WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN,POLAND

THE FACULTY OF MECHANICAL ENGINEERING AND MECHATRONICS

A. Majchrzycka, Z. Zapałowicz, D. Szyszka

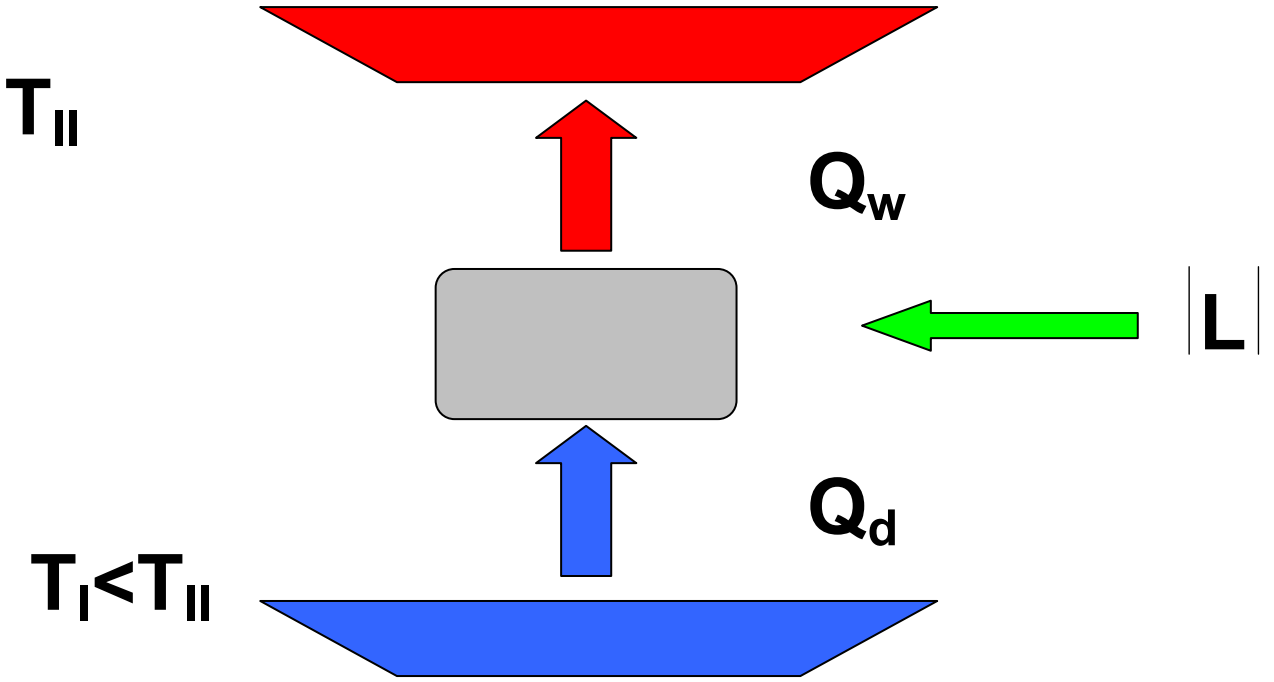
SOLAR COLLECTORS INSTALLATION IN COLLABORATION WITH A HEAT PUMP SYSTEM IN WEST POMERANIAN UNIVERSITY OF TECHNOLOGY,SZCZECIN

LOW TEMPERATURE SOURCES OF ENERGY

- Waste heat from technological processes:
  - air and gases,
  - sewage,
  - return water in heat systems.

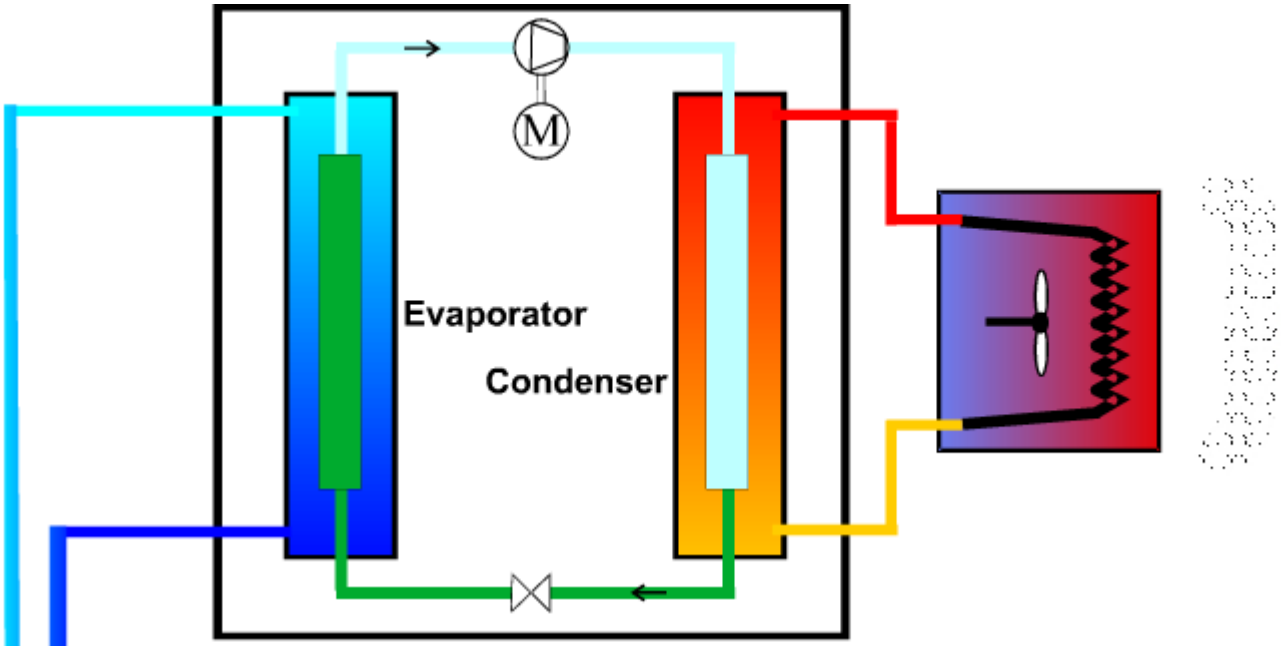
- Renewable sources:
  - atmospheric air,
  - ground,
  - water,
  - solar radiation.

HEAT PUMP



THERMAL EFFICIENCY OF HEAT PUMP

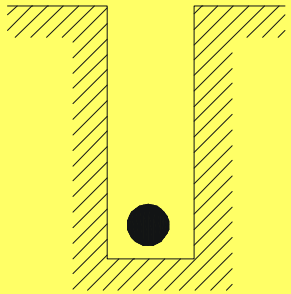
$$\varepsilon = \frac{Q_w}{|L|} = \frac{Q_w}{Q_w - Q_d} \qquad \varepsilon \rangle 1$$



Heat Pump

T_{II}

T_{I}



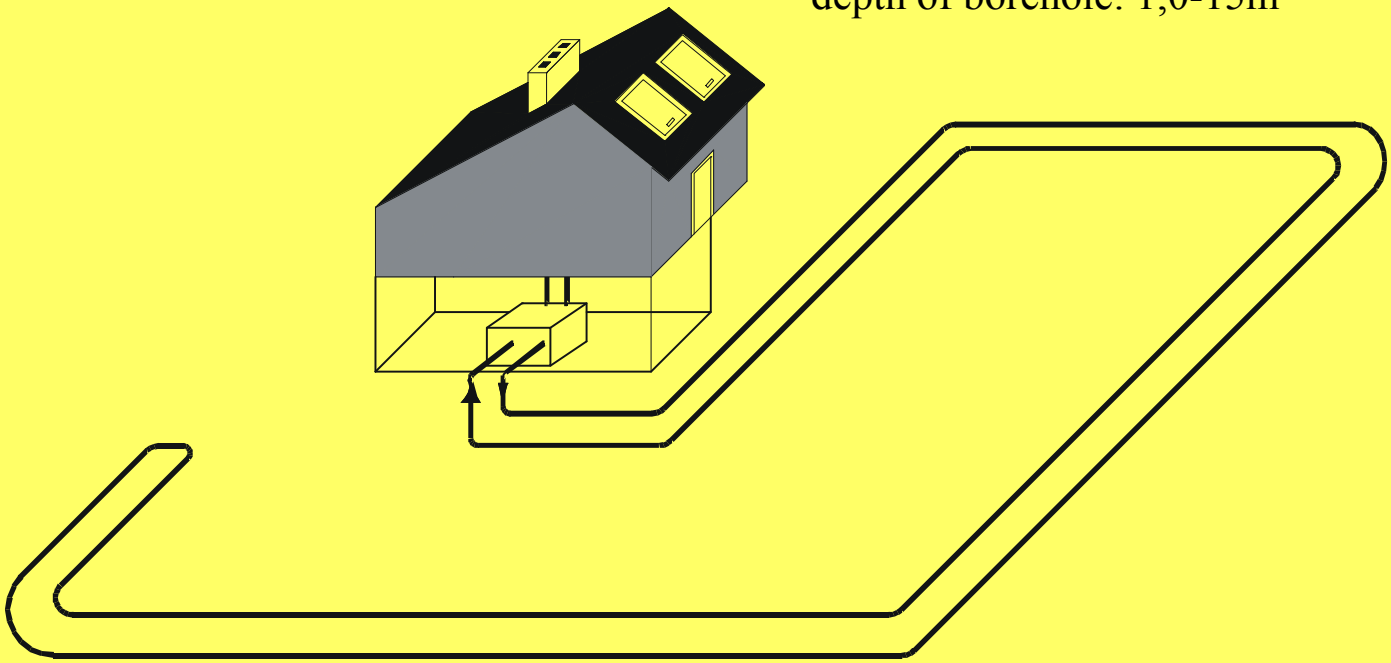
Characteristic:

flow: series

pipe diameters : 1 ¼”-2”

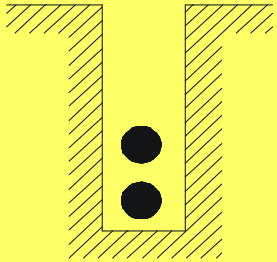
nominal pipes length: 28-45m/kW

depth of borehole: 1,0-15m



Ground heat exchanger – connection in parallel

Source; W.Nowak, R Sobański, M.Kabat, T.Kujawa



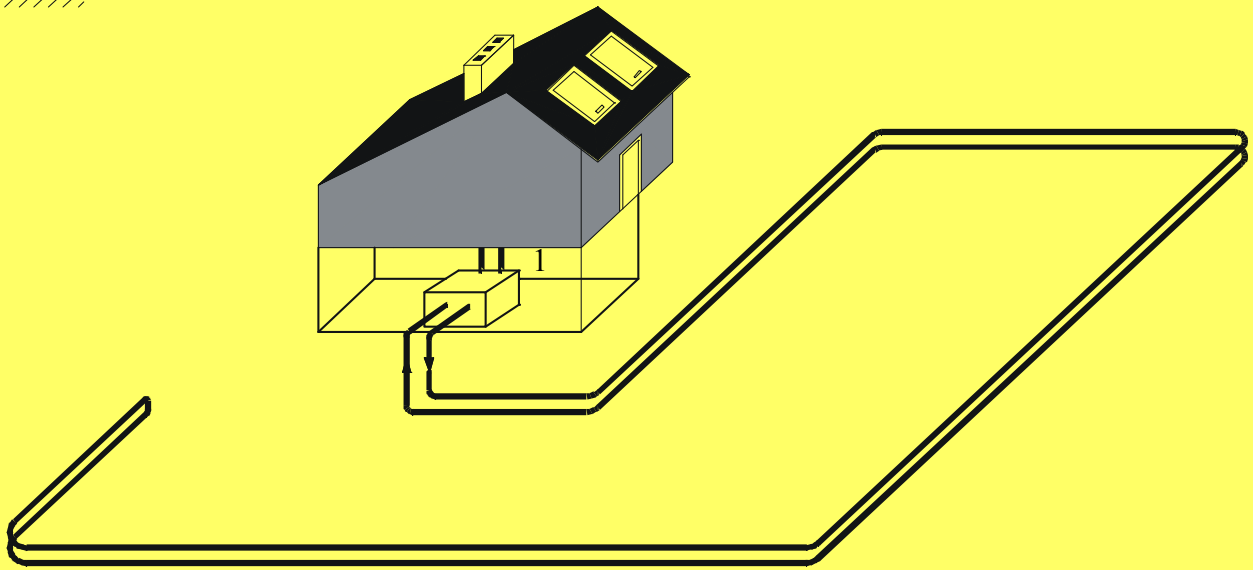
Characteristic:

flow: series

pipe diameters : 1 ¼”-2”

nominal pipes length: 35-50m/kW

depth of borehole: 0,0-15m



Horizontal ground heat exchanger - dual series connection (2x1)

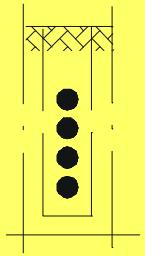
Source; W.Nowak, R Sobański, M.Kabat, T.Kujawa

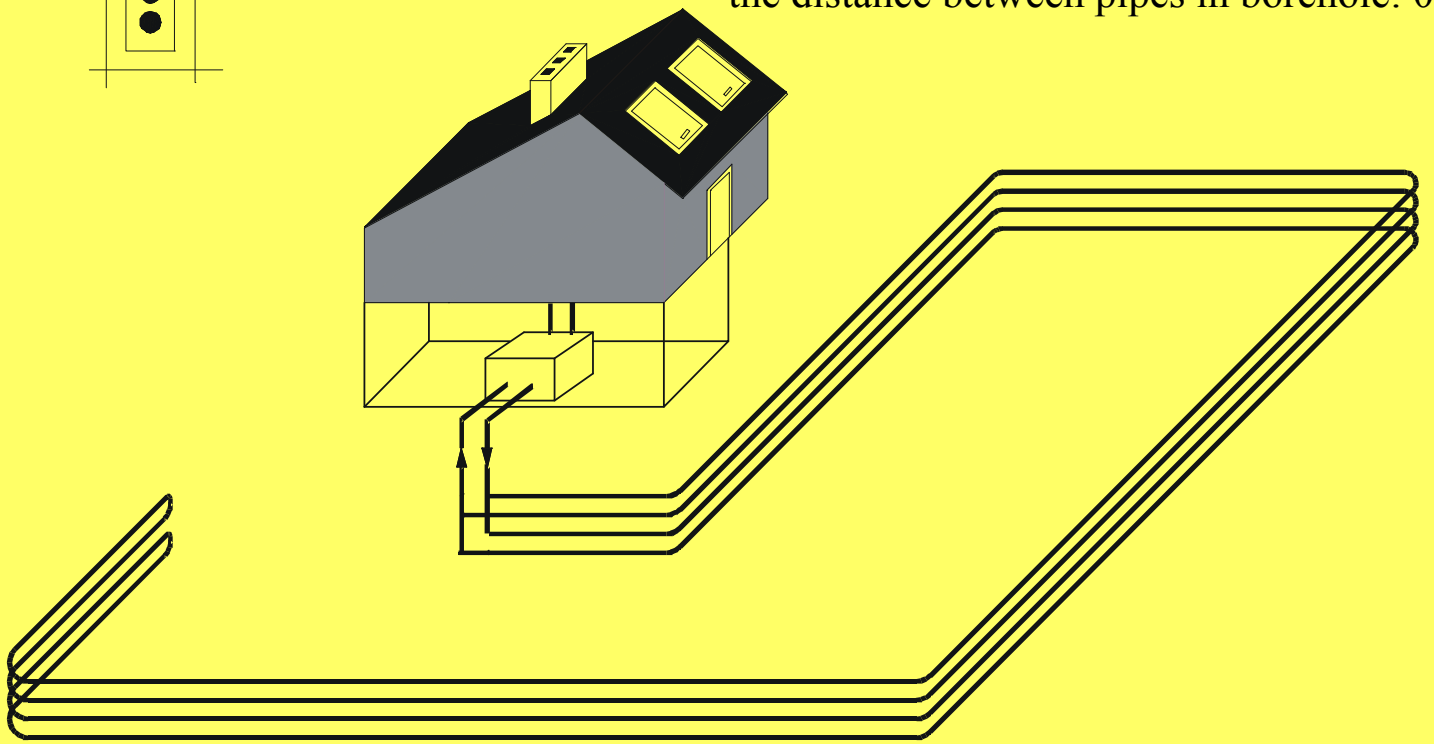
Characteristic:

flow: dual series parallel pipe diameters : 1 ½”-2”

nominal pipes length: 150m for pipes of ¾”,
230m for pipes of 1”

