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Geothermal Development in Papua New Guinea
A Country Update Report: 2000-2005

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ABSTRACT

Geothermal power development, presently focused on tiny Lihir Island, located about 700 kilometers northeast of the national capital, Port Moresby, forms part of the New Ireland Province of Papua New Guinea. Unusual challenges to the developer, Lihir Gold Ltd, arise from a combination of the geothermal resource, the mining environment, and the isolated location.

The mining and geothermal infrastructure are both confined within the Luise Caldera, a gravity collapse structure on the northeastern coast of the island. The original purpose of the geothermal wells was to assist the mining operations by depressuring and cooling parts of the geothermal resource ahead of mining operations. The potential to harness at least some of the local geothermal energy has always been recognized, and when the first deep production wells had been drilled and tested, a feasibility study was undertaken to examine the technical feasibility of small-scale geothermal power generation.

To date, 27 geothermal wells have been drilled, both deeper (up to 1800m) and medium depth (400 to 800m). In addition to the geothermal wells, 26 wide-diameter dewatering wells have been drilled to depths of 300 to 450m. The wells selected for power generation were originally located and drilled as depressurization wells and are outside the current pit area.

The deep resource fluid at about 1,000m BSL has a composition similar to seawater, with up to 100,000 g/l TDS. The successful deep producers tap liquid conditions at about 250°C at depths of about 1,000m, where maximum recorded temperatures are more than 300°C.

The deep well program, completed in 1999, was followed in 2000-2003 with drilling campaigns to complete medium-depth depressurization wells (400 to 800m), plus additional dewatering wells. A highly productive zone was found at depths of 500 to 600m BSL, where productive well feed zone temperatures are at about 240 to 250°C, with several wells having a potential to produce more than 10 MW equivalent.

A 6 MW backpressure plant supply contract was approved by the mine owner, Lihir Gold Limited, in June 2002, and the plant commissioned in April 2003—in less than 12 months. The new plant displaces diesel generation, with a fuel cost savings of US $2,000,000 per year. Over time, as drilling and testing of new wells proceeded, the geothermal potential was revised, and an additional 30 MW geothermal power project was approved in June 2003, with commissioning estimated to be early 2005.

There are no other recorded geothermal power projects planned elsewhere in PNG. Until 2003, approximately 65 per cent of the electricity was produced by thermal generation (mainly diesel), and about 35 per cent from hydro. There is private electricity generation by some industries for their own use, the larger examples being West New Britain Palm Oil and Lihir Gold Ltd.

Today, PNG government agencies are actively implementing policies and programs which are aimed at encouraging the diffusion of new and affordable renewable energy technologies, one of them being geothermal energy.

