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I.2.

KIZILDERE – NEW GEOTHERMAL POWER PLANT IN TURKEY

1. Stage 60 MWe Turkey's Biggest Geothermal Electricity Plant Development Project Privatization of Kızıldere Geothermal Power Plant and Current Approaches for the Field & Plant

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ABSTRACT

Kızıldere Geothermal Field is discovered in 1960s by General Directorate of Mineral Research and Exploration (MTA). After 24 years of operation by EÜA□, state-owned electricity production company, the government decided to privatize Kızıldere Geothermal Plant, and privatization took place on March 5, 2008. As a result of this privatization, the licenses and rights of this Field is transferred to Zorlu Energy Group on September 1, 2008, who won the tender. From that day forward, an intensive work towards developing the Field has commenced: Starting with a due diligence study followed by the gathering and evaluation of all data in hand, the Group plans to develop the geothermal field so as to meet both short term (15MWe energy production) and long term (60 MWe energy production) production targets. In this regard, while on one hand, a feasibility study is being prepared by a foreign consultant company, on the other hand, geophysical-geochemical studies, mechanical cleaning work, inhibitor tests and preparation of re-injection wells are continuing.

1. Introduction

Kızıldere Geothermal Field, located in south east of Aegean Region of Western Anatolia, in the province of Denizli, Turkey, (Figure 1) was discovered by General Directorate of Mineral Research and Exploration (MTA) in 1965. Following this discovery, various scientific studies have been conducted at the site with the ultimate aim of converting this geothermal resource into electricity. For this purpose, the first pilot power plant with 500 kWe capacity was constructed in 1974, followed by a 17.4 MWe capacity power plant commissioned by TEK (Turkish Electricity Authority) in 1984.

On September 1, 2008, Zorlu Group, one of the biggest holdings of Turkey, has acquired exploitation license for 70 km^2 Kızıldere Geothermal field and current Power Plant through a privatization tender. Receiving all legal rights for the exploitation of this resource, Zorlu Energy commenced working on this new project with the ultimate aim of constructing a new, sustainable power plant with 60 MWe capacity as the first stage of power expansion. As a first step in the project, the operating efficiency of the current power plant has been increased from 6 MW to 15 MW.

Meanwhile, a new exploration programme is prepared, and geochemical and geophysical (gravity and magnetic surveys, resistivity surveys) studies commenced in line with this programme. After the completion of required exploration and environmental studies, new wells are going to be drilled within the scope of this plan to produce electricity at the planned new power plant. In this regard, resource modeling studies still continue, along with the

feasibility studies, and environmental impact assessments to get necessary legal permits.

The Investor of this project, Zorlu Holding, has been active in energy sector since 1993 and has achieved a continuous growth in the sector with its Energy Group Companies. The company engages in the various activities in the energy sector including hydrocarbon exploration, production, distribution and trading, renewable energy development and power plant operations. In 2008, with the transfer of rights of Kızıldere Field, Zorlu Energy involved Geothermal Energy projects into its program and started to play a key role in exploration, production, well maintenance and operation services of the geothermal field. Company works with highly skilled human resources profile, and, professionals working in geothermal projects have long experience in geothermal resource development. The company also gets additional consultant services from reputable foreign consultant firms and academia when deemed necessary.

