WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN , POLAND

WIMiM

THE FACULTY OF MECHANICAL ENGINEERING AND MECHATRONICS

Department of Heat Engineering

Anna Majchrzycka, Tadeusz Kozak

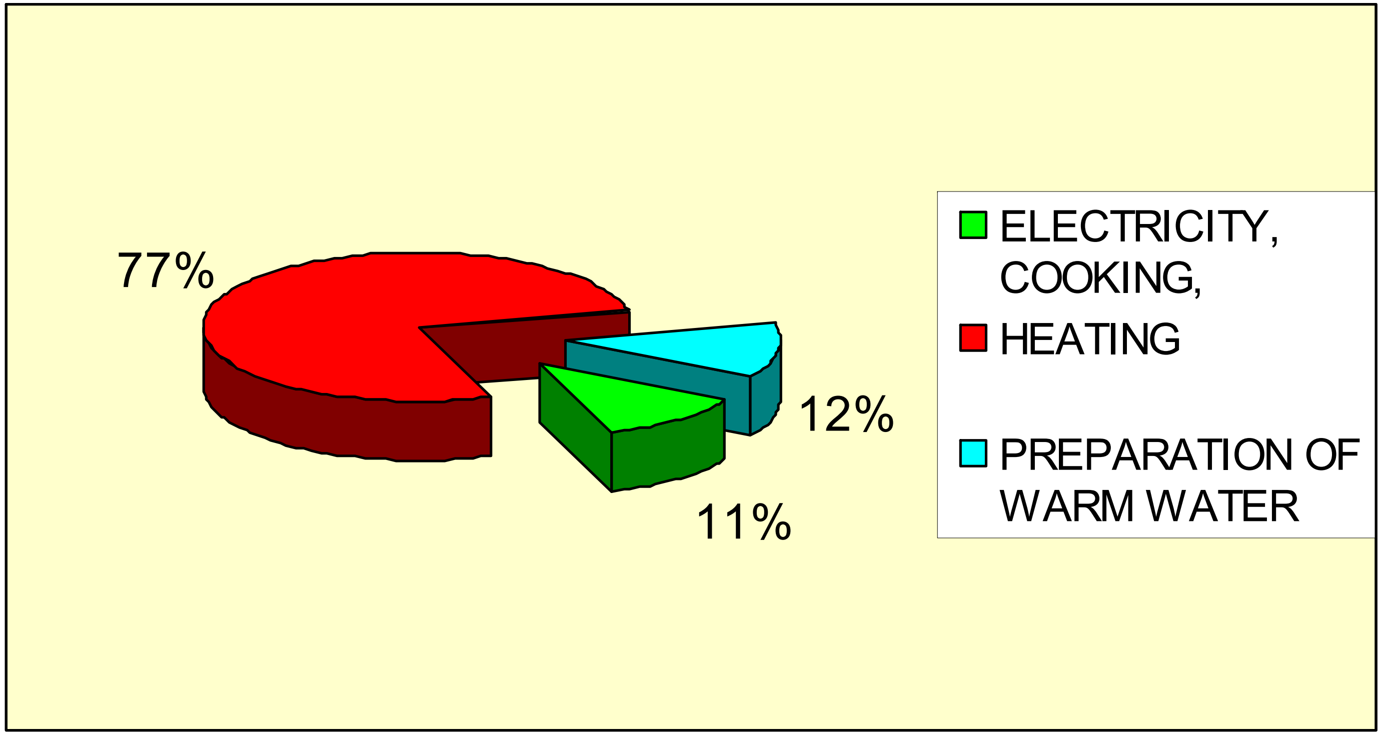
APPLICATION OF RENEWABLE SOURCES OF ENERGY FOR HEATING AND PREPARATION OF WARM WATER IN AN INDIVIDUAL HOUSE.

4.02.2011 UE Summit Meeting

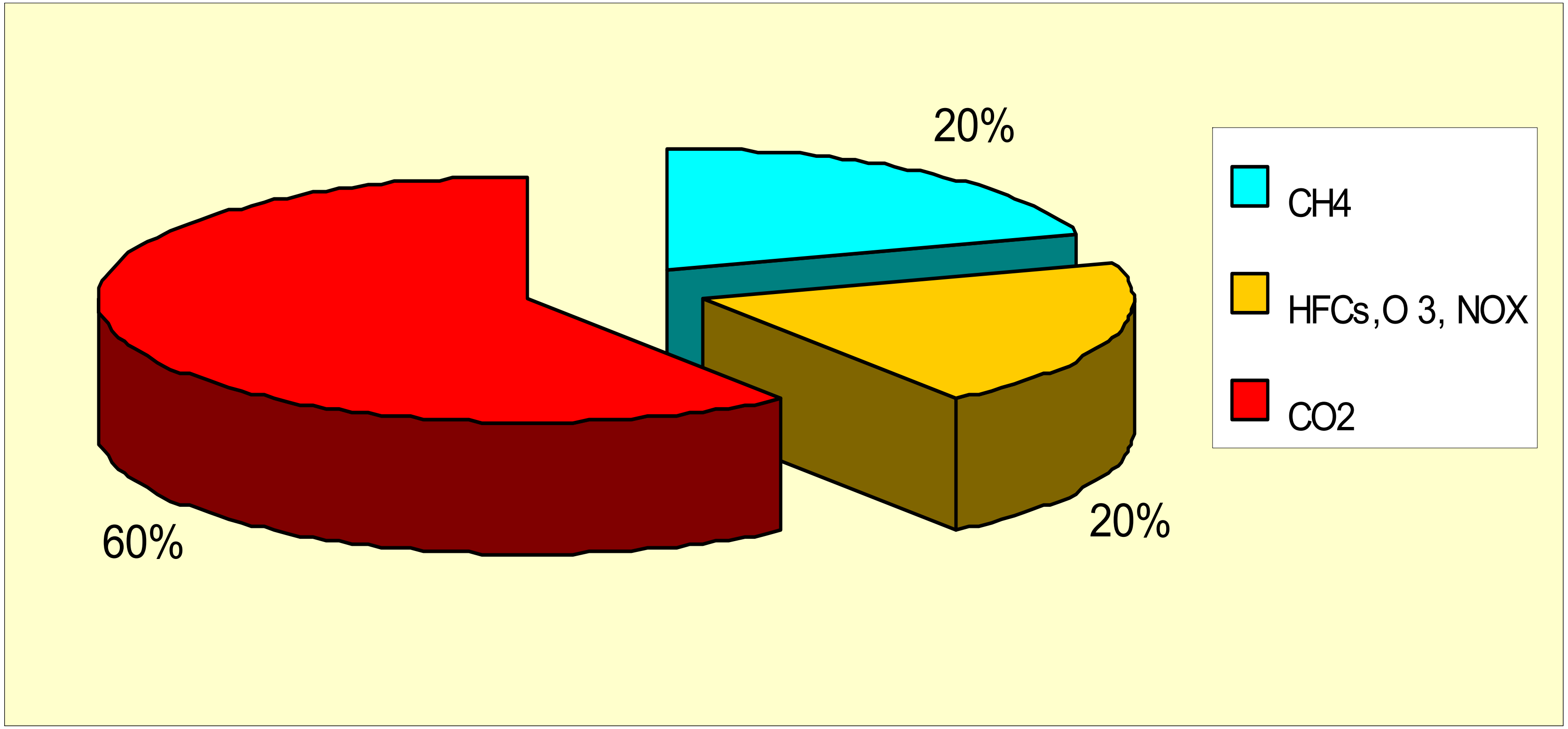
- Till 2015 EU energy market should be built
- **Guenther Oettinger –responsible for energy market**

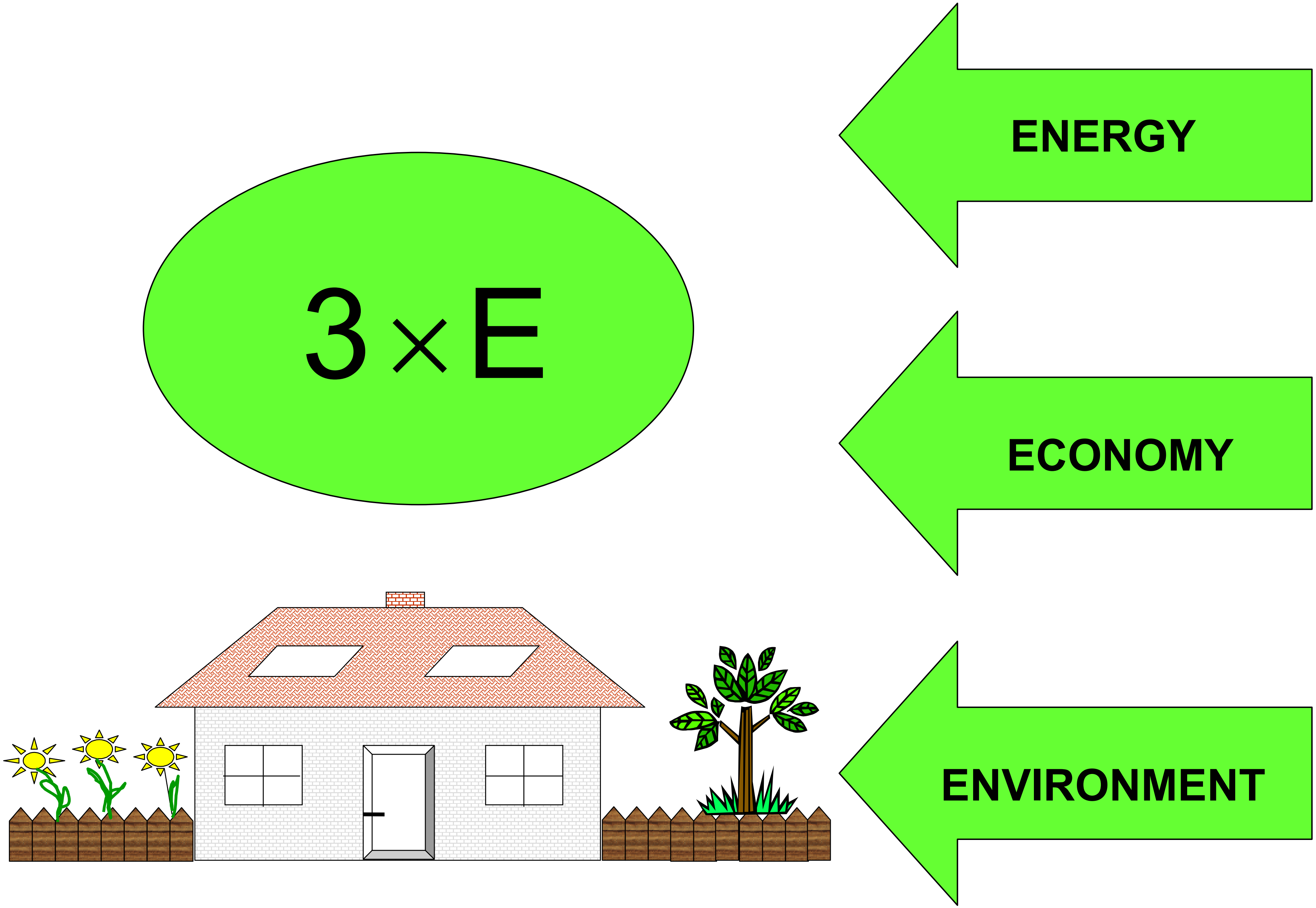
...,, to fulfill the main target i.e. 20% share for RES capital costs will be increased to 70 mld €/year,

