

**Advice on Harvesting the
Methane Resource and
Monitoring the Stratification of
Lake Kivu
-Rwanda-**

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TABLE OF CONTENTS

1. INTRODUCTION	1
2. THE REQUEST	1
3. NCEA ASSISTANCE	2
3.1 The workshop	2
3.2 The advice	2
4. OBSERVATIONS ON THE GAS RESOURCE AND ITS MANAGEMENT..	2
4.1 Safety aspects	2
4.2 Planning resource use and resource harvesting	3
4.3 Legal and organisational framework	4
5. RECOMMENDATIONS ON METHANE RESOURCE MANAGEMENT	6
5.1 Organisational and financial aspects	6
5.1.1 Planning of resource use	6
5.1.2 Management of resource use	6
5.1.2.1. General	6
5.1.2.2. Powers to regulate, inspect and enforce	7
5.1.2.3. Resource use management.....	7
5.1.2.4. Resource use monitoring.....	7
5.1.3 Funding of resource management.....	8
5.2 Publicity on resource management	8
5.3 Monitoring aspects	9
5.3.1 Organisation and communication	9
5.3.2 Methane harvesting.....	9
5.3.3 Kabuno Bay specific monitoring	10

1. INTRODUCTION

The Democratic Republic of Congo and Rwanda share Lake Kivu. In the third decade of the previous century it was discovered that gases are formed or injected in the lake and that its water column has a stable stratification that keeps the gasses locked in the deepwater in dissolved form. The concentration of the gases, of which carbon dioxide and methane are the main fractions, increased in the deep waters of the main basin by 15-20% between 1975 and 2004. It is generally assumed that, if the increase is ongoing at the same rate, gas concentrations will reach saturation in the main basin within a time scale of less than 150 years. It is generally believed that at the current gas concentration in the main basin, major events like extremely strong volcanic eruptions in the lake could trigger a devastating release of the gas mixture.

Recent carbon dioxide concentrations in Kabuno Bay are to be looked at as they are close to saturation near the surface, where they were already high in 1974-75, when carbon dioxide concentrations were 8 times higher than in the main basin.

Reduction of the methane and carbon dioxide content of the waters of Lake Kivu is generally considered necessary to reduce the risk of a sudden eruption of these gases and the risk of casualties that such an eruption would imply. The governments of Rwanda and the DRC have chosen to reduce the gas content of Lake Kivu waters in a profitable and environmentally sustainable way. Both countries have long been considering beneficial ways of exploiting the methane resource. A lot of research has been going on over time and both governments have the opinion that the time is right to start giving out concessions for methane harvesting. First concessions have now been awarded, foreseeing pilot installations and test periods.

Aware of the permanent risk of a sudden gas eruption, there has always been broad agreement that monitoring of both the stratification of the lake water column and the influence of methane harvesting on the lake stratification and on the environment is necessary. However, there was as yet no full agreement on which parameters should be monitored, how this should be done and who should do it. This lack of agreement has proven to hamper funding of the scheduled operations.

The Rwanda Ministry of Infrastructure through the Minister of State in charge of Energy, desiring to break the deadlock in the debate, decided to organise a workshop to come to agreement on these issues and invite all stakeholders in the Lake Kivu methane gas exploitation. The workshop was held in Gisenyi, Rwanda, from 26 – 28 March 2007¹.

2. THE REQUEST

The Minister of State in charge of Energy invited the Netherlands Commission for Environmental Assessment (NCEA) to assist him by:

¹ For the workshop report see <http://www.commissiener.nl/ncea/reportworkshoplakekivu/>

- supporting in organising the workshop
- facilitating the workshop and
- assuring the workshop secretariat.

It was the explicit wish of the Minister that the NCEA would provide adequate expert input in the workshop as to facilitate the settling of the debate. The Minister responded positively on NCEA's suggestion to additionally provide NCEA expert advice on harvesting of the methane resource and lake stratification monitoring. For the requests, see annex 1.

3. NCEA ASSISTANCE

3.1 The workshop

To respond to the request, the NCEA appointed a professional facilitator and a workshop secretary. In addition, the NCEA composed a working group of experts that covered the fields of expertise at stake. The facilitator was also appointed as chair of the expert working group, the secretary of the workshop was also appointed as secretary of the expert working group. The working group studied the background documentation provided by the Ministry of Infrastructure (UPEGAZ).

