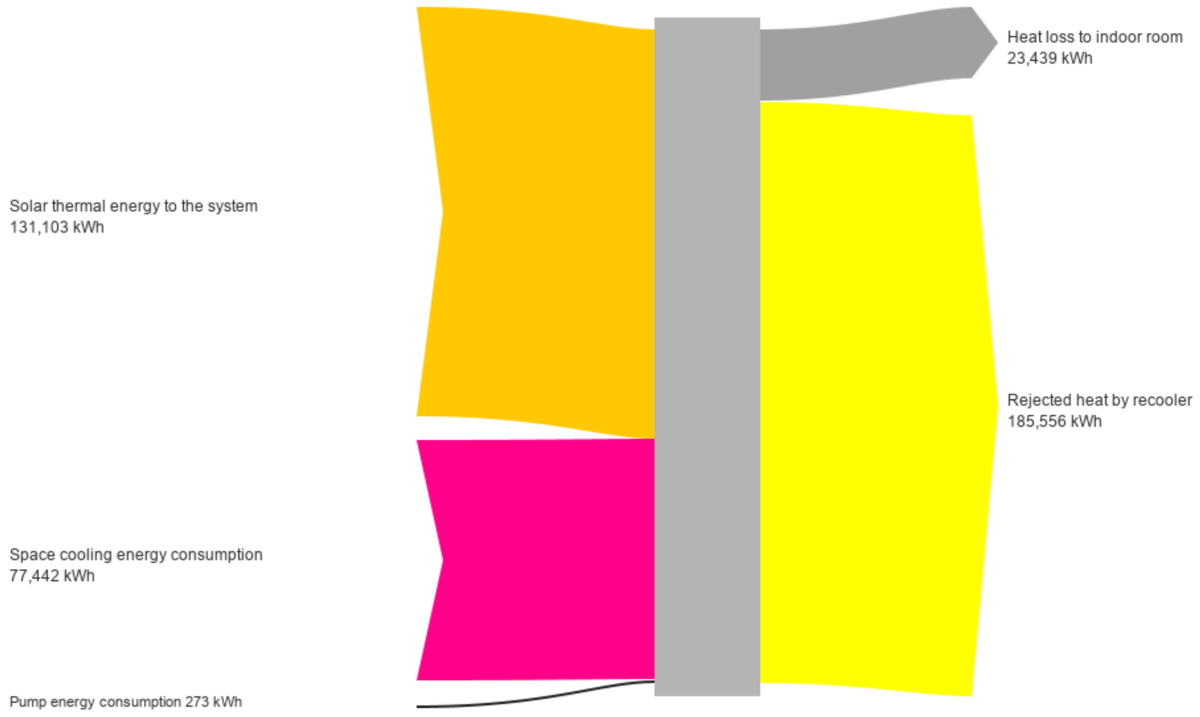
	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar thermal energy to the system [Qsol]													
kWh	131103	2398	3281	7662	11210	14563	16079	17221	17274	15632	14151	8997	2636
Heat generator fuel and electricity consumption [Eaux]													
kWh	4706	13	35	190	373	578	618	665	677	636	592	313	17
Total fuel and/or electricity consumption of the system [Etot]													
kWh	4979	16	39	203	395	611	653	701	714	669	624	332	20
Irradiation onto collector area [Esol]													
kWh	347892	23314	23673	31683	30604	31005	32193	33330	33213	31014	29356	25178	23328
Electricity consumption of pumps [Epar]													
kWh	273.1	2.7	4.2	13.1	22.7	33.6	34.9	36.4	36.4	33.8	32.6	19.8	3
Total energy consumption [Quse]													
kWh	77442	209	596	3383	6145	9280	10424	11338	11445	10320	9187	4846	268
Heat loss to indoor room (including heat generator losses) [Qint]													
kWh	23439	2023	2214	2660	2238	1899	1750	1712	1659	1597	1651	1936	2099
Total electricity consumption [Ecs]													
kWh	4979	16	39	203	395	611	653	701	714	669	624	332	20