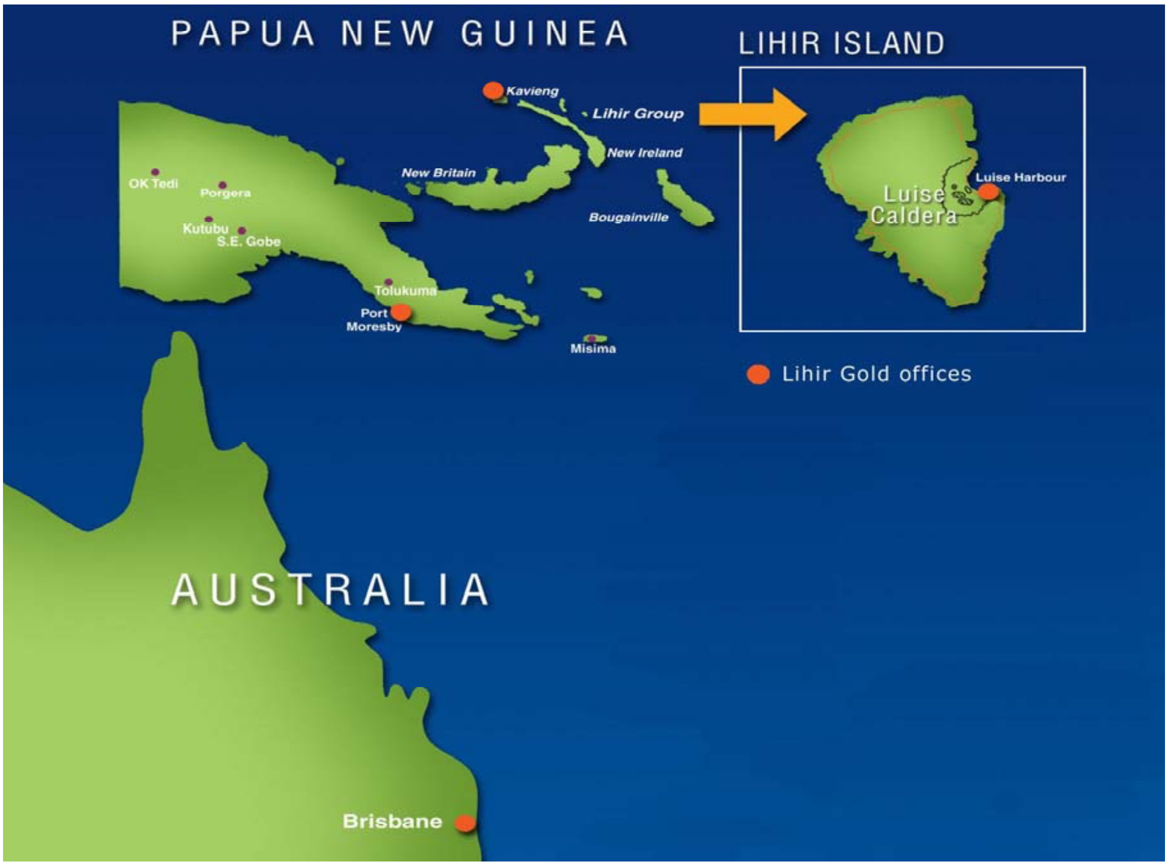
1. INTRODUCTION

Papua New Guinea is a nation of some 600 islands located in the South Pacific, north of Australia and east of Indonesia, and having a land area of 453,000 square kilometers. It is inhabited by nearly 5.3 million people having a cultural base of more than 800 languages and ethnic groupings.

Total electricity production in 2002 was 781.4 GWh, derived from hydro (65 percent, 512.7 GWh) and fossil fuels (35 percent, 268.7 GWh). There were no imports or exports of electricity (Hairai, 2004). Power rates are low, so renewable energy for power generation is not widely used. The average cost of producing a kWh of electricity in PNG from the PNG Electricity Commission's Port Moresby hydro plants is US$ 0.021, while for the diesel oil plants it is US$ 0.1750, over eight times more expensive (Hairai, 2004).

About 90 percent of the population lives in rural areas, and only 5 percent have electricity provided, mostly by diesel generation (Mongillo, 2004). Some industries generate electricity for their own use (e.g. West New Britain Palm Oil and the Lihir gold mining project), and there are also several small privately owned power generation facilities (Mongillo, 2004).

Geothermal energy development for power generation in Papua New Guinea is presently restricted to the 28-square kilometer Lihir Island, which is part of the New Ireland Province, located about 700 km northeast of the national capital, Port Moresby (Figure 1). The first use of geothermal energy for power generation was realized in April 2003, when Lihir Gold Ltd brought on-line a 6 MW backpressure unit (Figure 2) to support their gold mining and processing operations which produce over 600,000 ounces of gold each year. Lihir Gold Ltd's major shareholders are: Rio Tinto plc, the Papua New Guinea Government, Niugini Mining Ltd and Vengold (Lihir Gold Ltd, 2004).



