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Update on Geothermal Utilizations in Thailand

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ABSTRACT

There are one hundred eighteen hot spring manifestations in Thailand, exposed in the north and extended towards western and southern Thailand, with surface temperature ranges of 40-100°C. Thermal water is clear, but with white algae and white, yellowish and reddish of carbonate, sulfur and iron can be envisaged as spotted on ground surface. Chemical analysis indicates that the thermal water contains various concentrations of dissolved chemical species e.g. pH ranges of 6.4-9.5, conductivity ranges of 225-26,500 microsiemen/cm and fluoride ranges of 0.005-20.4 ppm. There are 9 hot spring areas in southern Thailand exhibiting brackish or saline water.

Preliminary studies of hot springs indicated different degree of mixing of thermal water with country rocks. Chemical compositions of hot spring not equilibrium caused some geothermometer calculations using Na, K Ca and SiO2 to be unreliable. Almost all geothermometer calculations provide a similar reservoir temperature where the five highest reservoir temperatures range from 180-210°C, namely San Kamphaeng, Fang, Mae Chan, Sop Pong and Mae Choke hot springs.

Hot spring manifestations can be classified related to rock types into two types as hot springs manifest in granitic rocks and hot springs manifest in sedimentary or metamorphic rocks. Heat sources anticipate as combination of five parameters. First, hot springs manifest in granitic rocks, receive heat exchange from thermal water and country rocks. Second, hot springs manifest in granitic rocks, comprise higher concentration of radioactive elements than world average, receive heat from decay of radioactive element. Third, hot springs manifest along high angle dipping fractures and faults, receive heat from tension between fault plane. Forth, hot springs manifest along N-S normal faults occurred wide spread along Tertiary basin in Thailand, receive heat from faults. Fifth, hot springs manifest in high heat flow area caused by thinner crustal thickness, receive heat from shallower hot intrusive rocks.

Geothermal resources in Thailand are classified into low-medium enthalpy. Hot spring manifestation in northern Thailand provides higher potential than in the other part. Many expert teams point out that there are suitable possibilities for small scale power plant i.e. 1-10 MWe. Hot springs manifest in western and southern Thailand are classified as low enthalpy and suitable for agricultural, tourist attraction sites and therapy bath. Currently, geothermal utilization as binary cycle power plant is 0.3 MWe and capacity for direct uses is 127.47 MWt. Direct uses are practically restricted to bathing and swimming pool in recreation area and therapy. Most possibilities for future geothermal activities in collaborating between private sector and government sector should be multipurpose utilizations e.g. binary power plant and direct uses drilled at depth less than 1,500 m and reservoir temperature around 130°C.

1. INTRODUCTION

Hot springs are a natural phenomena indicating that the earth's interior is hotter than its surface, has been studied since 1946. There are one hundred eighteen hot springs with surface temperatures ranging from 40 to 100□C, scattered from north to south, occur in Thailand (Figure 1). They appear not only within volcanic outcrops but also within granitic and sedimentary rocks of various ages. Surprisingly, there are no hot springs occurring in northeastern Thailand. Generally, the local community uses hot spring to boil their agricultural product e.g. bamboo shoots and eggs, or for recreational bathing.

Systematic studies to extract the geothermal energy have been conducted in northern Thailand by a working group comprised of Chiang Mai University (CMU), the Electricity Generating Authority of Thailand (EGAT) and the Department of Mineral Resources (DMR) since 1977. One of the main purposes is to utilize geothermal energy to generate electricity. Thermal water released from a power plant will be piped to agricultural-industrial processes and recreation (Ramingwong et al, 1979).

Various international organizations have cooperated on geothermal exploration. During 1982-1989, the EGAT and the Japan International Cooperation Agency (JICA) established technical collaboration to define geothermal potential at the San Kamphaeng geothermal field, Chiang Mai province (JICA, 1988). Reconnaissance survey of geothermal resources in northern Thailand, under the United Nations Development Programme (UNDP) on behalf of the working group, was established during 1983-1984. A pilot plan for utilization of geothermal energy to generate 300 kW electricity at the Fang geothermal field, Chiang Mai province, under cooperative between EGAT and the Bureau de Recherches Geologigues et Mineres (BRGM) of France, began in 1987. The first geothermal power plant in Thailand using binary cycle was installed and completed on December 1989.

