

# IEE Solar Combi+

## WP3 – Virtual Case Studies

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Fraunhofer Institute  
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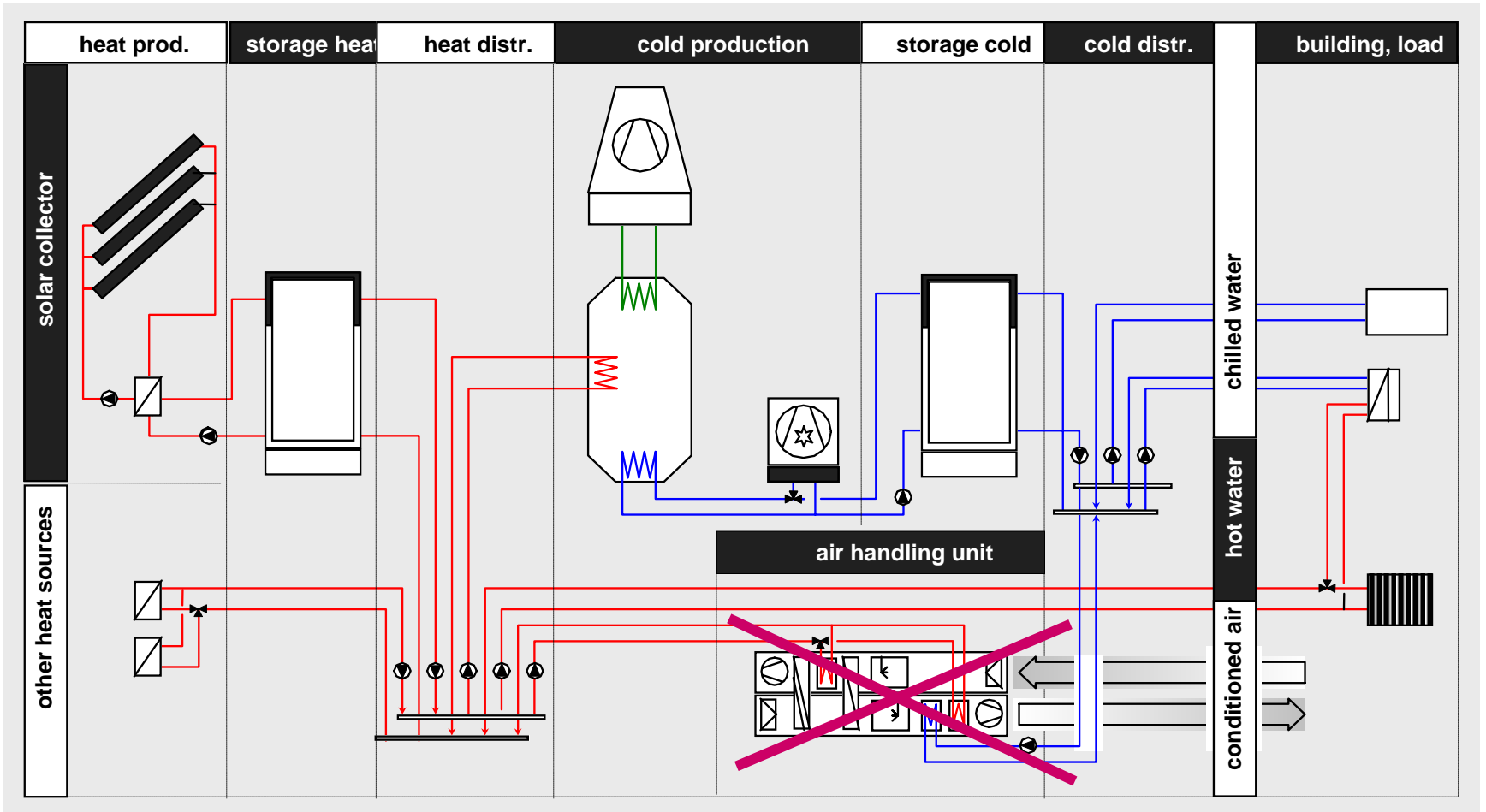
## Subtasks of WP3

- **3.1** Preparation of system implementation in simulation tools
- **3.2** Definition of applications (3-5) and locations to be studied
- **3.3** Determination of loads for the applications and locations
- **3.4** Determination of possible system configurations and control strategies

## Subtasks of WP3

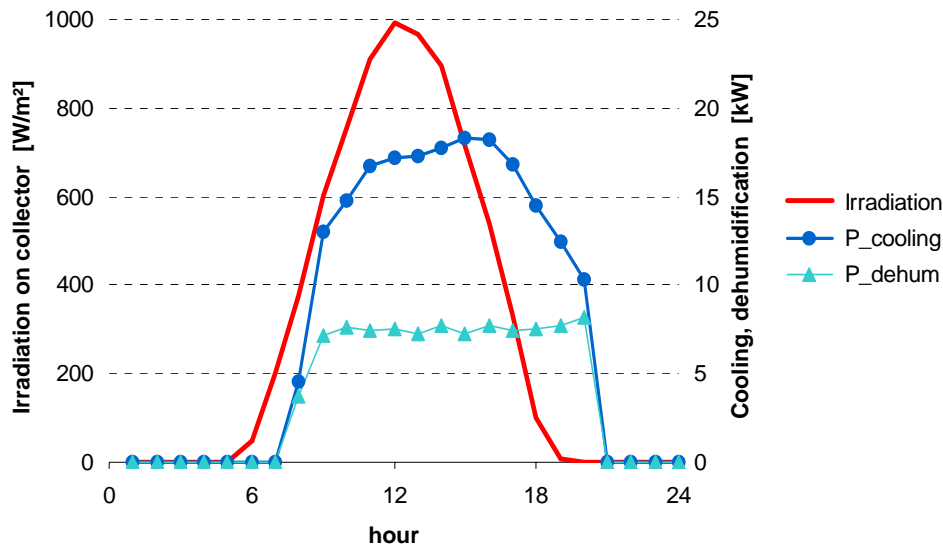
- **3.5** Simulation study (variation: load files, sizes and component characteristics)
- **3.6** Energy-related evaluation of case studies and comparison with reference systems
- **3.7** Economic-related evaluation of case studies and comparison with reference systems

# Systems in Solar Combi+



# Example: Economic study in 'Solar Air-Conditioning in Europe (SACE)'

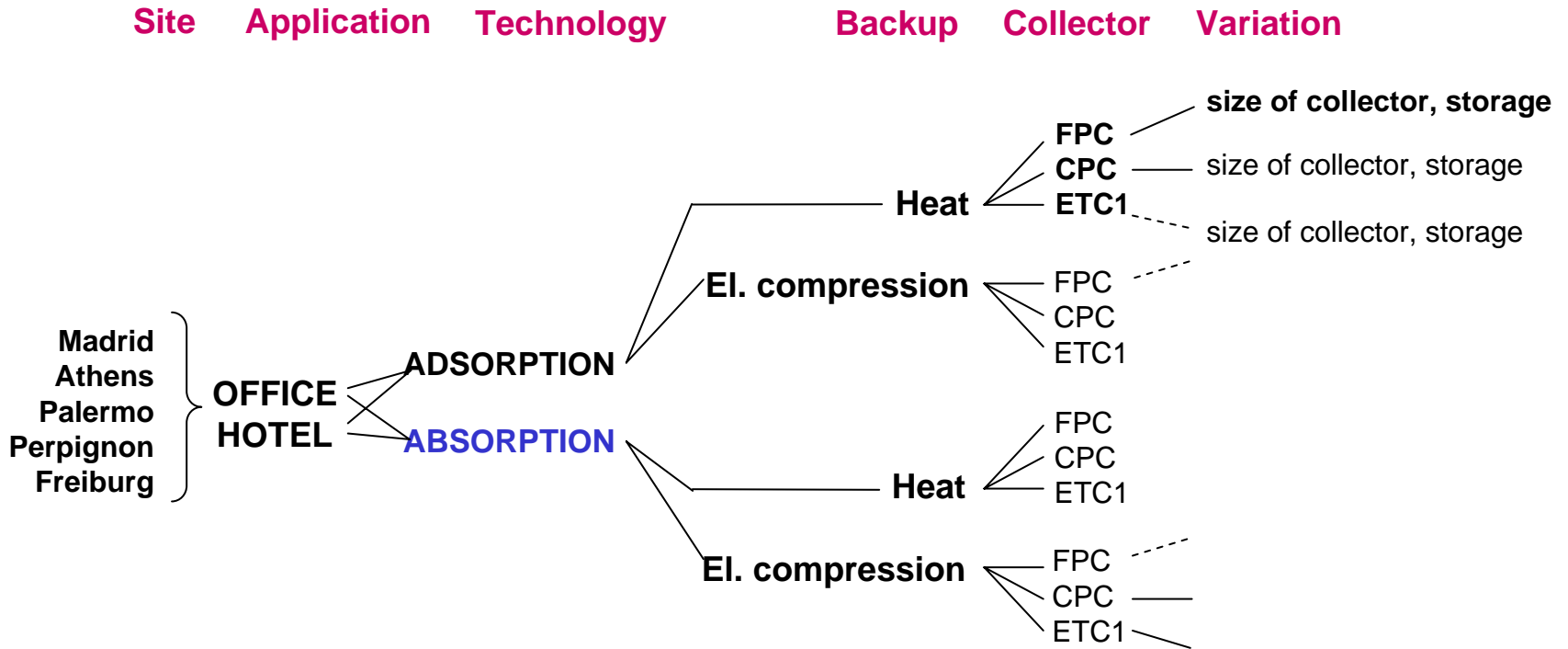
EU project, completed in 2003 [www.cop.tudelft.nl/ev/res/sace.htm](http://www.cop.tudelft.nl/ev/res/sace.htm)



