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Transfer of experience for the development of solar thermal products

Common Information Package

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PART III: SOLAR THERMAL APPLICATIONS

- TECHNICAL DESCRIPTION, SIZING AND CALCULATION METHODS OF LARGE SCALE COMBINED SOLAR SYSTEMS (ARSENAL RESEARCH)
- SOLAR THERMAL HEATING SYSTEMS IN EU (CRES)
- SOLAR AIR CONDITIONING (CRES)
- NEW APPLICATION FIELDS FOR SOLAR THERMAL SYSTEMS (ARSENAL RESEARCH)

Technical description, sizing and calculations methods of large scale combined solar systems

Gundula Tschernigg

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Table of content

- State of the art
- Plant hydraulics of combined solar systems in large applications
  - 2 pipe system
  - 4 pipe system
  - Connection of the heat producer
- Dimensioning of combined solar systems in dwellings
  - Collector area
  - Storage volume
- Connection of large solar fields

State of the art

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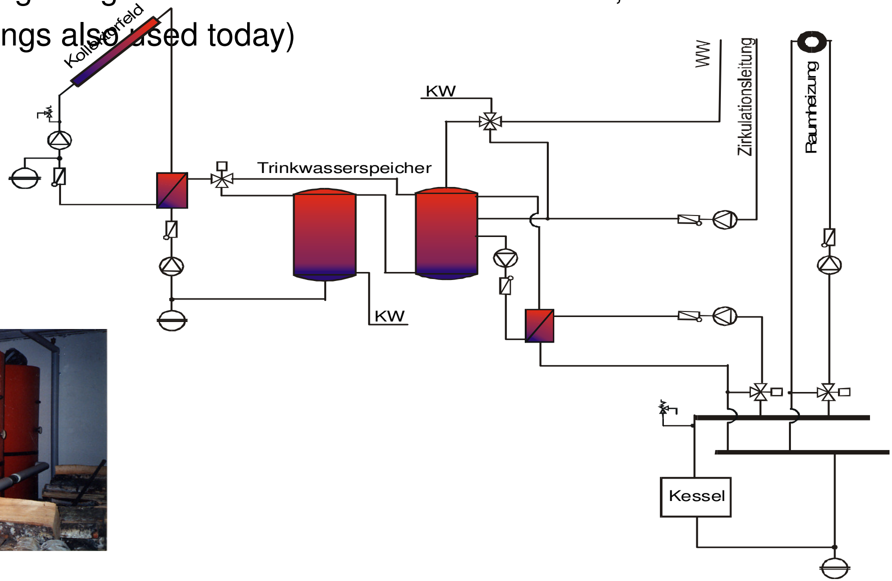
Development of combined solar systems

- Combined solar systems of the 1st generation in Austria

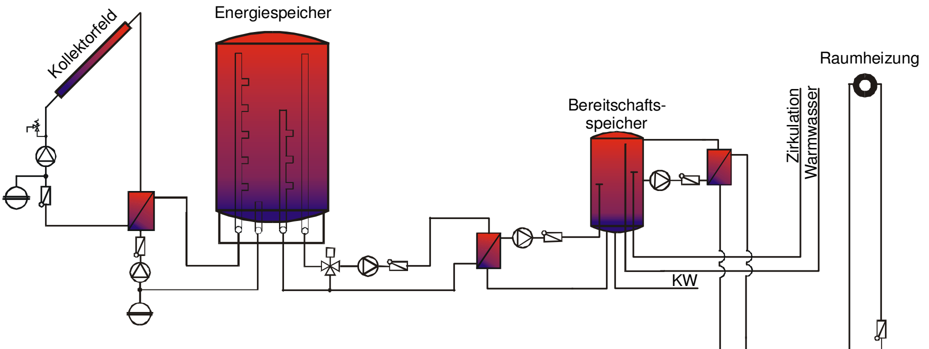
  (Started at the beginning of the 90's until the end of the 90's, at a small number of dwellings also used today)



Development of combined solar systems

- Combined solar systems of the 2nd generation in Austria

  (Started in the middle of the 90's until today)



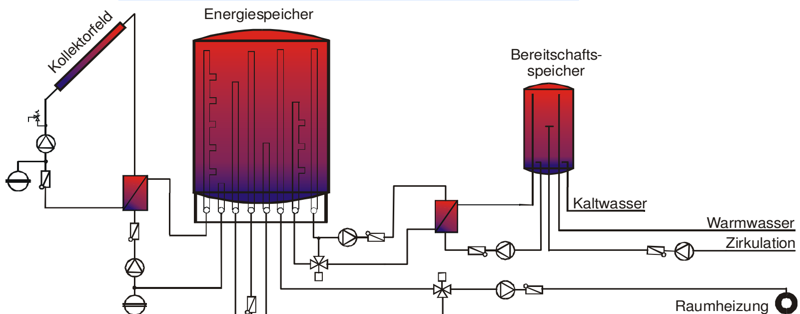
Numerous results of measurement showed….

- Solar supported distribution nets of the 1st and 2nd generation are not always working as efficiently as they should (losses!)
- Return temperatures are usually very high

Heat producer up to 20%

Heat storage up to 30% of the total heat demand

Heat distribution up to 40%



⇒ **low annual system performance (often 30 to 40%)**

⇒ **low specific solar gains and covering degrees**

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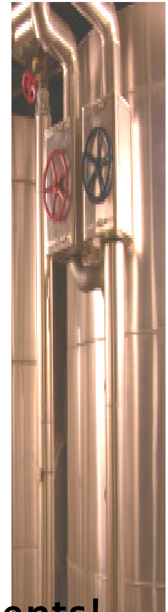
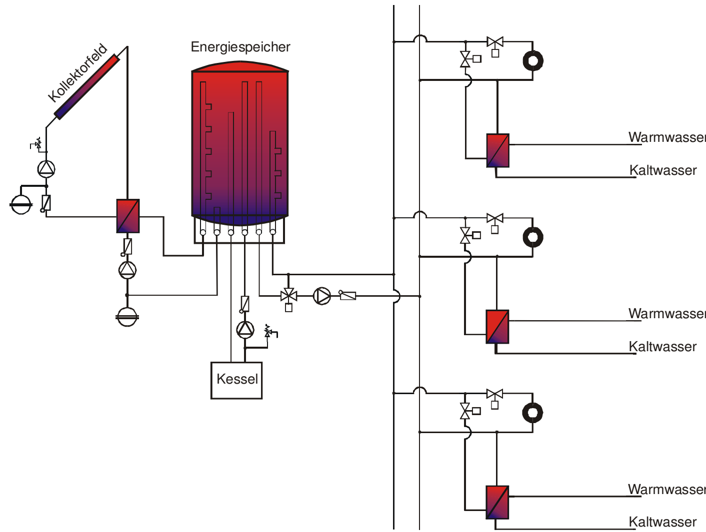
Requirements of solar supported heat nets of the 3rd generation



- Holistic systems
- Adapted basic conditions for the use of solar systems
- Conceptional reduction of calorific losses
- Highest comfort for occupants
- Hygienically harmless drinking water heating up
- Economically meaningfully
- Modern control of operating
- Apart from the employment in new buildings an employment in existing buildings must be possible

2-pipe nets can absolutely fullfill these requirements!

Plant hydraulics of combined solar systems in large applications



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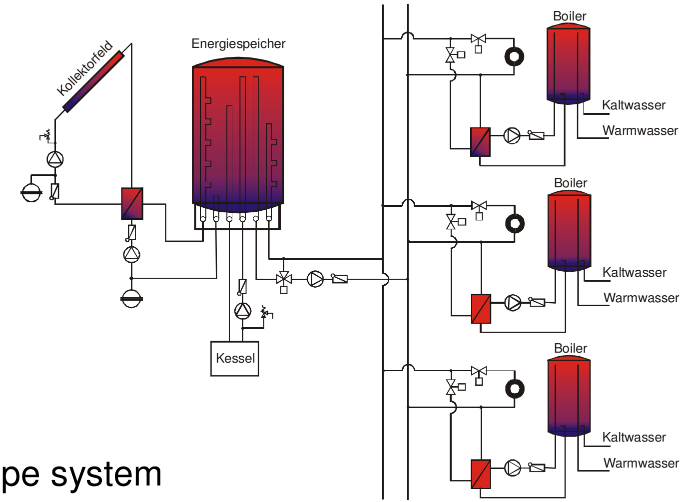
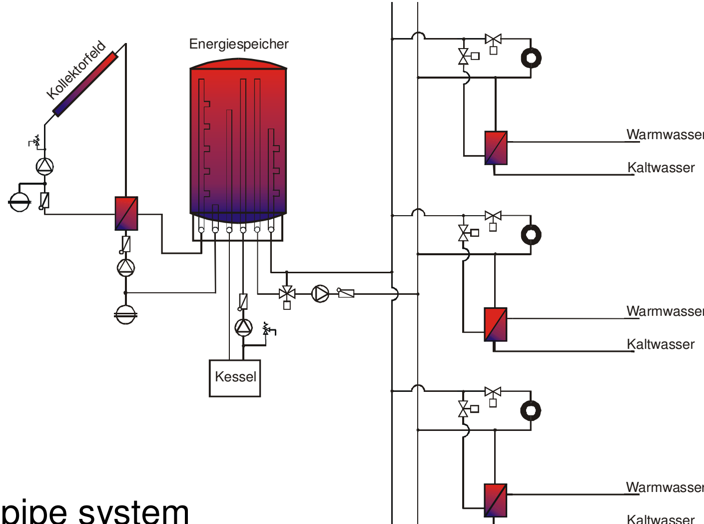
Solar supported heat systems of the 3rd generation in Austria



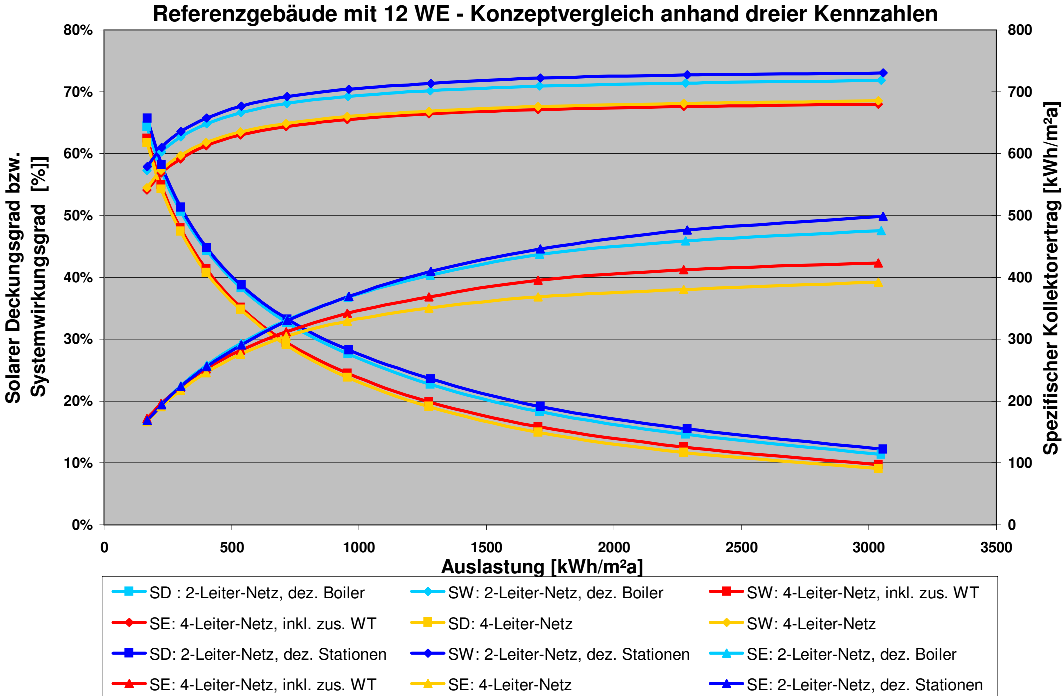
- Heat distribution from a 2-pipe system
- Hot water heating with a decentralised storage
- Meaningful employment with small energy densities (dwellings, etc.)

Solar supported heat systems of the 3rd generation in Austria



- Heat distribution from a 2-pipe system
- Hot water heating in a decentralised flow principle
- Meaningful employment with small and high energy densities

Advantages of 2-pipe systems



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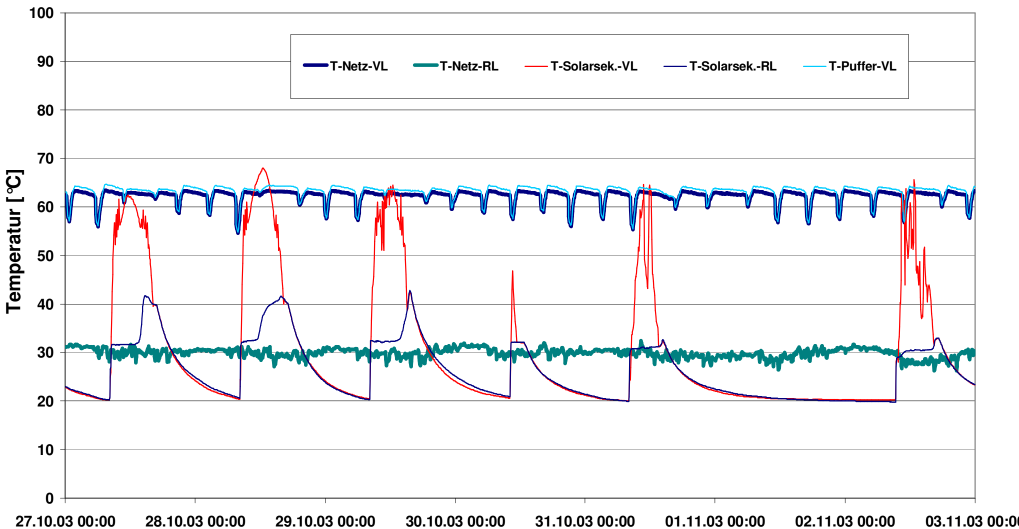
Advantages of 2-pipe systems

- Return is nearly constant at 30℃ and offers best conditions for the use of solar thermal systems



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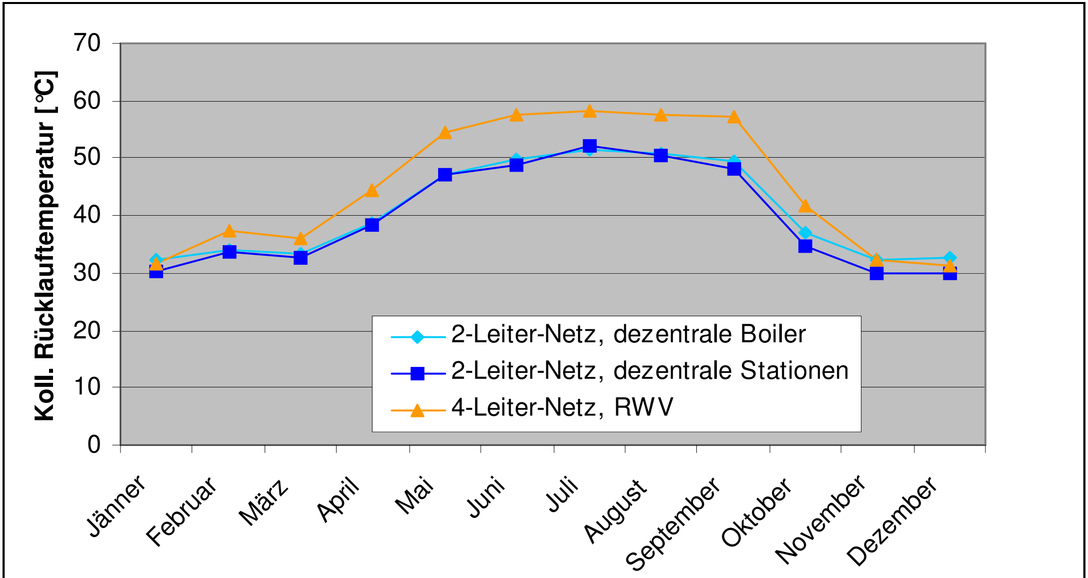
Advantages of 2-pipe systems

- Comparison of annual return temperatures of three different systems, 12 units, 20% solar covering degree

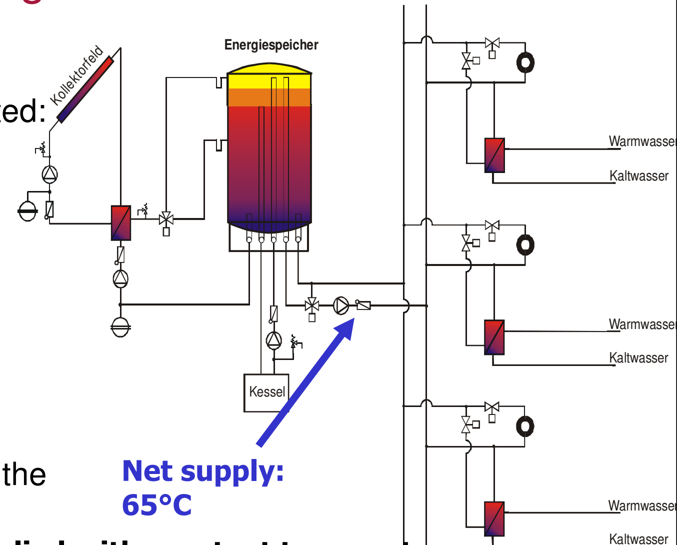


Advantages of 2-pipe systems

- Distribution losses are set to a minimum
- Because of the system a automatically heat support can be achieved
- Extensive tests show cheaper heat prices compared to 4-pipe systems
- A gain in comfort and absolutely harmless water hygiene
- Reduction of the error frequency in industrial manufactured housing stations and no auxiliary energy is needed

Solar supported energy nets: 2-pipe systems with decentralised district heating substations

- Solar system
  - If an energy storage is integrated:
    - Operational mode: Low (Matched) Flow
- Conventional boiler:
  - Feeds into the energy storage
- Heat distribution:
  - With a pair of pipes (2 pipes)
- Hot water preparation:
  - Decentralised flow principle in the flat



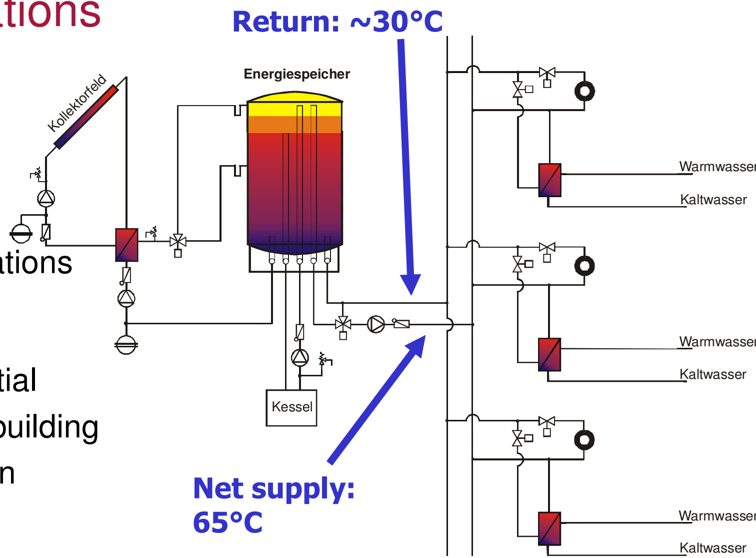
<u>Important</u>: The distribution net is supplied with constant temperatures (approximately 65 °C) during summer and winter

<u>Important</u>: the upper part of the storage needs to be kept on a minimum temperature (65°C) →security of supply

<u>Important</u>: Heater dimensioning 65/40

Solar supported energy nets: 2-pipe nets with decentralised district heating substations

- Important components:
  - Mixing valve
  - Pump
  - District heating substations
- Application:
  - New building, residential buildings in compact building method, reconstruction



Advantage: The hole year low return temperatures of approximately 30°C → few distribution net losses

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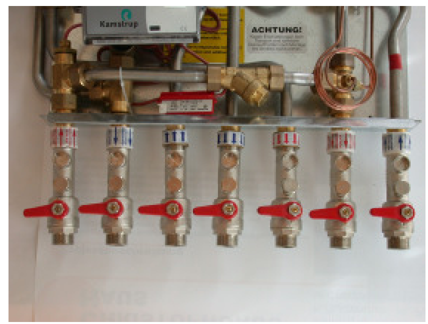
Substations

- Advantages of substations:
  - Industrial manufacturing
  - Highest quality criteria
  - No external energy requirement
  - Low investment costs
  - Individual design (finery, in the wall, different geometry)



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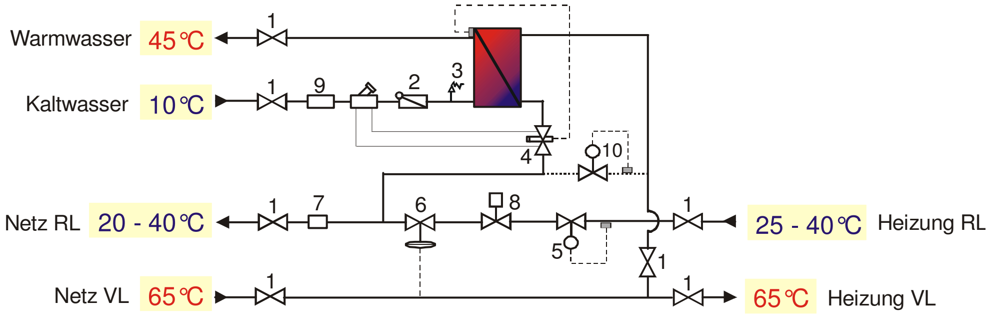
Construction of substations



1 Absperrventil
2 Rückschlagklappe
3 Sicherheitsventil
4 Durchflussgesteuerter Temperaturregler
5 Rücklauftemperaturbegrenzer
6 Differenzdruckregler
7 Zählerpassstück
8 Zonenventil
9 Passstück Kaltwasser
10 Zirkulationsbrücke

- Functions:
  - Hot water preparation
  - Heat supply

All components for decentralized hot water heating and space heating are contained

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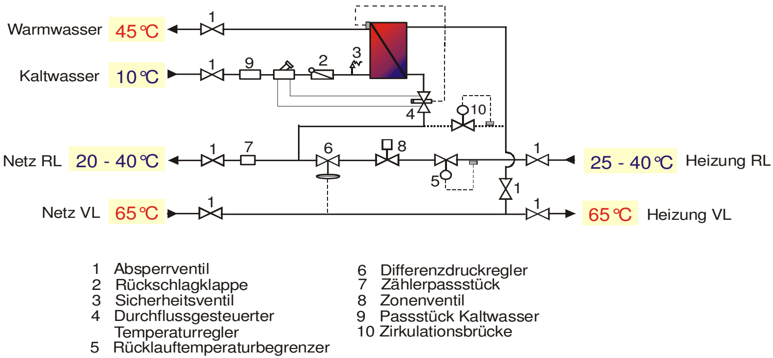
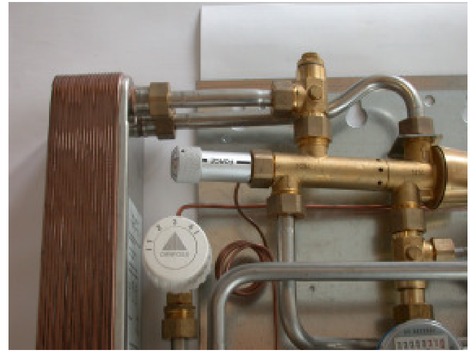
Functions of substations





- Important components for hot water preparation:
  - Plate heat exchanger: hot water is produced when its needed
    - Small risk of legionella
    - Highest hygiene
  - Proportional controller: regulates the hot water temperature and adapts the flow rate to the hot water consumption
    - No calcification because of the temperature limit

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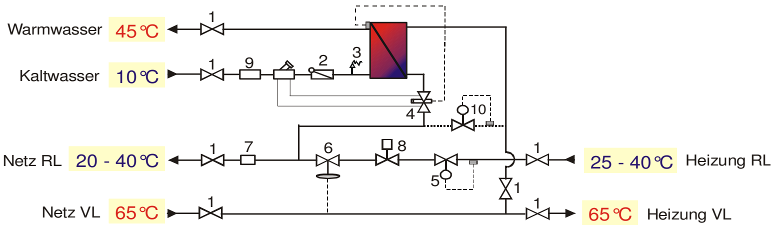
Functions of substations



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- Important components for heat preparation:
  - Differential pressure regulating valve: hot water is produce when its needed
    - Provide a constant mass flow in individual units of the dwellings
    - Inappropriate adjusting can be prevented by fixed pre-setting
  - Return controller: are used in the return and fixed on 40 °C
  - Thermostatic valve: control the temperature in the units

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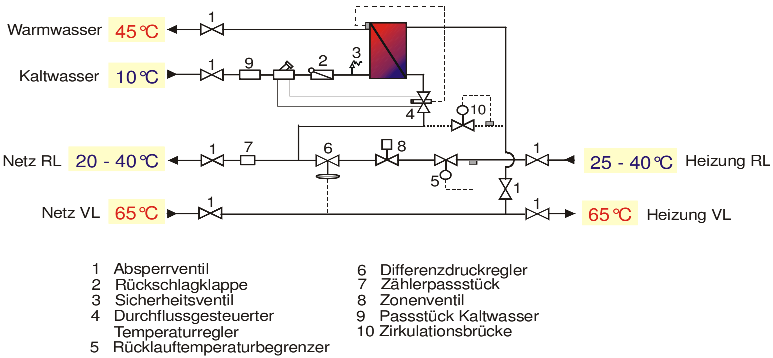
Measuring devices of substations



- Important components for measuring the demand:
  - Water meter
    - measures the total amount of hot water used in a unit
  - Heat meter
    - measures the total amount of hot water and heat used in a unit
  - Can be read out manually or via a bus-sytem

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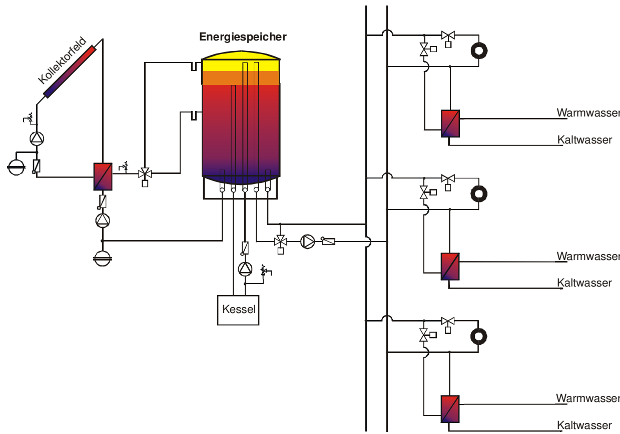
Distribution net

- Characteristics of 2-pipe systems with substations
  - Strongly varying flow due to the decentralized hot water preparation
  - Constant flow temperatures over an entire operational year

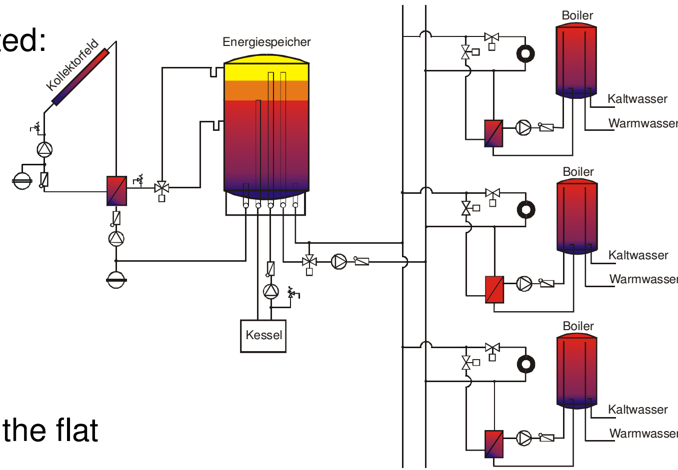


Distribution net

- Volume flow
  - Between summer and winter varying volume, usage of two pumps:
    - Pump for summer
    - Pump for winter
    - Reduction of the needed electricity
  - Ascending pipe needs to be regulated correctly, usage of a differential pressure regulating valve
  - Mixing valve: temperatures up to 95 °C during summer mean highest requirements on the mixing valve