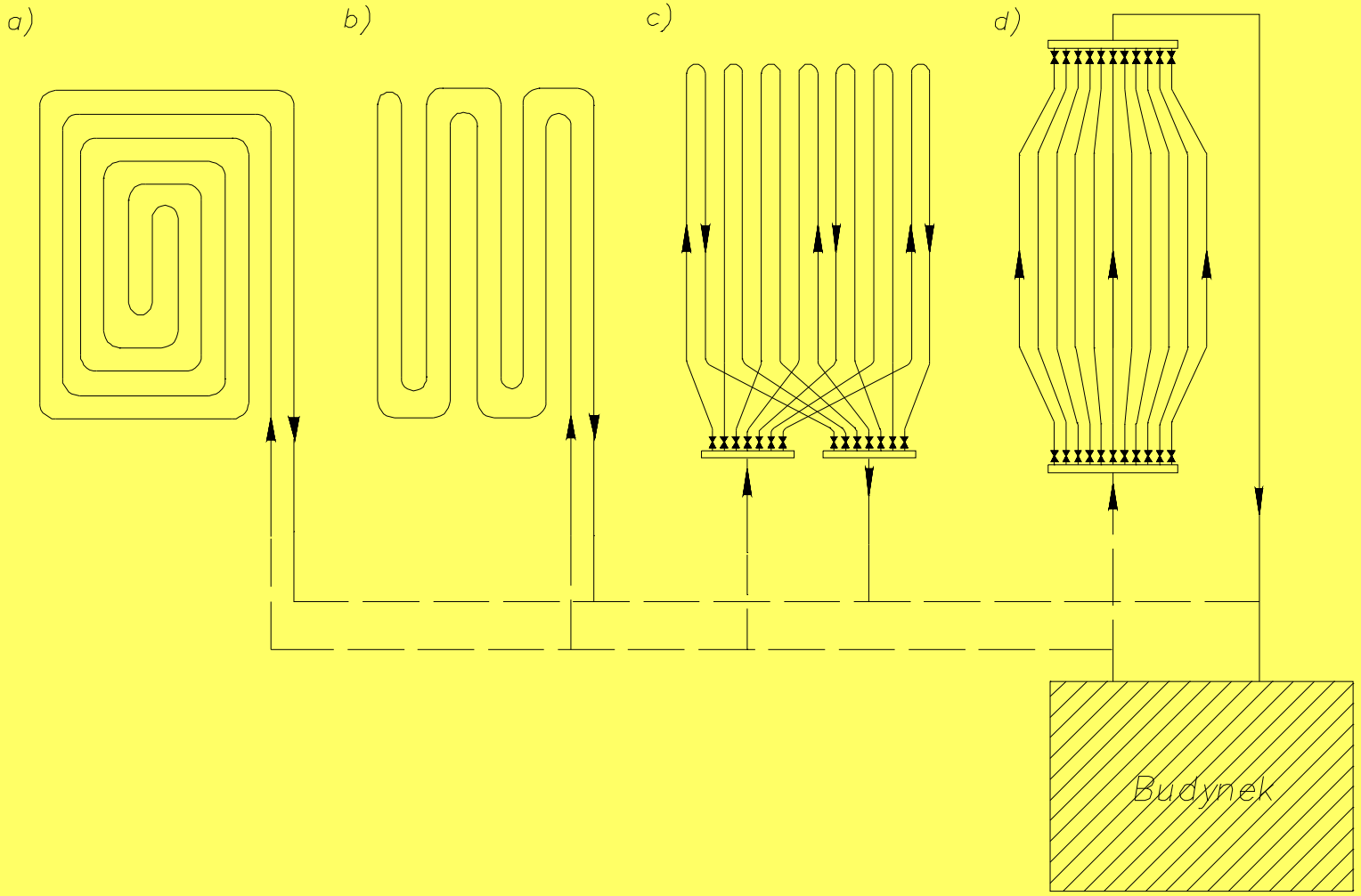
the distance between pipes in borehole: 0,3m





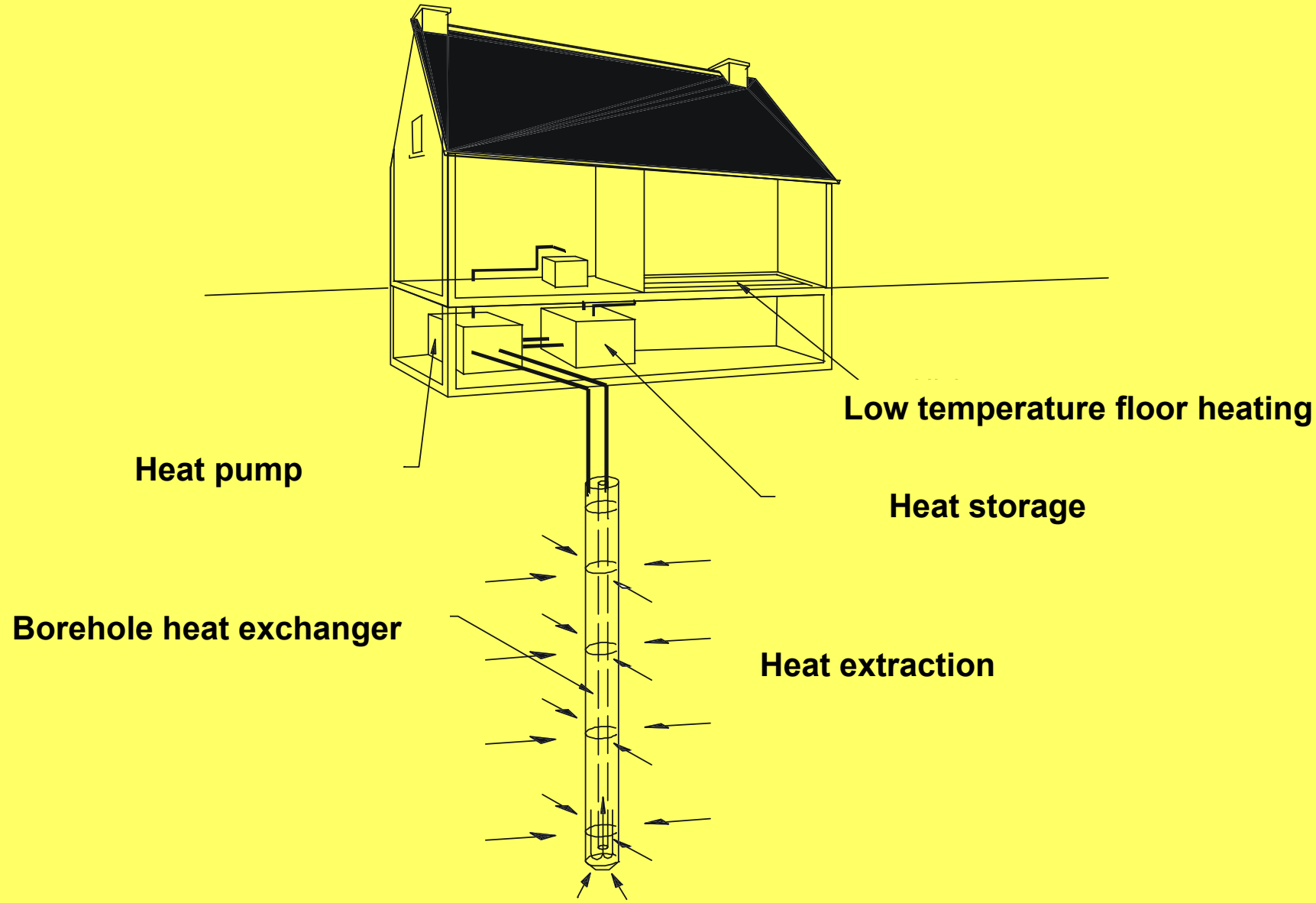
Horizontal ground heat exchanger - dual series parallel connection (2x1)

Source; W.Nowak, R Sobański, M.Kabat, T.Kujawa



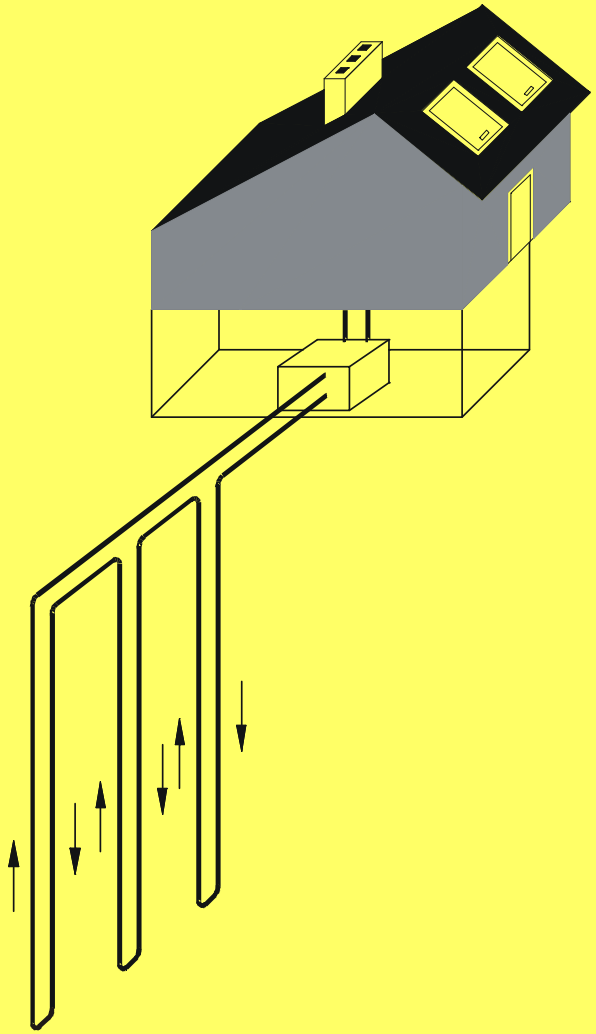
Types of pipe connections in ground heat exchangers:
a, b- coil, c-loop, d-parallel

Source; W.Nowak, R Sobański, M.Kabat, T.Kujawa



Groundwater heat pump. Floor heating in the building

Source; W.Nowak, R Sobański, M.Kabat, T.Kujawa

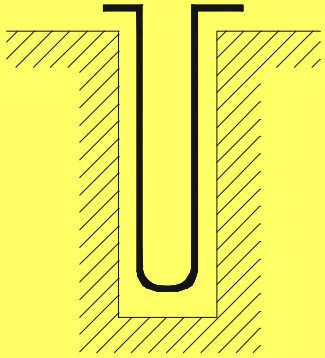


Characteristic:

flow: series connection

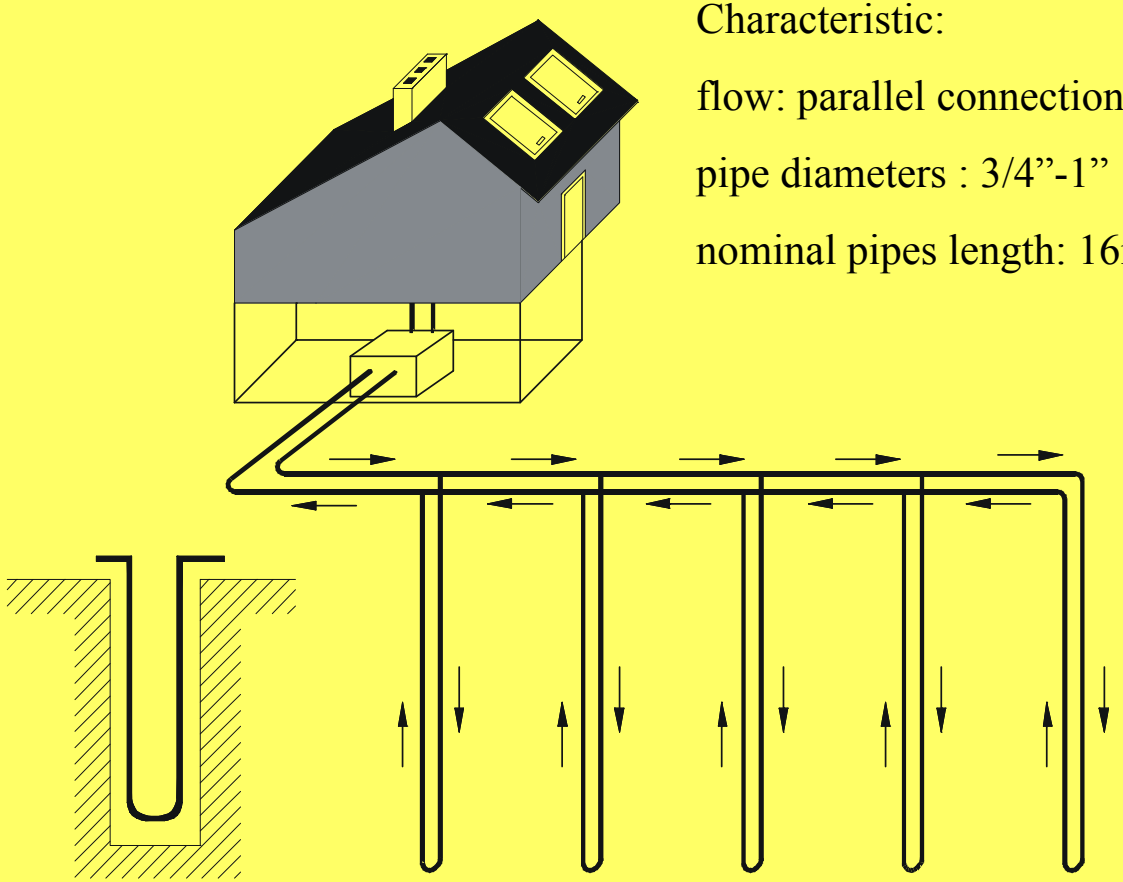
pipe diameters : 3/4”-2”

nominal pipes length: 15m - 30m /1kW



Borehole heat exchanger - connection in series

Source; W.Nowak, R Sobański, M.Kabat, T.Kujawa



Characteristic:

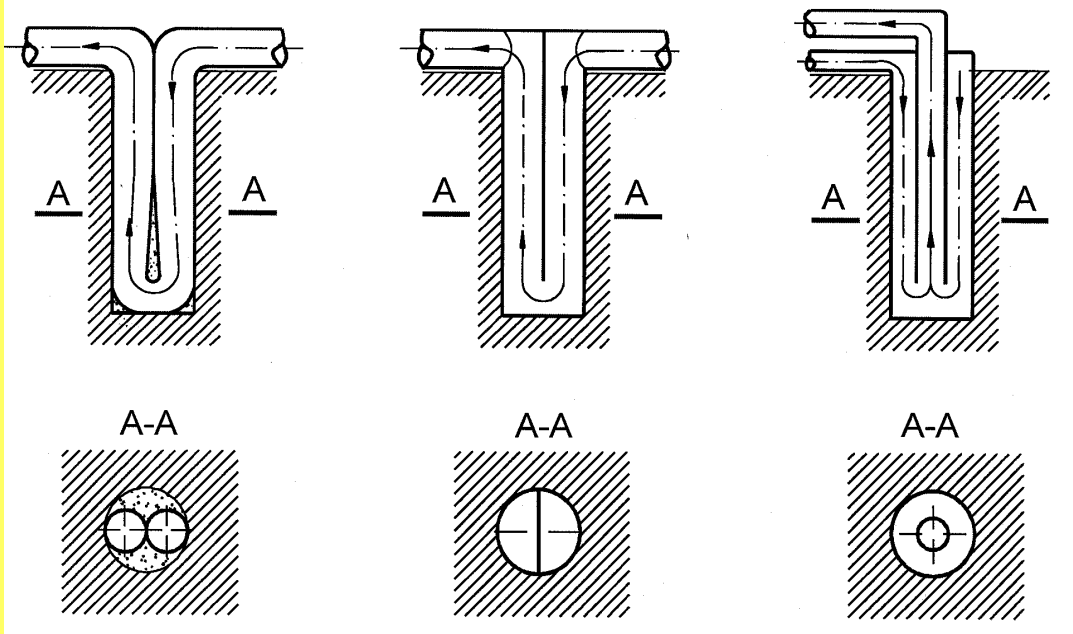
flow: parallel connection

pipe diameters : 3/4”-1”