- Model buildings, defined in IEA Task 25
  - Hotel
  - Office
  - Lecture Room
- Annual heating and cooling load profiles (time series with hourly data) for five European sites
  - Madrid
  - Athens
  - Palermo
  - Perpignan
  - Freiburg

Example: summer day load and radiation profile (lecture room, Palermo site)

# SACE: approach (closed cycle systems)



+ Reference calculation of a conventional system for each site and application

## SACE: approach

- Identification of most promising system size and configuration with respect to comparative primary energy savings (compared to the reference system); considering of complete energy balance (including pumps, fans, etc.)
- Cost figures
  - initial cost: complete investment for the entire system including cost for planning
  - complete annual cost: capital cost (annuity method) + operation cost based on annual energy balance + maintenance cost
  - “cost of saved primary energy” by comparison with a reference system

$$\text{cost of saved PE} = \frac{\text{extra annual cost of solar assisted system}}{\text{annual primary energy saving}} \left[ \text{€}/\text{kWh}_{\text{PE}} \right]$$

# SACE design tool with predefined configurations

**SACE Solar Cooling Evaluation Tool**

File Costs Calculate Help

Selected system: Variant 1

Components

- building specification
- (COL) solar collector
- (PSP) pump solar (primary)
- (SHX) solar heat exchanger
- (PSS) pump solar (secondary)
- (STH) heat storage
- (BAH) backup heater
- (PSH) pump heating circuit
- (ACH) thermally driven chiller
- (COT) cooling tower
- (PCT) pump cooling tower
- (PCP) pump chiller (primary)
- (AHU) air handling unit

Reference	File
Load and Meteo Data File	
Configuration	D:\programme\EASY_COOL\exe\ConfigFiles\SocoeasyDefault.cfg
Results	D:\programme\EASY_COOL\exe\ResultFiles\SolResult.txt

collector area: 100 m<sup>2</sup> storage volume: 0 m<sup>3</sup>

**Solar System**

Collector field

Collector type	SET_A2_Solar_Roof	K50, trans	0.980
optical efficiency	0.783 [-]	minimum collector area	100.0 m <sup>2</sup>
linear loss coefficient	3.230 W/(m <sup>2</sup> K)	collector area step	40.00 m <sup>2</sup>
quadratic loss coefficient	0.0111 W/(m <sup>2</sup> K <sup>2</sup> )	number of steps	7
K50, long	0.980	specific collector field costs	300.0 Euro/m <sup>2</sup>

Pump solar (primary)		Pump solar (secondary)	
nominal electric power	0.1500 kW/m <sup>2</sup>	nominal electric power	0.1000 kW/m <sup>2</sup>
costs	0.00 Euro	costs	250.00 Euro

Solar heat exchanger

temperature drop: 5.00 K

Heat storage

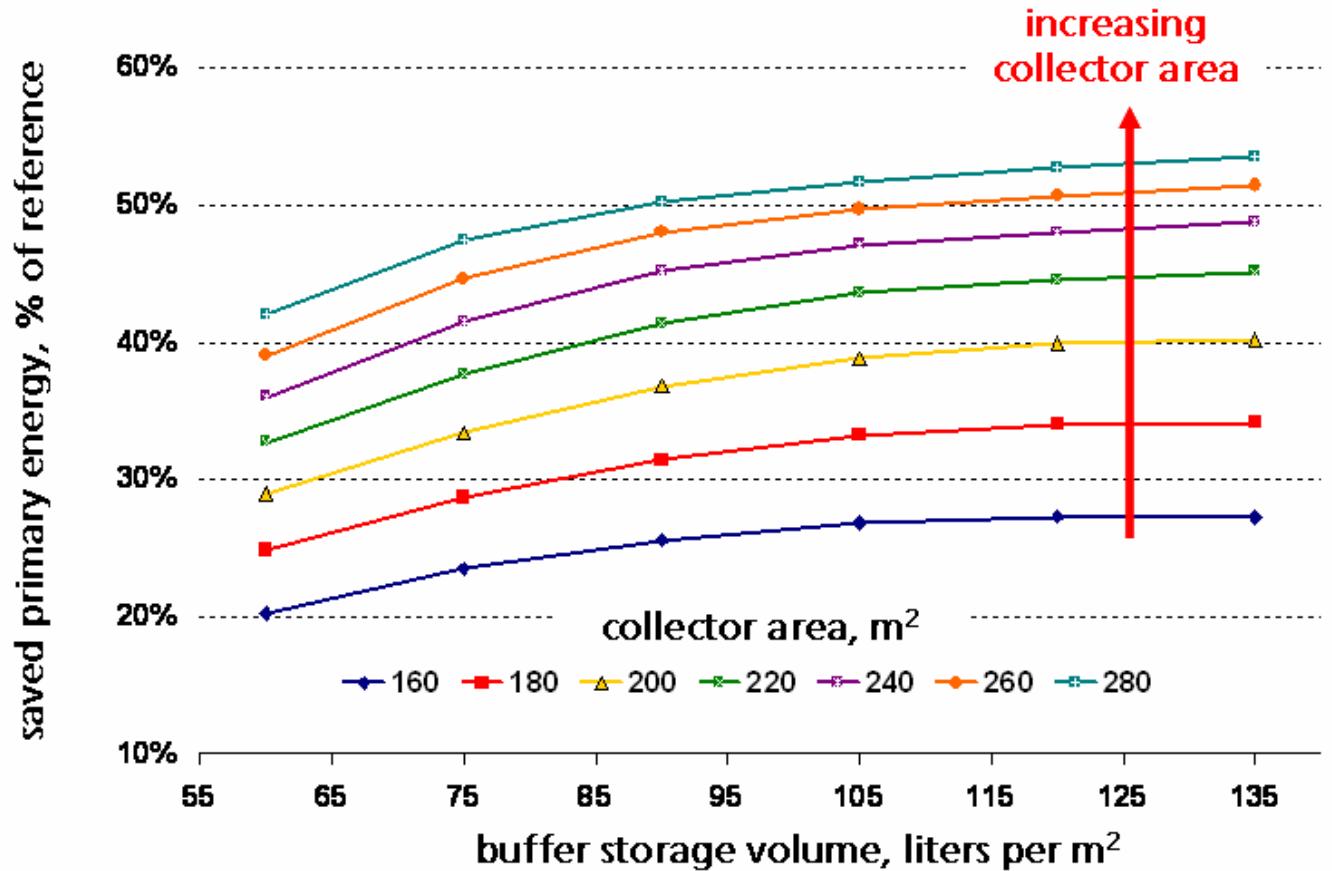
heat loss coefficient	0.80 W/(m <sup>2</sup> K)	minimum storage volume	0.030 m <sup>3</sup> per m <sup>2</sup> coll.
max. storage temperature	95.00 °C	storage volume step	0.030 m <sup>3</sup> per m <sup>2</sup> coll.
specific storage costs	500.0 Euro/m <sup>3</sup>	number of steps	7