Map courtesy of Lihir Gold Limited

Figure 1. Index Map of Lihir Island, Papua New Guinea

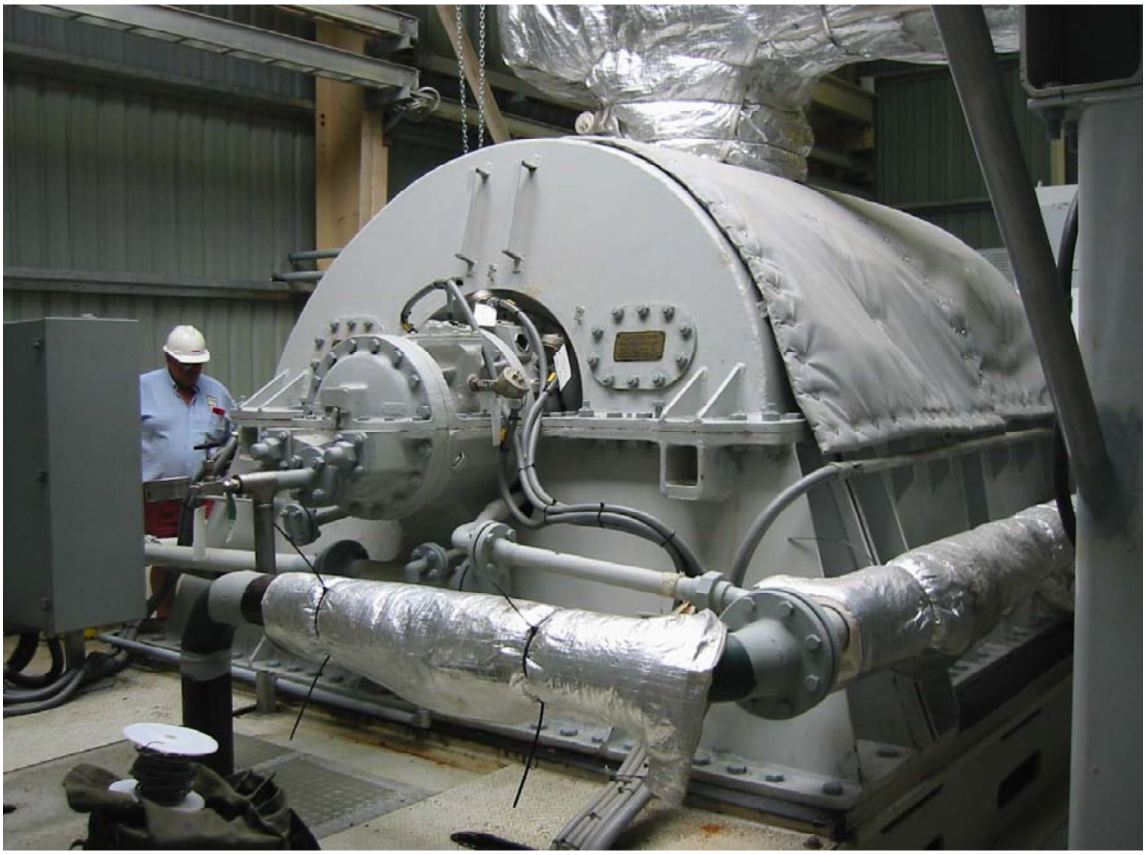


Figure 2. 6 MW Backpressure Turbine Unit

With respect to policy overview, the national government has jurisdiction over energy matters including overall policy. The generation, transmission, distribution, and sale of electricity are controlled by the PNG Electricity Commission (Elcom), which was incorporated in July 2002, and is now referred to as PNG Power Limited (Hairai, 2004; Mongillo, 2004). The Department of Finance and Treasury is responsible for setting prices or tariffs for electricity. The provincial governments work with PNG Power, and the Energy Division of the Department of Petroleum and Energy, and/or private companies, to organize new projects such as grid extensions or development of hydro or other renewable resources.

The Energy Division of the Department of Petroleum and Energy implements policies and programs which are aimed at encouraging the diffusion of new and affordable renewable energy technologies. It also works closely with PNG Power to increase the amount of electricity available. The Rural Electrification Policy is aimed at improved rural access to electricity.