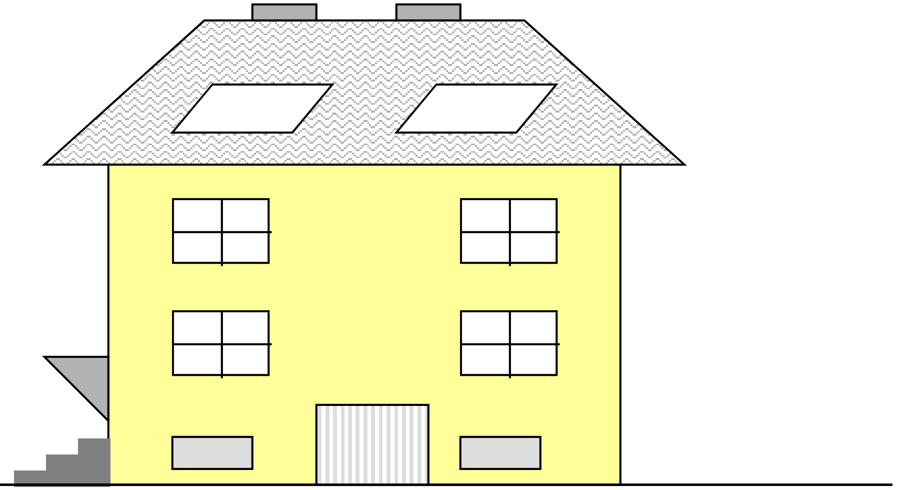
- energy companies and households should be strongly involved in that activity
- **There will be strong financial support from EU**



www.medsonspartec.pl/srodowisko.php


20%
20%
60%
CH4
HFCs, O 3, NOX
CO2


3×E
ENERGY
ECONOMY
ENVIRONMENT



t_e = - 16 °C

- Building with cellar,2 –floor detached house with the loft .
- Usable area A_u=133,85 m^2
- Cubature V=319 m^3

House heating-gas boiler

Preparation of warm water – 2 gas heaters

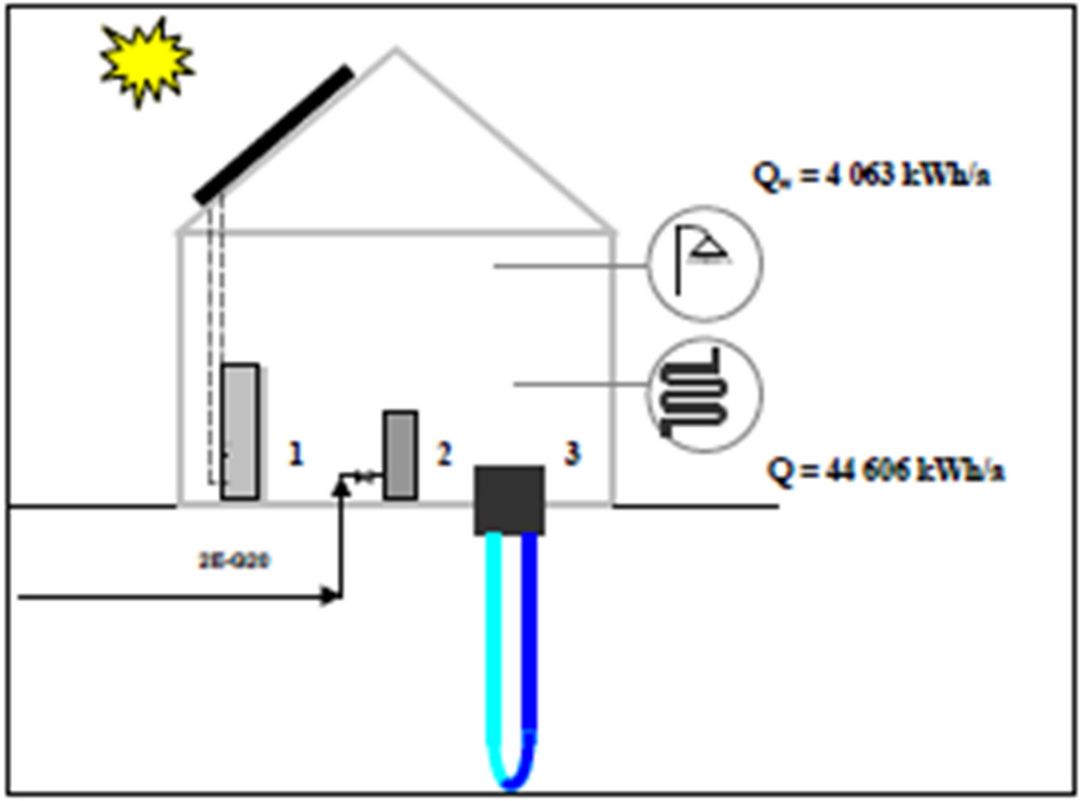


Fig.1 Scheme of the systems for house and water water heating: 1- thermal solar collectors , 2-gas boiler, 3-ground heat pump

Assumption

- I climatic zone , t_z=-16^oC,
- n = 4 habitants
- warm water consumption V= 60 l/24 hours capita
- cold water temparature t_{zw}=15 ^oC,
- warm water temperature t_{cw}=55 ^oC,

Systems of house heating and warm water preparation:

- gas boiler 2E-G20

- gas boiler + solar collectors

- gas boiler and heat pump with the ground heat exchanger

- gas boiler and heat pump with the ground heat exchanger and solar collectors

ENERGY DEMAND FOR HOUSE HEATING

Energy demand for house heating was determined according to Polish Standards from the following equation:

$$Q_d = \frac{Q \cdot S_d \cdot 24}{t_e - t_i}$$

where:

Q_d – heating demand , kWh/a,

Q - thermal power demand kW,

S_d -the number of degree days

t_e - mean internal temperature ,

t_i - mean outer temperature

$S_d = 3781$, $t_i = 20\ ^0C$, $t_e = -\ 16\ ^0C$.

The number of degree-days was calculated from the following equation:

$$S_d = \sum_{i=1}^{n} n \cdot (t_i - t_e)$$

n - number of days when heating is required

t_e - mean internal temperature

t_i -mean outer temperature

$t_i = 20\ ^0C$, $t_e = -\ 16\ ^0C$.

WATER CONSUMPTION IN 24 HOURS

$$G_{cwu} = n \cdot q_{śr}$$

where:

n - the number of inhabitants

$q_{śr}$ – mean twenty-four hours water demand per capita ,

$q_{śr}=60 \left[\frac{kg}{capita}\right]$

ENERGY DEMAND FOR PREPARATION OF THE WARM WATER

Twenty-four hours demand for energy necessary for preparing of the warm water is calculated from equation:

$$q_{cwu} = \frac{G_{cwu} \cdot C_{cwu} \cdot (t_{cw} - t_{zw})}{3600},$$

where:

q_{cwu}- twenty-four hours demand for energy necessary for preparing of the warm water, $\left[\frac{kWh}{d}\right]$

C_{cwu} -specific heat of water $C_{cwu} = 4,19\left[\frac{kJ}{kgK}\right]$;

t_{cw} - the temperature of the warm water, t_{cw} = 55 [ºC];

t_{zw} - the temperature of the cold water, t_{zw} = 15 [ºC];

G_{cwu} - twenty-four hours water consumption (4 persons) [kg].

