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# Hydrogeochemical and Isotopic Survey of Sarikaya (Yozgat-Turkey) Thermal and Mineral Waters

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## ABSTRACT

Sarikaya geothermal field is located 80 km SE of Yozgat city center (in Sarikaya town center). The basement complex is formed of Paleozoic aged schist, quartzite and marbles in this field. Eocene aged marl, claystone and limestone and alternating clayey limestone, sandstone and marl Pliocene deposits lie unconformably on this basement. Quaternary aged travertine and alluvium lie at the top. There are major fault lines trending E-W and NE-SW.

Temperatures of thermal and mineral waters obtained from springs and wells in the research area varies between 25-60.1$^{o}$C, and electrical conductivity is 400-1300 µs/cm. Thermal and mineral waters are characterized as calcium bicarbonate waters (Ca-$HCO_3$).

According to isotopic analysis, Sarikaya thermal waters have meteoric origin. Oxygen-18 (δ18O) values of thermal water vary between -10.2‰ to -11.4‰ and $\delta^2$H values from -79.6‰ to -80.6‰.

Low tritium contents relative to recent precipitation shows that groundwater released from the springs have a long term (30-40 years) residence time underground.

## 1. INTRODUCTION

Sarikaya geothermal field is located in Sarikaya town center on Yozgat-Sorgun-Kayseri road (Figure 1). To date, research is comprised of geological, geophysical and chemical analysis, balneological evaluations, isotope and boring studies (Ozmutaf 1989, IUMF, 1976, Simsek et.al; 1995, Hacettepe University-ORME, 2004, Hacettepe University; 2005-2008).

Thermal and mineralized waters have been used since the historical Roman Bath, and recently as New and Old spa facilities. In the research area there are 6 hot water exploration/production wells that were drilled from 131 m to 292 m by Yozgat Governorship for use in thermal instruction and district heating between 2005 and 2008.

In this research, we use the Graphic (diagram) approach that is widely used for hydrogeochemical evaluations. Circulation time of underground water in the aquifer is determined by one of the natural isotopes, tritium (3H). The origin of hot waters, feeding (water supply) and the circulation relationship is determined by Oxygen-18 ($^{18}$O) and deuterium ($^{2}$H). 2. geology and HYDROGEOLOGY

The oldest lithological units in the Yozgat Sarikaya field are the Kalkanlidag Formation, composed of various kinds of schist and quartzite, and marbles of the Bozcaldag Formation. Both formations are Paleozoic in age (Seymen, 1981, 1982; Tolluoglu, 1986; Kurt et al. 1991). These units outcrop in the Sarikaya area, Ortatepe and Bestepe in the south and Mehmettepe and Karatepe in the southwest (Figure 2). Within the research area, the Beycedere Formation is comprised of Eocene aged marl, claystone, conglomerate and limestone and Pliocene aged alternating clayey limestone, sandstone and marl. These deposits lie unconformably on the basement complex (Kurt et al. 1991). The Eocene units are seen to the west of Sarikaya Koprucek village, in the Sarikaya town center and at the back of government. Pliocene units are seen in the north of the research area, especially in Ilisu graben (Figure 2). The youngest visible units are Quaternary aged travertine and alluvium deposits.