Collector

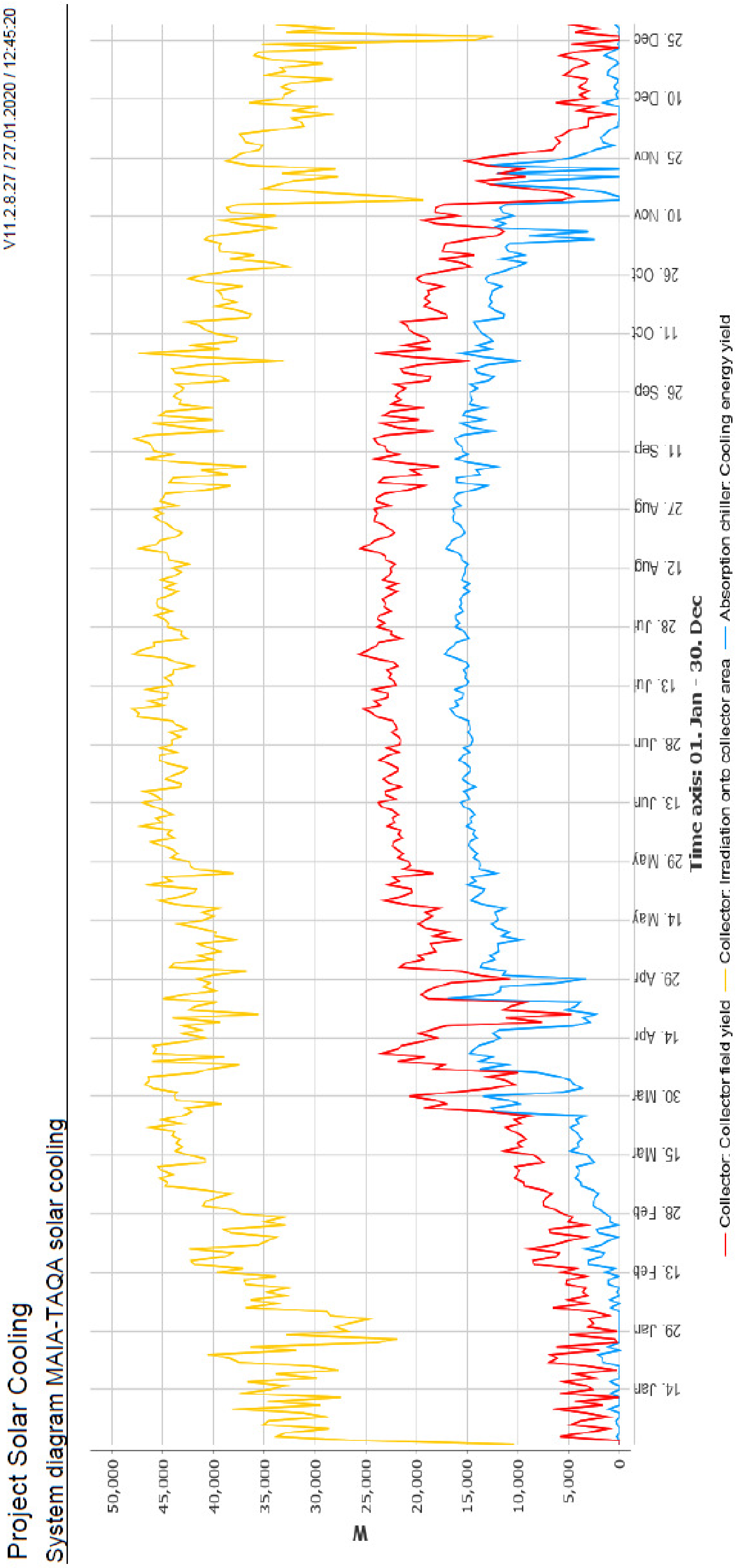
Daily maximum temperature [°C]



Energy flow diagram (annual balance)

