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The 100-MW Ngatamariki Geothermal Power Station A Purpose-Built Plant for High Temperature, High Enthalpy Resource

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ABSTRACT

Successfully and sustainably tapping high temperature geothermal reservoirs at around 300 ºC at 3000 meters below the ground, requires very special expertise: a delicate blend of precision multi-disciplinary engineering, mastering technological manufacturing and dedicated field-proven geothermal experience and knowhow.

Some authors have suggested over the years that pure binary systems have a low-efficiency conversion rate and are best suited in the utilization of boiling low-temperature reservoirs. In contrast to those suggestions, several medium-sized geothermal power stations such as the 30-MW Te Huka, 36-MW Rotokawa, 12-MW Kawerau KA 24, and the 30-MW Ngawha are well established examples of high-temperature binary systems operating successfully and sustainably in New Zealand.

1. INTRODUCTION

The 100 MW Ngatamariki geothermal power station operated by Mighty River Power features a modular binary power plant supplied and built by Ormat under an EPC contract. This is the largest, all binary single-site power plant ever constructed.

High-temperature geothermal fluid (193ºC steam and brine) extracted from 3 production wells feeds the power plant and is then reinjected entirely into 4 reinjection wells designed to preserve the pressure within the geothermal field, helping to sustain the life of the resource. Zero water consumption, reinjection of 100% of the exploited geothermal fluid, and recording one of the highest annual availability in the industry, are some of the features of the Ngatamariki geothermal power plant. This purpose-built plant benefits from technology innovation developed over 30 years of experience with binary plants in the geothermal industry.

This paper summarizes the experience of the first year of operation of this high-temperature geothermal binary plant and concludes that such facilities can be constructed and operated in a way that meets investment requirements.

2. BACKGROUND

The Ngatamariki power station is the third major geothermal power station Mighty River Power have built over the last eight years. Following the commissioning of the 100 MW Kawerau Geothermal Power Station in September 2008 and 140 MW Nga Awa Purua Geothermal Power Stations in 2010, (both power stations using flash technology) Mighty River Power turned to the Binary technology and started constructing the Ngatamariki geothermal station in July 2011.

Until now, on such resources, only steam turbines or Geothermal Combined Cycle plants were used. Applying this type of technology, Mighty River Power ensured that:

- 100% of the exploited geothermal fluid is reinjected,
- zero water consumption apply,
- minimizing to the lowest possible level the impact on the reservoir and environment and
- The sum of all recurring and one-time (non-recurring) costs over the full life span of the project (the life cycle cost) will achieve the lowest level when compared with the equivalent cost of the flash technologies.

The Ngatamariki Geothermal Field resides in the central North Island of New Zealand, close to the city of Taupo (Figure 1). The geothermal reservoir covers an area of about 7 square kilometres, and was identified as a high temperature geothermal resource in the 1950s

The geothermal plant consists of three production and four re-injection wells, each extending to a depth of more than 3,000m. The peak temperatures at the bottom of the production wells are up to 290°C. In addition, 21 monitoring wells were drilled to a depth of approximately 1,500 m to continuously monitor the behaviour of the reservoir.

The generated power is transmitted to the Nga Awa Purua power station at via a 220kV 8.5 km long transmission line where is feed into the National Grid.

The Ngatamariki project was completed in a record time of 21 months, from initial earthworks to handover, with more than 1 million person-hours worked on site. The workforce peaked at about 450 people.

The Ngatamariki geothermal power plant is expected to generate 700 GWh annually, which is sufficient electricity for approximately 80,000 households. It is fully owned by Mighty River Power while the fuel rights of the plant are jointly owned by Mighty River Power and Tauhara North No.2 Trust.

The plant first produced power in March 2013 and was officially inaugurated by the Prime Minister of New Zealand Mr. John Key in September 2013.