Solar supported energy nets: 2-pipe systems with decentralised hot water storage

- Solar system
  - If an energy storage is integrated:
    - Operational mode: Low (Matched) Flow
- Conventional boiler:
  - Feeds into the energy storage
- Heat distribution:
  - With a pair of pipes (2 pipes)
- Hot water preparation:
  - Decentralised flow principle in the flat



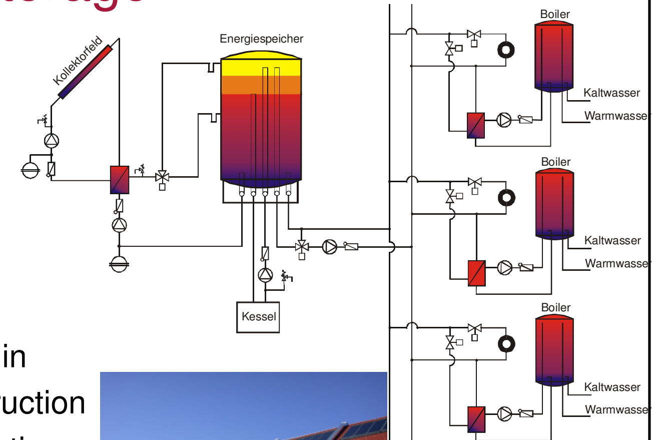
<u>Important</u>: The distribution net is used 22h to 23h for the heat supply and just 1h to load the boiler

<u>Important</u>: the upper part of the storage needs to be kept on a minimum temperature (65°C) →security of supply

<u>Important</u>: Heater dimensioning 65/40

Solar supported energy nets: 2-pipe systems with decentralised hot water storage

- Important components:
  - Mixing valve
  - Pump
  - District heating substations
- Application:
  - New building, residential buildings in compact building method, reconstruction (already existing devices can sometimes be further used)

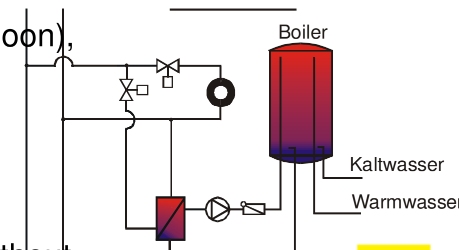


Advantage: Low return temperatures from the beginning of the boiler load

Advantage: Distribution losses are reduced during summer (pipes are heated up just once/day)

Hot water preparation / Space heat supply

- Hot water storage:
  - Dimensioning on a daily use of 150-200 litres
  - Placement: storage, toilet, bath, possibly cellars
    - Importantly: short ways to the taps
- Loading of the hot water storage:
  - external heat exchangers
    - Deep return temperatures can be obtained
    - Importantly: hydraulic uncoupling
- Loading:
  - Low loads, irradiation-strong time periods (at noon), load duration (1h)
- Space heat supply:
  - Dimensioning of radiators on a max. 65/40 °C
  - Usage of low temperature systems possible without any problems



Summary

2 pipe systems with substations

Application:
- new buildings
- reconstruction
- dwellings and terraced houses

Advantages:
- low investment costs
- hygienical hot water preparation
- compact
- low required space
- low distribution losses
- amount of hot water is unlimited
- comfort

Disadvantages:
- pump is used the whole year
- operating current

2 pipe systems with decentralized hot water storage

Application:
- new buildings
- residential buildings in compact building method
- reconstruction

Advantages:
- heats up the distribution net just ince a day (low distribution losses)
- hygienical hot water preparation

Disadvantages:
- higher investment cost because of the decentraized hot water storage
- more space is needed

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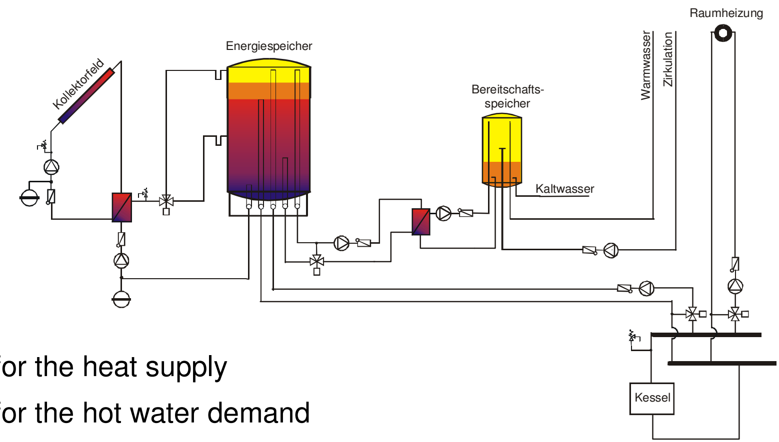
Solar supported 4-pipe systems

- Application
  - Reconstruction of buildings with already existing central hot water distribution



- Functions:
  - One pair of pipes for the heat supply
  - One pair of pipes for the hot water demand
- Separation in:
  - Systems with one storage (max. 10 units)
  - Systems with two storages (larger dwellings)

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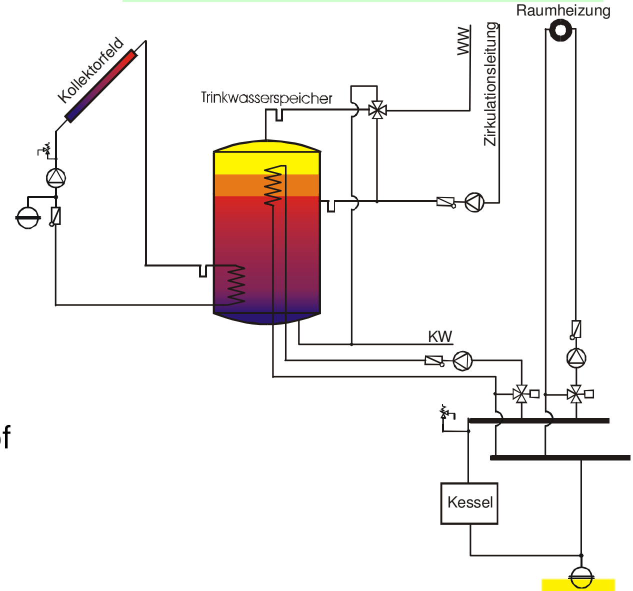
4-pipe system with hot water storage

- Application: for a maximum of 10 flats
- Hot water storage
  - Cost-intensive by interior coating or high-grade steel
  - high requirements on water hygiene
- Integration of the solar system
  - Internal heat exchanger
  - Plate heat exchanger
- Temperature delimitation of the storage on 60℃: Calcifying danger of the external heat exchanger

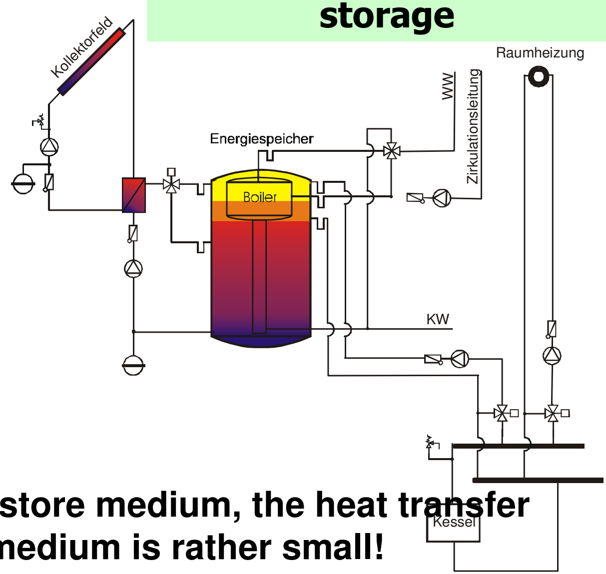
Systeme with hot water storage



4-pipe system with one steel storage

- Steel storage
  - Is used as energy storage
- Integration of the solar system
  - Internal heat exchanger
  - Plate heat exchanger
- Hot water preparation
  - Internal water storage
  - Internal tube heat exchanger

Systeme with steel storage



Because of the standing energy store medium, the heat transfer between hot water and storage medium is rather small!

Supply security is ensured by the provision of a large amount of hot water and large container or tube heat exchanger area

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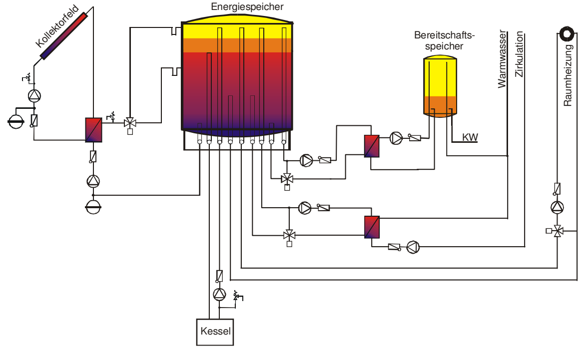
4-pipe system with two-storage systems

- Application
  - For large hot water consumption

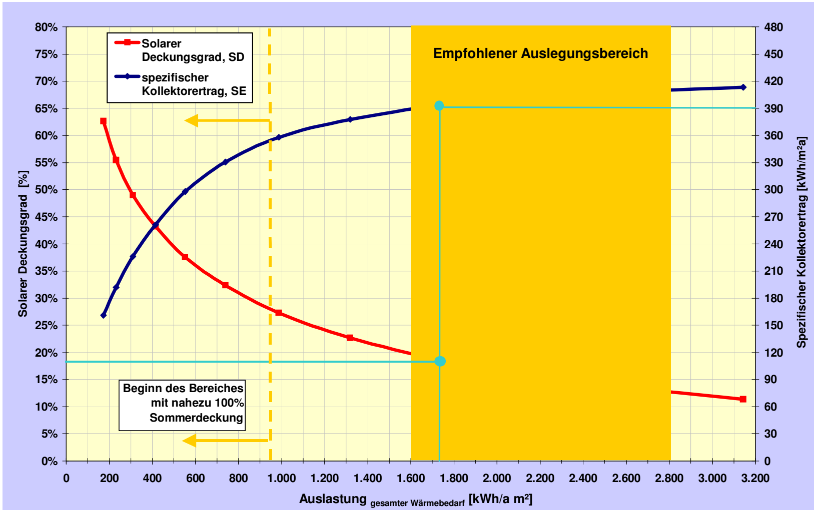


- Layout
  - Central energy storage (steel), Central hot water storage to cover peak loads
  - Conventional heat generator feeds exclusive in the energy storage
  - Energy storage supplies the space heating

Increased solar results up to 10% compared to solar systems for the hot water preparation -> should be included in heat heating system!

Sometimes old storages can be used!

Dimensioning of combined systems in dwellings



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Dimensioning of combined systems in dwellings

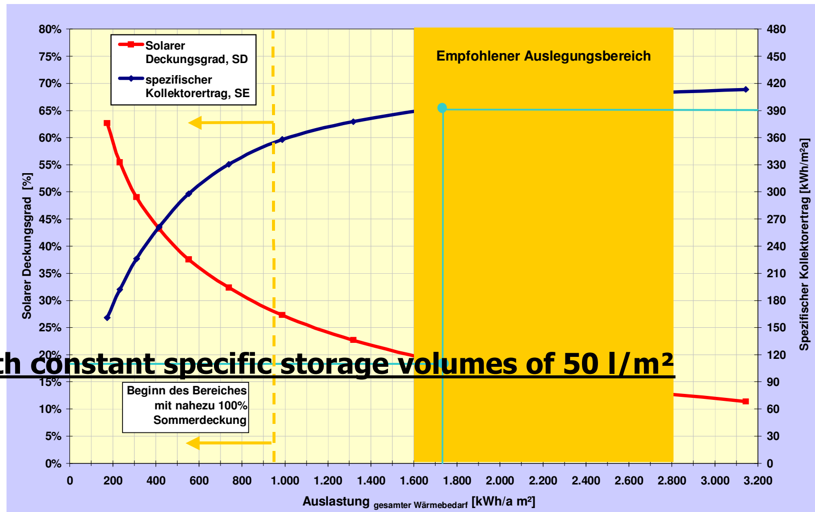
- Dimensioning of the characteristics:
  - collector surface [m ²]
  - Storage volume [litre]
- Are considered:
  - Energetic and economical aspects
  - Dimensioning with easy understandable nomographs

- Distinction between:
  - Dimensioning nomographs for combined systems / hot water systems
- Possible results:
  - Gross collector surface [m ²]
  - Solar storage volume [litre]
  - Solar covering degree at the total energy need [%]
- Conditions for the dimensioning; knowledge of:
  - Annual hot water and heat demand
  - Introduce an auxiliary characteristic number: load

$$load = \frac{total\ demand\ of\ heat\ and\ hot\ water}{net\ colle\cot or\ area} = \frac{kWh/\ year}{m^2}$$

Distinction of the dimensioning strategy

- Most important factors on investment and solar fraction – storage and collector area
- 1. Dimensioning in the cost/use optimum
  - Recommended collector area with a solar fraction of 12% appr. 0,9m²/person - 20% appr. 1,4m²/person
- 2. Dimensioning on almost 100% summer covering
  - Recommended collector area with a solar fraction of 28% appr. 2m²/person
- Fixed surface



<u>The nomograph works with constant specific storage volumes of 50 l/m² gross collector area!</u>

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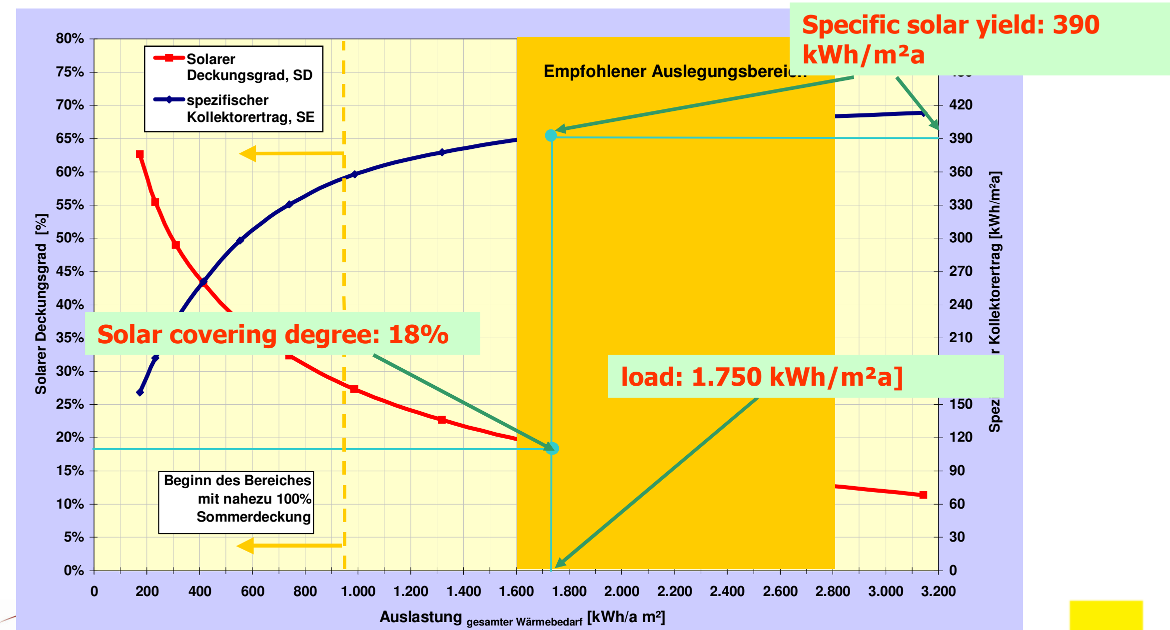
Dimensioning example

Residential building with 21 accommodation units
Heat demand: appr. 120.000 kWh/a
Hot water demand: appr. 32.000 kWh/a
Complete demand: 152.000 kWh/a
Desired solar covering degree for the energy demand: appr. 18 %

Wanted data:

Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]



Dimensioning example

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Complete demand: 152.000 kWh/a
Desired solar covering degree for the energy demand: appr. 18 %

Wanted data:
Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]

- **1.step: determination of the load -> 1.750 kWh/m²a**
- **2.step: determination of the collector area**

$$collector\,area = \frac{total\ demand\ of\ heat\ and\ hot\ water\,[kWh/a]}{load\,[kWh/m^2.\,a]} = area\,[m^2]$$

$$collector\,area = \frac{152.000\,kWh/a}{1.750\,kWh/a} = 87\,m^2$$

- **3. Step: storage volume: 87m²x50l/m² = 4.350l**
- **4. Step: annual solar yield**

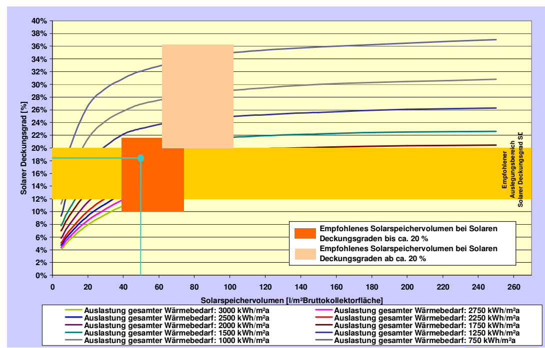
$$solar\ yield = specific\,solar\ yield\,[kWh/m^2.a] * gross\,collector\,area\,[m^2] = solar\ yield\,[kWh/a]$$

$$solar\ yield = 390\,[\mathrm{kWh/m^2a}]\ \mathrm{x}\ 87\,[\mathrm{m^2}] = 33.930\,\mathrm{kWh/a}$$

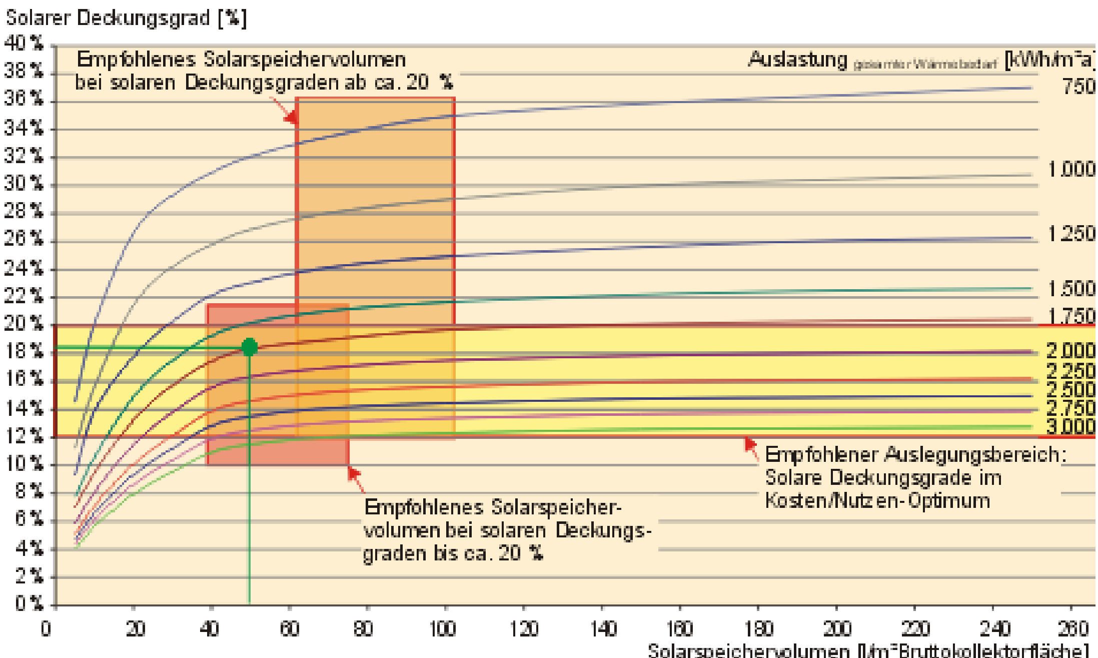
The previous dimensioning nomograph works with constant specific solar storage volumes [50 Liter/m ² Bruttokollfl.]

Valid with dimensioning in cost/use optimum (solar covering degrees between 12% and 20%)

If you want to dimension solar systems with higher solar covering degrees, you need use the following dimensioning nomograph!



Specific dimensioning nomograph - suitably even for higher solar covering degrees



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Complete demand: 152.000 kWh/a
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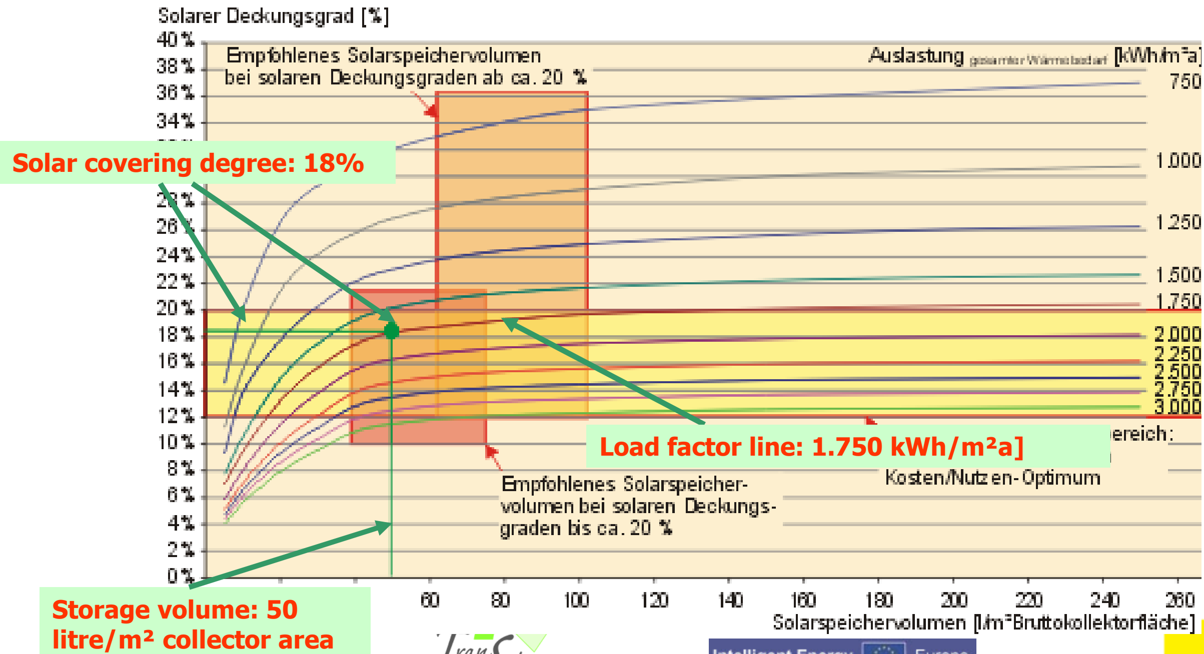
Wanted data:
Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]



Dimensioning example

Residential building with 21 accommodation units
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Complete demand: 152.000 kWh/a
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Wanted data:
Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]

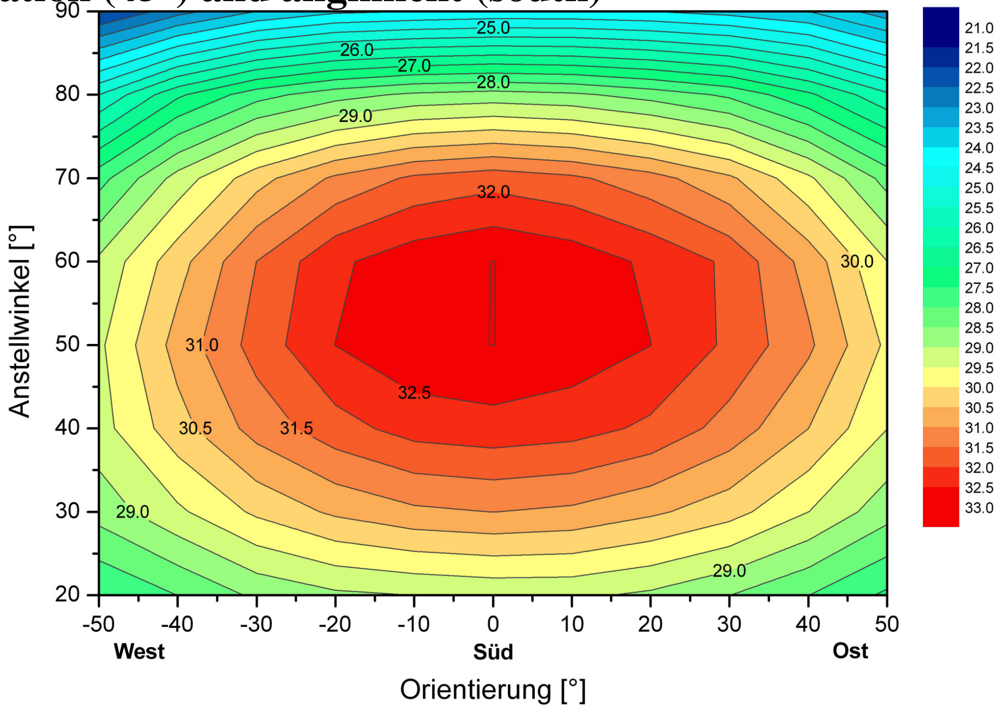
- **1.step: determination of the load factor line-> 1.750 kWh/m²a**
- **2.step: determination of the collector area**

$$collector\,area = \frac{total\ demand\ of\ heat\ and\ hot\ water\,[kWh/a]}{load\,[kWh/m^2.\,a]} = area\,[m^2]$$

$$collector\,area = \frac{152.000\,kWh/a}{1.750\,kWh/a} = 87\,m^2$$

- **3. Step: storage volume: 87m²x50l/m² = 4.350l**

This is a nomograph to correct the previous dimensioning nomographs which is based on a fixed defined collector inclination (45°) and alignment (south)



Ranges of recommended angles of inclination and alignment of collector surfaces in dependence of the solar covering degree

Desired dimensioning	Solar covering degree	Recommended collector angle of inclination	Recommended collector alignment
Dimensioning in cost/use optimum	appr. 12%	25 to 40°	preferable South, tolerable deviation eastward 45° and the
	appr. 20%	30 to 45°	preferable South, tolerable deviation eastward 45° and the west 45°
Dimensioning with 100% summer covering	appr. 28%	40 to 55°	preferable South, tolerable deviation eastward 45° and the west 45°

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Connection of large collector fields

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Requirements on collector connections

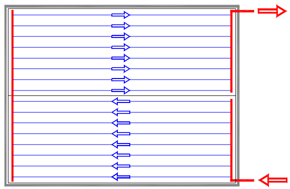
- Heat transfer between absorbers and heat distribution media as good as possible
- Pressure losses by the collector flow as small as possible
- Standard dimensions from the manufacturers should be used
- To reduce the calorific losses, the material and assembly costs a small cross section of pipes is needed

Serial connection is desired

Flow principle: „Low flow“

Advantages of large-scale installations compared to single collectors

- Large-scale installation



- Single collector

- Reduction in installation time by crane
- Reduction in connection number
- Daily performance of over 300m² collector surface (100m² inclusive elevation)
- Quality increase by process and locally reduced connection expenditure

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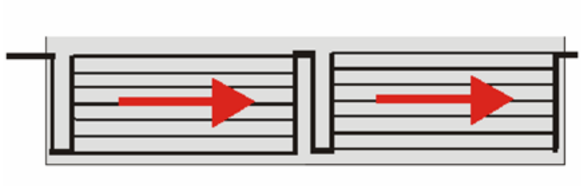
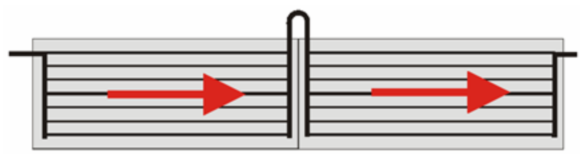
Expansion Compensation

Copper with 200 K ΔT: expansion: 3,5 mm/m

- Expansion loops in the collector



- External expansion loop with flexible pipe



- Collector manufacturer must indicate the maximum number of single collectors in series and/or the use of expansion loops

General Aspects

- Connect as much as possible collectors in series
- Turbulent flow in the collector should be achieved -> optimal efficiency
- Use of insulation valves in parallel collector fields -> separate purging of the collector fields
- In unequal parallel collector fields
  - Alignment of the different mass flows
  - Use of circuit control valves
  - Highest temperature-resistance
  - Positioning of valves so far as possible from the collector (mostly in the return)

Thank you for your attention!

