# Solar Water Preheating for Open District Heating Nets: CIS Potential

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**Abstract**

In heat and power plants with so-called open district heating nets, large quantities of cold water (e.g. 12°C) are heated up to supply temperatures (e.g. 60°C) using fossil fuels. This water, however, can be effectively preheated by uncovered collectors before heating up conventionally to the supply temperature. Due to high basic load, low inlet temperature and good climatic conditions in most parts of the Commonwealth of Independent States (CIS), extraordinary solar gains and very low solar heat costs can be achieved during the frost-free season. The objective of this investigation is to identify heat and power plants in the CIS which are appropriate for solar water preheating. For this purpose, large (or central as it is called in the CIS) operated heat and power plants were identified and evaluated. It was found that 38 out of 197 heat and power plants are in principle appropriate for this kind of solar thermal technology. In addition, this study includes an economic analysis of the technology based on previous experimental and theoretical results. Solar heat costs of less than 0.01 €/$kWh_{th}$ and a payback time of about 9 years are expected.

Keywords: uncovered collector, heat and power plants, district heating, CIS

## 1. Introduction

District heating nets for heat supply are very common in cities of the Commonwealth of Independent States (CIS) and are often combined with large heat and power plants. A representative situation can be found in Bishkek, the capital of Kyrgyzstan with similar latitude as Rome. Officially, about 350 thousands inhabitants in the center of Bishkek receive domestic hot water and energy for space heating from the central Heat and Power Plant (TEZ) of Bishkek City. The real number of consumers is estimated by the local authorities to be twice as much. The district heating net, however, shows some differences to common Central European technologies. It is constructed as an open-circuit system, where domestic hot water is taken by the consumers directly out of the net without any heat exchanger coupling (see Figure 1). Thus, the district heating net in Bishkek has to be refilled with about 3000 $m^3$ per hour of 12°C cold water. This is carried out at the central Heat and Power Plant. Cold water is heated up to 60°C, the temperature level required during summer when no space heating is needed and ambient air temperature is usually higher that 20°C even at night.

This water can, however, be preheated using solar energy before heating up conventionally to the supply temperature. For this purpose uncovered plastic solar collectors (cf. [1]) or multicomponent solar thermal systems (cf. [2]) can be effectively used due to the low water inlet temperatures and high ambient temperatures.

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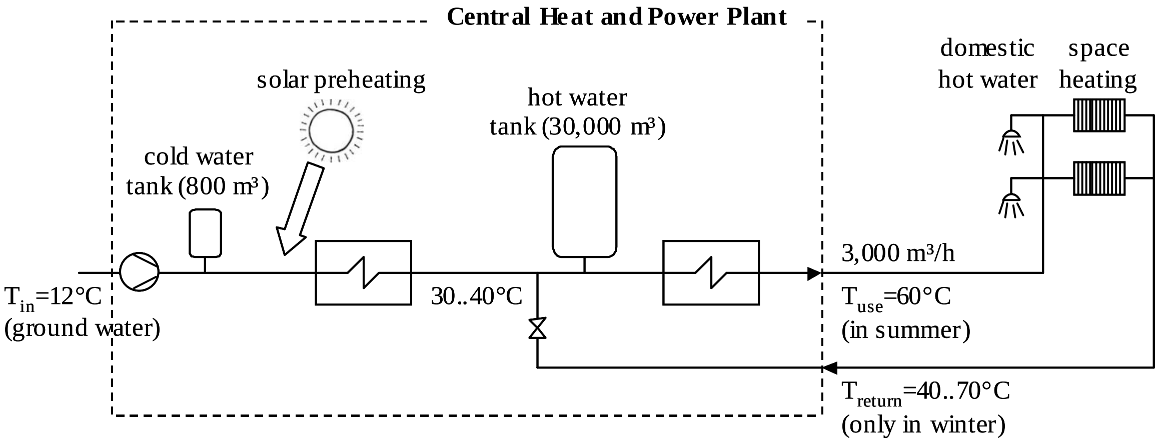


Fig. 1. Simplified hydraulic scheme of a typical open-circuit district heating net in CIS countries (usually without solar preheating), cf. [2]

For this application no solar heat storage is necessary because of the high basic load. Due to the low inlet temperature and excellent climatic conditions (high irradiation, high ambient temperature) very high solar gains can be achieved. For Bishkek specific solar gains are estimated to be around 1000 $kWh/m^2_{coll}$ during the frost-free season Mai – September, which is about four times higher than the solar gains typically achieved in swimming pool heating in Central Europe.

