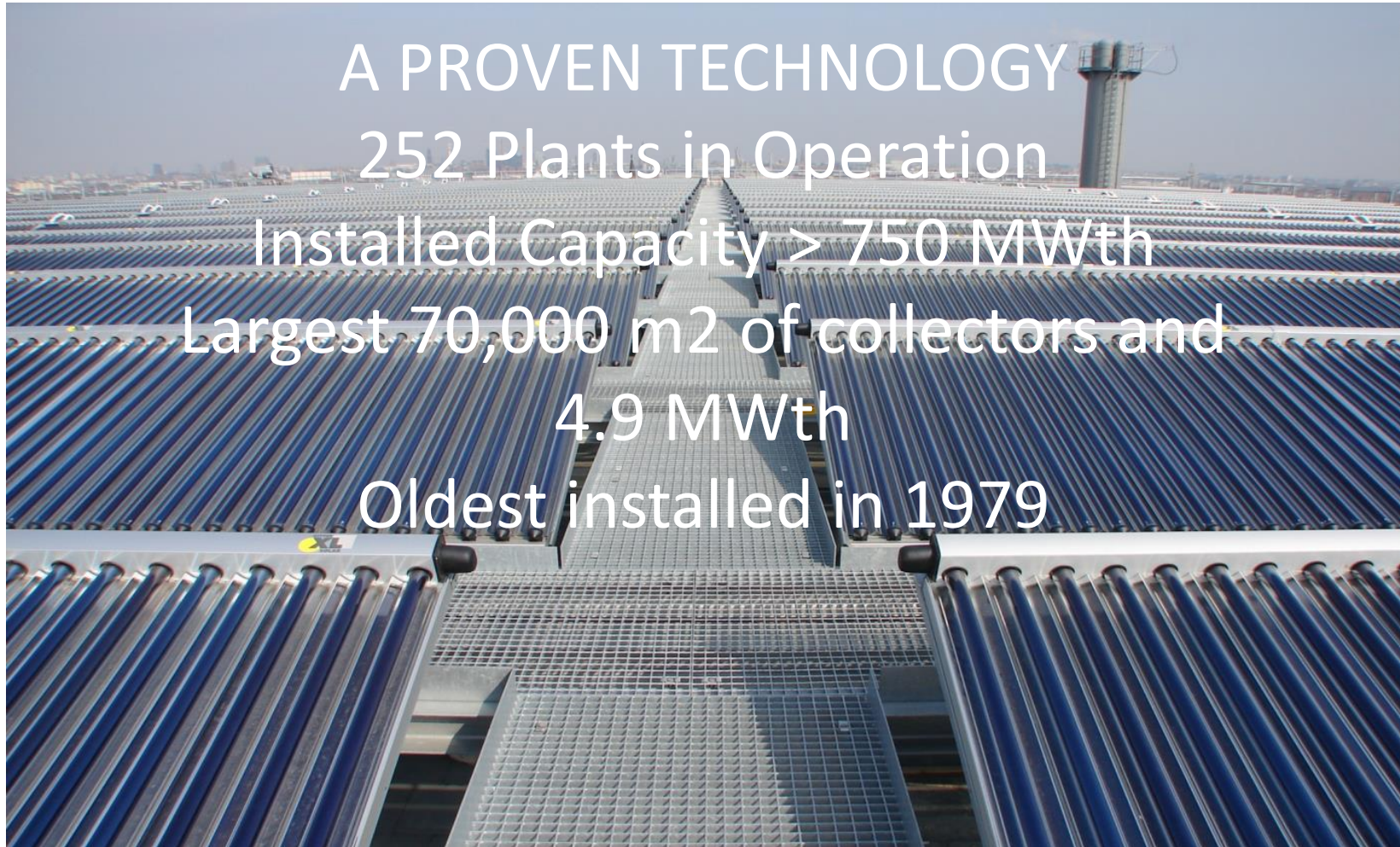




DISTRICT HEATING WITH SOLAR THERMAL SYSTEMS

Large Scale Solar Thermal Plants



A PROVEN TECHNOLOGY

252 Plants in Operation

Installed Capacity > 750 MWth

Largest 70,000 m² of collectors and
4.9 MWth

Oldest installed in 1979

Euroheat & Power
Solar District Heating

www.euroheat.org

www.solar-district-heating.eu

Reference Projects of District Energy Installations



District Heating network in Büsingen



**Total investment in Bioenergy
Project – 3.5 Mio. €**

Route length of 5 km

107 building connections; residential,
commercial and public

Collector Area: 1,090 m² (218 collectors)

Flow temperature: 80..90 °C (176..194 °F)