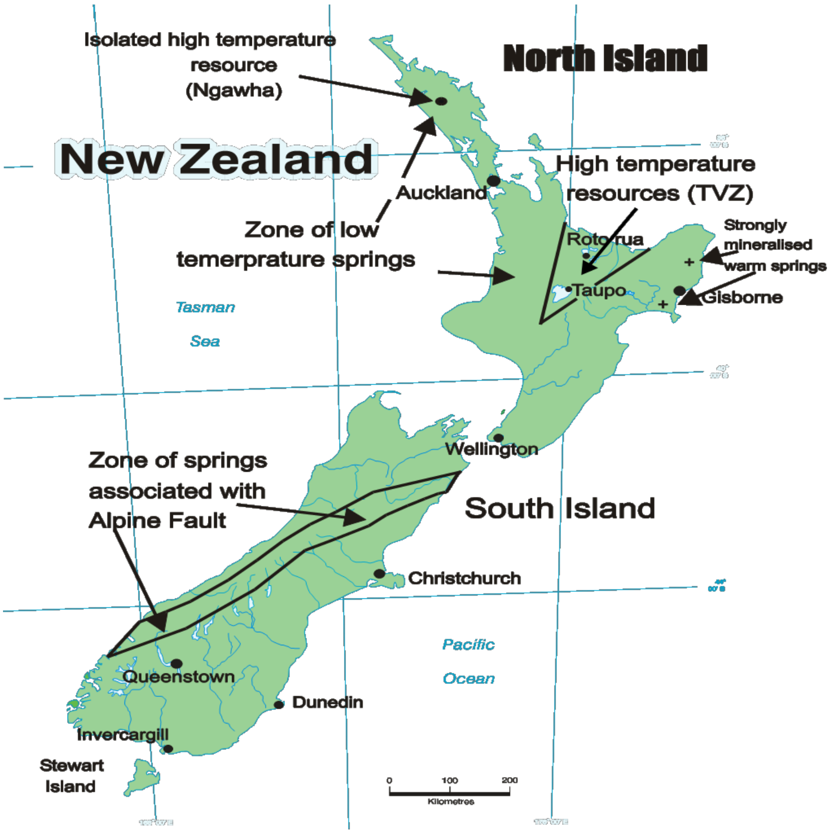

Figure 1: Location of the Ngatamariki geothermal field.

Starting its commercial journey with the TG1 (Tarawera Ormat Installation TOI) in 1989, the binary technology developed the private geothermal market in New Zealand offering a tailor made, reliable and environmentally sound solution .100 % reinjection and zero water consumption are among the most important features of this technology. Figure 2 describes the development of the geothermal industry in New Zealand, naming the power plants developed between the Wairakei plant in 1958 and the Ngatamariki plant in 2013.

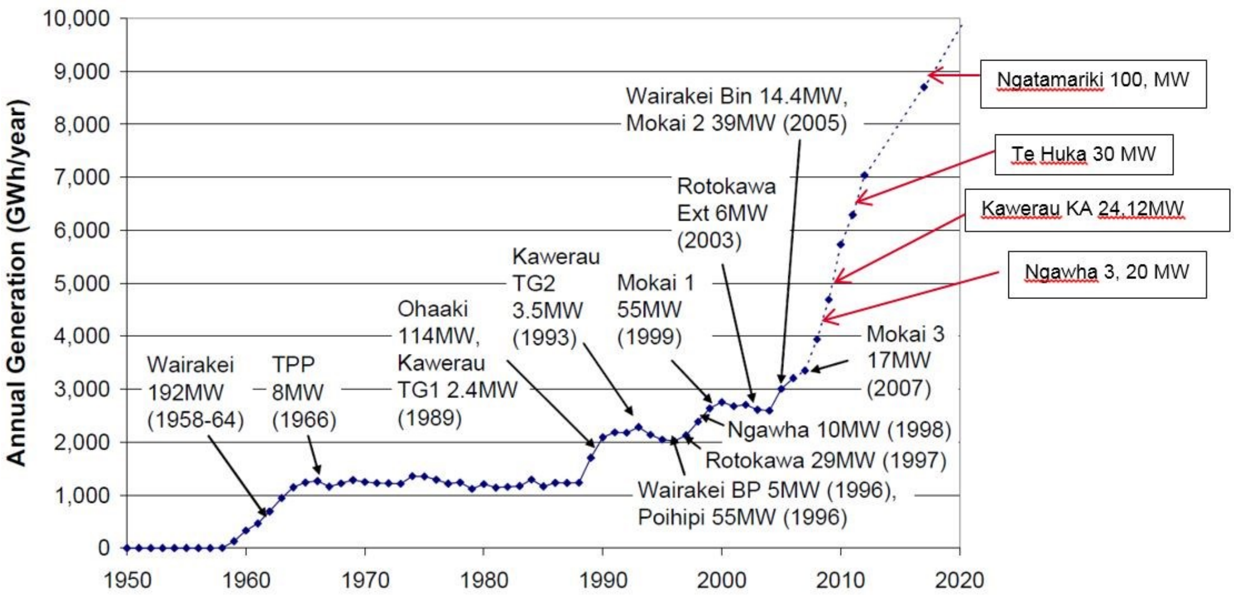

Figure 2: The development of the New Zealand geothermal industry.