But not all district heating nets in the CIS have similar boundary conditions so that not everywhere water preheating with uncovered collectors makes sense. Some district heating nets are not in operation in summer, but only during winter or space heating period. A number of district heating nets are constructed as a closed-circuit system with almost no need for water refilling and relatively high water return temperatures. For closed-circuit systems, other solar thermal technologies, e.g. flat plate collectors, can be used. These, however, are not yet economically competitive with still low, but rapidly increasing energy prices in the CIS and are therefore not considered in this study. Furthermore, some heat and power plants are operated in summer to produce as much electricity as possible use even cooling towers during summer. In this case, no uncovered collectors can be applied since there is no demand for low temperature heat.

The following technical characteristics of the heat and power plant are necessary in order to effectively apply the uncovered collectors or multicomponent solar thermal systems for water preheating

- high basic load (→ no storage is needed + large solar heating system)
- open-circuit or mix-circuit systems (→ low water inlet temperature)
- in operation in the frost-free period
- CHP-operation mode based on the heat load
- available area for uncovered collectors

The objective of this investigation is to estimate the potential of solar water preheating in the CIS by identifying heat and power plants where this technology can be effectively implemented. For this purpose, an attempt was made to identify and evaluate all large heat and power plants operating in the region.

## 2. Procedure to identify heat and power plants in the CIS

To gather information about the heat and power plants the following methods have been used:

- internet search at the website of the plant operator
- contact via fax and e-mail (with a special questionnaire)
- telephone calls
- pictures of the plants via Google Earth
- in some cases also on site visits

For a general overview of the existing heat and power plants, an internet search was carried out. This proved to be very effective because almost all heat and power plant operators have web sites[1]. Some technical parameters like installed power and heat capacity or produced energy can also be found in the internet. However, no information about the district heating net hydraulics (open, closed or mix systems), flow rate of cold water to be refilled, temperature level or operation mode can be obtained in this way. Thus, internet search alone does not provide sufficient information for an evaluation.

In a second step, heat and power plant operators were contacted via fax or mail with a special questionnaire about technical parameters. Unfortunately, but not completely surprising, no email or fax has been answered. With a telephone survey it was possible to obtain further technical information (like net hydraulic and summer operation) about the heat and power plant and district heating net. In general, it was unlikely to get information about the cold water flow rate, operation mode and energy generation or fuel costs.

Additionally, Google Earth was used to estimate the available area for installation of uncovered collectors. However, in all cases an on-site visit was found to be inevitable in order to gather all data required for a full evaluation. Figure 2 shows a comparison of the data collection methods used with regard to the data obtained.

| |  |  |  |  |
|---|---|---|---|---|
| location | | X | X | X |
| net hydraulic (open / closed / mix) | X | (X) | | X |
| summer operation (yes/no) | (X) | | (X) | |
| installed power and thermal capacity | X | (X) | | (X) |
| fresh water flow rate and inlet temperature | (X) | | | X |
| available areas for uncovered collector | | | X | X |
| used fuels | (X) | (X) | | X |
| costs (fuels, heat costs, etc.) | (X) | X | | (X) |

Fig. 2. Comparison of methods to collect information about heat and power plants in CIS

[1] English web sites are very rare, but all are available in Russian

## 3. Evaluation of the identified heat and power plants

Open-circuit district heating nets exist only in Russia and in Central Asia. Other CIS or former USSR countries either had only closed-circuit systems (Belarus, Ukraine, Azerbaijan etc) or reconstructed open-circuit systems to closed-circuit ones (Baltic countries).

In Russia and in Central Asia 197 heat and power plants were identified and 163 of them were evaluated so far.

Roughly half of the identified heat and power plants have a closed-circuit system and were, thus, not further considered (cf. Figure 3). 38 of the open- and mix-systems are in operation in summer (cf. Figure 4) and are, therefore, in principle appropriate for solar water preheating. Since no information about the operation mode had been available, it was impossible to evaluate how many heat and power plants are really appropriate for solar water preheating with uncovered collectors.

The geographical distribution of the 38 heat and power plants is shown in Figure 5.

