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GLIMPSE OF THE HISTORY OF HITAVEITA SUDURNESJA LTD. - THE RESOURCE PARK CONCEPT

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ABSTRACT

Harnessing geothermal and ground water resources in a sustainable way for more than three decades led Hitaveita Sudurnesja Ltd. to define a holistic procedure, the Resource Park Concept for harnessing a variety of unrelated resources in order to support sustainable development of the society. The Resource Parks in Svartsengi and at Reykjanes are outlined. The importance of innovative thinking, research and development and the instinct of self-preservation are highlighted as an important part of the Resource Park Concept. It is reasoned that in order to make a breakthrough in the geothermal industry, deep drilling and harnessing of supercritical reservoirs is inevitable. Whereas climate change and world politics call for clean power, Hitaveita Sudurnesja Ltd. entered into close cooperation with Carbon Recycling International for converting geothermal CO_2 into methanol for mixing with the gasoline pool. A demonstration plant producing 10 ton of methanol per day is planned to be up and running in the fall 2009.

1. THE HISTORY OF HITAVEITA SUDURNESJA IN A NUTSHELL.

Hitaveita Sudurnesja was formally established by law passed at Althingi and approved by the President of Iceland on December 31st, 1974. At that time there were seven municipalities on the Reykjanes Peninsula. The initial owner structure was as follows: the state of Iceland 40% and the municipalities 60%. The share of each municipality was directly related to the number of inhabitants in each municipality at that time. In the beginning, the main objective of the company was to produce district heating water for the municipalities as well as the Keflavik Airport military base. In January 1976, arbitration was passed on land use in Svartsengi including associated geothermal and groundwater rights for a district heating plant. The year 1980 is a certain milestone in the history of the company. This year a 6 MW_e back pressure turbine generator commenced power delivery to the national grid, thereby the company turned into a district heating / power company. Today the company has merged with two electrical utilities, water works at the Reykjanes Peninsula and the municipal electrical utility / water works / district heating company of Vestmannaeyjar. First of Icelandic power companies, Hitaveita Sudurnesja became a limited liability company in the year 2001. Today Hitaveita Sudurnesja Ltd. is a private municipal entity.

1.1 Pilot plant one

Two exploration wells, well nos. 2 and 3 drilled adjacent to the main road to Grindavik proved the existence of a high-temperature geothermal reservoir, with a brine temperature of 243°C and brine salinity of two thirds that of sea water. Whereas the brine could not been used directly for district heating mainly because of the high scaling and corrosion potential of the fluid the only way to harness the geothermal resource for production of hot water for district heating was to search for pure ground water of ample quantity embedded in the stratified lava field. Orkustofnun, now ÍSOR was assigned the task to undertake the geothermal and groundwater surveys as well as to come up with a heat exchange method for the production of hot water. Orkustofnun issued a report “Exploitation of saline high-temperature water for space heating” in 1975 written by the highly skilled and outstanding scientists Stefán Arnórsson, Karl Ragnars, Sigurdur Benediktsson, Gestur Gíslason, Sverrir Thórhallsson, Sveinbjörn Björnsson, Karl Grönvold and Baldur Líndal. In this report the layout of heat exchange schemes were revealed for the first time. Based on this report Orkustofnun designed, built and operated a pilot plant in 1976 to1977 adjacent to the exploration wells. Heat exchange processes, scaling and corrosion studies were carried out with very promising results.

At this time a group of five Icelandic consultant companies were hired to design a second pilot plant and a full scale demonstration plant. The consulting firms were: Verkfrædistofa Gudmundar og Kristjáns (power plant machinery), Fjarhitun (ground water system and civil engineering), Rafteikning (electrical systems), Verkfrædistofa Jóhanns Indridasonar (electrical and control systems for turbine generators) and Rafagnatækni (control systems). Fjarhitun was also entitled the design of the district heating system for the seven municipalities and the Naval Air base. The tasks of the consulting companies were to design, specify components and material for purchase and supervise the construction work.

1.2 Pilot plant two

The second pilot plant was built in the year 1976 adjacent to well no. 4, drilled in the year 1974, 1713 m deep, 9 5/8” production casing with a slotted liner. This pilot plant was designed by the consulting group and Orkustofnun. The main objective of pilot plant two was to investigate further heat exchange processes and degassing of heated ground water. The hot water produced in the pilot plant was pumped to the nearest village, Grindavik and distributed to the homes. The main outcome of the tests were that a direct contact heat exchange between geothermal steam and ground water should be applied in the first phase of the power plant, direct mixing of geothermal steam and ground water did neither lead to scaling of mechanical components nor precipitation of minerals in the water and degassing of “great” quantities (100 l/s) of heated ground water was achievable.