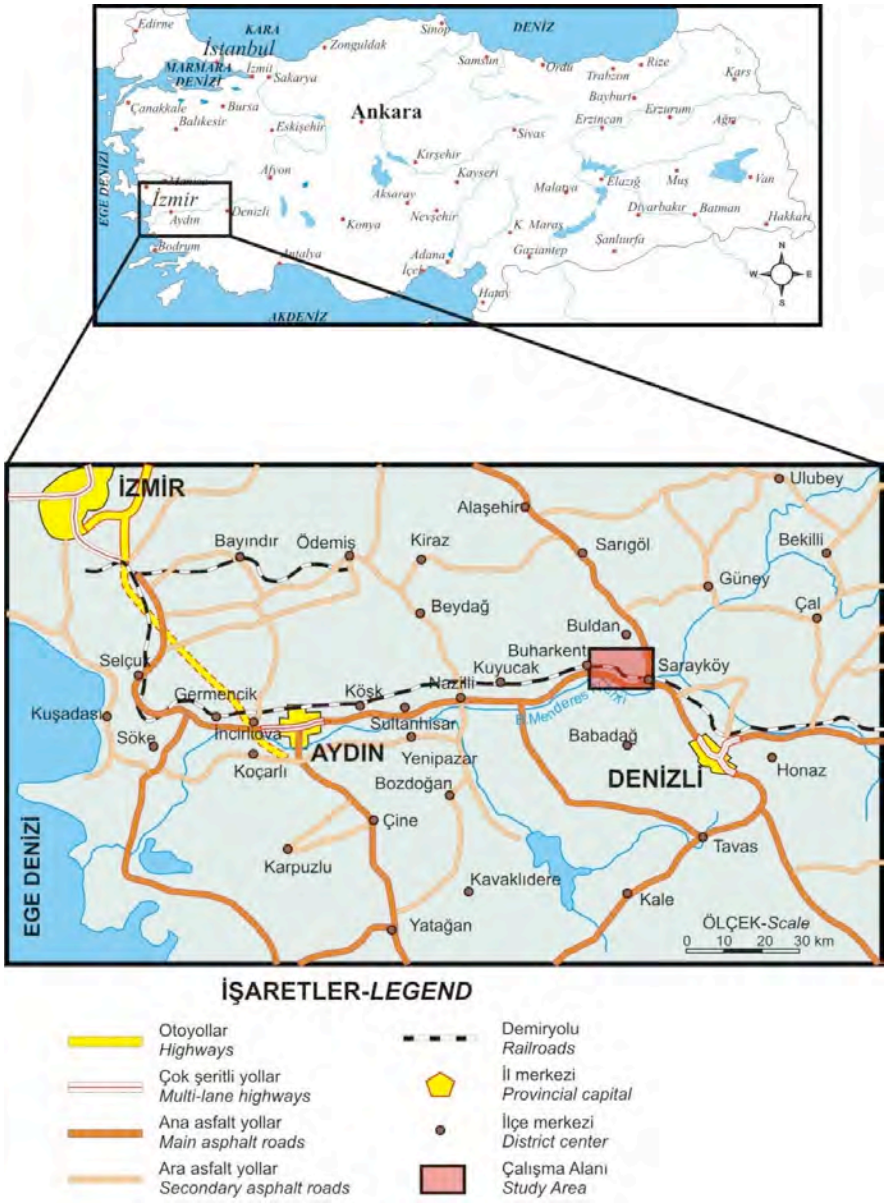

Fig. 1. Map of Turkey and Kızıldere Geothermal Field

Turkey is a net energy importing country and her energy policies are being constructed so as to achieve diversification of energy mix in the most environment friendly and energy efficient way. Turkey has ambitious targets in the development of renewable resources: By 2020, 25% of the electricity demand is expected to be met by renewable energy resources and

total installed geothermal power capacity is planned to be 600 MWe. Zorlu Energy is aware of these targets set forth for the next decade, and working to meet increasing energy demand in the most sustainable way, the Group invests in renewable energy projects some of which include hydroelectric power plants (190 MWe), geothermal plants, solar systems (120 KWe) and wind farms (225 MWe). Kızıldere geothermal field is the largest and most important geothermal field in Turkey, and Zorlu Energy is working hard to develop this resource to achieve clean and sustainable electricity production. Despite promising geological studies and reservoir estimations, the Field has been operated with low capacities and production rates over the last 25 years. Hence the development of the project will provide a source of clean, reliable, economical, indigenous electric power and will reduce the country's reliance on foreign oil and gas for power generation. The project will be a state-of-the-art geothermal facility, based on technologies developed around the world to make geothermal plants very efficient and reliable sources of electric power. Hence, this project is an innovator for new projects concerning the use of geothermal resources and the success of this project should reduce the perceived risk of development elsewhere in Turkey. Believing that sustainability is the key element in energy projects, Zorlu Energy is aware of the potential Kızıldere Geothermal Field carries and is dedicated to develop the field to achieve increased production targets.

1. History of Geothermal Energy in Kızıldere Field

Kızıldere is the first geothermal field used for electricity production in Türkiye. The geothermal field is named after Kızıldere city, which is located in the south east of Aegean Region of Western Anatolia. The license area covers partly Sarayköy and Buldan towns of Denizli and Buharkent town of Aydın (Figure 1).