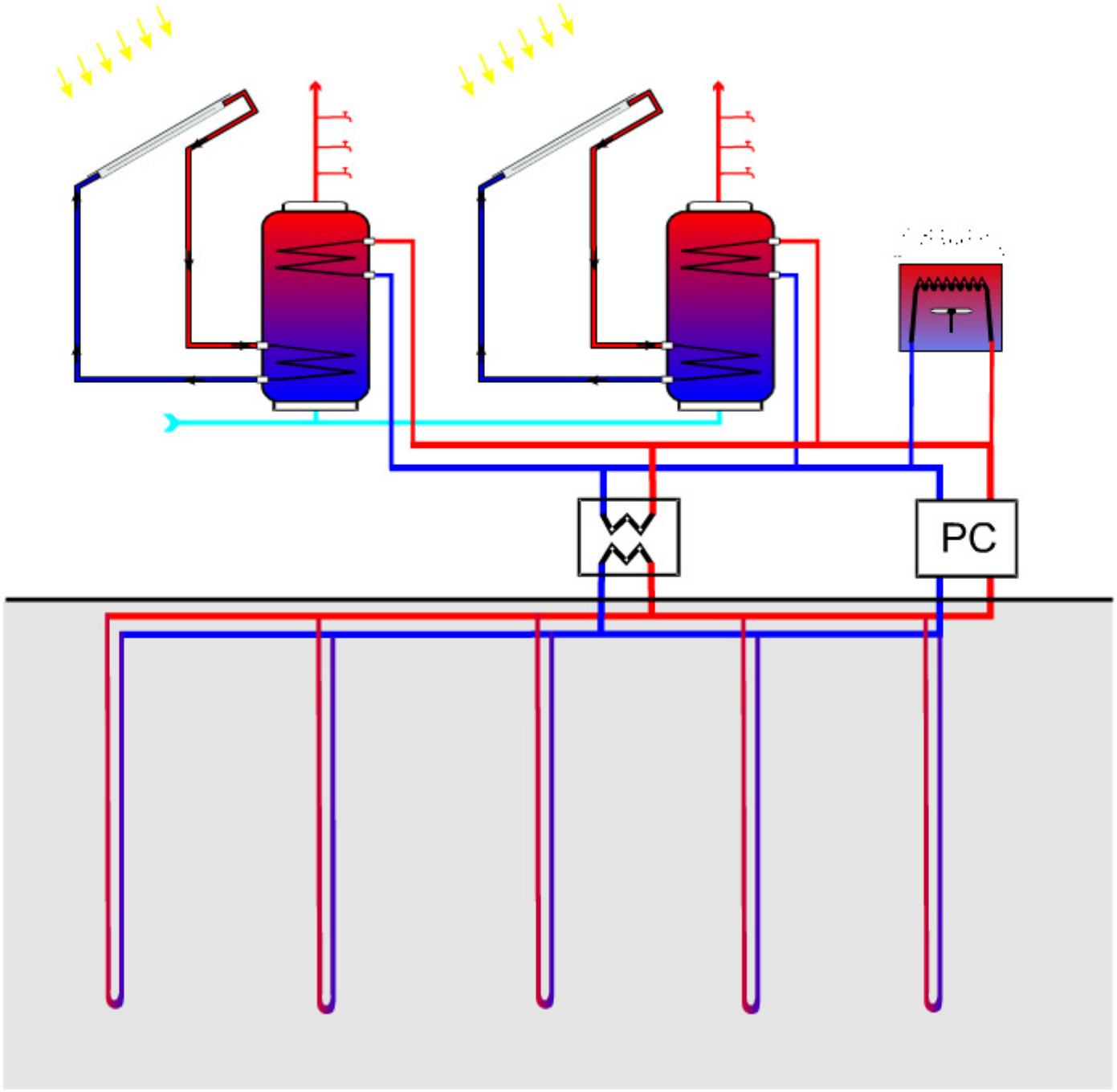
nominal pipes length: 16m - 32m /1kW

Borehole heat exchanger - connection in parallel

Source; W.Nowak, R Sobański, M.Kabat, T.Kujawa

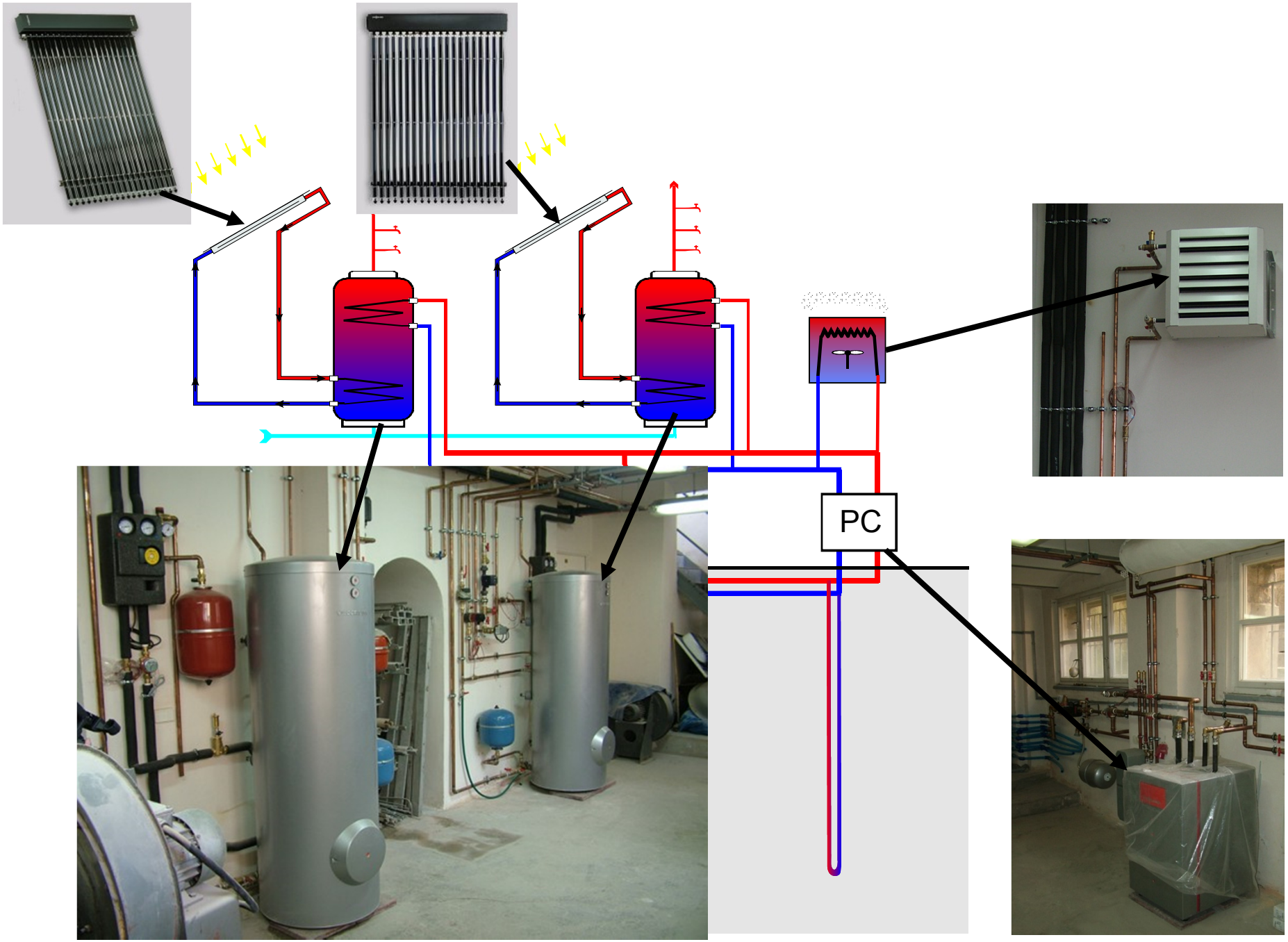


Configurations of borehole heat exchangers
a) U-pipe, b)backward flow ,c) concentric flow


PC

HYBRID SYSTEM AT DHE

- Solar collectors installation,
- Heat pump installation,
- Installations are connected by ground-heat energy storage,
- There are two borehole heat exchangers:
  - U-pipe,
  - Field tube (of concentric type).

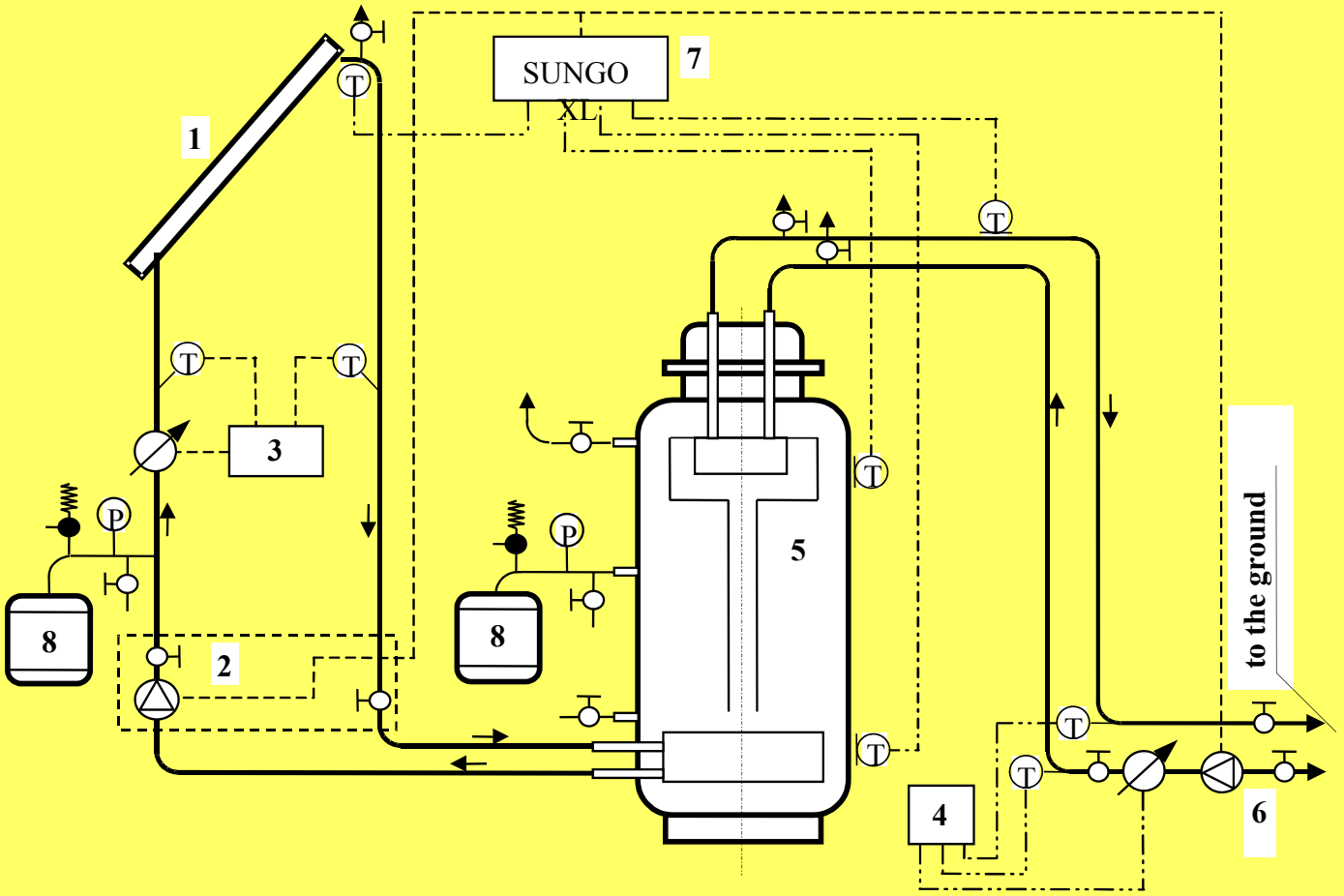

PC

SOLAR INSTALLATION

Solar collectors installation consists of :

- sun collectors manufactured by Wagner type LB76 (absorber area 7,6 m^2),
- water storage tank type Centro 500, capacity 0,5 m^3,
- pump station, type Cirko 3,
- control system ,type SunGo XL.

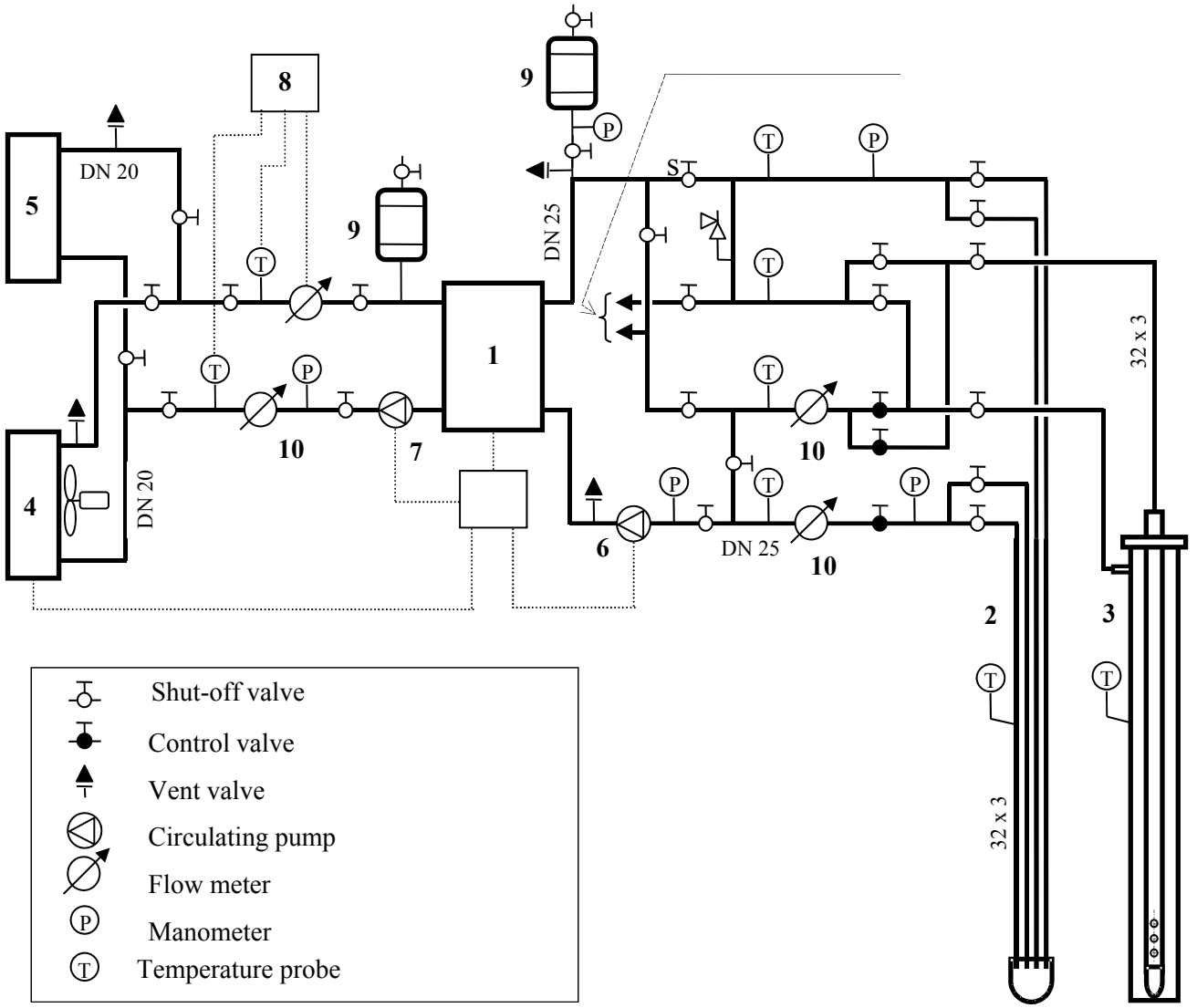
Solar installation



Solar thermal collectors installation

1.Flat plate collector, 2.Pump station, 3.4.Heat flow meter 5.Storage 6.Circulation pump, 7.Control and measurement device, 8.Compensation tank.