- Total thermal power demand:

$$\dot{Q} = 7,77 kW$$

- Annaual heating demand taking into accoucnt different seasons):

$$Q_{co} = 44606 \ kWh$$

- Annual thermal demand for house heating and prparation of warm water:

$$Q_a = 48669 kWh$$

48669

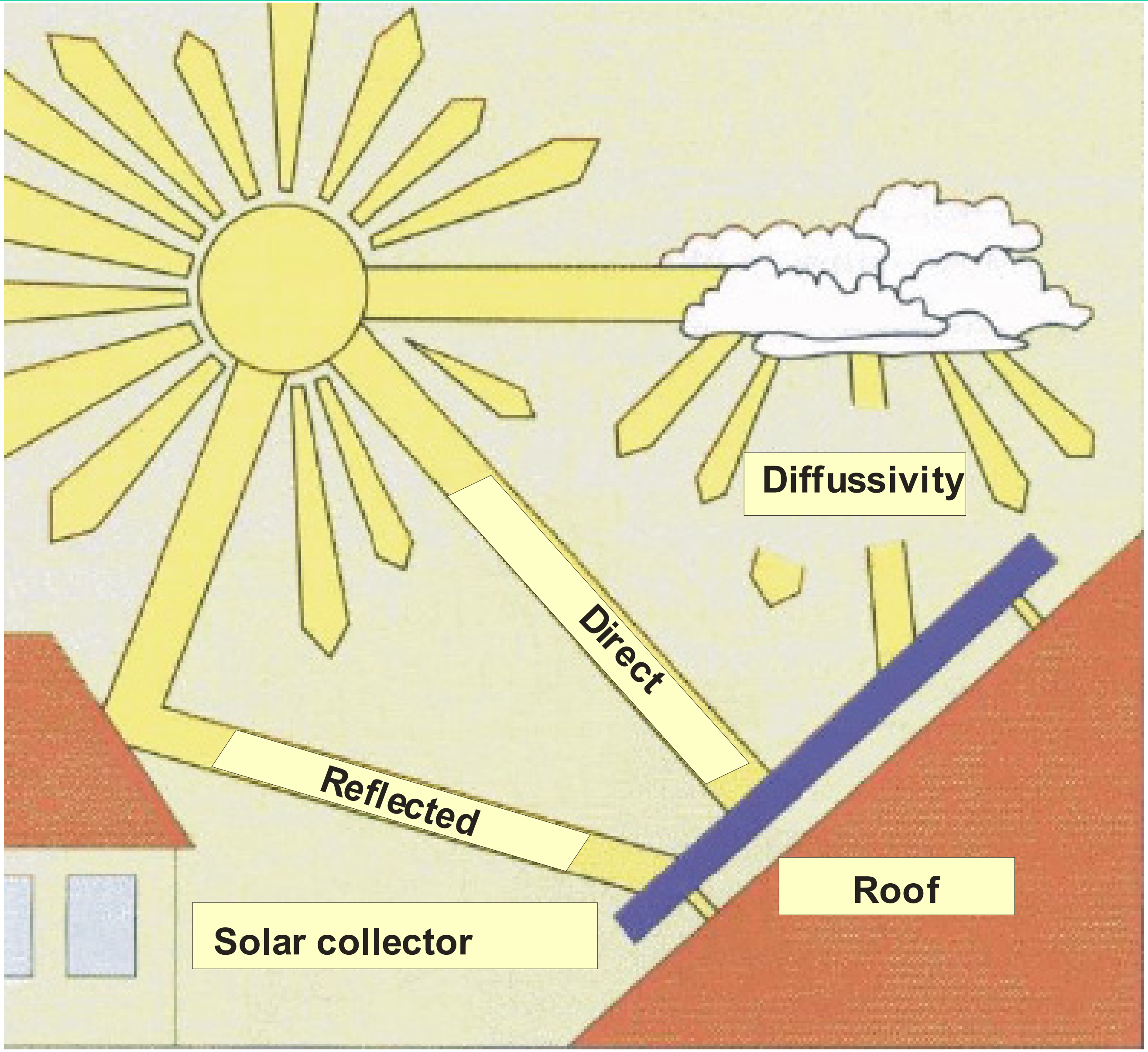
SELECTION OF HEATING APPLIANCES

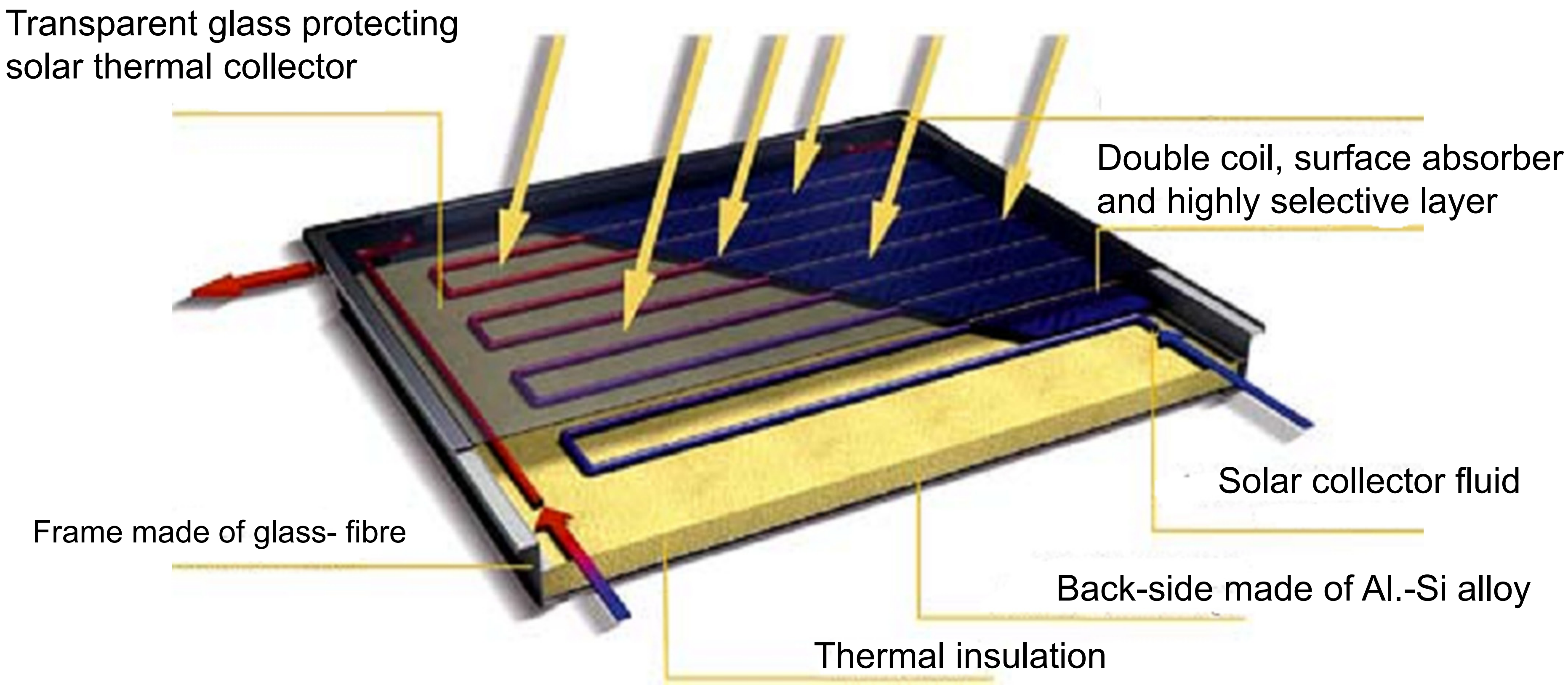
INSTALLATION WITH GAS BOILER 2E-G20

- Gas boiler Vaillant VUW 242-3 Plus
- Fuelled with gas 2E-G20 , Q_i = 35 MJ/um^3
- N= 8,9 kW,
- η = 0,9
- Gas consumption $\dot{B}_1 = 5562 m^3 / a$

Gas boiler as been selected , as an indiviual energy source or peak facility in an integrated house heating system.

