Löfbergs

suncool

Making a difference to your environment

Suncool conference

LIFE11 ENV/SE/000838
SUNCOOL

October 9th, 2014

Agenda

09.30-09.45	Welcome and introduction	Daniel Mugnier Per Olofsson	TECSOL ClimateWell
09.45-10.15	Presentation of the first results from subtask A: Survey of existing new generation systems	Tim Selke	AIT
10.15-10.45	Presentation of the research and development work, leading up to the Suncool collectors	Per Olofsson/ Göran Bolin	ClimateWell
10.45-11.00	Presentation of the system solution and control strategy	Olof	ClimateWell
11.00- 11.45	**Visit to the demonstration installation**		
11.45-12:00	Presentation of measurement data from the installation	Corey	ClimateWell
12.00-12:15	Presentation of lessons learned from the system engineering and installation	Olof/Corey	ClimateWell
12.15-13:30	Work-shop with Q&A and discussion around 2-3 research topics.	Olof/Corey	ClimateWell

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1. Presentation of the research and development work, leading up to the Suncool collectors [Per/Göran]
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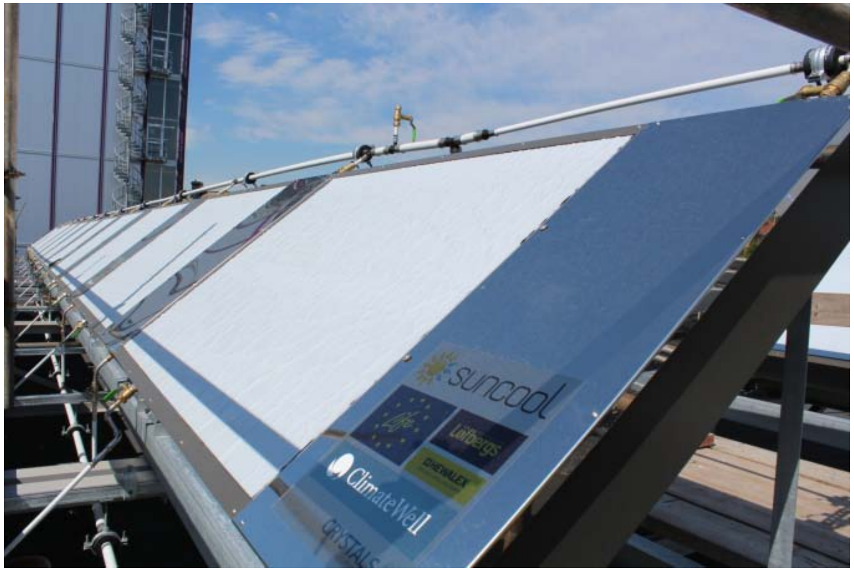
What will you see today?

- The solar heating and cooling installation in the world with the highest electrical COP:
  - Measured average of over 10 and maximum of 12
  - Potential to reach 15

- How? Integration of components and minimization of moving parts

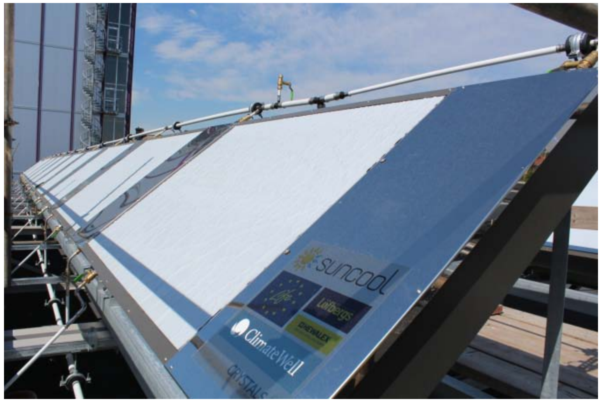


Background

- ClimateWell started developing a technology for solar cooling (and heating) in 2002 based on an absorption discovery
- The main difference towards conventional absorption was that it included mass transportation of the salt solution
  - In the first versions using pumps
  - Since 2006 using a proprietary capillary technology which eliminated the need for pumps
- The first product was a solar chiller called the SolarChiller. It was powered by conventional solar thermal collectors. More than 200 units of the SolarChiller were delivered.
- A lot was learned and the main conclusions were:
  - It works but it is too expensive
  - The installation is too complex
  - We need to get colder AC temperatures
  - We need to get a much higher electrical COP. Reduce the need for pumps and fans.

