Numerical simulation and performance assessment of an absorption solar air-conditioning system coupled with an office building

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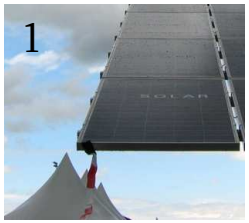
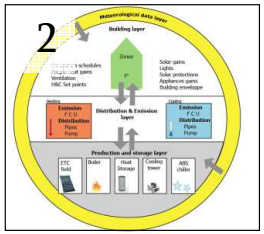
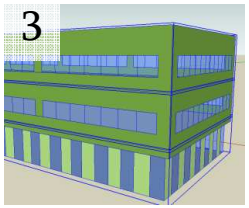
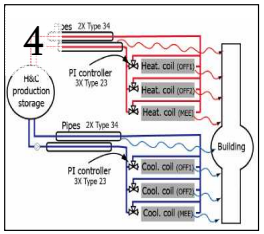
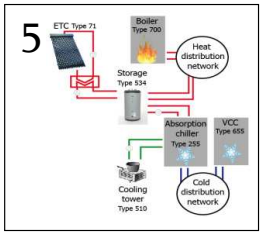
Presentation overview

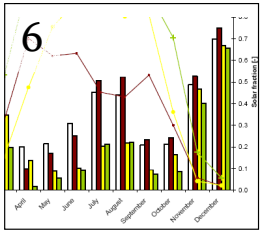












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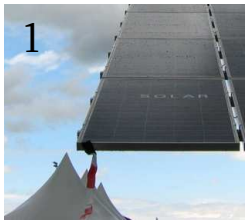
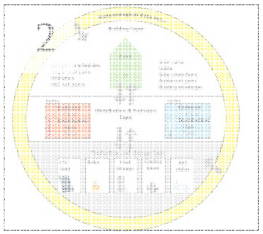
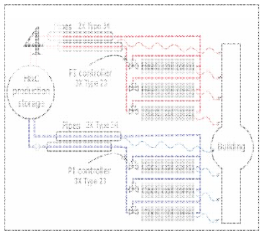
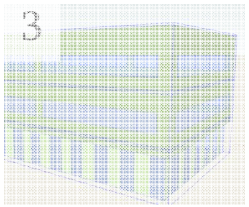
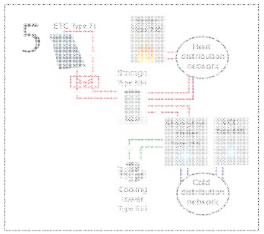
3. Building
4. H&C emission and distribution
5. H&C production and storage
6. Results & Conclusion

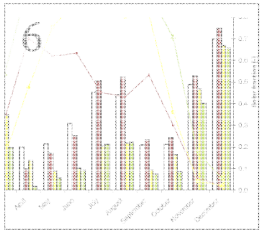












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Introduction : Solar air-conditioning context

Building cooling has an important impact on energy consumption, therefore on CO_2 emissions.

Moreover, strong increase in cooling installed capacity has been encountered last years.

Assets for solar energy :

- It is one of the largest renewable energy ressource

- Various technologies are available for cold production

- Sunny locations have more cooling needs

Market available solar cooling technologies

-Absorption chiller

-Adsorption chiller

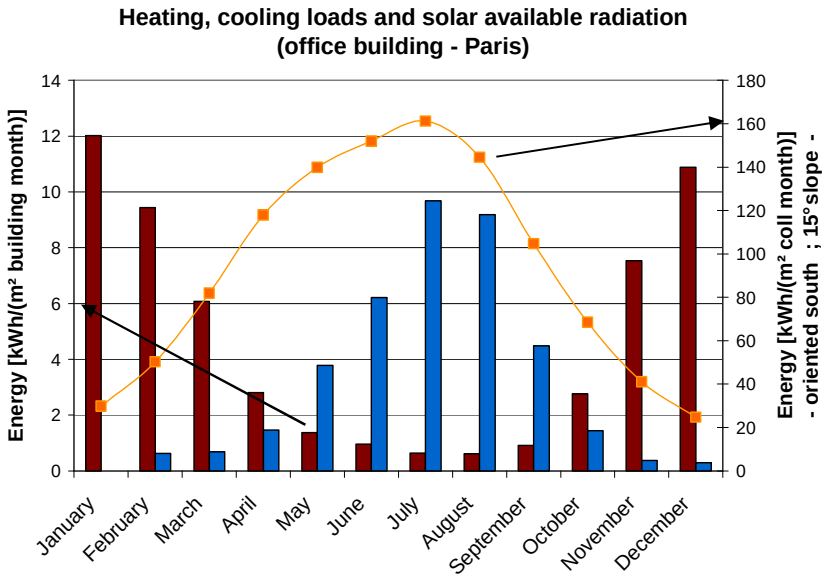
-Desiccant cooling system

-PV panels with classical vapour compression chiller

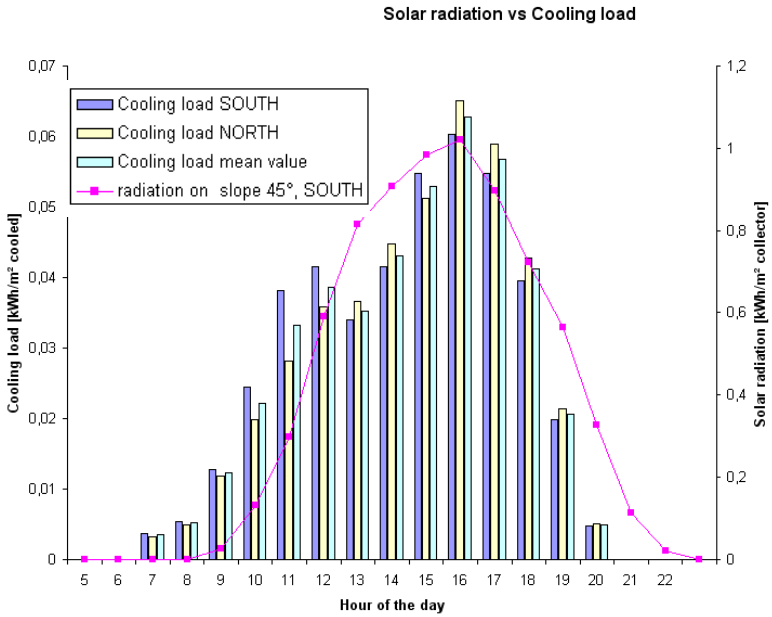
Introduction : key asset of solar energy

