AN INTEGRATED APPROACH TO REALISE GREATER VALUE FROM HIGH TEMPERATURE GEOTHERMAL RESOURCES: A NEW ZEALAND EXAMPLE

ROSS T. HARPER', IAN A. THAIN**, JAMES H. JOHNSTON***

* Senior Consultant, Fletcher Challenge Ltd., 810 Great South Rd, Auckland, New Zealand.
** Technical Manager, ECNZ Geothermal Group, Private Bag, Taupo. New Zealand
*** Assoc. Prof., Chem. Dept., Victoria University, P.O. Box 600, Wellington, New Zealand.

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ABSTRACT

A common interest of resource owners is to extract more value from geothennal fluid. Investigations into ways of increasing the overall value, utilization- efficiency and environmental acceptance of geothermal operations in New Zealand have been conducted. Development plans for Wairakei and Kawerau Resources are discussed. More value can be obtained from water dominated geothermal resources if silica is recovered in a valuable form. The value of silica extraction lies in the sale of precipitated silica and the use of additional heat. A valuable geothermal silica has k e n produced at Kawerau for industrial use in newsprint. Additional heat recovery and energy generation can be combined with silica extraction. At Wairakei, a combination of silica extraction, energy generation and direct use will increase the thermal utilization efficiency from a current 9% to 21%. The development outcomes discussed are valid for most high temperature water dominated geothermal resources.

1. INTRODUCTION

Present methods of exploiting high temperature water dominated geothennal resources result in poor overall utilization and in particular a low thermal efficiency. An integrated approach to the exploitation of high temperature water dominated geothermal resources provides several value added opportunities as outlined by Harper et. al. (1992). This paper describes the progress. plans and issues remaining in New Zealand to achieve more efficient utilization of high temperature water dominated geothermal resourccs. The need to adopt sustainable management practices in the development and exploitation of geothermal resources is valid worldwide. In New Zealand, the "Resource Management Act" (1991). requires management practices to be consistent with long term viability. The integrated development strategy and associated technologies discussed here are applicable to most other high temperature water dominated geothermal resources. The focus of this paper is on developments at Wairakei and Kawerau.

At Wairakei only 9% of the thermal energy extracted from the resource is converted into useful electrical energy. Investigations show that power generation at Wairakei could be increased by *20* MWe and over 180 MW thennal energy could be provided for direct use. At Kawerau a further 8MWe and 100 MW thermal energy could be recovered from separated geothermal water. In the past, the major issue which prevented the recovery of additional heat energy from these resources was the risk of encountering a serious operating constraint from amorphous silica deposition in the water gathering and reinjection system For some decades, the risk of amorphous silica deposition has plagued the more efficient use of high temperature water dominated geothermal resources, (Harper et. al., 1992). This paper documents some of the meaningful efforts being exerted to overcome the constraints imposed by silica deposition. Most traditional methods of inhibiting amorphous silica deposition as detailed below, come at a significant cost to the additional encrgy recovered. In some situations, the value of the additional energy does not justify silica inhibition techniques. In a silica extraction process. the risk of downstream amorphous silica deposition is significantly reduced. If the recovered silica has sufficient value, the process can stand alone economically and does not represent a cost to the additional heat recovered.

1.1. Integrated Geothermal Development - Definition

An integrated geothermal development is defmed as a group of processes which add value to a given resource by making use of both steam and water phases for power generation. direct use of heal, silica recovery and other chemical processes which provide for:

i) The sustainable use of the resource.
ii) Environmentally acceptable methods for disposal of separated water.

The key characteristics of an integrated system for high temperature water dominated geothermal resources which differ from the conventional development of moderate to high grade geothennal resources are considered to he:

i) Law discharge temperatures after energy recovery.
ii) Increased power generation per unit mass withdrawn.
iii) A valuable silica product.
iv) Direct Use of Heat.
v) Other minerals.
vi) Low temperature water disposal.

