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EIA – EXAMPLE FROM BJARNARFLAG IN ICELAND

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ABSTRACT

Environmental Impact Assessment (EIA) has been carried out four times for a geothermal power plant in Bjarnarflag, Iceland, the first one for a 20 MW_e plant, the second one for a 2×20 MW_e plant and a 132 kV power transmission line to the Krafla power plant, the third one for a 40 MW_e plant and a 132 kV power transmission line to the Krafla power plant, and the last one for a 90 MW_e plant and a 132 kV power transmission line to the Krafla power plant. The first three assessments were carried out in accordance with the first Icelandic Act on Environmental Impact from 1993. The first two reports were shelved due to negative reaction and probably an inadequate mechanism for dealing with such reaction. The third EIA got a ruling from the Planning Agency of Iceland that further assessment was required. These requirements showed up a flaw in the 1993 Act in that a scoping document to be adhered to during assessment and taken into account in comments and rulings was not needed. The last Environmental Impact Assessment was carried out with reference to an Act passed by the parliament in 2000 in which several alterations had been made, among them that a scoping document was mandatory and that in comments and rulings investigations not due according to that document could not be asked for. The Planning Agency then ruled in favour of the project. One deep well has already been drilled and two are due very soon.

1. INTRODUCTION

The first law on environmental impact assessment in Iceland was Act No. 63/1993 and Sólnes et al. (1995) carried out the initial environmental assessment in Bjarnarflag, which is a subfield in the Námafjall geothermal area (Figure 1), according to the stipulations of that Act. This was the second environmental assessment carried out in Iceland and the first one of a geothermal project. The assessment also needed to take into account Act No. 36/1974 according to which the whole of the commune within which the geothermal area lies, Skútustadahreppur, along with the river Laxá is a protected area. The main object of the protection is Lake Mývatn which is a biologically unique lake at its latitude, the geothermal inflow water contributing to its properties. The surrounding lavas also give it a special geological character. In this assessment the impact of a 20 MW_e power plant was assessed.

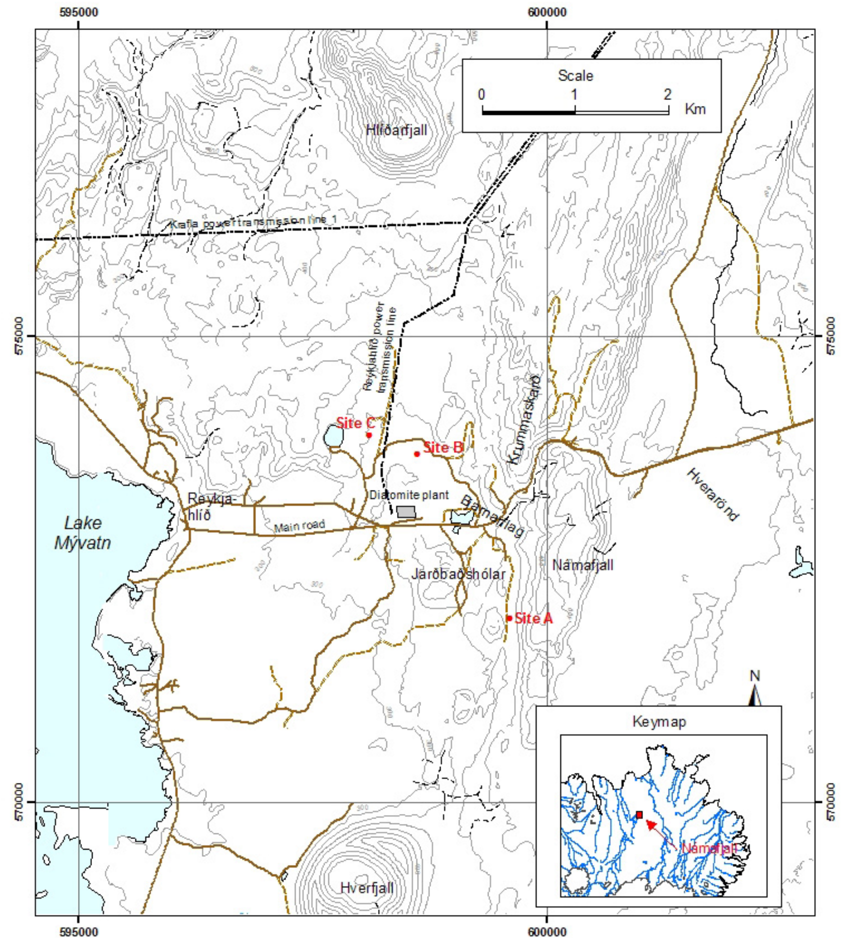

FIGURE 1: A map of the study area showing the three proposed sites, the present 11 kV power transmission line and the Krafla I power transmission line.