From:

To:



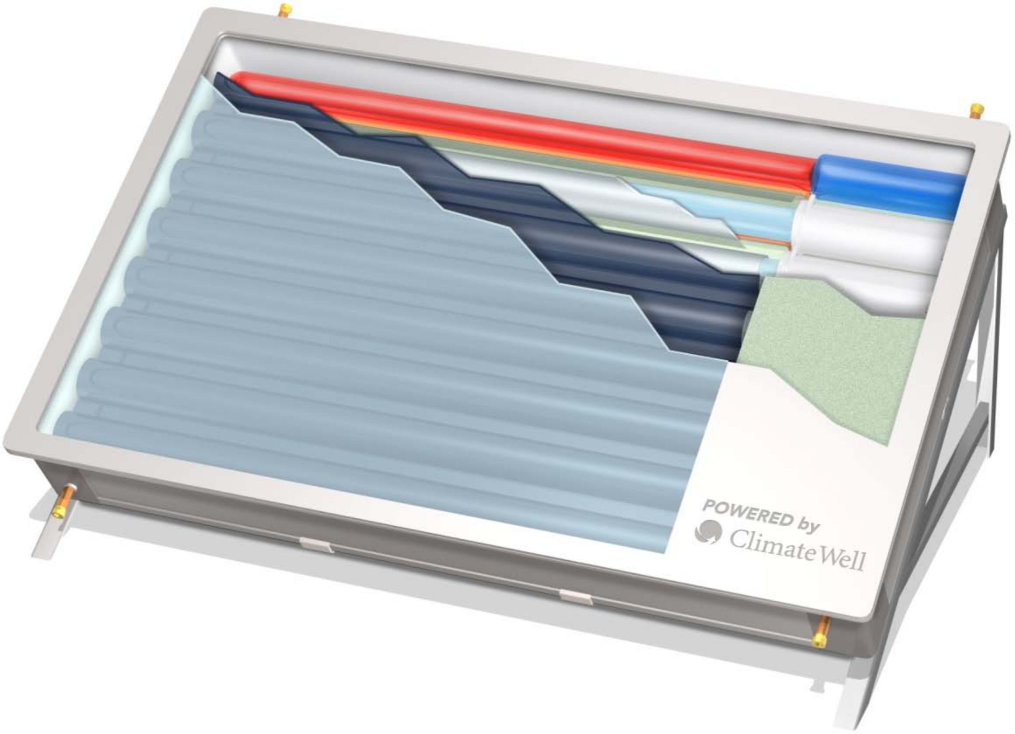
How?

Göran Bolin, CTO and founder of ClimateWell

The solution: Integration and simplification

- Integrate the sorption component directly into the solar collector
- Less complexity
- Less circuits
- Less losses
- Less control
- Lower cost
- Higher electrical COP

- And, do the charging during the day and the delivery of cooling during the night = reduced fan speeds and improves temperatures



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Löfbergs Life suncool

Tests…

- First we tested in our own test rigs, on an individual tube level

- Then we tested one collector at Fraunhofer ISE: during 2012

Fraunhofer ISE

- During summer 2013, we installed 4 collectors and placed them on a roof in Stockholm

- Now we have made the first full scale installation of 180 m^2 of collectors here in Karlstad together with Löfbergs

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Installation

- 130 collectors in 12 banks = 180m^2 aperture area
- Installed capacity: 40 kW (cooling)
- Orientation: South-west
- Heat rejection: Dry cooler
- Cooling system: Air handler pre-cooling 7/12°C, cooling baffles 13/18°C. Water/water chillers
- Heating system: District heating (heat recovery from production compressors)