- The cooling load of buildings is generally high when solar radiation is high

➔ yearly basis



➔ daily basis



For an office building in August in Paris

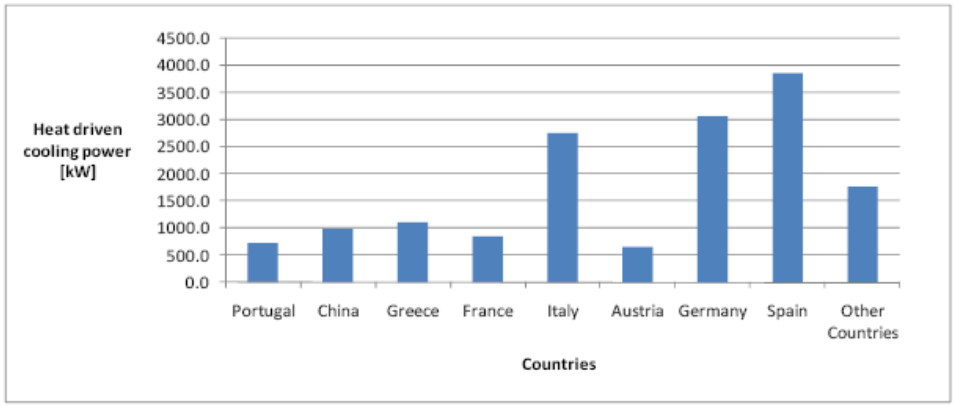
Introduction : Market status of Solar air-conditioning

World wide : 288 installations total of 16 MW

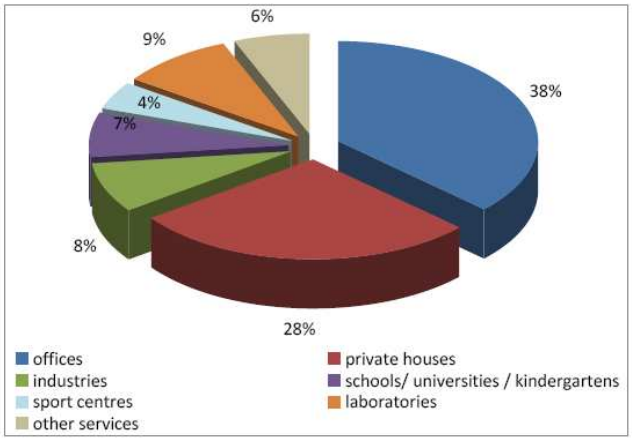
→ Small scale : 1.6 MW
≈ 200 syst<15kW

→ Large scale : 14 MW
≈ 100 Syst>15kW

Country distribution



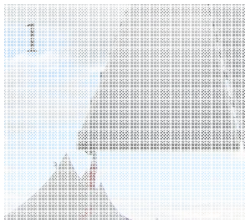
Type of building

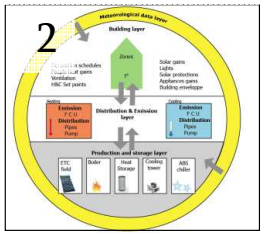


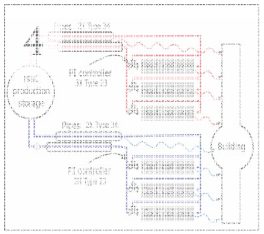
Technology distribution

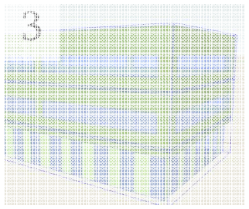
71% Absorption
16 % Desiccant (14% solid – 2% liquid)
13% Adsorption

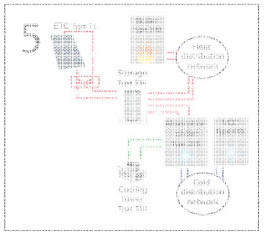
Src : IEA-SHC Task 38 Subtask B Reports 2009-11-12

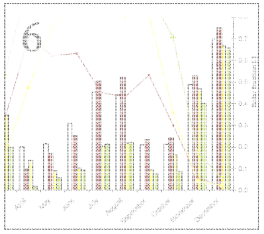












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Simulation environment overview

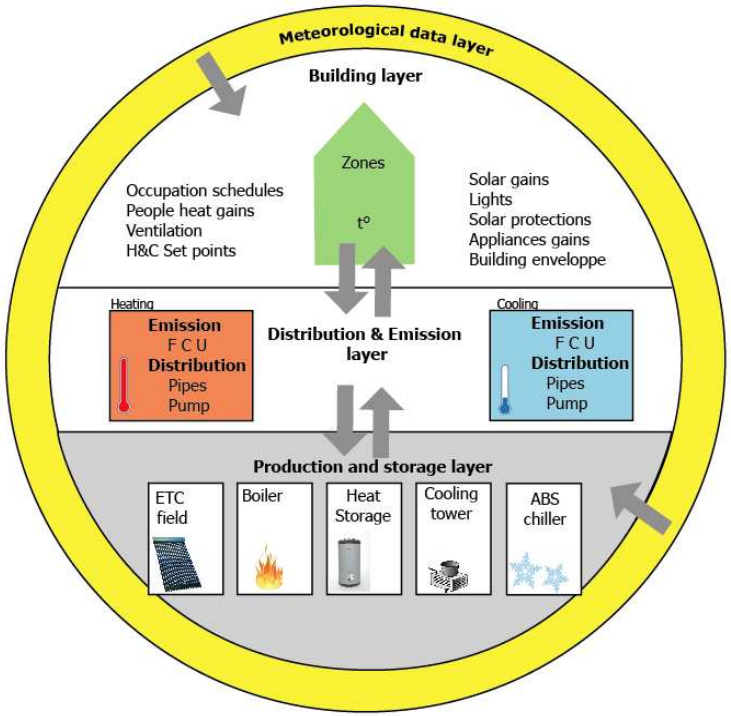
Integral approach to evaluate energy savings : Complete simulation environment is presented (…using TRNSYS)