1.3 Phase one out of six of the existing CHP plant

In 1976, the building of the first phase of the Demonstration Plant commenced. This was the first geothermal Combined Heat and Power Plant (CHP) in the world. In 1977 the operation of the plant started. Due to the high reservoir temperature and due to the unstable operation of the national grid in the area it was decided to install two 1 MW_e turbine generators. The power generated was only for the power plant itself, its subsystems and a pumping station located in the vicinity of the airport at a 12 km distance from the power plant. The turbine generators were manufactured by AEG Kanis in Germany and were “off the shelve” units not specially designed for geothermal operation. Therefore, all the problems related to scaling and corrosion of geothermal operation were faced in the beginning. This difficult time in the beginning was extremely valuable learning period fixing the research and development spirit of the company, still in full force. The power plant was a dual flashing plant with four identical heat exchange streams. The capacity of the plant was 50 MW thermal and 2 MW electrical power. Each heat exchange stream comprised a direct contact heat exchanger, a degasser, and plate heat exchangers and pumps. The degassing took partly place in the direct contact heat exchanger and partly in the degasser. The data gathered from the operation of the demonstration plant was extremely valuable for further development of the entire power plant. The demonstration plant is still operational but today it is only used for peaking and during maintenance and overhaul periods.

After the demonstration plant a service and a control building was constructed in 1978. The building housed a mechanical workshop, a control room and an open space for visitors. It has been the policy of the company from day one to welcome guests and educate them. Today the building houses the mechanical workshop for maintenance and development projects and a central control room from which the entire CHP plant in Svartsengi and the 100 MW_e power plant at Reykjanes are monitored and controlled.

1.4 Phase two out of six of the existing CHP power plant

Phase two was constructed in the years 1979 and 1980. The experience gained from the design and operation of the demonstration plant led to the design of a unique direct contact heat exchange and degassing column housed outside the building. As before the design was a combined effort of the consulting group, Orkustofnun and the employees of the company. The facility comprises three identical heat exchange streams delivering 75 MW (3x25 MW) thermal (125°C degassed ground water). The capacity of each stream is therefore twice that of a stream in the demonstration plant. Each stream comprises two hot water pumps, one direct contact heat exchange and degassing column, two sets of plate heat exchangers one fed by exhaust steam at 105°C from a 6 MW_e back pressure turbine and the other fed by high pressure steam at 6.5 bar, same as the intake pressure of the turbine. The facility is still in full operation and will be in service decades to come.

1.5 Phase three out of six of the existing CHP power plant

Phase three constructed 1979 to 1980 is housing a 6 MW_e back pressure turbine generator from Fuji Electric. The turbine is a conventional impulse turbine housing a two stage Curtis wheel. The unit started commercial operation in December 1980. The steam admission pressure is 6.5 bar-a and the exhaust pressure is 1.2 bar-a. Part of the exhaust steam is piped to the heat exchange process in phase two and the remaining steam is piped to the binary plant in phase four. The design of the turbine incorporated the valuable experience gained from the operation of the two 1 MW_e "non geothermal" turbines in the demonstration plant. The most important details were different material selection of the rotor material and turbine blades, integral shrouds of the blades instead of riveted shrouds, bolted labyrinth shaft seals with gland steam and stationary blade holders bolted to the turbine casing. Bolted stationary blade holders are today a standard feature of Fuji´s geothermal turbines. Because of the design, especially the bolted stationary blade holders, it takes less than a week to stop the unit, dismantle it, remove the mineral deposits with water blasting, mantle the turbine and run it up to full load. The excellent operating record of the turbine demonstrated that the design principles were sensible and today these have been further elaborated on.