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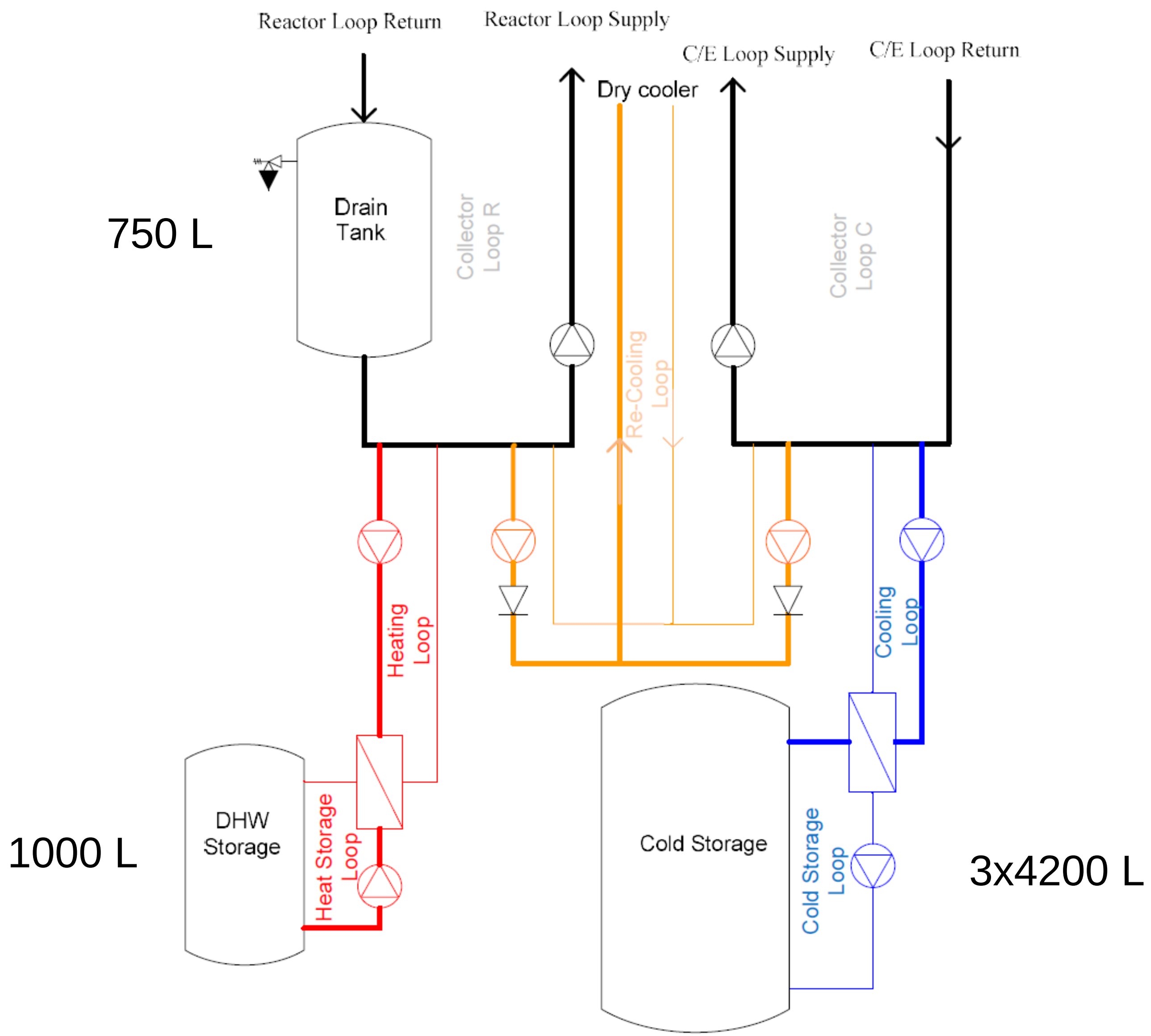
Solution, conceptual schematics



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Control strategy, introduction

- Three production modes

Desorption Mode	Absorption Mode	Winter Mode
Day-time Het rejection to ambient	Night-time Heat delivery to hot storage Heat rejection to ambient Cooling production	Day-time Heat delivery to hot storage

- Two delivery modes

Heating delivery	Cooling delivery
Whenever heat available	Whenever cooling available

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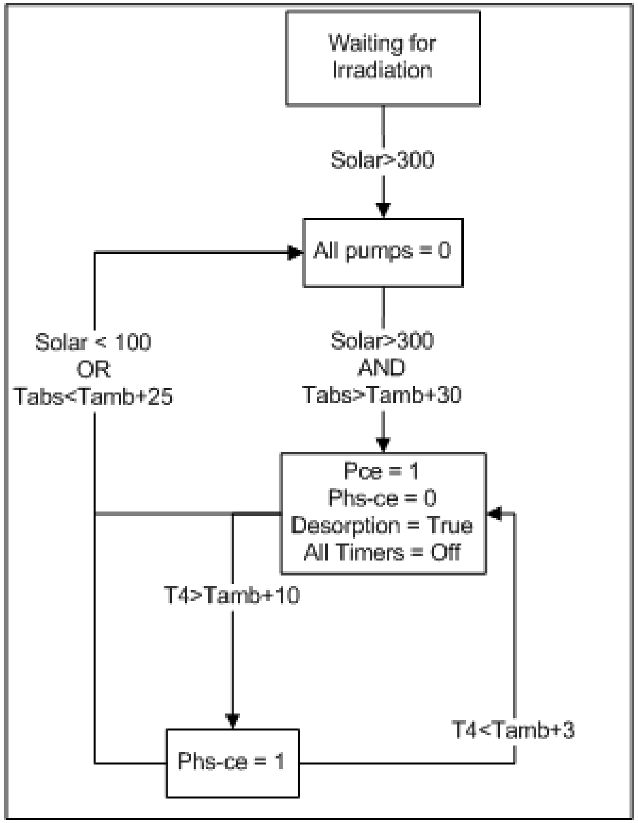
Control system I/O