The benefits of including these processes in an existing or new development are discussed in the following sections. The Electricity Corporation of New Zealand (ECNZ) continues to seek ways of making more efficient use and improving the environmental performance of its geothermal resources. A proposed development plan for Wairakei is shown in figure 1, which includes binary powcr plait, silica extraction and direct use of heat. A water gathering system which will initially carry 3,500t/hr of 130°C water has been constructed at Wairakei. ECNZ intends to install a binary plant to generate 16 MWe from this water when resource consents are obtained. Commercial silica extraction plants at Wairakei and Kawerau are being seriously considered. Definite markets for geothermal silica are a precursor to commercialization. Fletcher Challenge Ltd. (FCL), in conjunction with Tasman Pulp & Paper Co. Ltd. (a wholly owned subsidiary of FCL) have successfully developed a silica extraction technology which has been tested at Kawerau and Wairakei. Fletcher Challenge Ltd., is currently addressing all the issues affecting commercialization of geothermal silica production at Wairakei and Kawerau.

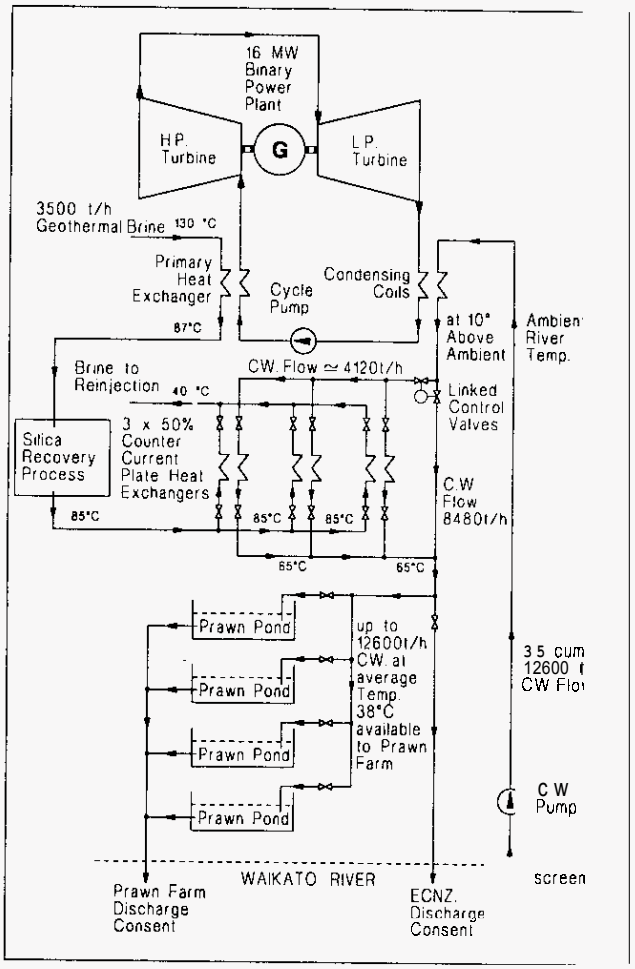


Figure 1. Development Plan for Wairakei Geothermal **Resource.**

2. SEPARATED WATER TREATMENT

The treatment of separated geothermal water **is resource** specific but final disposal usually involves reinjection, **surface** discharge or **a** combination of the two. Javellana (1993) concluded that reinjection posed the single biggest **risk** to Philippine geothennal development with amorphous silica deposition contributing **a** major part of this **risk.** The conventional treatment of separated water has been to maintain high separation temperatures to minimize the degree of supersaturation with respect to amorphous silica in water reticulation systems. This high temperature requirement limits the amount of heat that can be extracted. Lower separation temperatures **have** been selected where surface disposal is allowable. e.g. Wairakei (130°C), but still, the heat rejected **remains** substantial and amorphous silica deposits **require** regular cleaning of drainage canals. Chemicals which inhibit silica polymerization and deposition have been used with some success to reduce the risks of low temperature separation.

2.1 Silica Deposition

The options for inhibitmg amorphous silica deposition **were** reviewed by Weres et. al. (1980) and remain largely unchanged

i) pH adjustment.
ii) Reduction of total **silica** concentrations.
iii) Addition of scale inhibiting chemicals.
iv) Ageing.