BOREHOLE HEAT EXCHANGERS AND HEAT PUMP INSTALLATION



Heat pump

Storage tank, pump station and regulation of operating parameters in the system

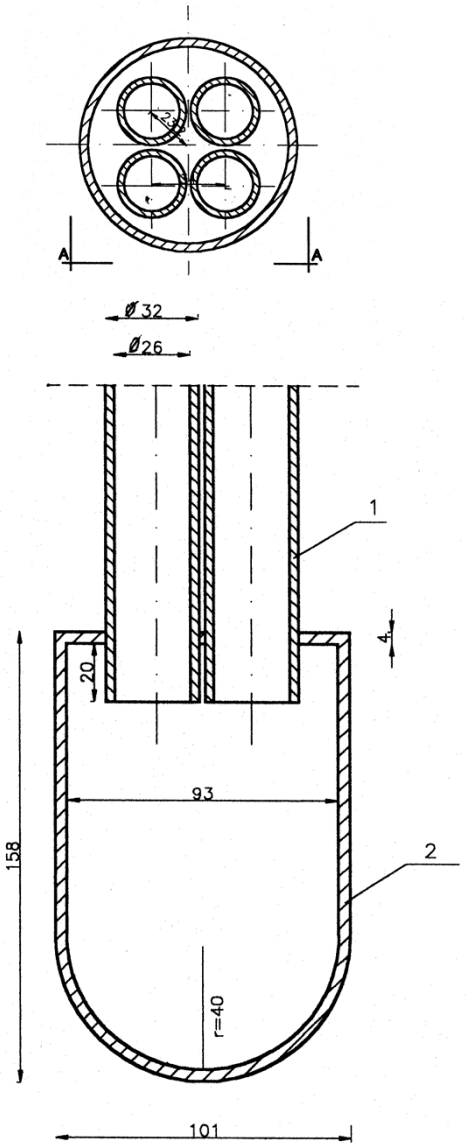
TECHNICAL DATA OF HEAT PUMP

- Manufactured by: Banze-Wärmepumpen,
- type – compression,
- heat power - 11 kW,
- medium - R22.

BOREHOLE HEAT EXCHANGER

- Distance between probes - 5 m,
- Medium: water - glycol mixture,
- Circulation pump Grundfos type CH-4-20,
- System of valves.

U-pipe probe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A
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1
4
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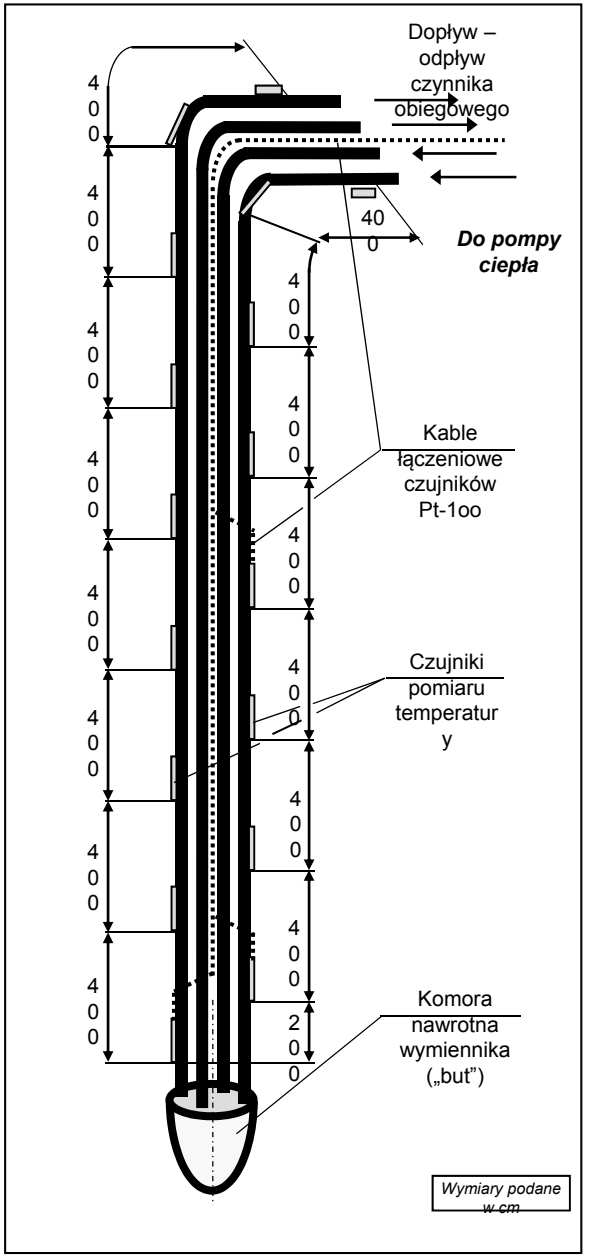
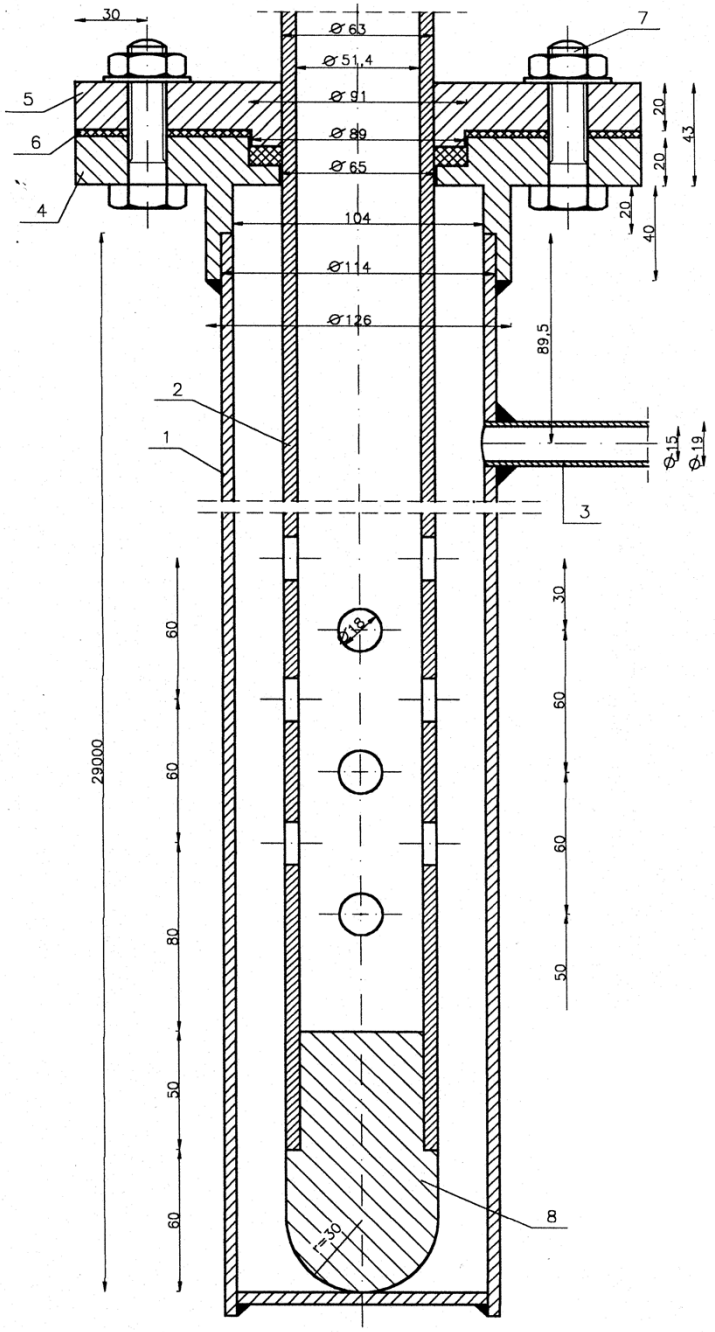
93
158
2
r=40
101


Dopływ – odpływ czynnika obiegowego
Do pompy ciepła
Kable łączeniowe czujników Pt-1oo
Czujniki pomiaru temperatur y
Komora nawrotna wymiennika („but”)
Wymiary podane w cm

U-PIPE PROBE

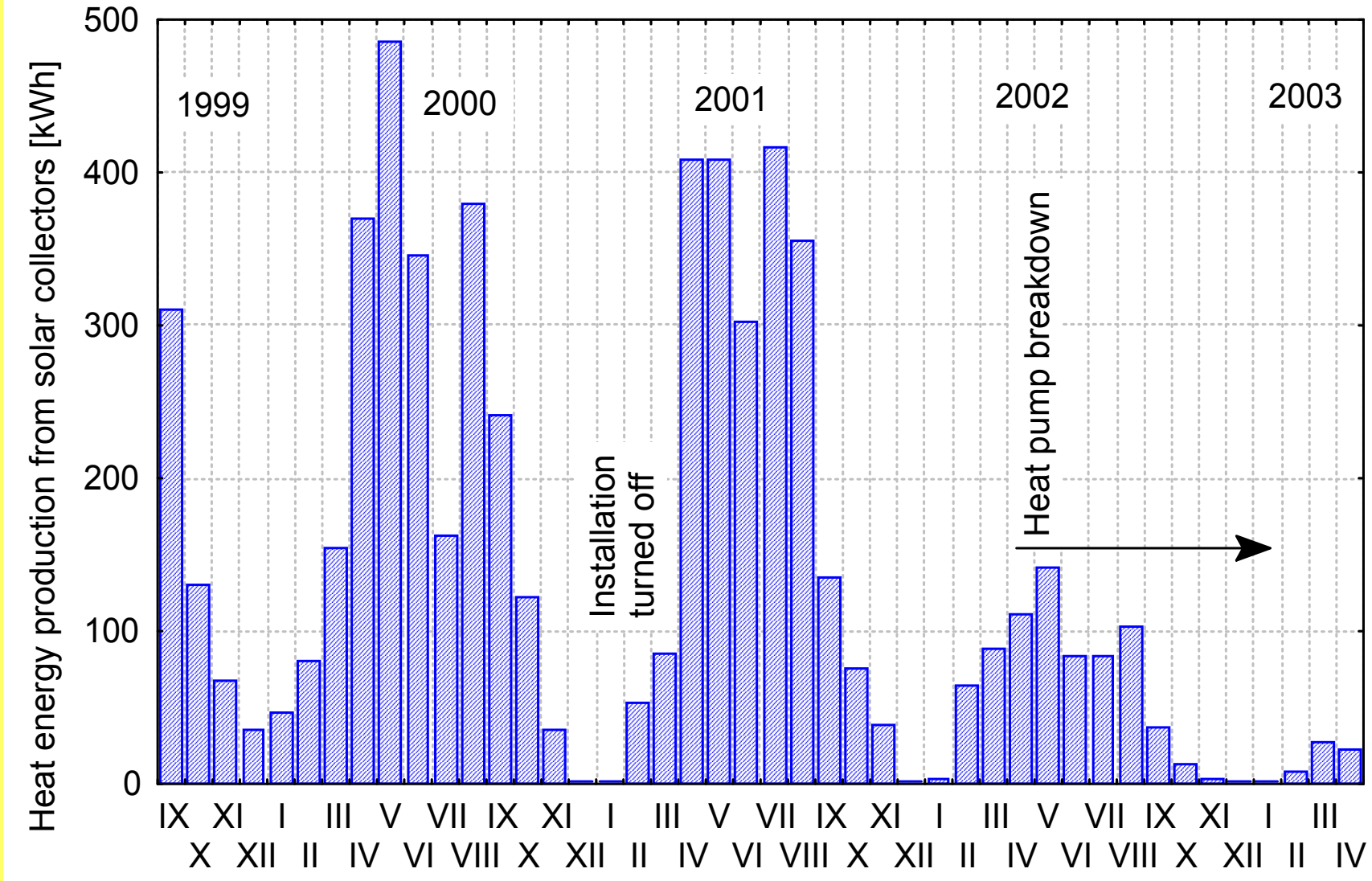
- Length of probe ~30 m,
- Material – PE,
- Outside pipe diameter -32 mm,
- Wall pipe thickness - 3 mm,
- Probe consists of 4 parallel pipes,
- Dimensions of probe ending – inside diameter 94 mm, wall thickness 4 mm, length 150 mm,
- Connection to heat pump – 4 PE pipes of outside diameter -32 mm.