The facilitator, the secretary and one of the experts visited Kigali from 27 February to 2 March 2007 to assist UPEGAZ in preparing the workshop. The complete NCEA working group attended the workshop itself.

After the workshop, the working group provided input for the "Mandatory Requirements and Guidelines - Rules and Regulations for the Design and Operation of Gas Extraction" document of UPEGAZ and for the WB-prepared Carbon Credits request.

In addition, the secretary produced the workshop report.

3.2 The advice

As last step in this advisory sequence, the working group formulated this independent advice on harvesting of the methane resource and monitoring of the stratification of Lake Kivu.

An initial objective in providing this advice was to give an independent expert view on conclusions that the workshop would reach or recommendations that the workshop would make in case these conclusions and recommendations would not represent the views of the working group. As the working group can agree with the workshop results, this advice will focus on recommendations with regard to the scientific and organisational aspects of the monitoring.

4. OBSERVATIONS ON THE GAS RESOURCE AND ITS MANAGEMENT

4.1 Safety aspects

The working group:

1. assumes that there are two main reasons for extraction of the gas from the waters of Lake Kivu:

- a) reduce the gas concentration in order to lower the risk of outbursts
 - b) harvesting the methane in order to use it as fuel.
- 2. observes that there is a clear necessity to reduce the gas content of the waters of the main basin and Kabuno Bay of Lake Kivu to reduce the risk of gas eruptions and the related occurrence of casualties.
- 3. assumes that a major gas eruption can only be triggered by a volcanic eruption in the lake or at the lake's borders. The probability that such an eruption will happen within the time span in which gas concentrations would reach saturation is low. Hence, from a safety perspective the working group sees no need to act overhasty, not allowing oneself the time to thoroughly prepare the reduction of the gas content and the way in which this is done;
- 4. observes that also the waters of the Kabuno Bay contain gases. Although the current concentrations are not of concern², one should realise that future harvesting in the main basin will not reduce gas concentrations in Kabuno Bay.
- 5. observes that incorrect re-injection of degassed water:
 - a) may devastate the build-up of future methane reserves
 - b) will accelerate nutrient cycles and increase primary production in the biozone surface layer. This will have a direct impact on the natural biotic communities.

4.2 Planning resource use and resource harvesting

The working group:

- 6. acknowledges that there may be economic reasons to make a quick start in harvesting the methane resource but has the opinion that the size and the nature of this resource merits thorough study and planning of its most advantageous uses in a policy or strategy.
- 7. identifies the following strategic decisions to be taken in relation to the methane resource use:
 - o the time scale of methane harvesting.
Each harvesting option has its own financial/economic, social and environmental advantages and disadvantages. Some options are:
 - a) harvesting at the maximum safe speed until resource depletion (i.e. when harvesting is no longer economically feasible)
 - b) harvesting at an intermediate speed. This will gradually reduce the risk, has limited impacts on the lake ecosystem and will not cause many operational problems and changes to the lake-internal methane storage. In addition, it will probably avoid electricity overproduction and problems related to grid capacity).
 - o the use of the resource. Until now the planned use focuses on power generation. During the workshop it became clear that there are more options for use of the methane e.g. piped gas for household uses. These other uses may be environmentally, socially and economically beneficial e.g. through their effect on conservation of forests, their low cost, etc.

² A recently established CO₂ profile shows that there is no danger in the deep water. The NCEA holds the opinion that the high level of saturation at the depth of 10 m cannot cause an eruption

- tuning with infrastructure development. During the workshop it also became clear that planning of grid development and power production from methane are as yet not tuned to each other.
 - regional power generation planning. Power generation from methane from Lake Kivu is included in the Strategic/Sectoral, Social and Environmental Assessment of Power Development Options in the NEL region³.
8. observes that with the present state of knowledge, methane production in Lake Kivu - beyond the harvesting of the currently known volumes - cannot be reliably forecasted.
 9. observes that early exploiters have an advantage compared to those that start exploitation later. It needs study whether or not this fact necessitates differentiation of the terms of concession contracts. Also, this fact may in future put stress on the relation between the two countries if one of both starts methane harvesting at a much higher rate than the other. Maybe compensation mechanisms need to be developed. Here, one can think of the option that electricity is sold and the benefits are shared between the countries
 10. notes that public safety is the issue of primary concern in the context of Lake Kivu. Public safety does not only concern 'real safety'⁴ but also 'perceived safety'⁵. The working group stresses that both are equally important. Good regulations and concession conditions and their stringent enforcement guarantee 'real safety'. Sharing of information on the regulations and concession conditions related to safety and sharing of information on (the results of) enforcement of the regulations and conditions can promote 'perceived safety'.