This was reconsidered and a year later a modified report for a 2×20 MW_e and a 132 kV power line to the Krafla power plant was issued (Hönnun,1996). Neither of these reports was presented to the Planning Agency for a decision. A new EIA was presented by Hönnun (2000), this time a one stage 40 MW_e power plant and a 132 kV power line were assessed and subjected to the whole process (2000). Comments and stipulations were rife and the operators decided not to pursue the matter further at the time. Shortly after that Act No. 106/2000 on environmental impact assessment was passed with significant changes to the previous act. When Landsvirkjun decided again to continue with plans for the Bjarnarflag power plant in 2003 it was decided to carry out yet another EIA but according to the new act and assess a 90 MW_e power plant and a 132 kV power line to Krafla. This assessment was subjected to the new procedure (Hönnun 2003a) and a licence to construct a power plant was issued. One new well has already been drilled and more are planned. In this article the history of geothermal utilization in Námafjall will be considered as well as details of the environmental assessments carried out.

2. HISTORY OF UTILIZATION

For centuries sulphur was an important export from Iceland, the first record of it being in 1198 to Bergen, Norway (Sverris saga, 1920). Námafjall was one of the places which were mined for sulphur. The latest mining company went bankrupt during the Second World War. In the 1950s interest in sulphur mining on a large scale was aroused again and 16 wells were drilled in the Hveraröind area of Námafjall for this purpose. At about the same time exploration for diatomite in Lake Mývatn showed positive results and it was decided to transfer activity to the Bjarnarflag area which is closer to Lake Mývatn. The Hveraröind boreholes were abandoned and some developed into powerful fumaroles that are now tourist attractions. From 1963 to 1970 nine wells were drilled in Bjarnarflag to depths from 342 to 1312 m with a moderate size drill rig, and a tenth well to a depth of 1809 m with a larger drill rig in 1975 mostly to supply the Námafjall Diatomite Plant but also a 3 MW_e back pressure turbine that was commissioned in 1969 (the first power production by geothermal steam in Iceland) and a district heating system for the neighbouring Reykjahlíd community. Most of these wells were damaged during the Krafla fires, 1975-1984, mostly in 1977 when magma from the fires flowed twice through the drilling area. To counteract this damage two deep wells were drilled outside the volcanically active area in 1980. The operation of the diatomite plant ceased in 2004 and of the 10 earlier wells one is still in operation as well as the two wells drilled in 1980.

3. ENVIRONMENTAL IMPACT ASSESSMENT

In the early 1990s Landsvirkjun showed an interest in commissioning a power plant in Bjarnarflag. Following a concerted exploration effort a feasibility report was published (Orkustofnun – VGK, 1994). The reason was given as increased demand for electricity due to the aluminium smelter proposed by Columbia Aluminium Corporation in the industrial area of Grundartangi, in west Iceland. The plant was planned to be situated under the western slopes of mount Námafjall, south of the main road but to the south of the Krummaskard fault (Figure 1). It was assumed that three new wells needed be drilled in addition to existing wells. In an EIA that followed (Sólnes et al. 1995) advantages of this plant were considered to be low cost per energy unit, short construction time and ease of expanding it to 40 MW_e. No direct harm was expected but surface discharge of effluent might cause considerable visual disturbances although the effluent water was not expected to contaminate the local groundwater. Reinjection was however considered desirable. To minimize visual disturbances the use of multiple well pads and careful design of pipelines and power transmission lines were recommended. Regular area and production monitoring would be effected.