INSTALLATION WITH SOLAR THERMAL COLLECTORS





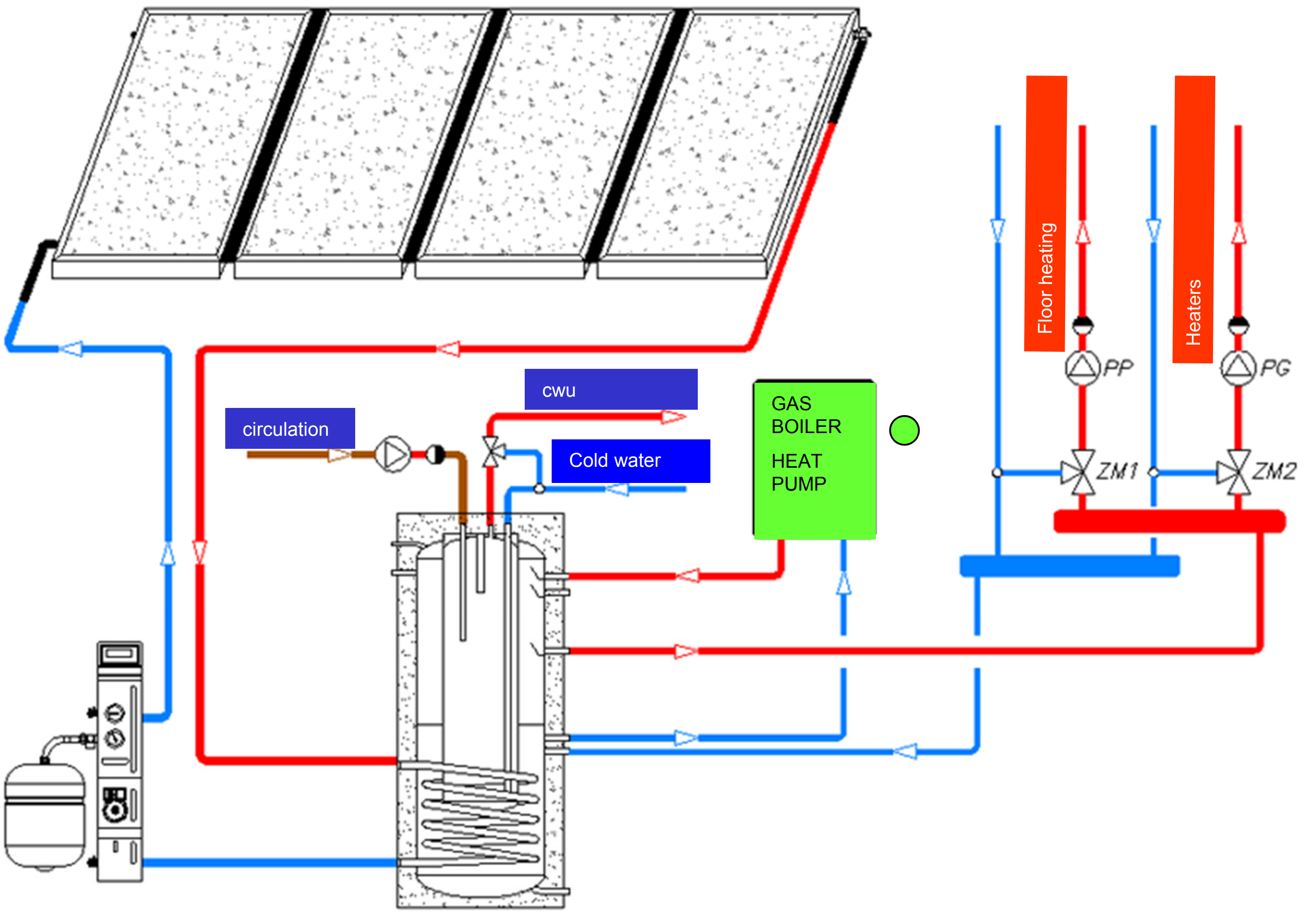
Scheme of solar thermal collector

Źródło: http://www.mojaenergia.pl

- Selected thermal solar installation consists of flat –plate solar collectors manufactured by Aquasolar, typ E KS 2000S, total surface area of 2,09 m^2 and absorber net effective surface area of 1,83 m^2.

- There are four flat-plate collector modules of the total absorber net effective surface area of 7,2 m^2 placed on the roof.

INSTALLATION WITH SOLAR THERMAL COLLECTORS



źródło:http://hewalex.com.pl/graph/schematy/sch4.png

INSTALLATION WITH SOLAR THERMAL COLLECTORS

http://hewalex.pl/page/images/stories/schem_instal.jpg

ENERGY OBTAINED FROM SOLAR COLLECTORS

Energy obtained from the solar modules installed on the roof was calculated from equation :

$$Q_{coll} = I \cdot n \cdot A$$

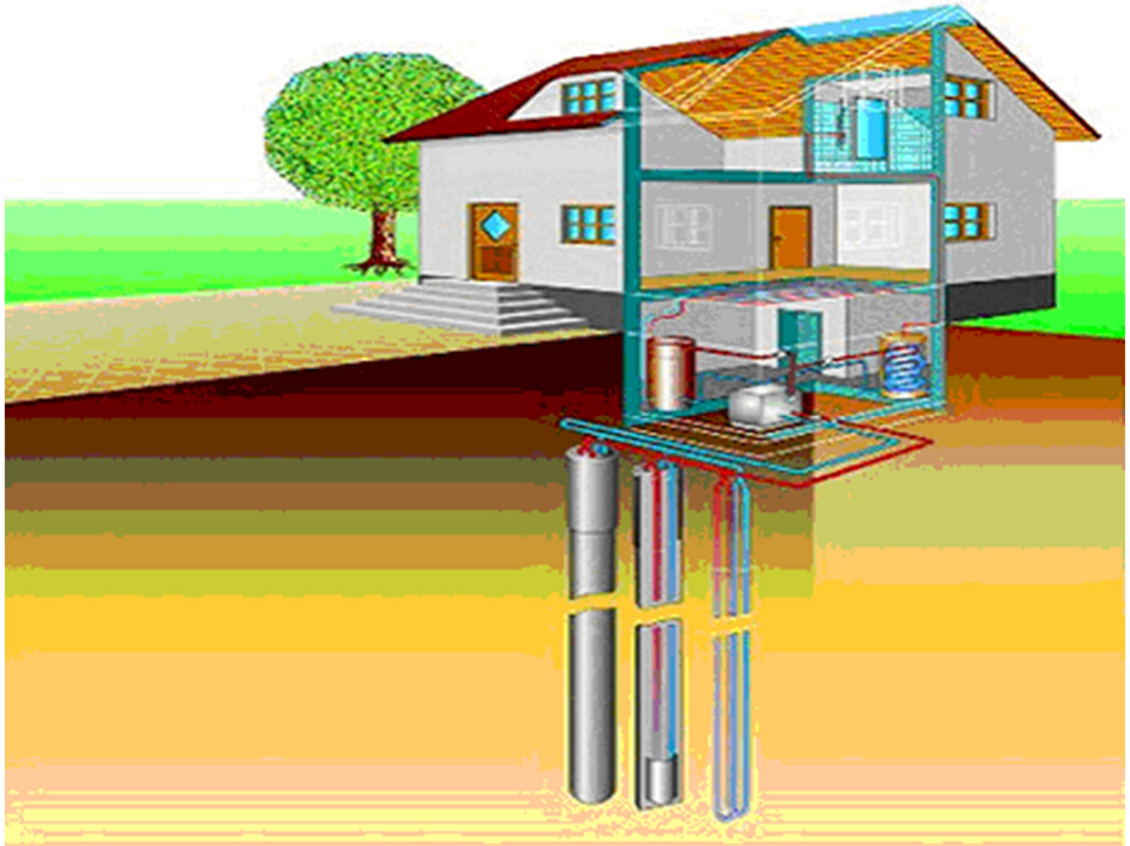
Q_{coll}- energy obtained from solar modules, [kWh]

I - monthly solar radiation $\left[\frac{kWh}{m^2}\right]$

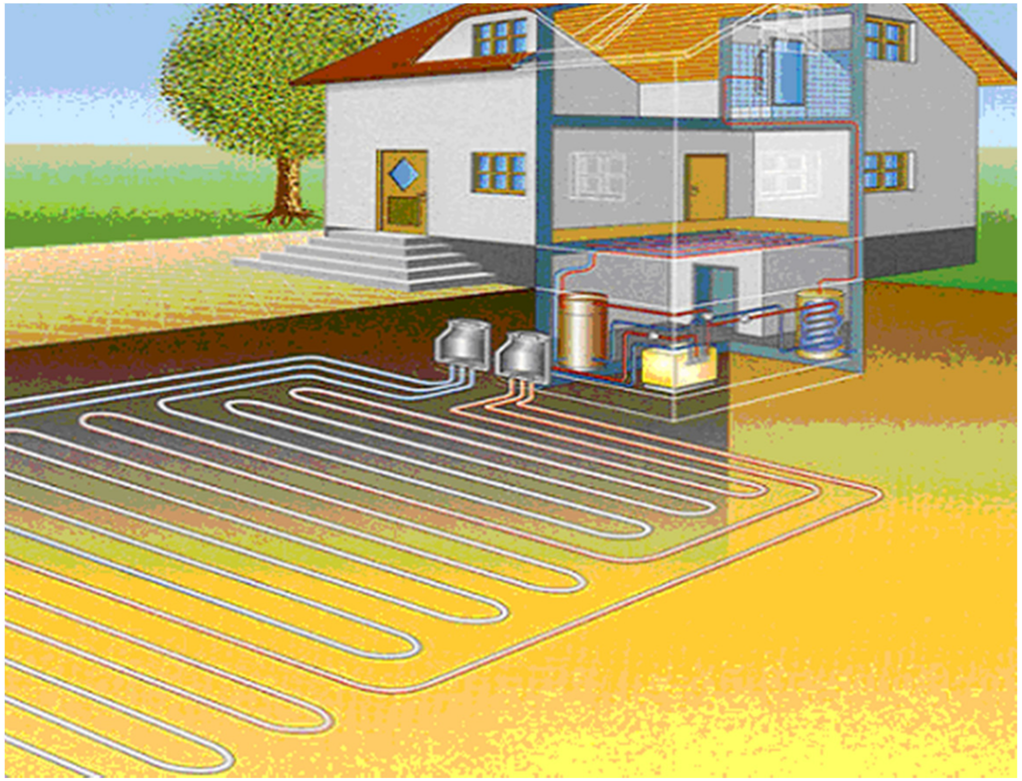
n – installation efficiency [%], n = 45%;