OK Cancel



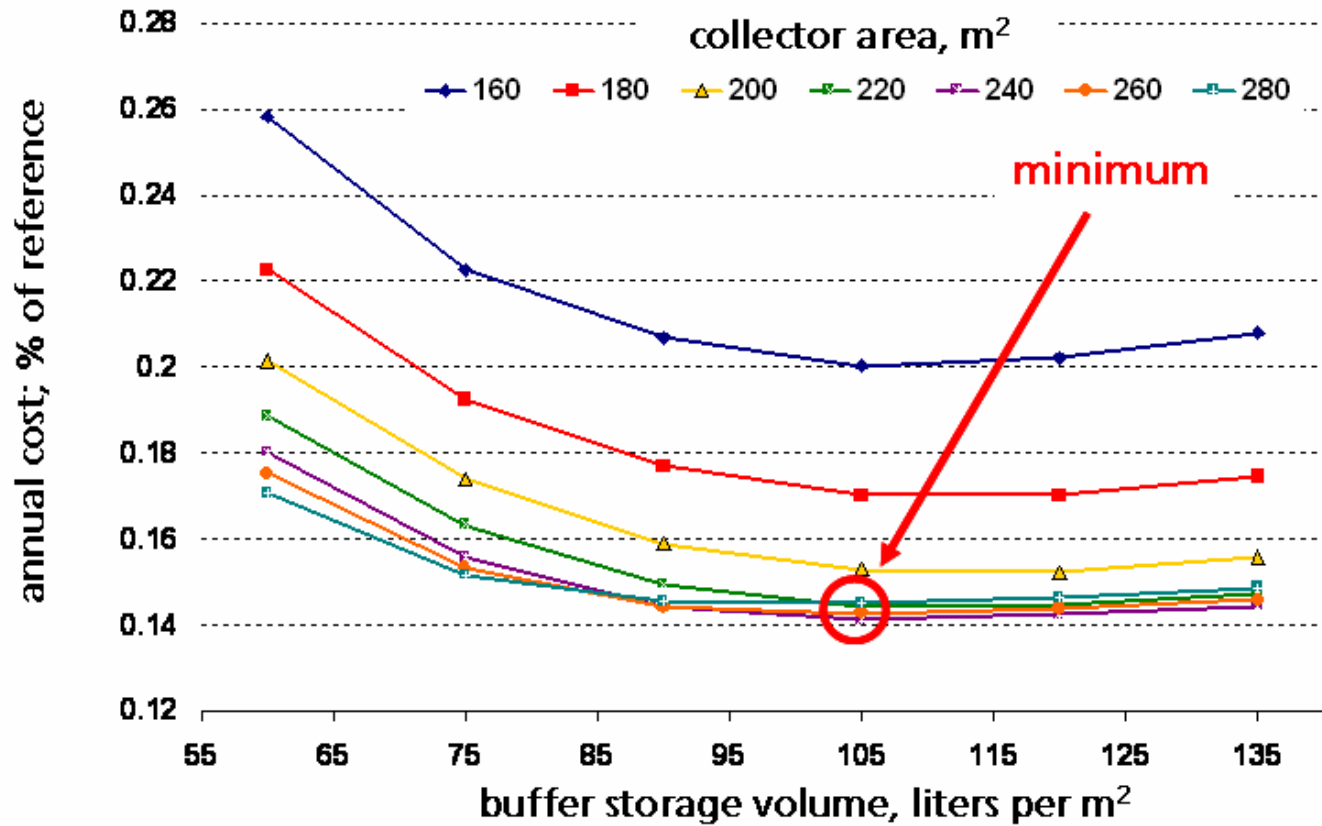
# SACE Pre-design tool; example

- Madrid
- office building
- flat plate collector
- back-up: boiler
- absorption chiller



# SACE Pre-design tool; example

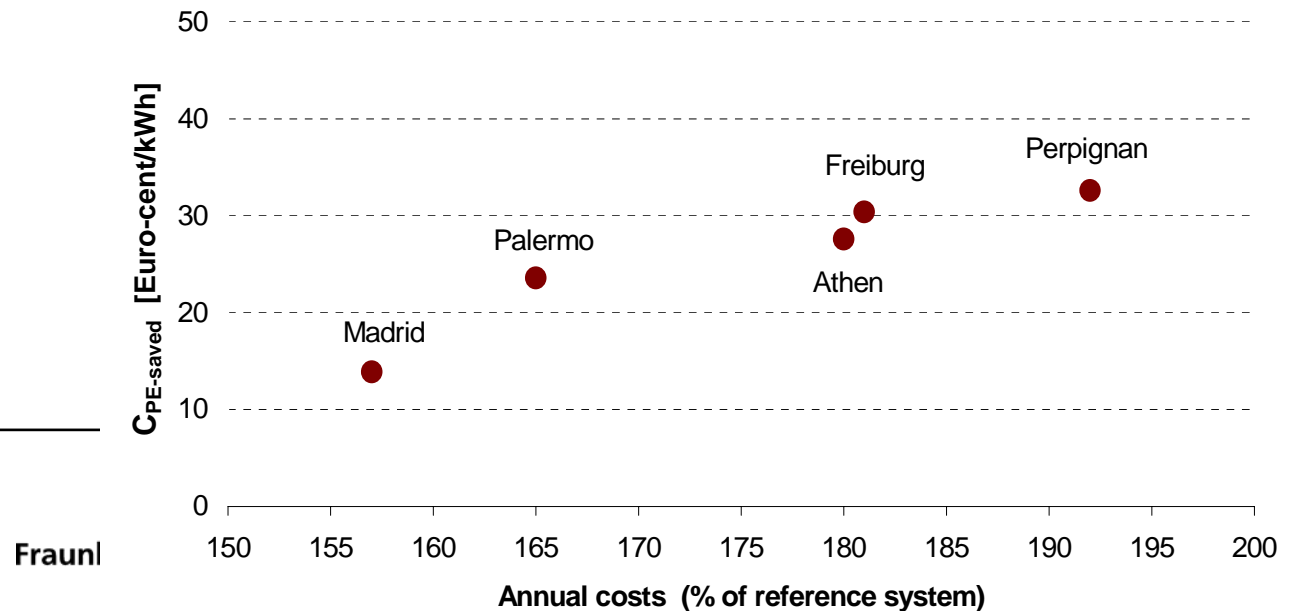
- Madrid
- office building
- flat plate collector
- back-up: boiler
- absorption chiller



# SACE study: results (office building)

- Conditions:  
primary energy saving > 25%;  
annual net collector efficiency > 20%

SITE	Collector type	Collector area per kW chiller	Heat storage size	Net collector efficiency	Chiller	Backup type	Annual cost of solar assisted cooling system	Primary energy saving	Cost of saved primary energy
Office at		m <sup>2</sup> /kW	hours	%			% of reference	%	Euro-cent per kWh
<b>MADRID</b>	CPC	3.3	4.2	21	ABS	heat	<b>157</b>	51	<b>13.9</b>
<b>ATHENS</b>	CPC	2.4	3.6	21	ABS	el. compr.	<b>180</b>	45	<b>27.6</b>
<b>PALERMO</b>	CPC	1.4	2.1	22	ABS	el. compr.	<b>165</b>	45	<b>23.6</b>
<b>PERPIGNAN</b>	ETC1	1.7	2.8	30	ABS	el. compr.	<b>192</b>	45	<b>32.6</b>
<b>FREIBURG</b>	ETC1	3.4	3.2	28	ABS	el. compr.	<b>181</b>	30	<b>30.4</b>



## Experiences from design studies

- The specific combined energy-cost-performance parameter 'cost per saved primary energy unit' supports the sizing and configuration of a solar assisted air-conditioning system
- Size and type of the collector and storage volume depends strongly on the site conditions, load structure and applied air-conditioning technology.  
A software tool is useful in the design of the system
- For thermal operated cooling processes with low COP and use of fossil fuels (heat back-up), a high percentage of solar thermal coverage is required in order to achieve savings in primary energy and CO<sub>2</sub> emissions.  
Alternative: electrically driven compression chiller as cold side backup ('fuel-saving' operation of solar thermal driven system) ⇒ more adequate for large systems
- In most cases solar assisted cooling is today not economically viable without funding, but shows a large potential in primary energy saving