3. NGATAMARIKI GEOTHERMAL PLANT CONSTRUCTION DETAILS

Ngatamariki Power Station is a green field geothermal power station project. The power plant consists of four identical Ormat Energy Converters (OEC's) units, each having an installed generating capacity of 25 MW; the total station installed capacity is 100 MW.

The energy for the four OEC's is supplied from three deep geothermal production wells located on well pads to the north and south of the station.

Heat is extracted from the geothermal fluid (steam and brine) in a series of heat exchangers where the energy is transferred to pentane; the high pressure pentane drives a turbine generator producing electricity. Exiting the turbine, the pentane vapors are condensed in an air cooled condenser and then returned to the preheater vaporizer by a series of high pressure pumps.

100 % of the cooled geothermal fluid is then piped to re-injection wells on the periphery of the steam field reservoir.

Until now, geothermal power plants utilizing high enthalpy resources similar to the Ngatamariki field were operated with steam turbines or Geothermal Combined Cycle systems only. (A geothermal Combined Cycle System consists of a steam Turbine and a binary unit).

Ngatamariki plant's unique design and configuration implements pure binary technology using the Ormat Energy Converter (OEC) units enabling 100% of the exploited geothermal fluid to be reinjected with zero water consumption and low emissions, minimizing the impact on the environment with no depletion of the underground reservoir.

The construction works included pipeline design comprising of production and hot and cold injection systems, construction of a 7 m-wide pipeline corridor and six well pads. The works also included setting up of nine water storage and soakage ponds, controls and instrumentation, and the pipeline insulation.

4. DEVELOPMENT & CONSTRUCTION

The EPC scope included the design and construction of the binary plant and grid connection, plus the steam and brine separator facility and its respective pipework connecting separation plant to the power plant and the plant to the existing re-injection system.

Construction was completed on time and on budget. The construction time from the release of the Notice to proceed through the reliability run was 24 months (Table 1).

Item	Figure
Environmental permits issued	May 2010
EPC signed and NTP released	July 2011
First unit synchronised to grid	March 2013
Reliability run complete	July 2013

Table 1: Development timeline of the Ngatamariki geothermal plant.

5. PLANT DESCRIPTION

5.1 Design & Configuration

The power generation equipment installed at the Ngatamariki power plant includes four identical Ormat Energy Converter (OEC) modules and additional accessories such as controls and monitoring required to convert the hot geothermal steam brine into useful electric power.

Figure 3: Ngatamariki, New Zealand geothermal plant.

The major components of each OEC module consist of preheaters, vaporizers, regenerators, turbines, generator and auxiliary systems, air-cooled condenser and motive fluid cycle pumps. Each module also includes automatic and manual control valves, instrumentation (gauges, switches and transmitters), internal piping, and power and control boards.

Operation process of the OEC is based on the Organic Rankine Cycle, in which an organic motive fluid absorbs heat from a heat source, causing the motive fluid to vaporize; it then expands in the turbine, producing rotational shaft power by transforming kinetic energy gained by the vapor's expansion process.

The separated geothermal steam flows through the individual vaporizer tubes while the brine flows to the preheaters. After exiting respectively the vaporizers and preheaters, the condensate and the brine are mixed and as a mix pumped to the reinjection wells. The geothermal fluid flows through the tube sides of the preheaters and vaporizer, while organic fluid flows through the shell side. The organic motive fluid thermal cycle is a closed-loop cycle. The OEC extracts heat from the geothermal fluid in a simple and highly efficient way without the complication of using mixtures of working fluids or operating in supercritical cycles.

A feed pump transfers the organic fluid from the condenser into the preheater tube section. The fluid is heated in the preheater to a temperature close to the boiling temperature and in the vaporizer the organic fluid reaches the boiling point and vaporizes. The organic vapor passes through the vapor inlet assembly, then enters the organic turbine and expands, thus dropping in pressure and temperature and producing rotational shaft power. The low-pressure vapor flows to the air-cooled condenser, condenses and then is pumped back into the preheater.