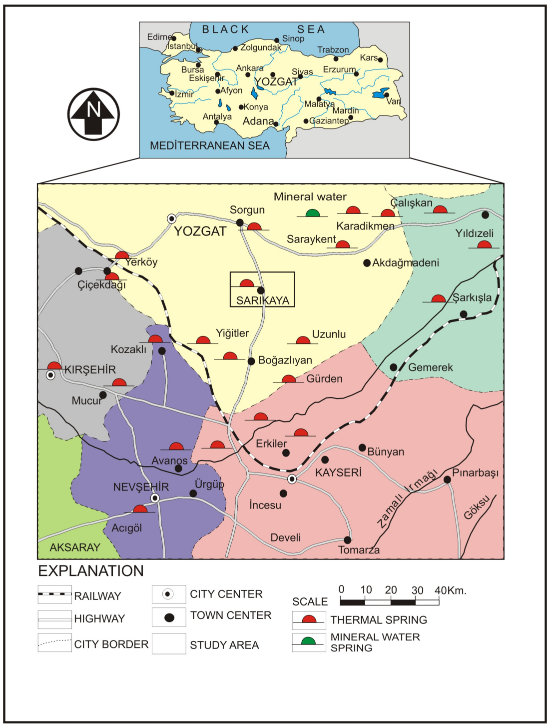


**Figure 1. Location map of study area**

In the Sarikaya geothermal field discharge of underground water from springs is relatively small except for thermal and mineralized waters. While the Eocene and Pliocene aged deposits are considered to be generally impermeable, the fault and fracture zones in the Paleozoic age marble, quartzite and schist of the basement complex are defined as permeable. Also, loosely cemented sandstone and conglomerate in the Eocene Beycedere Formation and Pliocene Kizilirmak Formations are important aquifers locally. In terms of hydrogeology, the Paleozoic metamorphic rocks form the reservoir rocks, and the alternating claystone, marl and sand-clay Cenozoic (Eocene and Pliocene) deposits form the cap rock (Figure 3).

