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Croatia Country Update 2015 and On

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ABSTRACT

In 2013, Croatia became a member of EU. A new attitude, aimed to ease and attract investors, is applied to raise the country's economy, especially within the long neglected energy sector. Over the last few years several international companies and local developers have worked on the potential geothermal fields. They have managed to get several new exploration licenses for power generation from geothermal energy. The object of their interest is proliferous fractured carbonate geothermal water aquifers, able to produce temperatures much higher than 100°C. International expert opinions about the studied prospect are exciting for now, considering that some locations are already tested. Currently, investors are faced with cutting investment costs for drilling, testing and producing at the depths of more than 2,000 m. The first privately invested deep well for direct utilization of geothermal energy was drilled several years ago to 1,300 m where a sandy geothermal water reservoir was found, with water temperatures near 100°C. All phases of exploration, drilling and final production had been carried out in agreement with legal, regional and environmental considerations. Here, clean renewable energy, despite high initial cost of drilling and construction of a deep well, has proven itself as reliable and favorable, in the long-term, than other locally available energy sources. Such production can also yield unconventional hydrocarbon productions from dissolved gas in regional aquifers, or enhance production in conventionally exhausted hydrocarbon fields, increasing profit and net production. Several projects using abandoned oil exploration and production wells are in the process of legalization and utilization, also for direct heat consumption. We expect that such projects, supported by changes in the current legal and economic system and followed by experienced technical support, can lead to reasonable levels of this resource consumption in the country. Exploration of new geothermal resources for electric power generation and direct utilization of existing objects improves understanding of local geology and sets new perspectives for low cost geothermal production. Those are attractive for fast developing, low temperature heat pump technology and hybrid energy systems. We see such projects moving from most prolific areas in the north Croatian Pannonian sedimentary basin, to the southwest Dinara range, where thermal events are rare, but with some future efforts can become significant. Realistic expectation of stable, electric power generation can reach nearly 100 MWe (2% of the existing capacity in the country) followed by several hundred MWt, as co-generation heat. From drilling at new sites and using several hundred existing oil and abandoned deep gas wells for utilizing direct geothermal heat, the country could reach an additional 500 MWt. Such growth of geothermal production can change the lethargic economy of the country, giving Croatia a fighting chance in today's tough world economy. Geothermal resources are not only important as an energy source, but also as a trigger to other types of activities. This article is aimed to present the potential for the successful start of geothermal electric power production in Croatia.

1. INTRODUCTION

Geothermal resources suitable for direct use, as well as for electricity generation, are found primarily in the northern part of the Republic of Croatia, in the Pannonian basin area (Figures 1 and 2).

In the Pannonian basin, in the massive Mesozoic carbonate aquifers and significant carbonates and sandstone bodies of the tertiary clastic cover have large geothermal potential. So far, the Dinarides mountainous chain along the Adriatic coast and in the west the Adriatic offshore geothermal potentials are not yet explored.

Since geothermal heat pumps are not so dependent on favorable geological conditions relying on relatively constant ground or ground/sea water temperatures, their utilization is possible all over the country even in the coastal area where direct geothermal resources are not so accessible. Thus, with increasing efficiency and market competitiveness of heat pumps, the use of such systems in the future can be expected in covering the peak demands in space heating.

In spite of discoveries of potential geothermal fields suitable for geothermal electricity production several decades ago, the first production is expected after 2015. Such icebreaking processes are dependent upon a number of factors including a tariff system for electricity production from renewable energy, and high geological and technological risks. Finally the government's support is crucial for achieving a breakthrough in geothermal electricity production and harvesting the significant, long term, stable, local, energy support of these clean, renewable energy resources. However, experienced and far seeing investors will hopefully make that breakthrough as it already has happened in direct heat use several years ago.

2. PRODUCTION OF GROTHERMAL ENERGY

Operating electricity production capacities and power generation in the Republic of Croatia as well as its part of nuclear production of electricity in the neighboring Slovenia are presented in Table 1. Source data are Annual Energy Reports Energy in Croatia (Vuk et al., 2010-2012) and data gathered from relevant governmental institutions.

Figure 1: Index map of situation in the Republic of Croatia in Europe.