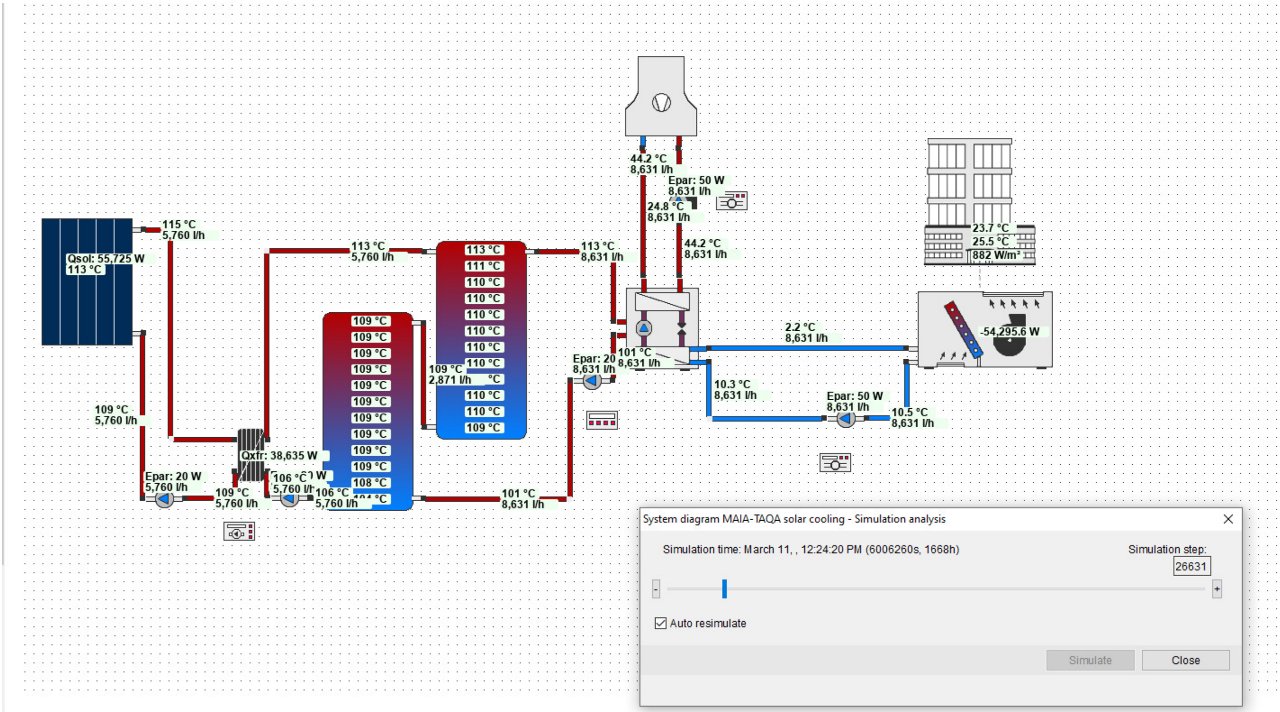


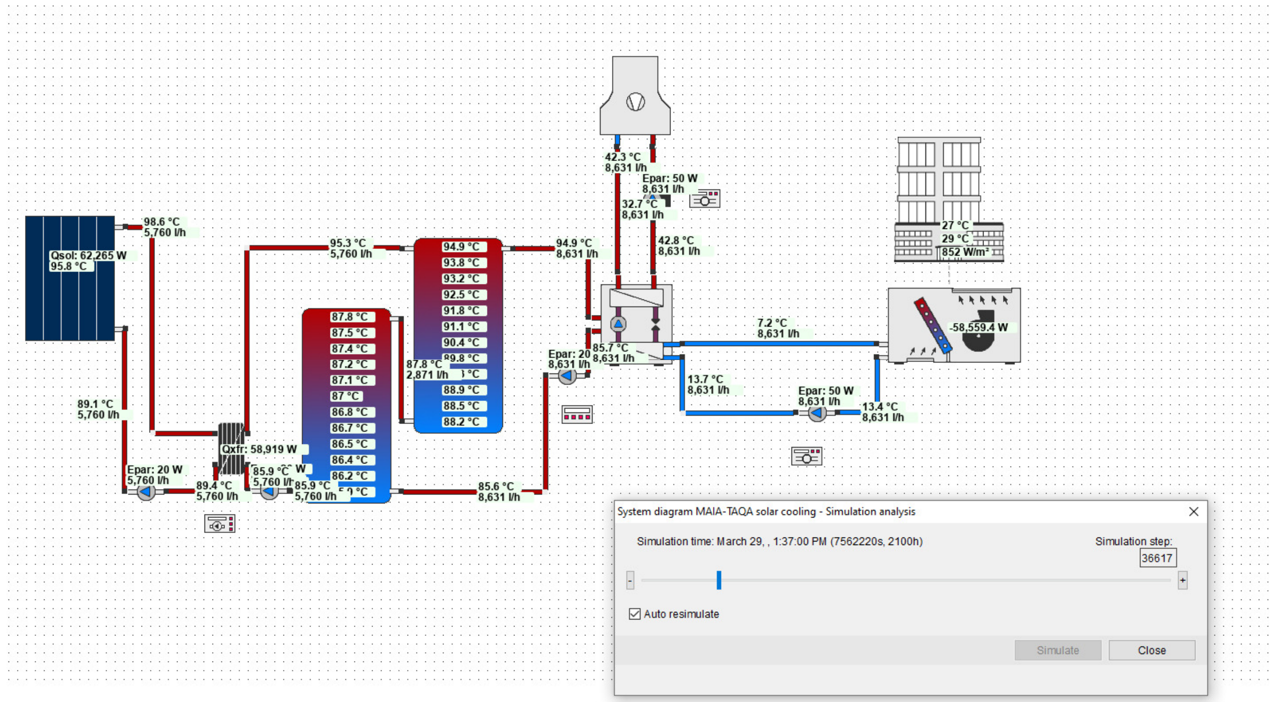
Graphical evaluation of the main ST values within a year