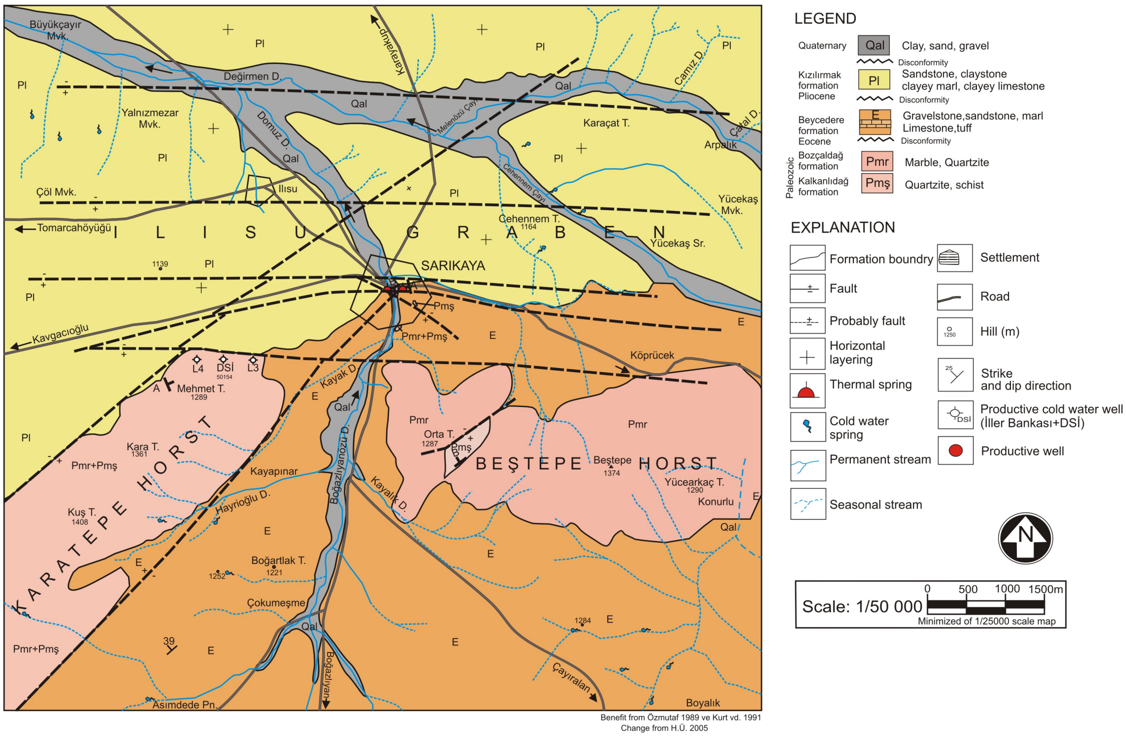


**Figure 2. Geological map of research area**

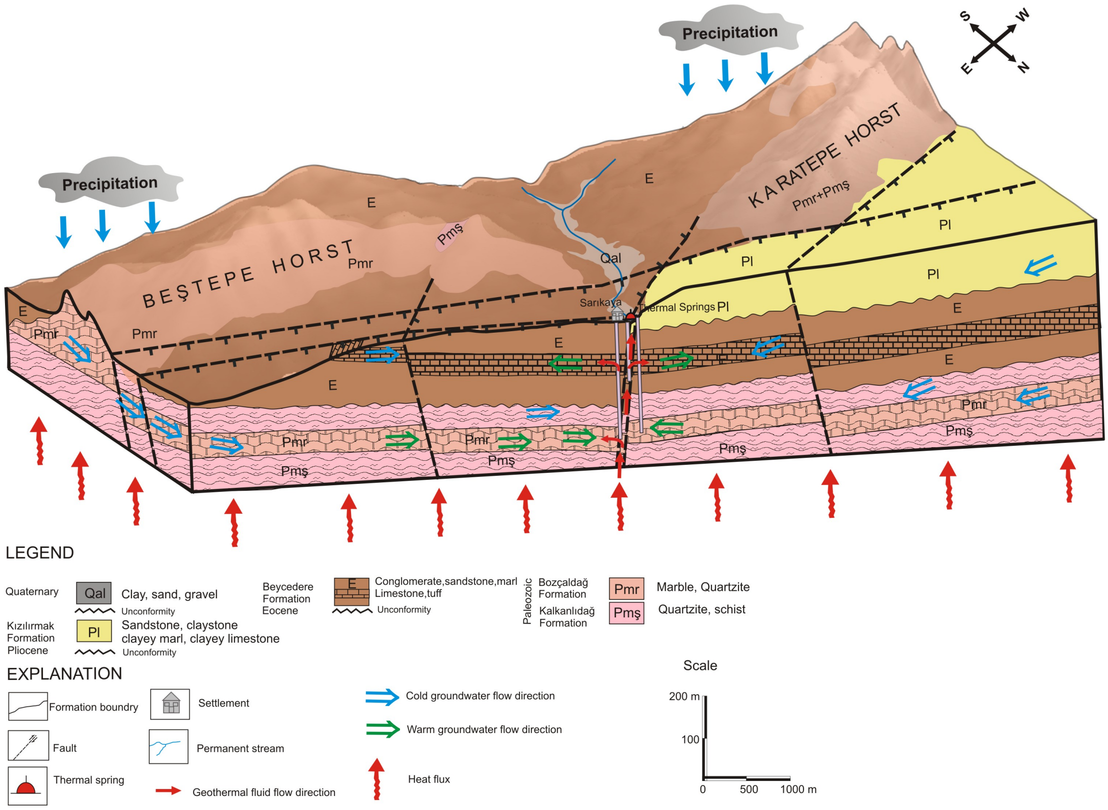


**Figure 3. Tentative hydrothermal model of Sarikaya geothermal field**

### 2.1. Thermal Water Springs

In the hot spring area there are 2 main hot spring captages. Old spa and new spa and some other hot spring areas and plants are fed from these. There is water discharge from 2 captages with a total of 27 l/s in the area and temperatures varying between 46-50.9$^{o}$C according to seasons. The new hot spring area is located 160 km west of the old hot spring area. Waters taken from these captages (4 l/s) are used for the new hot spring area.

Hot water is accumulated in the fractured marble and quartzite of the basement. The water rises along a normal fault zone crossing over a line combining two springs and comes to the surface from alluvium.

### 2.2. Thermal Water Wells

In the research area there are 6 hot water exploration/ production wells drilled by Yozgat governorship-Sarikaya Vicinity Governorship. Thermal water was discharged from well SK-1 with a 42.5 l/s flow rate and a temperature of 45ºC was obtained. The SK-2 search well is 105 m northwest of well SK-1 and was drilled to 272 m depth (30 ºC and approximately 5-10 l/s flow of water capacity). The SK-3 well is located about 63 m south west of SK-1 and 135 m south east of SK-2 and is completed to 292 m depth. Hot water with a temperature of 25ºC and 86 l/s flow was obtained. Well SK-4 is 190 m depth and has water with a temperature of 36$^{o}$C and 45 l/s flow. Artesian thermal and mineralized water can be obtained by this well. A flow of 50 l/s and a water temperature of 42$^{o}$C was obtained from well SK-5 (280 m depth). Finally, 60.1$^{o}$C hot water with a flow of 40 l/s was obtained in well SK-6 (Hacettepe University; 2008).