Solar fraction: ca. 13%

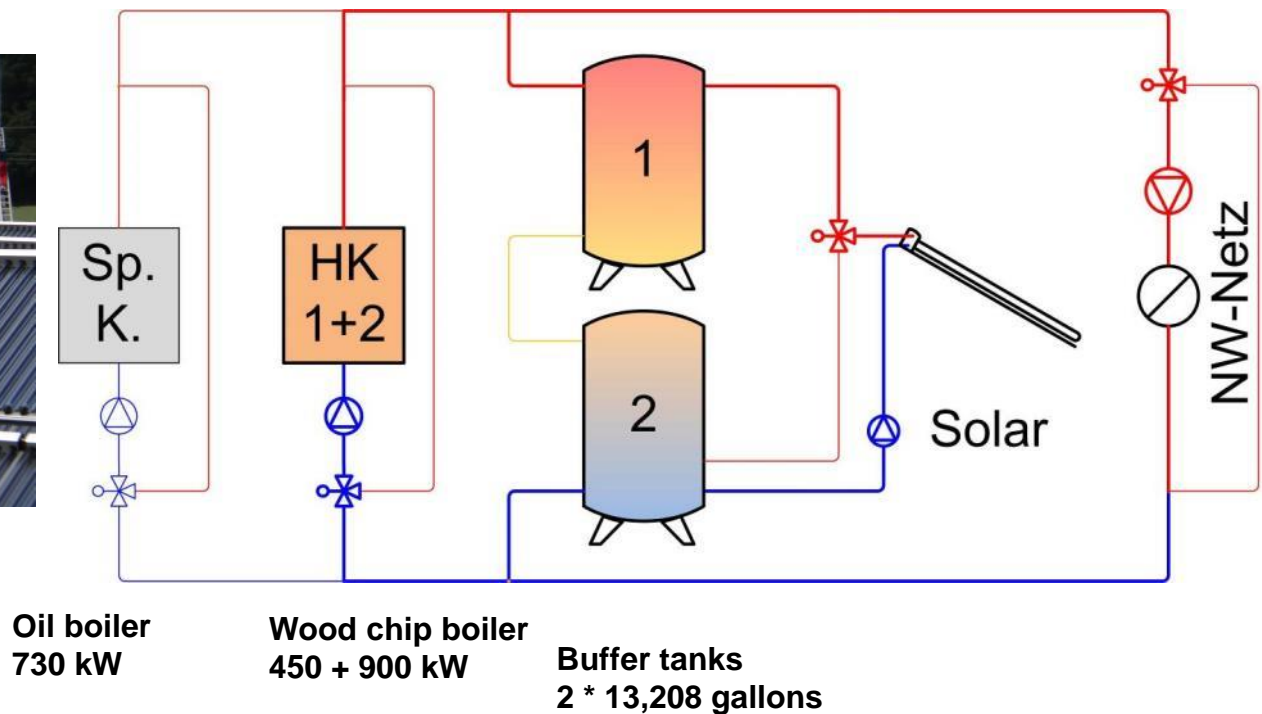
Annual yield: > 520 MWh

Specific yield: 470 kWh/m²a

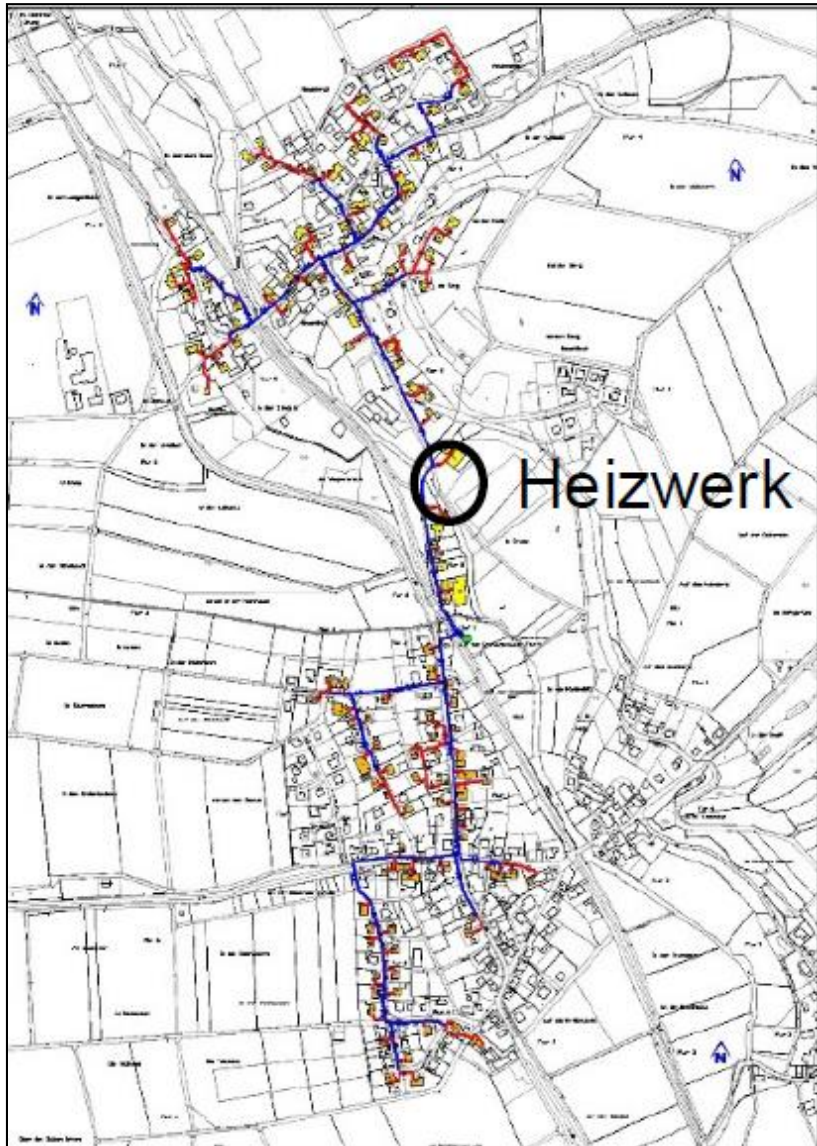
Solar heat generation
4,000 MWh / a

Büsingen: Hydraulic Intergration

- The solar system is connected directly without heat exchanger – only possible due to Aqua System.
- The solar system is connected just like additional boiler.
- The existing heat storage is sufficient for the solar system.



Heating Network Neuerkirch and Külz



Route length 6 km

- 143 building connections
- Predominately residential housing

Heat generation

- Approximately 3,100 MWh / a

Investment

- 4.8 Mio. €



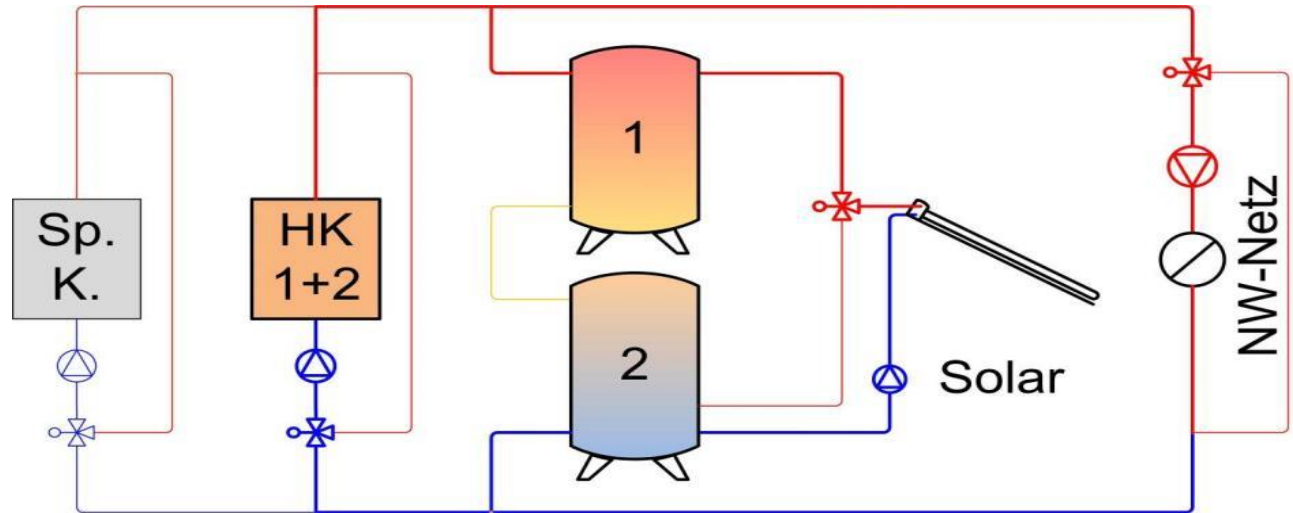
Heating Network Neuerkirch and Külz

Back-up heating:

1.6 MW oil boiler

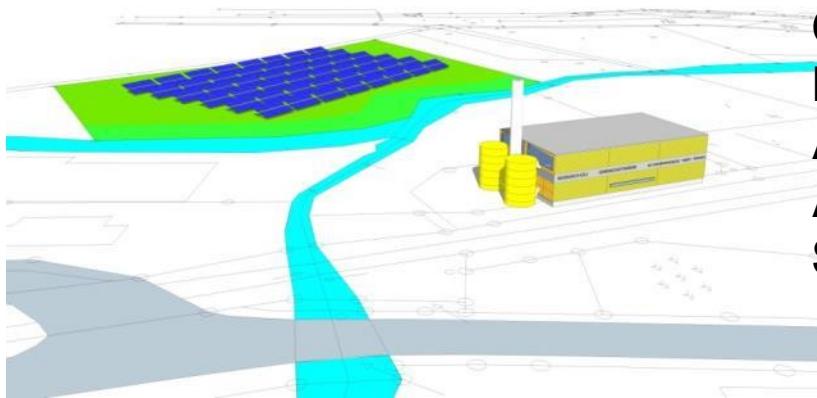
Wood Chip Boilers

360 + 900 kW



Buffer Tanks:

2 x 15,850 gallon



Collector area	1,422 m ² (290 collectors)
Flow temperature	80 ... 90° C (176..194° F)
Annual solar fraction	20%
Annual yield	625 MWh
Specific Yield	440 kWh / m ²

Energiebunker Hamburg

- Innovative conversion of a WW II anti-aircraft bunker into a renewable energy power plant.
- Project idea for the International Building Exhibition (IBA)
- Holistic energy supply into a residential district heating network covering 100 acre
- Large buffer for integrating industrial waste heat, wood chip boilers and solar.
- Implementation by the municipal energy provider Hamburg Energie



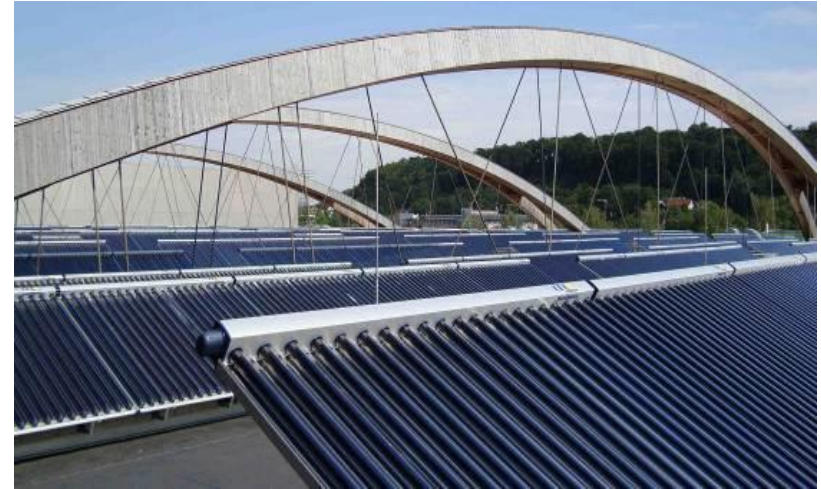
Energiebunker Hamburg



Gross collector area	1,348 m ²	(275 collectors)
Flow temperature	85 ... 95° C	(185 ... 203° F)
Annual yield	> 550 MWh	
Specific yield	410 kWh / m ²	
Max. power	750 kW	
Buffer	2,000 m ³	(528,000 gallons)
Solar heat price	<€ 30 / MWh	(<€ 0.88 / therm)

Heating network Wels, Austria

- Gross collector area:
 - 3,388 m² / 690 collectors
- Flow temperature:
 - 85... 100° C / 185...212 ° F
- Commissioned:
 - 2011
- Annual yield:
 - 1,300 MWh



- First decentralized solar field integrated into a district heating network
- First solar district heating system without solar storage
- First solar system with district heating fluid directly in solar collectors.