Sub-systems implementation :

- Building
- Heat and Cold distribution and emission
- Heat and Cold production and storage
- Climate

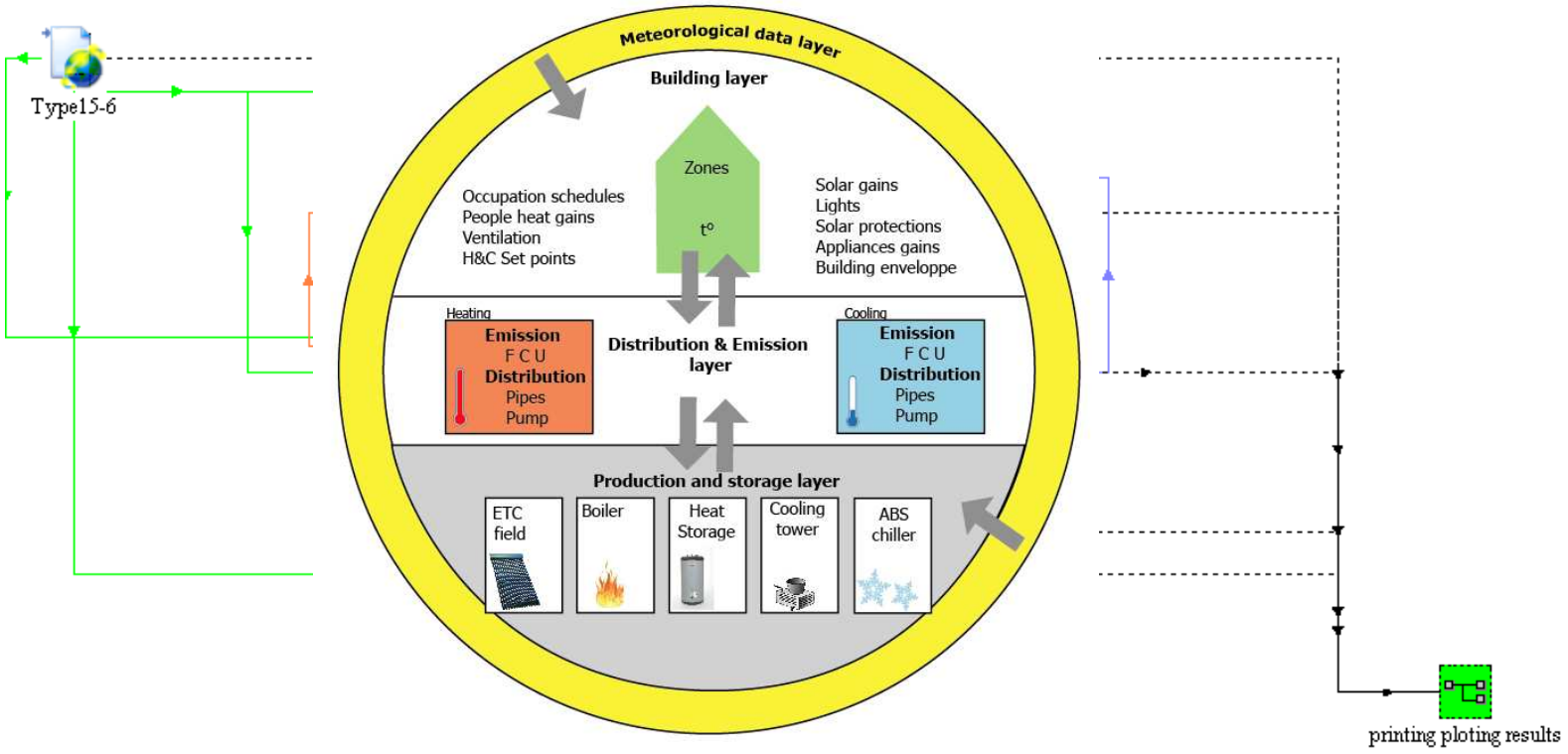
→ **Combined simulation of these sub-systems**

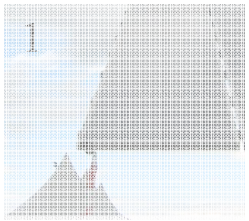
→ **Possibility to substitute components**