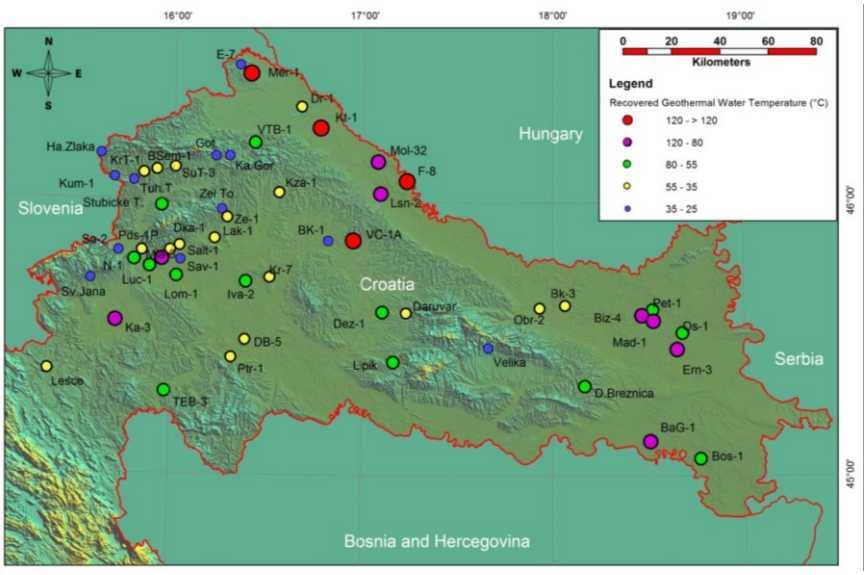

Figure 2: Known Geothermal Water Sources, are mainly developed in numerous natural geothermal sourcing areas in the Spa centers and also by drilling for fresh water supply and in exploration and production of hydrocarbons and directly for geothermal potential testing and consumption. They differ by the quality of waters, quantities and temperatures, and therefore the recovered temperatures at the surface, are taken as representatives of potential and shown on the map in several ranges (°C): 120 - > 120, 120 – 80, 80 – 55, 55 – 35, 35 – 55, and 35 - 25. They range from the ones with lowest temperature range useful for direct use or heat pumps to these with a temperature range favorable for electric power generation and cogeneration for direct heat consumption. Possible simultaneous appearance of other energetic or mineral sources is not discussed.

Geothermal water resources in the Republic of Croatia until now are discovered as numerous natural geothermal springs but also by drilling for fresh water supply and in exploration and production of hydrocarbons or directly for geothermal potential testing and consumption (Figure 2).

Thanks to the growing interest for geothermal E&P (exploration and production) in Croatia, great work was done, not only in the geological understanding and delineation of the most important geothermal reservoirs, but also in deep wells and surface facilities design, construction and final equipment for production. Focus was also set on improving testing technologies and interpretation of gathered data finally making legislative tasks viable. Efforts have been made to accomplish better understanding of already discovered geothermal objects and their development, expected objects and searching for new leads. Such an approach ensures appreciation of local and overall geothermal potential. Thus, regardless of overall economic crises, several domestic and international companies increased their activities in Croatia in the last five years. Efforts have been focused mostly towards power generation, but the feasibility of projects are directly dependable on excess heat utilization in different projects. Most of activities

have been concentrated at and around already existing production licenses at Lunjkovec-Kutnjak and Velika Ciglena geothermal fields, whereas 10 new exploration licenses were approved at: Draskovec, Prelog, Kotoriba, Legrad-1, Mali Bukovec, Ferdinandovac-1, Slatina and Babina Greda for electricity generation and Bošnjaci sjever and Sveta Nedelja in Zagreb area for direct use which together are occupying more than twice the area then previously existing production licenses (Figure 3).