4.3 Legal and organisational framework

11. The safety issues related to the presence of the gases and the risk and hazards related to the harvesting of methane⁶ warrant the permanent vigilance of an authority vested with such power and means that it can instantaneously take any measure or intervene in any way to avert risks and hazards. The fact that the lake is owned by two countries must not in any sense hamper the creation and functioning of such an authority.
12. In order to be able to perform adequately, this authority must have direct and immediate access to adequate and up-to-date information on safety-related issues. An important part of this information must be generated by monitoring. The goals of monitoring can be summarised as:
 - assure the safety of the personnel and public and assure the environmental safety at the plants;
 - assure re-injection of the gas-depleted water (after methane extraction) according to the Mandatory Requirements and Guidelines and adjust periodically the re-injection depth range as proposed in the Mandatory Requirements and Guidelines;

³ This assessment is carried out under the framework of the Nile Basin Initiative (NBI)

⁴ Defined as the chance of casualties occurring

⁵ The extent to which people feel safe: the feeling of being in danger can cause public unrest, opposition and worse

⁶ Eruption of gasses, loss of the resource

- follow the development of lake stratification and ecology, and adjust periodically the re-injection depth range as proposed in the Mandatory Requirements and Guidelines;
 - establish the possibility for revising the Mandatory Requirements and Guidelines upon unforeseen developments of the stratification and the lake ecology;
 - collect information on the gas inventory in the lake for management, planning and concession purposes.
13. The working group observes that it is the quality of the legal and regulatory framework and the quality of its enforcement by the institutional set-up that will give the investors and the public the confidence needed to engage in methane harvesting.
 14. Monitoring and inspection being crucial for effective enforcement (and thus for safety of the population), the necessity of lake-wide monitoring and inspection provides a natural opportunity for the two countries to join and develop their mutual monitoring and inspection capacity.
 15. The expected total non-discounted value of the resource at the targeted unit price can be calculated at some 20.000 million US\$. Assuming that an expenditure of 2% of that value is a reasonable target for expenditure on monitoring and inspection over an economic life span of the resource of 40 years, 10 million US\$ would be available for monitoring and inspection each year. This amount must cater for basin-wide monitoring (monitoring expenses, competence build-up, applied research and maintenance), international advisory services, inspection and reporting and other monitoring related issues (such as communication, information dissemination, etc). It is clear that monitoring set-up must be light in nature.
 16. Previous points have argued that the future of methane harvesting operations will largely depend on the confidence that investors and the public have that laws and regulations are of good quality and that they will be stringently enforced. The working group has the opinion that stringent enforcement can only be guaranteed when enforcing bodies benefit from structural funding.
 17. Knowledge on the methane and on lake stratification is now scattered world-wide. The working group observes that, once harvesting operations start, this knowledge needs to be locally available.

5. RECOMMENDATIONS ON METHANE RESOURCE MANAGEMENT

5.1 Organisational and financial aspects

5.1.1 Planning of resource use⁷

The working group endorses the workshop recommendation on planning⁸ and suggests:

- to identify the bi-national forum that should undertake strategy development on resource use and planning of resource harvesting;
- to implement the recommendation starting on the shortest possible notice;
- that the proposed resource use strategy⁹ and harvesting plan¹⁰ only refer to the presently existing methane reserves¹¹.

5.1.2 Management of resource use

5.1.2.1. General

The working group recommends:

- that both governments should design, establish and legally and logistically equip a structure that manages the resource and its risks in such a way, that it can decide and implement emergency measures related to public, resource and environment safety on its own authority¹²;
- that this structure should be functioning as soon as possible, preferably starting during the pilot phase of methane harvesting;
- that the structure should be lean, making use of existing (preferably local) structures and institutions as much as possible;
- that an adequate capacity development program is implemented for the structure and that, pending the winding-up of that program, adequate external management capacity is made available to the structure (see also footnote 16);
- that the structure has permanent access to an international sounding board of scientists and engineers¹³.