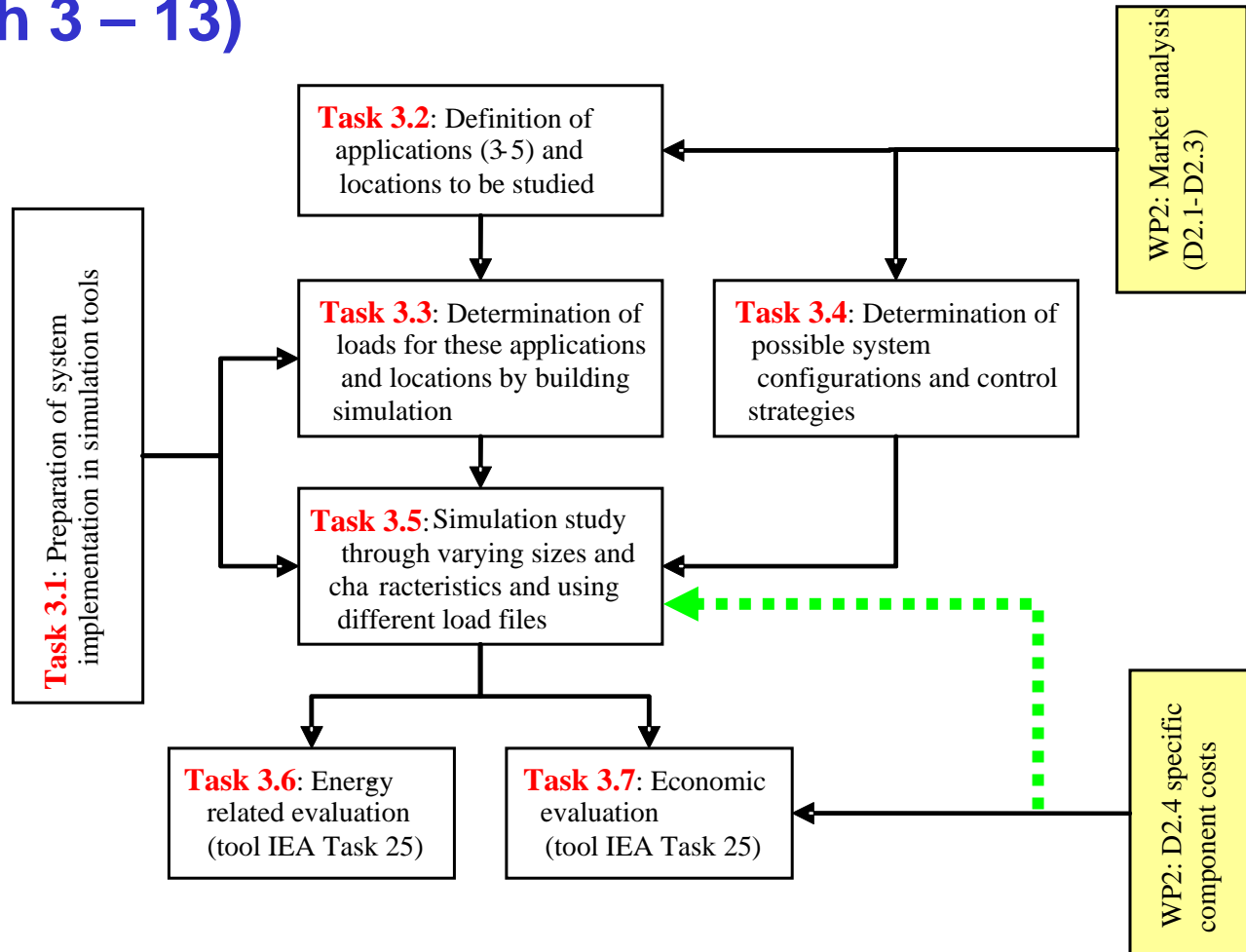
## Experiences from design studies

- Most effective in primary energy saving are systems with solar autonomous cooling operation. But comfort room air-states may not be guaranteed for all hours in this application.  
⇒ favourable in buildings with dominating external loads and usage during day hours
- The exploitation of the solar thermal system should be maximised, using the system for space heating support and DHW as well (promising perspective for small scale applications)

### In Solar Combi+:

- more precision on modelling, configurations, control
- actual performance and cost figures
- applications based on market analysis

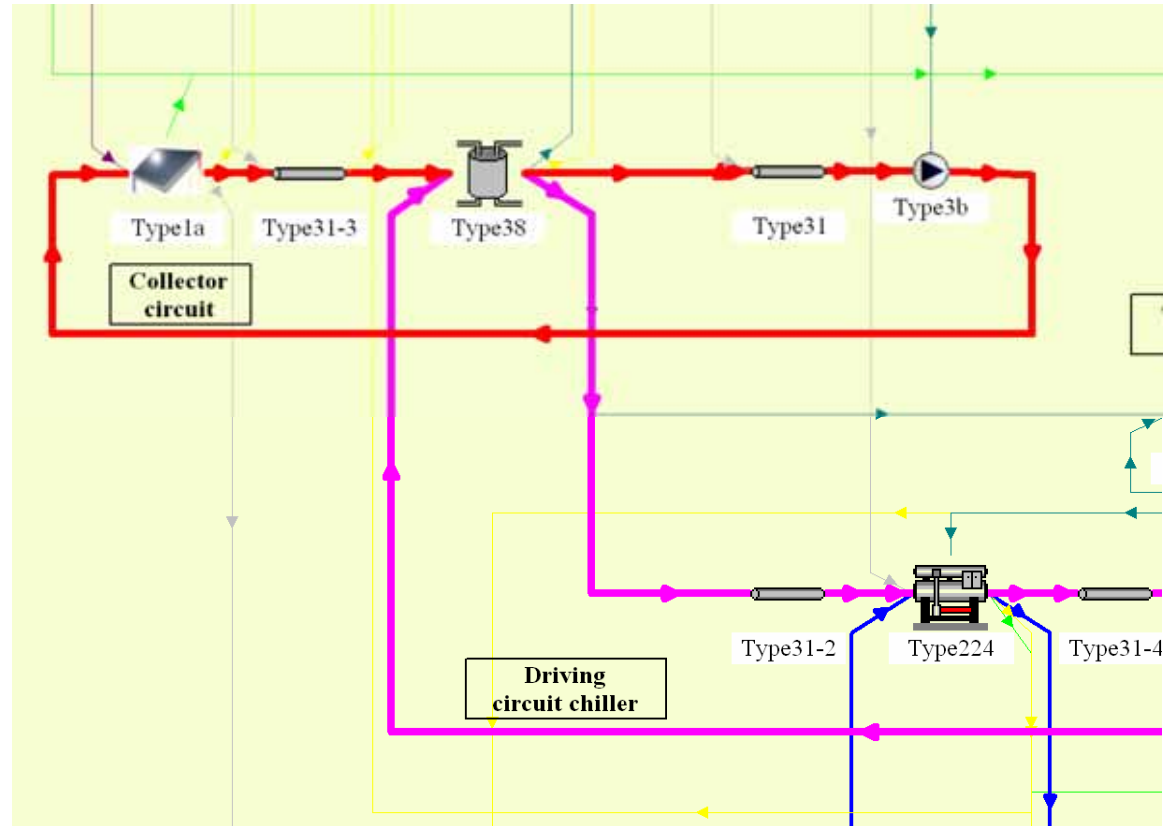
# Solar Combi+, Work package 3 (month 3 – 13)



## Subtask 3.1

# Preparation of system implementation in simulation tools

- Software tool: TRNSYS
- Types:  
standard or non-standard for collectors, storages,...
- Chiller types:
  - capacities
  - 'generic' model (scaling) or specific models
  - on base of characteristics, NO research on component models



## Subtask 3.2

### Definition of applications and locations to be studied

- Applications:
  - residential
  - commercial (small offices)
  - small hotels
  - ...

⇒ input from WP2, SOLCO, ..
  
- Sites:
  - consortium partner countries ?
  - meteorological data source?

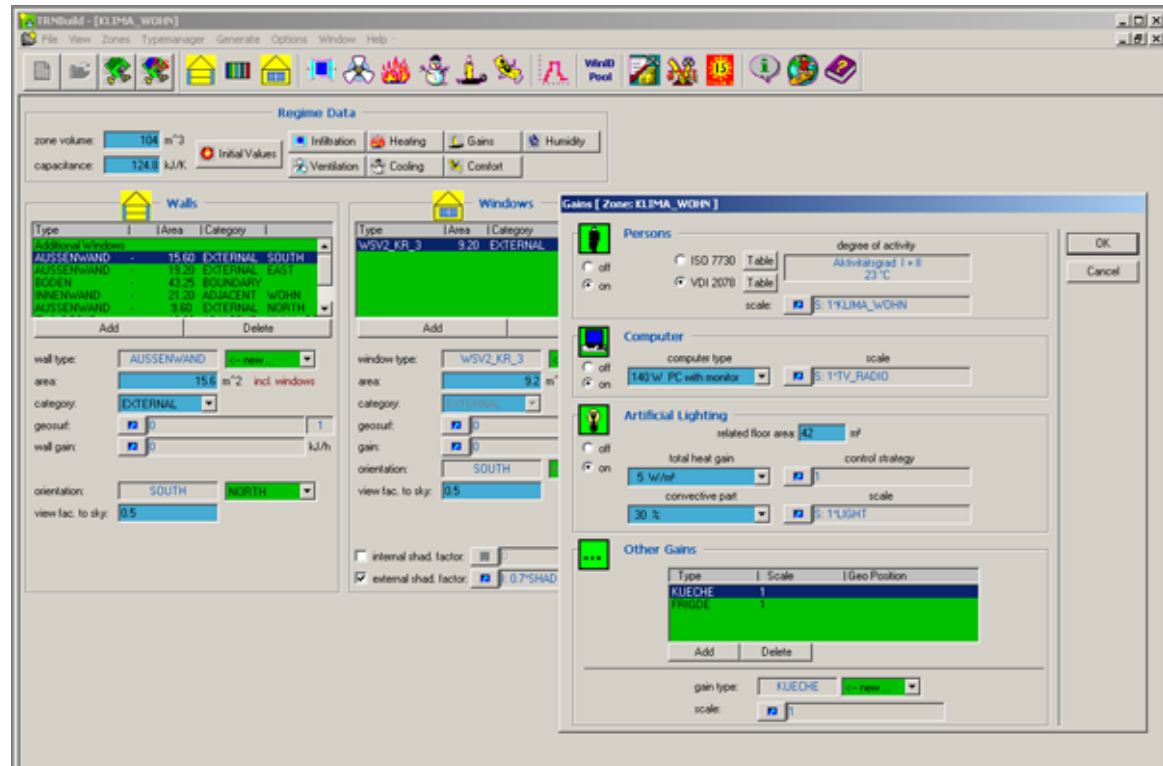
⇒ Input from ECOHEATCOOL,..