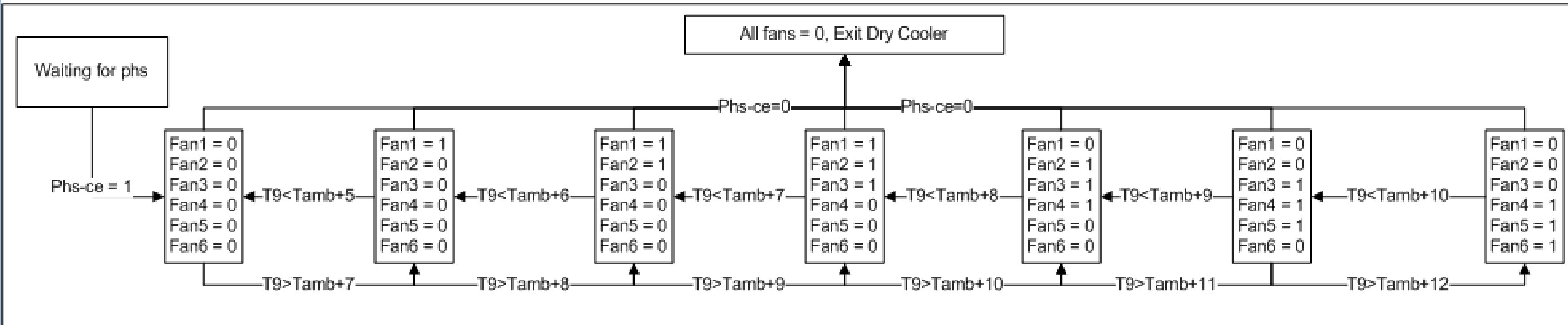
Input	Description	Output	Description
T1 (GT51)	Reactor return [°C]	Pre	Reactor primary pump
T2 (GT151)	Reactor flow [°C]	Pce	C/E primary pump
T3 (GT52)	C/E return [°C]	Phs-re	Reactor heat rejection pump
T4 (GT152)	C/E flow [°C]	Phs-ce	C/E heat rejection pump
T5 (GT39)	Lower hot store temperature [°C]	Pheat	Primary heating pump
T6 (GT40)	Upper hot store temperature [°C]	Pheat2	Secondary heating pump
T7 (GT42)	Upper cold store temperature [°C]	Pac	Primary cooling pump
T9 (GT38)	Return dry cooler temperature [°C]	Pac2	Secondary cooling pump
Tamb (GT114)	Ambient temperature [°C]	Fan1	Dry cooler fan 1&2
Tabs (GT101-GT112)	Collector absorber temperature	Fan2	Dry cooler fan 3&4
Solar	Global irradiation	Fan3	Dry cooler fan 5&6

Control system: Desorption

Inputs
T4 = C/E flow [°C]
T9 = Return dry cooler temperature [°C]
Tamb = Ambient temperature [°C]
Tabs = Collector absorber temperature
Solar = Insolation intensity [W/m^2]

Outputs
Pce = C/E primary pump
Phs-ce = C/E heat rejection pump
Fan1 = Dry cooler fan 1 low
Fan2 = Dry cooler fan 2 low
Fan3 = Dry cooler fan 3 low
Fan4 = Dry cooler fan 1 high
Fan5 = Dry cooler fan 2 high
Fan6 = Dry cooler fan 3 high





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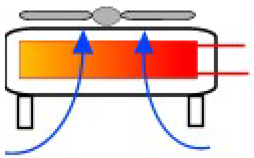
Nomenclature - Parameters