Germany Accelerates Solar District Heating



Project : Stadtwerke Senftenberg / direct delivery into district heating network

Gross collector area: 8,300 m² / 1,680 CPC collectors

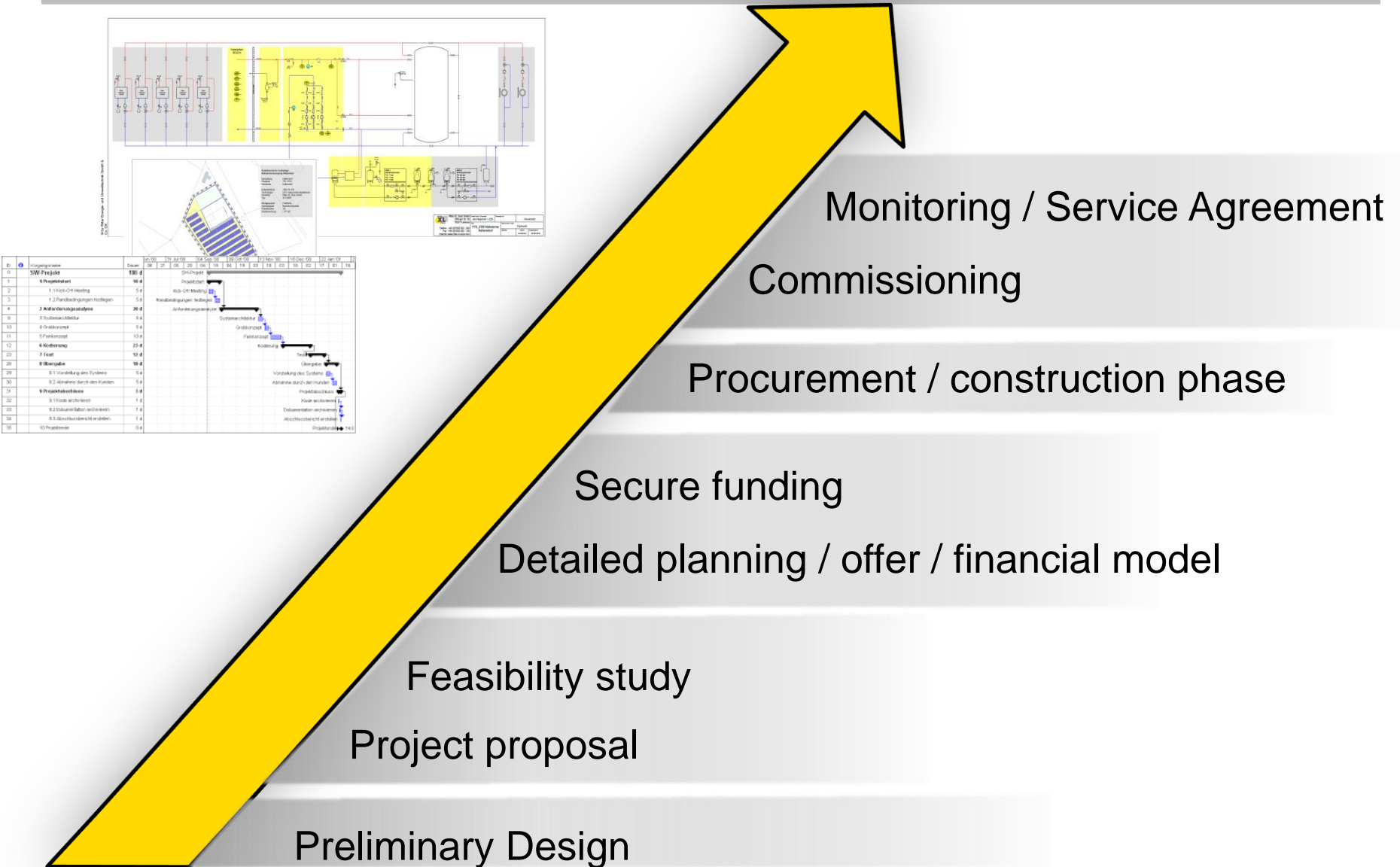
Annual yield: 3.8 GWh

Commissioned: September 2016



i The largest solar thermal plant in Germany

Typical Project Workflow

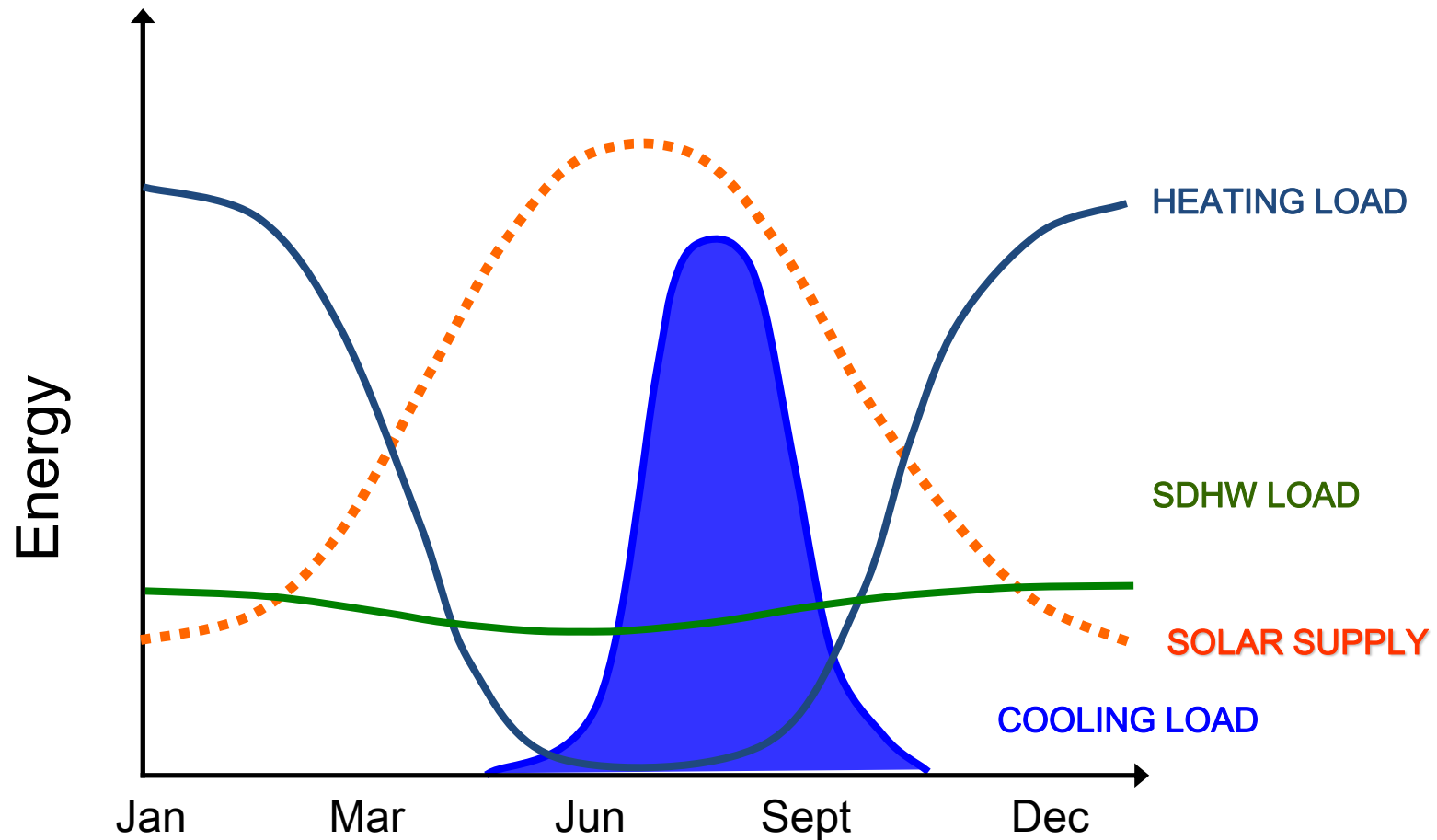


Preliminary Design Questions

Load balance analysis

- Solar production in July / August will be 4x December / January, so monthly load balance is necessary for efficient design.
- If summer load is covered by heat from CHP or waste heat capture, look into seasonal storage or absorption cooling.
- Recently developed CPC collectors have high efficiency at high temperatures, which match temperature requirements of single effect absorption chillers.
- Avoid stagnation
- Solar fractions of 20% to 50% are practical

Preliminary Design - Load Balance



Preliminary Design – Collector Mounting



Where to place collectors

- Ground mount – lowest cost for mounting structure and labor
- Roof mount – structural and wind force analysis - ballast system lowest cost
- Wall mount – lower production in summer; higher in winter

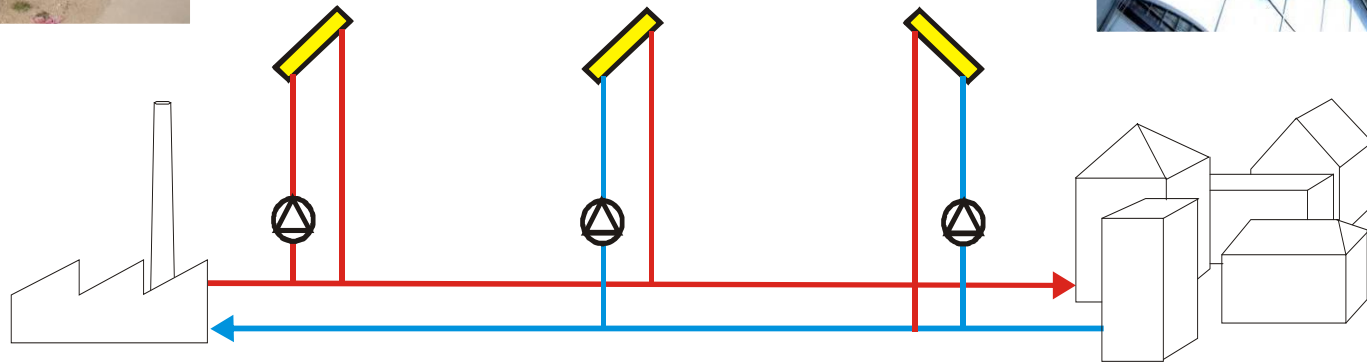


- Ground Mount pre-fabricated mounting system - 2, 3, or 4 high with 5 or 6 across