EGAT investigated geothermal potential at the Muang Rae and Muang Paeng geothermal area in the Pai district during 1994-1996 and concluded that the areas are suitable to utilize geothermal energy for agricultural purposes. The Mae Chan geothermal area exhibits high potential and has been recommended by many workers to extract thermal energy for direct uses (Ramingwong et al., 1980, 1985; Chuaviroj, et al, 1984; Geotermica, 1984; Manoonvoravong and Virapun, 1996).

During 2010's period, geothermal explorations were accelerated due to an abrupt increase in petroleum price. People are more aware of energy security with an affordable price. They explored for alternative energy and geothermal is one of the targets. Department of Alternative Energy Development and Efficiency (DEDE), Department of Ground Water Resources (DGR) and

Petroleum Authority of Thailand (PTT) have signed a contract since 2011 to research on multipurpose geothermal utilization. It is anticipated that the collaboration among them and the DMR will be successful to utilize geothermal for electricity generation at a scale of 1-10 MWe.

Geothermal energy potential has been classified as low, medium and high potential (Thienprasert, et al., 1987). Utilization schemes should be drafted and regulations should be endorsed as guidelines for the explorer and developer to utilize each hot spring area. Priority should be given for the benefit of the local people. The multipurpose utilization projects under auspices of government and foreign aid should be implemented. Government sector should encourage and provide incentive so that cutting trees as well as imported of energy can be reduced.

This paper gives update information on past, on-going and future geothermal research and development projects.

2. GEOLOGY BACKGROUND

Simplified geology of Thailand comprises rock ranging in age from Precambrian to Quaternary where the oldest rocks of Precambrian age exposed mostly in the northwestern part and rocks become younger to the eastern part. Lithologically, the Precambrian rocks comprise granitic to granodioritic gneisses, mica to hornblende schists, calc-silicate to marble and locally quartzite of amphibolite facies, are unconformably overlain by Cambrian to Ordovician siliclastics and carbonates which grade to sedimentary sequence of Silurian-Devonian of greenschist facies (Salyapongse, 2002). The whole sequences of the Paleozoic rocks are mainly of marine origin. The upper Paleozoic rocks, Carboniferous and Permian sedimentary rocks, mostly lie conformably on the lower Paleozoic rocks (Raksaskulwong, 2002). The Carboniferous strata can be recognized as pebbly rocks while the Permian strata composed mainly of limestone can be recognized by karstic topography.

Mesozoic sequence can be lithologically subdivided into two main facies, namely the marine and the non-marine facies. The marine Triassic and Jurassic sequences are restricted to the long narrow fault-bounded basins. The younger non-marine Mesozoic rocks of mainly N-S trending are composed of the Jurassic and Cretaceous red beds and evaporites.

The oldest igneous rocks are volcanic rocks and volcanogenic sediments mainly andesitic and rhyolitic composition, stratigraphically dated Silurian to Devonian. The most common intrusive rock is granite and related rocks (granodiorite and diorite) which can be grouped into three subparallel magmatic belts based on their field occurrence, petrography and chemical characteristics (Nakapadungrat and Putthapiban, 1992; Putthapiban, 2002). The Eastern Belt Granites occur as small batholiths of Triassic age and show I-type or Magnenite Series affinity. The Central Belt Granites occur as major batholiths and large complex plutons of mainly Triassic age and disclose S-type or Ilmenite Series affinity. The Western Belt Granites comprise a mixed population of major S-type and minor I-type, which are indicated as Cretaceous. The S-type granites occur as large batholiths whereas I-type granites occur as small plutons. The Indian-Eurasia collision during the Cenozoic caused tensional faulting which indicated by widespread fields of Neogene and Early Quaternary alkaline basalts in Thailand and Indochina (Bunopas, 1981; Mitchell, 1981; Bunopas and Vella, 1983, 1992; Gatinsky, 1986; Peltzer and Tapponnier, 1988). Tectonic influences in hot spring occurrences may be derived from granites and Cenozoic tensional faults (Figure 1).