5.2 Performance Specification

	UNIT	DATA
Power plant generating capacity	MW	100
Number of OEC units		4
Geothermal fluid		Separated steam and brine
Steam pressure	Bar	12.2
Steam temperature	°C	192
Brine temperature	°C	192
Cooling media	-	Air
Ambient temperature	°C	18
Turbine / generator configuration	-	Direct connected, rotating at 1500 rpm (No speed-reducing gearbox)
Reinjected fluid	%	100
Generator voltage/frequency	kV/Hz	11/ 50
Grid voltage	kV	220
Tested performance	%	104.2
Early (pre-testing) generation , recorded from the first synchronisation of unit 1 till start of testing	GWh	119

Table 2: Performance data at design conditions.

6. PLANT PERFORMANCE

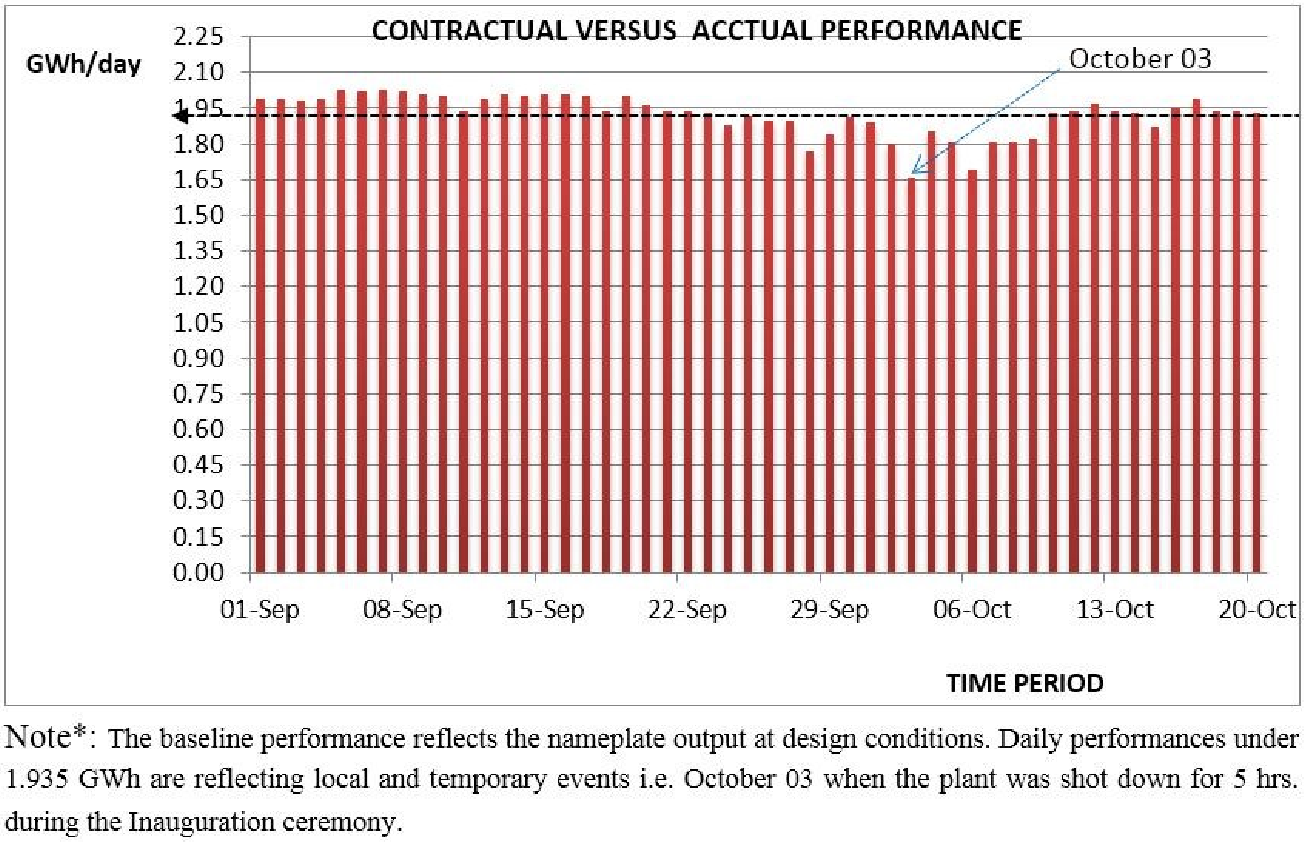

Figure 4: Plant production following takeover (GWh/day).