1.6 Phase four out of six of the existing CHP power plant

Phase four was constructed in two steps. The first part constructed 1988, housing three ground water cooled Ormat binary units, 1.2 MW_e net power per unit to the grid. The condensers were and are used today for pre-heating the ground water before it enters the heat exchange streams. This CHP binary power plant is the first in the world in which Ormat units/binary units are installed as bottoming units of a back-pressure steam turbine. This power plant was most likely the first binary plant in the northern hemisphere housed in a canopy for nearly four years. The power plant commenced commercial operation in 1989. The second part of the binary plant was constructed and erected in the year 1992. In the second part four air cooled 1.2 MW_e Ormat units were installed. The seven 1.2 MW_e Ormat units are now housed in a simple steel structure building. Even though the Ormat units were in a way in their childhood they have been a very reliable piece of machinery. The power plant generate in total 8.4 MW_e net to the grid. The experience today, gained from the operation of the binary units, is of great value and has contributed a lot to better understanding of the holistic approach to be taken in harnessing the geothermal resource.

1.7 Phase five out of six of the existing CHP power plant

This part of the Svartsengi CHP plant was constructed in the years 1998 to 2000 and the plant started commercial operation in the year 2000. The plant comprises of a 30 MW_e single-flow condensing turbine generator with two steam extractions (2 bar-a/1 bar-a) manufactured by Fuji Electric in Japan and a 75 MW_{th} heat exchange and degassing stream for potable hot water production. The turbine is the first commercial geothermal turbine in the world with two steam extraction feeding an industrial process. The detailed design of the turbine steam path was influenced by the experience gained from the operation of the earlier plants. The new design of the heat exchange and degassing stream was also based on experience gained from the operation of the earlier plants. With good result the steam path of the turbine was designed with the intension of minimizing the scaling build up on the turbine blades. In close cooperation with Fuji, the turbine has been used to develop on line steam/condensate cleaning procedure for deposit removal. By injecting condensate in a special way in the steam path in front of the control valves it is today possible to prolong the time between overhauls up to one year.

1.8 Phase six out of six of the existing CHP power plant

Power plant six, as the sixth phase is called, was constructed in 2006 and 2007 (Figure 1). The power plant is a 30 MW_e Fuji Electric, single-flow, multiple steam inlet/outlet condensing turbine generator. Commercial operation commenced December 2007. The turbine, the first in the world, is in a way a state of the art and tailor made unit. The turbine is designed for steam/brine cleaning. Whereas a powerful steam cap (19–24 bar) has developed in the reservoir and whereas the admission steam pressure of all the different power plant phases is 5.5 bar-a. The pressure of the steam from the steam cap had to be reduced over control valves with associated waste of energy. Therefore, installing a topping unit instead of the throttling valves at the well heads was studied. In the end a single flow turbine with three steam inlets/outlets (16/6.5/1.2/0.07 bar-a) was designed and constructed. The steam from the steam cap enters the turbine at 16 bar-a pressure, expands down to 6.5 bar-a and piped out of the turbine for feeding, as needed at each time in the other phases of the power plant. The steam from the back pressure turbines at 1.2 bar-a is piped partly to the binary units and partly to the 30 MW_e unit in order to gain the highest possible efficiency. The detailed design of the internals of the turbine is influenced by the experience gained from the operation of the previous Fuji units and the 100 MW_e power plant at Reykjanes. Because of the many steam pipes entering the turbine casing the unit has got the nick name Octopus.

FIGURE 1: A current view of the Svartsengi power plant

2. THE 100 MW_E (2X50 MW_E) POWER PLANT AT REYKJANES

The Reykjanes power plant was constructed 2004 to 2006 and commenced its commercial operation in 2006 (Figure 2). The geothermal reservoir at Reykjanes is a difficult one due to high temperature (around and above 300°C), high salinity similar to that of sea water and high contents of dissolved minerals. Therefore an autoclave was designed and constructed in order to map the most critical chemical reactions affecting the design of the turbines. The outcome of the chemical analyses was that in order to be well above the saturation curve of silica of this saline fluid the steam intake pressure to a turbine had to be 19 bar-a/210°C which is very high for a condensing turbine (the highest in the industry). After tendering procedure a double flow Fuji condensing turbine was chosen. Two 50 MW_e sea water cooled double flow turbine generators were installed. The detailed design of the turbine is in many respects special. Special design was needed in order to cope with the aggressive chemistry of the geothermal fluid, erosion and steam/brine washing. The sea water cooled (8/40°C) condenser is equipped with automatic pig cleaning system which has not yet been used. Whereas, the cold sea water is pumped out of wells drilled close to the coast, the sea water is filtered on its way from the ocean to the wells and that is a potential explanation why organic material does not build up in the condenser tubes. The steam supply system is a sophisticated one. The two phase flow from the well heads is piped to separators, the separated steam at 19 bar-a is piped through a 1200 m long, above ground steam pipe to a moist eliminator and from there into the turbine. The condensate is piped from the condenser through a 1200 m long underground pipeline to a static mixer in which it is mixed with the separated brine (19 bar-a/210°C). The condensate/brine mix is then piped to a static mixer/silencer 1250 m away, close to the powerhouse where the condensate/brine mix is diluted with 4000 l/s of 40°C sea water from the condensers. The condensate/ brine/sea water mix is in the end conveyed in a concrete conduit to the ocean. By doing this it is avoided that brine minerals precipitate and colour the coastline and the sea water at the coast. After 2 ½ years of operation of the power plant, enough experience has been gained in order to design a low-pressure (second flash, preliminary 2 bar-a/120°C) power plant coping with the high scaling potential of the brine. The turbine has today been pre-designed and it is planned that the power plant commences commercial operation late 2011.