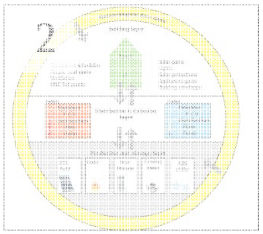


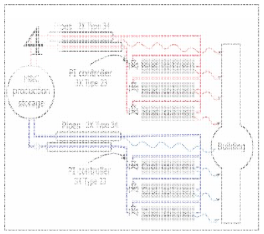
Simulation environment overview

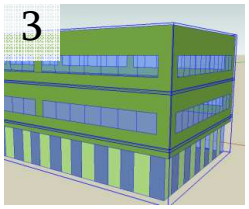
TRNSYS implementation of Sub-systems

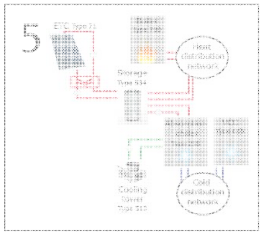


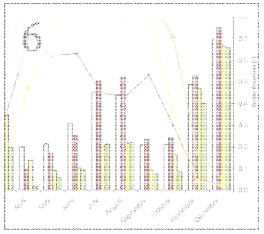












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Building modelling

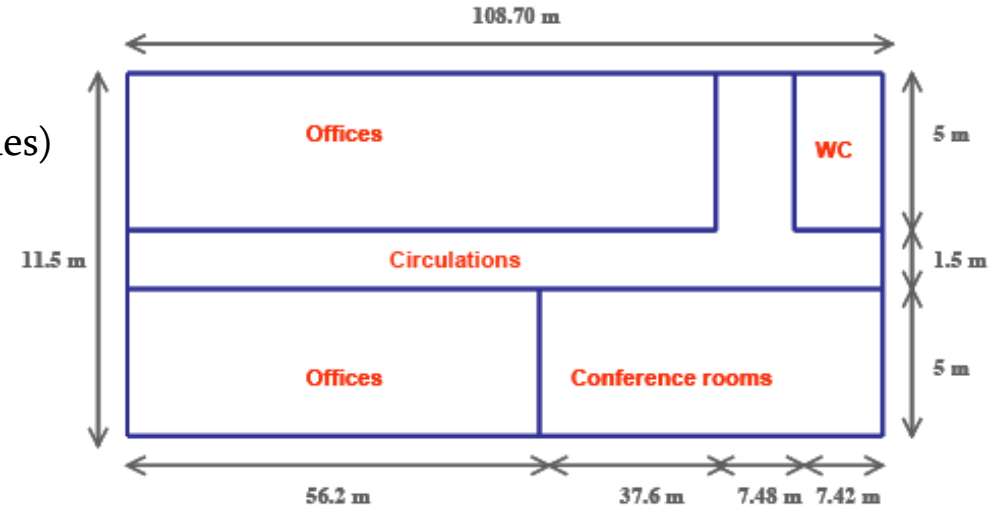
IEA-ECBCS 48 European typical office building 1-c

➔ Paris Climate

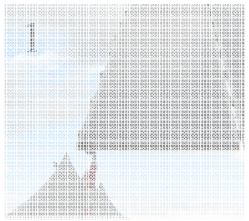
Building modeling (one floor) including :

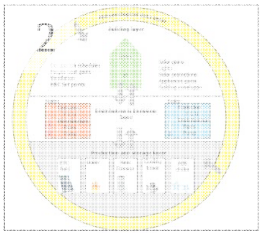
- 5 thermal zones (3 for H&C) (glazing on South and North facades)
- Ventilation
- External shading modulation
- Light intensity modulation
- Occupancy profile for each zone
- Internal gains profiles
  - > People
  - > Appliances
  - > Light

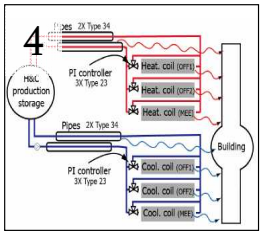
Total area : 3750 m² (1250 m²/floor)
Around 250 people

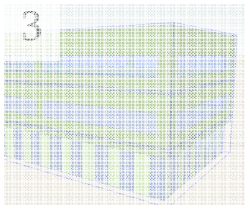


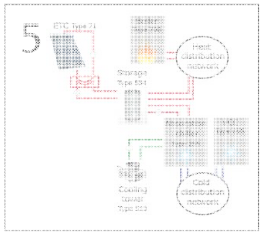
Stabat P. 2007. IEA48 – Description of Type 1c air-conditioned office buildings for simulation
IEA-ECBCS Annex 48 working document.

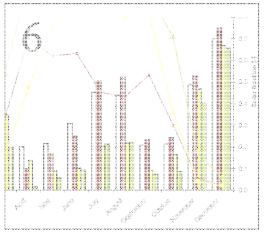












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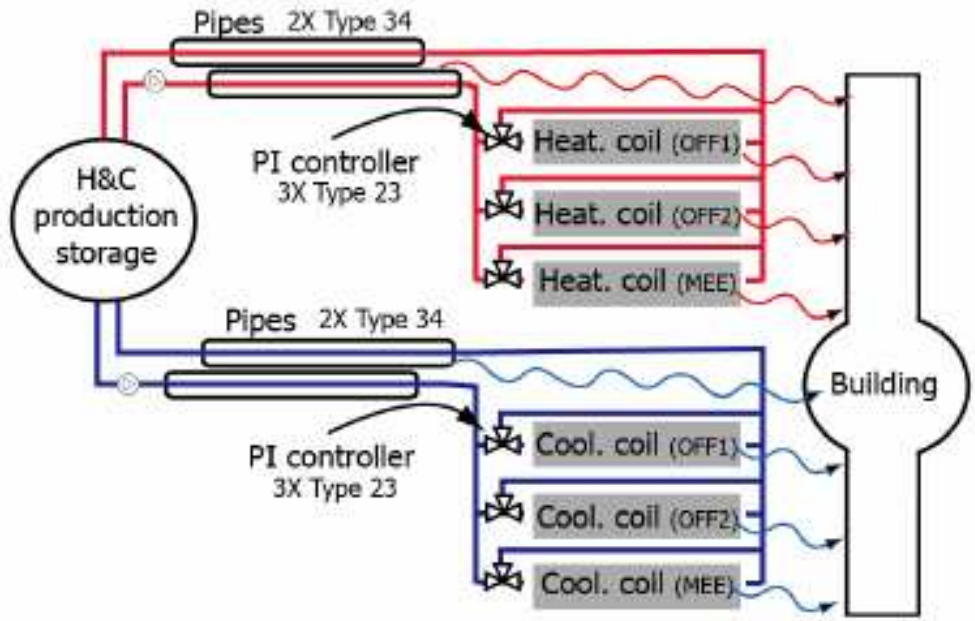
Heat and Cold emission and distribution