- Cooling Power
- Cooling Energy

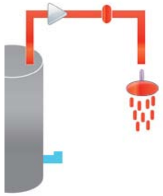
$$\dot{Q}_{cool} = c_p \dot{m}(T_1 - T_2)$$

$$E_{cool} = \int_{t_0}^{t} \dot{Q}_{cool}$$



- Re-Cooling Power & Energy

$$\dot{Q}_{hs-re} = c_p \dot{m}(T_5 - T_6) \qquad \dot{Q}_{hs-ce} = c_p \dot{m}(T_5 - T_6)$$

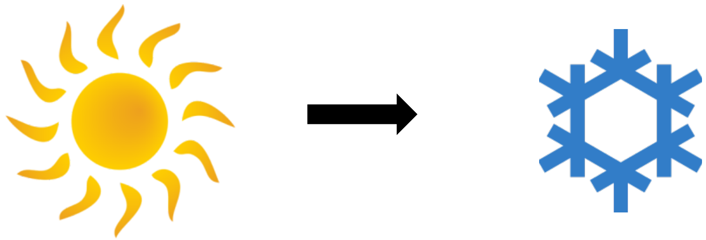


- Energy for Domestic Hot Water Preparation

$$\dot{Q}_{DHW} = c_p \dot{m}(T_3 - T_4)$$

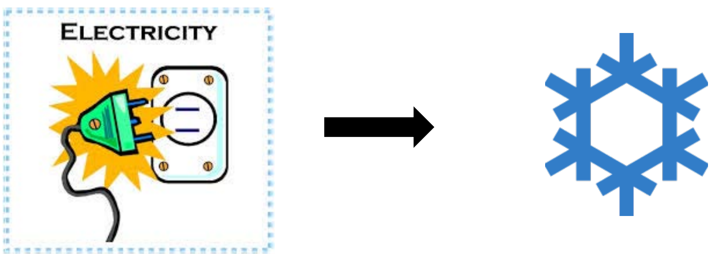
- Solar Insolation

Nomenclature - Indices



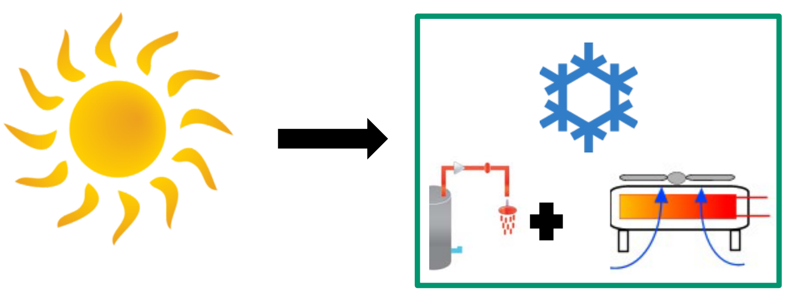
- Solar COP

$$COP_{solar} = \frac{E_{cool}}{HA}$$



- Electrical COP

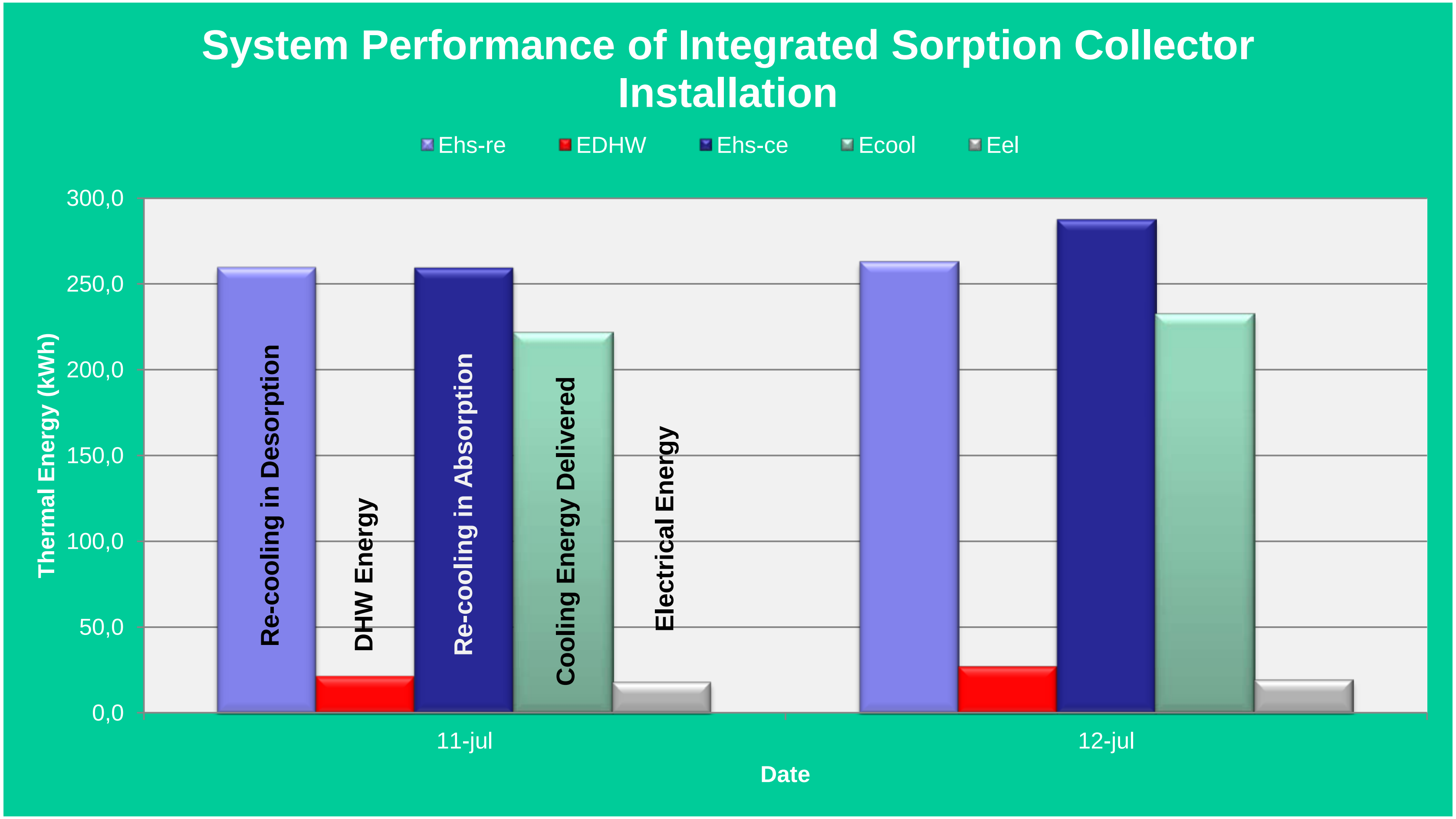