The initial exploration studies in the field go back to 1960s: In 1965, following geological and geophysical studies; MTA performed the first well drilling in the area to the depth of 540 meters, and observed 198°C of temperature in the well. Between 1965 and 1973, 16 more wells have been drilled in the field whose depths are varying from 370 to 1241 meters. In 1974 a 0,5 MWe pilot turbine is constructed by MTA and this turbine is mounted to KD-13.

With this pilot turbine, three nearby villages' electricity demand is supplied free of charge between 1974 and 1980. Following this pilot study, in 1984, the first geothermal plant which has a generator output of 15 MWe and a total capacity of 17, 4 MWe is constructed. Between 1985-1986, 3 new wells (KD-20, KD-21, and KD-22) were drilled to supply the plant with vapour, increasing the total number of wells in the field to 9.

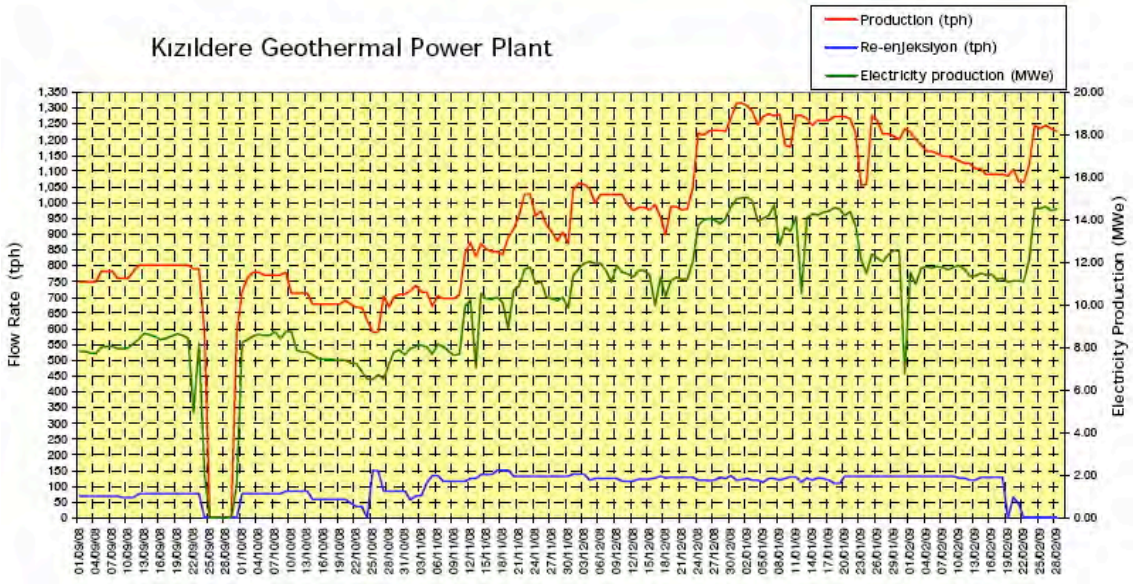

Fig.2 Production in Kızıldere Geothermal Power Plant

At first, R-1 was planned to be a reinjection well and drilled at a depth of 2261 m. in 2001. However it is discovered to have the highest temperature (242 °C) geothermal well in the field, as well as in Turkey, and because of its productivity and high enthalpy; it is now being used as a production well. R-2 is drilled to be used as a reinjection well in 2002 at a depth of 1428 m. This well is the only reinjection well of the field.

Three reservoirs have been identified in the Kızıldere region: First reservoir is Sazak Formation between Pliocene units. Second reservoir is Igdecik Formation of Menderes Metamorphics and third reservoir is gneiss and quartzite under the micaschists. Pliocene aged clay, marl and sandstone alterations represent the caprock in the geothermal system. Besides these discovered reservoirs, recent research studies indicate the possibility of a fourth and undiscovered reservoir with a temperature varying between 250-260°C. To prove the existence of this new reservoir, a new exploration well is planned to be drilled to a depth of 3000 m in the greenfield area. The reason of such a deep target depth is that the hotter reservoir will probably be under the depth of 2500 meters.

2. Geology of Kızıldere Field

The geological evolution of the region is explained by the principles of the "Plate tectonics" and it was concluded that Western Anatolia is important in terms of the fields where the greater slip-step fault zones and faults with different directions intersect or converge during the development of the geothermal graben in the region .