On a seasonal basis, the air-cooled condensers lift their performance (compared to design conditions) markedly during the winter (The southern hemisphere winter is June, July and August) (Figure 3). The corresponding decline in summer is modest. Major surveys are normally scheduled in November, resulting in a statistically lower output during that month over the seven years of production. This seasonal output profile matches New Zealand's electricity consumption (New Zealand's mild climate tempers electricity consumption in summer).

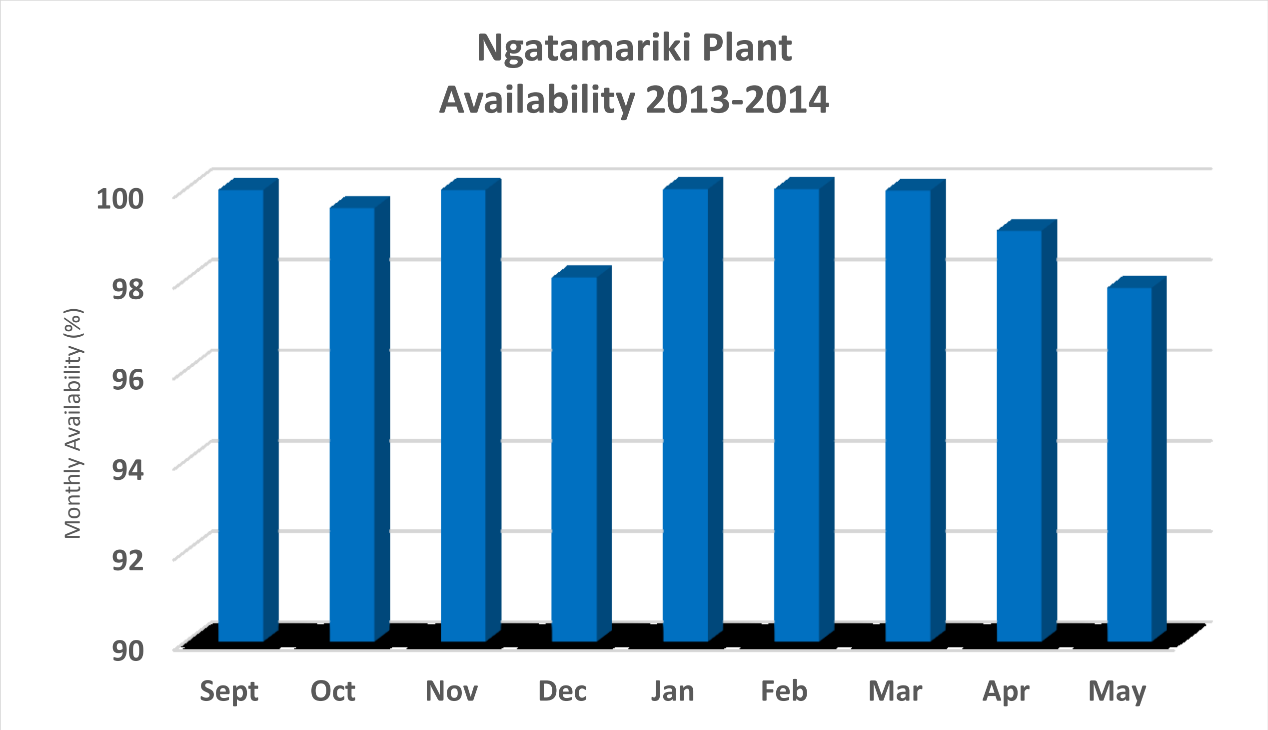

Figure 5: Ngatamariki plant monthly availability as recorded between September 2013 and May 2014. (Data: courtesy of MRP)

Monthly plant availability typically rates over 96%. The notable decreases from this trend reflect rather changes in the well performance and/or minor local events such as grid disappearance, dispatcher regulated shut downs etc.

The recorded load factors show that Ngatamariki binary performs at similar levels to other binary plants.

7. CONCLUSIONS

The Ngatamariki modular geothermal plant demonstrates that high-temperature binary projects are meeting their investment objectives while dramatically lowering the risks associated with a green-field geothermal development.

The project was constructed on time and on budget. Since commissioning, the plant has met or exceeded its production targets.

It is expected that the plant which was appropriately sized and configured will extend its generating capacity once the market demands will justify such an extension.

REFERENCES

B.R. White: Growth in the New Zealand geothermal industry

Ted Montague, Wayne Christi, and Hilel Legmann: The Wairakei Binary Power Plant: First Eight Years of Operation