## Subtask 3.3

# Determination of loads / building simulation

- Building standards
- Internal loads
- Heating / cooling / ventilation
- For each site and application: annual time series of sensible and latent heating / cooling loads



## Subtask 3.4

# Determination of system configurations

- Input from WP2 Market analysis
- Input from partners: configuration of marketed systems
- Advantages / disadvantages from realised systems
- Input to heating support and domestic hot water preparation configurations:  
IEA Tasks (e.g., Task 26  
Solar Combisystems)

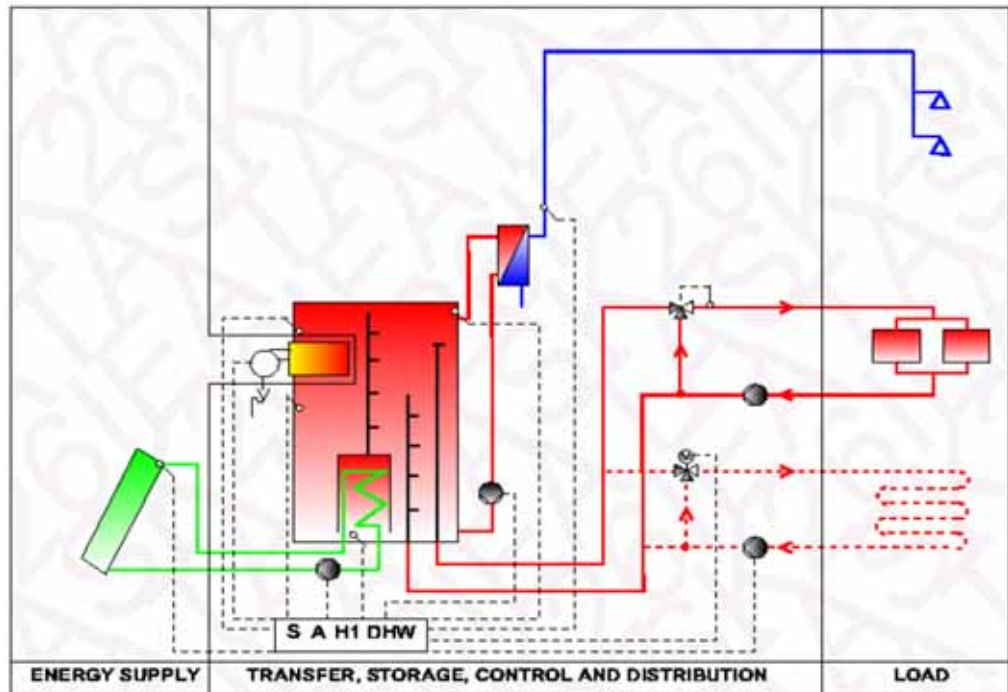
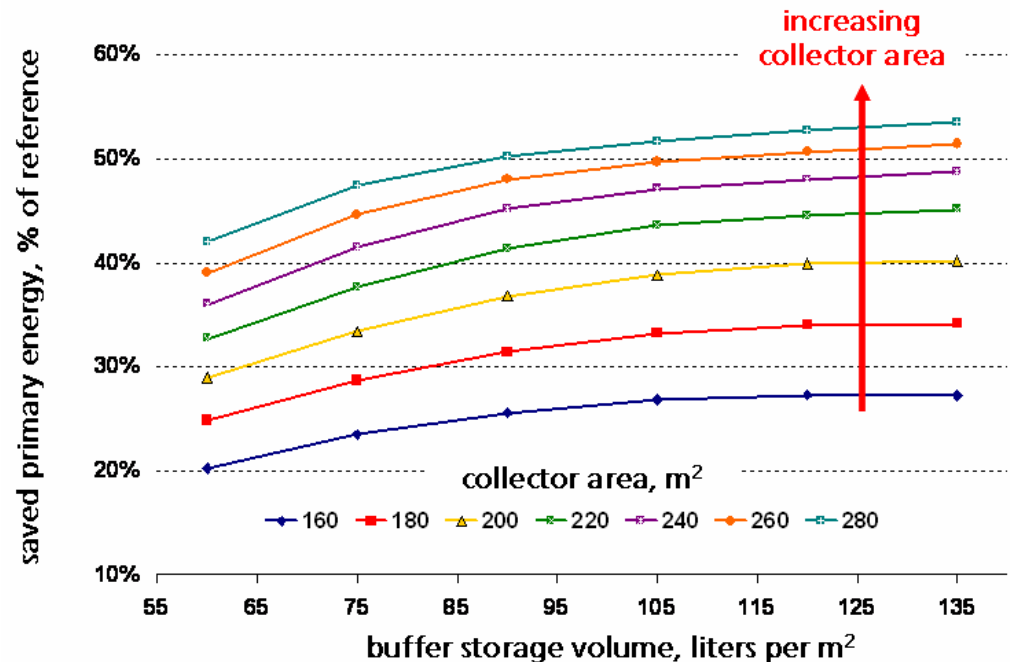


Figure from case study in Task 26 Slide 18

## Subtask 3.5 Simulation study

- Large number of simulations according to:
  - sites
  - applications
  - configurations
  - components sizes
  - control strategies
- Annual simulations runs to cover heating/cooling period
- Data base containing useful results



## Subtask 3.6, 3.7

# Energy-related and economic evaluation of results

- Definition of appropriate energetic/economic evaluation numbers
- Reference calculations with non-renewable energy supply, e.g., electrically driven compression chillers for cooling
- Identification of most promising system configurations for each application/site
- ⇒ Input to online accessible data base

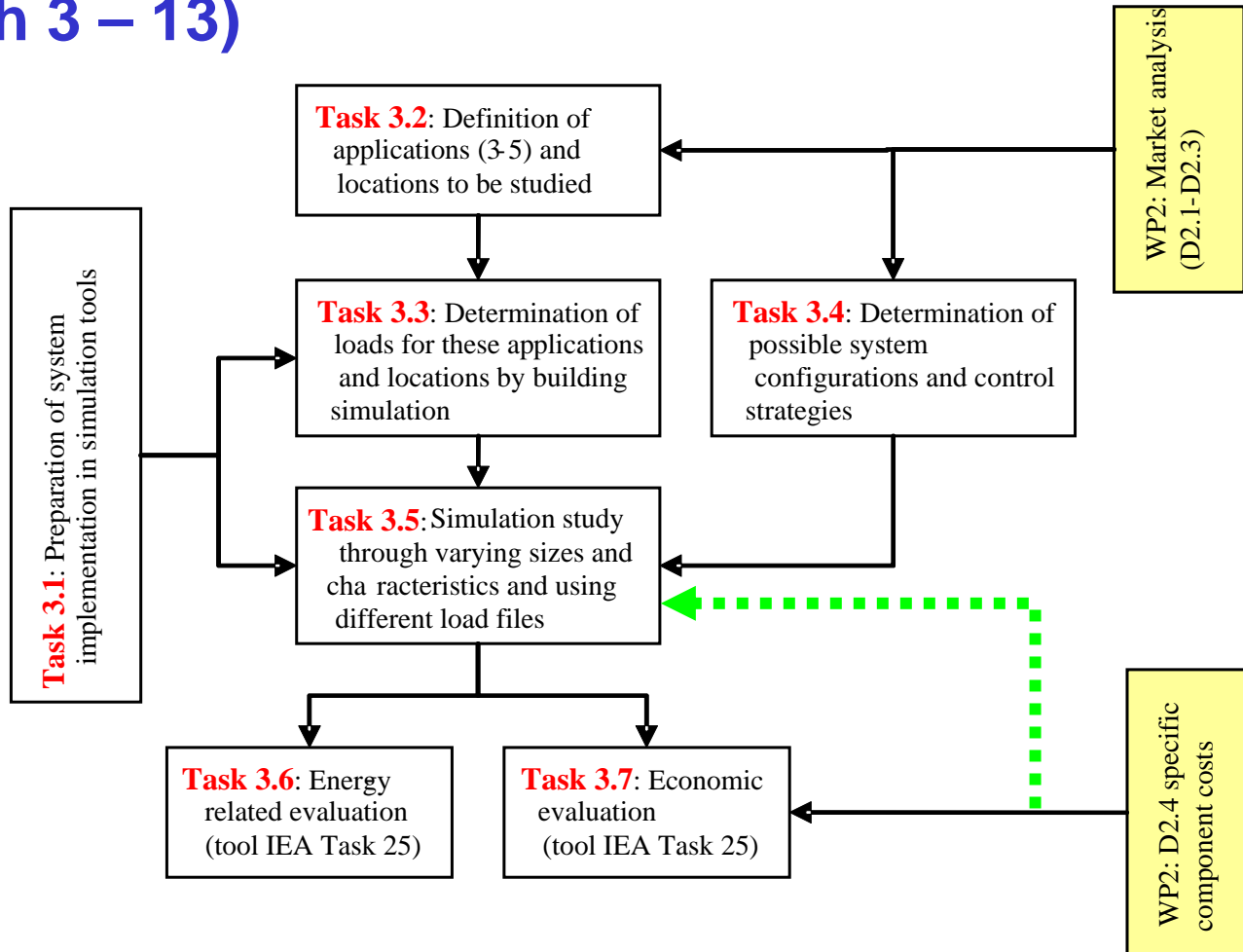
## Subtask 3

### Virtual case studies

#### Deliverables:

- D3.1  
Database with case studies: description and results  
month 13
- D3.2  
Report with description of methodology  
month 13
- D3.3  
Report on results  
month 13