As the stratigraphic units of the region, Paleozoic Menderes metamorphic basement takes place. The metamorphic mainly consists of gneiss, variety of schists, quartzite, micaschists and marbles. Cenozoic terrestrial-lacustrine sediments are overlying these metamorphic rocks.

At the Middle Miocene, the subduction zone developed from Taurus Mountains towards lower part of the Anatolides caused partial melting and igneous intrusions in the massif.

The dense ophiolite covered the massif transported southwards and generated the Lycian nappes. The Menderes massif, with its dome-like rise, has gained the feature of a tectonic window and as a result of the extension, the graben systems have developed. Another important factor that caused the development of the graben systems is the collision of the Anatolian- Arabic plates along Bitlis suture zone so the Anatolian plates move towards west with North and East Anatolian faults starting from Tortonian.

In the Plio-Quaternary, regional tectonic factors initiated the formation of grabens and the effects of these factors can still be observed today. The known and registered earthquakes also confirm this fact. The faults generating the grabens and horsts are generally parallel to each other and normal slipped. Also reverse faults' developments are conformable to graben tectonics.

Tectonic: The term of neo-tectonic means all the tectonism within a time from last tectonic change in regime in any region until today (Sengör, 1980). According to the definition, the neo-tectonic age in Turkey started with the collision of Anatolian and Arabic plates on Bitlis suture zone As a result, the Anatolia plate including Central and West Anatolia started to be pushed over Eastern Mediterranean lithosphere which can easily slip towards west from East Anatolia pressure region along with North and East Anatolia transform faults. Since the direction of North Anatolia transform fault changes into SW-NE direction, Hellenic shear zone at the west of the Saros Bay prevents the Anatolian plate from moving towards west and there is a pressure regime towards the east-west direction in all Aegean and West Anatolia.

At the same time, since the Eastern Mediterranean lithosphere (Levant oceanic crust) dive under the Anatolian plate, an anatexis zone was formed under the Menderes massif so the intrusions of the massif developed and the massif uplift (Sengör & Yılmaz, 1981).

Therefore, all these effects created the Aegean graben system. Menderes Massif is at the centre of the Aegean graben. Kızıldere geothermal field is at the intersection point of the Büyük Menderes and Gediz grabens in Menderes Massif

The edge faults of all grabens in the Aegean graben system, have a decreasing slope towards

deeper in accordance with listrique normal faults.

After Gökdere fault, that is the main fault of the Büyük Menderes graben at the north, the parallel folds are detected in Kızıldere Geothermal Area. The fold especially in front of the Kızıldere fault is covering faults of whose wave length decreased towards deeper. Similar folds can be seen in the graben tectonic locally (Goguel, 1952). The directions of the folds are almost E-W direction. The wave lengths decrease towards southward within 2 km. after Kızıldere fault. These folds are clearly seen in Gebeler stream valley where Kızıldere hot springs take place and natural profiles in the valleys which are parallel to that valley. The fractures and faults occurred where the folds are overpressured (**Ş**im**ş**ek et al., 2009).

Hydro-Geochemical Studies In Kızıldere Region: There are a few surface waters, cold springs and mineral water and thermal springs and fumaroles at the vicinity of the Kızıldere area

Since 1968, 25 deep wellbores are drilled in Kızıldere geothermal area and its vicinity. Today, 24 of these wellbores remain within Zorlu Energy license area. These wells, whose depths change from 370 meter to 2261 meter, have fluid temperatures varying between 137 °C to 242 °C.

Geochemical analyses of cold, hot springs and wells in the Kızıldere area and its surroundings show that three types of water exist in the region. (I) Alkaline bicarbonate waters (4500 ppm<TDS<6000 ppm) in Kızıldere geothermal wells (KD1, KD6, KD13, KD14, KD15, KD16, KD20, KD21, R1, TH2, R3) that interacts with high-grade metamorphic rocks for long time. (II) Alkaline earth bicarbonate waters (TDS<500 ppm) cold springs, (III) Alkaline sulphate waters (TDS <3000 ppm); Tekkehamam hot springs.

Thermal springs' characteristics mainly represent the existence of Na-K-Ca; HCO3-SO4-Cl and geothermal well waters characteristics represent the existence of Na+K-Ca-Mg and HCO3+CO3-SO4-Cl in the region.