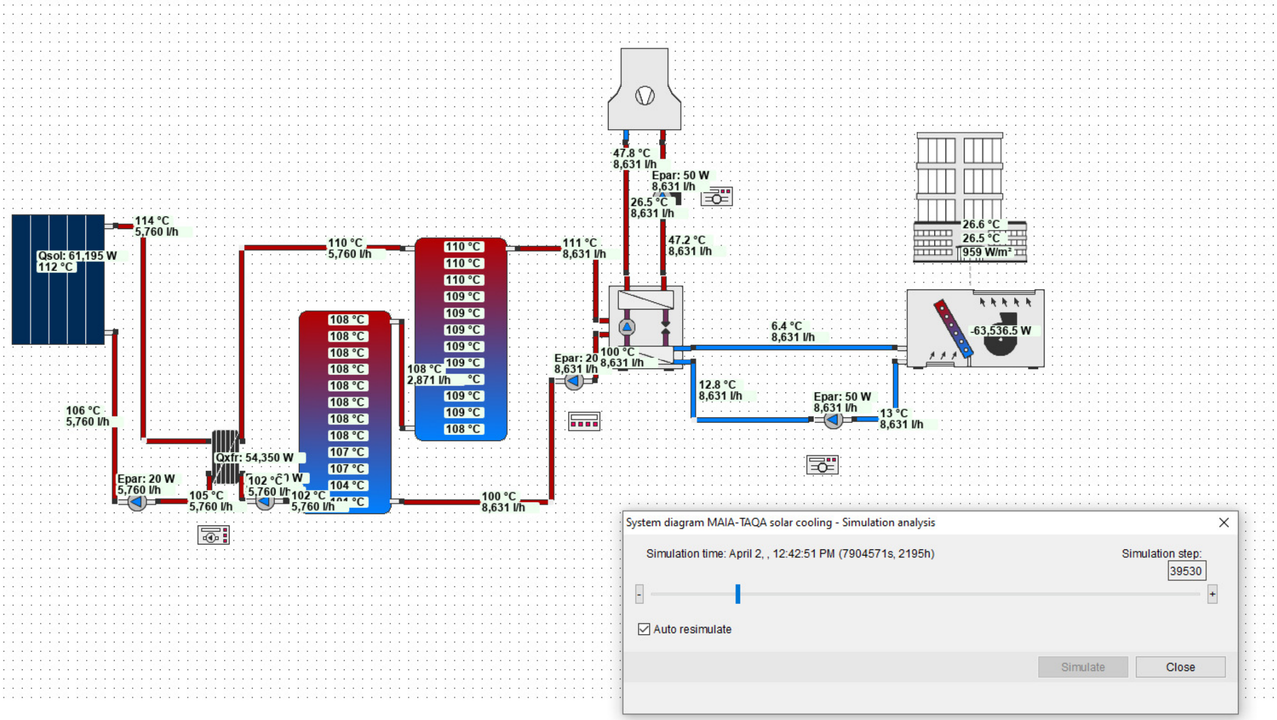
POLYSUN

Indicative operational diagrams
March

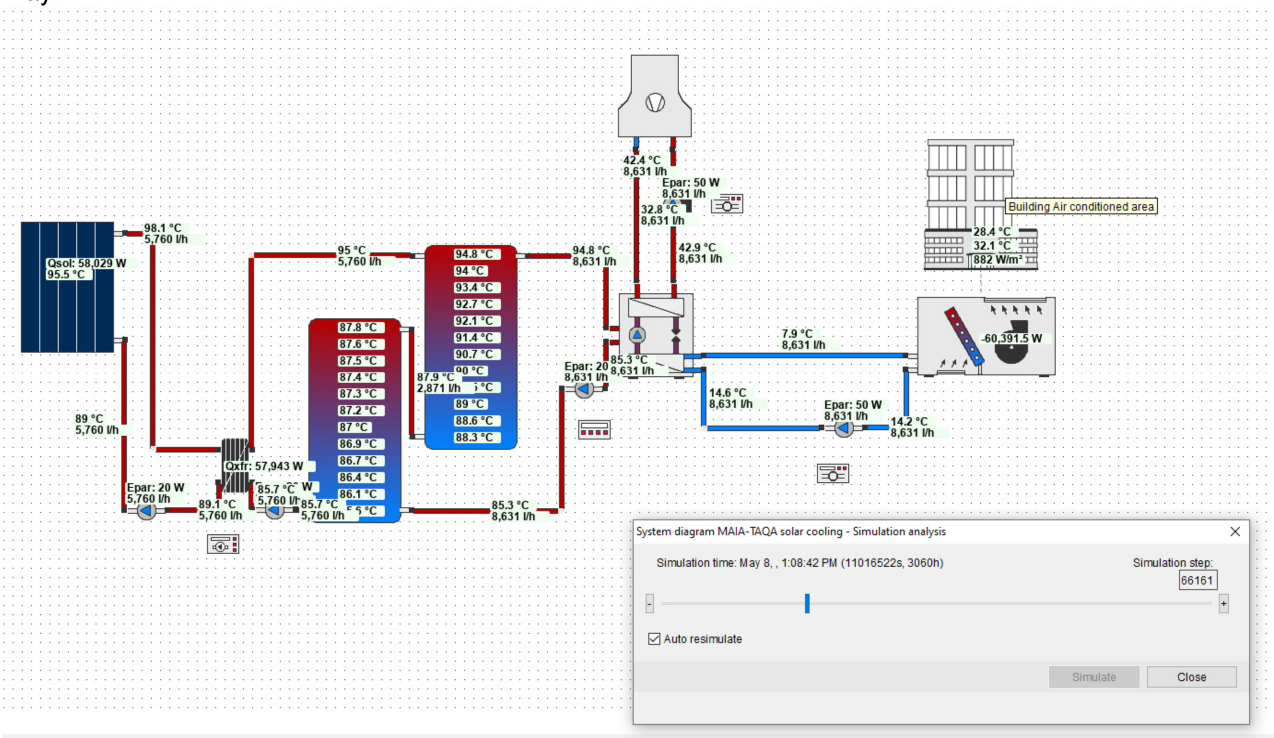




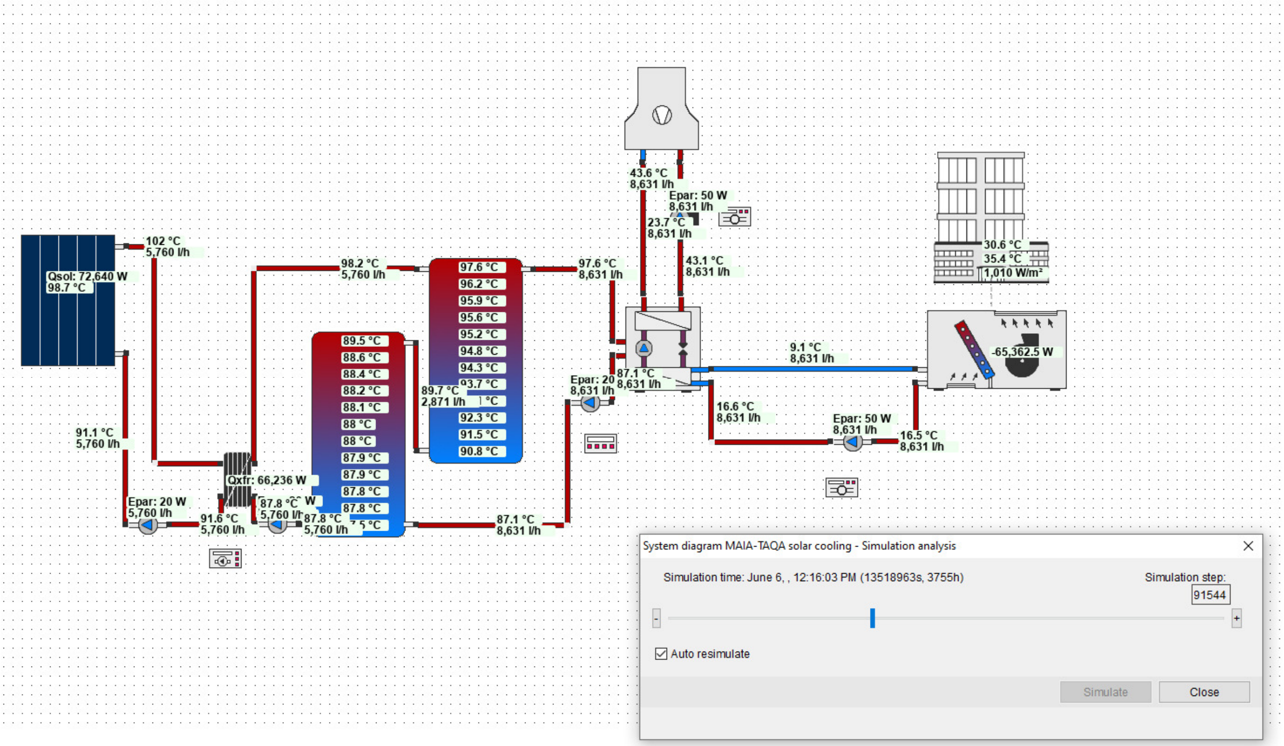
April


114 °C
5,760 l/h
Qsol: 61,195 W
112 °C
110 °C
5,760 l/h
111 °C
8,631 l/h
47.8 °C
8,631 l/h
Epar: 50 W
8,631 l/h
26.5 °C
8,631 l/h
47.2 °C
8,631 l/h
26.6 °C
26.5 °C
959 W/m²
6.4 °C
8,631 l/h
-63,536.5 W
106 °C
5,760 l/h
Qxfr: 54,350 W
Epar: 20 W
5,760 l/h
105 °C
5,760 l/h
108 °C
2,871 l/h
Epar: 20
8,631 l/h
100 °C
8,631 l/h
12.8 °C
8,631 l/h
Epar: 50 W
8,631 l/h
13 °C
8,631 l/h
100 °C
8,631 l/h
System diagram MAIA-TAQA solar cooling - Simulation analysis
Simulation time: April 2, , 12:42:51 PM (7904571s, 2195h)
Simulation step:
39530
Auto resimulate
Simulate
Close