This sub-system is linked with H&C production and building sub-systems



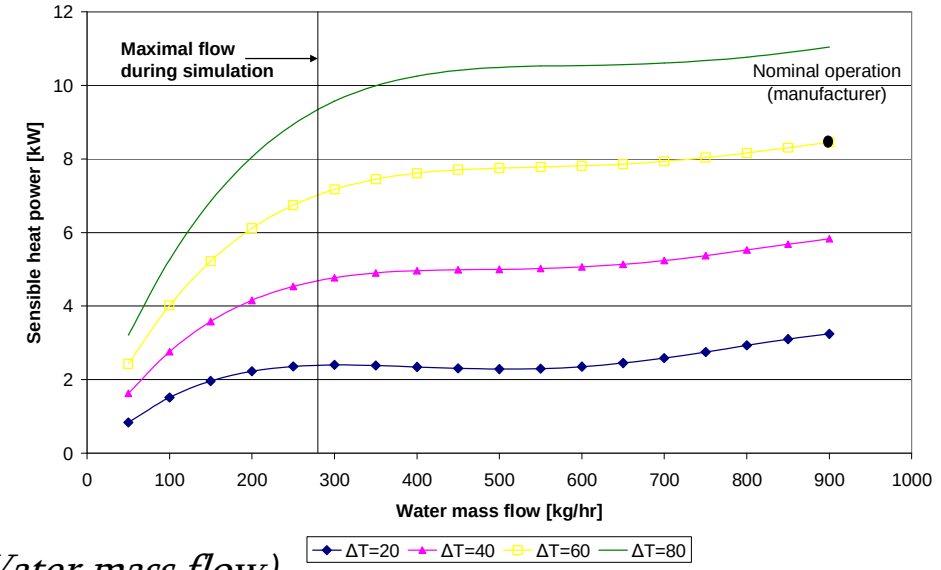
Pipes, pumps, control and fan coil units are modelled

Fan Coil Units modelling

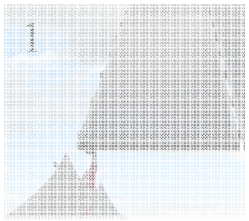
Objective : A real FCU where manufacturer data is available should be implemented.

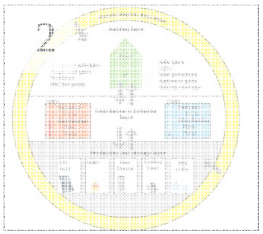
Existing heating/cooling coil classical TRNSYS models are not suited to this objective
➔
Polynomial approximation of the coil is implemented (based on manufacturer data)

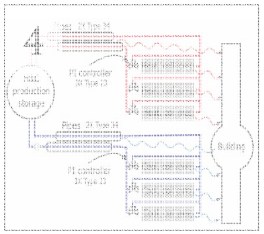
Head/Cold emission is controlled by a thermostatic valve (PI controller) modifying the water mass flow.

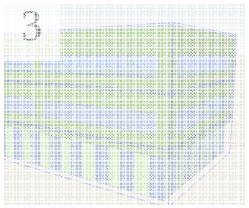


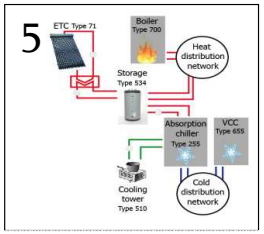
Heating coil sensible heating energy = f((Twater supply – Troom), Water mass flow)

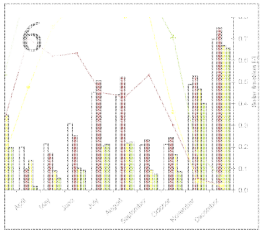












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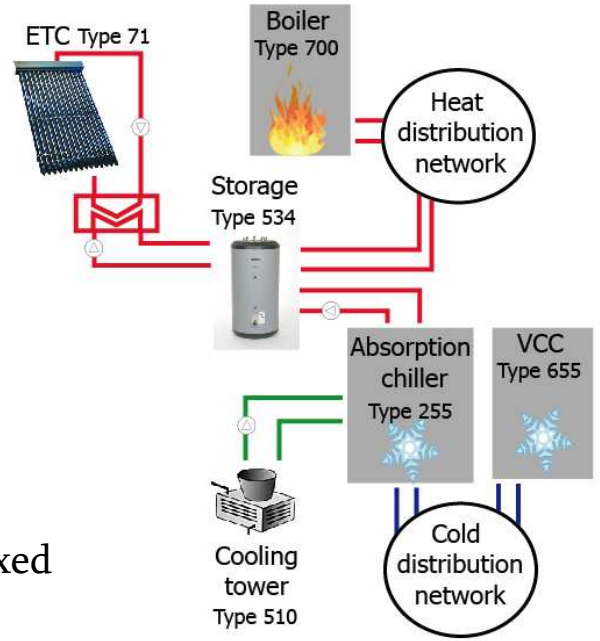
Heat and Cold production and storage

Sub-system main components (for one floor) :

- Evacuated tube collector 142 m²
- Storage tank 7 m³
- Absorption chiller (ABS) 105 kW_C
  COP_{nom} 0.695
- Back up gas boiler 150 kW
- Cooling tower 263 kW
- Backup chiller (VCC) 105 kW_c
  COP_{nom} 3.5

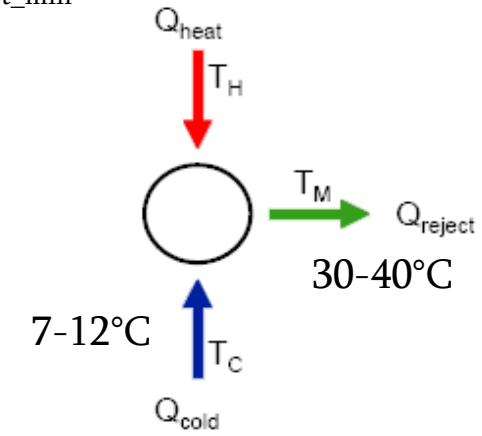
For each component, parameters have been fixed based on market available equipment.