Significant reduction in costs compared to flat roof installation

Preliminary Design Question: Main Line Connection



**operation
temperature
increase**

**standard
feeding**

**return flow
temperature
increase**





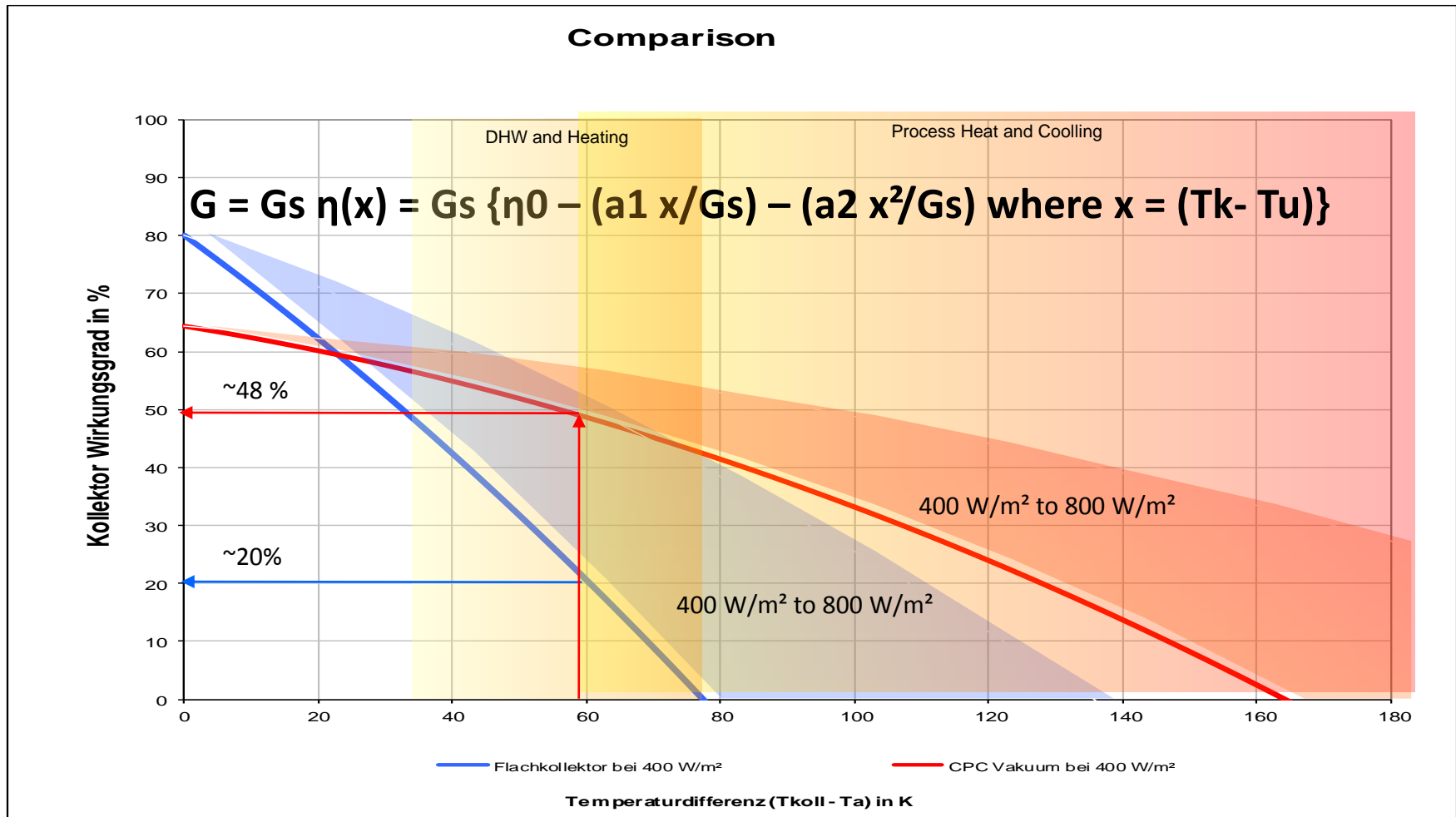
PLANNING DETAILS

COLLECTOR SELECTION

COLLECTOR FIELD PIPING

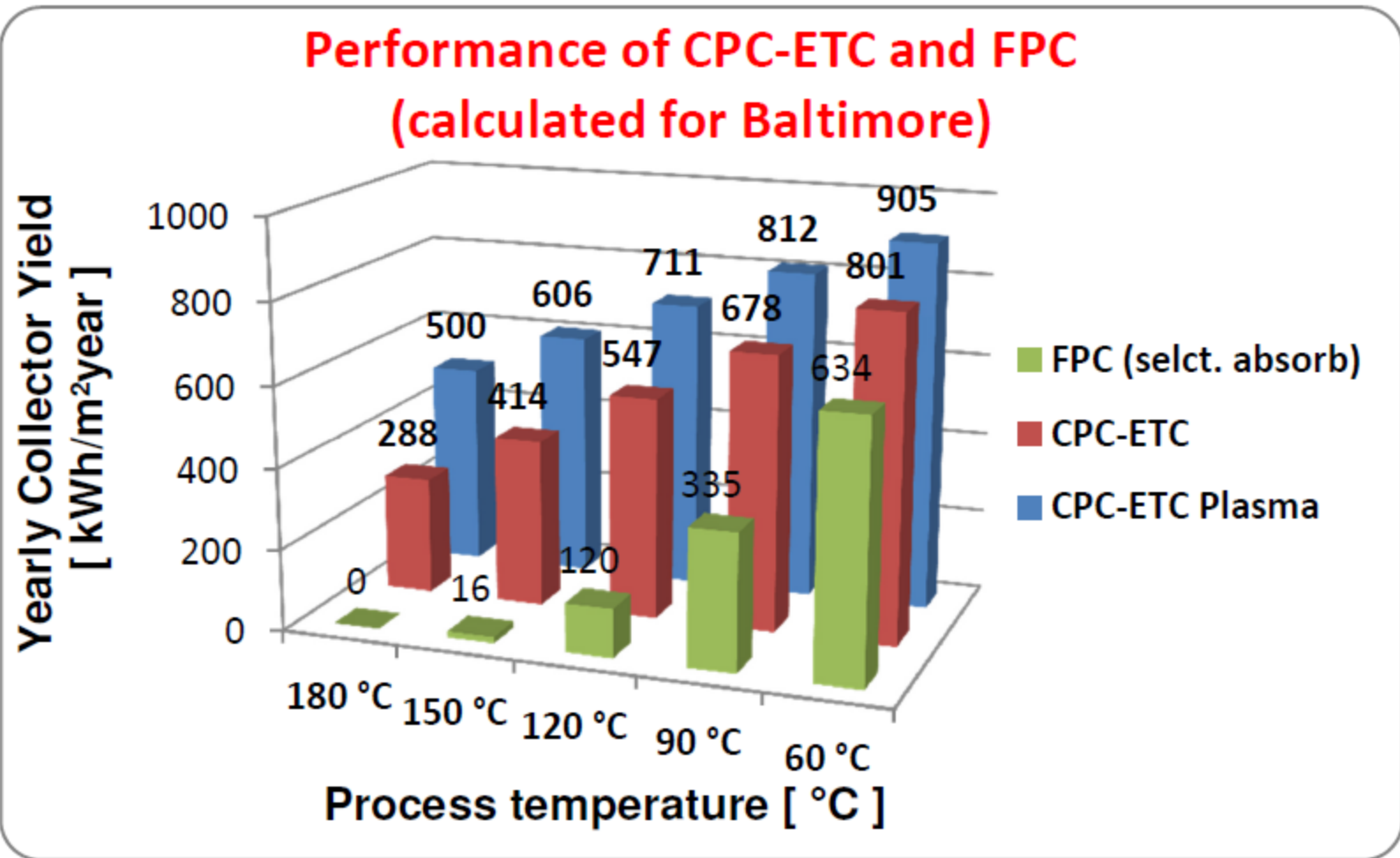
HEAT TRANSFER FLUID

Collector Selection – Performance Curves



Efficiency of CPC evacuated tube collector is twice as high as efficiency of flat plate collector at 60 K temperature difference with irradiation of 400 W/m^2 .