Geothermometry

(Na-K-Ca and SiO_2) show that the temperature of the reservoir is between 240 and 260oC in Kızıldere field.

Isotope Analyses

The isotopic compositions of water samples are taken from R-1 in the Deep Reservoir and from several wells (KD-6, KD-13, KD-15, KD-21) in the second reservoir (Simsek et.al. 2000). Stable isotope analyses of water samples indicate that the geothermal waters have a meteoric origin. There is a clear d18O shift from the MMWL and cold water values. This suggests that, water-rock interaction is an important process for geothermal fluids and implies deep circulation and high temperatures. Hot spring waters and deep geothermal well (Simsek et.al. 2000 and Simsek 2003).

Gas Measurement in the Wells

The non-condensable gas content of all wells except R-1 are approximately %1-1.8 by weight. For R-1, this value is %3 by weight.

Geophysical Studies In The Kızıldere Region: First geophysical studies around Denizli province was carried out by MTA: In 1965, a gravity survey in an area of 1500 km² and an electrical resistivity survey around Kızıldere-Tekkehamam field covering 40 km2 area were conducted (Tezcan, 1967). Following these studies, gradient wells approximately at 130 locations were drilled in Kızıldere, Tekkehamam and Karakova fields (Demirörer, 1967) and detailed 1/10000 scaled gravity surveys were completed in Denizli-Dereköy and Kızıldere fields (Ekingen 1970 and 1971). In the scope of these studies several seismic profiles were conducted around drilling wells (Tümer, 1970). Later on, additional gradient wells were drilled in Tekkehamam field (Simsek, 1977).

Within the scope of a project aspiring investigating geothermal possibility of Denizli province, systematic resistivity surveys were conducted in an area of 500 km², which also includes Kızıldere field (Turgay, Özgüler, Sahin, 1981). In 1985, additional resistivity survey was conducted to investigate reinjection possibilities in Kızıldere field (Özmen, 1985). In 1988, resistivity, magnetotelluric and seismic methods were applied at Kızıldere-Tekkeha-

mam fields, during ENEL-TEK joint site feasibility project. These anomalies overlapped in a geological map.

With the acquisition of the license area, Zorlu Energy has hired MTA as a sub-contractor to perform gravity, resistivity and vertical electrical drilling studies in the Kızıldere license area. Details of these studies are presented in Project Activities.

Gravity data provide information about general situation, direction and size of graben and horsts. The results of resistivity studies justify the geologic data and allow for the identification of some zones with low resistivity as well as the determination of the thickness of Neogene cap units. New well locations in Kızıldere geothermal field will be decided based on this information.

Totally 130 gradient wells were drilled in the caprock with depth range between 80-150 m to obtain more reliable results about Kızıldere geothermal area (and its vicinity) anomalies. 100 of these wells were drilled in Kızıldere whereas the reaming 30 wells were drilled in Tekkehamam area (Demirörer, 1967, Şimşek, 1977). Isothermal lines were drawn for 100 m depths of gradient wells in Kızıldere and Tekkehamam areas. Anomalies which were determined according these values are overlapped to isogradient lines. These anomaly values corresponding to 92 °C per 100 m in Kızıldere and up to 110 °C in Tekkehamam area. The lowest value was determined about 30 °C. Gradient value was taken as ground temperature per 10 m increment. This value was determined in a range between 1 °C/10 m and 10 °C/10 m.

Isogradient map constructed by gradient well data's of Kızıldere geothermal area shows an anomaly on W-E direction, from Kızıldere town toward to Tosunlar town. All of these anomalies are conformable with geological and other geophysical data. Deep wells were drilled at central part of this anomaly. While geothermal gradient of the anomaly observed in the geothermal wells located in middle of the field is 7.0 °C/10m, it is seen that these values fall down to 3° C/10 m at the deep wells located at the south of the field.

In 1988, ENEL conducted an electromagnetic survey at 25 points to define the conductive area. Thickness of the conductive zone was determined as 9 kilometers. This area can be interpreted as magma rising and getting close to the surface. Also, within the scope of this study, a total of 4 seismic lines were recorded for a total length of 25 km. The results were then evaluated and mapped together with electromagnetic and resistivity studies.