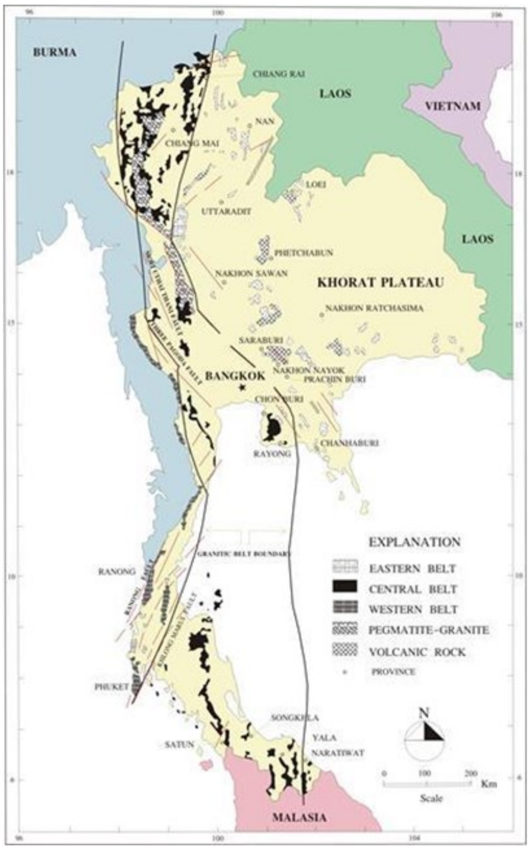

Figure 1 Map shows granite distribution and major faults in Thailand (Putthapiban, 2002).

3. GEOTHERMAL RESOURCES AND POTENTIAL

In Thailand, hot spring and geyser manifestations, associate with areas of high geothermal gradient and heat flow, have been suggested for possibilities of geothermal energy resource development.

3.1 Hot Springs

Hot springs have been investigated intensively in northern Thailand since 1977 whereas preliminary hot spring investigation has been conducted sometimes in other parts of Thailand. Natural hot water, discharged from the hot spring, is rather clear. Hot springs with surface temperature around 100°C, expressed as geyser, fumarole, bubbling and boiling springs whereas hot springs with surface temperature less than 80°C, are displayed as hot and seep pool.

The hot spring systems in Thailand can be classified, on surface temperature basis, into three systems as (Figure 2): (1) hot spring system indicates surface temperature of between 80 to 90°C, exposes in northern Thailand; (2) warm spring system indicates surface temperature between 40-80°C due to mixing of geothermal water with ground water during circulation and upflow to the surface. These hot springs represent most of the hot springs in Thailand; (3) geyser system yields surface temperature between 90-100°C, found only at the Sankamphaeng, the Fang, the Pongdeud, the Theppanom geothermal fields, in Chiang Mai province and the Maechan in Chiang Rai province (Ramingwong et al, 1979: Geotermica, 1984; Raksaskulwong and Chaturongkawanich, 2001).