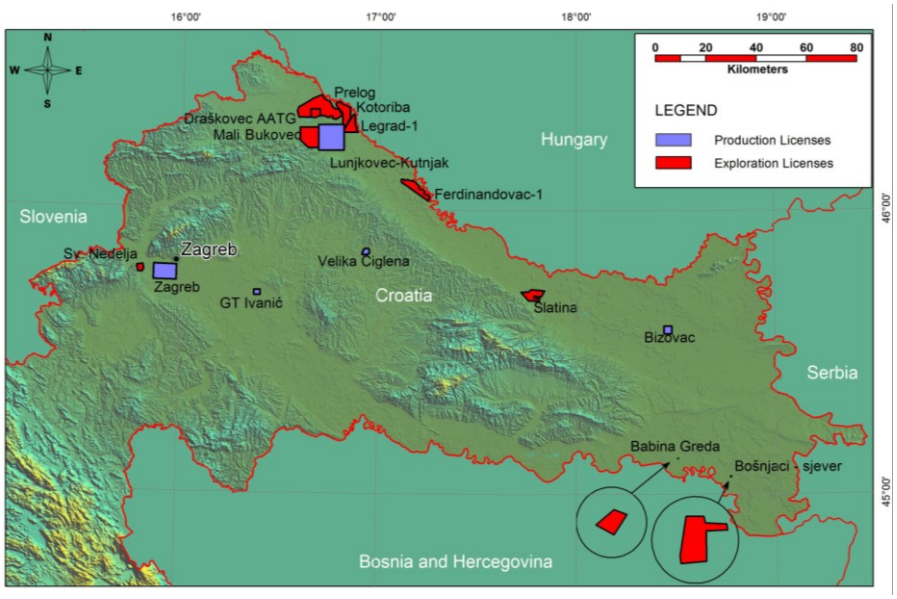

Figure 3: Geothermal energy, Exploration and Production blocks licensed by the government in the northern Croatia. Area is mostly covered by the tertiary sediments of the SW part of "Pannonian" basin. Important, deep part of these sediments, are mostly deposited into two main graben systems along the Drava and Sava Rivers. Heat flow to the surface is high regionally by the thermal "conduction" due to the thin Earth's crust which is less than 22.5 - 27.0 km thick in the Drava and 27.0 – 30.0 km thick in the Sava river range. Locally, heat flow can, due to the heat conduction through rock formations, be enhanced by heat "convection", in a massive fractured carbonate reservoirs by uprising of heated fluids, predominantly waters, encountered at the E&C (exploration and consumption) in the north west of the shown area: Blocks Mali Bukovec, Lunjkovec – Kutnjak, Legrad-1 and Kotoriba, Ferdinandovac – 1, Velika Ciglena and Babina Greda to the east, are intended for electric energy production and there are a lot of other perspective localities in the Pannonian part of Croatia.

The Velika Ciglena geothermal field is in a slightly more advanced position getting production license already, as a local developer is looking for a major investor. With increasing interest in power generation it is reasonable to expect the first production to start after 2015, increasing to over 20 MWe by the end of next decade.

Geothermal energy in the Republic of Croatia is mainly used in Spas and recreation centers for bathing and swimming and space heating. There is no electricity production from geothermal energy for now (Table 1) even though efforts are made in this direction.

There are 27 locations with a developed direct use of geothermal energy from which a total direct heat capacity is placed slightly above 75 MWt (Table 3). The temperature extraction level of geothermal wells production varies from 25^{o}C up to 85^{o}C. Annual utilization of thermal energy from all 27 geothermal localities, calculated on the basis of the average capacity factor of 0.27, could reach nearly 650 TJ/yr.

Utilization of geothermal energy for direct heat has started to grow recently which is noticeable by a growing number of exploration licenses: Bošnjaci sjever (Bos-1) and Sveta Nedelja (N-1) (Figure 2). Even though capacities (3 MWt at Bos-1; and 4 MWt at N-1) and annual production are not significant (Table 3) they can be understood as icebreaking projects which will hopefully be followed by many others. These two projects tend to transfer from exploration to a production phase, as during several years of testing their performances have shown geological, technological, economical, and environmental viability. In this report, following already proven policy, more reliable values of geothermal heat production parameters for all reported consumption locations were presented due to additional testing and reporting new facilities or refurbished ones (Table 3).

As a regulatory framework for heat pumps has not yet been developed in the Republic of Croatia existing installations are not reported to any governmental institutions. Hence, our attempt to report geothermal heat pump development in the country failed again, because of unreliable information on this important ongoing activity.

3. GEOLOGICAL BACKGROUND AND INITIAL GEOTHERMAL ENERGY CONSUMPTION

As is reported in previous country reports (Čubrić and Jelić, 1995; Jelić et al., 2000, 2005 and 2010) the Republic of Croatia can be divided generally into two different regions in a geological and geothermal sense: the Pannonian Basin and the Dinarides (Figure 1).

In the Dinarides area the temperature gradient ranges between 0.01 and 0.03°C/m and the terrestrial heat-flow density between 20 and 60 m Wm^{-2}. But even there we have the Istria spa - Livade (mainly 28°C) with more subtermal events along the Adriatic coast at Split, Sinj, Omiš and Mokošica near the town of Dubrovnik. In the transition zone to the Pannonian tertiary basins of SW Sava, there are several well-known Spas: Sveta Jana (26°C), Lešće (predominantly 30.7°C) and Topusko (in use 66.6°C).

Still, the main geothermal potential in Croatia is in the Pannonian area where the temperature gradient is commonly higher than 0.04°C/m and in places reaches values of more than 0.07°C/m. The terrestrial heat-flow density is also high, ranging from 60 to over 100 mWm^{-2}. High geothermal potential is indicated by numerous Spas in NW Croatia: Jezerčica (38.4°C), Krapina Spa (40.7°C), Stubičke Spa (53.4°C), Sutinske Spa - Zlatar (33.8°C), Tuhelj (32.9°C), Varaždin Spa (57.6°C), Samobor (Šmithen; 29.2°C) and Zelina (up to 42°C). Along the Slavonija Mountain rim, connected with the Sava basin in western Slavonia region there are more Spas such as Daruvar Spa (42.6°C), Lipik (58.7°C) and Velika (25°C). At these locations geothermal energy is used for bathing, and only in a few localities for individual heating of associated buildings such as hotels as indicated in Table 3.