FIGURE 2: The Reykjanes power plant

3. THE BLUE LAGOON

In the beginning, the brine effluent from the power plant at Svartsengi was diverted into a depression in the lava adjacent to the power houses. One day a man suffering badly from psoriasis began to bathe in the lagoon in order to see whether it affected the illness in a positive way. After three or four days of bathing the itching stopped and after bathing for three more weeks the rash totally disappeared. After this, things started to move fast. Today the Blue Lagoon is the most popular tourist attraction in Iceland (408,000 visitors in the year 2007) and worldwide very well known for its healing effect. Blue Lagoon Ltd. of which Hitaveita Sudurnesja Ltd. holds 30% of the shares runs today three main activities: the public spa, the clinic for treating psoriasis and some other skin disorders and the research and development centre. At the R&D centre different forms of silica is precipitated out of the brine piped from the power plant and the authentic blue green algae of the lagoon are grown. The silica and the algae are the active ingredients in all the skin care products of the Blue Lagoon Company. The work of the R&D centre is based on profound science.

4. THE RESOURCE PARK CONCEPT OF HITAVEITA SUDURNESJA LTD.

Harnessing different resources holistically, continuous active and innovative research and development work, evolution of the power plant, evolution of the company from a district heating company to a district heating and a power company to a district heating, power and water work company and the active participation in the development of the Blue Lagoon led to the definition of the Resource Park Concept (Figure 3). The key elements of the Resource Park Concept are: 1) multiple uses of a variety of subjective and objective resources of different nature, 2) to "equally" accentuate ecological balance, economic prosperity and social progress, 3) to bridge different technical and social cultures, 4) to endeavour not to waste any resource, 5) to be in the forefront of environmentally friendly technological development, 6) to effectively support a sustainable development of a society. Hitaveita Sudurnesja Ltd. is today a key player in two resource parks, the one in the Svartsengi area and the one at Reykjanes. The Resource Park Concept is today the key tool of Hitaveita Sudurnesja Ltd. to tread the bumpy road of sustainable development of the society which is the main goal of the company. Whereas it is a subject of a new book to define in detail the Resource Park Concept and which can not be dealt with in this short article, a short enumeration of the key elements of the Svartsengi and the Reykjanes Resource Parks is appropriate.