Subsequently it was decided to aim for a 2×20 MW_e power plant with a significantly different design. In the previous assessment the impact of the necessary power transmission line had not been assessed. Therefore it was deemed necessary to carry out a new EIA for the different plant and a 132 kV power transmission line to the Krafla I power transmission line (Hönnun 1996). Among the investigations that had been carried out after the appearance of the first EIA were an investigation into the atmospheric distribution of hydrogen sulphide in the vicinity, recording vegetation in the power plant area and along the track defining the position of the power transmission line, an investigation of the biological systems in the hot spring and fumarole areas of Bjarnarflag, Hveraröndh and Krafla. Soil temperatures had also been measured to define if and where power transmission lines could be buried, the temperature of the effluent pond was determined and noise measurements had been carried out both in Bjarnarflag and Krafla. Seven new wells needed to be drilled and used along with the existing wells and this time it was assumed that spent fluids would be reinjected. The impacts expected were similar to those considered in the earlier report. The National Trust was entirely opposed to the power plant, and the The Icelandic Institute of Natural History and the Mývatn Research Station also provided severe opposition and Landsvirkjun decided not to contest this opposition and shelved the report. The grounds for the opposition were doubts about potential effects of the power plant on the groundwater system, the Lake Mývatn ecosystem and mud pool and fumarole activity at Hveraröndh.

In 1999 Landsvirkjun went ahead again and stated the same reasons, i.e. growing general electricity market and plans for more energy intensive industries for the next few years and related the same advantages to the power plant as before. A new EIA with much added information including 12 appendices was published (Hönnun 2000). Now a 40 MW_e plant was planned with a capacity of 324 GWh annually, corresponding to 8100 h/year production time and time planned for construction 3 years. A 132 kV power transmission line was planned and should replace mostly the present 11 kV Reykjahlíd power transmission line which would be removed. The same site is recommended for most of the construction but alternative sites, one to the north of the main road which is inside the volcanically active area and a site further to the south of the main road were also considered. Again it was assumed that seven new wells are needed which will be drilled directionally and that effluent water will be reinjected into the geothermal reservoir. In the report environmental impact is considered at two stages, on the one hand environmental impact due to construction and on the other hand impact due to production. During construction the major impact involves surface disturbances due to excavation, construction and drilling as well as increased traffic and strain on the service industries in the area due to the relatively large workforce. During production the major impacts are due to mass removal from the geothermal reservoir, discharge of effluent water, noise level of discharging boreholes and visual effects. The most sensitive areas are Lake Mývatn and the fumarole area in Hverarönd but the data presented suggest that these areas will not be affected. Mitigation measures against noise and visual effects are proposed. Area and production monitoring are again proposed with the addition that effect on neighbouring areas will also be monitored. The report was sent to commentators and public hearings were given and then referred to the Planning Agency which after reviewing the comments gave the verdict that a further assessment was needed. The following reasons were among those given: Alternative sites for the power plant should be assessed specifically with regard to a visual comparison; the impact of stepwise development (as had been done in the 1996 report) should be assessed, the effects of burying pipes and transmission lines should be evaluated, the location of a potential effluent pond and the effect of reinjection should be considered, the groundwater flow with the potential risk to Lake Mývatn should be assessed more thoroughly, the possible effect on surface activity at Jardbadshólar (an old bathing place) and Hverarönd should be assessed, impact on tourism treated in more detail and operations in connection with eventual termination of the activity described. The major complaint of the operators was that many of the recommendations that came after the EIA had been carried out needed new research which would have been carried out during the assessment had it been asked for. This was in fact in line with one of the main criticisms of the 1993 Act, i.e. that a scoping document open to comments was not required and that new investigations could be stipulated. Landsvirkjun however decided not to go ahead and plans for a power plant in Bjarnarflag were yet again shelved. A new law on environmental impact assessment, Act No. 106/2000, was passed amending several flaws that had been experienced with the application of the initial act among them the requirement for a scoping document.