Performance Comparison Yearly Collector Yield

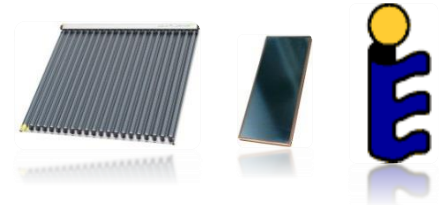
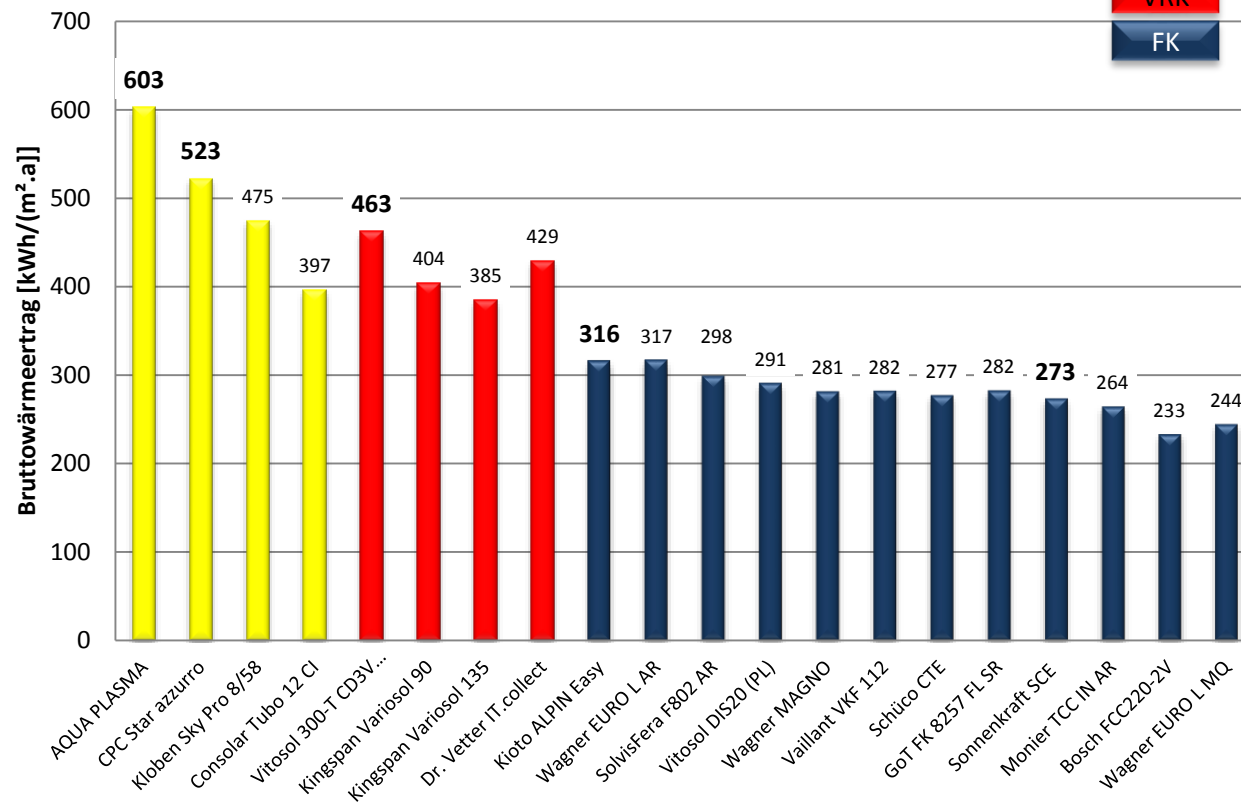


Gross collector yield - Solar Keymark




Good, Better, Best – Based on Independent Certification


Bruttowärmeertrag Solar keymark - 75°C



- Certificate Solar Keymark
- Yearly sum per m²
- Würzburg
- South, 35° inclination
- Gross collector area
- Temperature 75°C



TÜVRheinland®
DIN CERTCO



Page 2/2

Annual collector output based on EN 12975 Test Results, annex to Solar KEYMARK Certificate