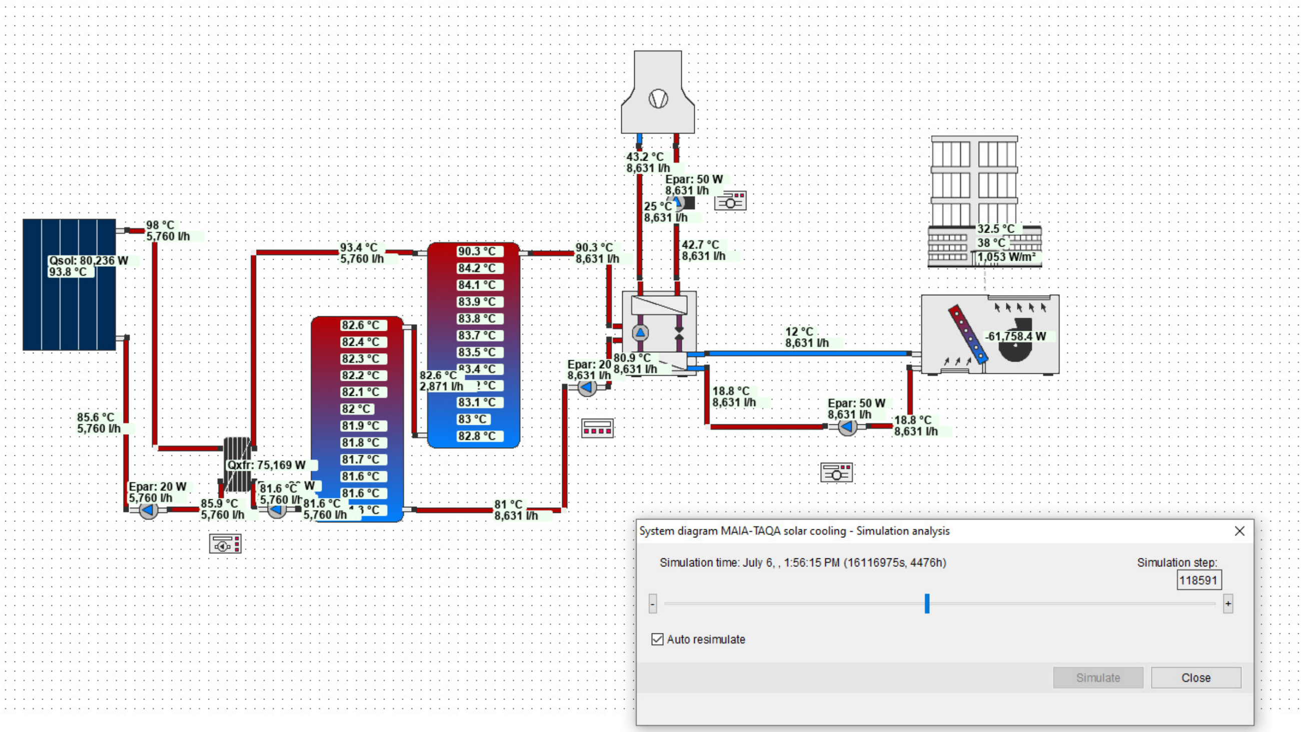
May


98.1 °C
5,760 l/h
Qsol: 58,029 W
95.5 °C
95 °C
5,760 l/h
94.8 °C
8,631 l/h
42.4 °C
8,631 l/h
Epar: 50 W
8,631 l/h
32.8 °C
8,631 l/h
42.9 °C
8,631 l/h
Building Air conditioned area
28.4 °C
32.1 °C
882 W/m²
7.9 °C
8,631 l/h
-60,391.5 W
89 °C
5,760 l/h
Qxfr: 57,943 W
Epar: 20 W
5,760 l/h
89.1 °C
5,760 l/h
87.9 °C
2,871 l/h
Epar: 20
8,631 l/h
85.3 °C
8,631 l/h
14.6 °C
8,631 l/h
Epar: 50 W
8,631 l/h
14.2 °C
8,631 l/h
85.3 °C
8,631 l/h
System diagram MAIA-TAQA solar cooling - Simulation analysis
Simulation time: May 8, , 1:08:42 PM (11016522s, 3060h)
Simulation step:
66161
Auto resimulate
Simulate
Close