Related to oil, gas and geothermal explorations in the Pannonian area several thousand wells were drilled and nearly fifty oil and gas fields and five geothermal fields were put in production in the last fifty years. In East Slavonia at Bizovac, geothermal water up to 85°C is used in an oil well born Spa. Geothermal field developed in the Zagreb area with a production of geothermal water with temperatures from 50°C to more than 80°C was followed by operation of geothermal field Ivanić Grad near the oil producing area, with the production of geothermal water with temperatures up to 60°C.

In the last 5 years, there has been a completely new trend connected with the geothermal activities in Croatia. Even though INA still controls established direct heat production at Zagreb, Bizovac and Ivanić Grad geothermal fields, INA ("Indrustrija Nafte" – upstream oil company) has not only lost production licenses at two most promising geothermal fields (Lunjkovec – Kutnjak and Velika Ciglena), which are suitable for electricity production, but it also lost all exploration rights outside production licenses which were recently covering almost all the Pannonian basin area in the Republic of Croatia. Local and foreign private investors overtook ex-INA's licenses and opened a number of new exploration licenses mostly for power production but also for direct use, what makes up the present picture (Figure 3).

General increase of geothermal energy production by cogeneration with the enhanced hydrocarbon production (Kolbah et al., 2007) and in the gas condensate fields of NW Drava, (Kurevija et al., 2008), as expected in the last country report, wasn't realized due to diminishing activities of the only active O&G (oil and gas) company INA in the area. With a low level of activities, the whole array of technologies associated with geothermal consumption, are waiting to be developed in the near future (Vulin et al., 2008).

The promotion of renewable energy (Golub and Kurevija, 2007; Brkić, et al., 2009, Kolbah et al., 2008, 2009; Kolbah, 2010a, 2010b, Kolbah et al., 2010, 2011, 2012, 2013) in the country and at the international level was crucial for raising of interest in the past half-decade. That interest triggered existing consulting services in geology and technology of E&P busting activities. Already prepared regional studies and within a reasonable time prepared individual case reports, for the already known or highly potential geothermal production areas and localities, constitute basis for overview and location of geothermal fields of interest for potential investors, as the most reliable information for new fields' development. In a way, that resulted in the fast growth of a number of exploration licenses and geothermal direct heat consumption and hopefully will lead to electric power generation in the country (Figure 3).

4. GEOTHERMAL POTENTIAL

In the past half decade, rising energy prices and supply instability led to a serious increase of interest to develop geothermal resources for electric power generation, and turned to a completely new way of understanding country's geothermal potential. At the already tested geothermal field Lunjkovec -Kutnjak, suitable for electricity production, basic development can result with much over 25 MWe. Together with the more advanced - in testing, development and power - geothermal field Velika Ciglena and the several recently claimed and awarded exploration areas that reasonable starting capacity could reach more than 100 MWe, with more to discover. This is already a significant value, of several percent, in the country where power generation capacity installed is less than 5,000 MWe (Table 1). Associated direct heat production capacities could reach another 500 MWt. Average energy capacity of geothermal direct heat consumption is 3 - 4 MWt and with 500 potential wells, what is a reasonable starting number for the area, there is another 1,500 to 2,000 MWt what could generate as much heat as generated by about 600 million m^3 of natural gas per year. This is about 1/5 of the country's yearly natural gas consumption.

5. CONCLUSION

Beside icebreaking development in the direct heat segment, finally we can reasonably expect first power production at the Velika Ciglena, testing of first 2.0 MWe, thus fulfilling our last country report's presumption. Challenged by the private, international initiatives a lot of work was done in understanding the nature and potential of that important national resource of energy and other goods, from additional hydrocarbon production, CO_2 management, to the different natural mineral resources and water recovery, to the balneology and development of continental tourism. Now is it clearly obvious that with more than 100 MWe potential geothermal resources can bring meaningful procreate of energy production, and realistic prediction of direct heat production can reach nowadays country consumption of natural gas, the most popular domestic and industry energy source. Historically recognized numerous spas in the country, finally will show strong reason to cure not only Roman Empire legionnaires as in the past, but also to strongly support development of the Croatian society in a XXI century fighting with sustainable development in already hardly wounded environment. With abundant natural resources, the young Croatian society still recovering from the deep wounds of recent war and global recession is growing into a stable, organized and modern country, with continuously high scientific and technological level of support. It also welcomes and needs international investments in development of its geothermal sources.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables		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			1891.7	4871.1	2140.9	4500.0	348.0	2700.0	351.2	811.2	4731.8	12882.4
Under construction in December 2014									22.6	54.8	22.6	
Funds committed, but not yet under construction in December 2014	2.0								22.6		24.6	
Estimated total projected use by 2020	16.0	126.7	1891.7	5000	2140.9	5426.2	348.0	2732.4	487.0	1140.0	4883.6	14425.3