Geothermal anomaly map is prepared by utilizing data obtained from geology and geophysics (MT and seismic studies). Main recharge area of the field is horsts where permeable formations are found. The limestones of Sazak formation and wide alluvial basin are also important recharge areas. Recharge of all geothermal reservoirs depends on surface recharge and also intensive fracture systems.

Heat sources: Meteoric water is heated in deep sections by magmatic emanations. Developments of geothermal possibilities were observed as a result of mainly big slip and intersecting deep faults formed by intense tectonism. Also, high rate of extension of grabens are important especially for recharging the area and for the circulation of geothermal fluids.

3. Exploration Activities in Kızıldere Field

Kızıldere first stage 60MWe Geothermal Power Plant Reservoir Assessment and Feasibility Studies still continue. Preliminary assessments regarding the project indicate that the project the power plant will utilize double flash system. Zorlu Energy is working with foreign engineering and consultancy companies, namely, Power Engineers (PEI), Geologica, APEX and Veizades and Associates, for the successful achievement of the project. However, it is not possible to comment on the type and engineering specifications of the planned plant before the completion of the feasibility studies.

For the 1st Stage 60MWe power plant to work efficiently (as a first stage), 25 production/re-injection wells are required. Therefore, if existing wells are to be used, 15 additional wells will be needed. In this regard, 10 wellhead equipment are ordered for the drilling of the new wells. The drilling activities at the site will commence on August 2009, depending on the delivery of the equipment to the site.

The planned and ongoing exploration and reservoir assessment activities in order to feed the first stage 60 MWe plant can be summarized as follows:

Geological investigation at the Site: Geological studies at the site started with gathering and filtering of all the available information up to date to assess current situation of the site.

This study, conducted by academicians from Middle East Technical University (METU) and Hacettepe University, was not only helpful in terms of providing a better understanding of the site geology and reservoir, but also allowed for defining a roadmap for the rehabilitation of existing production and re-injection wells, as well as identification of further exploration activities. Within the scope of this roadmap:

Geochemical exploration studies have started in March 2009, and still continue. These studies are aimed at determining the geochemical properties of the reservoir fluid, and foreign consultants from reputable institutions such as Institute of Geosciences and Earth Resources (CNR) and US based Power Engineers (PEI) are being involved in the testing process as well as the interpretation of the results.

Geophysical exploration including gravity-magnetic surveys and resistivity studies, on the other hand, started on March 2009. Gravity and magnetic surveys, conducted by MTA, are completed with the analysis of a total number of 888 point surveys. The results of this survey are being evaluated by the experts and the evaluation studies will be completed in May 2009. Resistivity and DES studies, again being performed by MTA, have started in April 2009, are expected to be completed in 1.5 months.

All exploration activities conducted so far are towards identifying successful new well locations which will allow for the most beneficial exploitation of the third reservoir with a temperature of 242°C, and prove the existence of a fourth, deeper and hotter reservoir (>250°C).

Drillings for these new wells are scheduled to start by the last quarter of 2009. For this purpose, a detailed drilling budget is prepared; main procurement items and contractual services are being identified; and a work plan is being prepared.

Reservoir Capacity Estimation and Feasibility Study: Reservoir modeling studies have been started on February 2009, and are expected to be completed by June 2009. The studies are being conducted by an international team of experts including academicians from METU and Hacettepe Universities, PEI, Geologica, Veizades and Associates, and experts from Zorlu Energy.

Permit Applications: Various legal permits are required for operating the power plant. These permits include; Exploitation License for Geothermal Field, Electricity Generation License from EMRA, Environmental Impact Assessment (depending on the legal status of the site). Exploitation license of the 70 km2 field has been acquired on 2008 for a period of 30 years. Other permit applications are still ongoing as the project progresses.

Detailed Engineering: After the completion of the feasibility studies, detailed engineering design of the first stage 60 MWe power plant will be done.

Power plant construction: After obtaining relevant permits, construction phase of the new power plant will commence. Total duration of the construction period is anticipated as 40 months.

According to existing data and reports, and preliminary results of the Feasibility Study conducted by PEI, the resource capacity has a 90% probability of producing 65MW electricity, 50% probability of 122MW and 10% probability of 203MW over 30 year life. Currently, the generated electricity is being transmitted via Nazilli, Sarayköy and Simav transmission lines according to the agreement that exists between ADÜAŞ (former operator of the existing power plant) and Turkish Electricity Transmission Company (TEİAŞ). As mentioned before, Turkish Renewable Energy Law secures the purchase of electricity produced from renewable energy resources. Hence, it is anticipated that main consumers of the electricity generated from this power production operation will be the Provinces of Aydın, Denizli, and Kütahya, and the electricity

will be purchased by State Electricity Generation Company (EÜA**Ş**).