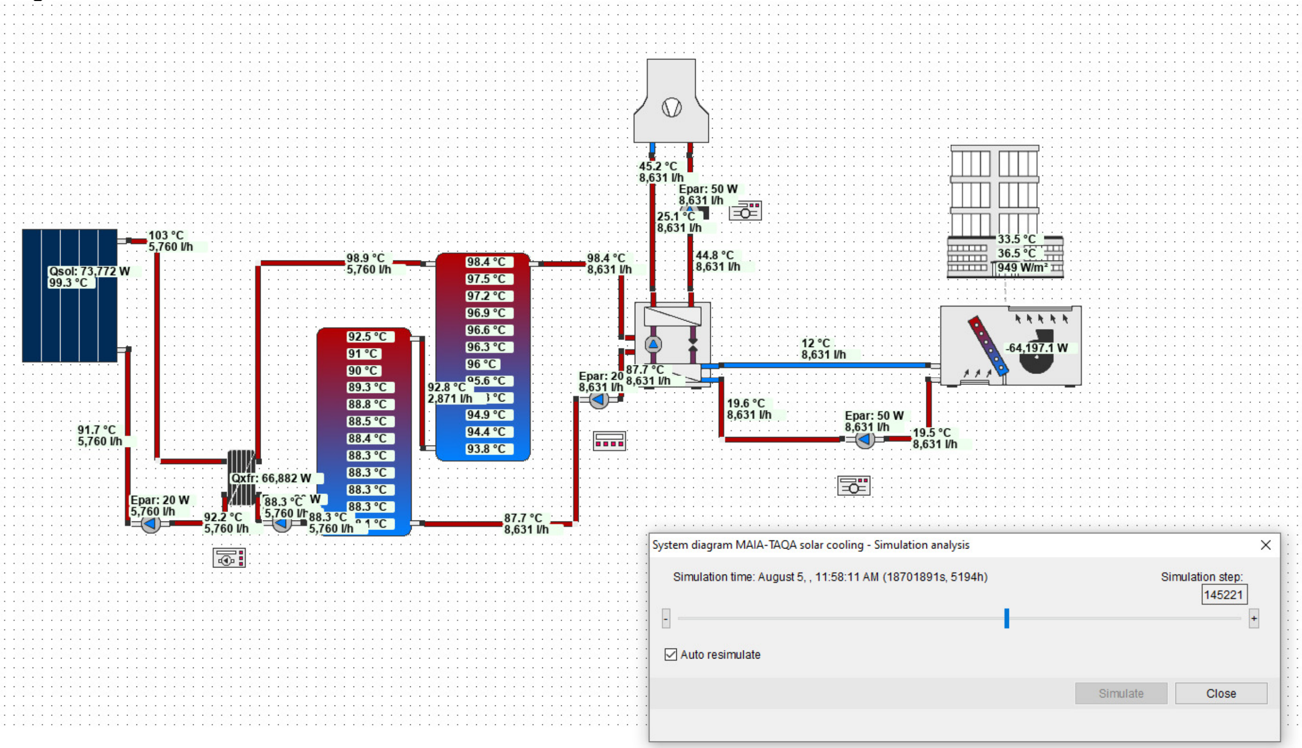
June


102 °C
5,760 l/h
Qsol: 72,640 W
98.7 °C
91.1 °C
5,760 l/h
Epar: 20 W
5,760 l/h
91.6 °C
5,760 l/h
Qxfr: 66,236 W
98.2 °C
5,760 l/h
97.6 °C
96.2 °C
95.9 °C
95.6 °C
95.2 °C
94.8 °C
94.3 °C
93.7 °C
92.3 °C
91.5 °C
90.8 °C
89.5 °C
88.6 °C
88.4 °C
88.2 °C
88.1 °C
88 °C
88 °C
87.9 °C
87.9 °C
87.8 °C
87.8 °C
89.7 °C
2,871 l/h
87.1 °C
8,631 l/h
97.6 °C
8,631 l/h
43.6 °C
8,631 l/h
Epar: 50 W
8,631 l/h
23.7 °C
8,631 l/h
43.1 °C
8,631 l/h
Epar: 20
8,631 l/h
87.1 °C
8,631 l/h
9.1 °C
8,631 l/h
16.6 °C
8,631 l/h
Epar: 50 W
8,631 l/h
16.5 °C
8,631 l/h
30.6 °C
35.4 °C
1,010 W/m²
-65,362.5 W
System diagram MAIA-TAQA solar cooling - Simulation analysis
Simulation time: June 6, , 12:16:03 PM (13518963s, 3755h)
Simulation step:
91544
Auto resimulate
Simulate
Close