2. GEOLOGY BACKGROUND

Papua New Guinea lies within a complex and active tectonic region of numerous plate boundaries, several microplates, and many areas undergoing active deformation (Tregoning, 2000). An active volcanic environment, common in nearby Indonesia and Philippines, has a significant presence on a number of the islands.

The Lihir Island is made up of five Miocene-Pleistocene age volcanic units, of which three are recognizable volcanic craters, including Luise Caldera, which is the youngest major volcanic center on the island (White and Others, 2003). The geothermal resource is located within the five by three kilometer Luise Caldera, a gravity collapse structure on the east coast of the island. The Caldera rim rises to about 600 meters above sea level, with the central area of the collapse structure where the mineralization is located up to 100 meters above sea level.

3. GEOTHERMAL RESOURCES AND POTENTIAL

The geothermal resource is generally offset from the Luise Caldera to the north and west from the present mine pit. To date, 27 geothermal wells have been drilled. Of these, ten are deep, deviated wells with drilled depths up to 1,800m and vertical depths around 1,000m. The remainder are medium-depth, 400 to 800m vertical wells. In addition to the geothermal wells, 26 wide-diameter dewatering wells (20-inch “production” casing with 13 3/8-inch perforated liner) have been drilled to depths of 300 to 450m (Bixley, 2003).

The wells selected for power generation were originally located and drilled as depressurization wells and are outside the current pit area (Figure 3). However, in the longer term (5-10 years), as the pit expands, some of the production wells will need to be relocated. The first eight wells were deep deviated wells, with drift angles about 60° from vertical reaching around 1,000 meters below sea level. The deep resource fluid at this depth has a composition similar to seawater with up to 100,000 g/l TDS. The successful deep producers tap liquid conditions at about 250°C at vertical depths of about 1,000 meters. Maximum temperatures of more than 300°C have been measured at 1,000 meters depth in the deep wells drilled toward the western margin of the “caldera”, according to Bixley (2003).

Photo courtesy of Lihir Gold Limited

Figure 3. Geothermal Drilling Adjacent to Open Pit

The deep well program was completed at the end of 1999, and was followed, between 2000–2003, with three further drilling campaigns to complete a series of medium-depth depressurization wells, plus additional dewatering wells. Nearly all of the depressurization wells have been 400 to 800m deep and vertical. These wells have located a highly productive zone at depths of 500 to 600m below sea level. The productive wells have their feed zones in boiling conditions at about 240° to 250°C, with several wells having a potential to produce more than 10 MW equivalent (Bixley, 2003).

Production tests have demonstrated that these wells have a greatly reduced scaling potential compared with the deep liquid wells. This is to be expected, as the production zone is at boiling point conditions with some steam-only feeds in the shallower zones. The combination of low scaling potential and high production rates favors these wells over the deep wells for power production.

4. GEOTHERMAL UTILIZATION

Being an island, Lihir is not connected to a larger power grid system. The power is generated solely for the Lihir Gold Ltd mine (Figure 4), process plant (Figure 5), and associated infrastructure (camps, offices, housing, and local villages). Of the total 55 MW load, 30MW is derived from the oxygen plant, with some other large individual uses being the ball mills and mine dewatering. Less than 5 percent of the total load is used offsite. The present generation plant comprises eleven 6 MW heavy fuel oil generators, plus the 6 MW backpressure geothermal unit.

On New Britain Island, also within the volcanic archipelago, low enthalpy geothermal heat is sometimes used to boil megapod eggs, and the megapods (local fowl) themselves use the hot ground in volcanic areas in incubate the eggs. These are harvested by locals, the harvesting being a bit of a tourist attraction. During World War II at Rabaul on the north end of the island, the Japanese used the hot springs for bath houses and, using oil drums split lengthways, evaporated sea water for the salt using a combination of the hot spring and solar heat (Saunders, 2004).