A – surface area, m^2

INSTALLATION WITH GAS BOILER AND HEAT PUMP WITH VERTICAL GROUND HEAT EXCHANGER



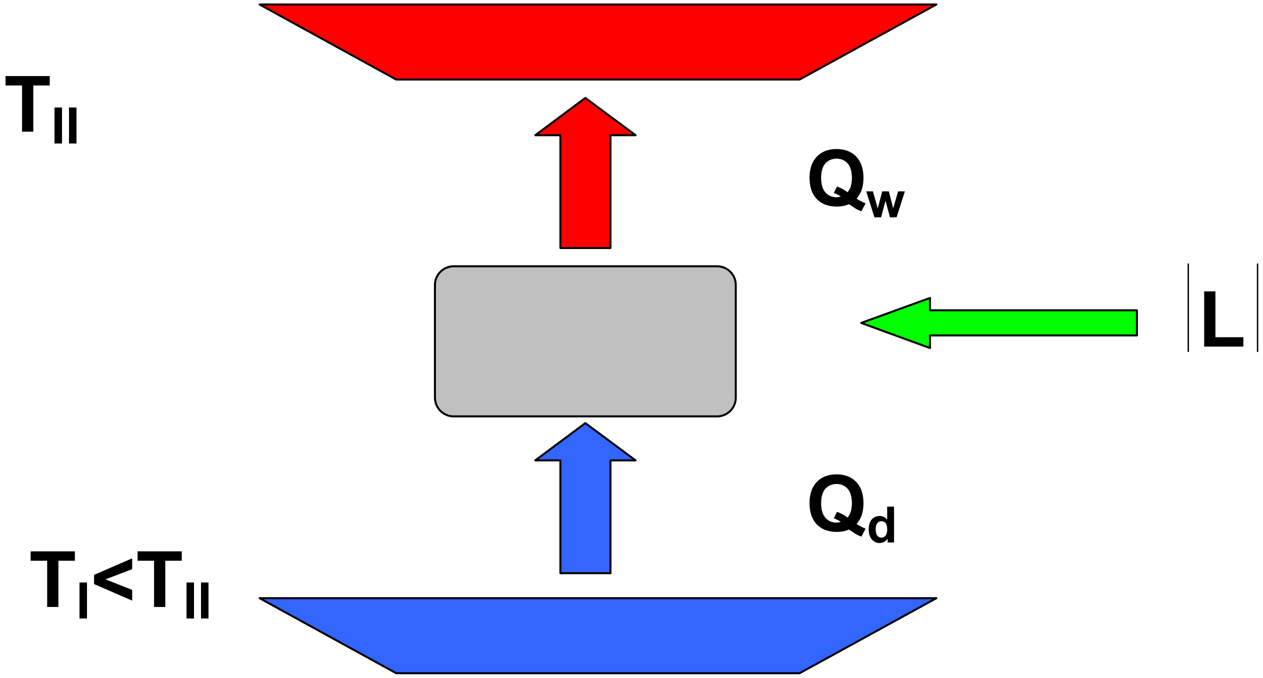
http://www.hydro-tech.pl



http://www.hydro-tech.pl

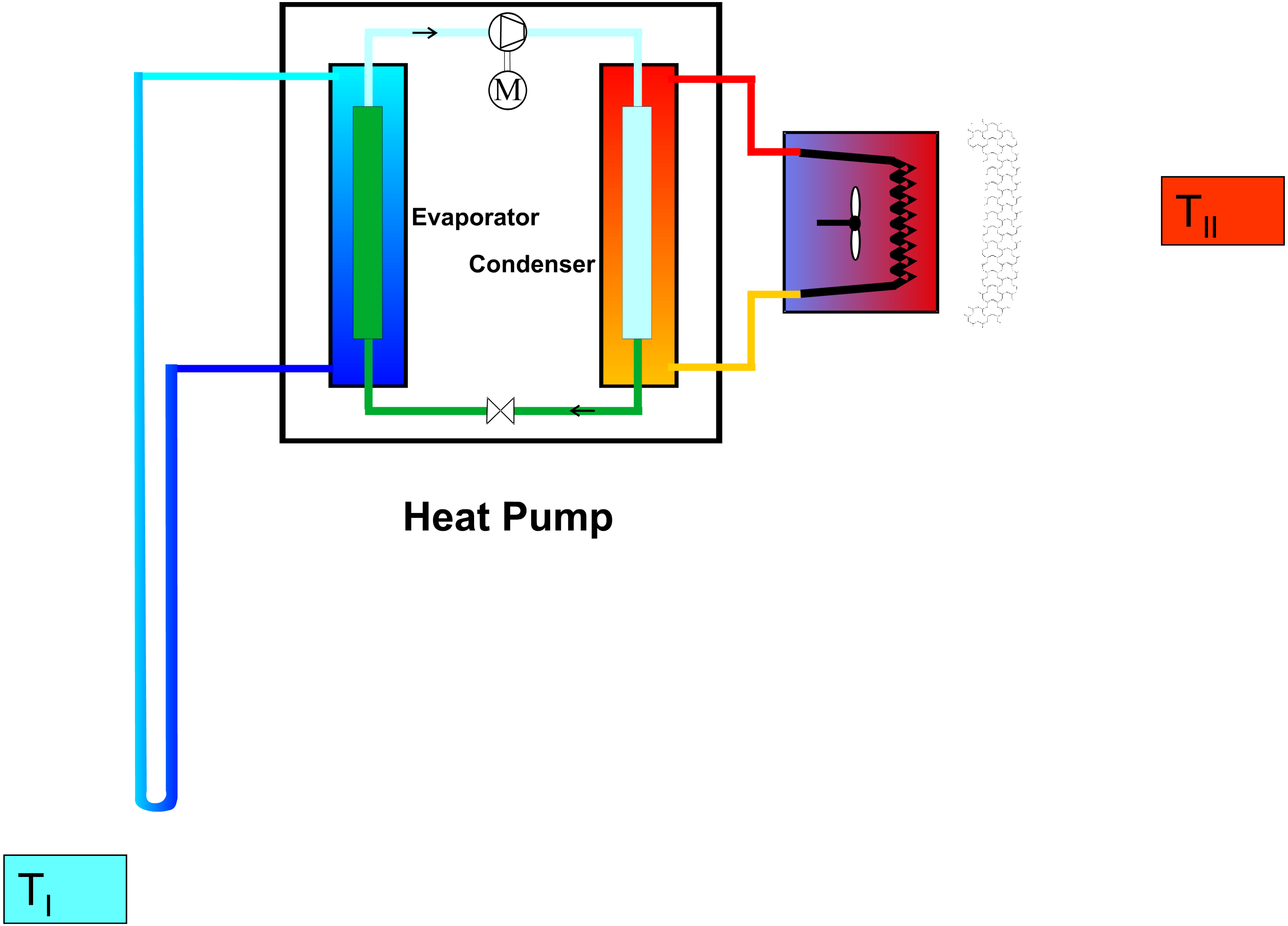
HEAT PUMP WITH HORIZONTAL GROUND HEAT EXCHANGER

HEAT PUMP



THERMAL EFFICIENCY OF HEAT PUMP

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


M
Evaporator
Condenser
Heat Pump
T_{II}
T_{I}

Ground heat pump manufactured by Solis, type SO-110X has been selected.

Operating parameters of selected ground heat pump are as follows:

- heating power of 10,8 kW,
- cooling power of 6 800 kW,
- input electric power 2,5 kW,
- water outlet temperature of 55°C,
- working fluids ethylene glycol and water.

Heat production cost consists of:

- supply energy costs (fuels, electricity),
- costs resulting form the investment outlays.

Cost resulting from the investment outlays depends upon:

- purchase and installation costs,
- annual heating consumption,
- the investment outlay,
- service rate.

The unit cost of heating produced by the different heat sources can be written as follows :

$$k_c = \frac{k_z}{\eta} + \frac{p \cdot I}{Q_a}$$

where:

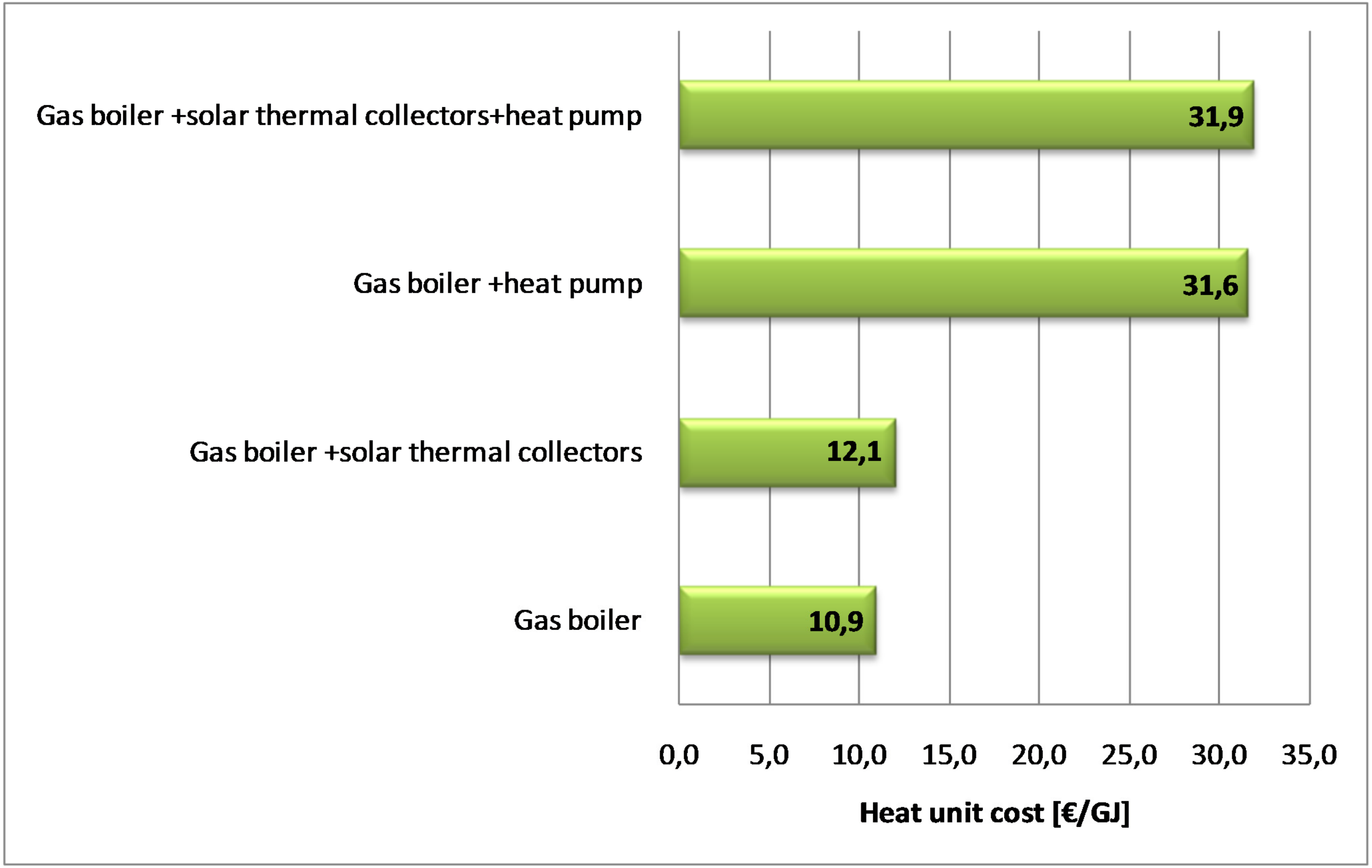
k_z – unit cost of supply energy, [€/GJ],