The addition of mineral acid to a separated water stream has been applied in Makiling-Banahaw, Philippines, (Bamett & Garcia, 1993). The reduction of total silica concentrations by dilution using various water sources was descnbed by Bamett & Garcia (1993) and it was concluded that the addition of steam condensate provided the most cost effective solution. Several workers, (US Department of **Energy.** 1981)have documented trials with proprietary anti-scaling chemicals although there does not appear to have been a commercial application specifically to eliminate amorphous silica scale. Ageing of separated water has been employed on **a** commercial scale to reduce amorphous silica deposition, (Yanagase et. al., 1970). The purpose of ageing is to polymerize silica so that the polymer or colloidal **silica sol** particles are of dimensions which producc a low depositional tendency. No one method of inhibition has been widely accepted by the geothermal power industry anti no **one** method represents the panacea for prevention of silica deposition Tha **is** due to the fact that the chemical characteristics of geothermal water differ widely between resources. Inhibition chemicals and processes have a place in the quest for additional heat recovery but fall shon of adding value in many resources. The existing methods of inhibiting silica deposition have one aspect in common. They represent **a** direct cost to the additional energy recovered at lower temperatures. In some **cases,** the value of the energy gained at lower temperatures is too low to justify the use of inhibitive chemicals. For example, the cost of reducing the pH at Kawerau of 1000t/hr of atmospherically separated water, to effect a significant induction period to polymerization would require 1.700 tonnes/annum concentrated HCl at a Cost of = US$450,000/annum. **This** operating cost would adversely affect the economics of direct heating applications of this **resource.**

The addition of steam condensate to **a** separated water stream at some stage during cooling, **offers an** acceptable solution to reduce pH and total silica concentrations. It is possible to reduce silica concentrations approaching that of the total discharge composition if Steam condensate **is** recombined with separated water. A further advantage is that the pH of the mixture will be reduced relative to separated water alone. Both these effects promote an induction period to silica polymerization. Organic Rankine Cycle Binary plant offers **an** efficient solution in this regard, and *makes* maximum use of the intrinsic qualities of geothermal fluid to minimize supersaturation and the onset of silica polymerization at low temperatures relative to flash processes, e.g. at 80°C.

The removal of silica from separated water as an alternative treatment to inhibition, reduces the risks of silica deposition and has been investigated by several workers in the past. (Harper et. al., 1992). However, the processes **were** always a direct cost to the additional energy recovered. The subject of silica extraction is dealt with separately in this paper in recognition of the value a new process technology holds for geothermal resource owners

3. SILICA EXTRACTION

No prior process has extracted **silica** as a high quality precipitate or reached **a** commercially meaningful stage. The value of energy in New Zealand at the present time does not justify silica extraction unless the silica itself has commercial value. Fletcher Challenge Ltd (FCL), in conjunction with Tasman Pulp & **Paper** Co. Ltd. (Tasman) have developed the technology to extract precipitated geothermal silica (PGS) under controlled conditions whereby the silica product has valuable propelties and is manufactured for specific end **use** applications. **The** technology will add value to **a** given resource from **revenue** gained by the sale of precipitated geothermal silica. The technology **also** offers the other benefits of additional energy generation, direct **use** of heat and low temperature desilicified water disposal. The technology is expected to have application in New Zealand because **of** these combined benefits. Substantial progress **has** been made with this technology since that documented by Harper et. al., (1992). Tasman's mill manufactures 380,000 tonnes of newsprint and 200,000 tonnes of market Kraft **pulp** per annum. Tasman's interest in geothermal silica arose from a need to improve newsprint quality in future years. Mineral fillers such **as** calcined clay **and** synthetic precipitated silicas are commonly used for this purpose. **There** are no **local** supplies of these fillers and Tasman faced the expensive prospect of having to import these materials. FCL and Tasman committed resources to the development of a unique process to manufacture specialty geothermal silicas which could have value in newsprint and other industries. The primary objective of the

Table 1 **Anhydrous** Chemical Composition of Geothermal Silica

SOURCE	CODE	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	Na_2O %	K_2O %	As mg/kg
KAWERAU GEOTHERMAL SILICA	PGS #KR2	98.1	0.36	0.04	0.27	0.21	0.10	2.0[2]
KAWERAU GEOTHERMAL SILICA	PGS #KR5	94.1	0.74	0.07	4.31	0.21	0.10	5.3[1]
WAIRAKEI GEOTHERMAL SILICA	PGS #WR6	98.7	0.33	0.01	0.32	0.37	0.19	4.1[1]
COMMERCIAL SYNTHETIC SILICA	PURE SiO_2	97.7	0.54	0.09	0.01	0.81	0.02	nil

[1] - analysis by XRF; at detection limit. [2] - analysis by digestion/atomic absorption.