5. DISCUSSION

On Lihir Island, upon completion of the Lihir Gold Ltd deep drilling program, a feasibility study for geothermal power generation showed that a small pilot backpressure plant using steam produced from the deep wells was a viable option, as long as wellbore scaling could be controlled. In the meantime, the continuing drilling and well testing results showed that using medium-depth production from wells drilled to the north of the pit would be a better option than the deep production, as there would be reduced or no scale inhibitor required for the production wells.

Approval to proceed with the 6 MW unit was given in June 2002. The Geothermal Development Associates generation package, using unused, modified, GE naval turbines with new gearbox, electrical and associated components, was chosen ahead of a more modern plant, as it had significant timing and cost advantages, and the difference in efficiency is not an issue in this case. The plant was commissioned in May 2003, less than 12 months after approval. This plant now saves Lihir about $2,000,000 per year in fuel oil costs (Lihir Gold Ltd, 2003).

Photo courtesy of Lihir Gold Limited

Figure 4. Lihir Open Pit Gold Mine

Photo courtesy of Lihir Gold Limited

Figure 5. Lihir Gold Ore Processing Plant (Foreground)

Booth and Bixley.

6. FUTURE DEVELOPMENT AND INSTALLATIONS

Part of the 6 MW strategy was to use this plant to confirm the viability of using geothermal steam for power generation in the mining environment before considering larger scale geothermal development. While the 6 MW plant was still under construction, a feasibility study for an additional 30 MW of geothermal capacity was carried out. Also at this time the final geothermal depressurization wells, with an average power generating potential of around 10 MW each, were being completed. In July 2003 approval was given to proceed with an additional 33 MW (gross)/30 MW (net) geothermal power facility, due to be commissioned early in 2005.

In 2000, the electricity sales for the country were 698.2 GWh, with a forecast growth of 2.9% per annum over the next 10 years. Increasing demand is anticipated to be 934 GWh in 2010, according to PNG Power (Mongolia, 2004).

It is suggested through a cursory comparison that PNG has geological and geothermal settings that lie between the Philippines and Iceland; thus, in comparison, PNG may have about 3,000 to 4,000 MW geothermal power generation potential (Hairai, 2004).

The development of renewable energy to replace power generation from fossil fuels, wherever economically justified, is a major objective of PNG Power Ltd. However, the emphasis and associated investment in these projects is not as intense as the company would like, because of financial constraints and the limited technical know-how in the organization (Hairai, 2004).

7. ACKNOWLEDGEMENTS

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8. REFERENCES

Asia Pacific Energy Research Center, 1998, Papua New Guinea – Energy Overview.

Bixley, P. F., 2003, Geothermal Development at Lihir Island, Papua New Guinea: Proceedings 25th NZ Geothermal Workshop 2003.

__________, 2004, Table 6 Statistics.

Bixley, P. F., Leech, S. J., White, S. P., and Berry, B. R., 2000, Open Pit Dewatering and Depressurization of the Lihir Gold Mine, Papua New Guinea: Proceedings 22nd NZ Geothermal Workshop.

Booth III, G. M. and Huttrer, G. W., 2002, Reconnaissance Geothermal Investigations in Western New Britain, Papua New Guinea and at the Emperor Gold Mine, Vatukoula, Viti Levu, Fiji Islands: Writers representing U.S. Geothermal Industries Corporation, for Bechtel BWXT Idaho, LLC, Under Terms of Contract No. 00000448, December.

Garrick, M., 2004, Tables 6, 7 and 8 Statistics.

Hairai, Peter, 2004, A review of the PNG energy and power status: PNG Power, Manager Engineering Planning Communication, February 29.

Lihir Gold Ltd, 2003, First Geothermal Power Station in PNG: Media Release, April 16.

__________, 2003, Official Launch of the 6 MW Geothermal Power Station: Lihir Mines Ltd. web site Presentations, April 27.