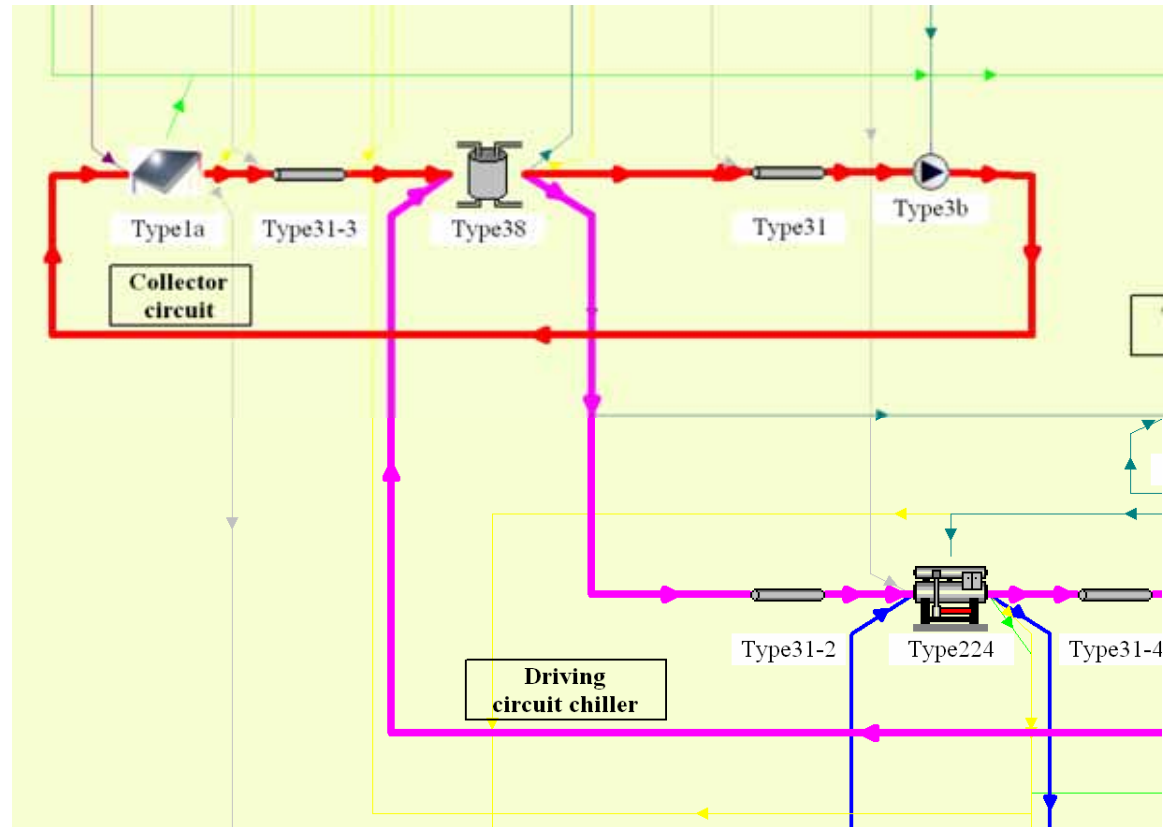
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## Subtask 3.1

# Preparation of system implementation in simulation tools

- Software tool: TRNSYS
- Types:  
standard or non-standard for collectors, storages, ...
- Chiller types:
  - capacities
  - 'generic' model (scaling) or specific models
  - on base of characteristics, NO research on component models



## Subtask 3.1

# Preparation of system implementation in simulation tools

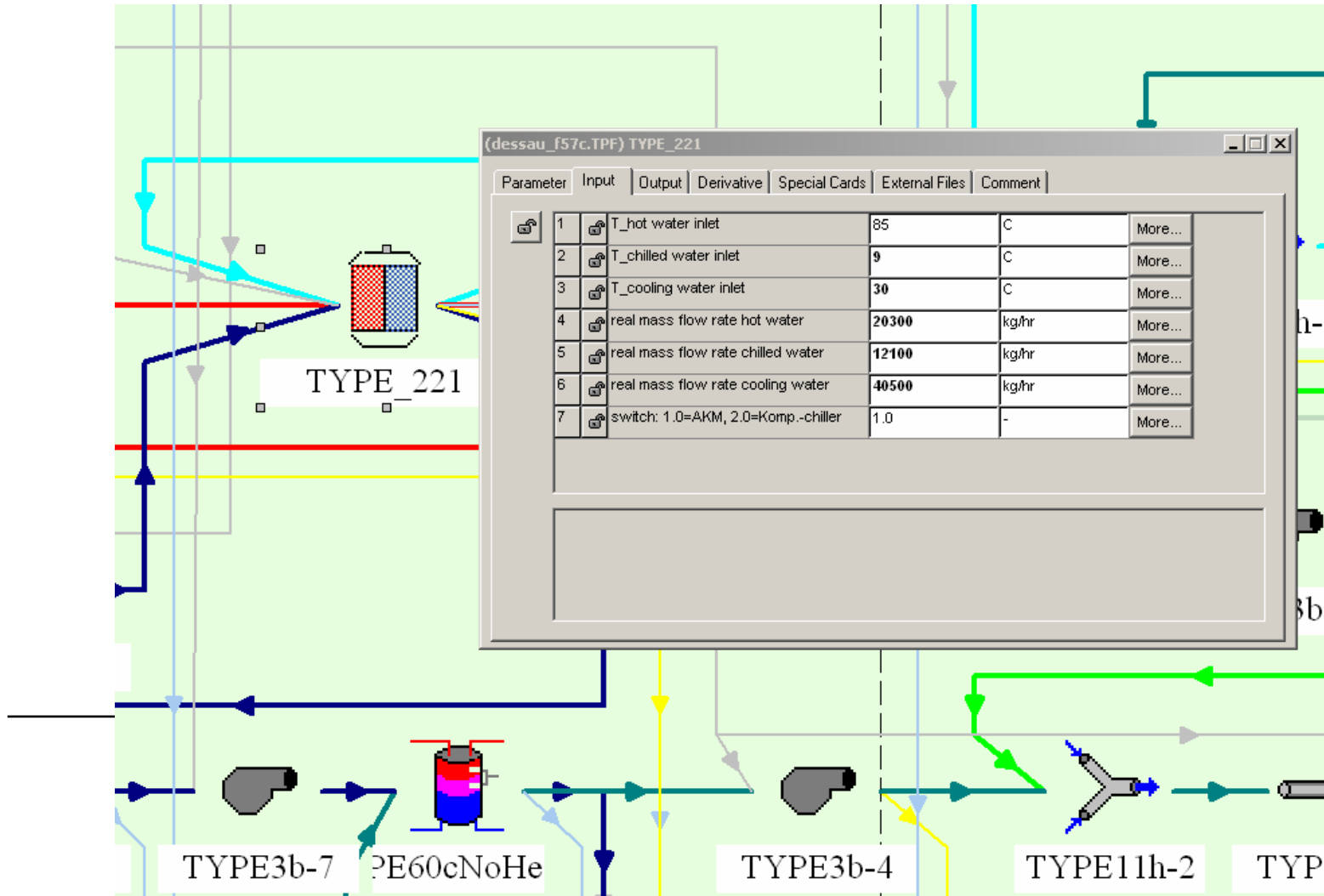
- Types:  
standard or non-standard for collectors, storages,..
- Chiller:
  - which capacity?
  - representing chiller models of manufacturers in SolarCombi+ Consortium?
  - or: representing a 'general' chiller type; variations on driving temperature, heat rejection temperature, chilled water temperature, nominal COP,...
  - model on base of steady state characteristics



## Subtask 3.1

# Preparation of system implementation in simulation tools

- To be defined: uniform input/output structure



## Subtask 3.1

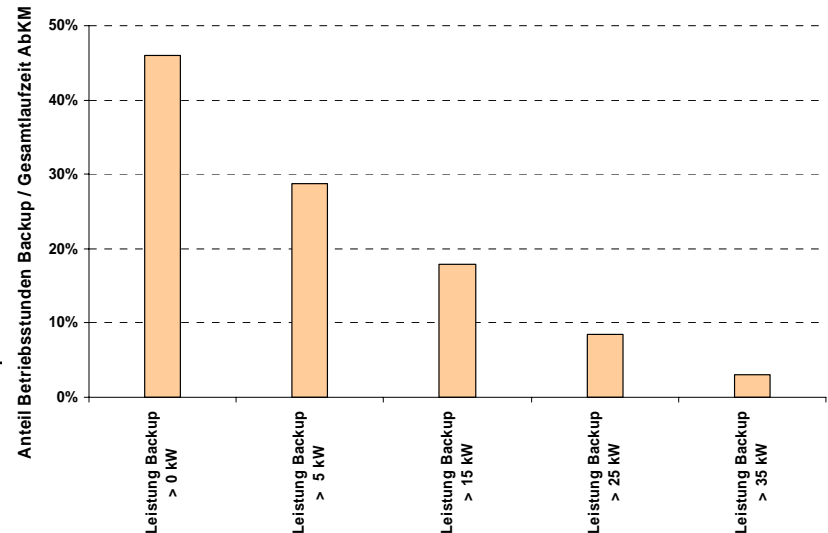
# Preparation of system implementation in simulation tools

- Available model from IEA Task 25: **ab**sorption chiller model, developed by J. Albers, TU Berlin. Parameter sets available:
  - Yazaki WFC10 (with bubble pump),
  - EAW Wegracal SE 15 (15kW)
  - special .exe for Suninverse (10kW); no source code
  - parameters for other machines may be extracted from appropriate data sheets
  
- Available model from IEA Task 25: **ad**sorption chiller model, developed by Fraunhofer ISE. Parameters available:
  - Nishiyodo / Mayekawa chiller; > 50 kW
  - parameters for other machines may be extracted from appropriate data sheets
  
- Climatewell?