Table 2.Physical Properties of Geothermal Silica

PROPERTY	KAWERAU PGS#KR2	KAWERAU PGS#KR5	COMMERCIAL Al-SILICATE
Refractive Index	1.45	1.45	1.45
Surface Area (BET) - $m^2 g^{-1}$	155	54	90
2° Particle Dimension - nm	10 - 15	20 -25	15 - 40
Agglomerate Size - 50 percentile; µm	8.6	0.4	0.6
Equivalent Pore Diameter - nm	15 - 20	> 200	> 200
Scattering Coefficient - $m^2 Kg^{-1}$	300	310	320
Whiteness (Berger) - %	n.a.	92.3	95
Reflectance - %	93	95	98
Oil Absorption (DBP) - g $100g^{-1}$	215	228	190
Tamped Density - g l^{-1}	n.a.	170	170
Valley Abrasion - mg loss	n.a.	12	8

Footnote: - for further explanation of the terms in this table refer, Harper (1994). n.a.; not analysed.

developmenr work continues to he the production of a precipitated georhennal silica which is competitive with other filler materials used in the newsprint industry **The** technology has attended to the nerds of interfacing the extraction process with upstream power generation, downstream direct use of heat and subsequent reinjection. **A** pilot plant was built at Kawerau in 1990 to produce silica from separated gcothemial water for extended paper machine trials. The pilot plant has processed over 30 million litres of atmospherically separared geothermal water and has produced = 30 tomes of georhennal silica. Five paper machine trials have **been** completed and the newsprint filled with geothermal silica has been printed in commercial press rooms. The **results** of these press room trials are discussed below. FCL has **assumed** the responsibility of establishing a commercial silica plant to supply the requirements of Tasman's mill. **At** this stage, Kawerau and Wairakei are considered to be the sites of initial commercialization in New Zealand, with the bulk of the silica being supplied to the Tasman **mill for use** in paper production. The functional propenies of FCL geothermal silica and its performance in newsprint *are* presented in tables 1 and **2** and figure **2.**

3.1 Properties **of** Precipitated Geothermal Silica

The anhydrous chemical composition of geothermal silica precipitated from **Kawerau** and Wairakei separated water **at** ≈ 80°C is shown in table I and is compared with a commercial synthetic precipitated silica used in newsprint. Geothermal **silica** of high punty can be manufactured from waters with a chemistry similar to Wairakei and Kawerau. Arsenic **is** one of the trace elements of a geothermal silica. The silica extraction process developed by FCL has achieved a low arsenic content in geothermal silica which makes it acceptable in many **industrial** applications. A wide range of physical propenies can be obtained through the controlled precipitation processes developed by FCL. These physical propenies are established through controlled growth of the secondary particles to form **a** tertiary **network** silica structure. **The wet** strength of **this** tertiary **network** structure determines the pore volume of the silica upon drying. Such properties **as** surface area, pore **volume.** wet and dry strength, reflectance, oil absorption capacity, bulk density and particle sire can be modified through control of the precipitation parameters. FCL's technology has produced precipitated geothermal silicas with physical characteristics that are close to the range established by synthetic manufacture.

3.2 Industrial Applications

The proven application of FCL's precipitated geothermal silica ***has*** been in newsprint and key results from this *are* discussed below. Considerable emphasis is now **being** placed an other industrial applications **for** geothermal silica. FCL has completed a major analysis **of** the industrial applications it believes are imponant to the use of geothermal silica.