Contact:

DI (FH) Gundula Tschernigg
arsenal research

Giefinggasse 2, 1210 Wien, Austria
ph: +43 (0) 50550-6374, f: +43 (0) 50550-6613
mobile: +43 (0) 664/ 825 11 75
gundula.tschernigg@arsenal.ac.at
www.arsenal.ac.at/eet

Budapest
16 April 2009

Solar thermal heating systems in European Union

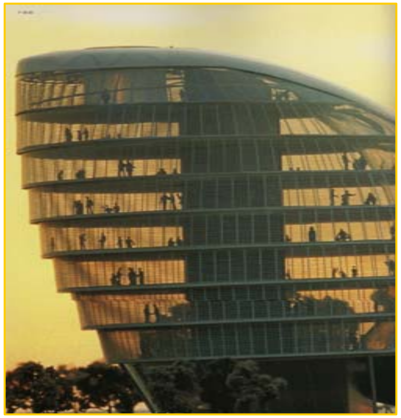
Christodoulaki Rosie
MSc Environmental design & engineering
BSc Physics
Centre for Renewable Energy Sources – Solar Thermal dept.

КАПЕ
CRES

1. Primary energy demand

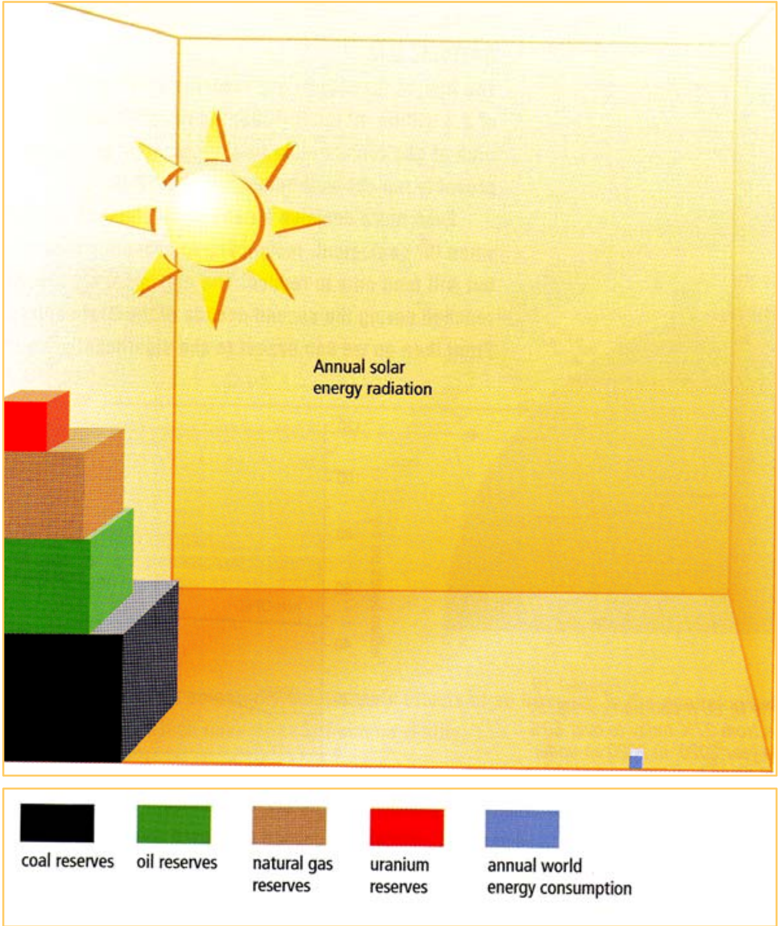
- **Energy consumption in commercial and residential buildings**:
  - 40% of Europe's energy bill.
  - 435 Mtoe in 2002.
- **Increased demand for air conditioning in buildings**:
  - Higher living and working standards
  - Adverse outdoor conditions in urban environments
  - Installed a/c has increased 5-fold in the last 20 years in Europe
  - Total a/c floor space: 30 million m^2 in 1980, over 150 million m^2 in 2000.
  - Annual energy use of room a/c was 6 TJ in 1990, estimated 160 TJ in 2010.
- **CO_2 emissions are expected to increase 20-fold from 1990 to 2010**, only in the EU

Solar thermal systems can help alleviate the problem!
Pool heating
Domestic hot water
Space heating
Space cooling

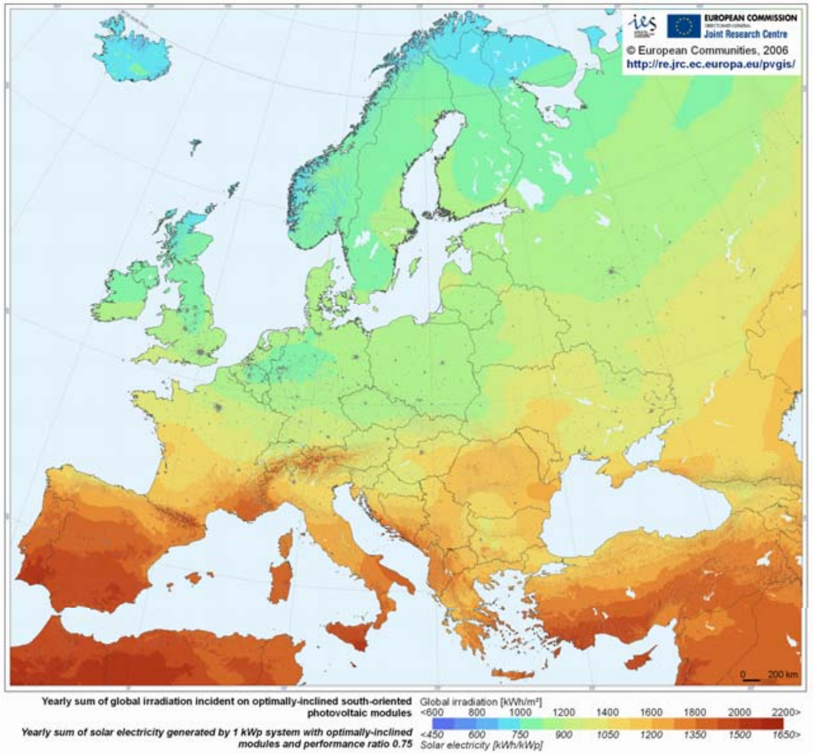


The solution : Solar Energy

- **Radiation** supply from sun carries a **5 billion year guarantee**
- Annually, **the sun provides $1.5*10^{18}$ kWh**, that is more than 10,000 times the energy that human race needs.

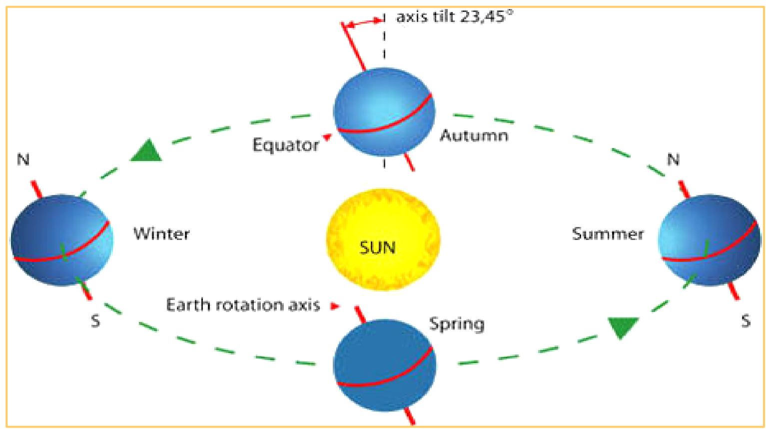


Source: *Planning & Installing Solar Thermal Systems: A guide for installers, architects & engineers*, EarthScan publications



Average annual solar irradiance is an important value for designing a solar plant. It depends on the geographical location, i.e. Saharan desert has 2.2 times higher radiation that Europe.

The **average solar irradiance is higher at lower latitudes**, since the rotation axis of the earth forms an angle of 23.45^0 with the perpendicular.



2. Solar Collectors Optimum Angle

Geographical location

- **Winter use**: geographical latitude of area + 15^0
- **Summer use**: geographical latitude of area - 15^0
- **Annual use**: collector angle = geographical latitude

RESULTS OF INCIDENT RADIATION ON COLLECTORS (FROM TSOL)
Place: Athens
Azimuth: 0

G Inclined, Specific[kWh/m²]
acording to collectors inclination (in degrees °)

From:	To:	0	10	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
1/ 1/	1/ 2/	66	80	91	96	100	104	107	109	111	112	113	112	111	109	107	104	100
1/ 2/	1/ 3/	75	84	91	93	96	97	99	99	99	99	98	96	94	91	88	84	80
1/ 3/	1/ 4/	104	112	116	118	119	119	119	118	116	114	111	108	104	99	94	89	83
1/ 4/	1/ 5/	146	151	152	152	151	149	147	143	139	134	129	123	116	108	101	92	84
1/ 5/	1/ 6/	182	183	181	178	175	170	165	159	153	145	137	128	119	109	100	90	79
1/ 6/	1/ 7/	200	200	195	191	185	180	173	166	158	149	139	128	118	108	96	85	75
1/ 7/	1/ 8/	213	214	210	205	199	194	187	180	171	162	151	139	128	117	105	91	80
1/ 8/	1/ 9/	200	206	206	204	202	199	194	188	182	174	165	155	144	132	121	109	96
1/ 9/	1/10/	156	168	176	179	180	181	180	178	175	171	166	161	154	146	138	128	118
1/10/	1/11/	106	120	130	134	138	140	142	143	142	142	140	137	134	130	125	119	113
1/11/	1/12/	66	77	86	90	94	96	99	100	101	102	102	101	99	97	95	92	88
1/12/	1/ 1/	53	63	72	76	79	82	85	87	88	89	89	89	88	87	85	83	80
	Sum YEAR	**1567**	**1658**	**1706**	**1716**	**1718**	**1711**	**1697**	**1670**	**1635**	**1593**	**1540**	**1477**	**1409**	**1334**	**1252**	**1165**	**1075**
hotels season:1/4 to 1/11		**1203**	**1242**	**1250**	**1243**	**1230**	**1213**	**1188**	**1157**	**1120**	**1077**	**1027**	**971**	**913**	**850**	**784**	**714**	**645**
heating season: 1/11 to 1/4		**364**	**416**	**456**	**473**	**488**	**498**	**509**	**513**	**515**	**516**	**513**	**506**	**496**	**484**	**468**	**450**	**430**
"winter": 1/12 to 1/3		194	227	254	265	275	283	291	295	298	300	300	297	293	287	280	270	260

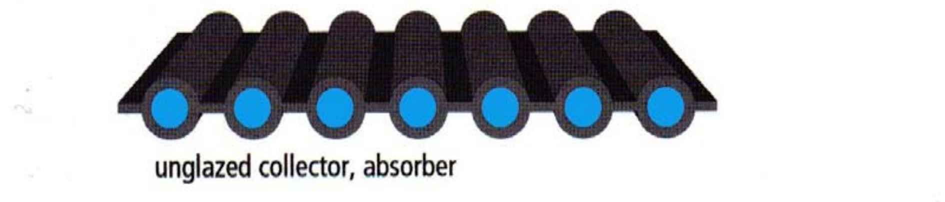
Unglazed collectors

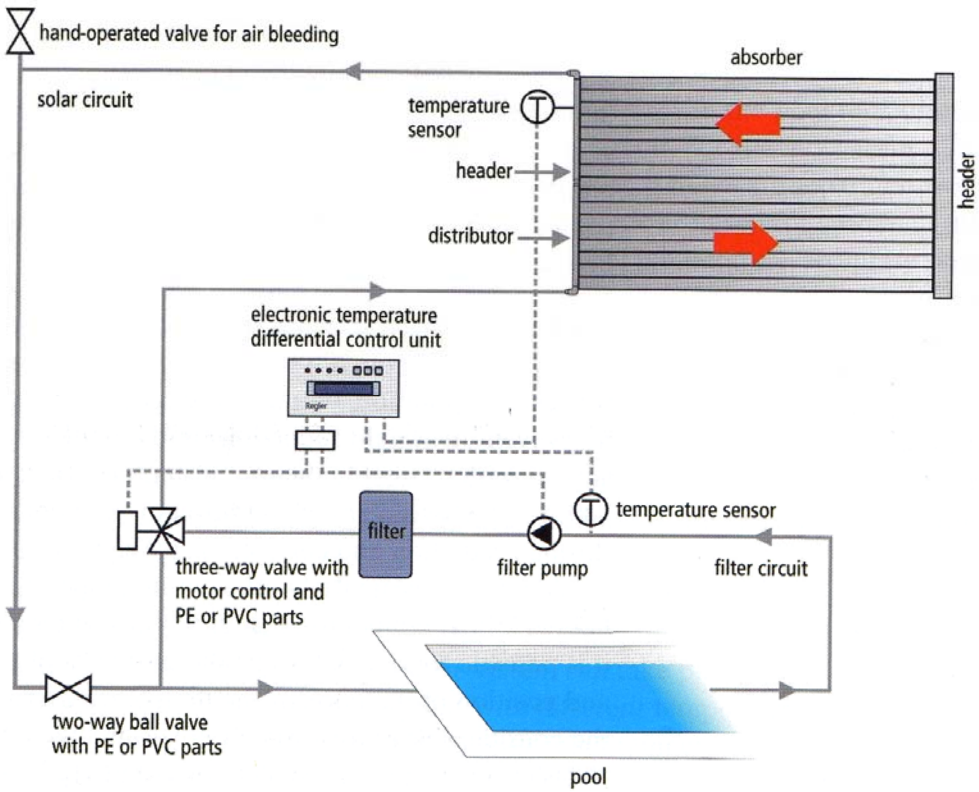
Properties

- No glazing, no insulation
- Low operation temperature
- Low cost, average payback time 1-5 years
- High thermal losses, low performance

Applications

- Pool heating only. Warm climates: to extend the swimming period from April-October.





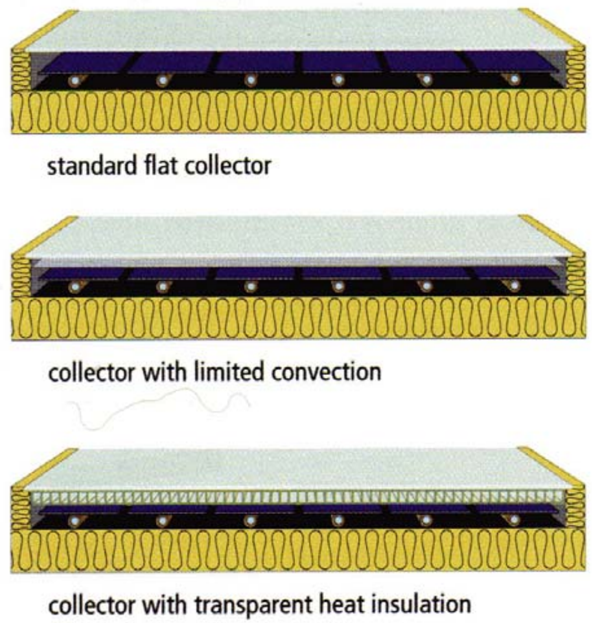
Flat plate collectors

Properties

- Middle cost: more expensive than unglazed, but cheaper than vacuum
- Higher operation temperature
- Thermal insulation on back & edges
- Fragile, heavier: 20-32 kg/m^2
- Transparent cover: black paint or spectral-selective coating (black chrome, black nickel, blue titanium)
- Spectral-selective coating: conversion of short-wave solar radiation into heat (light absorption capacity) is optimized, while thermal emissions are kept low. Absorption rate: 90-95%, emission rate 5-15%
- Stagnation temperature: 160-200^{0}C

Applications

- DHW
- Space heating
- Solar air conditioning (selective coating)



Collectors Comparison

Collector type	Cost	Performance (kWh/m^2a)	Application
Unglazed	Low	300	Pool heating
Flat plate (black paint)	Middle	650	Pool heating, Hot water
Flat plate (selective coating)	Middle	700	Hot water, space heating, solar a/c

The solar collector converts the light that penetrates its glass into heat. The generated heat flows then to the hot water store.

- **Thermosyphon**

No pumps, since gravity is used for liquid transport

- **Forced circulation**

Circulating pumps required, in Northern - Central Europe

- **Direct (drainback) system**

Direct circulation of domestic water through the collector, heat transfer medium: water. When the collector pump is switched off, the collector drains completely.

- **Indirect (filled) system**

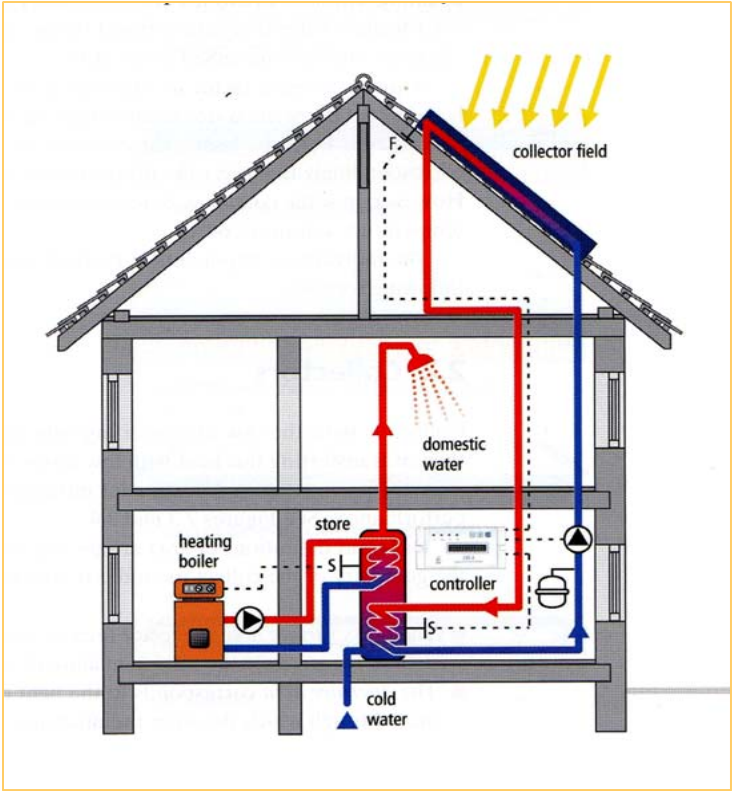
Solar circuit is separate from domestic water circuit, heat transfer medium: water-glycol. The collector circuit is partially or completely filled.

- **Open system**

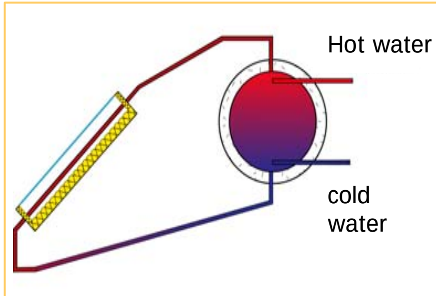
Open container at the highest point of solar circuit, which absorbs the volumetric expansion of the liquid caused by T changes

- **Closed system**

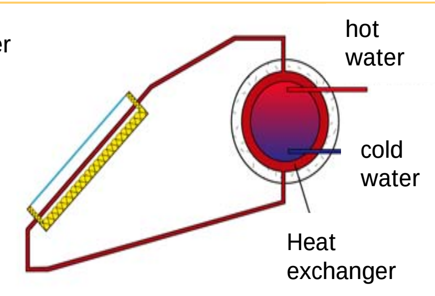
Operate at high pressures (1.5-10 bar), which influences the $T_{evaporation}$ of the liquid.



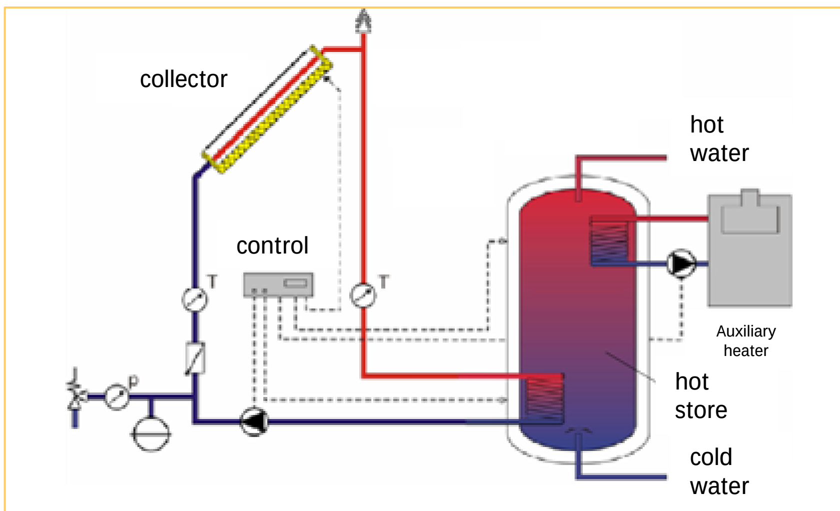
Thermosyphon direct



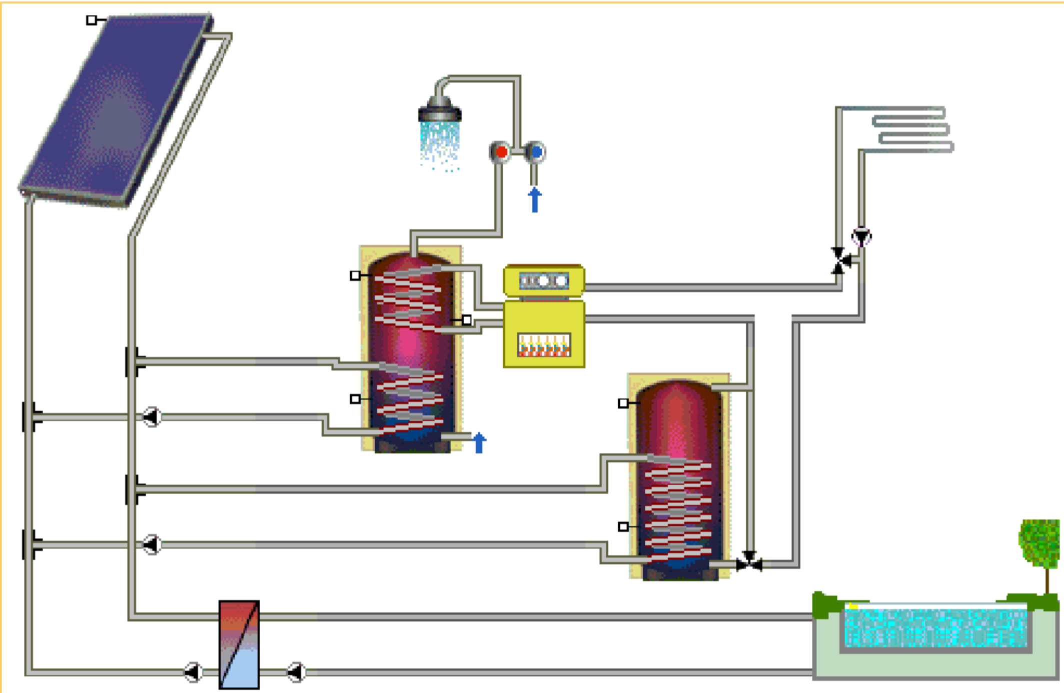
Thermosyphon Indirect

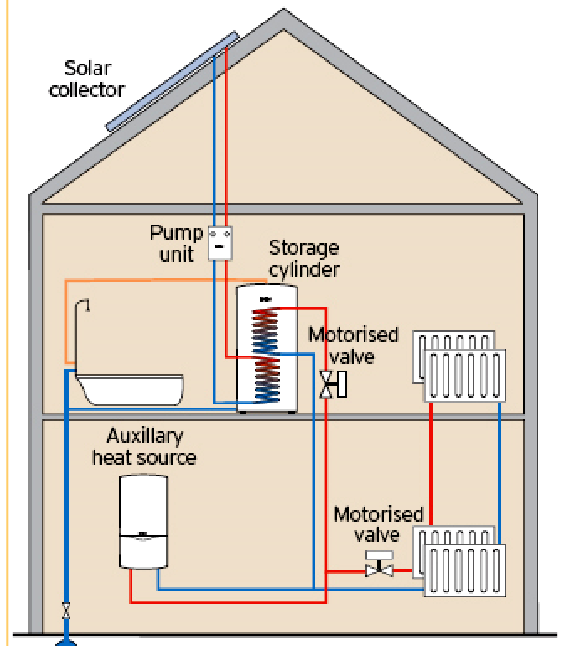


Forced circulation, indirect



Combi Systems





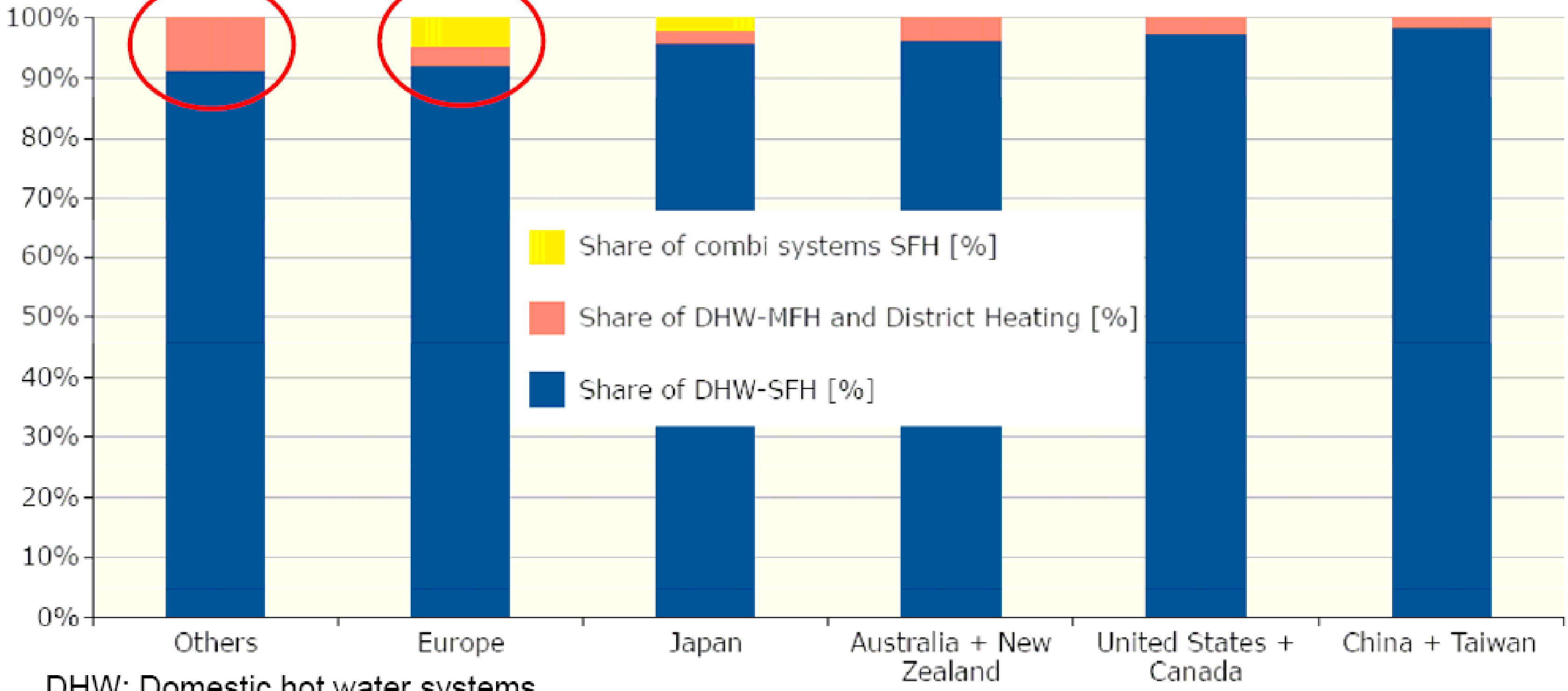
A typical solar installation and heating system