In 2003 Landsvirkjun decided yet again to aim for a power plant in Bjarnarflag. It was decided to carry out a new EIA in accordance with the new act but this time a 90 MW_e power plant and a 132 kV power transmission line were assessed. In May 2003 a scoping document including all the stipulations of the Planning Agency in 2000 and which had been commented on (Hönnun 2003b) was presented to the Planning Agency. An EIA was carried out in accordance with this scoping document, with 15 appendices reporting previous and additional research (Hönnun 2003a, 2003c), including an extensive treatment of potential building areas, a study of the potential effects on Jardbadshólar and Hverarönd, effects on vegetation and birdlife, effects of the discharge of effluent on groundwater and of gas discharges, visual effects, a survey of tourism, assessment of burying pipes and transmission lines and a description of proposed work on a model of the area to be used as a reference to keep production sustainable. The construction of the power plant is planned in two to three stages, each stage with a capacity of 162-486 GWh per year and the total for the plant 729 GWh pear year which corresponds to a full load production for 8100 hours annually. The power transmission line planned is a 10 km line from the Bjarnarflag power plant to the Krafla power plant. The same reasons for and advantages of the project are given as before. Previous utilization is described and said to be equivalent of 15 MW_e power production for the preceding 30 years. The production from the 3 MW_e back pressure power plant will be discontinued. Site A (Figure 1) was considered to have least environmental impact but site C not an option, the power transmission line is expected to be buried to where it meets Krafla transmission line I but above ground alongside the Krafla power transmission line as far as the Krafla power station. Three alternative routes for the buried line are suggested, one from site B and two from site A. In the environmental impact assessment of the construction phase it is noted that site A has already been disturbed by levelling, potato growing and a track. Thick loose strata cover this site and can be used for construction thus minimizing the need for excavation elsewhere. Production wells will be directionally drilled from relatively small drilling pads, one south of the main road and another to the north of it. Silencers will be constructed for each drilling pad to keep the noise level within legal limits. No new tracks will be built for the construction of the power transmission lines. No archaeological remains will be disturbed, during construction employment will rise and there will be a temporary boost to some service industries. In the environmental impact assessment for the production period it is noted that new exploration results suggest that the area is more extensive than previously thought and it should be able to sustain a 90 MW_e production. With a view to changes in altitude due to volcanic activity subsidence due to production is predicted to be negligible. A tracer study shows a 100 million fold dilution of the effluent from the present effluent pond to a fissure 2 km away due to mixing with a powerful groundwater current. Thus it is considered safe to use the same effluent pond and discharge into the groundwater current as effect on Lake Mývatn another 2 km further is considered negligible. Activity at Jardbadshólar increased during the Krafla fires and is now waning and is expected to do so from natural causes but not due to power production and it is considered very unlikely that production can affect fumaroles and mud pools at HveraröND. Although there will be some increase in CO_2 discharge to the atmosphere it is negligible compared to the total CO_2 discharge from the country and H_2S is considered to be precipitated soon after its emission. The vegetation in the production area has little protection value and all possible sensitive vegetation is avoided by the choice of the route for the power transmission line. Animal life is not expected to be affected. Noise will be dampened by hills to the west of the power plant. The power plants buildings will hardly be seen except from the tourist viewpoint in Námaskard pass where structures other than boreholes are on the periphery of vision. Three to four new permanent job positions will be created and social and economic effects are small except that the commune will receive a considerable property tax. From experience of other geothermal power plants the number of tourists in the area is expected to increase and the spa and reception will be designed to make their visits pleasant. Several comments were received and replied to by Landsvirkjun. Some of these follow:

Comment: The EIA considers site A to be most desirable even though site B is more desirable for visual quality. *Reply:* Other factors have to be taken into consideration namely the risk of disaster which is much higher at B due to possible tectonic movements and possible lava flow. Location A is not considered unspoiled due to levelling, potato growing and the presence of a track although it was outside the area affected by the diatomite plant.

Comment: Reinjection alternatives have not been adequately assessed. *Reply:* Tracer studies of the groundwater system suggest that the present discharge system should be adequate. For the last 40 years about 200 million tons of geothermal effluent have been discharged into the groundwater current with no noticeable effect except over very short distances. However careful monitoring of the groundwater system will be continued as required by the Environment and Food Agency. Reinjection wells have been situated and will be drilled and used should any suspicion of contamination be indicated from the monitoring results.

The Planning Agency ruled that the plans for the plant could go ahead provided that area monitoring (surface manifestations, temperature and water table in springs and fissures, chemical composition of fluid in same and fumaroles, soil temperature) and production monitoring (well temperature, pressure, chemical composition) is carried out according to its stipulations. This ruling was not challenged and the first additional borehole was drilled in 2006 and two are due to be drilled in early 2008.

4. FURTHER PROCESSING AND USE OF GIS FOR THE 2003 ENVIRONMENTAL IMPACT ASSESSMENT

Noorollahi (2005) processed the data provided in the report of Hönnun (2003) and used the methods of GIS and remote sensing with the aim of choosing locations for drilling and power production taking into account economical and environmental factors. For well siting data layers including geothermal manifestations, volcanic craters and faults and fractures are overlain and intersected, followed by overlaying weighted geophysical and fracture distance raster maps to provide the suitable drill sites (Figure 2).