## Subtask 3.1

# Preparation of system implementation in simulation tools

- In general: coupled system / building simulation?  
(TRNSYS building model and system description in one simulation deck file)
  - + allows solar autonomous cooling operation  
(feedback to building type)  $\Rightarrow$  more flexibility
  - more stability problems with simulation, more complexity,  
remarkable increase in running time
- compromise: separate load files  
and statistics of hours with  
auxiliary energy demand for  
cooling



## Subtask 3.1

# Preparation of system implementation in simulation tools

### NEXT STEPS:

- Chiller models:  
characteristics, models (manufacturers)
  - ROTARTICA, CW, SorTech, SK, SOLution?
  
- Type of collectors, storages,.. Considered:
  - ISE, AEE INTEC, EURAC, CRES, TECSOL, UNIBG,..?
  
- General arrangements on TRNSYS decks:  
(solar autonomous or not, version, ...)
  - ISE, AEE INTEC, EURAC, CRES, TECSOL, UNIBG,..?

## Subtask 3.2

### Definition of applications and locations to be studied

- Maximum cooling loads?
  
- Applications:
  - residential
  - commercial (small offices)
  - small hotels
  - ...

⇒ input from WP2, SOLCO, ..
  
- Sites:
  - consortium partner countries ?
  - meteorological data source?

⇒ Input from ECOHEATCOOL,..

## Subtask 3.2

# Definition of applications and locations to be studied

### NEXT STEPS:

- Selection of applications:
  - ...?
  
- Selection of sites, preparation of meteorological data files:
  - ...?

# Subtask 3.3

## Determination of loads / building simulation

TRNBuild - [KLIMA\_WOHN]

File View Zones Typemanager Generate Options Window Help

Regime Data

zone volume: 104 m<sup>3</sup>    Initial Values

capacitance: 124.8 kJ/K

Infiltration Heating Gains Humidity

Ventilation Cooling Comfort

Walls

Type	Area	Category
Additional Windows		
AUSSENWAND	15.60	EXTERNAL SOUTH
AUSSENWAND	19.20	EXTERNAL EAST
BODEN	43.25	BOUNDARY
INNENWAND	21.20	ADJACENT WOHN
AUSSENWAND	9.60	EXTERNAL NORTH

wall type: AUSSENWAND    area: 15.6 m<sup>2</sup> incl. windows  
 category: EXTERNAL  
 geosurf: 0    wall gain: 0 kJ/h  
 orientation: SOUTH    view fac. to sky: 0.5

Windows

Type	Area	Category
WSV2_KR_3	9.20	EXTERNAL

window type: WSV2\_KR\_3    area: 9.2 m<sup>2</sup>  
 category: EXTERNAL  
 geosurf: 0    gain: 0  
 orientation: SOUTH    view fac. to sky: 0.5  
 internal shad. factor: 0  
 external shad. factor: 0.7\*SHAD

Gains [ Zone: KLIMA\_WOHN ]

Persons

off     ISO 7730 Table    degree of activity: Aktivitätsgrad I + II 23 °C  
 on     VDI 2078 Table    scale: S: 1\*KLIMA\_WOHN

Computer

off    computer type: 140 W PC with monitor    scale: S: 1\*TV\_RADIO  
 on

Artificial Lighting

off    related floor area: 42 m<sup>2</sup>  
 on    total heat gain: 5 W/m<sup>2</sup>    control strategy: 1  
 convective part: 30 %    scale: S: 1\*LIGHT

Other Gains

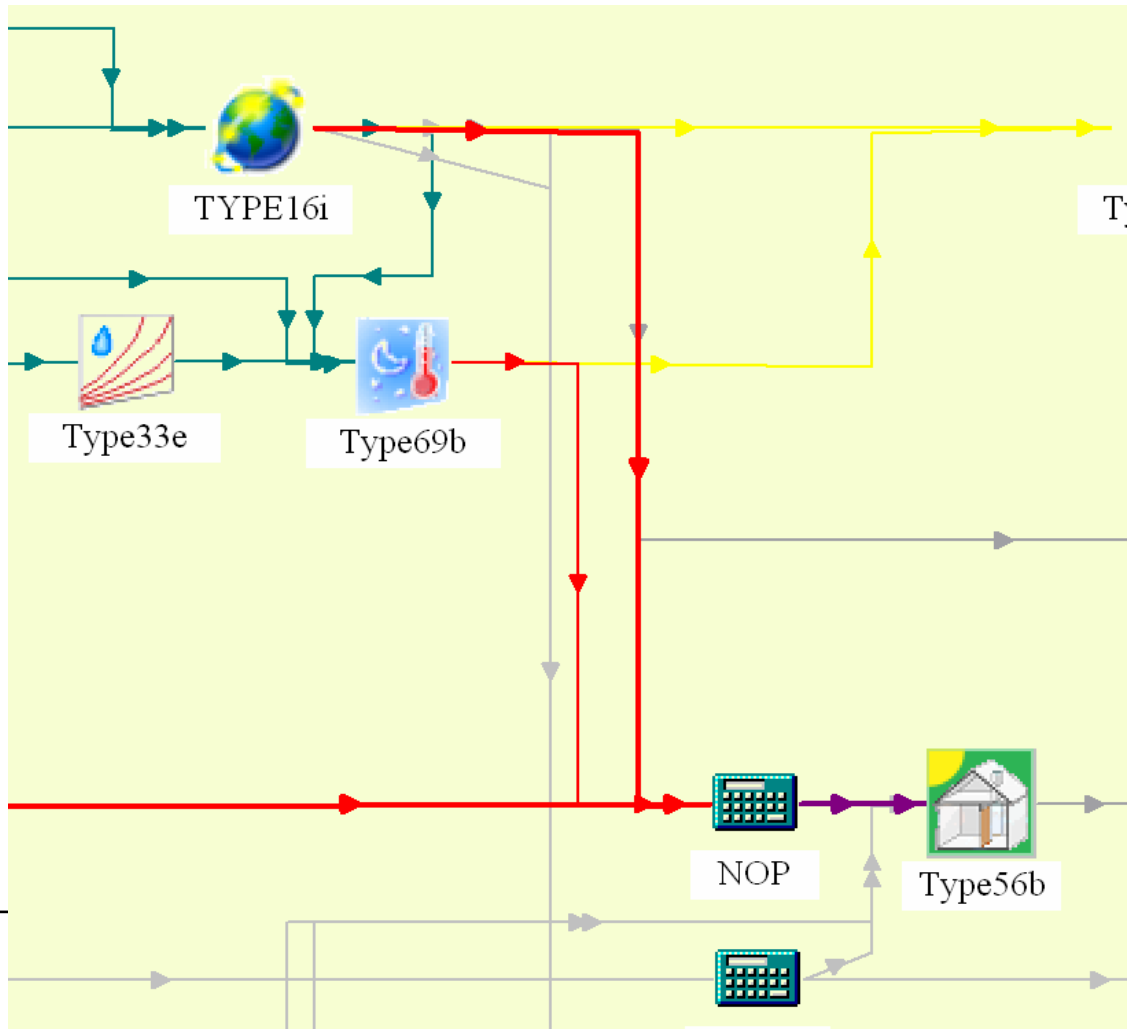
Type	Scale	Geo Position
KUECHE	1	
FRIGIDE	1	

gain type: KUECHE    scale: 1

## Subtask 3.3

### Determination of loads / building simulation

- TRNSYS / PREBID?  
⇒ depends on decision on coupled or separate building / system simulation
- Generation of load data files





## Subtask 3.3

### Determination of loads / building simulation

- Definition of building standards:
  - on base of present building standards
  - on base of national / European directives for new / refurbished buildings
- Definition of typical buildings for the defined applications (3.2)
- Definition of internal loads, equipment, ventilation,...

## Subtask 3.3

# Determination of loads / building simulation

### NEXT STEPS:

- Building standards:
  - EURAC, CRES, ISE, AEE-INTEC, UNIBG, TECSOL?
  
- Definition of typical buildings shells, internal loads,...:
  - EURAC, CRES, ISE, AEE-INTEC, UNIBG, TECSOL?
  
- Calculation and Preparation of annually load files?
  - ...?