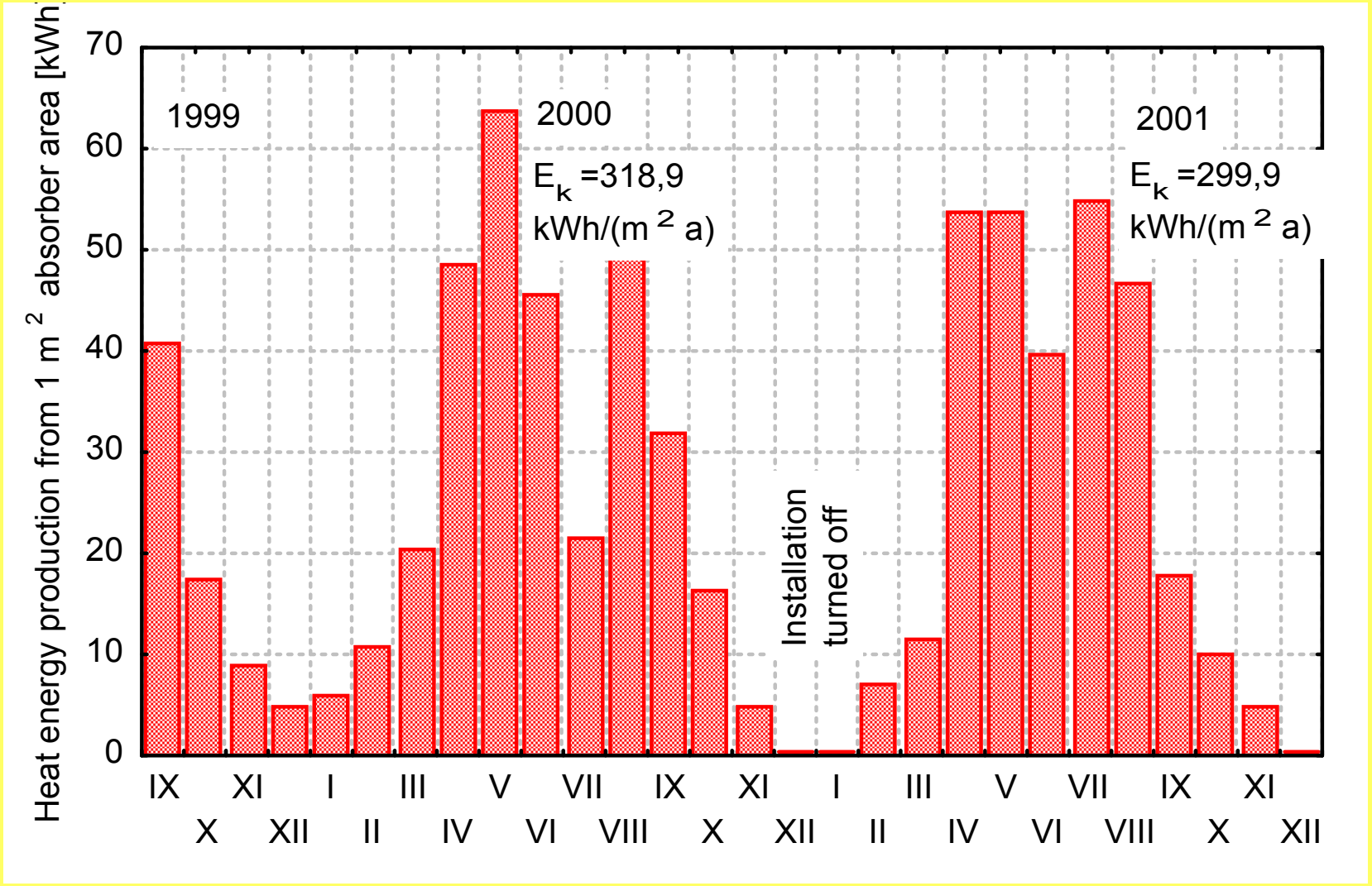
Field exchanger

CONCENTRIC DOUBLE – PIPE HEAT EXCHANGER

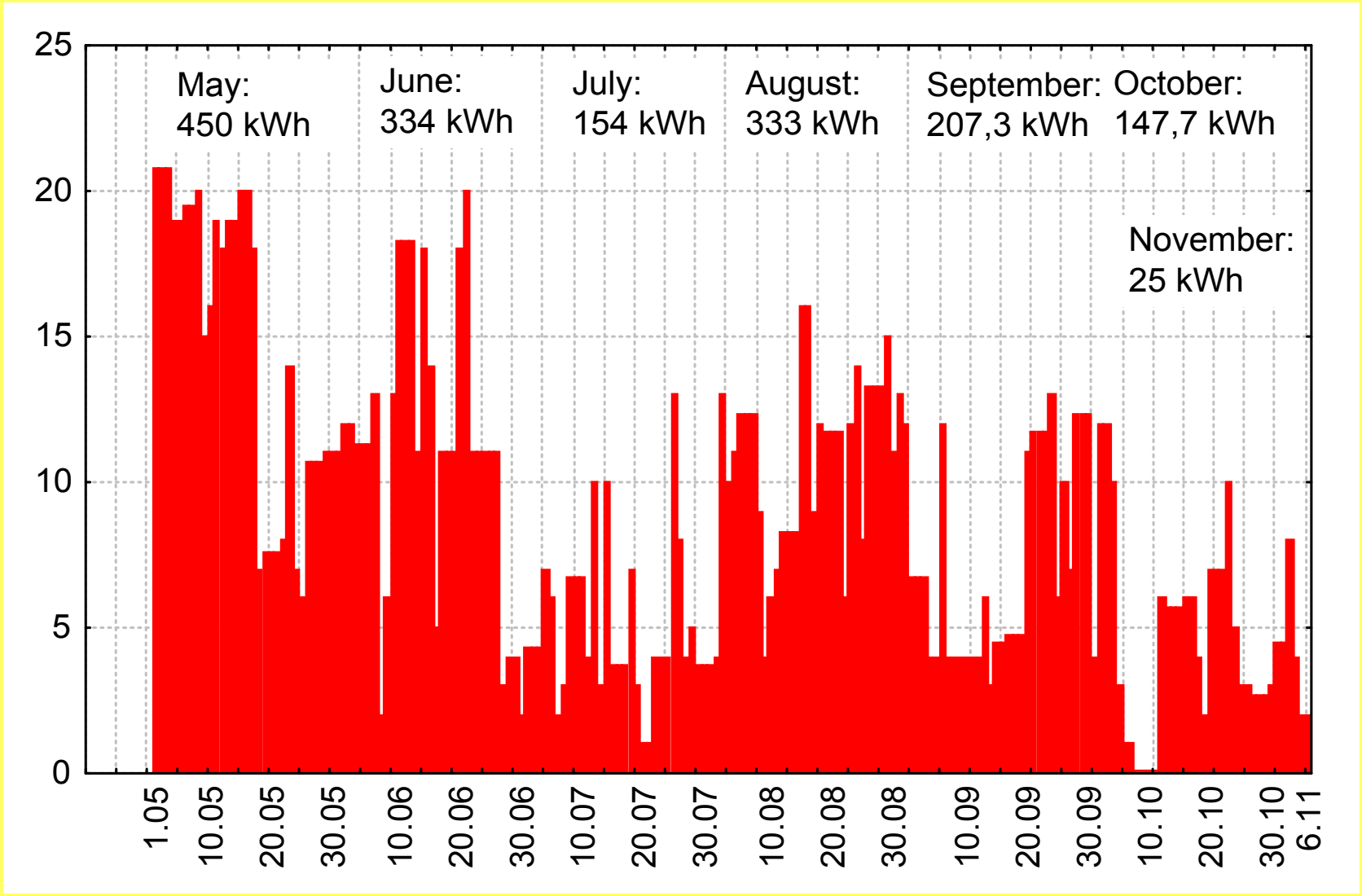
- Length of probe - ~29 m
- Material of the outside pipe - steel
- Steel pipe diameter - 114 mm
- Wall steel pipe thickness - 5 mm
- Material of internal pipe - PE
- PE pipe diameter - 63 mm
- Wall PE pipe thickness - 5,8 mm
- The end of internal pipe is blanked
- There are 12 holes in end of inside pipe
- Hole diameter - 18 mm
- Connection to heat pump – 4 PE pipes of outside diameter - 32 mm



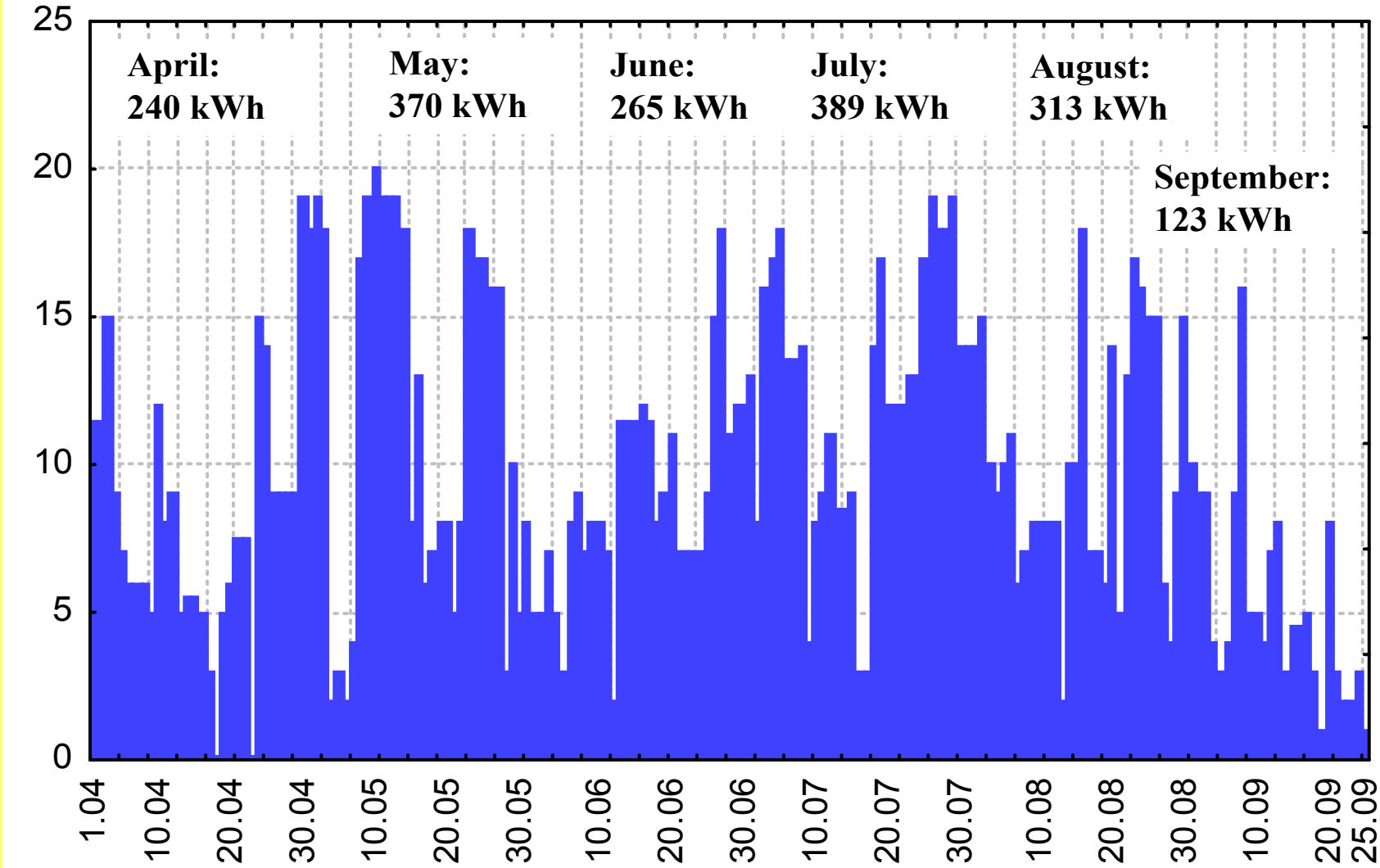
Monthly production of heat energy from solar collectors array
7,6m^2 – 2423,7 kWh



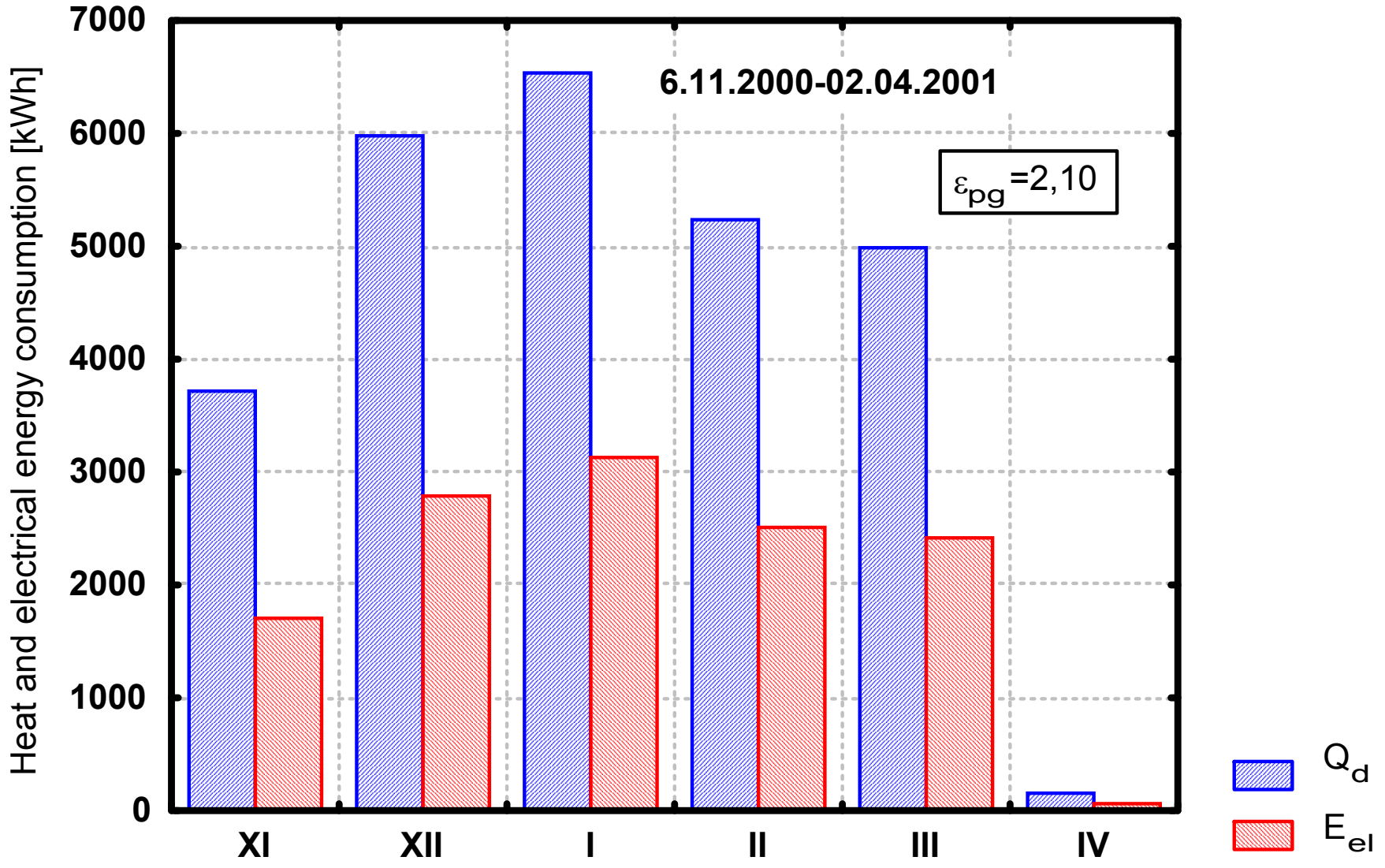
Monthly production of heat energy from 1 m^2 absorber area of solar collector (318,9 kWh/m^2 a)



Heat energy delivered to the ground in year 2000
1651 kWh, (217,2 kWh/m^2 a)

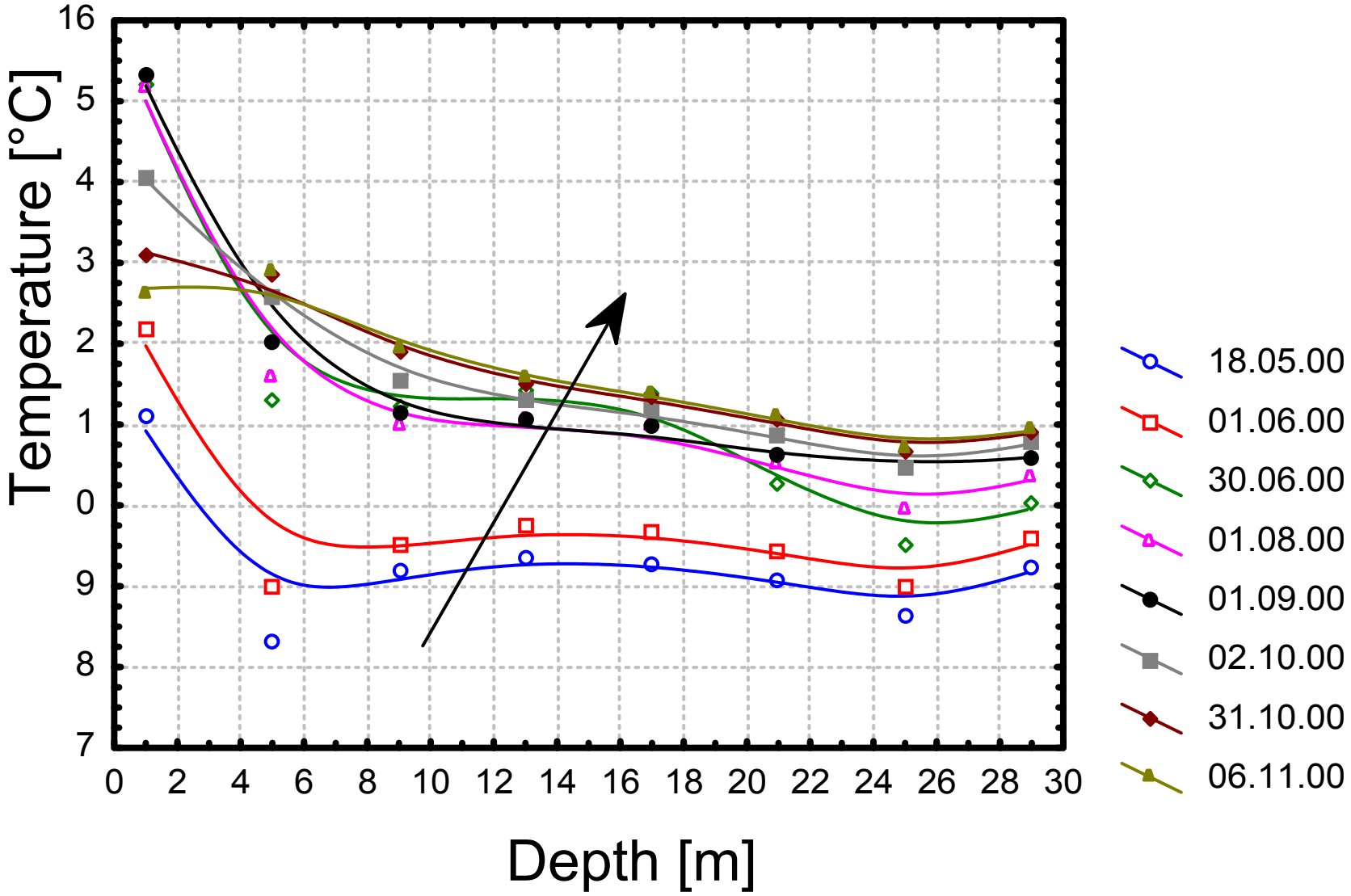


Heat energy delivered to the ground in a year 2001
1700 kWh, (223,7 kWh/m^2 a)