$$COP_{el} = \frac{E_{cool}}{E_{el}}$$



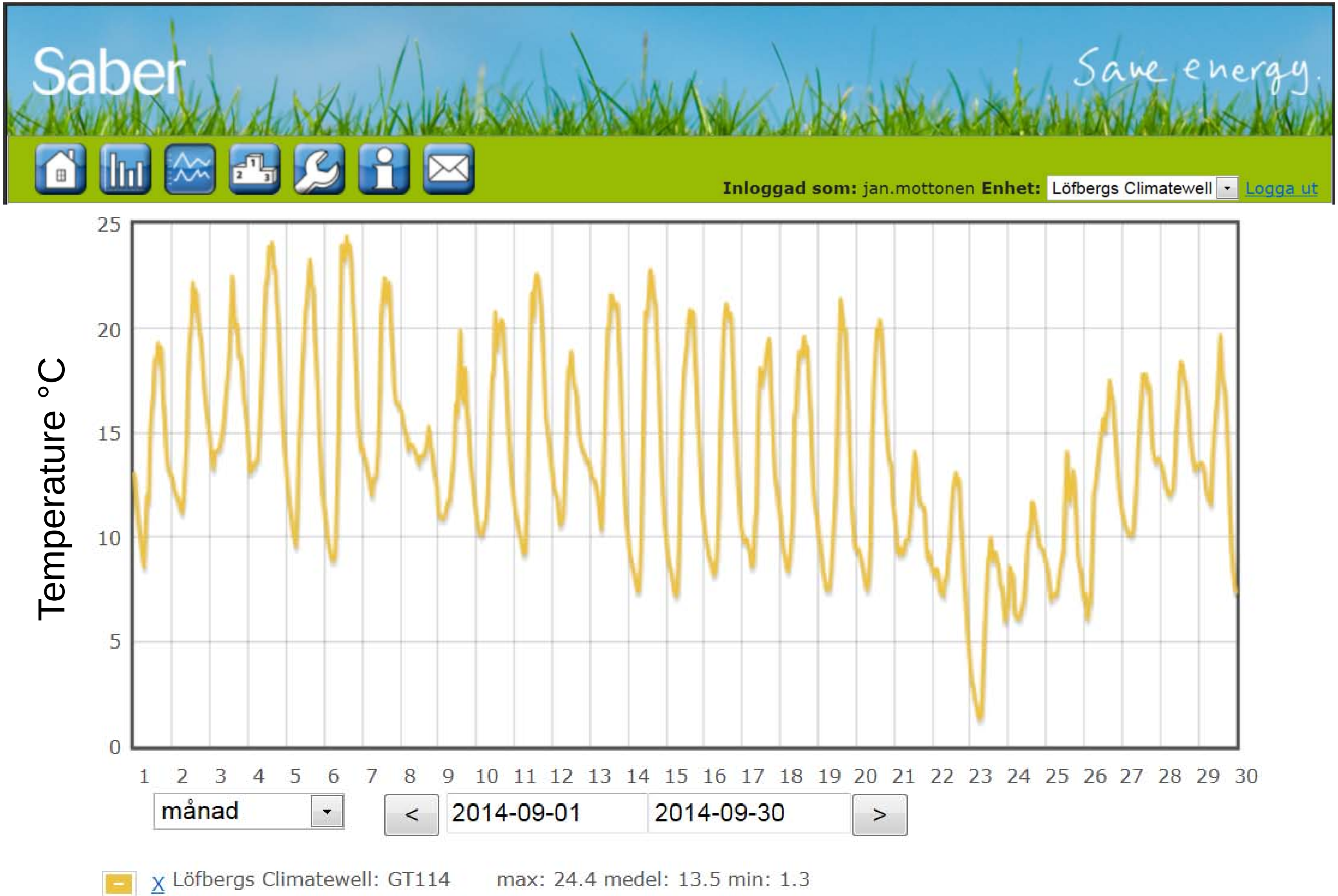
- Total Efficiency

$$\eta_{total} = \frac{E_{total}}{HA}$$

Typical Days



Continuous monitoring



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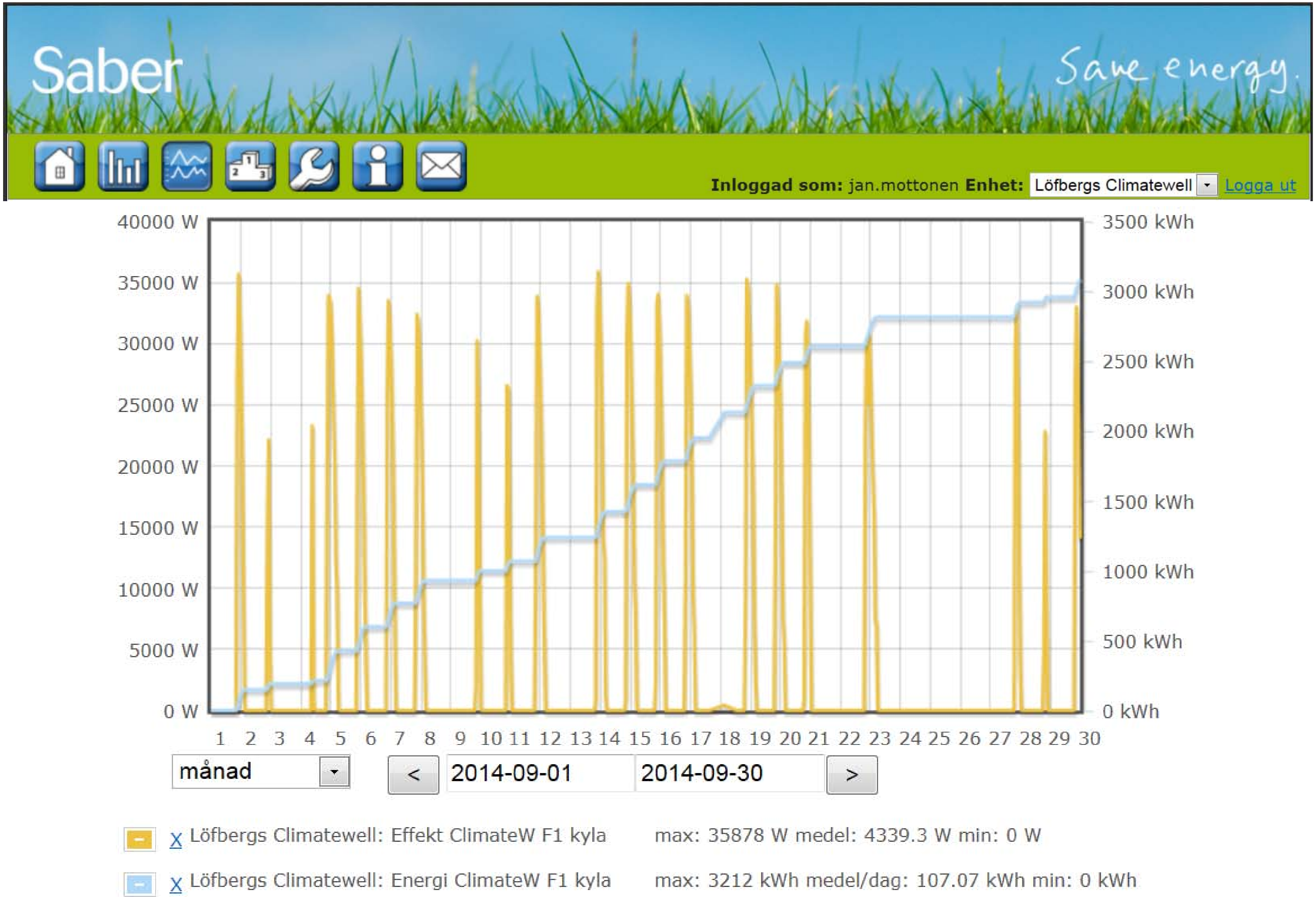
Continuous monitoring