Newsprint

Tasman's directory paper (45 g m^{-2}) **was** filled with gcothcnnal silica, calcined clay and aluminium-silicate at loadings shown in figure *2.* The print quality of the filled directory paper was tested in

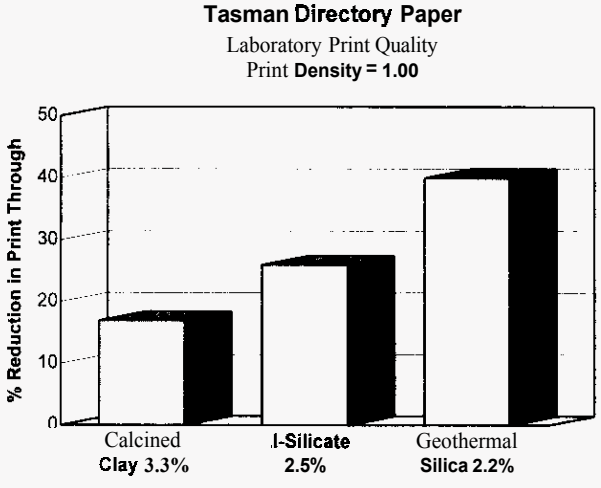


Figure **2.** Print-through performance of paper filled with Geothermal Silica compared with commercial Calcined Clay and Aluminium Silicate.

the laboratory and a commercial press-room. The geothermal silica ourperformed both the calcined clay and aluminium silicate and is considered to be the preferred filler for Tasman's newsprint in the future. A measure of the performance advantages of geothermal silica **over** the commercial products is shown in figure 2. Print-through is an important property in paper-making and is a measure of the "hiding power" of newsprint sheet when ink is applied. Geothermal silicaplays an important **role** here, because it contributes to the intrinsic opacity of the paper sheet as well as preventing **ink** penetration. The print-through results shown in **figure 2** indicate that geothermal silica will reduce the print-through of Tasman's directory paper by up to 50 % at a loading of **25** Kg SiO_2/tonne of **paper** and in general terms only half as much is required relative to calcined **clay** to achieve the **same** quality. Other beneficial properties are imparted to the newsprint such as increased opacity, brighmess and coefficient of friction.

Other Applications

Synthetic precipitated silicas have wide application in industry. Some of the more important applications include rubber, paint, plastics, coatings. anti-caking and as a carrier for various chemicals (e.g. pesticides). FCL have manufactured geothermal silica at the pilot plant in Kawerau with properties similar to commercial silicas used in these applications. Testing has been completed for several of the applications mentioned with encouraging results. It is believed that geothermal silica will have application in several existing indusmal sectors.

3.3 The Market for Geothermal Silica

Where energy values are low, the viability of silica extraction is dependent on the value of the silica product. In turn, the value of geothermal silica is dependent on **a** market and the cost this market is willing to tolerate. The newsprint application has shown that geothermal silica can have attributes which make it distinct and therefore more valuable than its commercial counterparts. FCL has completed an extensive market survey far geothermal silica. In short, it is believed that geothermal silica does have **a** position in the commercial market-place bur that some industrial applications are likely to provide more value than others. Geothermal silica as manufactured by the FCL process has now gained an acceptable profile with existing synthetic precipitated silica manufacturers **and** end **users.**

3.1 The Future of Geothermal Silica

The future of geothermal silica extraction technology is encouraging if a commercial plant is built **on** the basis of supply to the Tasman mill. Such a plant will confirm the merit of the inclusion of silica extraction technology into geothermal resource operation and substantiate the **value** that can be created by its **use.** The FCL silica extraction technology has attracted significant interest within the geothermal energy and silica manufacturing industries. **The** level of interest has resulted from the operation of the pilot plant at Kawerau, the demonstrated success of geothermal silica in newsprint at Tasman and the result of other application testing conducted by interested thud parties. The superior performance of geothermal silica in commercial newsprint confirms its application in **a** major industry. The newsprint application selves as a good foundation for further development of geothermal silica in other applications.

3.5 The Yield and Value of Geothermal Silica

The Wairakei and Kawerau Geothermal Resources will produce = 7.500 and 3,000 tonnes/annum respectively, of high quality precipitated silica. Commercially available amorphous silica has a minimum landed cost in New Zealand **of US$** 1,30011. The commercial worth of geothermal silica of the quality produced by the FCL **process,** could be **up** to US$9.75m and US$3.9m per annum at Wairakei and Kawerau respectively. Tasman's forecasted requirements could exceed the tonnage available from Kawerau and hence the Wairakei resource could be a preferred initial or supplementary source. Additional markets would **be** required to justify a full scale plant at Wairakei. The opportunities discussed here for the manufacture of a valuable precipitated geothermal silica at Wairakei and Kawerau ***are*** potentially available from most high temperature water dominated geothermal resources. The value of high quality precipitated geothermal silica demands that the net benefits of silica deposition inhibition processes **be** closely examined.