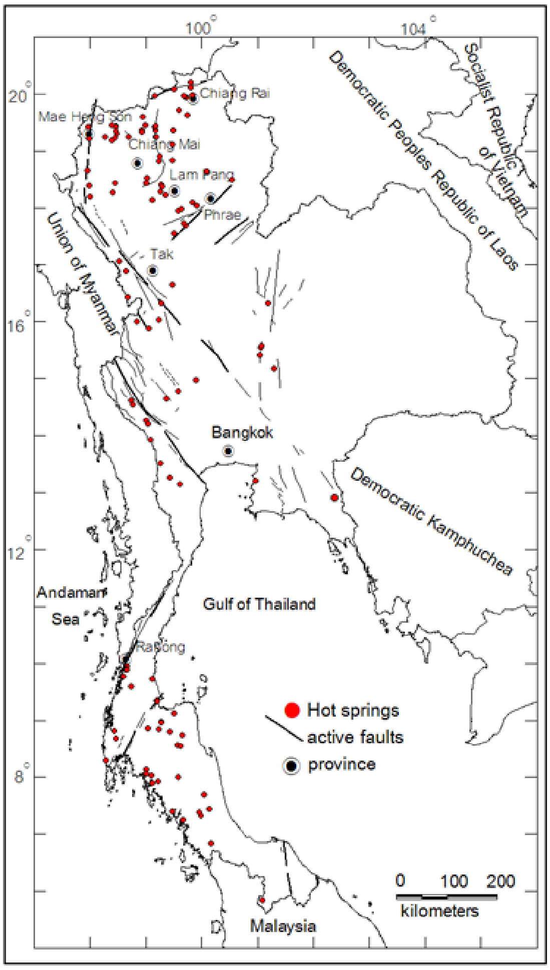

Figure 2 Map shows hot spring distribution and active faults in Thailand.

3.2 Geochemical Characteristics

Thermal water discharges from hot springs in Thailand are rather clear, colorless and pH ranges are from 6.4 to 9.5. The thermal water is very young, probably has been derived from meteoric water and rain, infiltrated through underground. The water receives heat transfer from hot rock then heated up and exposed to surface.

Generally, the water contains a low concentration of dissolved chemical species and is characterized by high alkali-sodium and bicarbonate (Takashima and Jarach, 1987, Thienprasert et al, 1987). In northern Thailand, fluoride concentration is rather high especially where hot springs manifest near granitic rocks and sulphide smell is rather strong whereas in southern Thailand, the fluoride concentration is rather low and sulphide smell is rather mild. In southern Thailand, chemical compositions of some hot springs disclose high chloride content affected by mixing between thermal water and sea water e.g. at the Krabi, Trang and Suratthani provinces. Most of the geothermal resources in northern Thailand are classified as medium enthalpy (Geotermica, 1984; JICA, 1988).

There are neither active volcanoes nor recent volcanic rocks associated directly with hot spring manifestations. However, about two-thirds of the hot springs have been found to be related to some active geologic fractures, lineaments and granitic plutons of various ages (Figure 1 and 2)(Takashima, et al, 1989; Curray et al, 1978; Bunopas, 1981; Bunopas and Vella, 1983; Vella, 1983).

4. GEOTHERMAL UTILIZATION

A preliminary geothermal study revealed that there were many high-potential hot spring areas in northern Thailand with main reservoir temperatures reaching 200°C. Two geothermal areas of the first priority group, viz., San Kamphaeng and Fang, were selected for detailed studies in 1980. These studies were carried out in collaboration with foreign geothermal expert groups, indicated a moderate geothermal potential. The Fang geothermal field provides a good scheme for multipurpose utilization in the area of medium enthalpy resources. Present and planned production of electricity using different driven forces in Thailand is shown in Table 1. Geothermal utilizations in Thailand are described below.

4.1 Power Plant

A joint technical cooperation project between the BRGM, Geowatt of France and EGAT was formulated during 1981-1984. The purposes were to model geothermal reservoir and to appraise geothermal enthalpy targeting for electrical generation. The first geothermal power plant in Thailand using binary cycle was installed and completed on December 1989. The inlet vaporizer temperature, after passing through air released tank, varies between 115°C to 120°C and the temperature of the hot water released from vaporizer outlet is approximately 80°C (Korjedee and Prasatkhetwittaya, 1997). The thermal waters released from the power plant, since these are very clean, are planned to be exploited downstream for non-electrical utilizations and will be discussed later. Output from the 300 kW plant is connected to the local distribution grid system of the Provincial Electricity Authority (PEA) and provided 1.2 million kWh annually (Table 2).

4.2 Direct Uses

4.2.1. Drying Process

Faculty of Engineer at the Chiang Mai University, incorporated with the Mae Cho Agricultural Technology Institute and EGAT, had collaborated in extraction of the geothermal energy for tobacco curing and drying agricultural products in 1986. The first pilot drying house had been constructed at the Sankamphaeng geothermal field. Experiment for curing and drying tobacco, banana, chili, garlic, maize, peanut etc. shows satisfactory results compared to an old drying style using firewood and lignite.

At the Fang geothermal field, a drying house was also built and experiments have been performed on chili, tea, garlic, onion, lichee, tobacco potato, etc. The geothermal energy released from the binary cycle power plant can be exploited at downstream for agricultural-industrial and so on. Thermal water, released from the binary cycle power plant temperature 77°C, is fed to the process.