Cold production : Absorption chiller

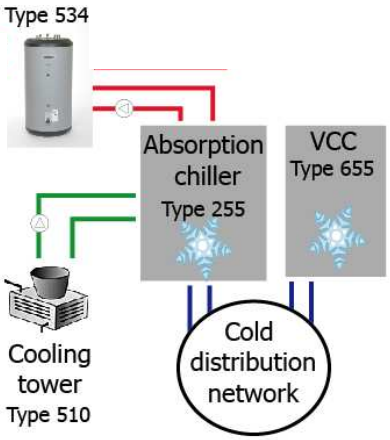
Thermodynamic scheme

$T_{hot\_min} = 70°C$



$$0.55 < COP = \frac{Q_{cold}}{Q_{hot}} < 0.73$$

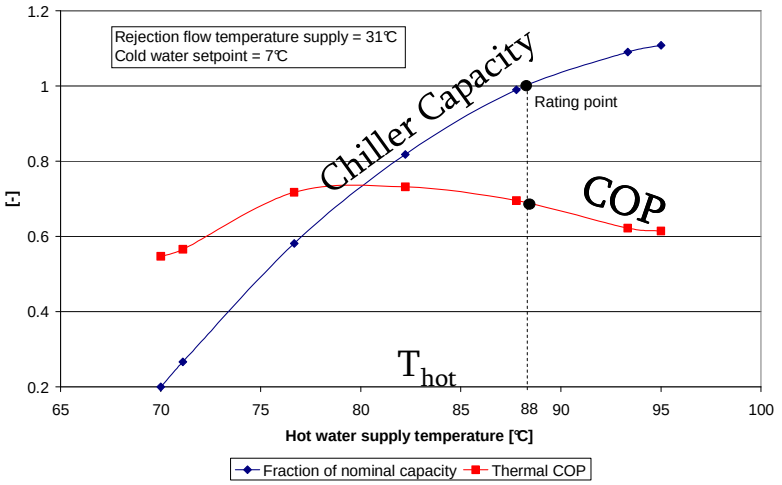
ABS chiller model in TRNSYS :
Energy balance
No transient effects !



Cooling control:

Absorption chiller switched on if storage temperature high enough.

Vapour comp. chiller in every other case

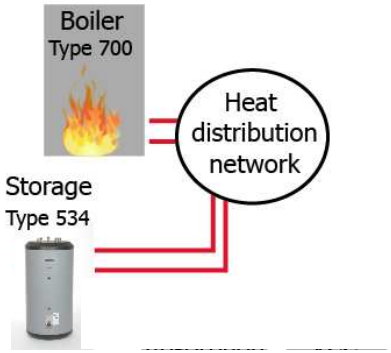


Heat production : Gas boiler and storage tank

Gas boiler
Efficiency depends on
part load ratio : 88.2-89.2 %

Losses at 0% load : 1.3 kW

Boiler set point : heating curve

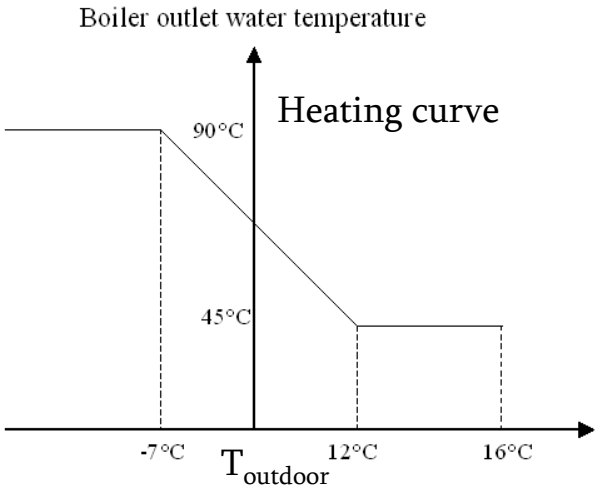


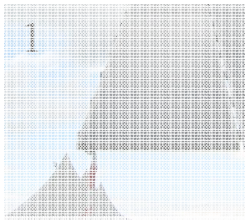
Heating control:

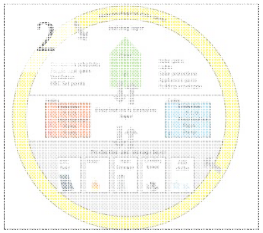
Hot water comes from Storage if temperature higher than heating curve
.
Gas boiler
in every other case

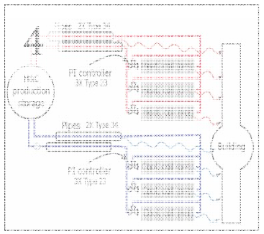
Storage tank
Heated by solar collectors only

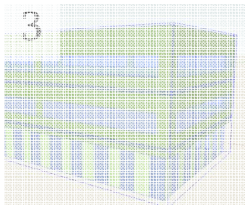
Two heat sinks :
- building heating network
- absorption chiller