4. Current Site Activities

Zorlu has acquired the operation license of the current 17.4 MWe Power Plant along with the exploitation license of the field, and by law, is obliged to operate the Power Plant with maximum efficiency.

Following the acquisition of the Field, the increase in the efficiency of the Power Plant can be observed clearly: While before privatization the Plant was operated with a capacity of 5.4 MWe, at the moment its average capacity is 15 MWe. To keep the efficiency at this level, Zorlu gives outmost importance to the maintenance of the current wells. In this regard, the mechanical cleaning of the 9 production wells is still in progress. Selection of the CaCO3 scale inhibitor process on the other hand is completed, and installation of the inhibitor injection system is on the way (equipment is ordered, installation is expected to be done in 2009 May). Re-injection rehabilitation work plans are continuing, and unused production wells are being prepared for re-injection instead of drilling new wells. In this re-injection frame work over has started and is continuing. The related well production parameters can be observed in Figure 3.

Mechanical Cleaning of Production Wells KD-13, KD-14, KD-15, KD-6, KD-20 KD-21, KD-22 and R-1 wells' cleanup facilities are performed by MTA with the assistance of Petrogas. Well cleaning operation and testing of the production well is in progress.

Well Name	Bottom Hole Temp. °C	Estimated Welhead Enthalpy (kJ/kg)	Well Altitude (m)	Well Head Pressure (barg)	Total Depth (m)	Flow Rate Brine (tph)	Production Flow Rate Brine (tph)	Flow Rate Steam (tph)	% steam in brine	Flow Rate CO_2 (tph)
KD-6	196	834,3	184	10	851	135	132	13,2	10	2,0
KD-13	195	829,8	189	12,7	763	171	160	16	10	2,4
KD-14	207	883,9	197	13	597	177	160	19,2	12	2,9
KD-15	205	874,9	215	11	510	147	130	15,6	12	2,3
KD-16	211	902,2	201	11	666	200	180	21,6	12	3,2
KD-20	201	856,8	195	10	810	175	160	19,2	12	2,9
KD-21	202	861,3	205	11	898	160	140	16,8	12	2,5
KD-22	202	861,3	193	10	888	160	140	16,8	12	2,5
R-1	242	1047,1	146	26	2261	300	210	36,54	17,4	3,7
Total						1625	1412	174,9		24,4

Figure 3. Well production parameters

Figure 4. $CaCo_3$ scaling formed in KD 13.

$CaCo_3$ scaling formed in the production wells and surface facilities is cleaned by mechanical reaming and (HCl) acidizing operations. To prevent $CaCO_3$ scaling in production wells; 10 different inhibitors of 8 different companies from Italy, Germany, USA and Turkey are tested. Tests were started at 24 November 2008; and completed in a month successfully. For the inhibitor test existing wellhead equipment, down hole equipments and injection system was overviewed and prepared for the test. As a result of these studies, it is observed that 5 of the inhibitors are succeeded in preventing scaling.

Re-injection Studies Re-injection is indispensable to preserve the reservoir balance. In this regard, a re-injection action plan was prepared. The studies are continued to re-inject the remaining part of the geothermal fluid, after the separation of the steam.

Simulation of Current Potential Re-injection Wells Within the scope of this work, produced fluid in reservoir (1250 ton/hour) will be re-injected to 6 reinjection wells. Cleanup and development surveys for this purpose are still going on. Simulation studies are conducted in order to determine the injectivity indexes of re-injection wells and as a result of this study, wells which can be used for this purpose are determined and are being improved. Also, the contract is awarded for surface facility design and finalized.

Turkey's highest capacity 60 Mwe geo-thermal power plant is going to be constructed in Kızıldere in a few years by Zorlu Holding. Not only the current activities in the field such as mechanical cleaning of wells and reinjection studies but also the prospective exploration activities by gathering the geoscience disci-plines like geology, geophysics, geochemistry and reservoir, Kizildere geothermal project is going to addressed as a unique example and leader in Turkey geothermal milestone.