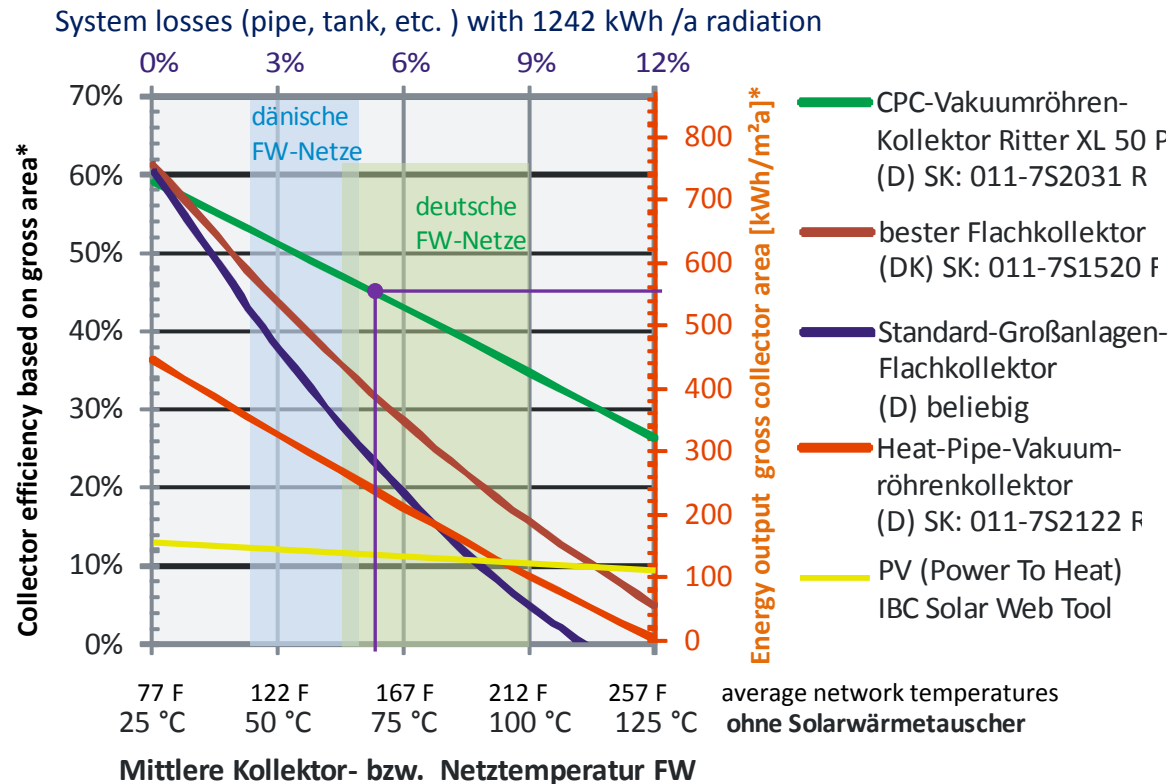
Certificate No. 011-75089 R
Issued 15.10.2012

Annual collector output kWh

Location and collector temperature (Tm)

Collector name	Athens				Dessau				Stochheim				Würzburg			
	25°C	50°C	75°C	95°C	25°C	50°C	75°C	95°C	25°C	50°C	75°C	95°C	25°C	50°C	75°C	95°C
CPC 14 Star azurro	2.350	1.795	1.242	1.080	2.350	1.795	1.242	1.080	2.420	1.865	1.310	1.148	2.420	1.865	1.310	1.148
CPC 21 Star azurro	3.850	3.137	2.168	1.596	3.850	3.137	2.168	1.596	3.850	3.137	2.168	1.596	3.850	3.137	2.168	1.596
CPC 30 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000	5.040	3.986	2.705	2.000
CPC 40 Star azurro**	5.040	3.986	2.705	2.000	5.040	3.986										

Solar system annual yields for district heating



*Location Würzburg, Germany; 30 degree, due south, ScencoCalc Software (Solar Keymark)

* Based on water systems. Glycol systems would produce 3 % to 5 % less.

Quelle:
ITW Stuttgart, Stephan Fischer:
Comparison of Thermal Performance of
Different Solar Collector Technologies
for Solar District Heating
Systems Based on Solar Keymark
Certificates and SCEnOCalc, Poster SDH
Hamburg (2014)

CPC Vacuum Collectors Have Highest Yields

Heat Transfer Fluid – Water is Best

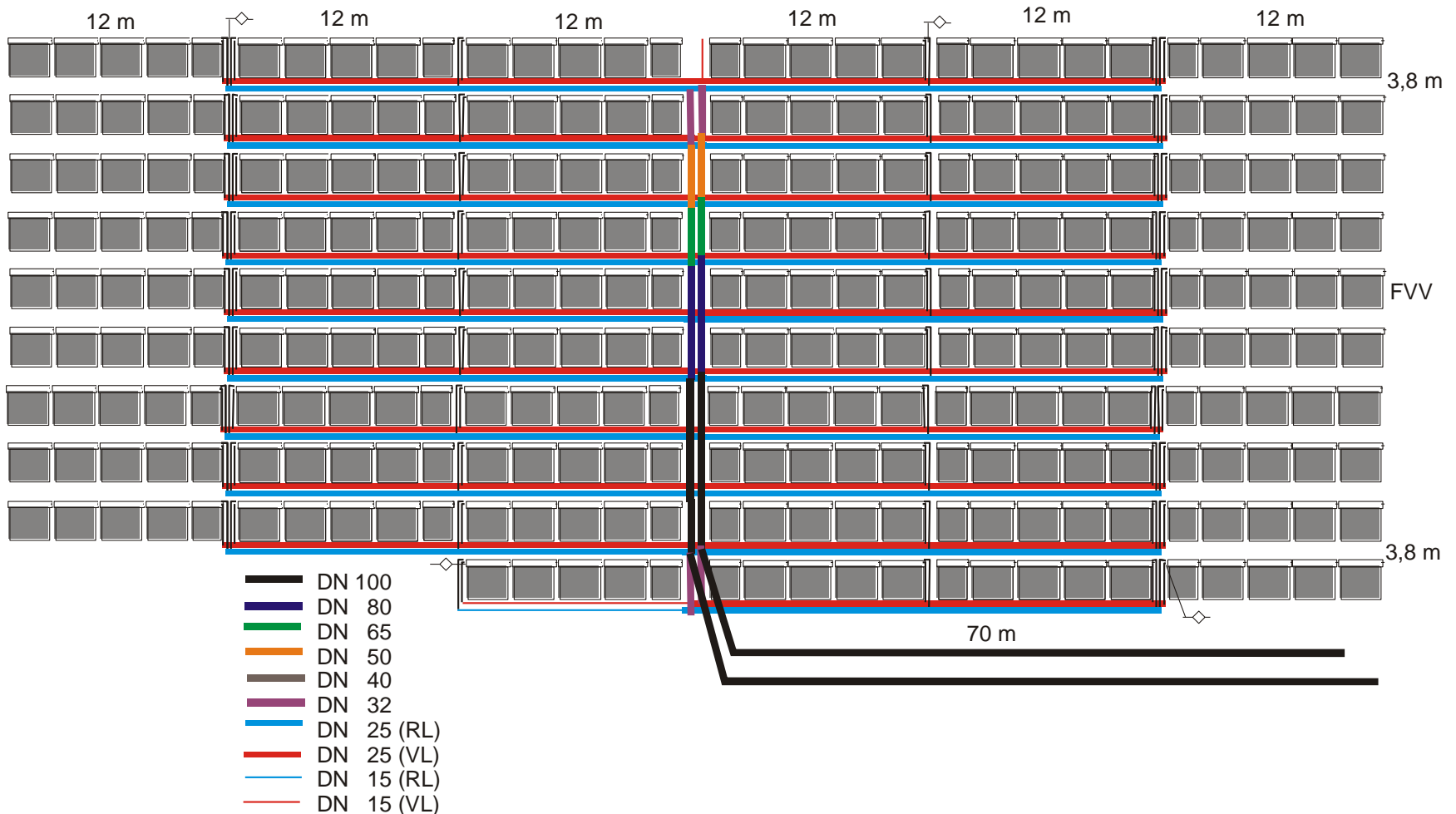
Characteristics	Water	Glycol mixture
specific heat capacity	100%	88%
kinematic viscosity	100%	380%
heat conductivity	100%	62%
Reynolds number	100%	25%
heat transfer coefficient	100%	75%
pressure loss	100%	142-485 %
gross price	100%	> 240.000 %
chemical durability	extreme consistant	oxidation, cracking, cloting, separation
purchasing	water tap	retail market
filling	water tap	special devices
disposal	drainage	dumpsite
danger of freezing	yes	no
overall comparison	outstanding	problematic



Comparison is valid at temperatures of 40 °C / 104 ° F.