## 3. HYDROGEOCHEMISTRY

In the research area temperatures of thermal and mineralized waters vary between 25-60.1$^{o}$C. Electrical conductivities (EC) vary between 400-1300 µs/cm. The dominant cation order of ion contents in thermal and mineralized water from the research area is Ca>Na+K>Mg and anion order is $HCO_3$>Cl>$SO_4$ (Table 1).

The relationship between thermal water springs, lithology and hydrogeochemical evolution processes induced through circulation systems are explained using Piper diagrams (Figure 4). The origin of waters that are grouped together in the same part of the diagram is the same. As it is explained above for ion arrangements, hot waters are classified as Ca-$HCO_3$ type waters and these springs are fed by an aquifer of carbonate origin. Cold water springs in the area are generally classified as having Ca+Mg-$HCO_3$ type water. A low Cl value in waters from well SK-3 shows shallow circulation relative to hot waters and high mixture with cold water. SK-4 spring water resembles hot spring water in terms of ionic content and has typical cold water mixtures. A semi-logarithmic Schoeller diagram is formed to determine the similarities and differences between hot water springs (Figure 5). According to this diagram, hot water springs in the area have the same chemical character and show big differences from the cold water springs with high Na+K and Cl contents. It has been determined that thermal and mineralized waters taken from SK-4 and SK-1 springs resemble hot water areas in terms of ionic and chemical composition, but due to mixing with cold underground water the temperature and dissolved material content of these waters is decreased.

**Table 1. Chemical analysis results of water samples taken from research area.**

| Sample ID | Type | Date | T (ºC) | pH | EC (µS/cm) | Ca (ppm) | Mg (ppm) | Na (ppm) | K (ppm) | Cl (ppm) | $SO_4$ (ppm) | $HCO_3$ (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Old Spa | Spring | October 2005 | 50.9 | 6.48 | 814 | 100.85 | 6.91 | 78.28 | 9.94 | 92.04 | 62.89 | 292.79 |
| Roma Bath | Spring | October 2005 | 50.9 | 6.59 | 812 | 102.63 | 6.29 | 72.92 | 9.28 | 77.85 | 52.66 | 300.92 |
| Yeni Spa | Spring | October 2005 | 50.9 | 7.07 | 805 | 98.10 | 5.56 | 73.04 | 9.38 | 76.16 | 50.65 | 288.72 |
| Orta Tepe | Spring | October 2005 | 15.6 | 7.23 | 360 | 58.96 | 8.64 | 8.95 | 1.08 | 4.66 | 11.69 | 191.12 |
| Pliyosen | Spring | October 2005 | 16.6 | 7.72 | 707 | 101.58 | 17.17 | 31.48 | 1.36 | 35.83 | 20.29 | 288.72 |
| Iller Bankası Well | Well | October 2005 | 15.9 | 7.87 | 370 | 71.02 | 3.58 | 10.16 | 1.20 | 3.65 | 8.83 | 219.59 |
| Rain water | Precipitation | July 2004 | 15.0 | 8.80 | 60 | 18.77 | 0.91 | 4.871 | 7.32 | 2.33 | 87.68 | 31.95 |
| SK-1 | Well | October 2005 | 50.6 | 7.33 | 804 | 95.53 | 5.59 | 73.54 | 8.58 | 72.12 | 47.52 | 292.79 |
| SK-3 | Well | October 2005 | 25.0 | 7.43 | 405 | 80.96 | 3.16 | 9.45 | 1.70 | 7.80 | 20.75 | 227.72 |
| SK-4 | Well | October 2005 | 35.5 | 7.50 | 592 | 91.77 | 4.74 | 36.05 | 3.31 | 34.38 | 30.86 | 268.39 |
| SK-5 | Well | June 2006 | 42 | 7.37 | 613 | 75.25 | 4.17 | 30.87 | 3.71 | 35.08 | 36.30 | 245.39 |
| SK-6 | Well | June 2008 | 60.1 | 6.1 | 1062 | 99.23 | 5.76 | 91.80 | 12.63 | 135.97 | 67.34 | 306.65 |
| Old Spa (2008) | Spring | June 2008 | 50 | 6.25 | 813 | 92.78 | 4.73 | 51.67 | 6.42 | 67.53 | 45.35 | 300.40 |
| K-1 Koprucek cold water well | Well | June 2008 | 15 | 6.31 | 706 | 100.45 | 12.57 | 13.09 | 0.699 | 11.027 | 24.41 | 315.94 |