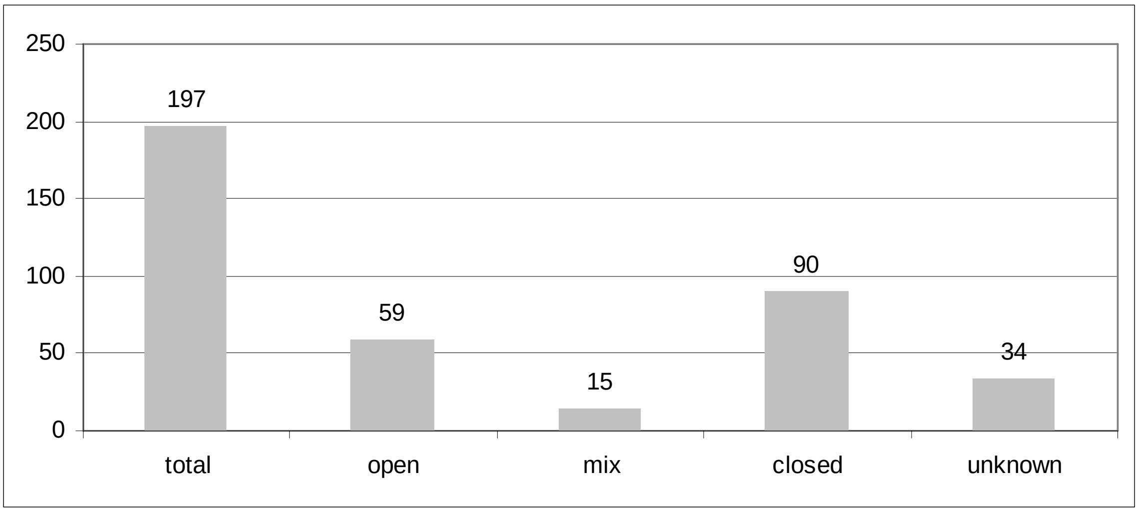


Fig. 3. Identified heat and power plants in Russia and in Central Asia by circuit system

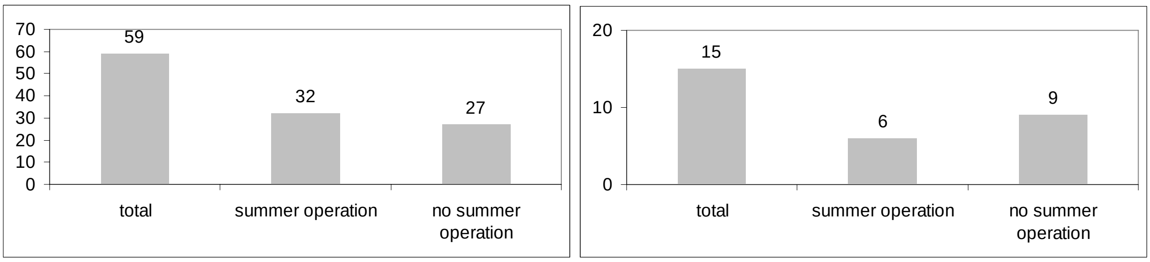


Fig. 4. Number of identified heat and power plants with open (left) and mix (right) -circuit systems by operation conditions

In this investigation only large heat and power plants with a possible potential for several thousand square meters of uncovered collector were identified and evaluated. Beside these, various small heat plants exist (without power generation). Some of them have cold water flow rates of 50..100 $m^3/h$, which corresponds about 500 and 1000 $m^2$ of collector. For example, the 6 largest heat plants out of 58 operating in Bishkek have a total potential of approx. 3000 $m^2$ of uncovered collector.

Furthermore, large closed-circle district heating nets could benefit from solar preheating due to their water losses. E.g. the closed-circle in Moscow runs approximately 3 million $m^3$ of water. Hourly water losses of 0.1 % of the net capacity correspond to 3000 $m^3/h$ in required feeding water, possibly offering an opportunity for solar preheating.


Fig. 5. Geographical distribution of heat and power plants, technically appropriate for a solar preheating

## 4. Economic analysis

Estimation of annual heat gains is based on the local climate data as well as on the thermal performance of the uncovered collectors. For Bishkek, three sources of meteorological data are available [3]: the program “Meteonorm”, a local weather station “Frunze”, and measurements since 2004 on a pilot solar thermal system in Bishkek [2]. A commercial water preheating system will be working in the frost-free period, in Bishkek from May to September (5 months). Based on simulation calculations with the program TRNSYS[2] with conservative climate data energy, solar heat gains of about 1000 $kWh/m^2a$ can be expected. The technical and economical potential for the heat and power plant TEZ in Bishkek is approx. 32 $MW_{th}$ (45000 $m^2$ of uncovered collectors), which is more than two times larger than the currently largest solar thermal heat plant in the world[3].