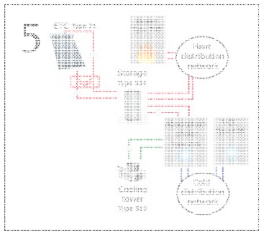


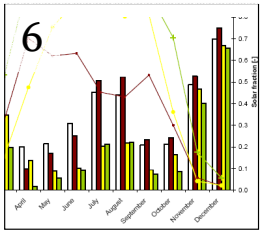








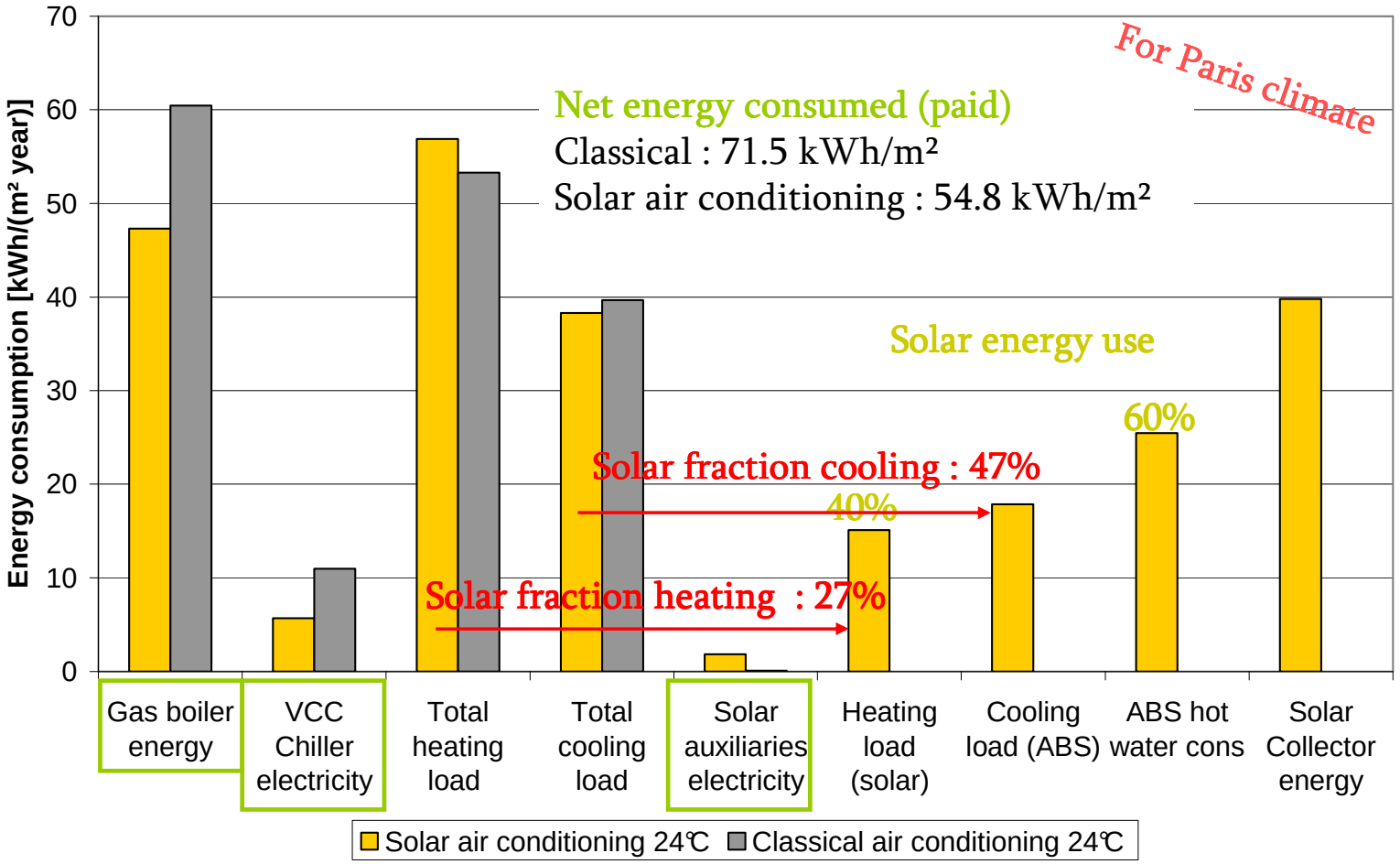




Presentation overview

1. Introduction
2. Simulation environment overview
3. Building
4. H&C emission and distribution
5. H&C production and storage
6. **Results & Conclusion**

Yearly results : net energy for heating and cooling



Yearly results : performance indicators and auxiliaries

Performance indicators

Case	Solar fraction	Solar fraction Cooling	Collector energy	Primary energy savings per collector area	Yearly ABS COP	Elec. COP
Units	[-]	[-]	[kWh/m²coll]	[kWh/m²coll]	[-]	[-]
24°C Set point	0.43	0.47	350.19	192.12	0.70	9.85

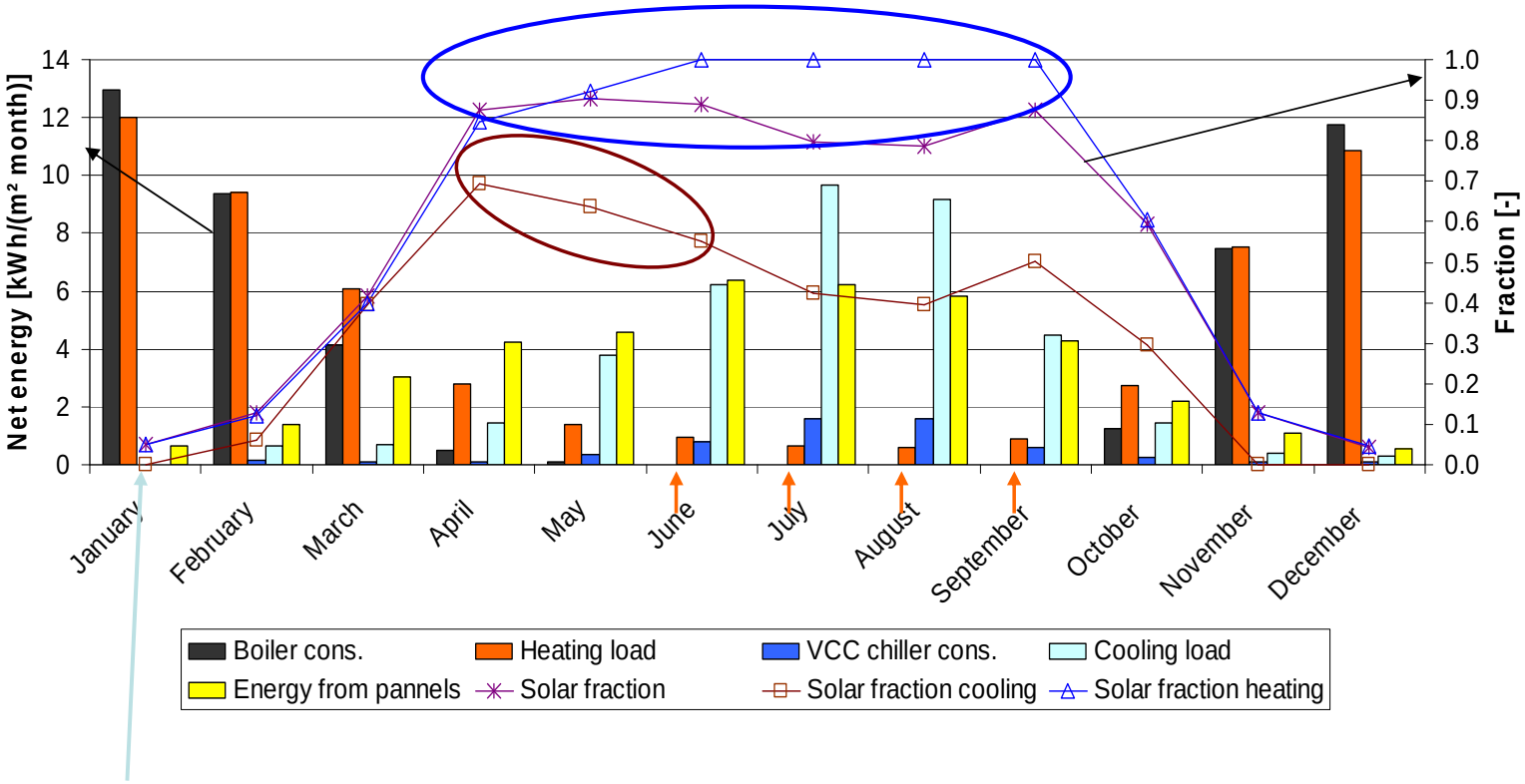
$$SF = \frac{Collector\ energy}{Collector\ energy + Boiler\ cons. + VCC\ cons.}$$