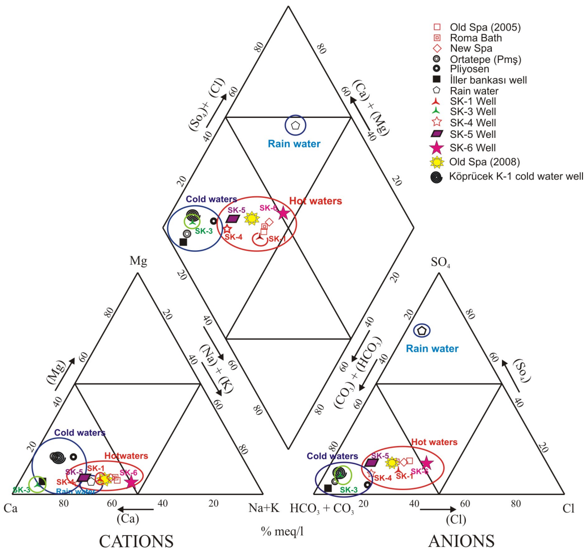


**Figure 4. Piper diagrams formed for water springs in research area.**

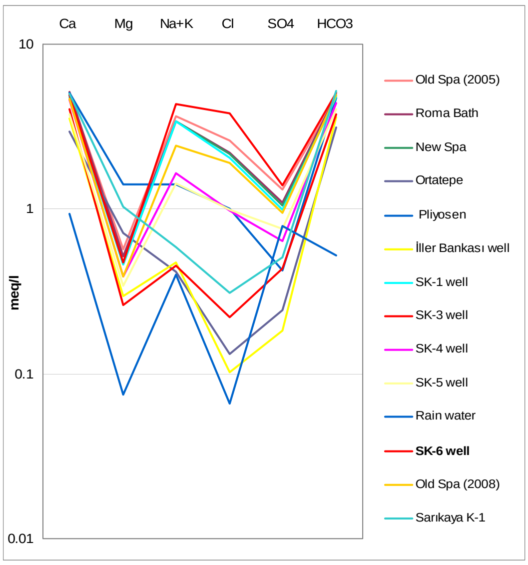


**Figure 5. Schoeller diagrams formed for water springs in research area.**

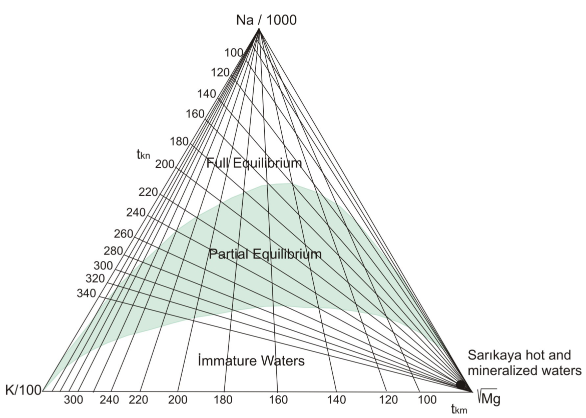


**Figure 6. Position of Sarikaya thermal springs on a Giggenbach, 1988 diagram.**

Geothermal water has heat transfer with contact rocks until coming to surface and they have lower temperatures than the temperature values of the reservoir due to various rates of mixing with cold underground waters. Thus, reservoir rock temperatures of thermal and mineralized waters are calculated by a geothermometer method. Thermal and mineralized water within the research area is examined on Na-K-Mg diagrams (Giggenbach, 1988) (Figure 6). All of the hot water in the Sarikaya geothermal area is located in the "immature" zone and consequently it is not suitable to perform cation geothermometers on these springs. However, silica geothermometers give acceptable values. While reservoir temperatures for the Sarikaya geothermal field are calculated to be 53-96 ºC by quartz geothermometers, they are calculated as 53-69 ºC by calcedon geothermometers.

## 4. EVALUATION OF ISOTOPE ANALYSIS

In this research, 3H analyses were performed in H.U Geological (Hydrogeological) Engineering Department Tritium Laboratory and stable isotope (18O and 2H) analyses were performed in TUBITAK Marmara Research Center (MAM) Environment and petroleum laboratories.