The lower the temperatures the worse the properties of the glycol mixture

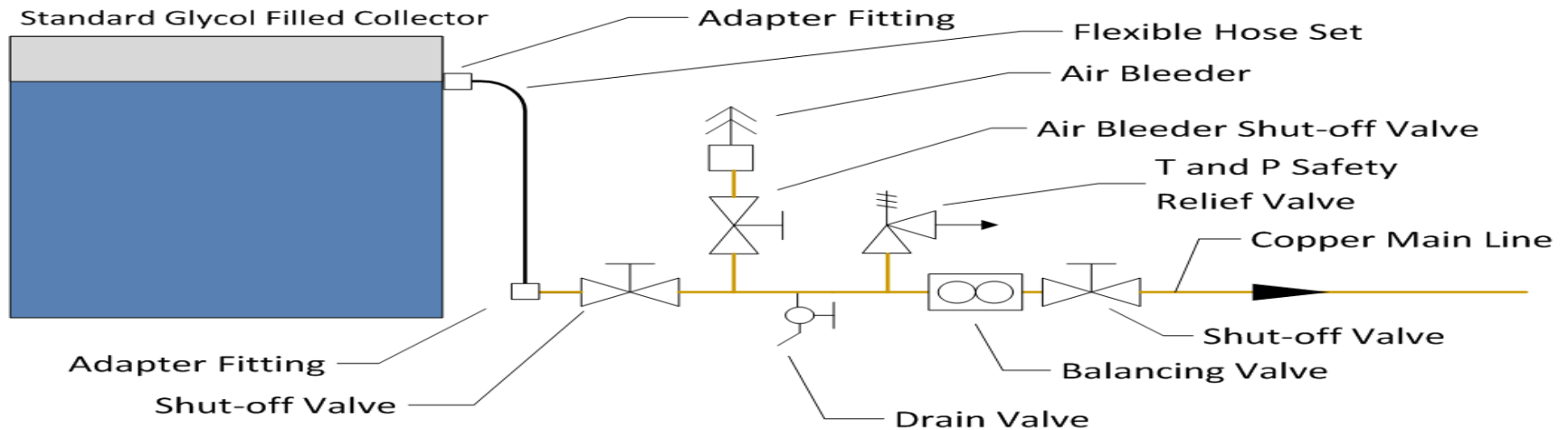
Piping – Asymmetric is Best



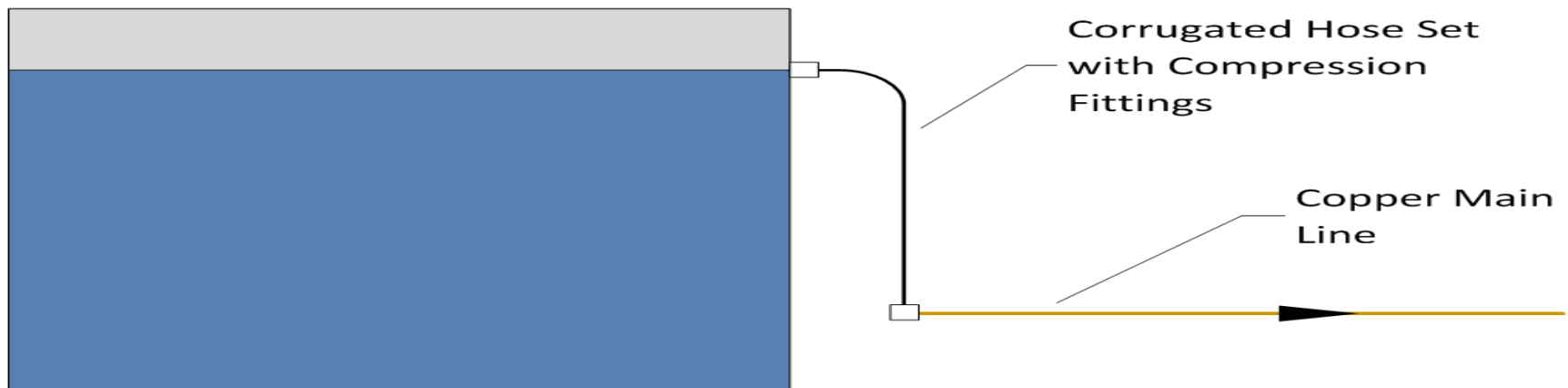
Asymmetric XL-piping (no Tichelmann) is highly advantageous with regard to volume flow control, automatic balancing, self-filling, self-deaerating, controlled emptying by extending steam, less piping and minimization of heat losses.

Choice of Heat Transfer Fluid Effects Pipe Design

Typical Glycol Fittings Found on Roof for Heat Pipe and Flat Plate Collectors



Typical Aqua System Fittings Found on Roof for Ritter CPC Evacuated Tube Collectors



- **Cost of the plant –\$500 to \$800 m² gross collector area**
 - Collectors 40%, mounting 5%, pipe 10%, mech. room 10% - total mat'l 65%
 - Labor, OHD, Profit 35%
- **Accurate energy modeling**
 - Solar operating temperatures
 - Consumption profile (7 days a week / 5 days a week / ...)
 - System design (surplus in summer, storage, ...)
- **Tax status – non-profit or taxable entity - PPA**
 - Federal and state grants and tax credits
 - Depreciation tax benefit – accelerated write-off
- **Value of solar energy - intangibles**
 - Reduced fossil fuel energy buy – less carbon
 - Energy inflation rate – known and stable energy price for 25 years

Summary – Solar District Heating

- Solar thermal energy can make a major contribution to achieving CO2 reduction goals – Solar thermal reduces 4 times the amount of carbon than solar PV per installed area
- High solar fractions in summer lead to large load reduction of district heating boilers
- Simple and effective integration of solar thermal energy into existing networks.
- Solar fields do not have to be near main boiler plant.
- Buffer tanks not necessary.
- Continuous high temperatures possible, even in winter.
- 30 year fixed energy price



THANK YOU FOR YOUR ATTENTION



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