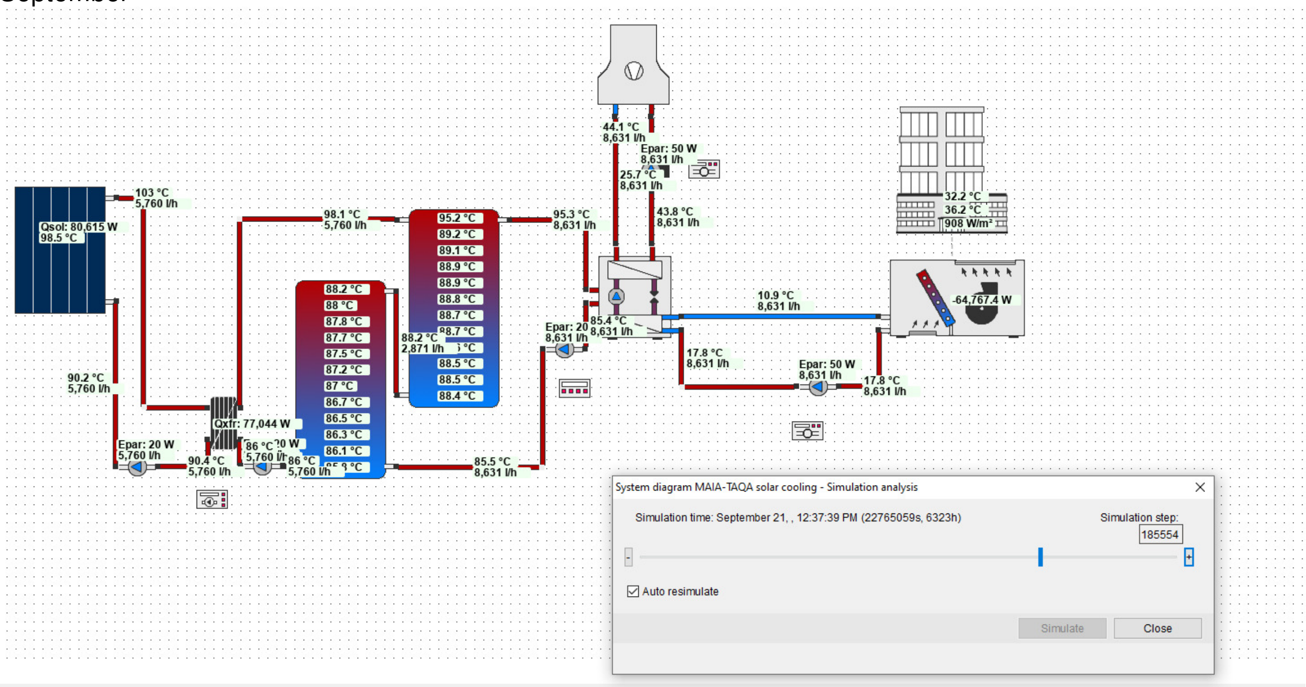
July


98 °C
5,760 l/h
Qsol: 80,236 W
93.8 °C
85.6 °C
5,760 l/h
Epar: 20 W
5,760 l/h
85.9 °C
5,760 l/h
Qxfr: 75,169 W
93.4 °C
5,760 l/h
90.3 °C
84.2 °C
84.1 °C
83.9 °C
83.8 °C
83.7 °C
83.5 °C
83.4 °C
83.1 °C
83 °C
82.8 °C
82.6 °C
82.4 °C
82.3 °C
82.2 °C
82.1 °C
82 °C
81.9 °C
81.8 °C
81.7 °C
81.6 °C
81.6 °C
82.6 °C
2,871 l/h
81 °C
8,631 l/h
90.3 °C
8,631 l/h
43.2 °C
8,631 l/h
Epar: 50 W
8,631 l/h
25 °C
8,631 l/h
42.7 °C
8,631 l/h
Epar: 20
8,631 l/h
80.9 °C
8,631 l/h
12 °C
8,631 l/h
18.8 °C
8,631 l/h
Epar: 50 W
8,631 l/h
18.8 °C
8,631 l/h
32.5 °C
38 °C
1,053 W/m²
-61,758.4 W
System diagram MAIA-TAQA solar cooling - Simulation analysis
Simulation time: July 6, , 1:56:15 PM (16116975s, 4476h)
Simulation step:
118591
Auto resimulate
Simulate
Close