- Pool heating, hot water and space heating
- Integration into existing fan coil units
- High energy saving potential
- Required collectors: 20% of space for 40-50% covering
- 100% covering with solar collectors & biomass

Systems Cost

2008			
System	**Use**	**Cost (incl. installation)**	**Characteristics**
Pool heating	Pool heating	100 € /m² collector	Uncovered collectors, m² collector ≈ m² pool
Thermosyphon	Hot water	1,400 €	150 lt boiler, 2.5 m² flat plate collector
	Hot water	1,600 €	150 lt boiler, 2.5 m² selective flat plate
Combi	Hot water, Heating	500-750 € /m² collector	1000 lt boiler, 15 m² selective flat plate
	Professional: Pool heating, Hot water, heating & air-conditioning	400-650 € /m² collector	30.000 lt boiler, 500 m² selective flat plate

Distribution of solar thermal systems by application



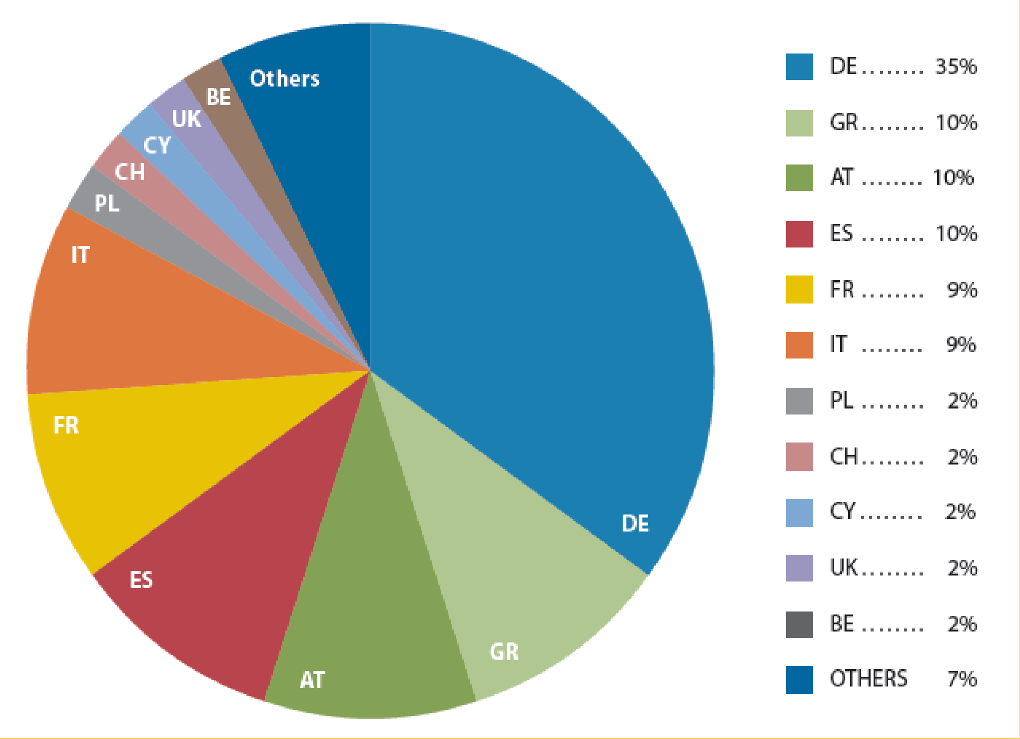
DHW: Domestic hot water systems
SFH: Single family houses
MFH Multi-family houses
Combisystems: Systems for DHW and space heating

Source: IEA-SHC, Solar Heat Worldwide Edition 2008, www.iea-shc.org

Others: Barbados, Brazil, India, Israel, Jordan, Mexico, Namibia, South Africa, Tunisia and Turkey

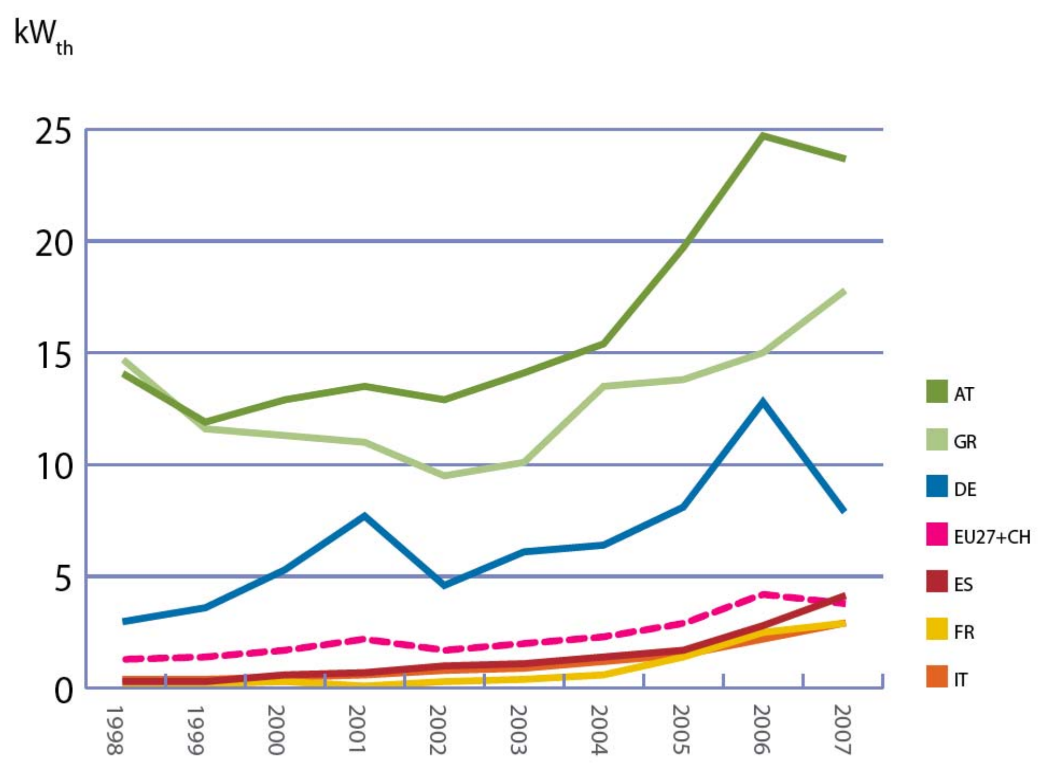
4. Solar Thermal Market in Europe, 2007

Breakdown per country, 2007



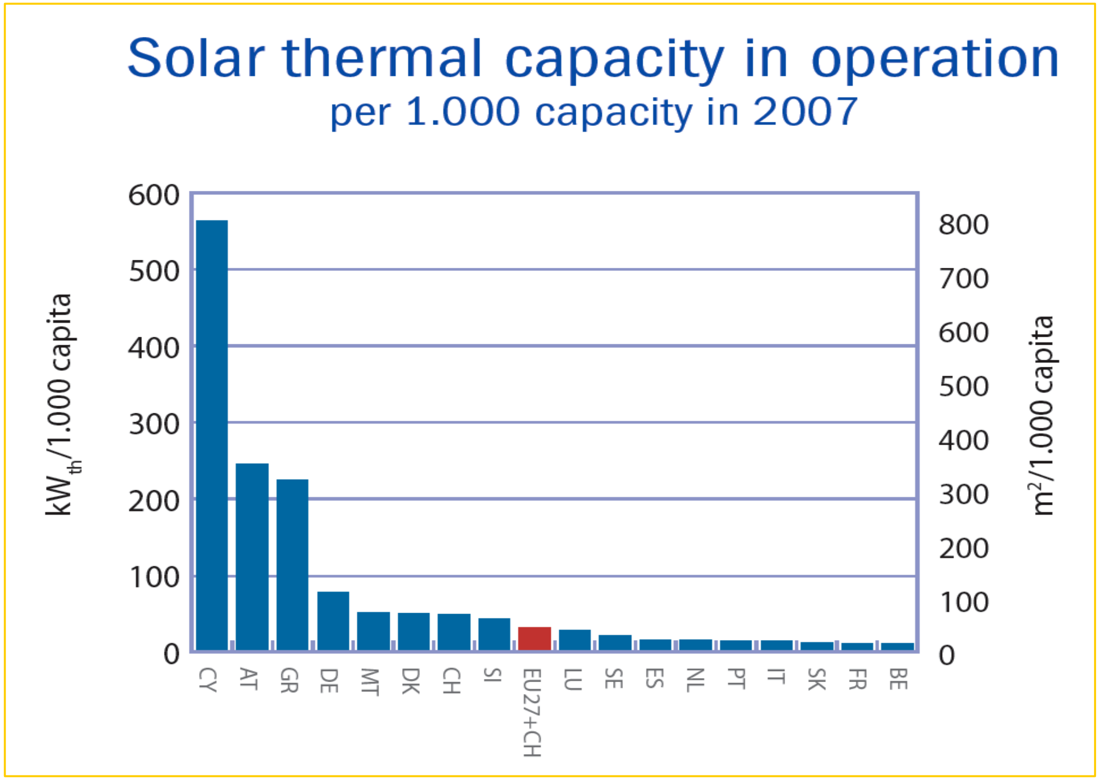
- Concentration in the European market is decreasing
- **5 countries account for ¾ of the total** – just a few years ago the same share was held by Germany, Austria and Greece only
- **Greece accounts for 9-10%** of European sales.

Newly Installed Capacity per Capita in Europe, 2007



- Big advance of **Austria: 23,7 kWth per 1.000 capita**, almost 3 times than Germany and more than 6 times than EU average (3,8 kWth per 1.000 capita)
- **Greece** has slowly and quietly increased its per capita market since 2002. Their **17,7 kWth per 1.000 capita** is 4,5 times as big as the Eu average.
- **France and Italy**: Strong growth in recent years, but only **2,9 kWth installed per 1.000 capita** each.

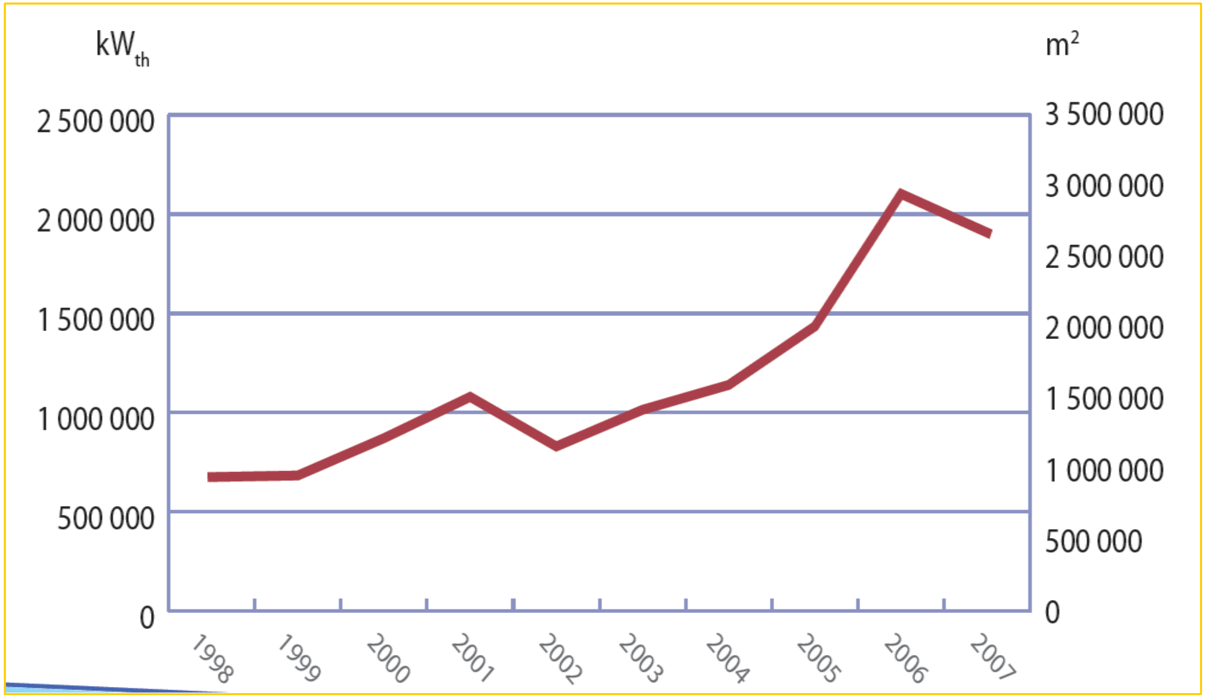
Solar Thermal Capacity in Operation, 2007



- **Cyprus is 1st: 562 kWth** in operation per 1.000 capita
- **Greece is 3rd**
- **EU average: 30,7 kWth** /1,000 capita.
- Austria shows the rest what is possible: 244 kWth/1.000 capita, 8 times the EU average

The figures relate to all installations built in the past and deemed to be still in operation (ESTIF assumes a life-time of 20 year for systems installed after 1989) and to today's size of the population.

Solar Collectors area in operation, 2007



- **2001: 12.3 million m²** glazed collectors in operation
  - 11,7% increase collector in operation
  - 13,6% increase new collector area
  - 1.6 million m^2 glazed collectors for pools
- **2007: 21.9 million m²** glazed collectors in operation

Conclusions/Remarks

- **Large market growth potential**

In Greece only 25% of the buildings are equipped with a solar thermal system (>90% of the owners are satisfied)

- **Seasonal storage**

For transferring the energy from low heating season to high heating season.

- **Solar Cooling**

Better utilization of solar energy throughout the year

Law modernization

solar thermal system project study compulsory for every large building

Financial incentives

to cover part of investment & construction costs

Thank you for your attention!

KAΠE
CRES

Centre for Renewable Energy Sources

Solar Thermal Department

19klm. Marathonos av., 19009, Pikermi
tel. 00302106603300, fax. 00302106603301
www.cres.gr
R. Christodoulaki
rozi@cres.gr

Solar Air-Conditioning Systems

in small - medium scale applications

Christodoulaki Rosa
MSc Environmental design & engineering
BSc Physics
Centre for Renewable Energy Sources – Solar Thermal dept.

The problem

- **Ozone layer depletion**

  CO_2 higher now than in last 400,000 years

  CO_2 emissions are expected to increase 20-fold from 1990 to 2010, only in the EU

- **IPCC predicts temperature rise of 1.5 - 5.8 degrees**

  Humans: 150,000 deaths directly attributable to climate change in 2000

  Climatic zones shifting 7 times quicker than plants can follow

- **New directives on air quality**

  2008/50/EC, *'Ambient air quality and cleaner air for Europe'*

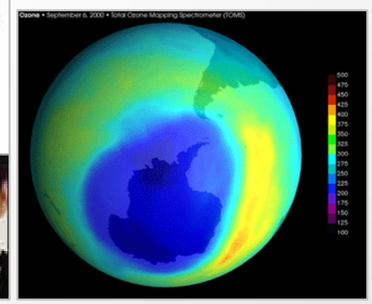
  2008/1/EC, *'Integrated pollution prevention and control'*

- **Inefficient conventional a/c units**

  \- **VCS** operate at a temperature colder than the supply air dew-point temperature, so **the air is overcooled** and needs reheating before entering indoors

  \- **Energy consumption** in commercial and residential buildings: **40% of Europe's energy bill**

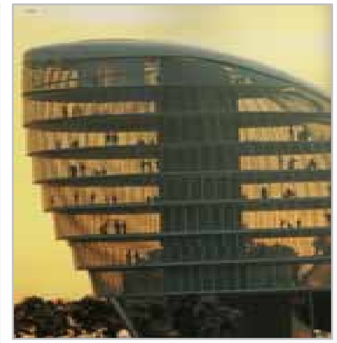
- **Global increase in air-conditioning demand**

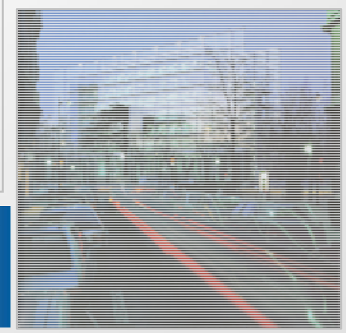


Global sales of air conditioning units, 2000-2008

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Japan	7.791	8.367	7.546	7.307	7.679	7.500	7.500	7.500	7.500
Asia	13.897	16.637	17.761	23.650	26.430	28.312	30.340	32.524	34.881
Europe	1.673	1.730	1.804	2.218	2.366	2.515	2.604	2.660	2.717
M. East	2.907	2.918	3.412	4.359	4.799	5.087	5.382	5.694	6.118
N. America	12.322	11.894	12.910	13.075	12.876	12.881	12.889	12.897	12.905
S. America	2.109	1.939	2.036	2.243	2.331	2.418	2.473	2.530	2.592
Africa	664	758	700	814	850	885	915	944	978
Australia	512	593	671	712	815	825	868	913	963
Total	**41.874**	**44.834**	**46.840**	**54.379**	**58.147**	**60.422**	**62.970**	**65.663**	**68.654**

JRAIA (Japan Refrigeration and Air Conditioning Industry Association)



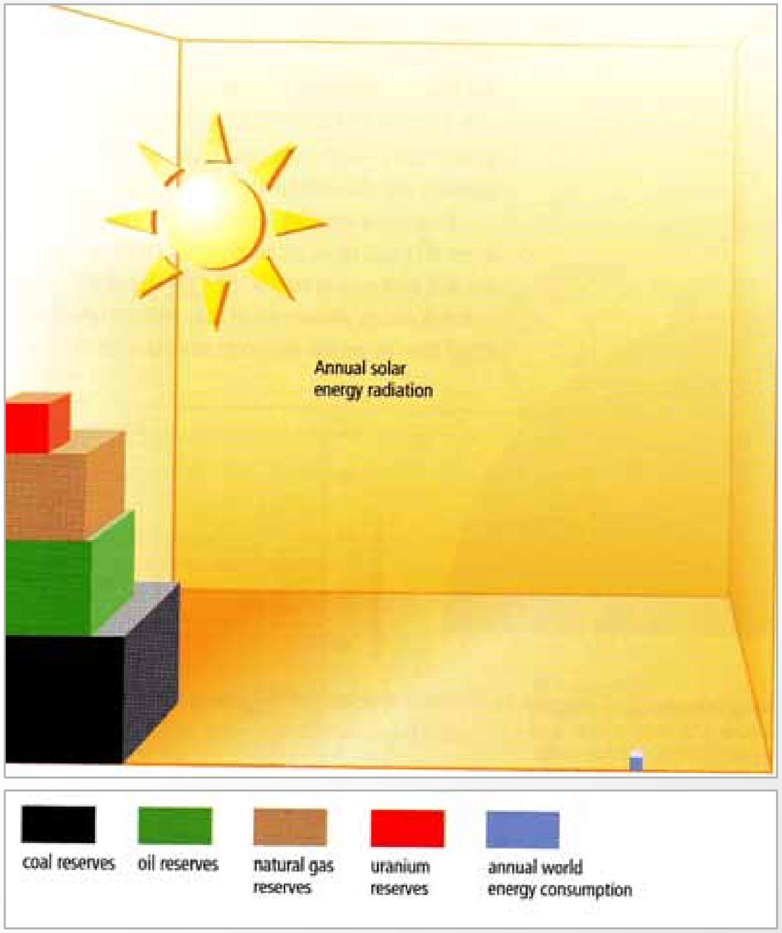


- Higher living / working standards
- Adverse outdoor conditions in urban environments
- Reduced prices of air-conditioning units
- Installed a/c has increased 5-fold in the last 20 years in Europe
- Total a/c floor space: 30 million m^2 in 1980, over 150 million m^2 in 2000.
- Annual energy use of room a/c was 6 TJ in 1990, estimated 160 TJ in 2010.

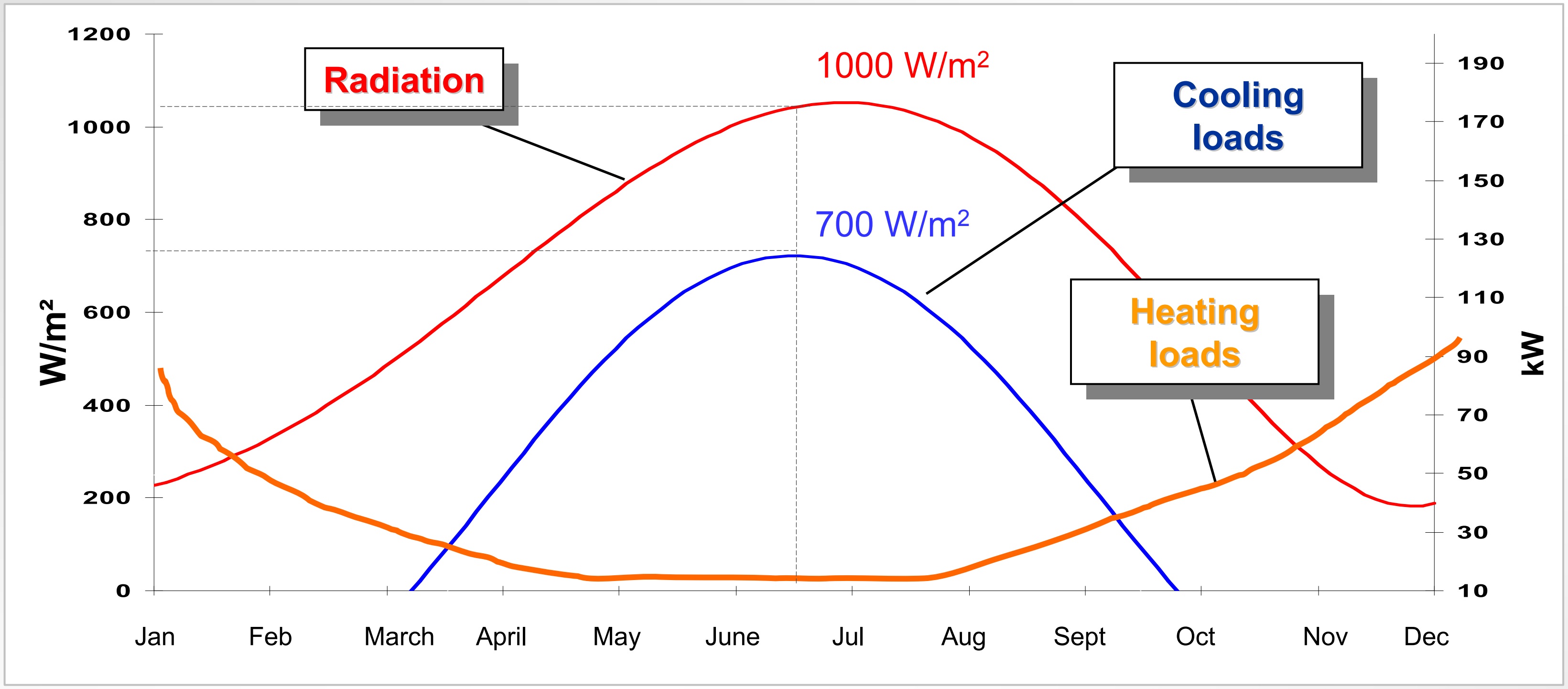
We need an a/c system that controls temperature and provides air of high quality, with high efficiency and low CO_2 emissions!

The solution : Solar-driven air-conditioning

- **Radiation** supply from sun carries a **5 billion year guarantee**
- Annually, **the sun provides $1.5*10^{18}$ kWh**, that is more than 10,000 times the energy that human race needs.



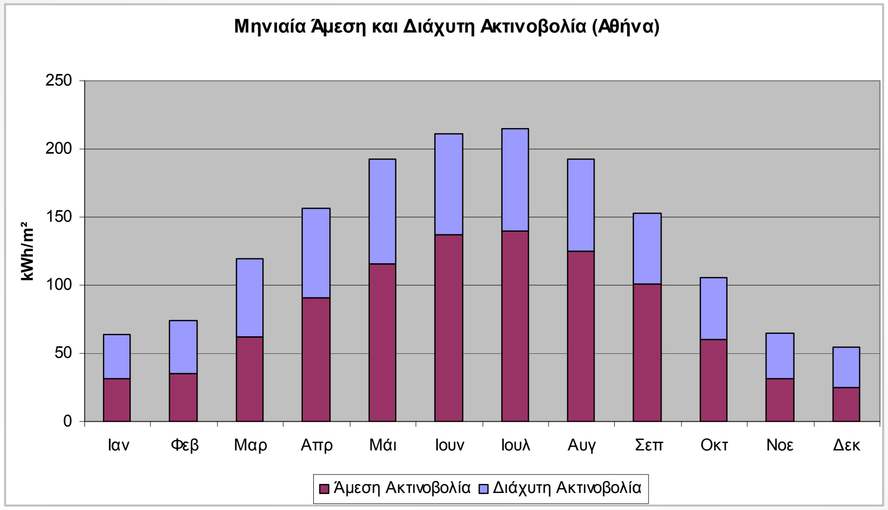
Source: *Planning & Installing Solar Thermal Systems: A guide for installers, architects & engineers*, EarthScan publications



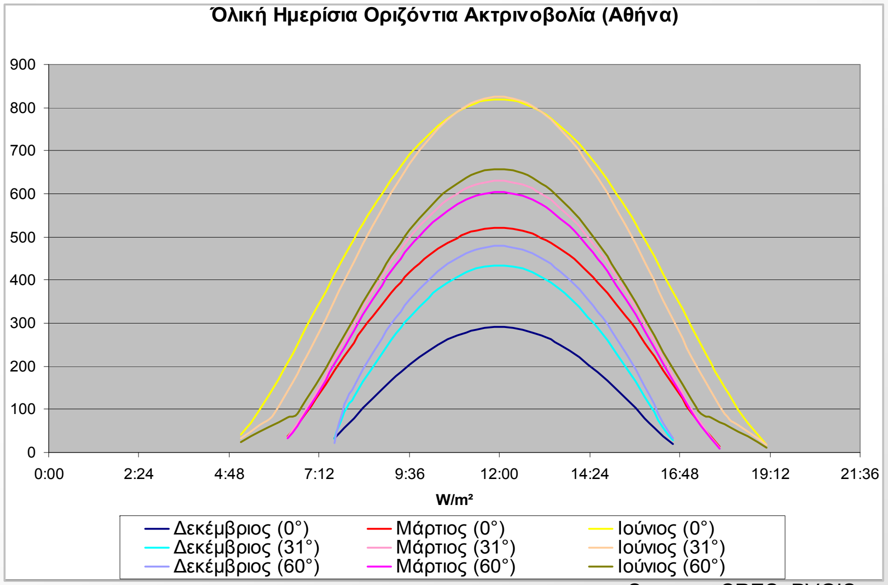
Solar radiation is in tune with air conditioning demand

Source : TECSOL for SOLAIR project

- Annual solar irradiance (sum of direct and diffuse) in Greece is approximately **1,600 kWh/m²**.
- This amount of energy, corresponds to **160 lt oil.**



- Daily solar irradiance for 3 representative dates (in winter, summer and spring) is shown in the next diagram.
- The area that receives the biggest amount of radiation has an inclination of **60^0 in December** and **0^0 in June**.



Source : CRES, PVGIS

Optimum collector angle: depends on the geographical location and the system's type of use.