For environmental suitability vegetation cover and vegetation cover density maps are overlain to provide a suitable area map which then is overlain by a weighted protected area, slope and elevation and special criteria maps to select the final most suitable area (Figure 3).

TABLE 1: Relative influence of 13 factors on the three proposed power plant sites

Environmental & economic factors	**Relative influence (%)**	**Site A**		**Site B**		**Site C**	
		Relative value	**In-fluence**	**Relative value**	**In-fluence**	**Relative value**	**In-fluence**
Air pollution	9	9	81	8	72	6	54
Visual quality	9	9	81	6	54	3	27
Vegetation	9	7	63	9	81	4	36
Waste water	7	9	63	7	49	6	42
Noise	8	9	72	8	64	6	48
Land stability and subsidence risk	7	8	56	5	35	7	49
Slope and surface disturbance	7	6	42	7	49	8	56
Geology, natural risk	9	9	81	5.5	49.5	4.5	40.5
Faults, pipeline risk	8	9	72	6	48	4	32
Land use, operation	8	5	40	4	32	9	72
Distance to production field	8	8	64	9	72	6	48
Access road required	6	9	54	7	42	8	48
Transmission line	5	7	35	8	40	9	45
Accumulative weight	**100**		**804**		**687.5**		**597.5**

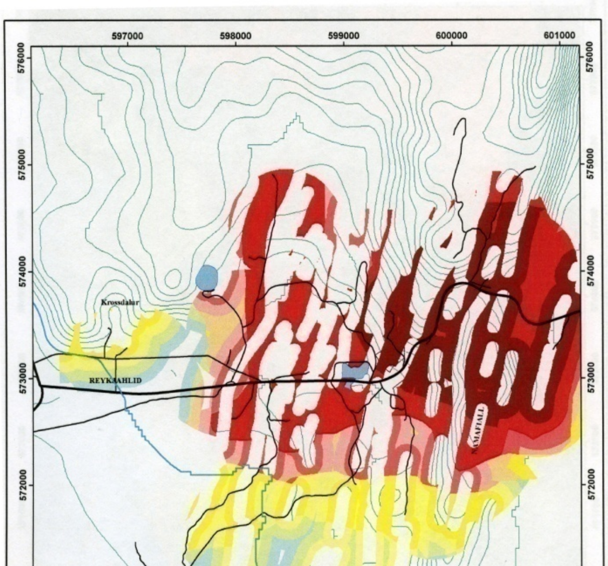

FIGURE 2: Ranking of study area according to the suitability of geothermal resources