4.2.2. Cooling Storage Process

Hypothesis of this research, technically and economically consideration, is to extract energy of the released thermal water to develop a cold storage. The project, using the absorption refrigeration system, commenced in 1988. The pilot cold storage, dimension 3x4x2.2 meters could store 5 tons of agricultural products, was insulated with polystyrene. The cold capacity was 24,000 btu/hr and provided cold temperature at 4°C. Agricultural products used in the experiment were lemon, onion and lichee. Periodical evaluation of the system performance indicated that spoliation of the products has been decreased to only 8.2% loss of lemon and 10% loss of lichee within one month.

The Chiang Mai University also installed a drying process and cold storage at the Maechan geothermal field. All drying process and cold storage experiments have been shut down due to maintenance and budget difficulties.

4.2.3. Public Water and Recreational Ground

Hot spring baths have long been believed to provide medical therapy. Thermal water contains an average temperature higher than 40oC, which is suitable for therapeutic bathing. Many private sectors as well as local communities express their interests in promoting hot spring water for the touring visiting places. Hot spring bathing in a prestigious spa, offered at a hotel, is one of the best alluring commercials in Thailand. In many places, the local community plays an important role to monitor use and preserve hot springs in the area. It is fashionable to decorate the area as a tourist visiting place as well as to provide hot spring utilization to private sector. The utilization of seventy nine hot springs for bathing, swimming and balneology is 1,168,898 TJ/yr (Table 3).

4.2.4 Heat Pump

This research, technically and economically consideration to extract subsurface energy for heat pump, is cooperation work among the Japan government organizations, the DGR, the Kasetsart University and the Chulalongkorn University. Utilization of heat pump at Kamphaengphet province was published in Bull. Geol. Surv., vol. no. 9/10 (whole volume) in 2009, Japan but the utilization at Chiang Mai province and the Kasetsart University are not published. Presently, only one system at the Chulalongkorn University is operating (Takashima personal contact). Amount of energy extracted is not available for this paper.

5. DISCUSSION

Thailand is neither situated in a recent volcanic area nor in a seismicity zone. There are one hundred eighteen hot springs with surface temperatures ranging from 40°C to 100°C, scattered from the north through the south, occurring in Thailand. The regional N-S trending tensional and extensional normal faults, widespread in Southeast Asia during Tertiary, play a key role in providing channels to heat sources at depth. High geothermal gradients near the hot spring areas may be affected by uprising of deep circulating waters to the surface (Takashima et al., 1989: Raksaskulwong and Thienprasert, 1995).

Systematic studies to extract the geothermal energy have been conducted in northern Thailand, where there are 66 hot spring manifestations. The multipurpose projects, under the auspices of foreign experts, are to utilize geothermal energy to generate electricity. A good example of multipurpose utilization of thermal water is at the Fang geothermal field. The installation of the geothermal power plant of 300 kW electricity applying binary cycle technique was completed on December 1989. The inlet vaporizer temperature varies between 115°C to 120°C and the temperature of hot water released from the vaporizer outlet was approximately 80°C. Output from the 300 kW generator is connected to the local distribution grid system and provides additional 1.2 million kWhr annually to the grid. The thermal waters released from the power plant are exploited downstream for drying house, cooling storage room and bathing recreation.

Hot springs manifest in granitic and sedimentary rocks, provide low-medium enthalpy. Careful and detailed investigation can locate areas yielding a capacity of 1-10 MWe which can be used by a binary cycle. Multipurpose utilization and combine with hydropower generation should be planned. Tourist and health related sectors have played a key role to the development of tourist destination.

Thai Universities do not provide degree directly towards geothermal studies. Geothermal research and development personnel come from organizations interested to extract energy at each period. It can be said that people conducted geothermal studies strictly worked for the organizations during 1977-1986.

Geothermal exploration and utilization have not been governed by any laws or regulations. There are some concerns about laws that prospecting organizations should take into considerations. In the case that hot spring locations situated in forest reserve area or public community, the exploration and utilization licenses should be requested from that organization. DGR regulates and governs the ground water act, which stated that any ground water well of a depth more than 30 meters should get drilling license and utilization license. Commercial bottled drinking water and bottled mineral water is governed and licensed by the Ministry of Public Health. The cooperation among DEDE, DGR, PTT and DMR will lead to the draft of geothermal regulation.