- **Winter use**: geographical latitude of area **+ 15^0**
- **Summer use**: geographical latitude of area **- 15^0**
- **Annual use**: collector angle **= geographical latitude**

RESULTS OF INCIDENT RADIATION ON COLLECTORS (FROM TSOL)

Place: Athens

Azimuth: 0

G Inclined, Specific[kWh/m²]

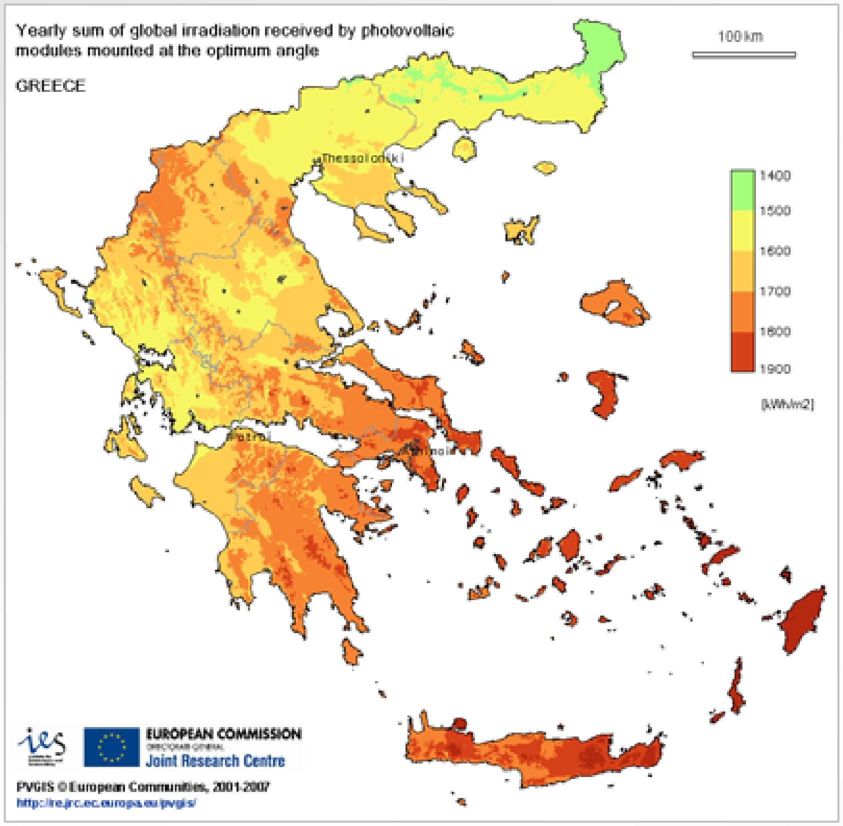
acording to collectors inclination (in degrees °)

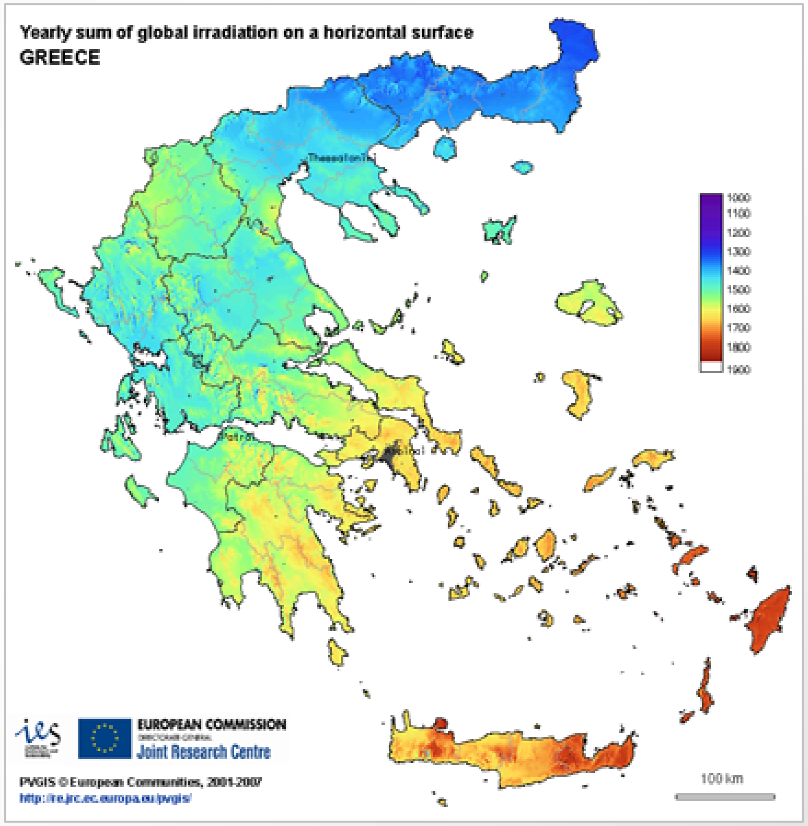
From:	**To:**	**0**	**10**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**
1/ 1/	1/ 2/	66	80	91	96	100	104	107	109	111	112	113	112	111	109	107	104	100
1/ 2/	1/ 3/	75	84	91	93	96	97	99	99	99	99	98	96	94	91	88	84	80
1/ 3/	1/ 4/	104	112	116	118	119	119	119	118	116	114	111	108	104	99	94	89	83
1/ 4/	1/ 5/	146	151	152	152	151	149	147	143	139	134	129	123	116	108	101	92	84
1/ 5/	1/ 6/	182	183	181	178	175	170	165	159	153	145	137	128	119	109	100	90	79
1/ 6/	1/ 7/	200	200	195	191	185	180	173	166	158	149	139	128	118	108	96	85	75
1/ 7/	1/ 8/	213	214	210	205	199	194	187	180	171	162	151	139	128	117	105	91	80
1/ 8/	1/ 9/	200	206	206	204	202	199	194	188	182	174	165	155	144	132	121	109	96
1/ 9/	1/10/	156	168	176	179	180	181	180	178	175	171	166	161	154	146	138	128	118
1/10/	1/11/	106	120	130	134	138	140	142	143	142	142	140	137	134	130	125	119	113
1/11/	1/12/	66	77	86	90	94	96	99	100	101	102	102	101	99	97	95	92	88
1/12/	1/ 1/	53	63	72	76	79	82	85	87	88	89	89	89	88	87	85	83	80
	Sum YEAR	**1567**	**1658**	**1706**	**1716**	**1718**	**1711**	**1697**	**1670**	**1635**	**1593**	**1540**	**1477**	**1409**	**1334**	**1252**	**1165**	**1075**
hotels season:1/4 to 1/11		**1203**	**1242**	**1250**	**1243**	**1230**	**1213**	**1188**	**1157**	**1120**	**1077**	**1027**	**971**	**913**	**850**	**784**	**714**	**645**
heating season: 1/11 to 1/4		**364**	**416**	**456**	**473**	**488**	**498**	**509**	**513**	**515**	**516**	**513**	**506**	**496**	**484**	**468**	**450**	**430**
"winter": 1/12 to 1/3		194	227	254	265	275	283	291	295	298	300	300	297	293	287	280	270	260

Source : T-SOL

Energy yield

Optimum angle: 1700-1800 kWh/m²   Horizontal surface: 1300-1400 kWh/m²





Source : PVGIS

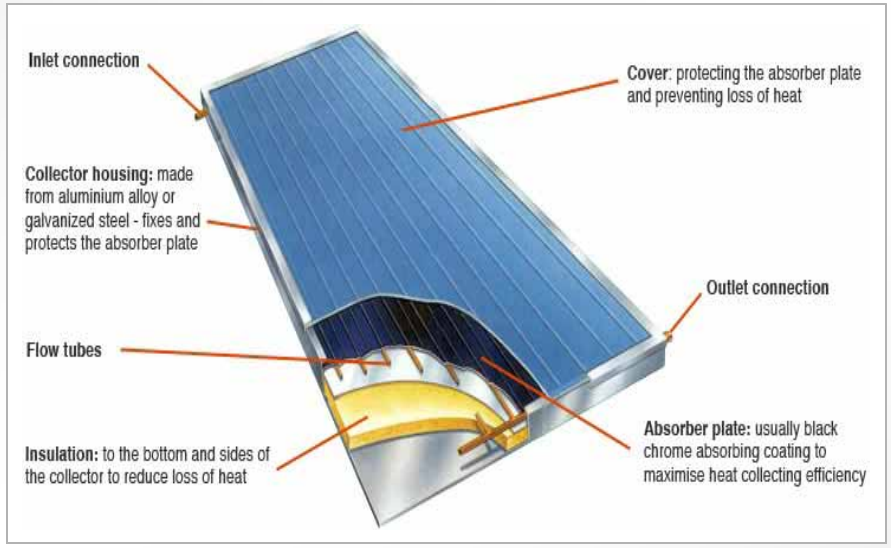
Properties

- Middle cost: more expensive than unglazed, but cheaper than vacuum
- Higher operation temperature
- Thermal insulation on back & edges
- Fragile, heavier: 20-32 kg/m^2
- Absorber: black paint or spectral-selective coating (black chrome, black nickel, blue titanium)
- Spectral-selective coating: conversion of short-wave solar radiation into heat (light absorption capacity) is optimized, while thermal emissions are kept low. Absorption rate: 90-95%, emission rate 5-15%
- Stagnation temperature: 160-200^{0}C

Applications

- Space heating
- Solar air conditioning (selective coating)

Planning & Installing Solar Thermal Systems: A guide for installers, architects & engineers, EarthScan publications

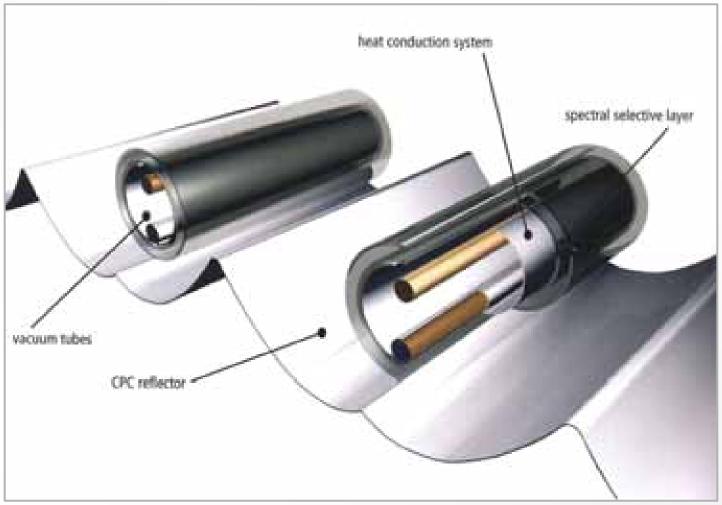


Properties

- High cost
- Minimal convection thermal losses (tube pressure < 10^{-5} bar)
- Low radiation losses
- High efficiency, even with low radiation
- Low weight
- Average annual efficiency 45-50% (with 1000kWh/m^2 irradiation, the energy yield is 450-500kWh/m^2a
- Stagnation temperature: 200-350^{0}C

Applications

- Solar air conditioning
- Industrial applications (steam generation)



Planning & Installing Solar Thermal Systems: A guide for installers, architects & engineers, EarthScan publications

Vacuum types

- **Direct-flow**: Internal U-tube, South-oriented.

Concentrated: Double tube (external tube: absorber surface, internal tube: U-type), 2 external reflector surfaces

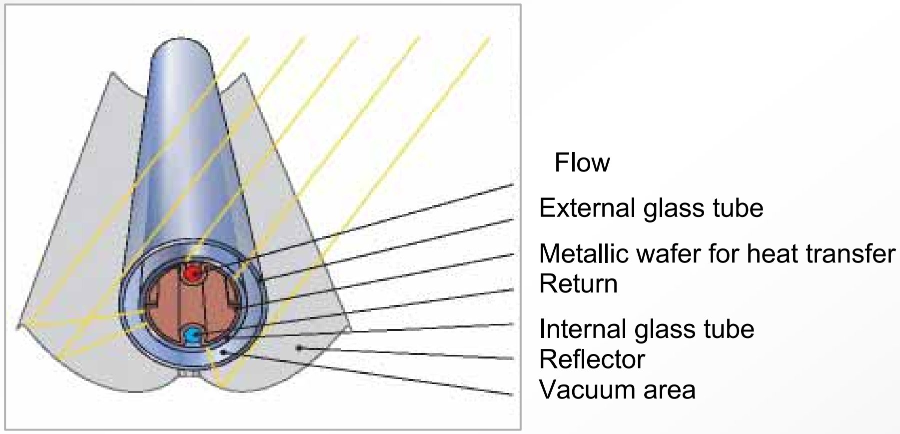
- **Heat-pipe**:

Horizontal absorber area placed inside a vacuum tube. The tube is connected to an evacuated heat pipe with a solution inside. The solution evaporates ($T_{evaporation}=25^0C$) and its heat is transferred through a heat exchanger in the medium.

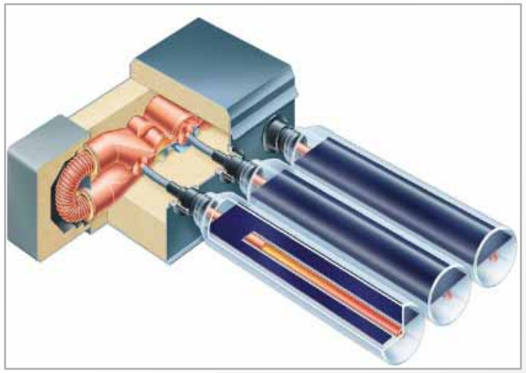
Dry connection: the heat transfer takes place from the condenser via the tube wall to the medium, so defective tubes are replaced without emptying the solar circuit)

Wet connection: the condenser is immersed in the medium, so defective tubes are replaced by emptying the solar circuit.

Planning & Installing Solar Thermal Systems: A guide for installers, architects & engineers, EarthScan publications



Concentrated vacuum collector

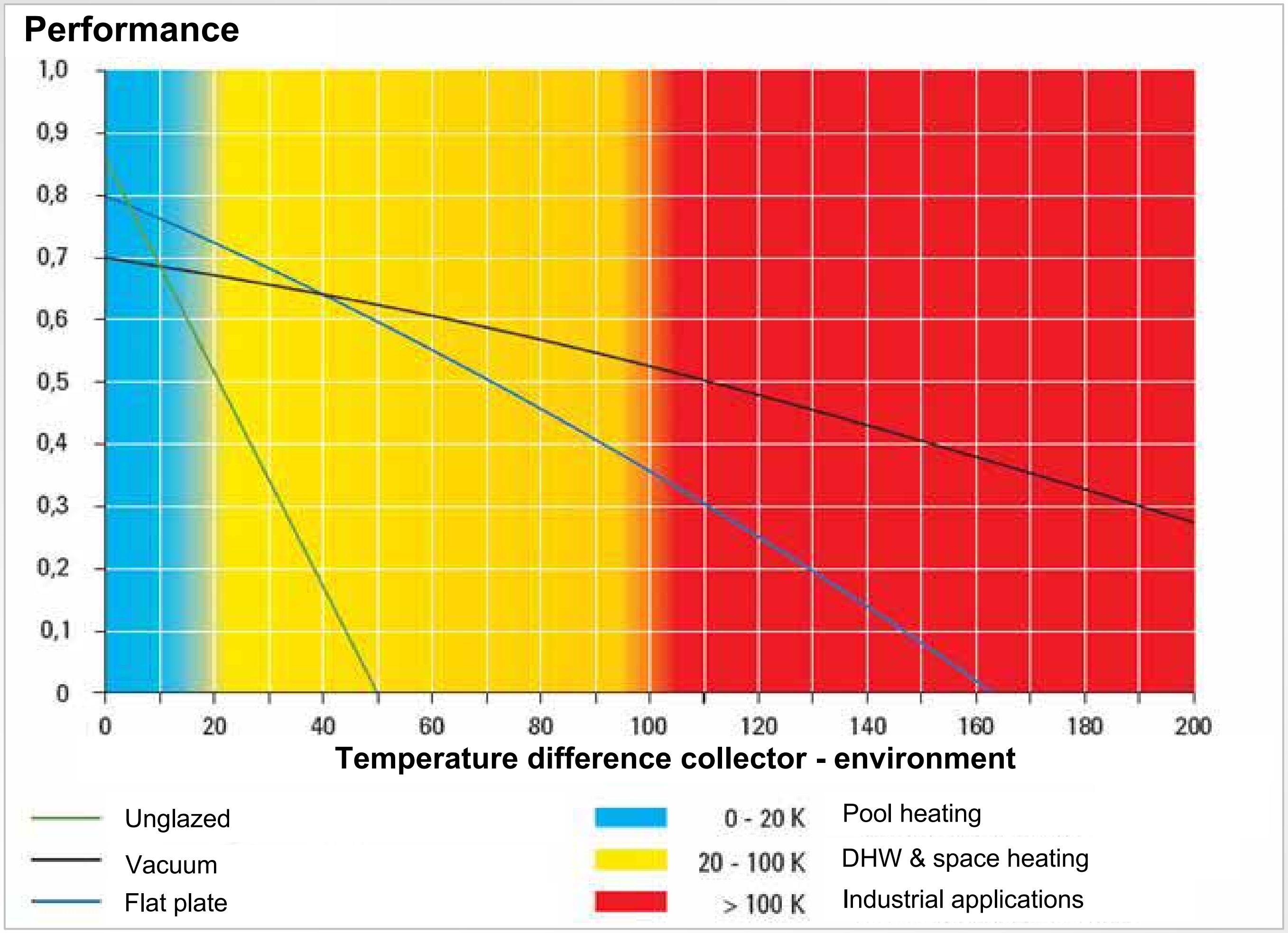


Cross section of heat pipe dry connection

Cross section of heat pipe wet connection

Collectors comparison

Collector type	Application	Performance (kWh/m^2a)
Unglazed	Pool heating	300
Flat plate (black paint)	Pool heating, Hot water	650
Flat plate (selective coating)	Hot water, space heating, solar a/c	700
Vacuum	Solar a/c, industry	850



Planning & Installing Solar Thermal Systems: A guide for installers, architects & engineers, EarthScan publications

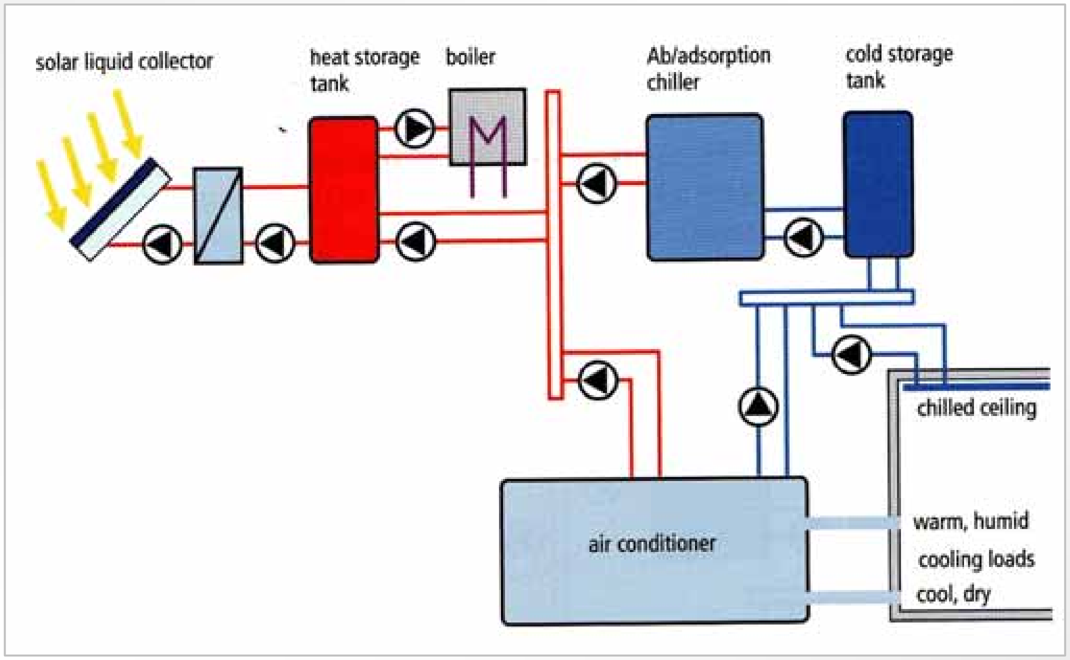
Systems

- **Open cycle DEC**

Production of air conditioned air
Dehumidification and evaporative cooling

- **Closed cycle**

Production of chilled water for space cooling through fan coil, chilled ceiling, floor heating
Absorption (liquid)
Adsorption (solid)

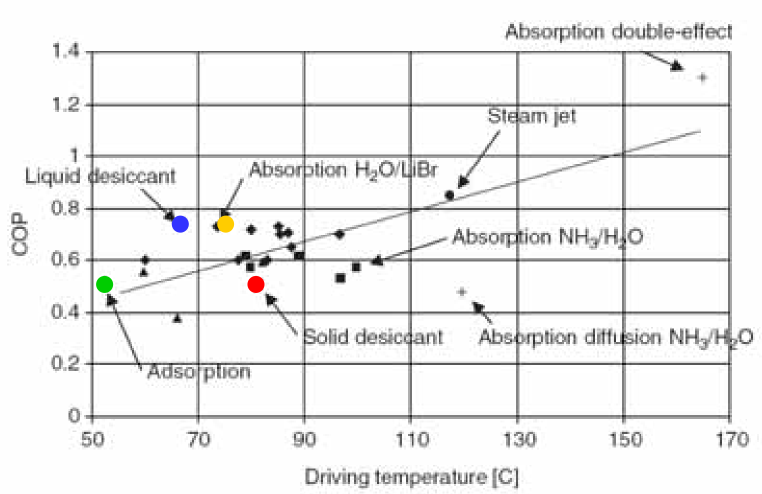


Characteristics

✓ Air conditioning load in tune with the solar radiation
✓ Solar systems can be integrated in existing air-conditioning units (fan coils, floor heating systems)
× Small scale solar a/c systems: under research
× Small scale chillers (<30kW): High initial cost, 2,000 €/kW.

Method	Closed cycle		Open cycle	
Refrigereant cycle	Closed refrigerant cycle		Refrigerant (water) is in contact to the atmosphere	
Principle	Chilled water		Dehumidification of air and evaporative cooling	
Phase of sorbent	solid	liquid	solid	liquid
				
Typical material pairs	water - silica gel	water - lithium bromide ammonia - water	water - silica gel, water - lithium chloride	water - calcium chloride, water - lithium chloride
Market available technology	Adsorption chiller	Absorption chiller	Desiccant cooling	Close to market introduction
Typical cooling capacity (kW cold)	50 – 430 kW	15 kW – 5 MW	20 kW – 350 kW (per module)	
Typical COP	0.5 – 0.7	0.6 – 0.75 (single effect)	0.5 – >1	> 1
Driving temperature	60 – 90 °C	80 – 110 °C	45 – 95 °C	45 – 70 °C
Solar collectors	Vacuum tubes, flat plate collectors	Vacuum tubes	Flat plate collectors, solar air collectors	Flat plate collectors, solar air collectors

Source : EU Altener Project Climasol



Efficiency – Operational temperature, 2007

Open systems

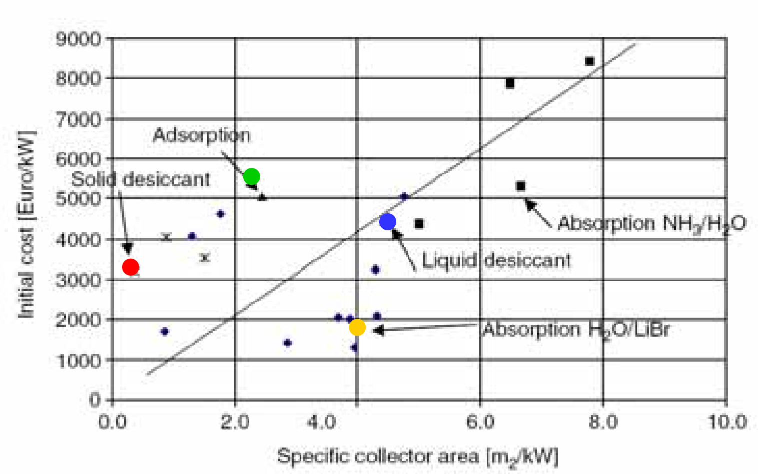
Liquid DEC: T = 60C, COP = 0.7

Solid DEC: T = 80C, COP = 0.5

Closed systems

Absorption: T = 75C, COP = 0.7

Adsorption: T = 55C, COP = 0.5



Initial cost – Collector area needed, 2007.

Open systems

Liquid DEC: 4500 €/kW, 5 m²/kW

Solid DEC: 3500 €/kW, 0.5 m²/kW

Closed systems

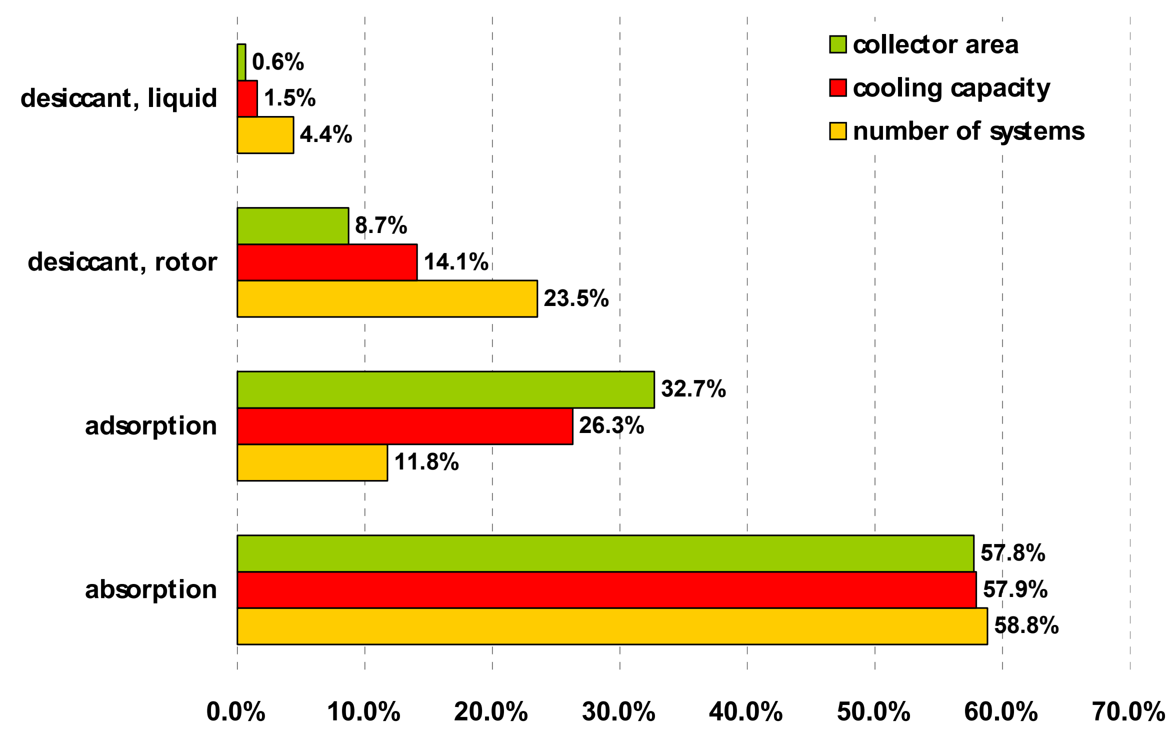
Absorption: 2000 €/kW, 4 m²/kW

Adsorption: 5500 €/kW, 2.5 m²/kW

Source : CA Balaras, G Grossman, HM Henning, *Solar Air-Conditioning in Europe - an overview*, Renewable Energy & Sustainable Energy Reviews, 11, 2007, 299-314

Solar Cooling Systems installed in Europe

- Absorption: 58%
- Solid DEC: 23%
- Adsorption: 12%
- Liquid DEC: 4%



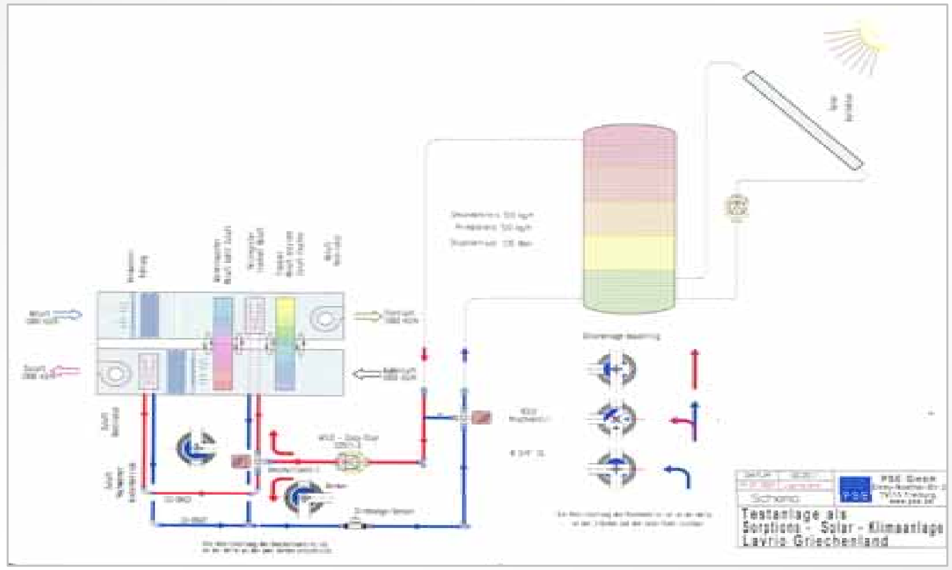
Source : HM Henning, *Solar Assisted air conditioning of buildings – an overview*, Applied Thermal Engineering, 27, 2007, 1734-1749.