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Bizovac (Biz-4)	HB	6.0	85.0	30.0			1.38	5.01	36.35	0.83
Bošnjaci (Bos-1)	G	20.0	65.0	30.0			2.93	12.00	55.40	0.60
Daruvar Spa(Daruvar)	B	21.0	42.6	27.6			1.32	5.44	10.76	0.26
Ivanić Grad Spa (Iva-2)	B	3.0	60.0	30.0			0.38	0.02	0.08	0.01
Jezerčica Spa (Stubicke T)	B	10.0	38.4	23.4			0.63	2.50	4.95	0.25
Krapinske Toplice (KrT-1) (Krapina Spa)	HB	81.6	40.7	26.0			5.02	20.40	39.55	0.25
Krapinske Toplice (Greenhouse)	G	10.0	45.0	30.0			0.63	7.00	13.85	0.70
Lešće Spa (Lesce)	B	6.2	30.7	15.7			0.39	1.55	3.07	0.25
Lipik Spa (Lipik)	HB	23.0	58.7	43.7			1.44	5.75	11.38	0.25
Livade Spa (N Istria)	B	2.0	28.0	13.0			0.13	0.50	0.99	0.25
Samobor Spa-Šmidhen(Sa-2	B	19.7	29.2	14.2			1.24	4.93	9.75	0.25
Stubičke Toplice - Spa (Stubicke T)	HB	95.0	53.4	38.4			5.96	23.75	46.99	0.25
Sveta Jana (Sveta Jana)	B	53.0	26.0	11.0			3.33	13.25	26.22	0.25
Sveta Nedjelja (N-1)	G	25.0	63.0	25.0			3.97	20.00	100.24	0.80
Topusko Spa (TEB-3)	HB	151.0	66.6	51.6			9.48	37.75	74.69	0.25
Tuhelj Spa (Tuh.T)	B	85.0	32.9	17.0			5.65	21.25	44.57	0.25
Varaždinske Toplice - Spa (VTB-1)	HB	95.0	57.6	42.0			6.20	23.75	48.87	0.25
Velika Spa (Velika)	B	35.0	25.0	10.0			2.20	8.75	17.31	0.25
Zagreb (Mla-3)	HB	12.0	80.0	30.0			2.51	5.15	33.96	0.43
Zagreb-Univ.Hosp.(Zagreb)	H	65.0	80.0	30.0			13.60	1.11	7.32	0.02
Zagreb Lucko (Luc-1)	H	2.0	50.0	30.0			0.17	0.49	1.29	0.24
Zelina Spa (Zel.To)	B	30.0	40.0	25.0			1.88	7.50	14.84	0.25
Zlatar Spa (Sut-3)	B	80.0	33.8	18.8			5.02	20.00	39.57	0.25
TOTAL		930.5					75.44	247.85	641.99	0.27

H = Individual space heating (other than heat pumps), B = Bathing and swimming (including balneology), G = Greenhouse and soil heating

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	31.99	291.79	0.29
District Heating [4]	13.77	8.61	0.02
Air Conditioning (Cooling)			
Greenhouse Heating	7.53	169.49	0.71
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	22.15	172.1	0.25
Other Uses (specify)			
Subtotal	75.44	641.99	0.27
Geothermal Heat Pumps			
TOTAL	75.44	641.99	0.27

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)					
Production	>150° C					
	150-100° C					
	<100° C		2			2.1
Injection	(all)					
Total			2			2.1

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	3	3	3	3	2	5
2011	3	3	3	3	2	5
2012	3	3	3	3	2	5
2013	3	3	3	0	2	5
2014	3	3	3	0	2	5
Total	15	15	15	9	10	25

TABLE 8. TOTAL INVESTMENTS 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$	%	%
1995-1999	0	0	0	0	0	0
2000-2004	0	1.0	1.0	0	0	100
2005-2009	0	0.5	0.5	0	0	100
2010-2014	0.5	3.0	3.0	0.5	100	0