4. ADDITIONAL POWER GENERATION

In most water dominated resources reinjection of separated water is becoming mandatory. The cost of reinjection constitutes 30-35% of the total capital required for the steam-water gathering system The amount of **energy** recovered from the fluid is dictated by the separation temperature which in turn is selected to minimize the risk of silica deposition in the reinjection lines and wells. If a low risk of silica deposition existed with low temperature reinjection, 10-20% more power could be generated **per** unit mass withdrawn for the same capital invested. Low temperature flash and/or **binary** plant in conjunction with reinjection of geothermal water require that the risks of silica deposition be appropriately assessed If the **process** of reinjection is compromised by **silica** deposits the availability of **power** plant is similarly. adversely affected. Inhihitian methods may protect flash vessels and heat exchangers from silica deposits, but in most resources the long term integrity of the reinjection pipelines and wellbore hold more significance and are not necessarily protected. Silica extraction or deposition inhibition provide the opportunity to **access** the additional heat and therefore power available from geothermal fluid. Ideally, the FCL silica extraction process is operated at about 80°C which is compatible with the discharge temperature of binary plant. Electricity generation from heat recovered down to about 80°C provides the necessary cooling for silica extraction and approaches the thermodynamic limits of the Organic Rankine **(binary)** Cycle.

Tasman's geothermal silica pilot plant at Kawerau, extracts silica from water which has been conductively cooled from **172°C** to 105°C through a hinary plant and in this sense the interface of the two processes has been established The residual monomeric silica concentrations after colloidal silica recovery are at or **below** saturation with respect to amorphous silica solubility. In this condition, the dissolved silica remaining in the water can not polymerize and is compatible with reinjection. Two **binary** cycle plants (Ormat Turbines Ltd.) owned and operated by Bay of Plenty Electricity generate ≈ **5.7 MWe** net from part of the total separated water flow available at Kawerau. The interface of **a** full scale commercial silica plant with additional binary plant would allow for an extra 8MWe to be generated from the balance of the separated Water flow. At Wairakei, it is planned to produce at least 16MWe from 3,500tonne/hr separated water by installation of **binary** plant prior to reinjection. The water at Wairakei will be conductively cooled from 130" to = 90°C. The **planned** additional generation by binary plant at Wairakei represents 10% of the existing 157 MWe capacity sourced from steam. Together with other efficiency gains the gross output at Wairakei will increase to **178** MWe, (figure 3).

5. DIRECT USE OF HEAT

The exploitation of high enthalpy water dominated geothermal resources results in substantial quantities of low grade heat in the form of separated water and steam condensate after **use** is made of the steam fraction for **power** generation. The heat contained by these fluids is often not used and is reinjected or dissipated at the surface with the fluid. The constraint to recovering heat from separated water for direct use is the risk of amorphous silica deposition in the energy recovery devices such as heat exchangers. The risk of silica deposition can exist **over** a large temperature range; e.g. 40 - 150°C. Large ***scale*** use of separated water would be possible given **a** proven silica extraction process such as that described above. Lindal (1992) identified worldwide industrial uses of geothermal steam and water. New Zealand and Philippines were notably absent from the list of countries which make industrial **use** of the energy contained in separated geothermal water. Both countries have high temperature **resources** and therefore high silica concentrations in separated water. The **risk** of silica deposition has ***so*** far prevented widespread **use** of