__________, 2004, Lihir Gold Mine, Papua New Guinea: Lihir Mines Ltd. web site Industry Projects.

Matha, P., 2004, Tables 1 and 2 Statistics.

Mongillo, M. A., 2004, Energy Situation in Papua New Guinea, Reference – PNGEC (Papua New Guinea Electricity Commission) 2000, and Generation and Systems Development 10-Year Engineering Plan 2001-2010, prepared by Corporate Strategy and Planning, Development and Engineering Services Departments, December 2000: Geo-Imaging Services Limited, Taupo, New Zealand.

Papua New Guinea Electricity Commission, 2000.

Saunders, S., 2004, Letter to Bruce Alexander, Chairman Rabaul Chamber of Commerce Relative to Siting a Geothermal Power Station at Rabaul: Department of Mining, Geological Survey of PNG, Rabaul Volcano Observatory, New Britain, PNG.

Tregoning, Paul, McQueen, Herb, Lambeck, Kurt, Jackson, Russell, Little, Rod, Saunders, Steve and Rosa, Robert, 2000, Present-Day Crustal Motion in Papua New Guinea: Letter in Earth Planets Space, vol. 52, pp. 727-730.

White, Stephen P., Creighton, Ashley L., Bixley, Paul F., and Kissling, Warwick M., 2003, Proceedings, TOUGH Symposium 2003, Lawrence Berkeley National Laboratory, Berkeley, California, May 12-14.

World Fact Book, 2003, Papua New Guinea.

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal (1)		Fossil Fuels (2)		Hydro (2)		Nuclear		Other Renewables (specify)		Total (2)	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity (3) MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2004	5.5		335	0.900	219	0.750					554	1.650
Under construction in December 2004	30										30	
Funds committed, but not yet under construction in December 2004												
Total projected use by 2010												

(1) Lihir Gold Ltd. gold mining and processing, Lihir Island; Matha (2004)

(2) Year 2000: Energy Information Administration, U.S. Dept of Energy
Country Energy Data Report

(3) Lihir Gold Ltd has a total 55 MW load with ~30 MW of this load from oxygen plant and other large individual uses such as ball mills and mine dewatering. Less than 2.75 MW of capacity is used offsite. Pre-geothermal power supply is 11 X 6 MW heavy fuel oil generators (Bixley. 2003).

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Data for 2004 if available, otherwise for 2003. Please specify which.

Locality	Power Pla Name	Year Com-missioned	No. of Units	Status1)	Type of Unit2)	Total Installed Capacity MWe	Annual Energy Produced 2004 3) GWh/yr	Total under Constr. or Planned MWe
Lihir Island		2003	1		1F	5.5	17169	30
Total								

Source: Martha (2004)

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled [(a)]				Total Depth (km)
		Electric Power [(b)]	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)				25	>12
Production	>150^{o} C	7				>4
	150-100^{o} C					
	<100^{o} C					
Injection	(all)					
Total		7			25	>16

Source: Garrick (2004)

[(a)] 32 geothermal wells: of these 10 are deep deviated wells with drilled depths up to 1,800 m a vertical depths around 1,000 m (Bixley and others, 2001), and the remainder are medium de 400 to 800 m, vertical wells (Bixley, 2003; Garrick, 2004)

[(b)] Four wells, initially drilled for purposes of cooling and depressuring the mine provide steam for the 6 MW plant (Lihir Gold Ltd, 2003)

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	0	0	0	2	0	1.5
2001	0	0	0	2	0	1.5
2002	0	0	0	3	0	1.5
2003	0	0	0	4	0.5	1.5
2004	0	0	0	5	0	1.5
Total	0	0	0	16	0.5	7.5

Source: Garrick (2004)

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) 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$	%	%
1990-1994	0	0	0	0	0	0
1995-1999	5	0	0	0	100	0
2000-2004	18	13	0	43	100	0

Source: Garrick (2004)