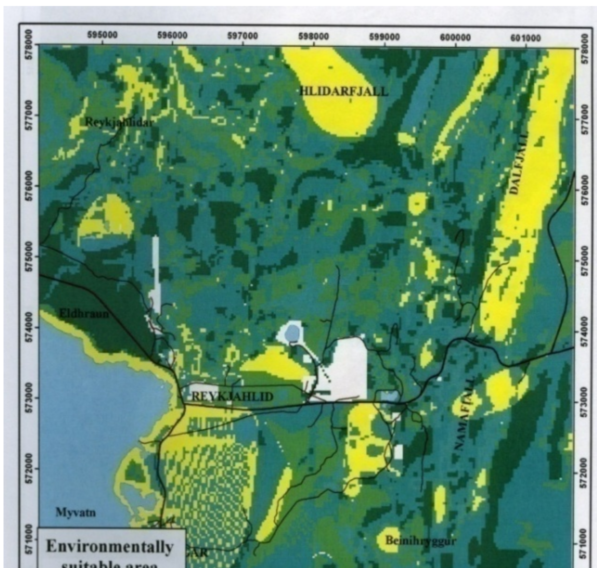

FIGURE 3: Environmental suitability map for the study area

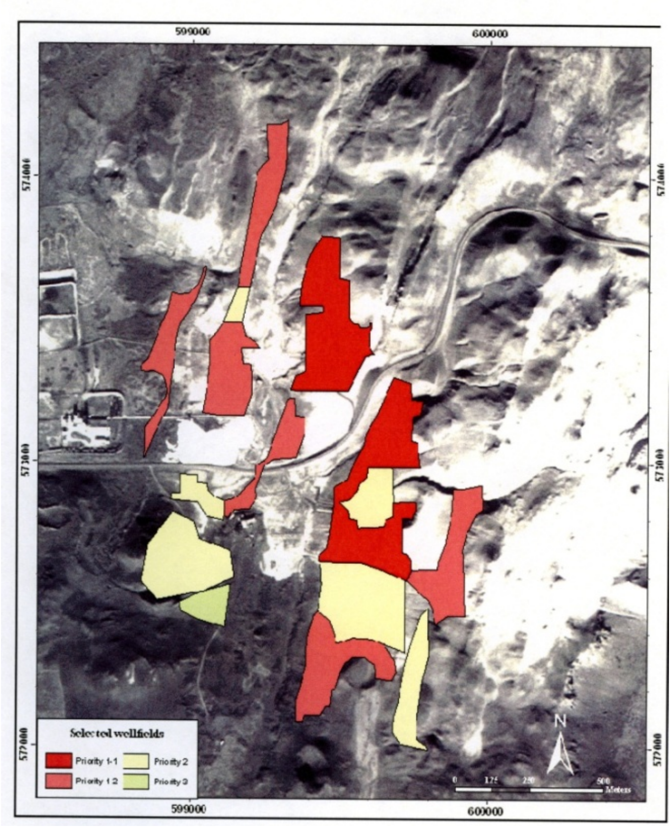

FIGURE 4: Prioritization of sites for drilling

The combined map showing the most suitable areas for drilling is shown in Figure 4 and as expected he proposed drilling pads are situated in the most suitable drilling areas evaluated earlier. For power plant selection Noorollahi (2005) considered the three alternative sites considered by the project developer (Figure 1) and evaluated thirteen different environmental, natural risk and economic factors. A relative value from 0 to 9 was assigned to each factor and then the factors were assigned a weighting with respect to each other. For air quality data on gas concentrations in previous wells, results of measurements of gas concentrations in atmospheric air and information on the prevailing wind direction in the area was used. Effective visibility based on the visibility from a 30 m buffer on both sides of main roads, tourist stops and a residential area was calculated using ArcInfo-3D Analyst for the three sites and the relative value obtained from the result. The importance of plant species was considered as well as the plant cover area for the vegetation factor. The distances to the proposed effluent pond and the projected reinjection well are used to evaluate the influence of waste water.
The distance from habitation and the inverse distance weighting method are used to estimate the effects of noise at inhabited places and tourist spots. Results of TEM soundings and a map of the intensity of alteration were combined to estimate subsidence risk. The slope and surface disturbance risk was estimated with the aid of the digital elevation map of the area. Geology and site stability risk were evaluated on the basis of results of analysis of material stability, estimates of geological stability, presence of fractures and faults and danger of lava flows. Possible routes for pipelines have been mapped with respect to faults and fractures to estimate risk. For land use the minimum area needed for the constructions is evaluated. The distances of the central points of the two well fields proposed in the drillsite study (Figure 4) from the proposed power plant site were calculated with respect to pipeline routes defined. The state, of present tracks and the length of necessary additional access roads for each site, was evaluated. The distance from the respective sites to the existing Reykjahlíd power transmission line was estimated and relative values given. The outcome of this total evaluation is that site A is the most desirable site for the power plant which is the same outcome as presented in the Environmental Impact Report (Hönnun 2003a).

5. SUMMARY AND CONCLUSIONS

Environmental impact assessment for the proposed Bjarnarflag power plant in Námafjall, NE Iceland was carried out four times from 1995 to 2003, three times according to Act No. 63/1993, but the last one according to Act No. 106/2000. The experience shows that the first act lacked an adequate mechanism to deal with serious opposition such as had been voiced in comments from the National Trust and others. The wide-ranging comments and the stipulations made by the National Planning Agency in response to the third EIA which the operators considered to amount to a demand for a new

EIA process showed that a major flaw in the initial act was the lack of a provision for a scoping document that should be open to comments, and with reference to whose final version the EIA should be carried out. This had been amended in Act No. 106/2000 and comments could be replied to and mitigation measures suggested without much trouble and the ruling of the National Planning Agency was not contested. Production drilling has already started

The use of GIS techniques for situating boreholes and power plant sites shows great promise and is likely to become a widely used tool in environmental impact studies in the future.

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