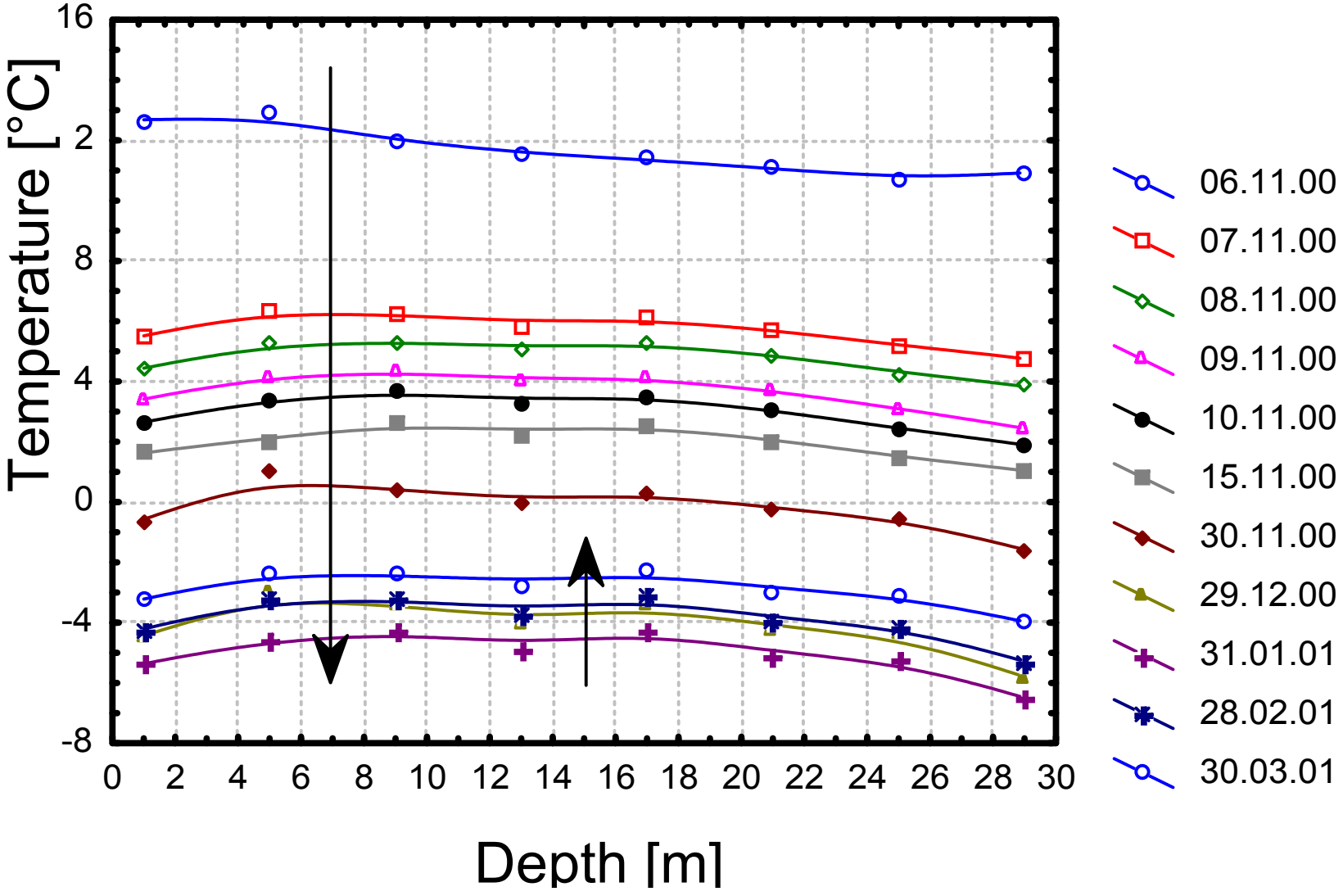


Heat energy transferred to interior heating system by heat pump and total electrical energy consumption

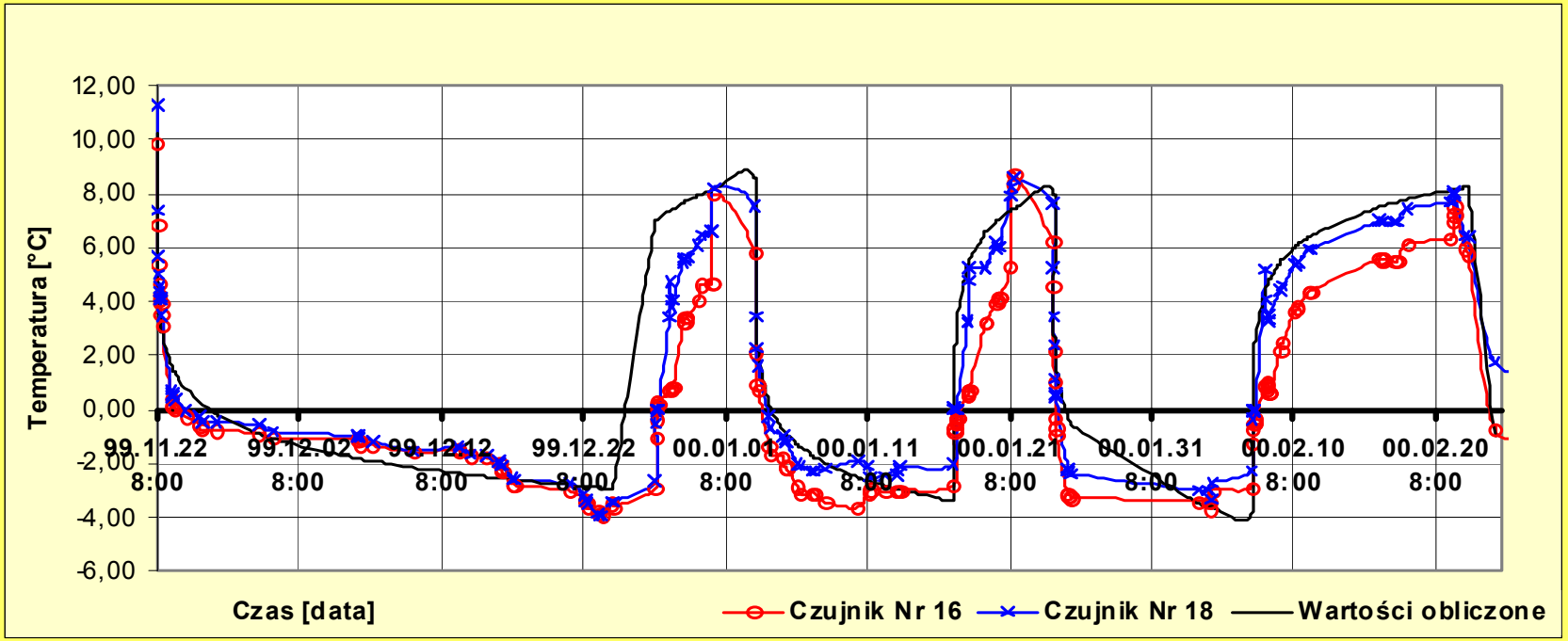
- Heat energy transferred to interior heating system by heat pump
  – 26585,8 kWh
- Total electrical energy consumption by heat pump
  – 12661,0 kWh
- Energy transferred to the ground in 2000
  – 1651,0 kWh
- Energy transferred to the ground in 2001
  – 1700,0 kWh

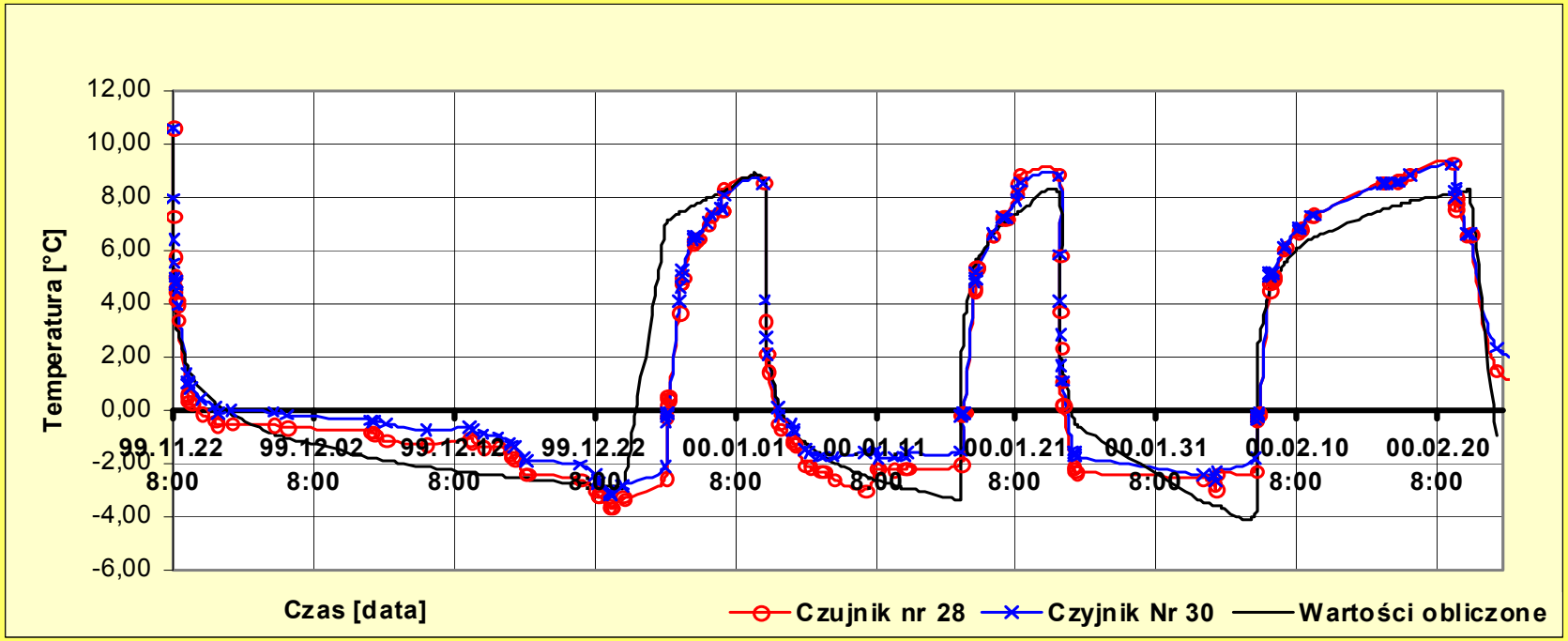


Temperature distribution in the ground Summer 2000



Temperature distribution in the ground during heating season 2000-2001


12,00
10,00
8,00
6,00
4,00
2,00
0,00
-2,00
-4,00
-6,00
Temperatura [°C]
99.11.22 8:00
99.12.02 8:00
99.12.12 8:00
99.12.22 8:00
00.01.01 8:00
00.01.11 8:00
00.01.21 8:00
00.01.31 8:00
00.02.10 8:00
00.02.20 8:00
Czas [data]
Czujnik Nr 16
Czujnik Nr 18
Wartości obliczone


12,00
10,00
8,00
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-2,00
-4,00
-6,00
Temperatura [°C]
99.11.22 8:00
99.12.02 8:00
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Czujnik nr 28
Czyjnik Nr 30
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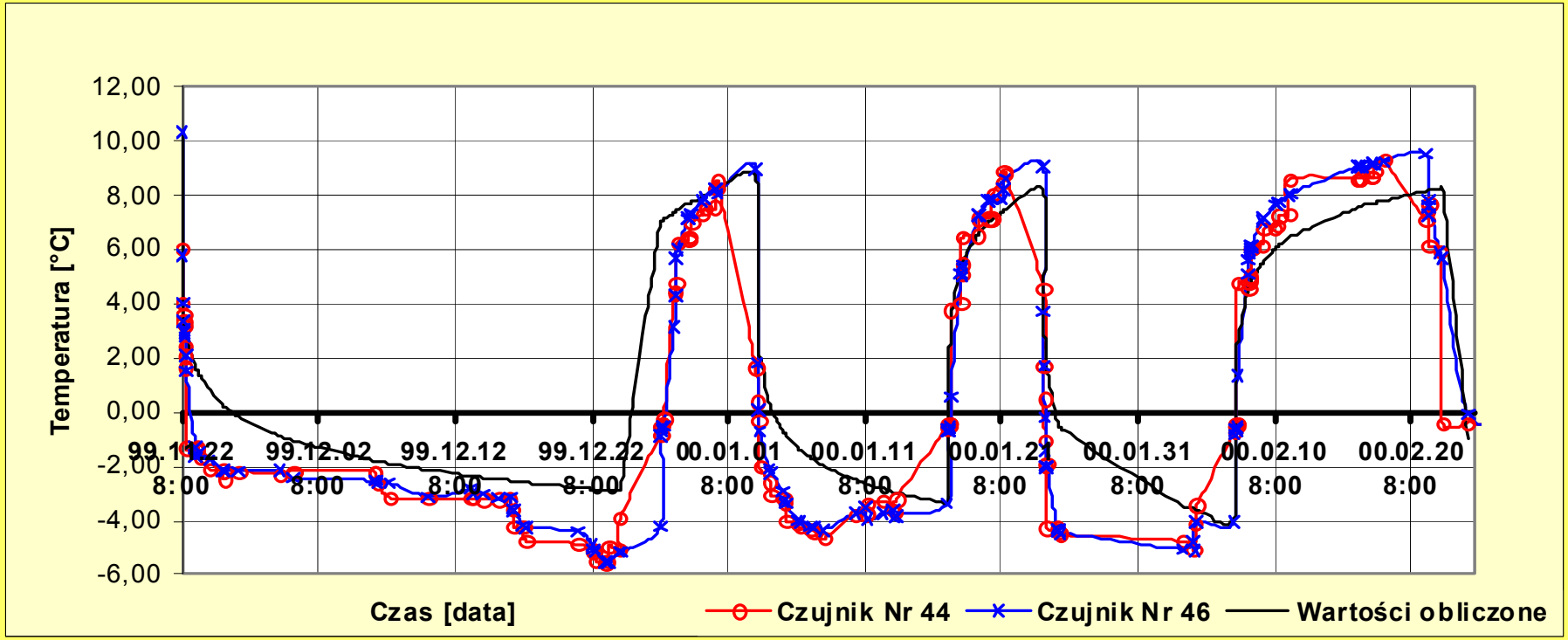
12,00
10,00
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Temperatura [°C]
99.12.22 8:00
99.12.02 8:00
99.12.12 8:00
99.12.22 8:00
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00.01.21 8:00
00.01.31 8:00
00.02.10 8:00
00.02.20 8:00
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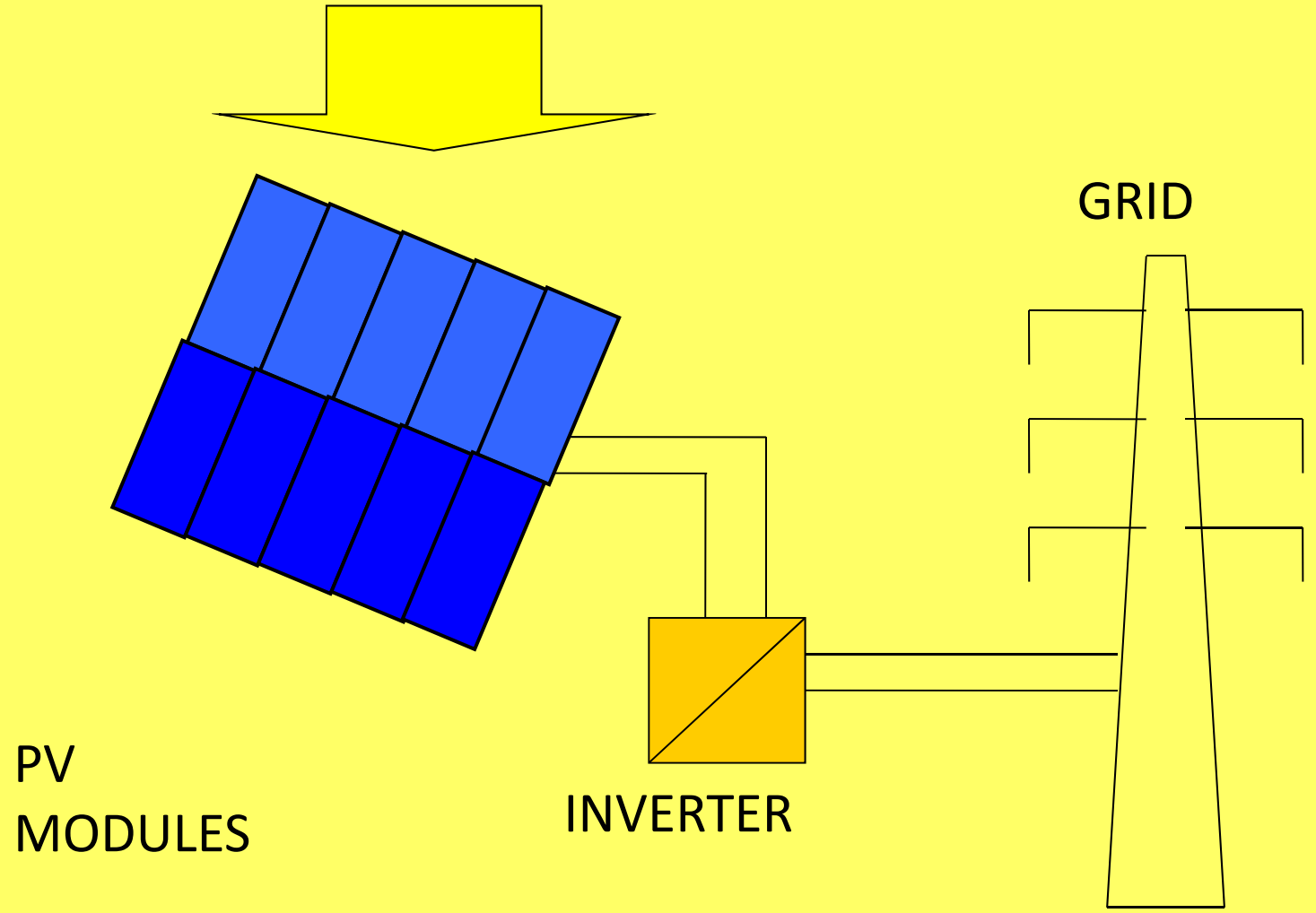
Czujnik Nr 44
Czujnik Nr 46
Wartości obliczone