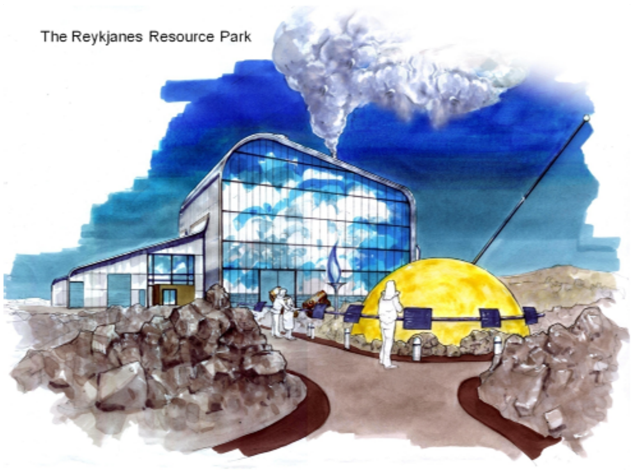

FIGURE 3: Schematic illustration of the Resource Park Concept

4.1 The Resource Park at Svartsengi

The Resource Park largely comprises the following key elements: 1) a state of the art CHP geothermal power plant (75 MW_e power/ 75 MW_t/ 750 l/s ground water, geothermal brine and steam for the, spa, clinic and the R&D unit of the Blue Lagoon), 2) Conference and education centre at Eldborg, 3) Blue Lagoon spa, 4) Blue Lagoon clinic, a dermatology unit treating people with psoriasis and various other kinds of skin disorder, active in research and development, 5) Blue Lagoon R&D unit growing authentic blue green algae, precipitating silica of different forms from the brine, production of skin care products and doing fundamental biological research, 6) ground water and geothermal resources, 7) clean environment 8) the integral infrastructure of the power plants and the Blue Lagoon, 9) the global and local position of the Resource Park: Iceland located between two continents, Iceland straddling two tectonic plates, presence of Keflavík Airport, harbours, effective road systems, proximity to the city of Reykjavík etc., 10) history of Iceland and its geothermal industry and the history of Hitaveita Sudurnesja Ltd., its power plants and the Blue Lagoon 11) human resources, skilled people with higher education in many fields, innovative atmosphere, melting pot for new ideas, 12) close cooperation with manufacturers of quality components from every corner of the world, 13) continuous close cooperation with consulting companies and research institutes during the design period and once in operation, 13) greenhouse for high tech molecular farming producing very specific proteins in the seeds of barley, located 500 m away from the power plant, 14) hard wood drying facility located down town Grindavik, 15) an environmental friendly “refinery” getting geothermal CO_2, geothermal steam, electricity and ground water from the power plant for converting geothermal CO_2 to methanol; a demonstration plant producing 10 ton/day of methanol for mixing with gasoline will commence its production in Svartsengi in the fall of 2009, 16) the resource park as an R&D platform for developing special equipment, special working procedures and new-fangled business opportunities, 17) highly skilled mechanics and computerized operation; only 16 skilled mechanics collect valuable operational data, monitor, operate, maintain and modify the power plant in Svartsengi and at Reykjanes, 18) distributed risk, the Resource Park generates over 15 independent revenue streams instead of only one from a conventional power plant.

4.2 The Resource Park at Reykjanes

At Reykjanes the existing 100 MW_e geothermal power plant founds the basic building block of a new Resource Park very different from the one in Svartsengi. Geothermal steam and ground water is today delivered to two fish drying facilities. Today, three research and development projects are worked on in the park, electromagnetic treatment of brine, development of self cleaning brine heat exchanger, and in close cooperation with Fuji Electric corrosion of materials, scaling mechanisms and steam/brine cleaning of turbine blades are tested. In addition to this, Hitaveita Sudurnesja Ltd. is today in close and active cooperation with its consultants, ISOR and Jardboranir Ltd. on harnessing the geothermal resource in an environmental friendly way. The unique exhibition Power Plant Earth has now been officially opened in the turbine building for encouraging people to visit the Resource Park and to educate them about the role of energy in their everyday life. The company is today planning and designing infrastructure of the area for tourists. Today, it is effectively working on finding ways to harness the wasted brine, the pure 40°C sea water coming from the condensers of the power plant and the geothermal CO_2. Aquaculture, algae included and bio fuel are among the possibilities looked into.