CRES, demo project, Lavrio, Athens

PENA, Lavrio
Solar cooling **Solid DEC system**
Demo & research application for CRES

In operation since	2007
Air conditioned area	84m²
Collector type	10 m^2, Calpak flat-plate
Collector fluid	water-glycol
Operation temperature	60°C
Nominal air flow rate	1100 m^3/h
Min. air volume flow rate	373 m^3/h
Desiccant cooling system	solid LiCl
Brand of desiccant unit	Klingenburg

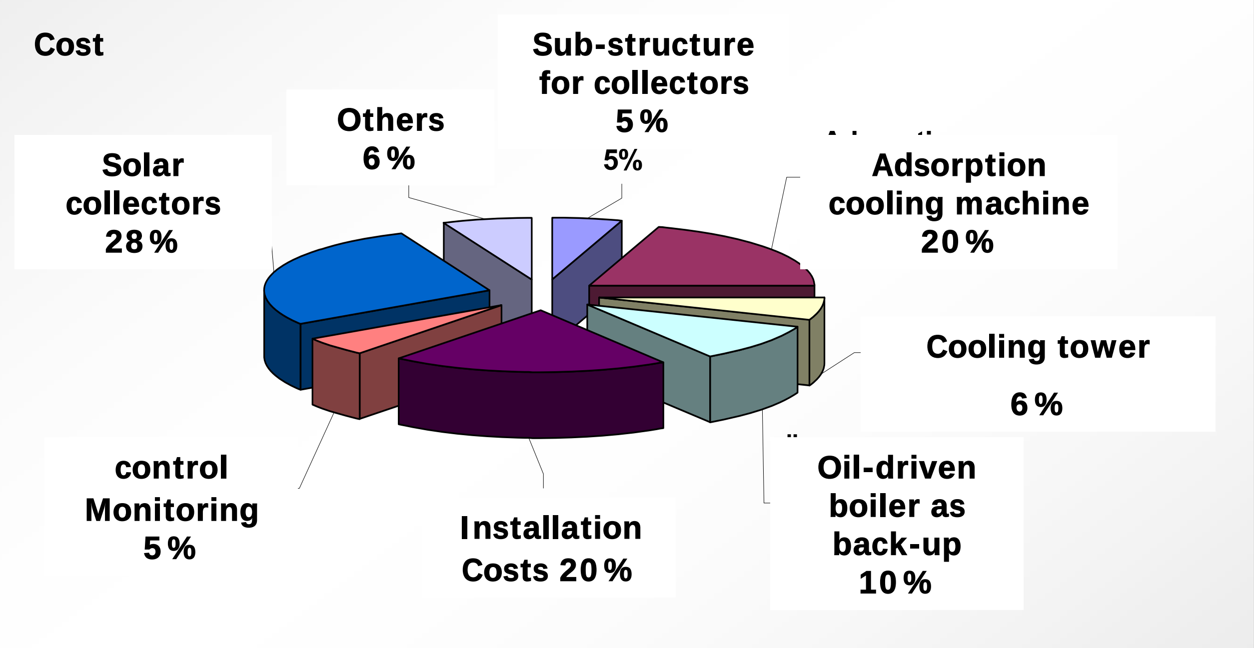
Source : CRES



SARANTIS, Industry, Inofita Viotias

Solar cooling of a production site for cosmetics
- In operation since 1999
- One of the largest installations in the world
- 2,700 m² flat plate collectors (SOLE)
- 2 **adsorption cooling** machines, with 350 kW cooling power each
- 3 compression cooling machines with 350 kW air cooling and fan-coils
- Concept: economisation of electricity (Power and Work)

Source : CRES



Rethimno Village Hotel, Crete

In operation since 20/08/00
Solar air-conditioning system, fan coils
Air-conditioned area 1000 m^2
450m^2 flat plate collectors (SOLE)
Absorption chiller LiBr, 105 kW_c
Performance: $COP_{thermal}$ =0.6, $COP_{electrical}$=0.52
Initial cost: 146,000 € (2000)
Annual electrical energy savings: 70,000 kWh (7,000€)
Annual oil savings: 20,000 lt (8,000€)
Payback in 10 years, without incentives.
870,000 kg less CO_2 annually

Source : SOLE

Conclusions

- **Solar Cooling is not yet widespread** in Greece
  - 8% of the solar thermal market
  - lack of real incentives
- However, there is **large growth potential**, because
  - only 25% of the buildings are equipped with a solar thermal system (>90% of the owners are satisfied)
  - steady increase in demand for a/c units

Law modernization

solar cooling system project study compulsory for every large building

Financial incentives

to cover part of investment & construction costs

Thank you for your attention!

Centre for Renewable Energy Sources
Solar Thermal Department
19klm. Marathonos av., 19009, Pikermi
tel. 00302106603300, fax. 00302106603301
www.cres.gr
R. Christodoulaki
rozi@cres.gr

New application fields by solar thermal systems

Gundula Tschernigg

arsenal research

Table of content

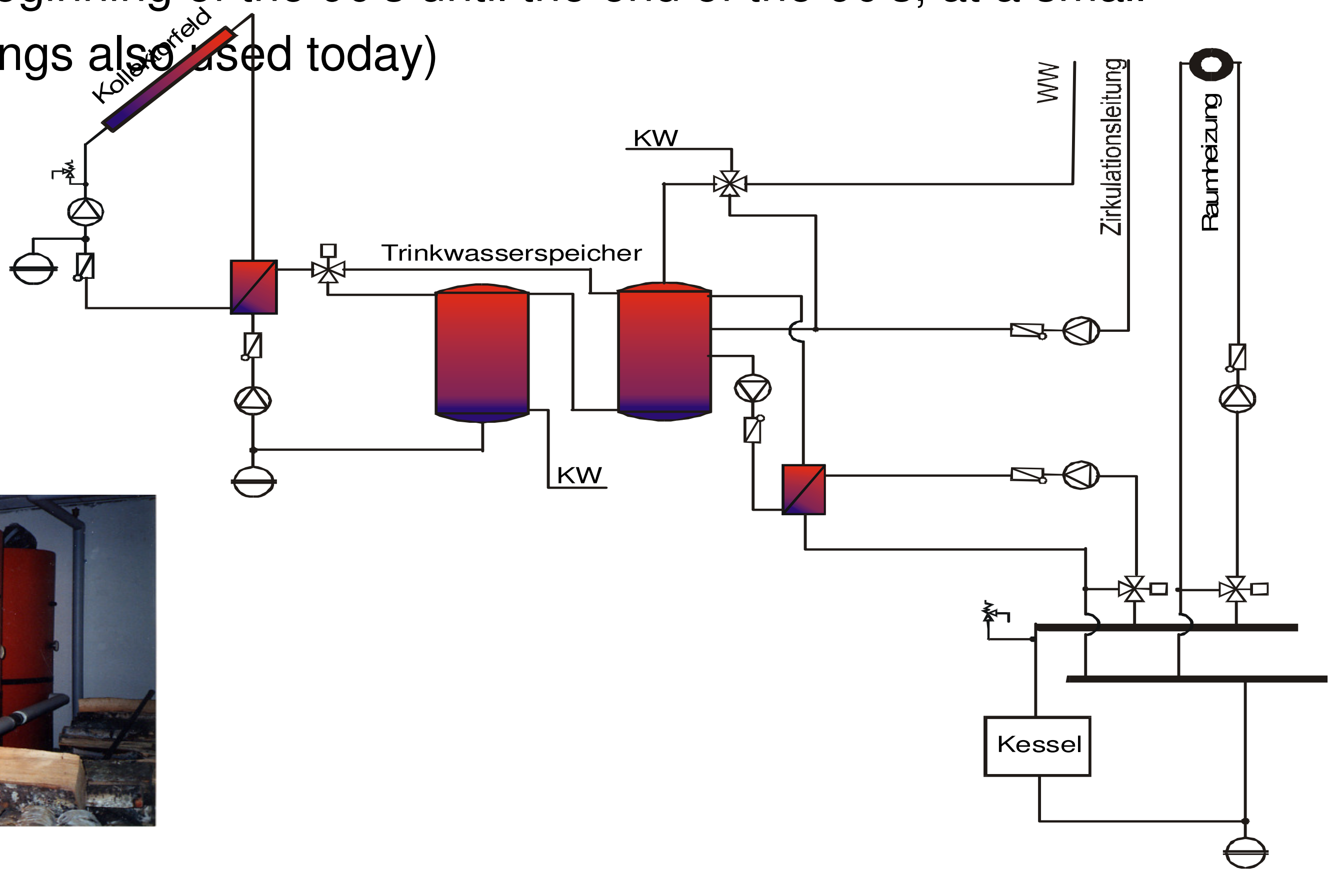
- State of the art
- Plant hydraulics of combined solar systems in large applications
  - 2 pipe system
  - 4 pipe system
- Building integration
- Some impressions – the good, the bad, the ugly

State of the art

Development of combined solar systems

- Combined solar systems of the 1st generation in Austria

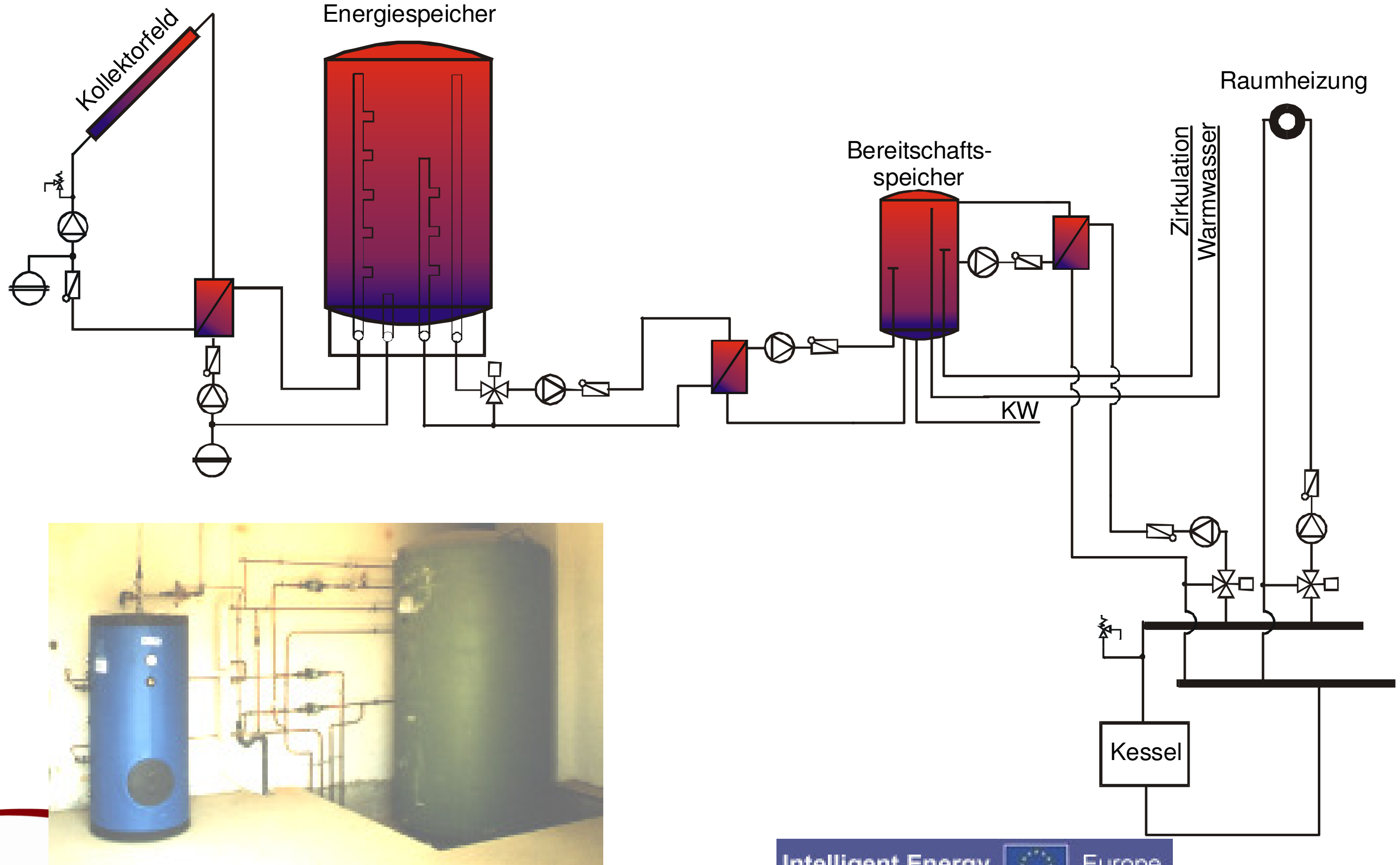
(Started at the beginning of the 90's until the end of the 90's, at a small number of dwellings also used today)



Development of combined solar systems

- Combined solar systems of the 2nd generation in Austria

  (Started in the middle of the 90's until today)



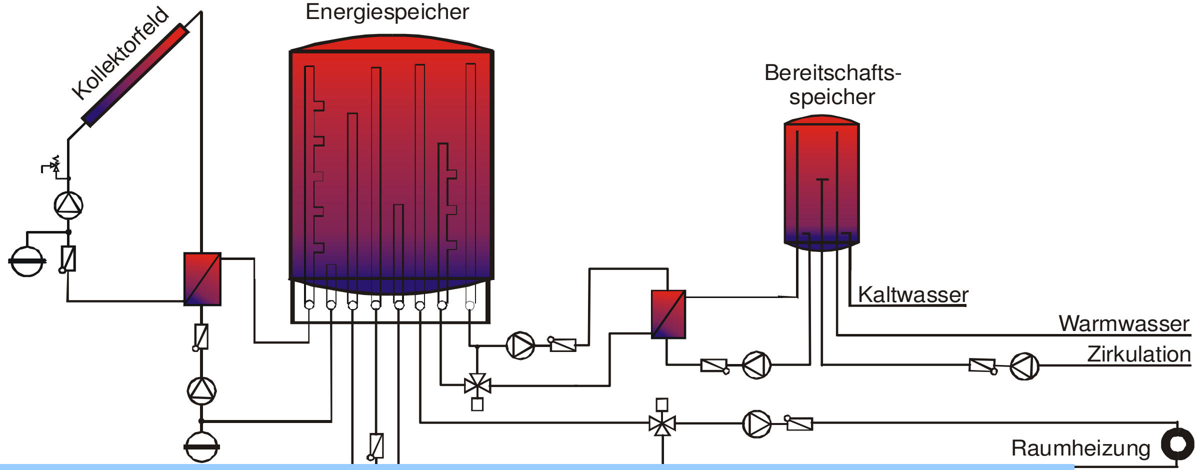
Numerous results of measurement showed….

- Solar supported distribution nets of the 1st and 2nd generation are not always working as efficiently as they should (losses!)
- Return temperatures are usually very high

Heat producer up to 20%

Heat storage up to 30% of the total heat demand

Heat distribution up to 40%

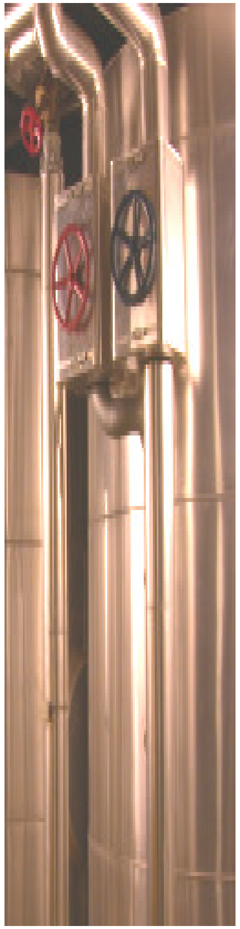


⇒ low annual system performance (often 30 to 40%)

⇒ low specific solar gains and covering degrees

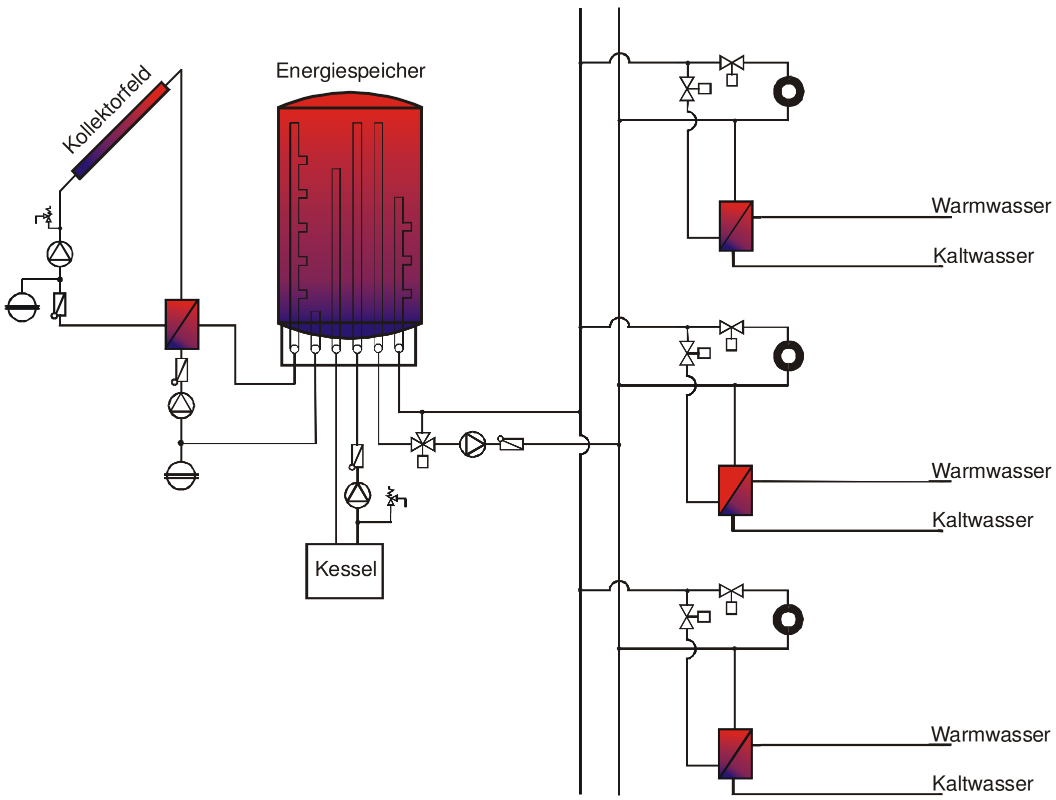
Requirements of solar supported heat distribution nets of the 3rd generation

- Holistic systems
- Adapted basic conditions for the use of solar systems
- Conceptional reduction of calorific losses
- Highest comfort for occupants
- Hygienically harmless drinking water heating up
- Economically meaningfully
- Modern control of operating
- Apart from the employment in new buildings an employment in existing buildings must be possible



2-pipe systems can absolutely fullfill these requirements!

Plant hydraulics of combined solar systems in large applications



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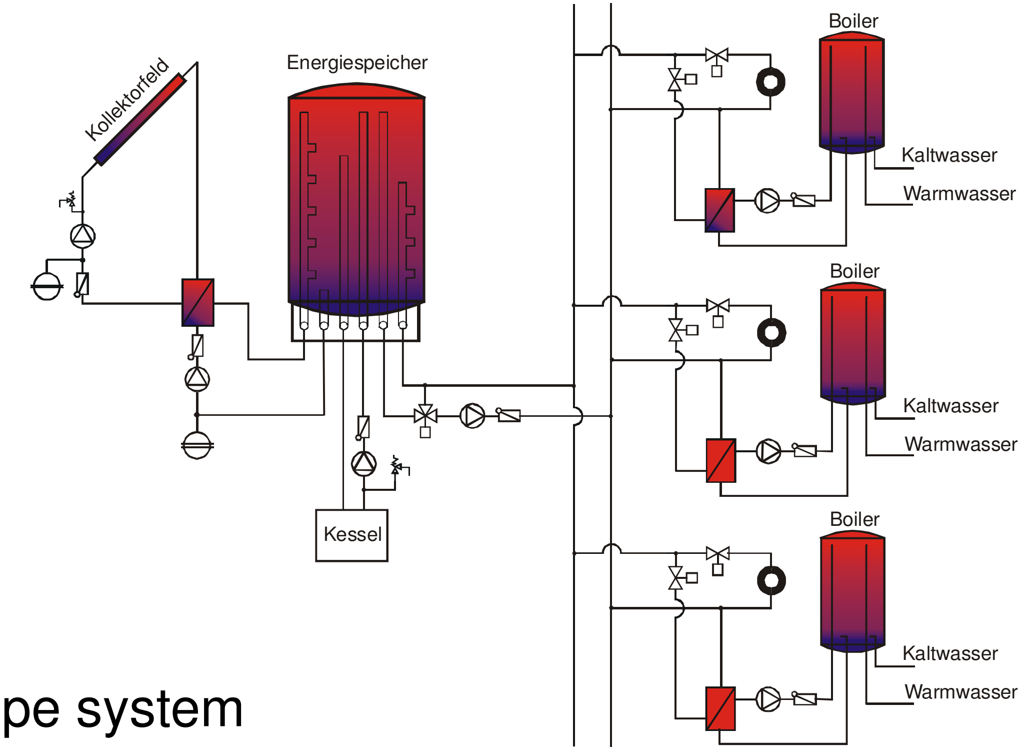
Solar supported heat systems of the 3rd generation in Austria



- Heat distribution from a 2-pipe system
- Hot water heating with a decentralised storage
- Meaningful employment with small energy densities

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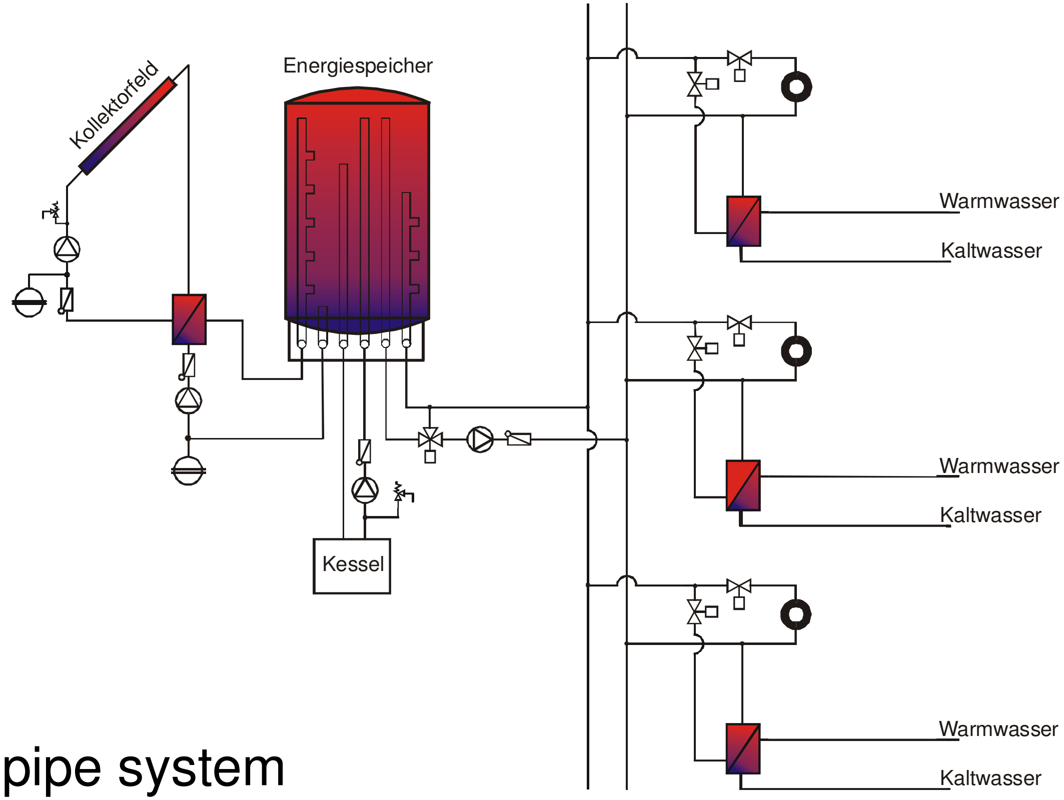
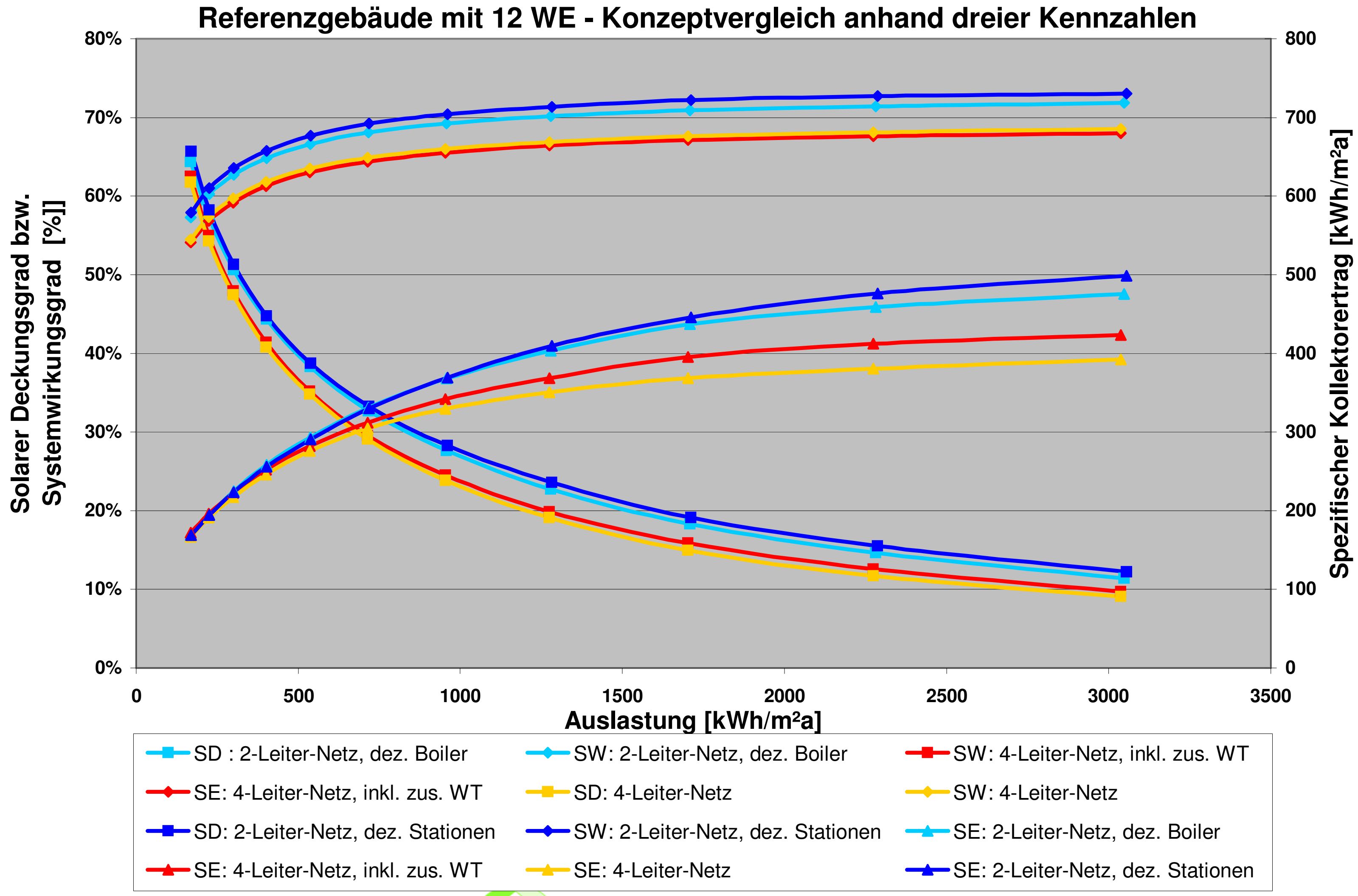
Solar supported heat systems of the 3^{rd} generation in Austria