geothermal water as a direct heat source. The largest industrial user of geothermal steam in the world is Tasman's mill at Kawerau which generates power and clean steam for its paper making process. The geothermal resource produces about 35 % of Tasman's clean steam requirements. None of the energy for Tasman is derived from separated water. At Wairakei. an aquaculture business fanning fresh water prawns. makes use of heat from separated water to supply ponds with fresh water at a temperature of 38°C. The prawn farm's ponds currently occupy 6 hectares and there are plans to expand to 30 hectares. It is unlikely that this expansion can proceed without provision for silica extraction or inhibition to protect heat exchangers. Figure I shows heat exchange of water which has been processed through a silica extraction plant. It is proposed that the silica plant will extract silica from water discharged by the binary plant at about 87°C. The temperature drop through a silica plant is expected to he low and of the order 2-3°C. The geothermal water will then be heat exchanged from 85°C to 40°C and reinjected. This will raise the temperature of 4120t/hr fresh river water from ambient to about 65°C. The 65°C fresh water will be combined with a balance of river water to provide a total flaw of 12600t/hr fresh water at 38°C, sufficient to supply 30 hectares of prawn farm ponds. The energy used in this process amounts to 181 MW thermal.

6. OTHER MINERALS

Constituents of geothermai water other than silica have potential value and some of these were reviewed by Harper et. al., (1992). The removal of silica is considered advantageous to downstream processes which use immobilized materials for extraction of other constituents. If silica is not removed, the immobilized substrates become transformed into an amorphous silica surface thus reducing the efficiency of extraction of the species of interest.

Lithium holds the most interest from a commercial extraction standpoint. A potential production rate of over 300 tomes per annum from Wairakei with a market value of = US$ 18m per annum gives rise to this interest. The recovery of lithium. from separated geothermal water is still at the development stage. Research conducted by Victoria University of Wellington, and pan funded by ECNZ. has made progress in the development of a lithium ion selective sieve material for use in geothermal fluid. Preliminary testing an Wairakei water has shown the selective material to be quite efficient in lithium uptake. A commercial process must contend with the large tonnages of separated water at relatively low concentrations of lithium. These factors present significant constraints to a commercial application. The high potential value of lithium justifies continued efforts to overcome the technical and commercial issues which remain outstanding. The market for lithium is strong and its future appears assured with an imponant application in high energy density rechargeable batteries.

Arsenic is an important constituent in geothermal water from an environmental perspective. Separated geothermal water at Wairakei is currently discharged to the Waikato River. Arsenic, as a constituent of this discharge, is considered to have a significant environmental impact on this waterway. The removal of arsenic from separated water at Wairakei is now being considered by ECNZ. Research has shown that arsenic concentrations may be reduced to levels which permit continued discharge of separated water to the river. A technical feasibility study (ECNZ, 1993) has shown that up to 80% of the arsenic may he removed from separated geothermal water. in a continuous process. The arsenic concentration in the Waikato river would he reduced to 16 ppb at a mean river flow of 160 $m^3 sec^{-1}$, which is considered to be equivalent to river arsenic concentrations prior to the exploitation of the Wairakei Geothermal Resource. Formal acceptance of this reduced arsenic concentration has yet to be obtained from the environmental regulatory authority concerned. ECNZ considers this treatment to be a serious alternative to reinjection at Wairakei and it offers the opportunity to have flexibility in rhe management of separated water. The treatment relies an the adsorption of arsenic species on to ferric hydroxide precipitates which are formed after addition of ferric chloride to the separated water. The removal of the arsenic-ferric hydroxide sludge will involve either dissolved air flotation or conventional clarification techniques ECNZ have built a pilot plant at Wairakei, to test this technology on a meaningful scale. The pilot plant has the capacity to treat 120t/hr separated water.

7. RESOURCE MANAGEMENT

The Resource Management Act (1991) in New Zealand, has prompted geothermal resource owners and managers to review their expectations of high temperature reinjection when alternative treatment processes offer better overall utilization of the resource. The integrated development plans for Wairakei and Kawerau geothermal resources provide a more flexible approach to the treatment of separated water. Integrated development assists resource management by allowing a better balance of water disposal through a combination of surface discharge and reinjection. FCL's silica extraction technology allows for maximum thermal utilization and produces a valuable silica product whilst providing desilicified water far disposal in an environmentally acceptable manner. *An* example of the improved thermal efficiency possible at Wairakei through the application of these processes is shown in figure 3.