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Measured Performance (July 11 - 25, 2014)

Performance Parameters	Max	Min	Ave
Solar Cooling COP (COP_{solar})	**0.21**	**0.02**	**0.17**
Cooling Power Index[$kW\ m^{-2}$]	0.25	0.14	0.19
Cooling Energy Index[$kWh\ m^{-2} day^{-1}$]	1.52	0.06	1.16
Daily Solar Insolation (H) [$kWh\ m^{-2} day^{-1}$]	7.9	2.7	6.7
Heating Energy for DHW [$kWh\ m^{-2} day^{-1}$)]	0.39	0.10	0.21
Total Efficiency (η_{total})	**0.73**	**0.16**	**0.63**
Electrical COP (COP_{el})	**12.6**	**1.7**	**10.6**

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Comparison

Installation	COP_{cool}	COP_{solar}	COP_{el}
Rottweil 680 kW	0.56	0.21	5.80
Festo 1050 kW	0.43	0.17	2.95
Butzbach 20 kW	0.53	0.13	4.82
Large-scale installation 40kW	-	0.17	10.60
Large-scale installation 40kW (including cold store)	-	0.14	8.40

Source: Solarthermie 2000plus Programme (2013)

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Winter's Coming!!

Solar heating measurements to come

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Lessons Learned, 1

- Hydraulic communication between reactor and C/E
  - Pressure less drain back circuit
  - Over pressure during day = leakage of air through plumbing
  - Under pressure during night = air enter system, also C/E circuit
  - Air in C/E circuit leads to stagnating collectors and leakage from jacket
- Solution
  - Separation of reactor and C/E circuits by means of heat exchanger

Lessons Learned, 2

- Buffer storage/Cooling production night time
  - Delivering cooling night time saves compressor cooling night time (high COP)
  - Storing to day time saves compressor cooling day time (low COP), but gives additional losses and lower efficiency of the system.

- Solution
  - Look at the complete system including conventional cooling and see how primary energy can be reduced.

Lessons Learned, 3

- Heat rejection
  - Heat rejection with dry cooler means temperatures >35°C during day
  - Continuous cycle (SolarChiller) this gave problems (low cooling power)
  - Collector losses relative to ambient temperature

- Consequence
  - Desorption with same efficiency regardless of ambient temperature
  - System equally efficient in Saudi Arabia as in Germany (less irradiation)

Future work

- Optimize flow rates with respect to electrical/thermal efficiency
- Investigate if variable flow control can be used
- Improve accuracy of the measuring equipment with better calibration
- Incorporate the SunCool simulation model with dynamic simulation models of entire cooling system (including chiller, building loads etc.)

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Research Questions

- Will solar thermal cooling be able to compete with PV-solar cooling?
  - What about grid stability?
  - What about systems for both heating and cooling?
- How can complete systems be evaluated based on primary energy consumption?
  - Reference systems?
  - What to compare with?
- How can solar thermal cooling systems be further simplified?
  - Stand alone systems
  - Air based systems