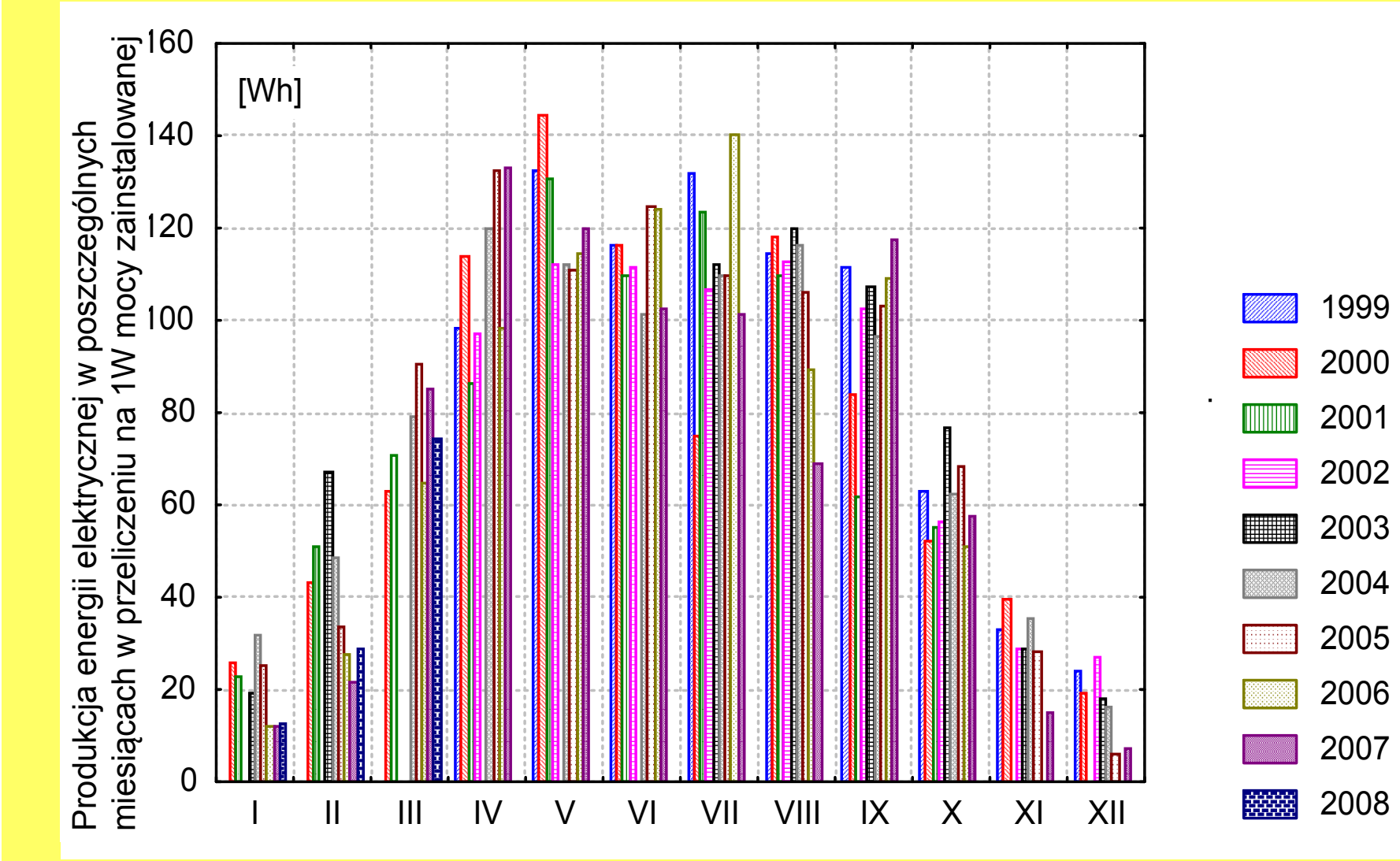
CONCLUSIONS

- For Szczecin (and its environs) an annual production of heat energy from 1m^2 flat plate collector absorber area is 300–320 kWh,
- A proper selection of heat pump and total length of boreholes heat exchangers are essential for exploitation and efficiency of the system,
- Sun energy storage in summer time is favourable for bed recovery before next heating season.

PV INSTALLATION



Grid connected PV system at West Pomeranian University of Technology, Szczecin


Produkcja energii elektrycznej w poszczególnych miesiącach w przeliczeniu na 1W mocy zainstalowanej
[Wh]
160
140
120
100
80
60
40
20
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I
II
III
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IX
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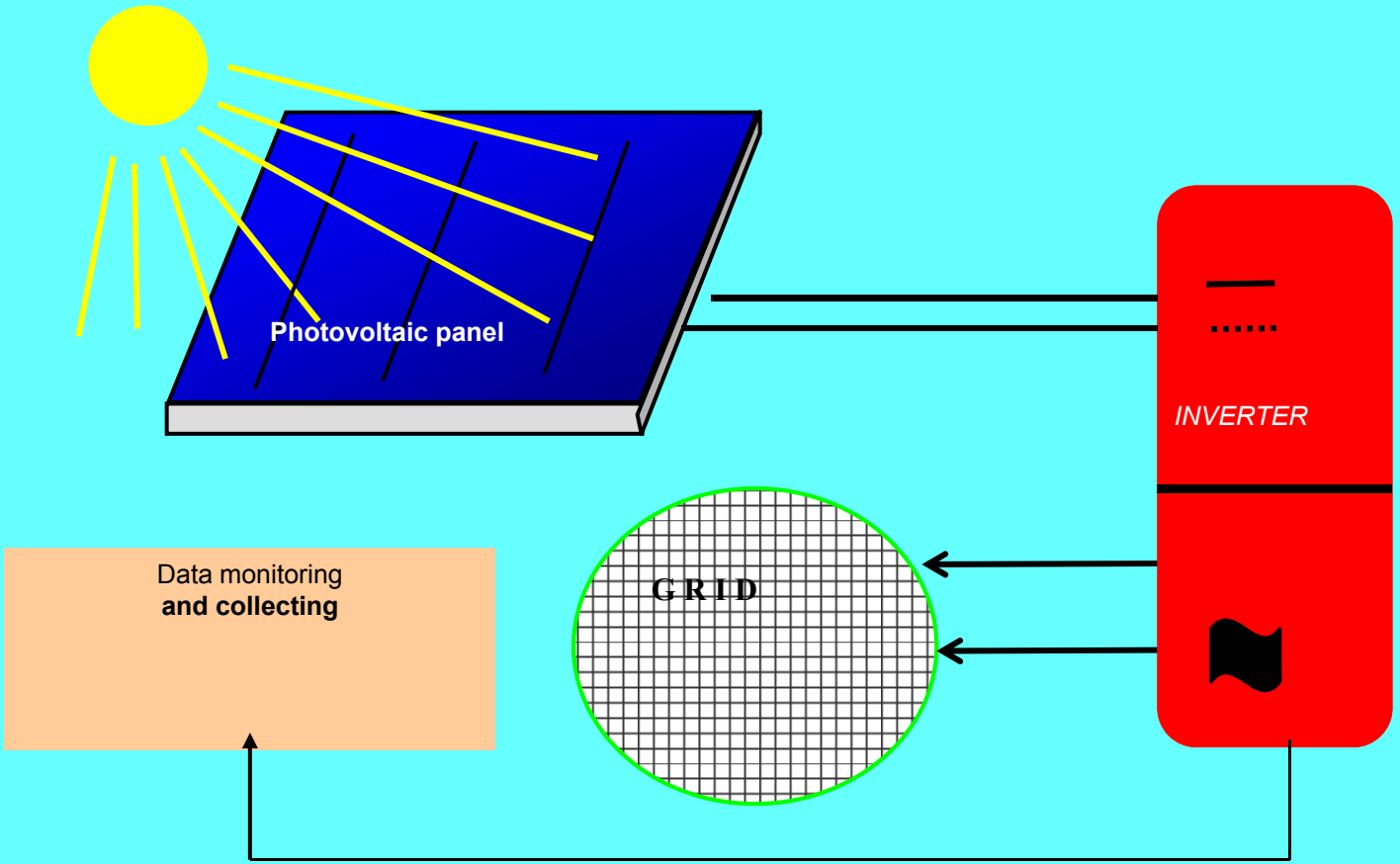
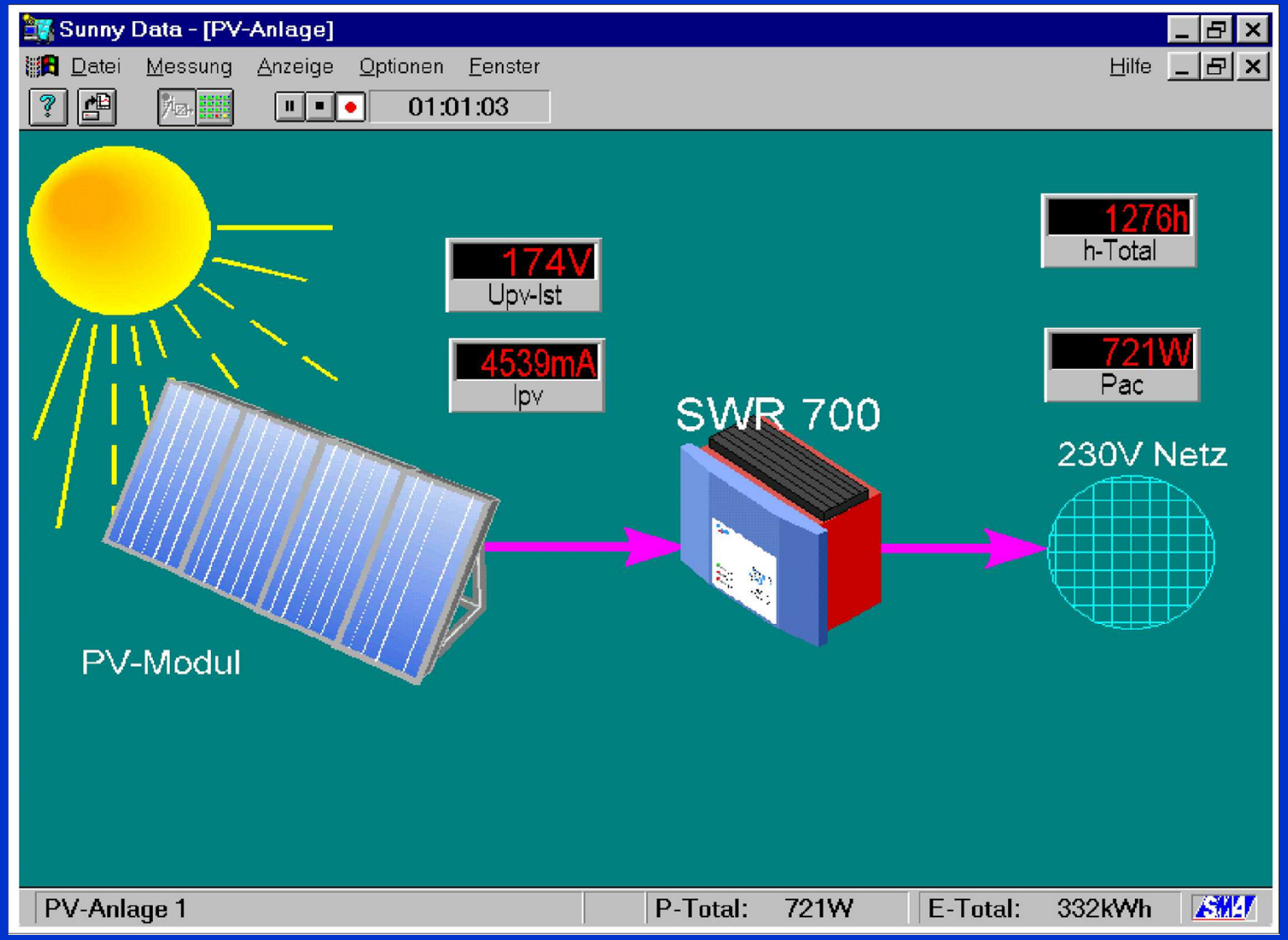


Grid connected PV system
at West Pomeranian University of Technology



„Sunny Data” main window

PV SYSTEM AT HEAT ENGINEERING DEPARTMENT

- 10 solar modules of the type M110 (Siemens),
- Total power of PV system 1100 $W_{p,}$
- Location: direction S, inclination: 44°

Technical parameters of solar module type M110 (Siemens)

Solar module	Value	Unit
Maximum power [PMAX]	110	W
Open circuit voltage [UOC]	43,5	V
Short-circuit current [ISC]	3,45	A
MPP voltage [UMPP]	35,0	V
MPP current [AMPP]	3,15	A
Length/width [l/w]	1307/652	mm
Weight [m]	9,5	kg

Source:www.siemens.de

Inverter of the type

Sunny-Boy SWR 850

METEOROLOGICAL STATION IN DHE

View of the station

PARAMETERS MEASURED BY THE METEOROLOGICAL STATION

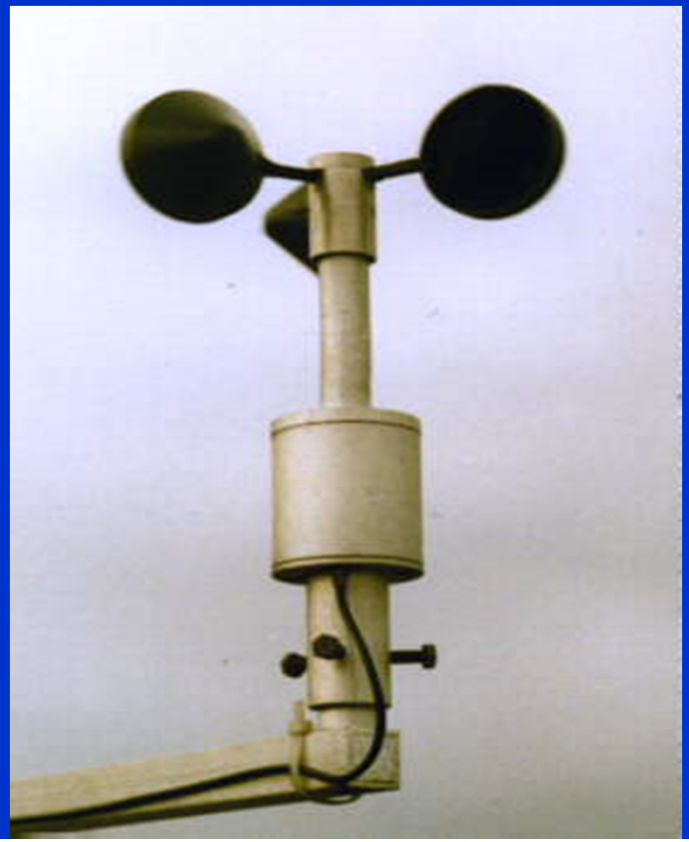
- direct and diffuse solar radiation,
- pressure, temperature and relative humidity of air,
- power and direction of the wind,
- PV module surface temperature.