- Heat distribution from a 2-pipe system
- Hot water heating in a decentralised flow principle
- Meaningful employment with small and high energy densities

Advantages of 2-pipe systems



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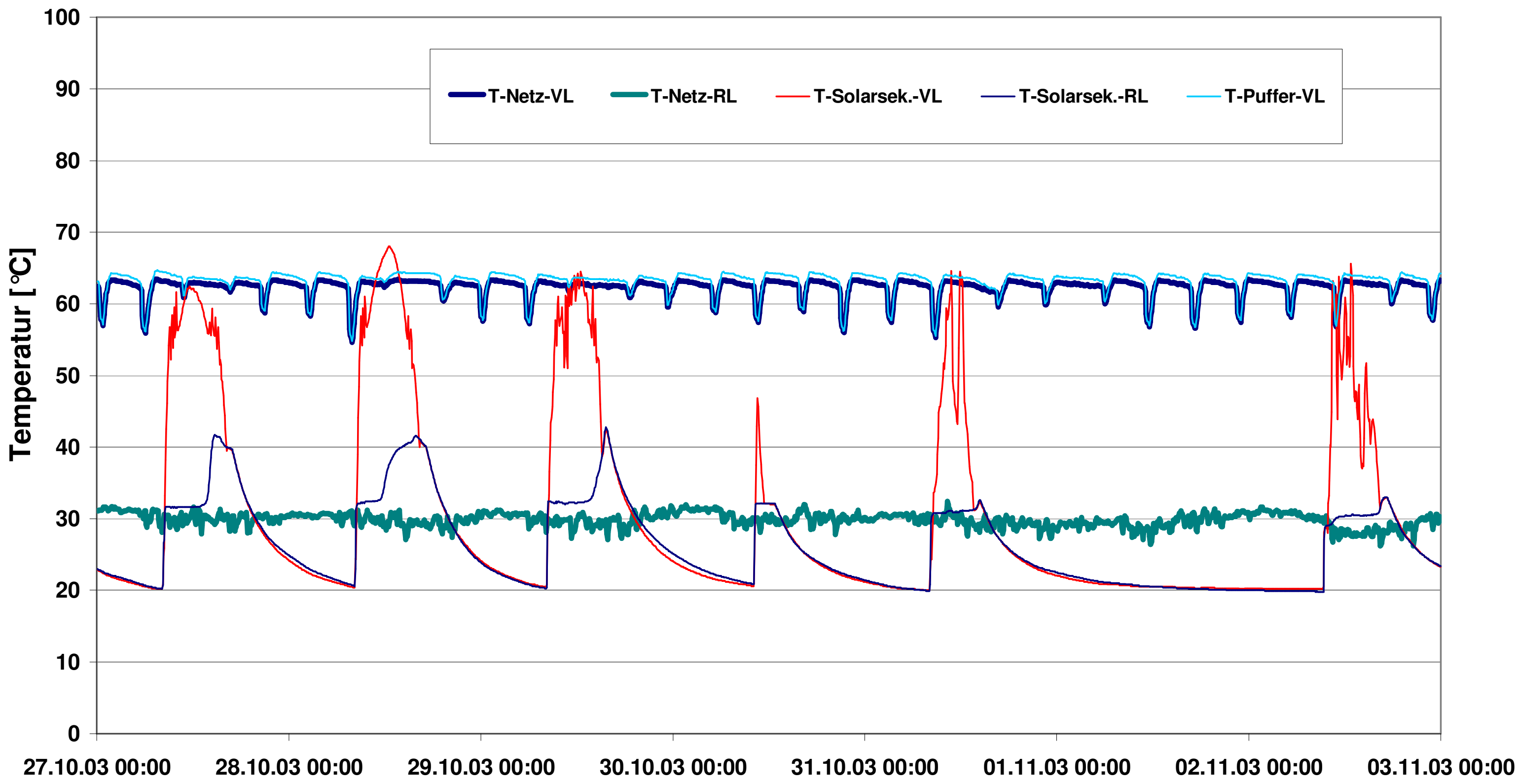
Advantages of 2-pipe systems

- Return is nearly constant at 30℃ and offers best conditions for the use of solar thermal systems



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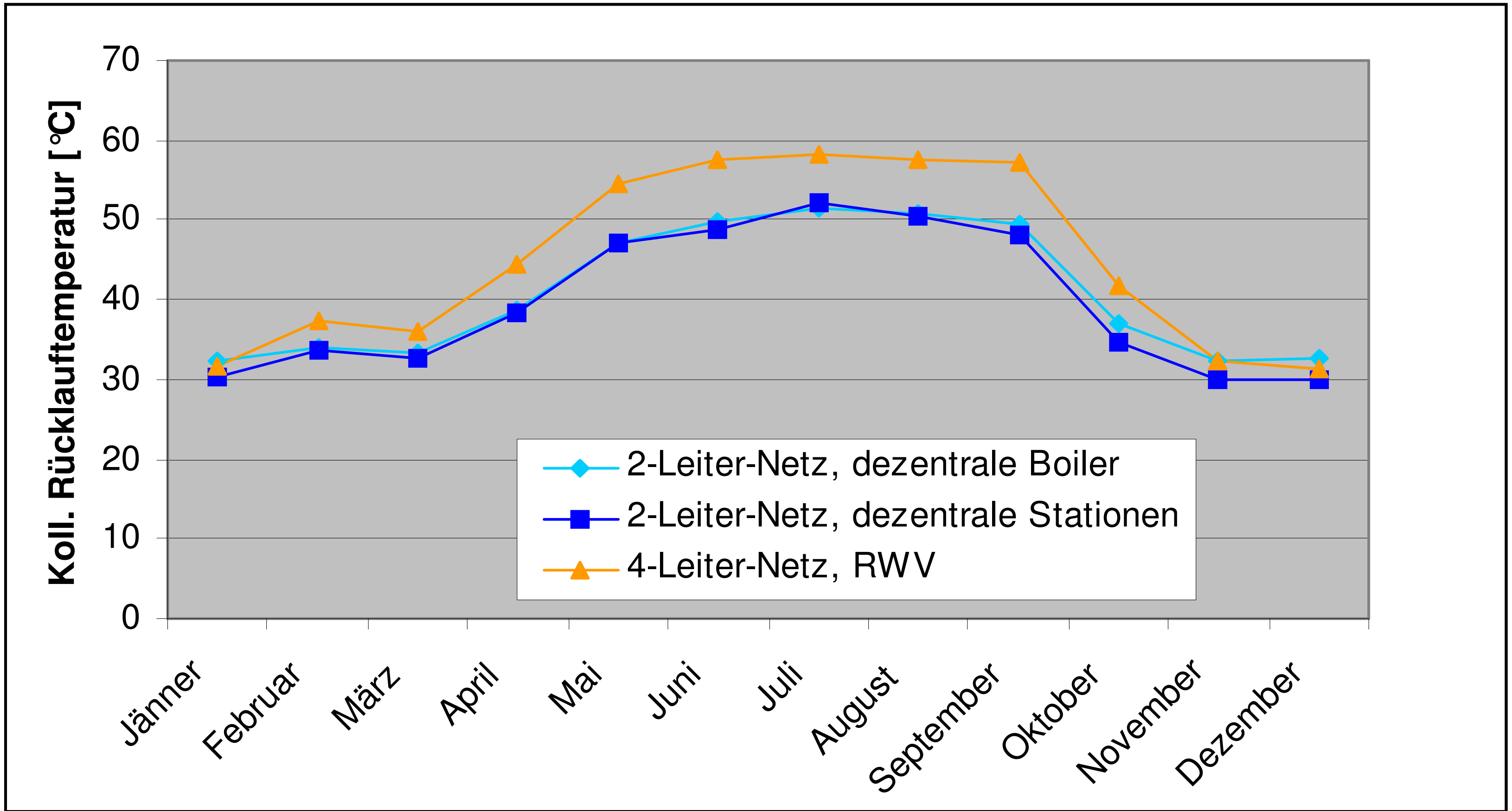
Advantages of 2-pipe systems

- Comparison of annual return temperatures of three different systems, 12 units, 20% solar covering degree



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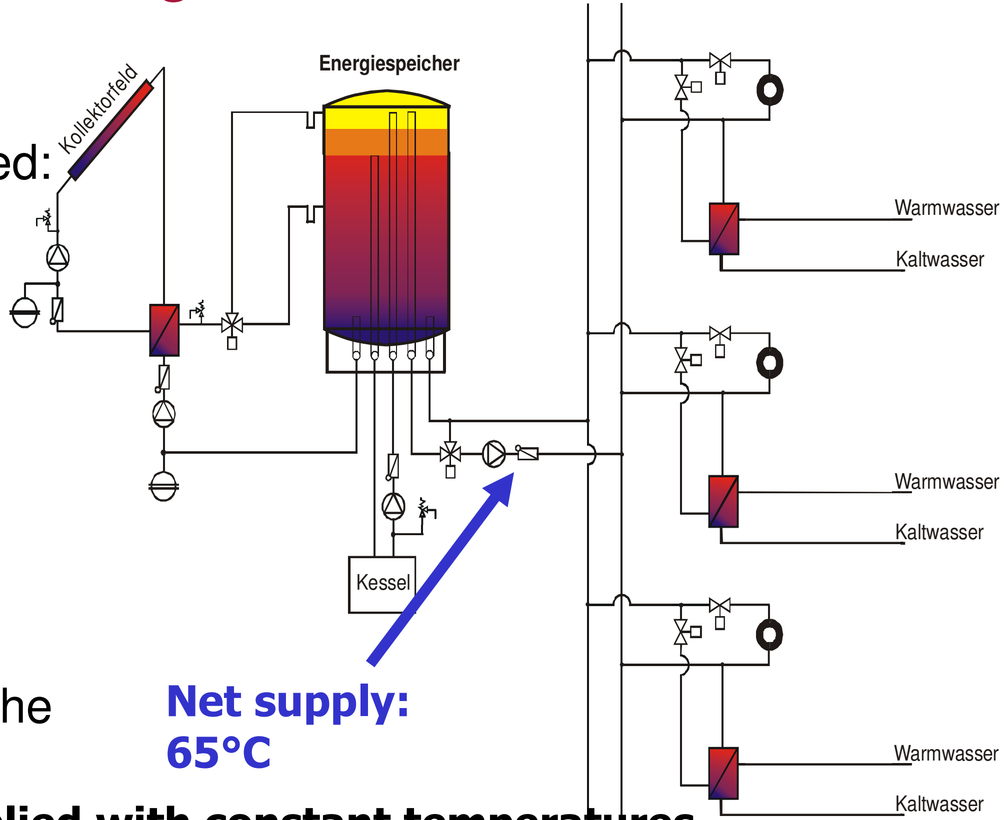
Advantages of 2-pipe systems

- Distribution losses are set to a minimum
- Because of the system a automatically heat support can be achieved
- Extensive tests show cheaper heat prices compared to 4-pipe systems
- A gain in comfort and absolutely harmless water hygiene
- Reduction of the error frequency in industrial manufactured substations and no auxiliary energy is needed

Solar supported energy distribution nets: 2-pipe systems with decentralised district heating substations

- Solar system
  - If an energy storage is integrated:
    - Operational mode: Low (Matched) Flow
- Conventional boiler:
  - Feeds into the energy storage
- Heat distribution:
  - With a pair of pipes (2 pipes)
- Hot water preparation:
  - Decentralised flow principle in the flat



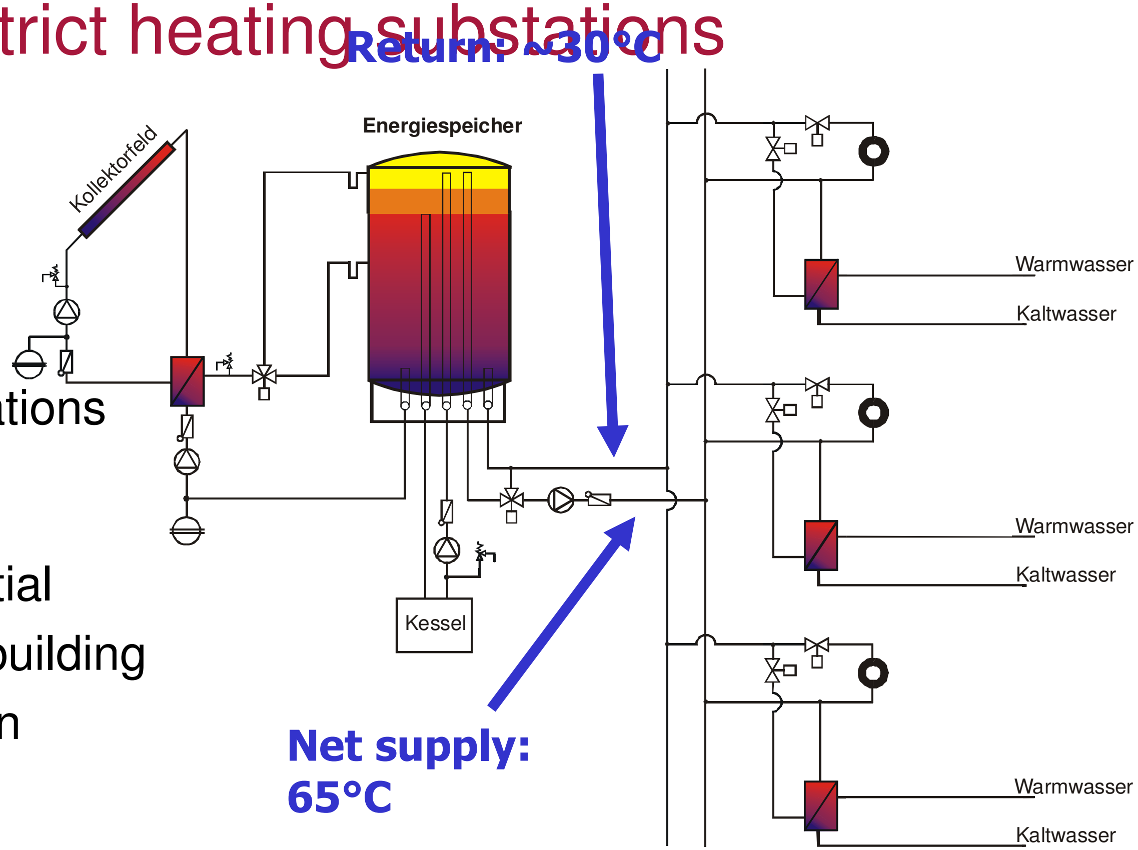
<u>Important</u>: The distribution net is supplied with constant temperatures (approximately 65 °C) during summer and winter

<u>Important</u>: the upper part of the storage needs to be kept on a minimum temperature (65°C) →security of supply

<u>Important</u>: Heater dimensioning 65/40

Solar supported energy distribution nets: 2-pipe systems with decentralised district heating substations

- Important components:
  - Mixing valve
  - Pump
  - District heating substations
- Application:
  - New building, residential buildings in compact building method, reconstruction



Advantage: The hole year low return temperatures of approximately 30°C → few distribution net losses

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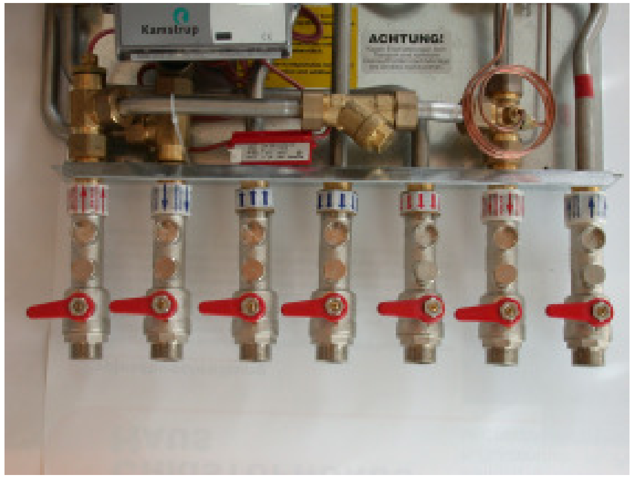
Substations

- Advantages of substations:
  - Industrial manufacturing
  - Highest quality criteria
  - No external energy requirement
  - Low investment costs
  - Individual design (finery, in the wall, different geometry)



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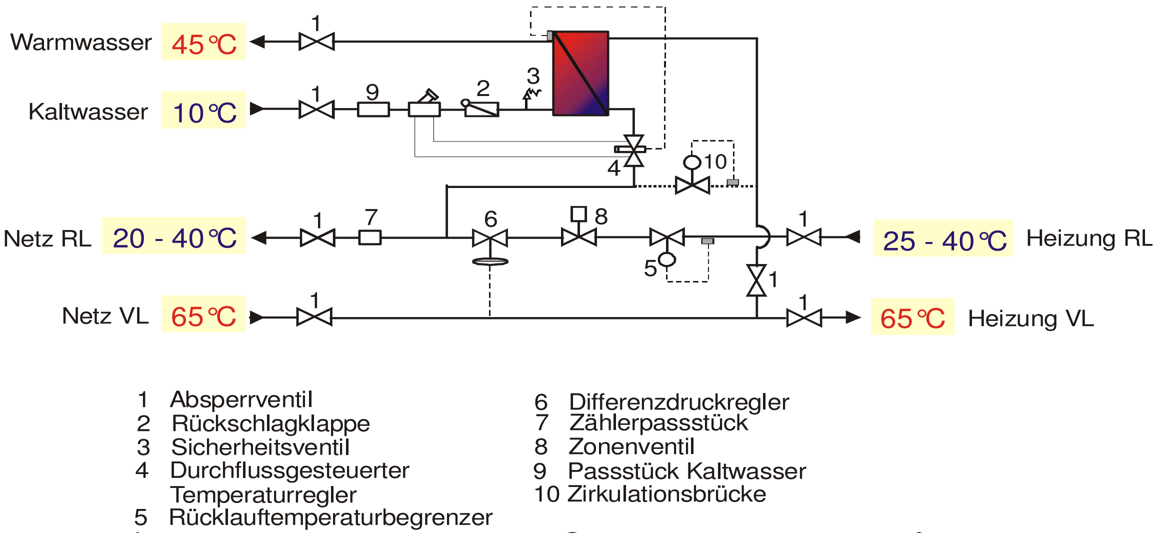
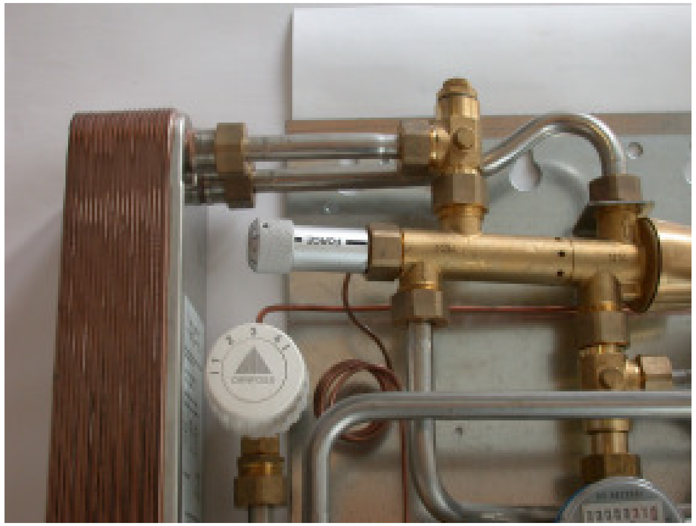
Functions of substations

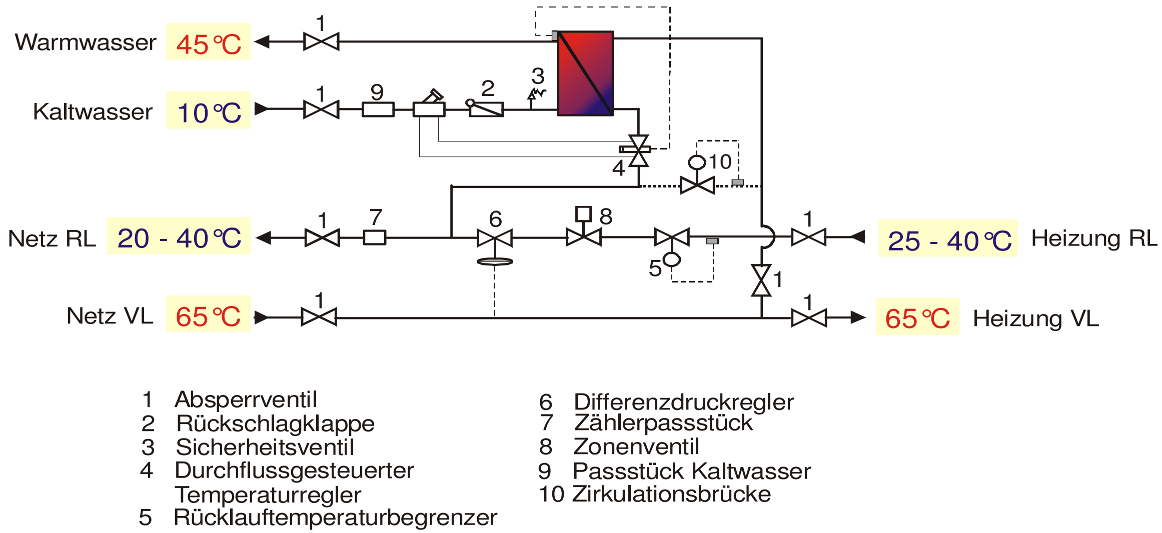




All components for decentralized hot water heating and space heating are contained

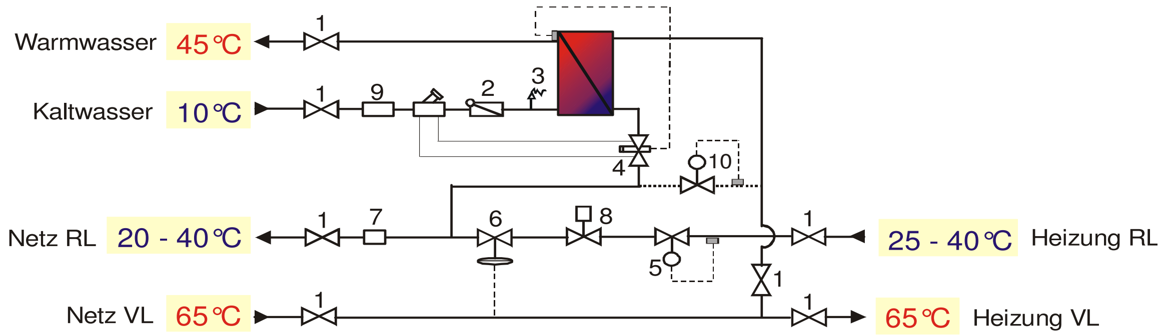
- Important components for hot water preparation:
  - Plate heat exchanger: hot water is produced when its needed
    - Small risk of legionella
    - Highest hygiene
  - Proportional controller: regulates the hot water temperature and adapts the flow rate to the hot water consumption
    - No calcification because of the temperature limit

Functions of substations



- Important components for heat preparation:
  - Differential pressure regulating valve: hot water is produce when its needed
    - Provide a constant mass flow in individual units of the dwellings
    - Inappropriate adjusting can be prevented by fixed pre-setting
  - Return controller: are used in the return and fixed on 40 °C
  - Thermostatic valve: control the temperature in the units

Measuring devices of substations

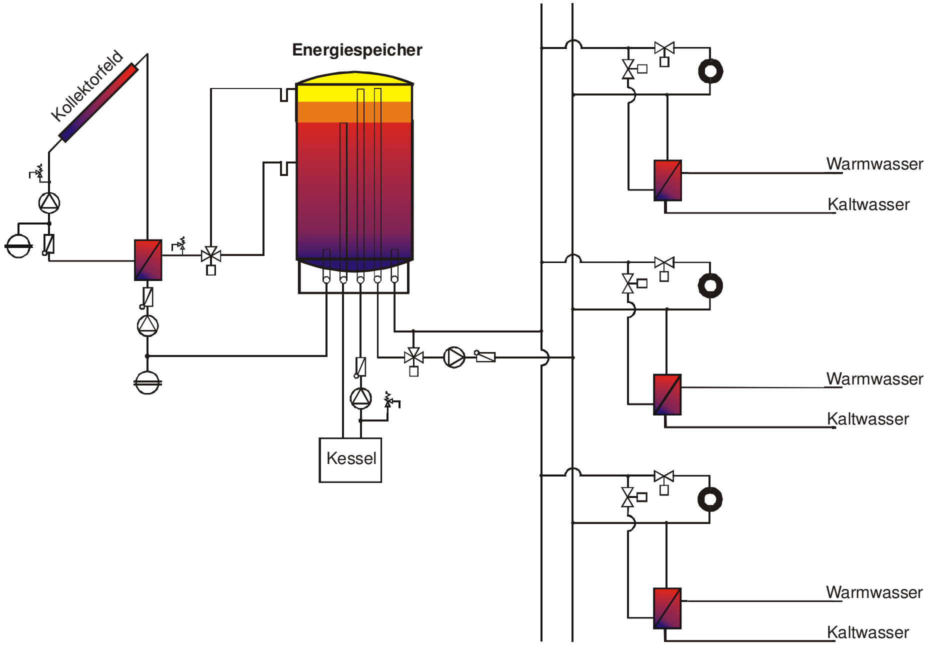


1 Absperrventil
2 Rückschlagklappe
3 Sicherheitsventil
4 Durchflussgesteuerter Temperaturregler
5 Rücklauftemperaturbegrenzer
6 Differenzdruckregler
7 Zählerpassstück
8 Zonenventil
9 Passstück Kaltwasser
10 Zirkulationsbrücke

- Important components for measuring the demand:
  - Water meter
    - measures the total amount of hot water used in a unit
  - Heat meter
    - measures the total amount of hot water and heat used in a unit
  - Can be read out manually or via a bus-sytem

Distribution net

- Characteristics of 2-pipe systems with substations
  - Strongly varying flow due to the decentralized hot water preparation
  - Constant flow temperatures over an entire operational year



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Distribution net

- Volume flow
  - Between summer and winter varying volume, usage of two pumps:
    - Pump for summer
    - Pump for winter
    - Reduction of the needed electricity
  - Ascending pipe needs to be regulated correctly, usage of a differential pressure regulating valve
  - Mixing valve: temperatures up to 95 °C during summer mean highest requirements on the mixing valve