⁷ Before individual concessions are granted (or while the first concessions are granted), the working group recommends that a strategic plan or policy is needed for the use of the resource for the next 50 years. Such a plan will allow for formulation of a harvesting plan that is agreeable to both countries. That plan would form a solid base for the individual allocations / concessions and the allocations for the DRC and Rwanda

⁸ See the workshop report on <http://www.commissiener.nl/ncea/reportworkshoplakekivu/>

⁹ The working group recommends to study the resource use options and the required speed of their development

¹⁰ The working group recommends to coordinate methane resource harvesting for power production with grid development planning and with regional power production planning (see also observation 7)

¹¹ Which will most probably primarily depend on the productivity of the lake eco-system and secondarily on the harvesting. Both effects - including potentially other sources of methane - cannot be precisely predicted

¹² For efficiency reasons, the working group would consider it wise to vest the proposed structure with the power to oversee all the different risk management-related aspects of the gas harvesting: concession granting and withdrawal, monitoring and inspection of safety, environmental impact, social impact, micro- and macroeconomic impacts and communication.

¹³ Structure consisting of a government representative of both the DRC and Rwanda, a scientist from the DRC and Rwanda (We would propose "scientists from both countries having expertise in Lake Kivu and/or limnology

5.1.2.2. Powers to regulate, inspect and enforce¹⁴

The working group recommends:

- that legally binding documents should be published that define and attribute the powers to regulate, inspect¹⁵ and enforce¹⁶;
- that the concessions and power purchasing agreements (PPAs) and the Mandatory Requirements and Guidelines that are part of these concessions refer to these (possibly future) legal documents;
- that the mandated body applies a strict interpretation of enforcement of legal requirements, concession conditions and Mandatory Requirements and Guidelines.

5.1.2.3. Resource use management

The working group recommends:

- that legally binding documents should be published that define and attribute the powers to manage the resource;
- that the concessions and power purchasing agreements (PPAs) and the Mandatory Requirements and Guidelines that are part of these concessions refer to these legal documents;
- that the resource should be managed according to the agreed resource use strategy and harvesting plan (see 5.1.1), respecting the terms and conditions laid down in the Mandatory Requirements and Guidelines;
- that resource use management should be adapted and the Mandatory Requirements and Guidelines reviewed in line with the findings of on-plant monitoring and lake-wide monitoring.

5.1.2.4. Resource use monitoring

The working group recommends:

- that legally binding documents should be published that define and attribute the responsibilities for monitoring;
- that the concessions and power purchasing agreements (PPAs) and the Mandatory Requirements and Guidelines that are part of these concessions refer to these legal documents;
- that on-plant monitoring:

and/or aquatic ecology”), an international expert in the field of physics/geochemistry, an international expert in the field of geochemistry/plankton and an international expert in the field of plankton/fisheries. The working group suggests that while composing this group special attention is paid to the constructive and collaborative attitude of its members.

¹⁴ For credibility and confidence of the public and the investors, the tasks of monitoring and the task of inspection need to be spelled out and detailed in the legal documents that constitute the proposed structure and in the Mandatory Requirements and Guidelines that are part of the Concession and of the Power Purchasing Agreement (PPA). These documents must be complementary and coherent and include all tasks to be performed in monitoring and inspection

¹⁵ The mandated Inspectorate must be scientifically and technically fully qualified and equipped and have the mandate to perform inspections at all times at all installations. Equal level inspection must be operational at both sides of the borders and, in order to guarantee mutual trust between the countries, establishment of mechanisms of mutual verification on the frequency and quality of inspections is recommendable

¹⁶ The working group suggests that a vast part of the monitoring and inspection should be carried out by local scientist, after a period of competence build-up. Best would be if these lake-related scientists are located at the two countries universities in Bukavu (DRC) and Butare (RW) or Kigali IT (RW). Some common infrastructure (such as a small research vessel and a laboratory / staging facility) could be used by both groups when located in the border area of Goma/Gisenyi. With applied research the two groups should be able to maintain the competence, with some outside input from the sounding board of scientists and engineers (see footnote 13)

- is made the direct responsibility of the concession holder;
 - is to be done according to a prescribed format and frequency (e.g. once a week) ¹⁷;
 - results steer harvesting technology development.
- that all near-plan and lake-wide monitoring functions are the responsibility of the governments' structure.