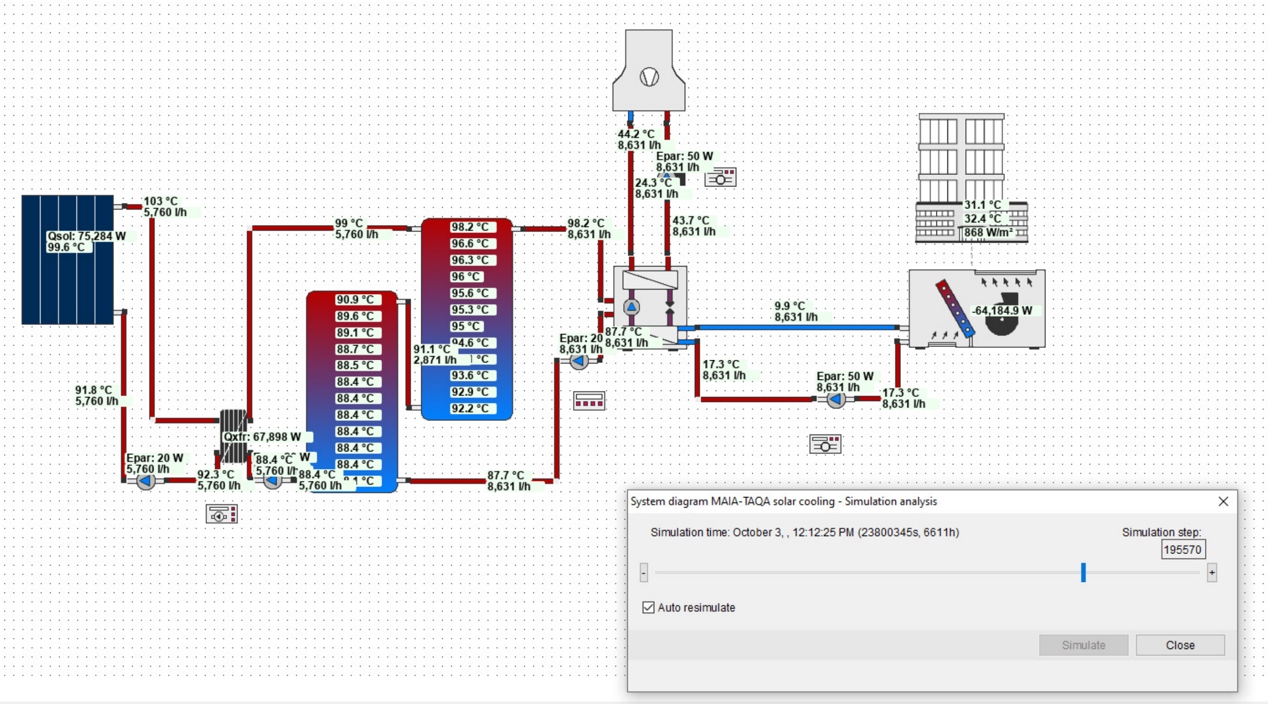
August



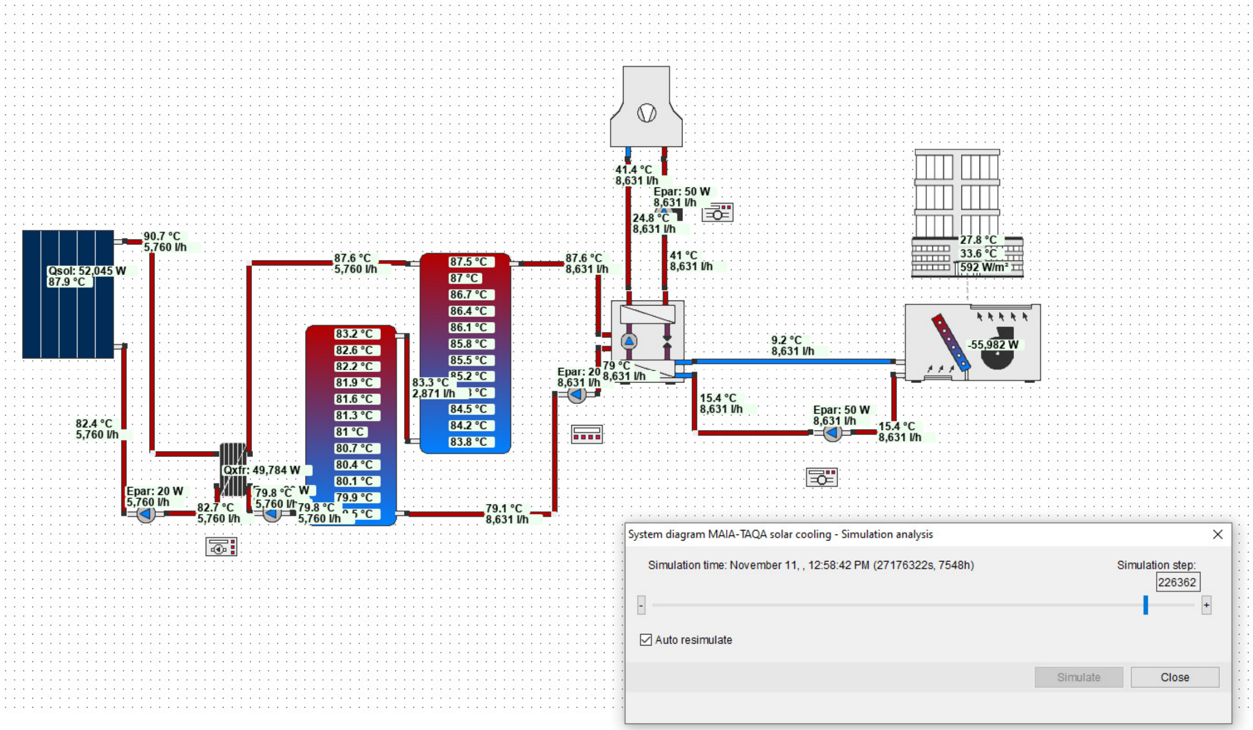
September



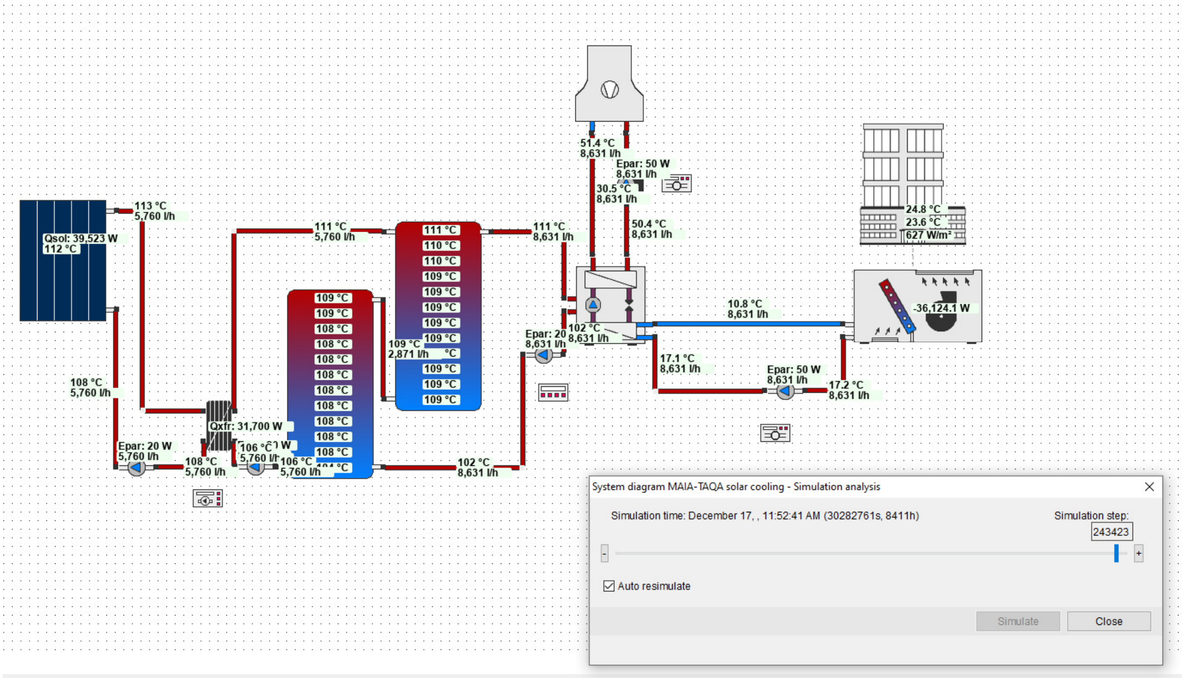
October



November



December


51.4 °C
8,631 l/h
Epar: 50 W
8,631 l/h
30.5 °C
8,631 l/h
50.4 °C
8,631 l/h
113 °C
5,760 l/h
Qsol: 39,523 W
112 °C
111 °C
5,760 l/h
111 °C
8,631 l/h
24.8 °C
23.6 °C
627 W/m²
10.8 °C
8,631 l/h
-36,124.1 W
102 °C
8,631 l/h
17.1 °C
8,631 l/h
Epar: 50 W
8,631 l/h
17.2 °C
8,631 l/h
108 °C
5,760 l/h
Qxfr: 31,700 W
Epar: 20 W
5,760 l/h
108 °C
5,760 l/h
102 °C
8,631 l/h
System diagram MAIA-TAQA solar cooling - Simulation analysis
Simulation time: December 17, , 11:52:41 AM (30282761s, 8411h)
Simulation step:
243423
Auto resimulate
Simulate
Close