Solar supported energy nets: 2-pipe systems with decentralised hot water storage

- Solar system
  - If an energy storage is integrated:
    - Operational mode: Low (Matched) Flow
- Conventional boiler:
  - Feeds into the energy storage
- Heat distribution:
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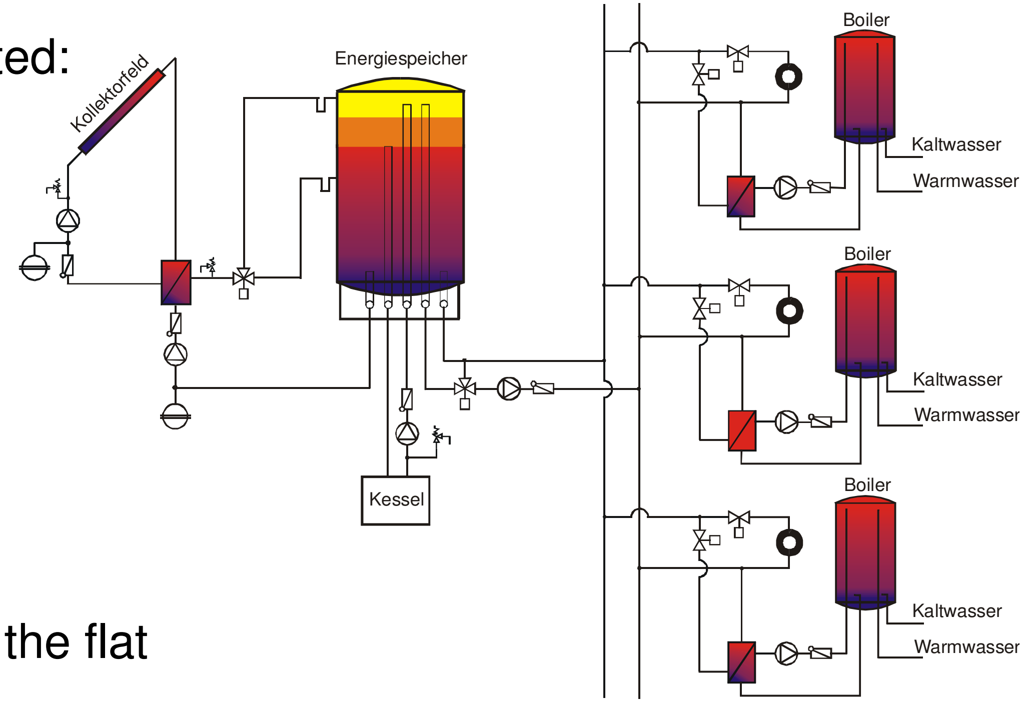


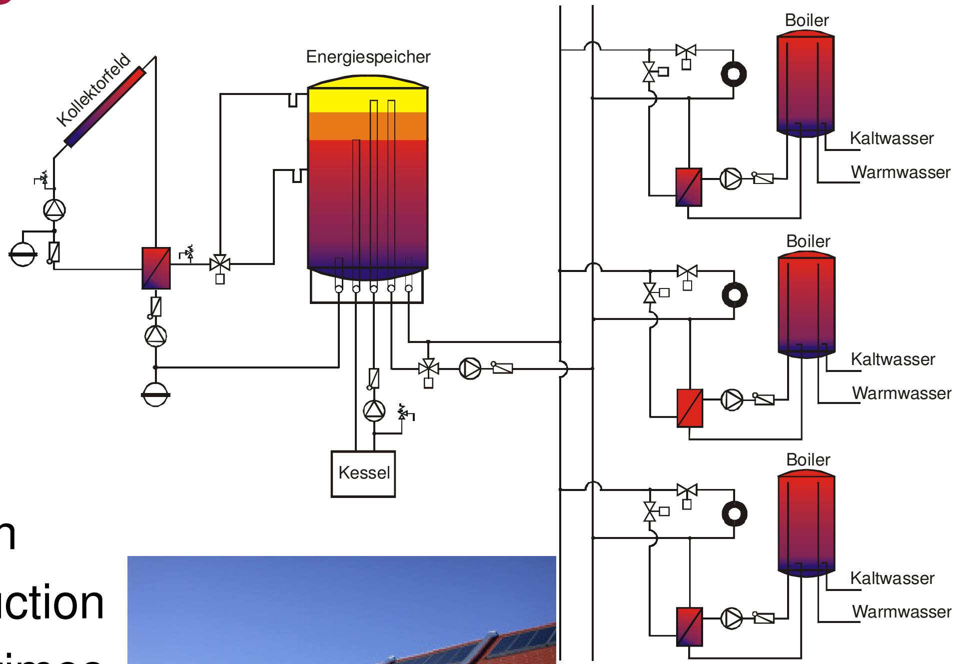
Important: The distribution net is used 22h to 23h for the heat supply and just 1h to load the boiler

Important: the upper part of the storage needs to be kept on a minimum temperature (65°C) →security of supply

Important: Heater dimensioning 65/40

Solar supported energy nets: 2-pipe systems with decentralised hot water storage

- Important components:
  - Mixing valve
  - Pump
  - Decentralized load substations
- Application:
  - New building, residential buildings in compact building method, reconstruction (already existing devices can sometimes be further used)

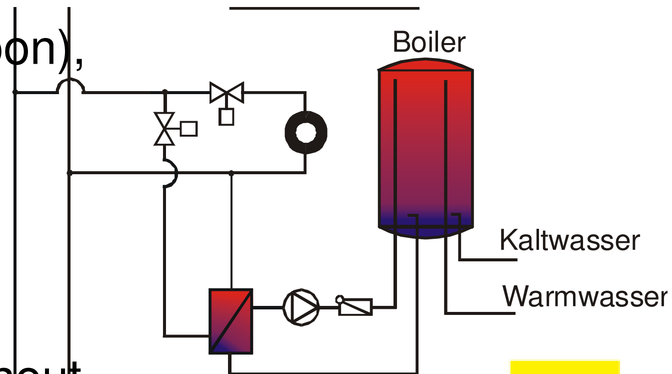


Advantage: Low return temperatures from the beginning of the boiler load

Advantage: Distribution losses are reduced during summer (pipes are heated up just once/day)

Hot water preparation / Space heat supply

- Hot water storage:
  - Dimensioning on a daily use of 150-200 litres
  - Placement: storage, toilet, bath, possibly cellars
    - Importantly: short ways to the taps
- Loading of the hot water storage:
  - external heat exchangers
    - Deep return temperatures can be obtained
    - Importantly: hydraulic uncoupling
- Loading:
  - Low loads, irradiation-strong time periods (at noon), load duration (1h)
- Space heat supply:
  - Dimensioning of radiators on a max. 65/40 °C
  - Usage of low temperature systems possible without any problems



Summary

2 pipe systems with substations

Application:
- new buildings
- reconstruction
- dwellings and terraced houses

Advantages:
- low investment costs
- hygienical hot water preparation
- compact
- low required space
- low distribution losses
- amount of hot water is unlimited
- comfort

Disadvantages:
- pump is used the whole year
- operating current

2 pipe systems with decentralized hot water storage

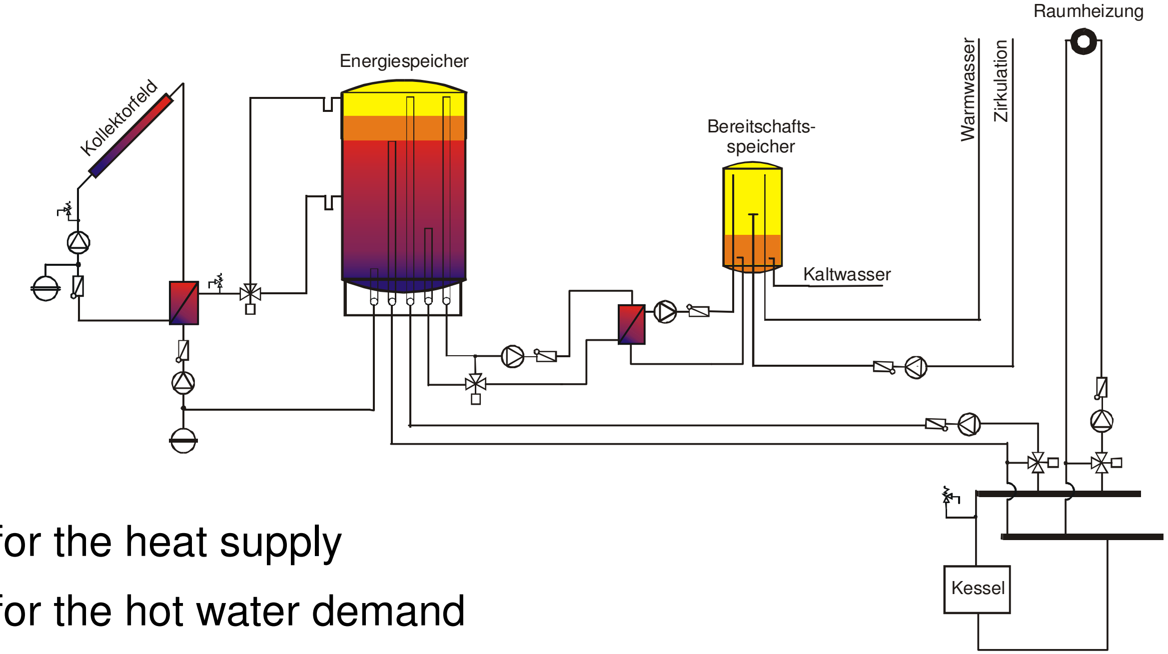
Application:
- new buildings
- residential buildings in compact building method
- reconstruction

Advantages:
- heats up the distribution net just once a day (low distribution losses)
- hygienical hot water preparation

Disadvantages:
- higher investment cost because of the decentraized hot water storage
- more space is needed

Solar supported 4-pipe systems

- Application
  - Reconstruction of buildings with already existing central hot water distribution

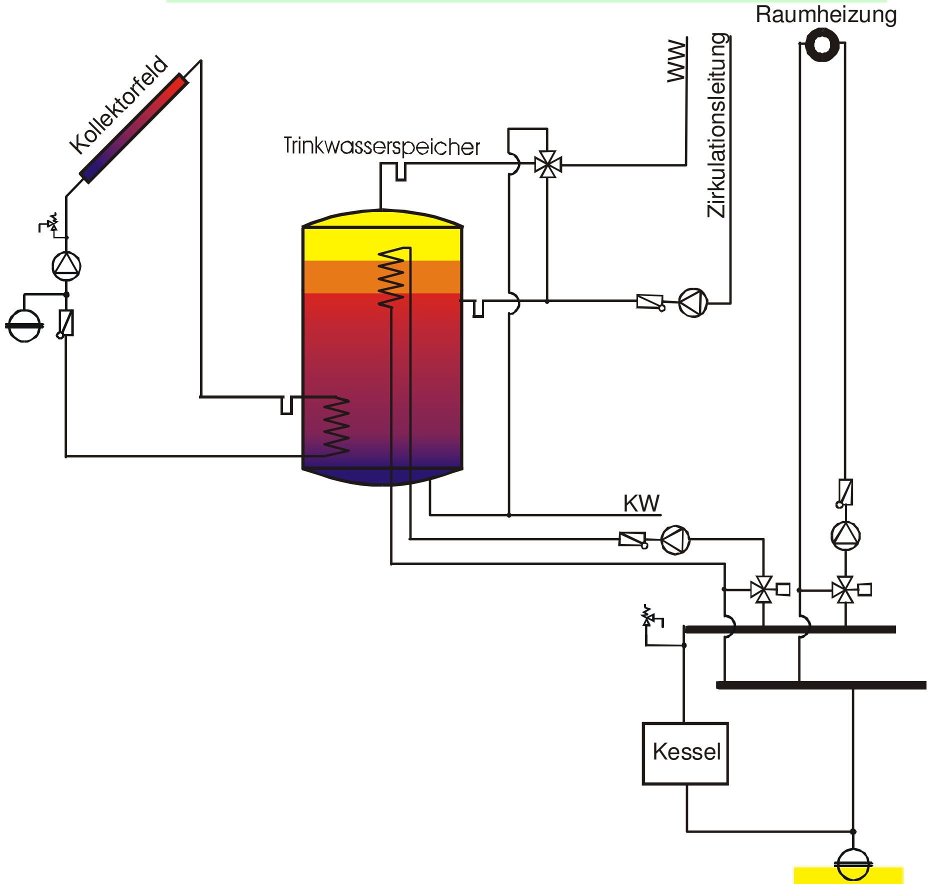


- Functions:
  - One pair of pipes for the heat supply
  - One pair of pipes for the hot water demand
- Separation in:
  - Systems with one storage (max. 10 units)
  - Systems with two storages (larger dwellings)

4-pipe system with hot water storage

- Application: for a maximum of 10 flats
- Hot water storage
  - Cost-intensive by interior coating or high-grade steel
  - high requirements on water hygiene
- Integration of the solar system
  - Internal heat exchanger
  - Plate heat exchanger
- Temperature delimitation of the storage on 60°C: Calcifying danger of the external heat exchanger

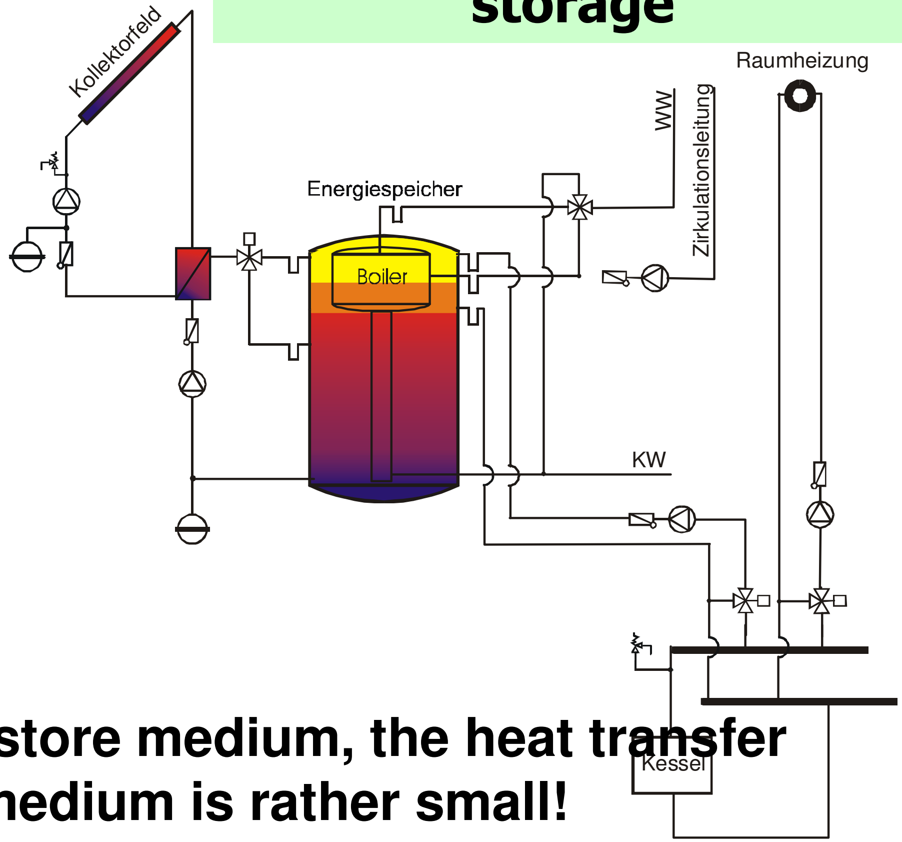
Systeme with hot water storage



4-pipe system with one steel storage

- Steel storage
  - Is used as energy storage
- Integration of the solar system
  - Internal heat exchanger
  - Plate heat exchanger
- Hot water preparation
  - Internal water storage
  - Internal tube heat exchanger

Systeme with steel storage

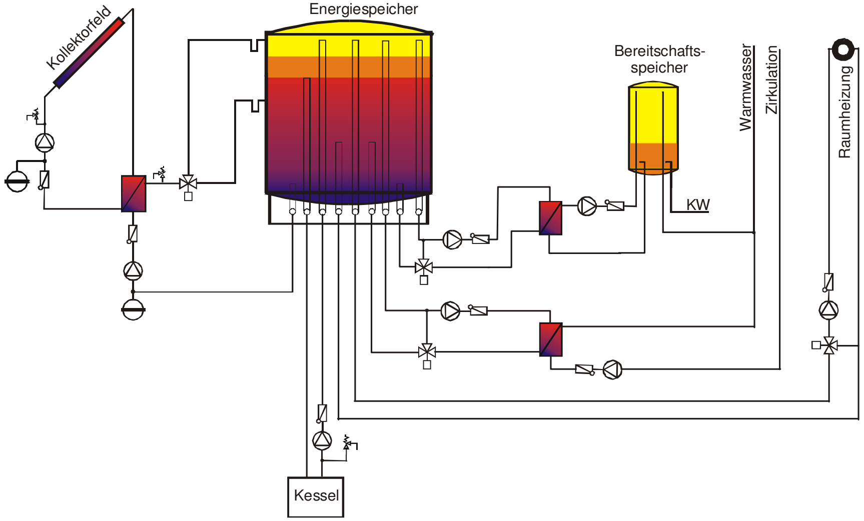


Because of the standing energy store medium, the heat transfer between hot water and storage medium is rather small!

Supply security is ensured by the provision of a large amount of hot water and large boiler or tube heat exchanger area

4-pipe system with two-storage systems

- Application
  - For large hot water consumption



- Layout
  - Central energy storage (steel), Central hot water storage to cover peak loads
  - Conventional heat generator feeds exclusive in the energy storage
  - Energy storage supplies the space heating

Increased solar results up to 10% compared to solar systems for the hot water preparation -> should be included in heat heating system!

Sometimes old storages can be used!

Ranges of recommended angles of inclination and alignment of collector surfaces in dependence of the solar covering degree

Desired dimensioning	Solar covering degree	Recommended collector angle of inclination	Recommended collector alignment
Dimensioning in cost/use optimum	appr. 12%	25 to 40°	preferable South, tolerable deviation eastward 45° and the
	appr. 20%	30 to 45°	preferable South, tolerable deviation eastward 45° and the west 45°
Dimensioning with 100% summer covering	appr. 28%	40 to 55°	preferable South, tolerable deviation eastward 45° and the west 45°

- Building Integration

Potential

- New buildings
- Old buildings / redevelopment
- Requirements for architects

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Architecture – New buildings

- design flexibility
  - Integration
  - Presentation

Architecture – Old buildings / redevelopment

- design flexibility
  - „After war buildings“ of the 50ties to the 70ties
  - Combination with a redevelopment of the faacade

- Monumental protection
  - In the city
  - old part of town

Architecture - requirements

- Standard sizes
- Special sizes available
- Colored absorbers
- Colored cover strip
- Large surfaces

Collector integration

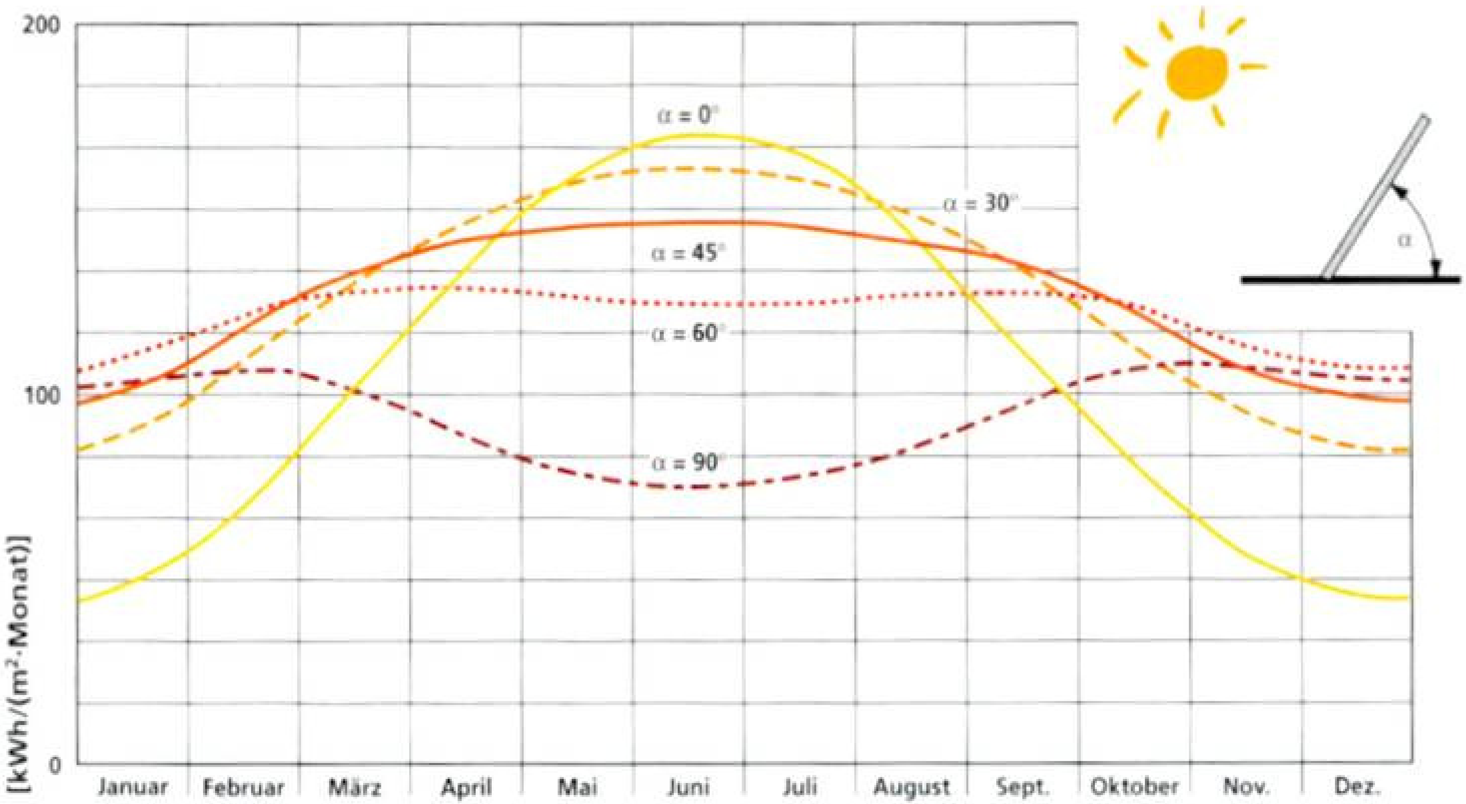
- To take care of:
  - Variations in temperature (particularly by construction units closely linked to other parts of the building)
  - Bird-ate
  - Note!
    - > Life span of the roofing and/or the roof framing
    - > Weight - collectors 20-30 kg/m2
    - > Wind and suction forces

Facade integration

- Multiple use of facade collectors
  - Solar collector
  - Weather protection of the front
  - Design element
  - Noise control
- facade collectors with backing ventilation
  - no problems from the building design aspect
- facade collectors without backing ventilation
  - brings auxiliary use to thermal insulation
  - passive-solar element
- Advantages
  - Reduction of calorific losses
  - Cost saving by multiple use
  - small/no preservation work
  - Old building and new building-suited

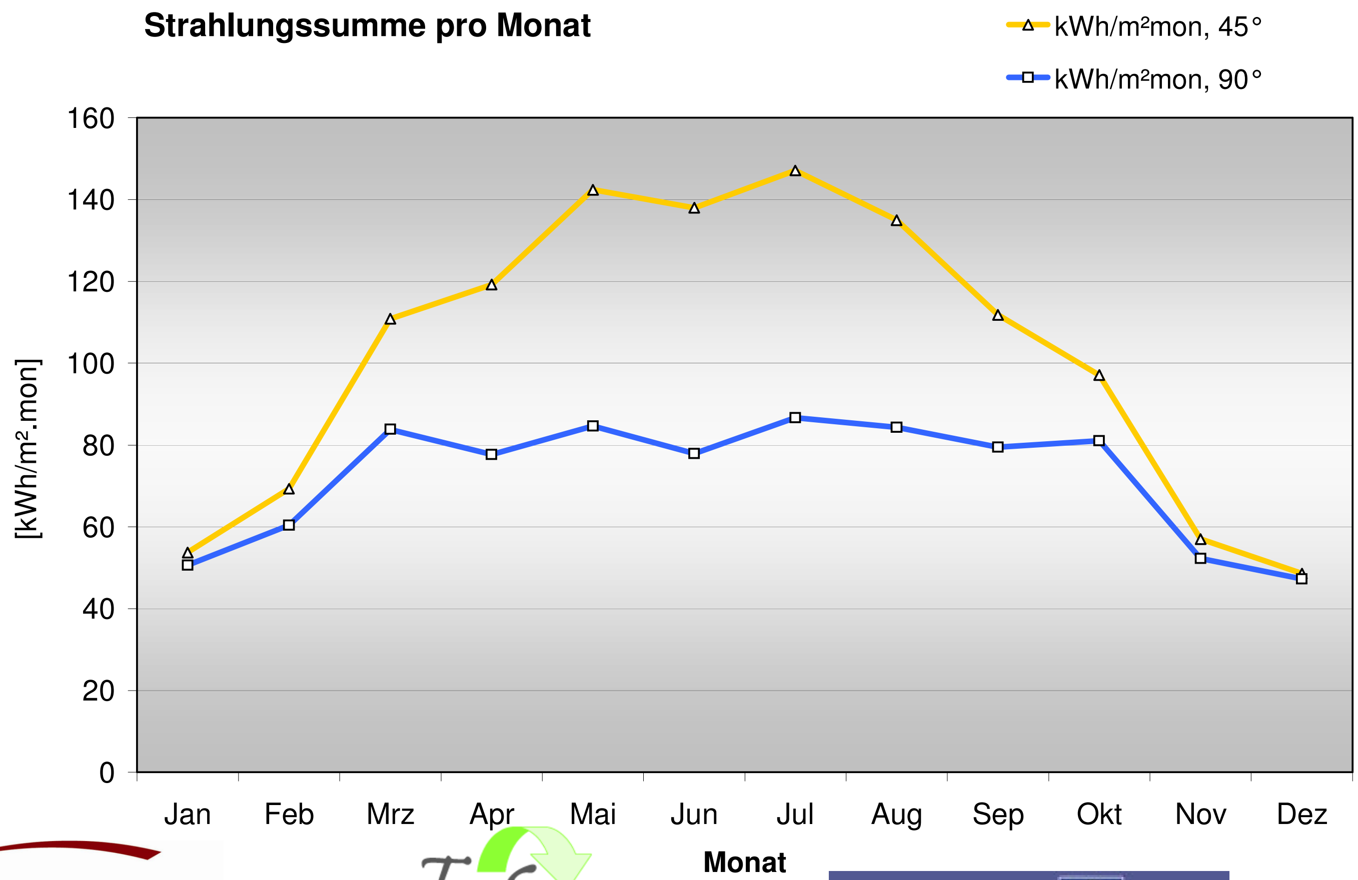
Adjustment and inclination of collectors

Yearly variation of the global radiation on inclined surface in kWh/m ², month



Irradiation in the facade

- Irradiation approx. 30% smaller than on inclined surface



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Colored absorbers

- smaller selective layer
- larger collector surfaces necessary

Enlargement of the collector surface

- With colored absorbers the surface must be increased between 20% and 70% to selectively coated absorbers
- Combined systems need less enlargement than plants for water preparation

Anlage	Solarer Deckungsgrad [%]	Solarlack zu selektiv [m²/m²]	Grün/blau zu selektiv [m²/m²]	Rotbraun zu selektiv [m²/m²]
Einfamilienhaus, 4 Personen, WW-Bereitung	70	1,5	1,5	1,7
Einfamilienhaus, 4 Personen, WW-Bereitung und 8 kW Heizlast	40	1,2	1,3	1,4

Facade integration

- Costs
  - Collector surface must be increased
  - Piping more dificult
- Use
  - Reduced calorific losses
  - Saving of glass facade (if planned)
  - No preservation work (Painting…)
  - Noise control
  - Element architectural value

the good, the bad and the ugly

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Thank you for your attention!

Contact:

DI (FH) Gundula Tschernigg
arsenal research

Giefinggasse 2, 1210 Wien, Austria
ph: +43 (0) 50550-6374, f: +43 (0) 50550-6613
mobile: +43 (0) 664/ 825 11 75
gundula.tschernigg@arsenal.ac.at
www.arsenal.ac.at/eet