6. FUTURE DEVELOPMENT AND INSTALLATIONS

Development of low-medium enthalpy geothermal resources located in non-volcanic area and sedimentary basins should be sophisticatedly planned. Table 4 indicates total investigation during 2010-2014. This expense concentrates on prefeasibility study and part of a feasibility study e.g. shallow well and one deep well drilling carried out by the DEDE, DGR, PTT and DMR. Most of the expense of is paid by the DGR (90%) and 10% is paid by the PTT for total sum of 1,515,151.52 US$. They plan to summarize the possibility for geothermal power plants at 1-5 MW in 2017.

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STANDARD TABLES

Table 1. Present and planned production of electricity.

	Geothermal		Fossil Fuels		Hydro		Nuclear		biomass		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014	0.3	1.2	26494.49	152050.43	3436.18	17846.83	0	0	288.6	3414.91	30219.57	173313.37
Under construction in December 2014	na		na		na		na		na		na	
Funds committed, but not yet under construction in December 2014	na		na		na		na		na		na	
Estimated total projected use by 2020					5926.38		0	0	2378.7		50389	

Table 2. Utilization of geothermal energy for electric power generation as of 31 december 2014.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe*	Total Running Capacity MWe*	Annual Energy Produced 2014[3)] GWh/yr	Total under Constr. or Planned MWe
Fang, Chiang Mai	Fang Geothermal Power Plant	1989	1	active	Binary (Rankine Cycle)	0.3	0.2	1.2	0
Total						0.3	0.2	1.2	0

* Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced.

Table 3. Utilization of geothermal energy for bathing and swimming (B) as of December 2014.