# Subtask 3.4

## Determination of system configurations

Collector type and size  
driving temperature;  
hot water storage:  
site conditions,  
load profile,  
chiller type,  
system concept

Heat rejection:  
site conditions,  
chiller type

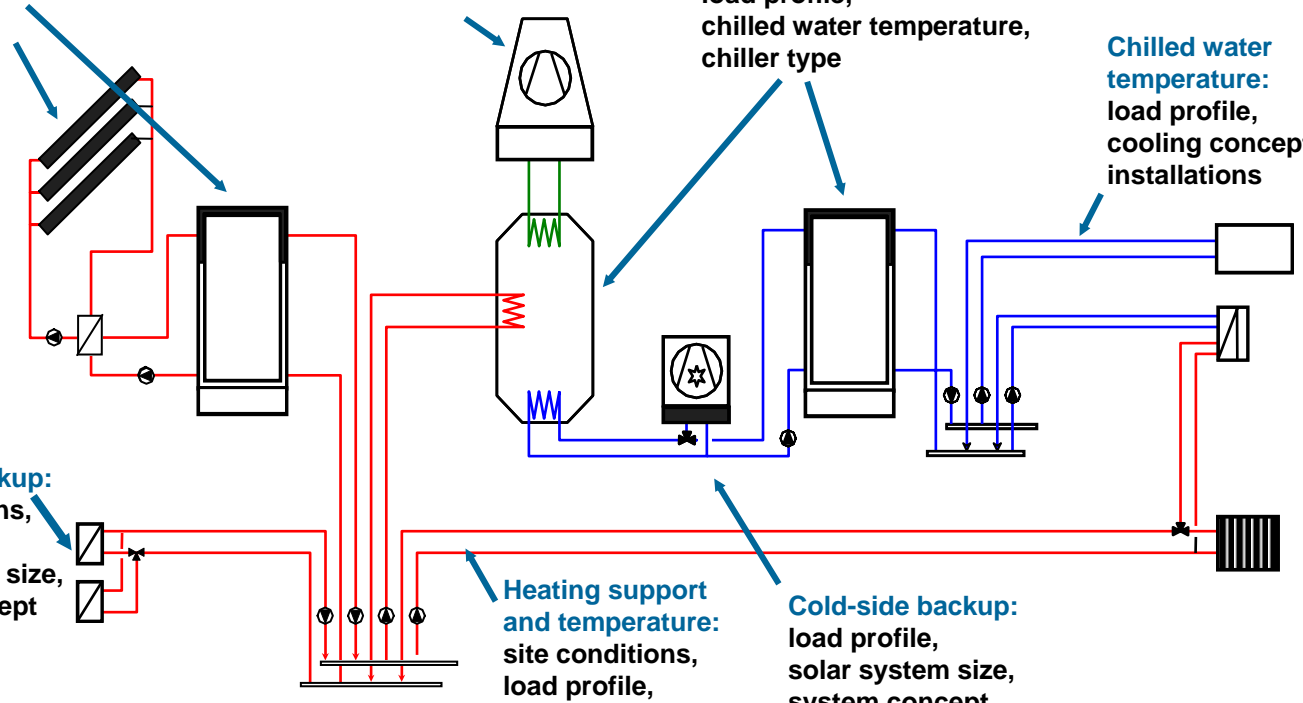
Chiller type, capacity,  
chilled water storage:  
load profile,  
chilled water temperature,  
chiller type

Chilled water temperature:  
load profile,  
cooling concept,  
installations

Hot-side backup:  
site conditions,  
load profile,  
solar system size,  
system concept

Heating support  
and temperature:  
site conditions,  
load profile,  
heating concept

Cold-side backup:  
load profile,  
solar system size,  
system concept



## Subtask 3.4

# Determination of system configurations

- Input from WP2 Market analysis
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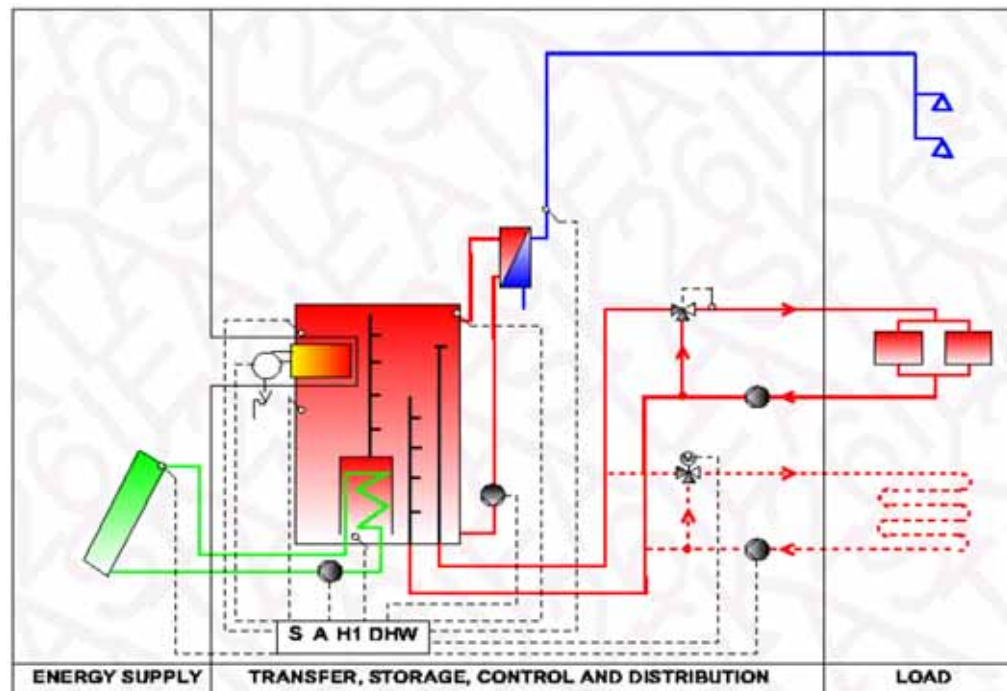


Figure from case study in Task 26

## Subtask 3.4

### Determination of system configurations

- **Collector:**

- type of collector, fluid
- heat exchanger (no/external/in storage)
- pumps: controlled/fix speed

- **Storages:**

- hot side / cold side / additional storages (DHW,..)
- additional buffer for adsorption chillers

- **Heat rejection:** wet / closed / dry /ground

- **Auxiliary sources:** CHP / gas boiler / compression chiller

- ....

## Subtask 3.4

# Determination of system configurations

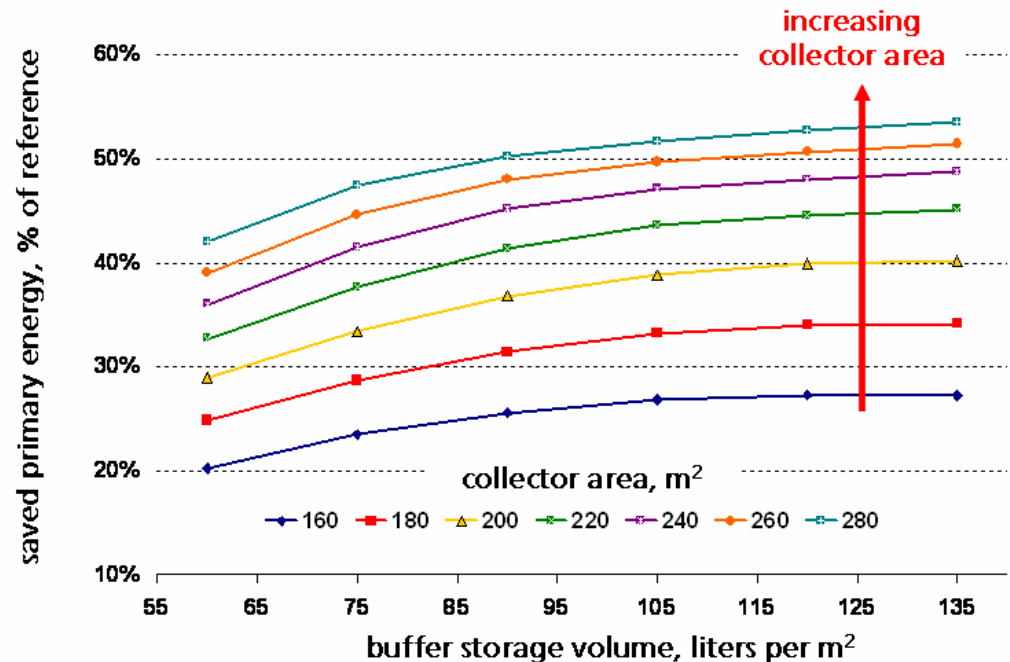
### ■ Pre-selection of appropriate configurations:

- which configuration for which climate?
- which chiller type for which application?
- which collector for which chiller?
- which heat rejection system for which configuration?



## Subtask 3.5 Simulation study

- Large number of simulations according to:
  - sites
  - applications
  - configurations
  - components sizes
  - control strategies
- Annual simulations runs to cover heating/cooling period
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## Subtask 3.6, 3.7

# Energy-related and economic evaluation of results

- Definition of appropriate energetic/economic evaluation numbers
- Reference calculations with non-renewable energy supply, e.g., electrically driven compression chillers for cooling
- Identification of most promising system configurations for each application/site
- ⇒ Input to online accessible data base



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### Virtual case studies

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