8. CONCLUSIONS

o The current practice for many resource owners of using only the steam fraction of fluid produced from water dominated geothermal resources is considered to be short-lived. The continued selection of high separation pressures to protect water gathering systems from amorphous silica deposition ignores technological advances which have been made in the field of silica extraction and deposition inhibition.

o High temperature reinjection of separated water to avoid amorphous silica deposition significantly undervalues the amount of energy brought to the surface with the fluid.

o Significant progress is being made in New Zealand to gain more value from geothermal fluid by increased utilization of available steam and water. ECNZ have embarked on a development programme at Wairakei which includes additional power generation by Binary Plant, silica extraction and/or deposition inhihition and the supply of heat from separated geothermal water to a large aquaculture industry. Collectively these processes will improve the thermal utilization efficiency at Wairakei from 9% to 21%. Silica extraction would result in a silica product having a commercial wonh of US$ 9.75m/annum.

o A silica extraction technology developed by Fletcher Challenge Ltd. has proven the application of precipitated geothermal silica in the newsprint industry The technology has the capability to manufacture geothermal silica with a wide variety of industrial applications. The silica product is of a high quality and has many attributes consistent with commercial synthetic precipitated silicas. The newsprint application has shown geothermal silica to have superior qualities compared to existing commercial fillers. The potential value of the geothermal silica means that the silica extraction process can stand alone economically. There is no direct cost to the additional energy recovered when geothermal silica has sufficient value.

o The removal of lithium from geothermal water in New Zealand is of high commercial interest.

o The chemical processing of separated geothennal water to reduce arsenic to environmentally acceptable concentrations is being advanced by ECNZ to a pilot scale operation. The success of such a technology will provide for more flexible management of the disposal of separated water.

o The overall benefits and value obtained from an integrated approach to exploitation of water dominated geothermal resources can no longer be ignored given the progress which has been made in the chemical processing of geothermal water. The processes discussed offer a real alternative to reinjection of the separated water at high temperature and therefore provide far flexible and sustainable management of geotheimal resources.

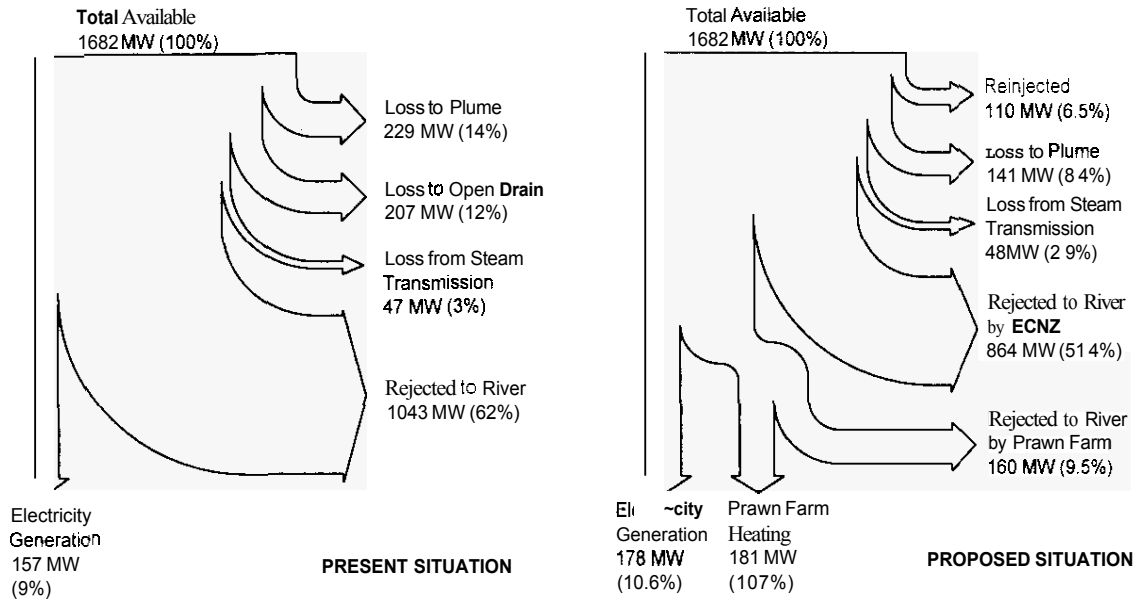


Figure 3. A comparison of energy utilization at Wairakei for the current and proposed operation.

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