Locality	Type[1)]	Maximum Utilization			Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Huaimakliam, Chiang Rai	B	14	80	36	2.577	7	40.625	0.5
Huaisaikhao, Chiang Rai	B	6	60	36	0.602	2	6.331	0.333
Maechan, Chiang Rai	B	30	93	36	7.155	7	52.628	0.233
Phasert, Ciang Rai	B	10	80	36	1.841	4	23.214	0.4
Pongphrabath, Chiang Rai	B	20	60	36	2.008	7	22.159	0.35
Pongpufueng, Chiang Rai	B	15	72	36	2.259	6	28.49	0.4
Soppong, Chiang Rai	B	30	92	36	7.029	7	51.705	0.233
Yangphakiew , Chiang Rai	B	10	85	36	2.05	4	25.852	0.4
Ban Pong, Chiang Mai	B	10	72	36	1.506	3	14.245	0.3
Doisaket, Chiang Mai	B	17	78	36	2.987	7	38.779	0.412
Fang, Chiang Mai	B	80	99	36	21.087	7	58.168	0.087
Malika, Chiang Mai	B	8	70	36	1.138	3	13.454	0.375
Nong krok, Chiang Mai	B	12.5	72	36	1.883	5	23.742	0.4
Pong Deud, Chiang Mai	B	22.7	99	36	5.984	5	41.549	0.22
Pongmen, Chiang Mai	B	4	70	36	0.569	11	49.331	2.749
Sankamphaeng, Chiang Mai	B	80	96	36	20.083	10	79.14	0.125
Thepphanom, Chiang Mai	B	14.4	99	36	3.796	5	41.549	0.347
Maeumlongluang, Maehongson	B	8	76	36	1.339	3	15.828	0.375
Muangpaeng, Maehongson	B	15.6	95	36	3.851	4	31.128	0.256
Nonghaeng, Maehongson	B	10	85	36	2.05	4	25.852	0.4
Phabong, Maehongson	B	9	63	36	1.017	4	14.245	0.444
Phuclone, Maehongson	B	15	70	36	2.134	7	31.392	0.467
Pongsak, Maehongson	B	16	85	36	3.28	5	32.316	0.312
Thapai, Maehongson	B	8	78	36	1.406	6	33.239	0.75
Jaeson, Lampang	B	14.7	78	36	2.583	8	44.318	0.544
Pongnamron, Lampang	B	7	60	36	0.703	3	9.497	0.428
Wiangnua, Lampang	B	7	55	36	0.556	3	7.518	0.428
Maechok, Phrae	B	20	82	36	3.849	6	36.404	0.3
Panjane, Phrae	B	7	53	36	0.498	4	8.969	0.571
Watsalaeng, Phrae	B	4	59	36	0.385	2	6.067	0.5
Ponglampang, Sukhothai	B	5	41	36	0.105	2	1.319	0.4
Huainamnak, Tak	B	6	58	36	0.552	2	5.804	0.333
Maekasa, Tak	B	10	75	36	1.632	4	20.576	0.4
Phraruang, Kamphaengphet	B	6	54	36	0.452	2	4.748	0.333
Namron, Phetchabun	B	8	42	36	0.201	4	3.166	0.5
Wangkham, Phetchabun	B	8	52	36	0.536	2	4.221	0.25
Bansamothong, Uthaithani	B	8	67	36	1.038	2	8.178	0.25
Bantonlamyai, Kanchanaburi	B	4	42	36	0.1	2	1.583	0.5
Hindad, Kanchanaburi	B	24	40	36	0.402	7	3.693	0.292
Watw angkanai, Kanchanaburi	B	20	42	36	0.502	7	5.54	0.35
Boklueng, Ratchburi	B	6	56	36	0.502	2	5.276	0.333
Phunamron, Ratchburi	B	5	50	36	0.293	2	3.693	0.4
Nongyaplong, Petchburi	B	5	47	36	0.23	2	2.902	0.4
Lamae, Chumporn	B	5	50	36	0.293	2	3.693	0.4
Pornrang, Ranong	B	10	45	36	0.377	5	5.936	0.5
Ratchkrood, Ranong	B	4	46	36	0.167	2	2.638	0.5
Thungyo, Ranong	B	4	40	36	0.067	2	1.055	0.5
Wattapotharam, Ranong	B	14	65	36	1.699	8	30.601	0.571
Khaonanghe, Suratthani	B	4	40	36	0.067	2	1.055	0.5
Khaonoi, Suratthani	B	4	53	36	0.285	2	4.485	0.5
Khaophu, Suratthani	B	4	58	36	0.368	2	5.804	0.5
Khaotok, Suratthani	B	4	62	36	0.435	2	6.859	0.5
Phunamron, Suratthani	B	4	45	36	0.151	2	2.374	0.5
Rattanakosai, Suratthani	B	4	70	36	0.569	2	8.969	0.5
Wattharnnamron, Suratthani	B	4	51	36	0.251	2	3.957	0.5
Bonamron, Nakhornsrithamratch	B	4	60	36	0.402	2	6.331	0.5
Uttayanbonamron, Nakhornsrithamratch	B	4	55	36	0.318	2	5.012	0.5
Bodan, Phangnga	B	4	45	36	0.151	2	2.374	0.5
Bonamron, Phangnga	B	4	47	36	0.184	2	2.902	0.5
Klongpaiphu, Phangnga	B	4	60	36	0.402	2	6.331	0.5
Rommanee, Phangnga	B	4	63	36	0.452	2	7.123	0.5
Namron, Krabi	B	10	47	36	0.46	5	7.255	0.5
Klongbonamron, Krabi	B	6	47	36	0.276	2	2.902	0.333
Namtoksaphanyoong, Krabi	B	10	47	36	0.46	7	10.156	0.7
Uttayanbonamron, Trang	B	14	52	36	0.937	5	10.552	0.357
Khaochaison, Phattalung	B	18	57	36	1.582	5	13.85	0.278
Nathungpho, Phattalung	B	4	50	36	0.234	2	3.693	0.5
Tonpanan, Satun	B	5	50	36	0.293	3	5.54	0.6
Tanomaero, Yala	B	10	80	36	1.841	5	29.018	0.5
TOTAL					127.47		1,168.90	0.451

Table 4. Total invesments in geothermal in (2014) US$.

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
2010-2014	1,515,151.52	0	na	0	20	80

remark 1 US$=33 Baht