η - heat source efficiency,

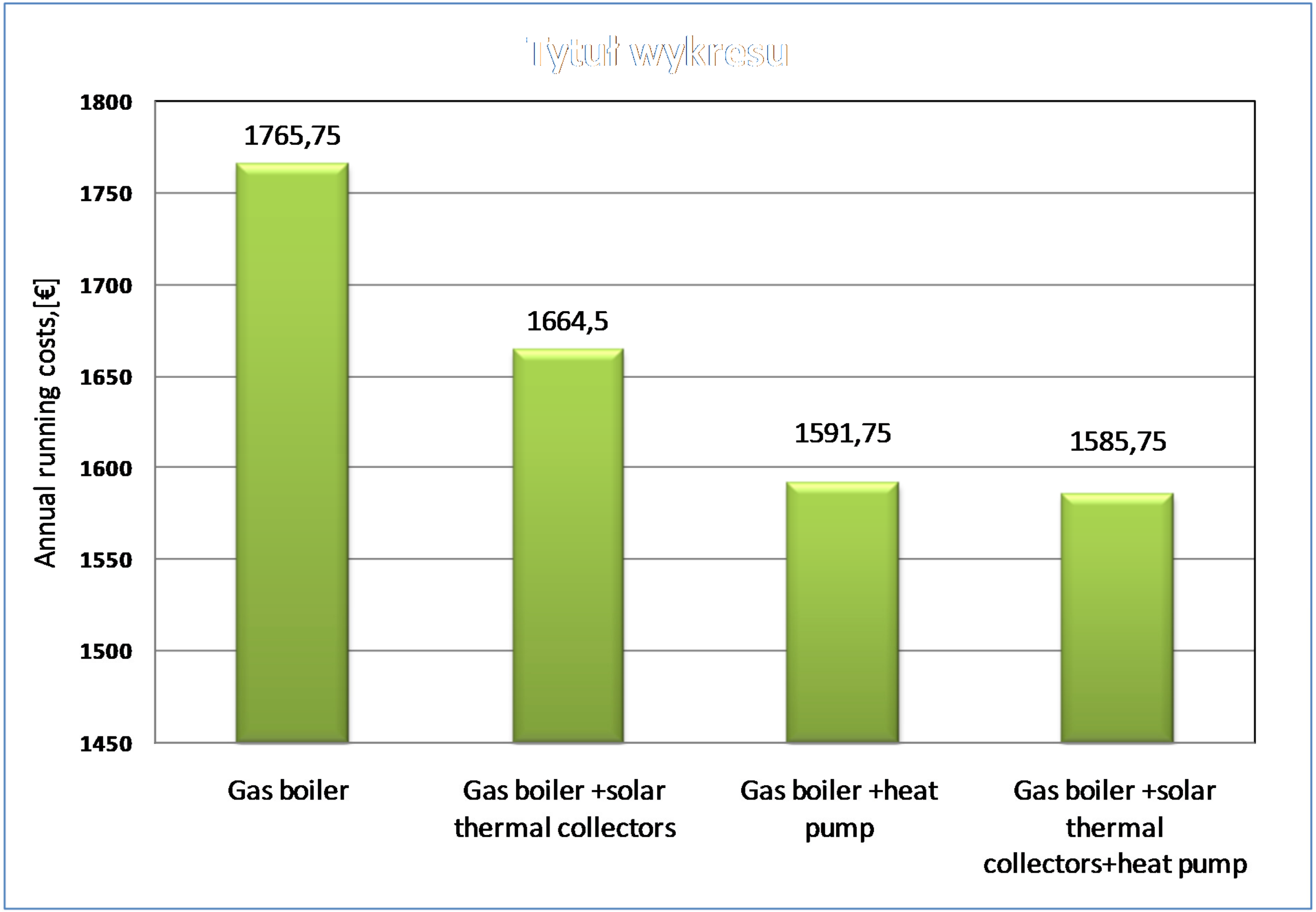
p – annual investment outlays service rate,

I - heat source investment expenditures, [€],

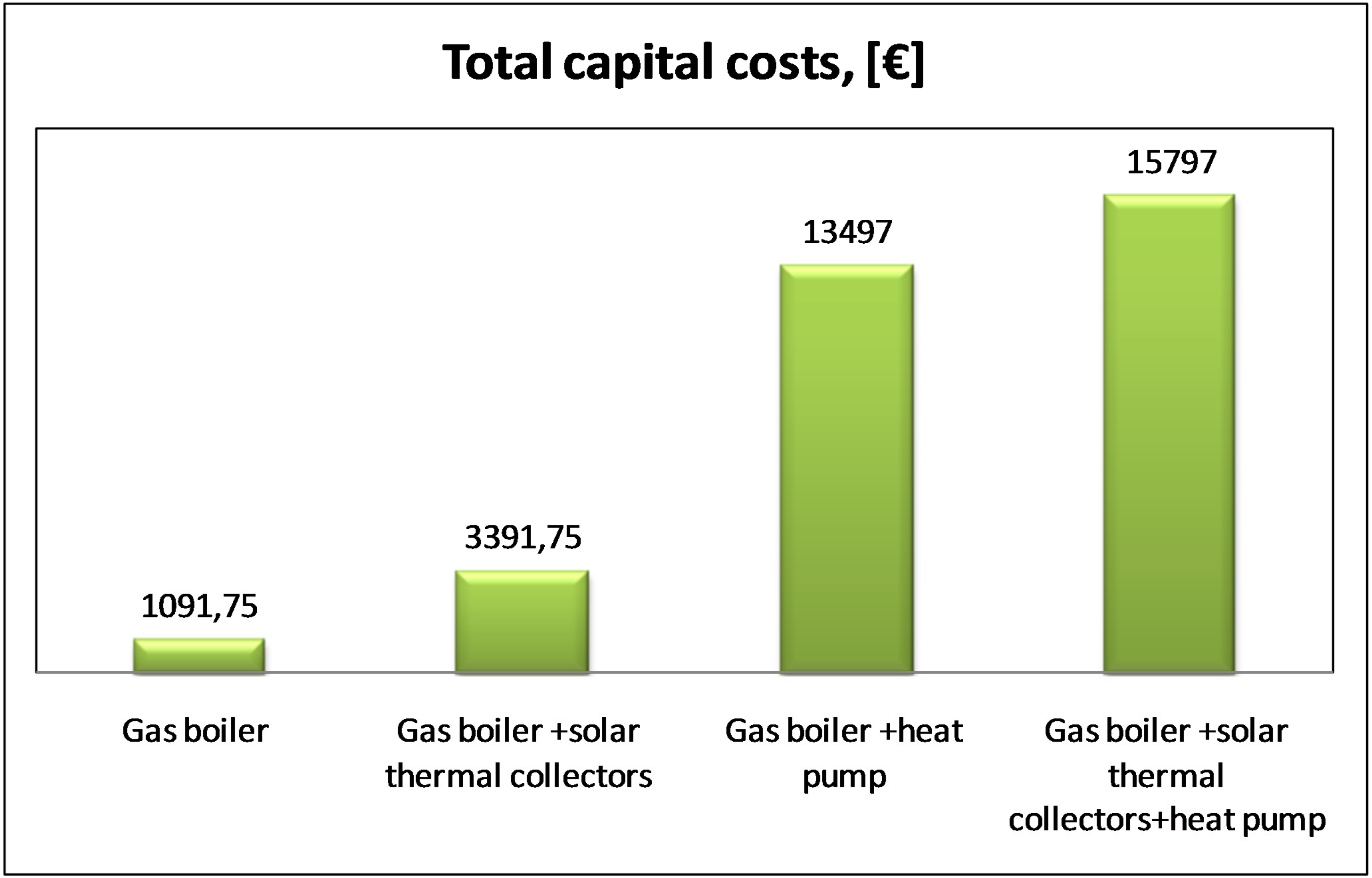
Q_a - annual heat demand, [GJ/a].



Heat unit costs for the different house heating systems.



Annual running costs of the different heating systems



Capital costs of the different heating systems

Economic effect covering the whole exploitation period of the heating system is usually described as Net Predicted Value, NPV.