5. RESEARCH AND DEVELOPMENT ENDEAVOUR OF HITAVEITA SUDURNESJA LTD.

In the spirit of nothing ages faster than the future, do it yourself, do what you can with what you have and if you can dream it, you can do it. Hitaveita Sudurnesja Ltd. has and is today undertaking alone, or in cooperation with a number of companies, different research and development projects. Whereas research and development is such an important part of the Resource Park Concept, it is appropriate to enumerate some of the R&D projects undertaken: 1) first in Iceland to operate high-temperature wells with 13 3/8 production casing, 2) first in Iceland to introduce reinjection in a high-temperature field, 3) pilot plant studies on heat exchange mechanism, fouling of heat exchangers and degassing of potable ground water, 4) development of vertical and horizontal steam separators, 5) development of silencers; 5´th generation now in operation, 6) TWHC, Total Well Head Concept comprising an inflatable packer for changing master valves while the well is vented, mobile silencer for work over and measuring well characteristics, special working procedures and maintenance methods and silencers for keeping wells alive during maintenance and tests, 7) five static tests on corrosion of materials, 8) one extensive fatigue test on steel materials, 9) one test on scaling build up on turbine blades and steam/brine washing of turbine blades, 10) steam/brine cleaning of turbines in operation, 11) tests on degassing potable ground water, 12) developing, designing and manufacturing of well head control valves for two phase flow, 13) development of underground collecting pipes from well heads, 14) developing static mixers for controlling the temperature of the Blue Lagoon bathing area, 15) first in the world to use a binary unit as a bottoming unit, 16) in a close cooperation with Fuji Electric developing steam/brine cleaning of turbines in operation, geothermal turbine with two steam extractions delivering steam for an industrial process, double-flow turbines with the highest intake steam pressure in the industry, 17) developing a sophisticated maintenance software, now widely used in the Icelandic power industry and specific maintenance procedures for the geothermal operation of the company, 18) development of a method to precipitate commercial grade silica out of the brine, 19) treating brine in an electromagnetic field in order to avoid fouling of heat exchangers and to make valuable products for other applications, 20) static and dynamic tests on an Dutch designed fluidized bed heat exchanger, 21) development of a proper mix of brine and condensate in order to cope with the scaling problem associated with reinjection and fouling of pipes and heat exchangers, 22) growing algae in cooperation with the Blue Lagoon, 23) cooperating with Carbon Recycling International on making bio fuel from the geothermal CO_2 released from the power plant, 24) development of educative tourist industry, 25) development of a variety of environmental solutions to harness the geo resource in an environmental friendly way. Even though this lengthy enumeration is not at all complete, it reflects the vast possibilities the geothermal industry has to develop environmentally sound and commercially viable products.

5.1 The Icelandic Deep Drilling Project – IDDP

As mentioned before one of the main goals of Hitaveita Sudurnesja Ltd. is to support the sustainable development of the society as defined in the Brundtland report. An intrinsic part of this concept is the time scale. Realizing that Iceland and the Reykjanes Peninsula will be inhabited the next centuries to come, Hitaveita Sudurnesja Ltd. took the leading step to unite the Icelandic power companies in a common endeavour to harness supercritical geothermal reservoirs in the slow spreading zone of Iceland. Taken into consideration the climate change, oil and gas prices through the roof and demand of oil and gas in the world sky rocketing, Hitaveita Sudurnesja Ltd. is of the opinion that a clear breakthrough in the geothermal industry worldwide is needed today. Harnessing the Reykjanes geothermal field located in a slow spreading zone of two tectonic plates, fed by sea water from failures in the ocean crust and presumably with many physical similarities, at great depths to the black smokers on plate boundaries in deep oceans, Hitaveita Sudurnesja Ltd. has keen interest in deep drilling in the field and is of the opinion that it could contribute a lot to increased knowledge on geothermal systems on ocean floors which will be harnessed in the future. Deep drilling in Iceland is a vital next step in harnessing the abundant geothermal resource in a sustainable way. The main goal and mission of the Icelandic Deep Drilling Project is: 1) drill 4000-5000 m deep wells to harness supercritical fluid for enhanced power production, 2) explore the possibilities to recover valuable minerals and metals from the brine, 3) explore the nature of the deep seated reservoirs, can they be harnessed?, temperature, pressure, chemistry of the fluids, mechanism of heat and chemical transfer, is the resource renewable?, 3) explore the volume of the "shallow" and deep seated reservoir, 4) explore the possibilities of heat sweeping by enhanced deep reinjection. If natural supercritical geothermal fluids can be harnessed, new dimensions would be open to the geothermal industry.

6. SUMMARY AND CONCLUSIONS

The outline of the history of Hitaveita Sudurnesja Ltd. is accounted for. The evolution of the power plant and the Blue Lagoon is discussed and how it resulted in the definition of the Resource Park Concept which is the guide for Hitaveita Sudurnesja Ltd. to tread the bumpy road of sustainable development of the society. The Resource Park Concept is a general concept well suited for the power industry in the world. In harnessing the geothermal and ground water resource in a sustainable way, the Resource Park Concept is a valuable argument in the environmental debate of today. In order to reach a breakthrough in harnessing geothermal resources worldwide, research and development, and changed mind set is needed which the Resource Park Concept supports very much. As experienced in Svartsengi and at Reykjanes, the spirit of do it yourself, do what you can with what you have and if you can dream it, you can do it, is the only attitude needed to harness geothermal resources for generating clean power and geothermal related valuable downstream products. An inevitable and integral part of a modern geothermal power plant of today should be a gas treatment plant producing valuable products like bio fuel.

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