METEOROLOGICAL STATION IN DHE

View of the station

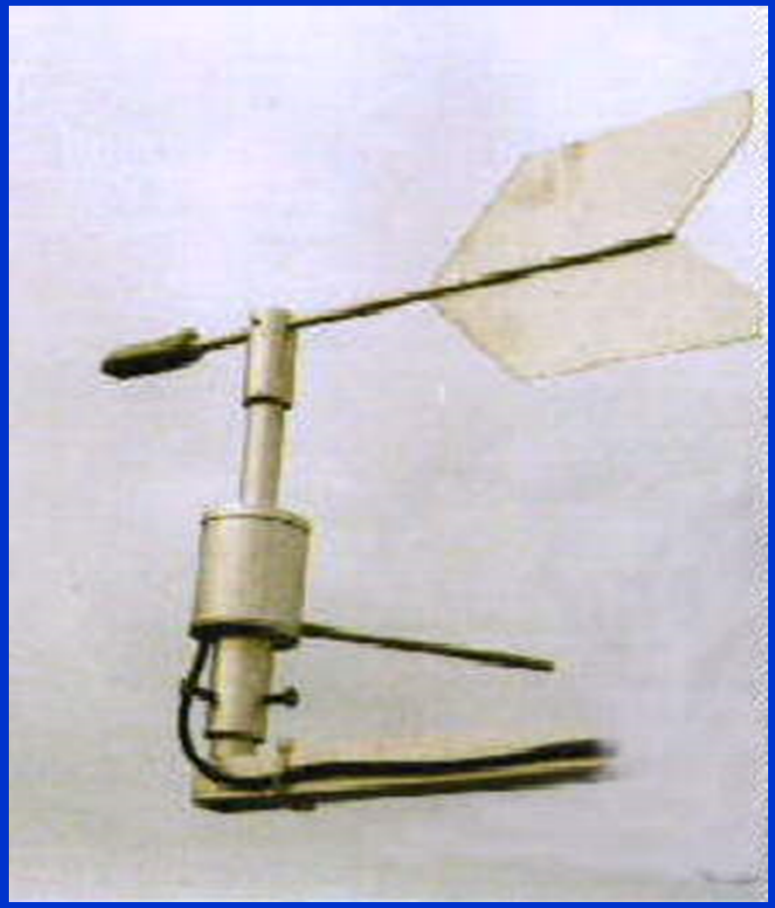
WIND VELOCITY SENSOR

- Measuring range : v = 0 – 50 m/s
- Accuracy: discrimination threshold v =0,5 m/s
- Impulse output 20 imp/s = 1 m/s



WIND DIRECTION SENSOR

- Resolution - 11,5°
- Accuracy -discrimination threshold 0,5 m/s



SENSORS OF SOLAR RADIATION

View of sensor and the shadow ring

SENSORS OF SOLAR RADIATION

- Pyranometrs CM11 produced by Kipp&Zonen according to the ISO 9060/WMO standards
- Secondary standard, high quality
- Spectral range (50% points) - 305 – 2800 nm
- Sensivity - 4 – 6 μV/W/m
- Response time (95%) - 12 s

SENSORS OF SOLAR RADIATION

- Zero offsets:

  thermal radiation (200 W/m^2) – ± 7 W/m^2

  temperature change (5 K/h): ± 2 W/m^2
- Non stability (change/year): ± 0,5%
- Non linearity (0-1000 W/m^2): ± 0,6%
- Directional error (at 1000 W/m^2): ± 10 W/m^2
- Temperature dependence of sensitivity: ± 1% (-10 - +40°C)
- Tilt response (at 1000 W/m^2): ± 0,2%

ATMOSPHERIC PRESSURE SENSOR

- Measuring range: 850 –1100 hPa
- Accuracy: 1 hPa
- Resolution: 0,1 hPa

RELATIVE AIR HUMIDITY SENSOR

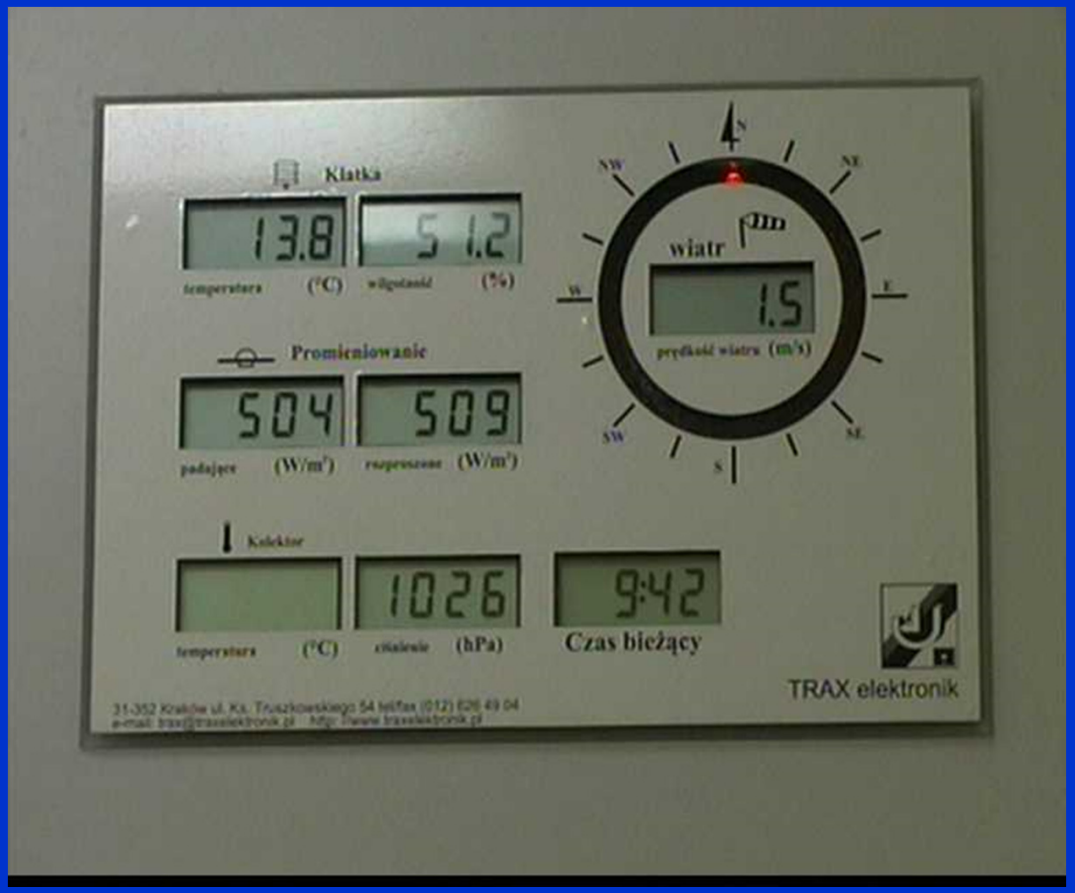
- Measuring range: 30 –98%
- Accuracy:

  2% in range 30-85%

  3% in range 85-98%
- Resolution - 0,1%

RECORDER TYPE RC12

- Measurement period 2-60 min
- RS connection directly to computer



Training and Research Center for Renewable Energy Sources - Ostoja

FORMER IN STRUCTURE OF AGRICULTURAL UNIVERSITY

SINCE 2009 IN STRUCTURE OF

WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN

- In November of 2008, two off-grid PV installations were set in operation in Training and Research Center for Renewable Energy Sources in Ostoja (suburb of Szczecin).

- The installations were financially supported from European Regional Development Funds within the INTERREG PROGRAMME IIIA Poland (West Pomeranian Voivodeship –Meklemburg Vorpommern/Brandenburg).

6 mono-crystalline PV modules of the STP 180S-24/Ac type, produced by Suntech Power.

12 thin CIS layer, PV modules of the type SCG50 HV, produced by Sulfurcell.

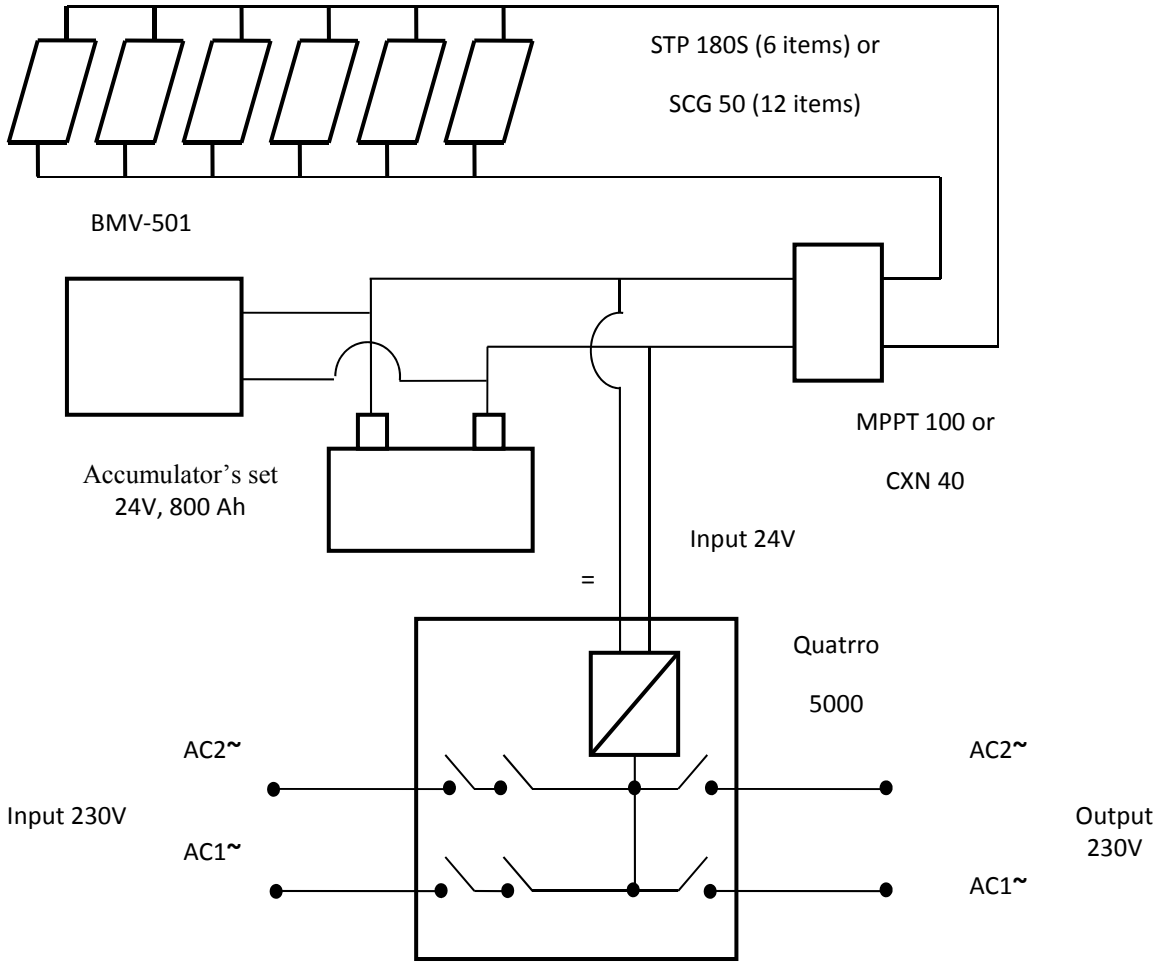


Fig. 1. Scheme of PV installations in Ostoja center

Fig. 2. View of mono-crystalline panel
(photo D.Szyszka)

Fig.3. View of CIS panel (photo D.Szyszka)

Fig. 4. View of accumulators' set, inverter and control charging device
(photo D.Szyszka)

Installations in the Center in Ostoja are free-standing, of off-grid type, and they differ from each other by applied photovoltaic cells that form modules .

First of the installations consists of 6 mono-crystalline PV modules of the STP 180S-24/Ac type, produced by Suntech Power.
The latter one is equipped with 12 thin CIS layer, PV modules of the type SCG50 – HV, produced by Sulfurcell.

In both cases, the panels are mounted on movable frameworks, the so called trackers.

Table 1. Technical data of PV panels and modules

Parameter	Unit	Value	
Module		STP 180S-24/Ac	SCG50 - HV
Number of cells in module	items	72	80
Maximal power	W_p	180	50
Guaranteed minimal power	W_p	174,6	47,5
Open circuit voltage	V	44,8	50
Short circuit current	A	5,3	1,65
Voltage at maximum power (in MPP point)	V	36	37,5
Current at maximum power (in MPP point)	A	5	1,35
Temperature coefficient of short circuit current	A/K %/K	0,06	0,04
Temperature coefficient of open circuit voltage	V/K mV/K	-155	-130
Temperature coefficient of power	%/K	-0,5	-0,3
Length/Width	m	1,580/0,808	1,256/0656
Area of module	m^2	1,277	0,824
Mass	kg	16	13,7
Panel			
Number of modules in panel	items	6	12
Panel's power	W_p	1080	600
Area of panel	m^2	7,662	9,888

Parameter	Unit	Sunny-Boy SWR 850	Quattro 24/5000/120
Nominal power	W	850	5000
Input voltage	V	125-250 DC	180-265 AC 19-33 DC
Output voltage	V	196-253	210-245
Frequency	Hz	49,8-50,2	50
Maximal efficiency	%	>93	94
Height	m	0,090	0,444
Width	m	0,322	0,328
Length	m	0,180	0,240
Masse	kg	18,5	30
Recommended capacity of accumulators set	Ah	-	400-1400

- Direct current produced in PV installation is used to charge the set of solar accumulators, or it is transferred directly by the inverter of the type Quattro 5000. There, the current is converted into alternating current.

- Optimal working conditions for the direct current installations are provided by charging regulators of the type MPPT 100/20-1 (for mono-crystalline modules) and CXN 40 (for CIS modules).

- Monitoring of parameters of accumulator sets for each PV installation is carried on by means of BMV-501 units. Each set of accumulators consists of 12 batteries and the voltage rating for each one equals 24V. Capacity of the sets equals 800 Ah.

•PV installation with CIS modules supply 2 lamps with total power of 150 W, whereas the PV installation with mono-crystalline modules supplies 2 lamps with total power of 300W.

•Lighting in the property is switched on automatically by a dusk sensor.

Table 1. Specification of amount of produced and consumed electric energy in the period from October till December 2009

	PV installation with CIS modules		PV installation with mono-crystalline modules	
Month /Unit	Electric power production	Electric power consumption	Electric power production	Electric power consumption
	[kWh]	[kWh]	[kWh]	[kWh]
October	35,51	61,09	55,24	132,76
November	19,40	51,10	32,36	165,82
December	10,18	77,57	9,36	198,55
Total	65,09	189,76	96,95	497,13
Average of month	21,70	63,25	32,32	165,71

THANK YOU FOR YOUR ATTENTION