$$NPV = \sum_{t=0}^{t=n} \frac{(CI_t - CO_t)}{(1+r)^t}$$

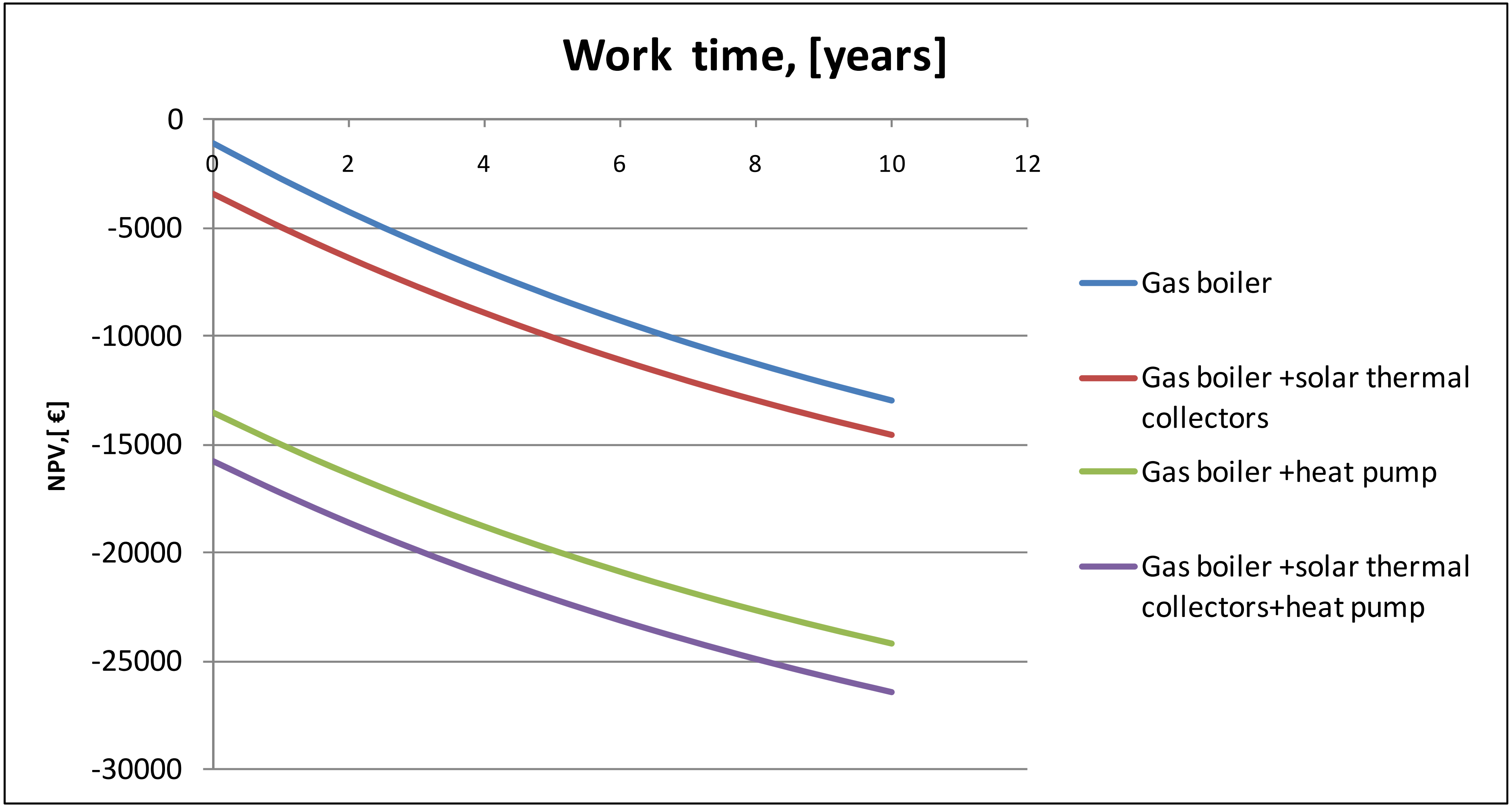
CI_t - cash inflow, €,

CO_t - cash outflow,€,

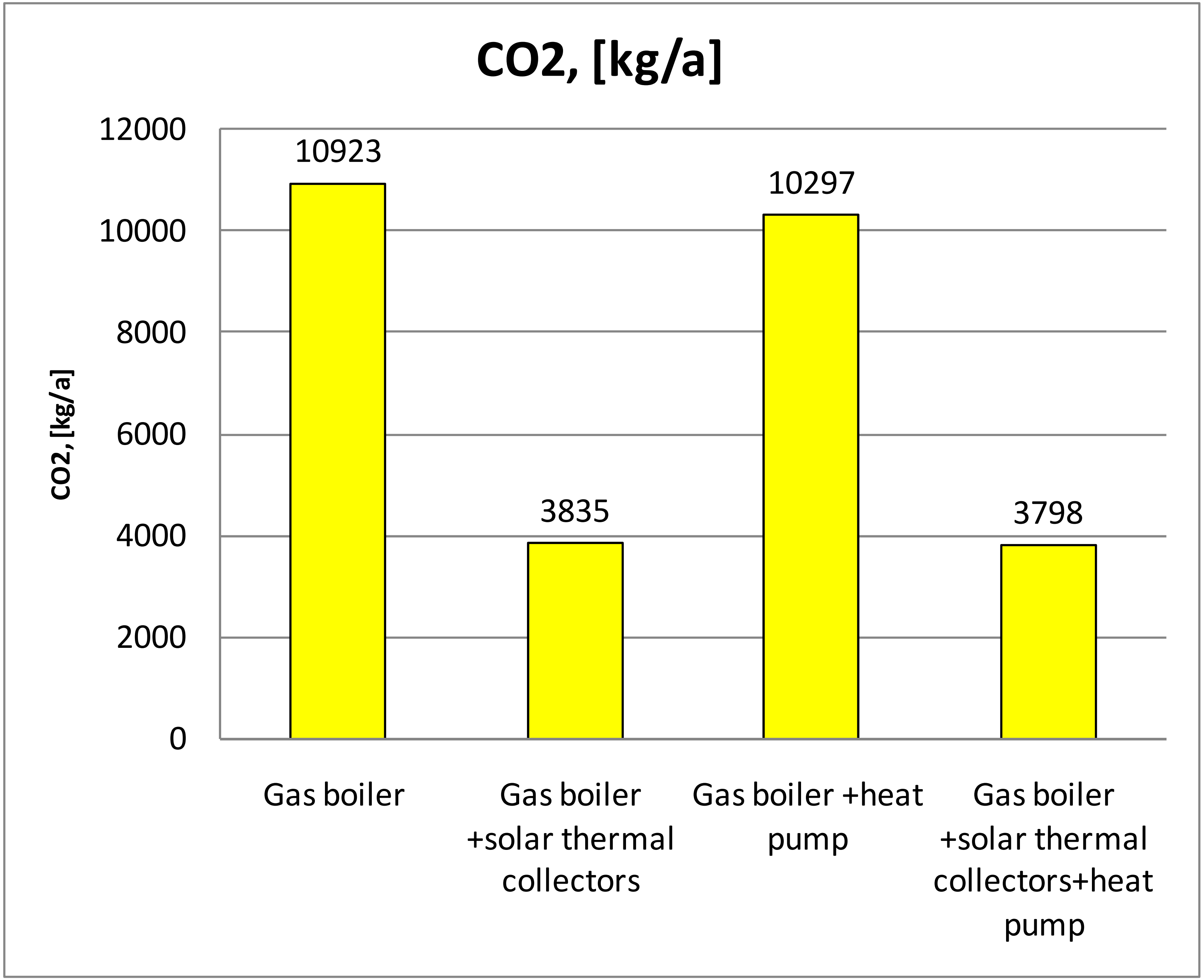
r - discount rate,it was assumed r=8%

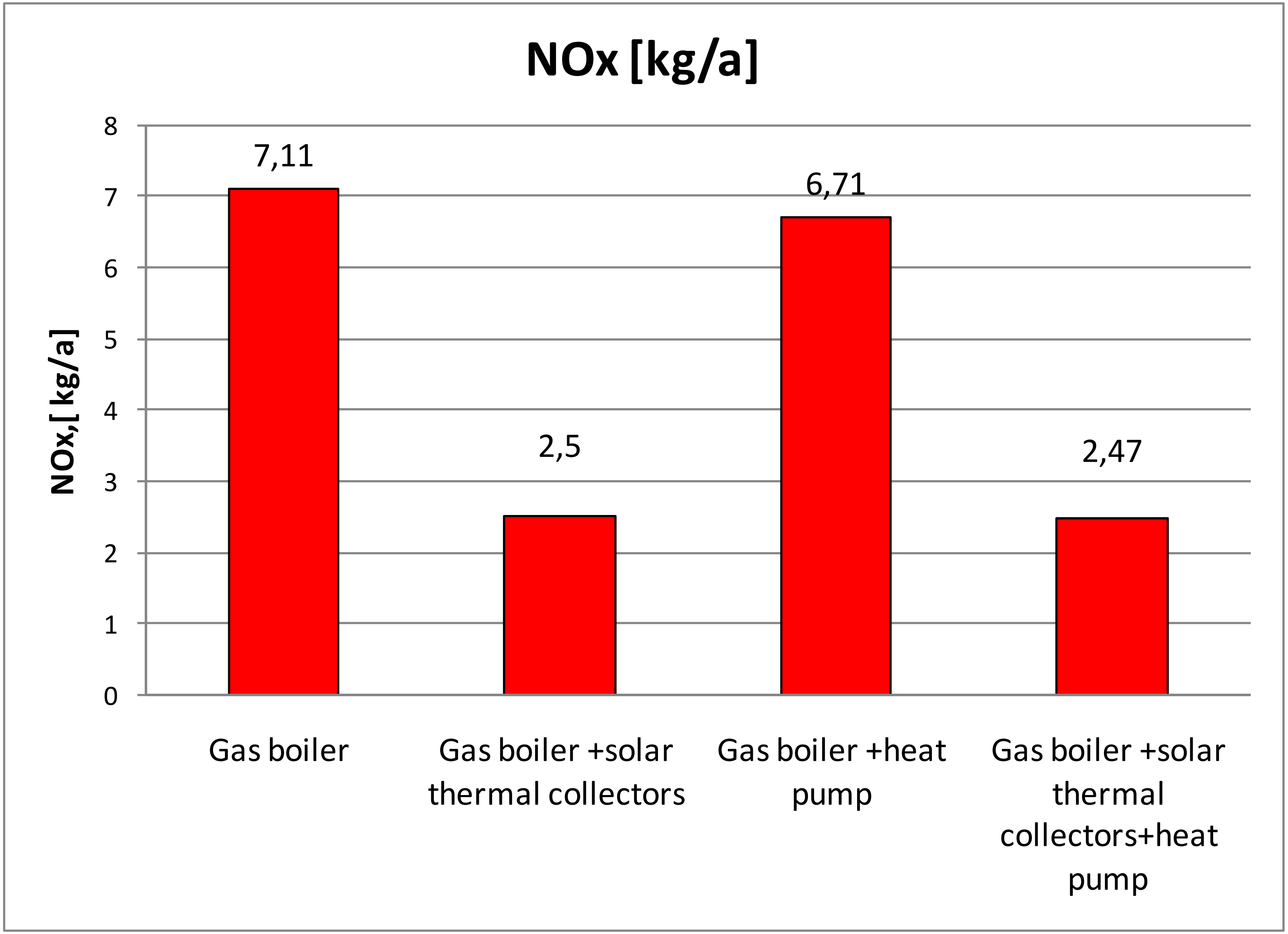
t - successive year of exploitation,

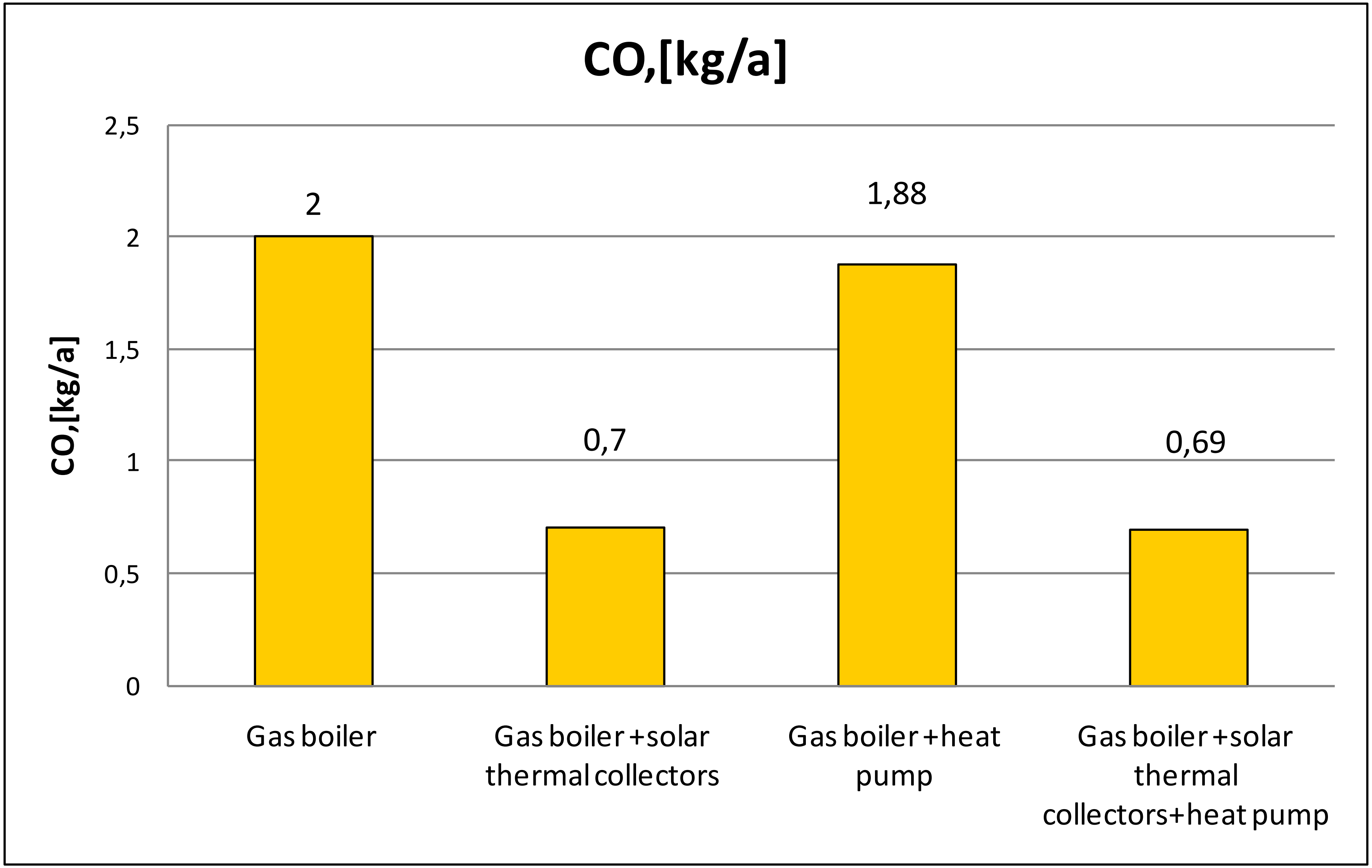
n - operating time for installation,years



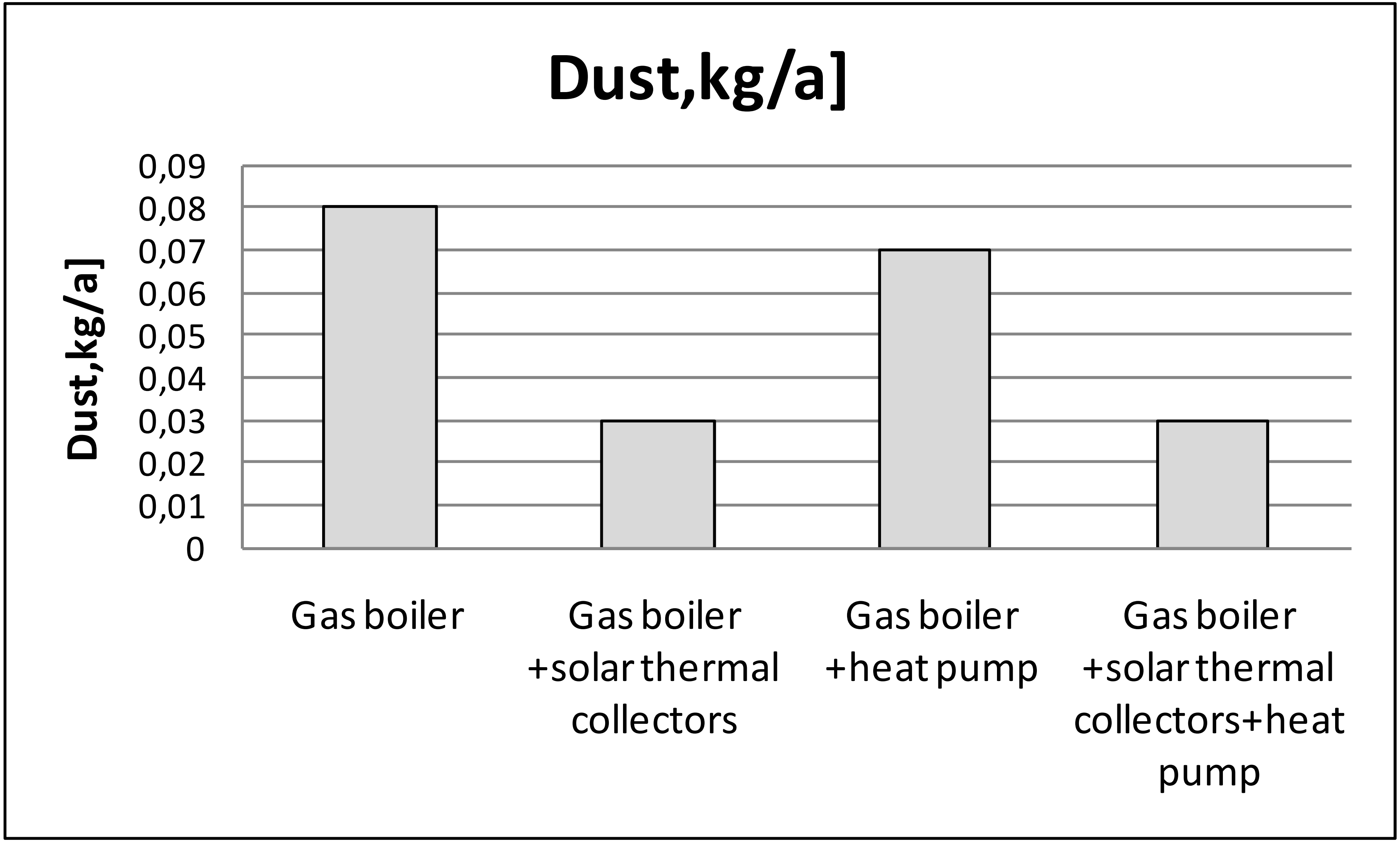
NPV for the different house heating systems


CO2, [kg/a]
12000
10000
8000
6000
4000
2000
0
CO2, [kg/a]
10923
3835
10297
3798
Gas boiler
Gas boiler +solar thermal collectors
Gas boiler +heat pump
Gas boiler +solar thermal collectors+heat pump


NOx [kg/a]
NOx,[kg/a]
8
7
6
5
4
3
2
1
0
7,11
2,5
6,71
2,47
Gas boiler
Gas boiler +solar thermal collectors
Gas boiler +heat pump
Gas boiler +solar thermal collectors+heat pump



CO,[kg/a]
2,5
2
1,5
1
0,5
0
CO,[kg/a]
2
0,7
1,88
0,69
Gas boiler
Gas boiler +solar thermal collectors
Gas boiler +heat pump
Gas boiler +solar thermal collectors+heat pump


Dust,kg/a]
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0
Dust,kg/a]
Gas boiler
Gas boiler +solar thermal collectors
Gas boiler +heat pump
Gas boiler +solar thermal collectors+heat pump

CONCLUSIONS

- Selection of an optimum house heating system providing heat and hot water depends upon many factors: practical requirements, technical and investment potential, running costs and the other factors,

- taking into consideration the lowest unit cost of heat production and NPV, heating system with gas boiler was found as the most profitable one, however, considering running costs it is the costly system,

- because of variable solar conditions in Poland, application of thermal solar collectors for exclusive house heating and providing hot water is not recommended, installation of thermal solar collectors is cost-effective only in case of exclusive water heating,

- heat pump can be alternative heat source for the different heating systems provided that there are technical and investment potentials for utilization of the low temperature heat sources,

- however, capital costs of an integrated systems with solar thermal collectors and ground heat pump are high but running costs , moreover because of low CO_2, CO, NO_X, and dust emission the systems are considered as environmentally friendly,

- it is worth to accentuate that depending on the kinds of low temperature heat sources, ground heat pump can be replaced by the other types of heat pumps, for example air heat pump ,as such solution is less costly because there is no need to install ground heat exchanger of high capital cost.