The feeding area of geothermal fluids, and the origin and water-rock interaction processes are explained by examining isotope analysis of thermal and mineralized water springs and cold water springs.

This research uses the Local Meteoric Water Line ($\delta D = 8*\delta^{18}O + 14$) that was determined for the Yozgat province research area by Simsek et al. (1995). Points are located between this line and world meteoric water line and this shows that geothermal system is fed by meteoric precipitation (Figure 7).

Sarikaya thermal and mineralized waters are filtered through faults, fractures, etc., are heated by the geothermal gradient and come back to the surface again through permeable layers.

In the research area samples from hot and cold water springs are taken. $^{3}H$ contents of Sarikaya hot waters vary between 1.25 ± 0.29 and 3.45±0.28 TU. Low $^{3}H$ contents, high electrical conductivity and high Cl values show that springwater has a relatively long term passing time (30 – 40 years) and is fed by underground waters (Figure 8).

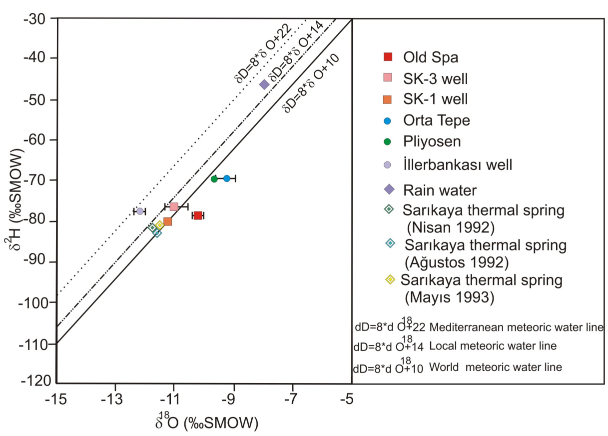


**Figure 7. Relationship $^{18}$O and $^{2}$H in the Sarikaya geothermal field**

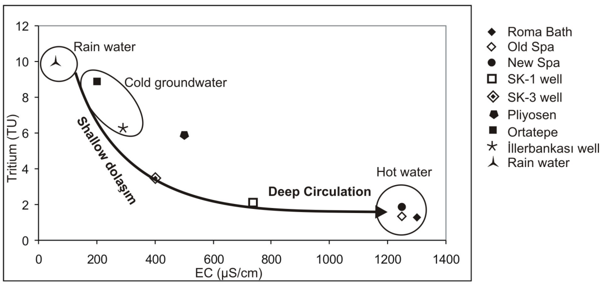


**Figure 8. $^{3}$H–EC Graph of spring waters in research area**

## 5. CONCLUSION AND RECOMMENDATION

The results of the geology, hydrogeology, hydrology, geochemical and isotope analyses performed for determining hydrogeochemical properties of the Sarikaya geothermal field are listed below:

- In the research area hot water springs are grouped in the same part. This shows that hot waters have the same origin (meteoric). They are classified as Ca-HCO3 type water and this signals that springs are fed by a carbonate aquifer, in which marbles are the main lithology.

- In the research area thermal and mineralized waters come from the same origin according to the Schoeller diagram and they show differences from cold water springs with high Na+K and Cl contents.

- Thermal and mineralized waters taken from wells SK-4 and SK-1 resemble hot spring areas with ionic composition, but have cold water mixture.

- Mineral contents get higher with increasing temperature in wells. However, due to mixing with cold underground waters, the dissolved material content of waters conformably decrease.

- The reservoir temperature of the Sarikaya geothermal area is about 53-69oC, according to geothermometer calculations and reservoir temperatures up to 60.1oC determined by drilling works.

- Low tritium content of hot water springs shows that the springs are fed by underground waters having a relatively long term passing time (30-40 years). According to the hydrothermal model developed by geological, hydrogeological and geochemical data obtained in the research area, thermal and mineralized waters in Sarikaya area are formed by rain and snow precipitation filtered through a faulted and fractured zone, then heated by the geothermal gradient and returned to the surface through permeable rock. Existing fault zones, young volcanic activity around Saraykent and hot water springs show that the geothermal gradient in this region is higher than other regions.

- Feasibility works in the area aimed towards tourism and heating is still going on.

- In the first stage, started in 2008, a total of 130 house equivalence central heating was produced.

## 6. ACKNOWLEDGEMENTS

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