A promising option is thereby the recognition of the solar thermal plant as a so-called CDM project in the framework of the Kyoto protocol, which can lead to additional financial gains by the generation and selling of emission certificates. An average emission factor for TEZ Bishkek equals 0.282 t $CO_2/MWh_{th}$ when calculated with the specific emission factors of the Intergovernmental Panel on Climate Change (IPCC) and fuel mix of the TEZ Bishkek. This corresponds to an annual

[2] An advanced TRNSYS-Type for uncovered collector is described in [4]

[3] The world’s currently largest solar thermal system in Marstall, Denmark, has an installed thermal capacity of approx. 13 $MW_{th}$.

emission reduction of 0.31 t $CO_2$ per $m^2$ collector area[4]. An economic calculation of an uncovered collector located in Bishkek was carried out with following assumptions:

- investment (system costs)[5] = 44 € per $m^2$ of uncovered collectors
- solar energy gains = 1 $MWh/m^2a$
- interest rate = 13 %/a
- maintenance = 1 % of system costs
- certificate price (CER) = 6 €/t $CO_2$
- system size = 45000 $m^2$ (corresponds to 2 million € investment)
- operation time =14 a
- fossil price increase rate = 2 %/a

For fuel prices in 2007 (e.g. gas 0.98 ct/kWh) a solar heat price of 0.5 ct/kWh and a payback period of 9 years are calculated. Thus, the heat price for solar thermal heat generation lies significantly below the price for fossil fuels. Without recognition as a CDM project a solar heat price of 0.7 ct/kWh and a payback period of 12 years are expected. If the uncovered collector loop and the district heating net must be separated with a heat exchanger, the solar heat price will rise by another 0.1 ct/kWh.

Furthermore, an economic study[6] for different locations in the CIS was carried out (cf. Figure 6). Energy gains are based on simulation calculations using climate data of the program Meteonorm 5.1. Here, the simulation period is Mai to September instead of the frost-free period to have better comparability between the different sites. The water inlet temperature was set to 12°C for all locations. Some locations, however, were also simulated with the water inlet temperature of 15 and 20°C. The specific flow rate of uncovered collectors in the simulations is 100 l/m²h.

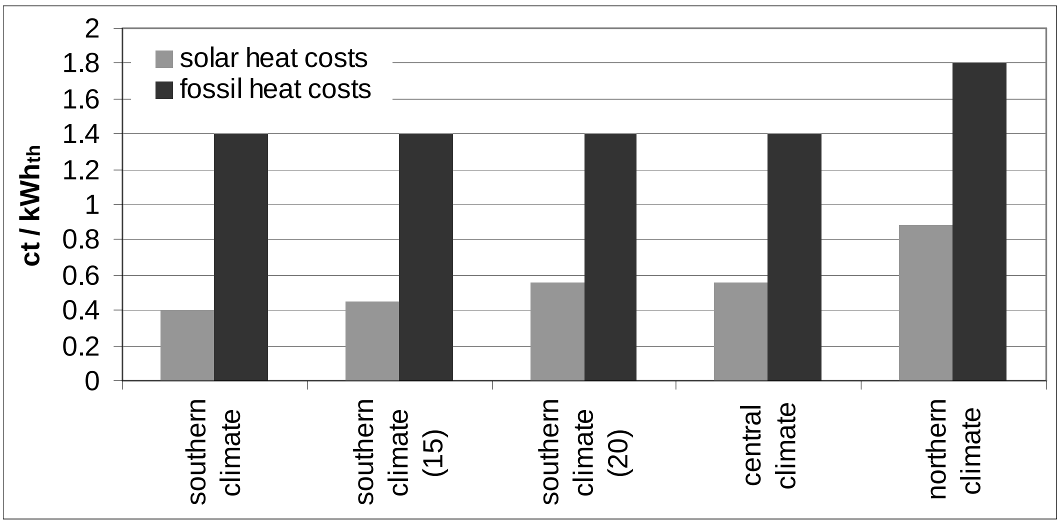


Fig. 6. Solar and conventional heat costs for different locations in the CIS. (15) and (20) represents the water inlet temperature of 15°C and 20°C respectively. Otherwise an inlet temperature of 12°C was assumed.

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[4] Assumptions: solar energy gain = 1 $MWh/m^2a$; efficiency heat plant = 0.9.
[5] including transport, installation, etc. but excluding Kyrgyz duty and taxes
[6] Without recognition as a CDM project

## 5. Conclusions

Uncovered collectors can be effectively applied to preheat water for open-circuit district heating nets in cities of the Commonwealth of Independent States. In Russia and in Central Asia in total 197 heat and power plants were identified and 163 of them were evaluated. 38 heat and power plants seem to be technically suitable for solar preheating. Solar heat costs of less than 0.01 €/$kWh_{th}$ can be expected for many sites of the CIS. Large solar heating systems can be recognized as a CDM project to receive additional financial gains.

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