$$SF\ Cooling = \frac{Load\ met\ by\ ABS\ chiller}{Load\ met\ by\ ABS\ chiller + Load\ met\ by\ VCC\ chiller.}$$

Building auxiliaries consumption

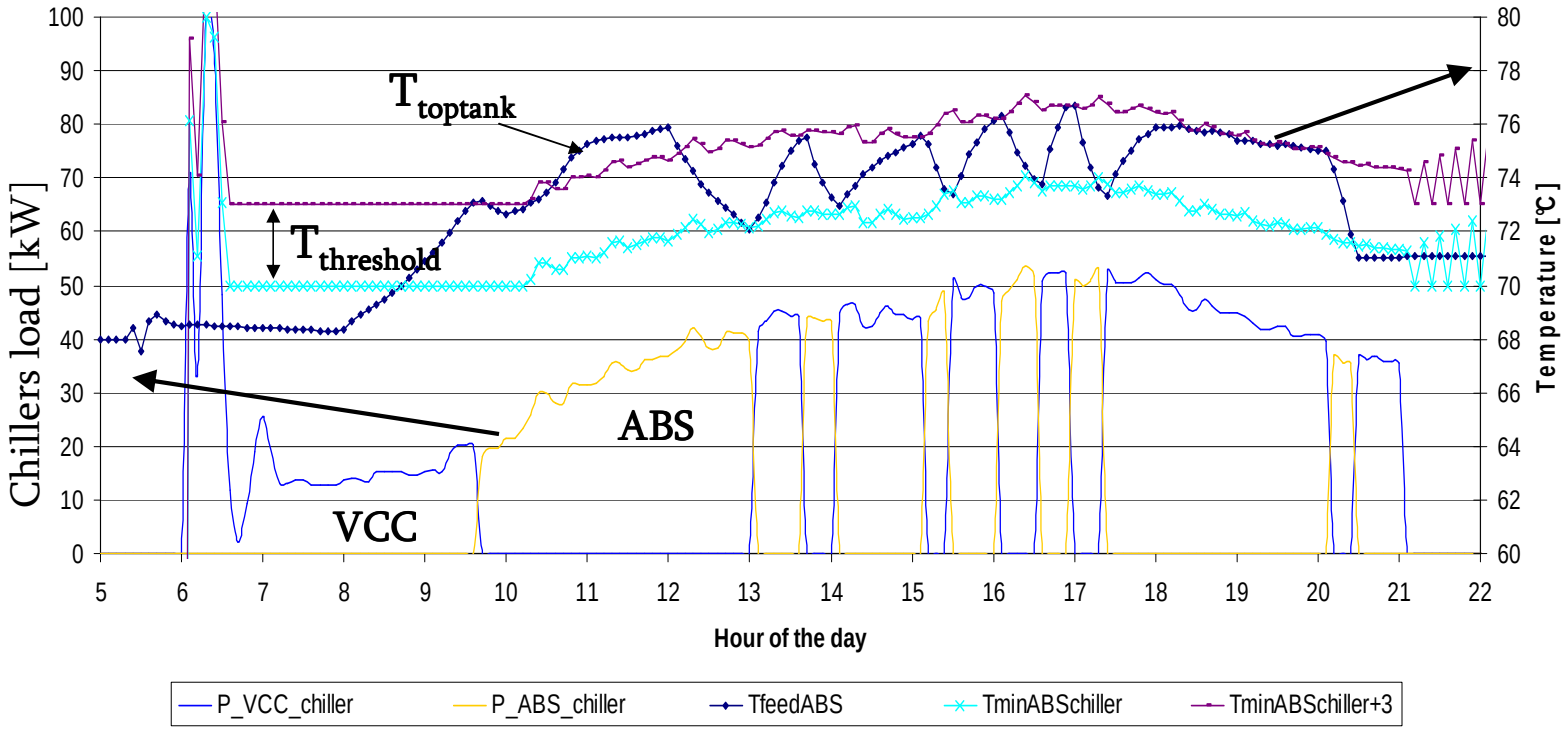
	Auxiliaries sum (primary)	Auxiliaries sum (elec.cons.)	Hot pump	Cold pump	FCU Fans	Ventilation	Appliances	Light
$\frac{kWh}{m^2\ year}$	180.03	72.01	1.09	10.40	8.08	3.72	25.56	20.36

Monthly results : Energy for heating and cooling



No cooling load

Daily results : one typical hot day



Conclusions and next developments

A comprehensive coupling between an office building and a solar air-conditioning application and provided results about the whole energy consumption.

Solar collector field and absorption chiller achieve considerable energy savings 22-23 % compared to classical air-conditioning using electricity driven vapour compression chiller. Moreover some performance indicators are presented that gives the possibility to assess energy efficiency of such systems.

Solar air-conditioning is efficient when used in efficient buildings. Work can be done to decrease cooling load. In actual office building simulations, auxiliaries have a great impact on the whole building energy consumption.

Limitations:
Steady state absorption chiller model, handling of the latent load not accurate

Next development :

Parametric analysis : internal load variation, collector field size,…