5.1.3 Funding of resource management

The working group recommends

- that both governments should provide structural funding for all government resource management tasks;
- that the principle should be adopted that, after a subsidised start-up phase, the costs of these structures must be covered by a levee on harvested methane¹⁸;
- that the principle should be adopted that on-plant monitoring is an obligation of the operators and must be funded by the concessionaires;
- that interested donor agencies should provide financial assistance for a timely¹⁹ establishment, training and operation of the resource management structure, with a priority for the governments' monitoring structure, the inspectorate and the sounding board of scientists and engineers. This assistance should gradually be reduced commensurate with the stage of development of methane harvesting and should end when income from methane harvesting has reached a level at which it reasonably may be assumed sufficient to support these government tasks.

5.2 Publicity on resource management

The working group recommends that both governments agree on a policy of full openness and publicity of methane resource management.

This would imply a.o.:

- That a reference to this policy should be made in all legal documents;
- That the responsibilities of the proposed management structure (see 5.1.2.1) should include the task of 'communication';
- That the proposed management structure (see 5.1.2.1) publishes:
 - the legal text that establishes the structure
 - Mandatory Requirements and Guidelines its resource use strategy
 - its harvesting plan
 - concession agreements
 - power purchase agreements (PPAs)
 - lake-wide monitoring results
 - on-plant and near-plant monitoring results

¹⁷ According to the Mandatory Requirements and Guidelines

¹⁸ In order to guarantee its economically viable and sustainable functioning, the working group recommends mandating the proposed resource managing body to put a 'monitoring and enforcement levee' of 2% of the unit price of methane

¹⁹ Preferably prior to the pilot phase in which harvesting technology is developed

- inspection data and results
- results of the applied research by the monitoring groups
- publications of the scientific investigations on Lake Kivu and its methane.

5.3 Monitoring aspects

5.3.1 Organisation and communication

The working group recommends monitoring institutional development, institutional functioning and the effectiveness of communication on resource management.

- 1) Monitoring of development and functioning of resource management capacity. Monitoring parameters should include:
 - i) progress in development of a methane resource use policy, a harvesting plan and a legal and regulatory framework for methane resource use;
 - ii) progress in developing structural funding for institutional development;
 - iii) speed and adequacy of development of the institutional set-up for resource management;
 - iv) speed and adequacy of capacity development within the institutional set-up;
 - v) functioning of the institutional set-up.
- 2) Monitoring of effectiveness of communication on resource management. Monitoring parameters should include:
 - i) accessibility of the information;
 - ii) information use (who makes use, at what frequency);
 - iii) timeliness of provision of information and sufficiency of information.

5.3.2 Methane harvesting

The working group recommends that whole-lake limnological and ecological monitoring be carried out with adequate periodicity, with a special attention to (i) lake stratification, (ii) gas contents in the lake²⁰, (iii) nutrient cycling and eutrophication risk²¹, and (iv) the sustainability of the lake fishery. The working group recommends distinguishing the following monitoring tasks:

- 1) Monitoring on and near the extraction and re-injection plant. Monitoring parameters should include:
 - i) compliance with Mandatory Requirements and Guidelines; in particular the re-injection depth and the properties of the re-injected water (density-related parameters and gases)
 - ii) compliance with concession and power purchase agreement (PPA) conditions
 - iii) Gaseous emissions from the plants / extraction facilities
 - iv) plume formation and re-stratification of the re-injected water

²⁰ The extraction operations that get concessions should be done in such a way that they allow the build-up of future methane reserves and prevent losses of current methane resources.

²¹ The extraction operations that get concessions should be done in such a way that the modification of ecosystem functioning is minimal

- v) near-plant nutrient concentrations in the biozone and transparency;
- 2) Monitoring of the lake at large. Monitoring parameters should include:
 - i) all density-related parameters;
 - ii) the main geochemical constituents, nutrients, phytoplankton, zooplankton and primary production-related parameters²²;
 - iii) the gases.
 - 3) Monitoring of the fish stocks. Monitoring parameters should include:
 - i) fish stock assessment by whole-lake acoustic survey (i.e. for *Limnothrissa miodon*);
 - ii) seasonal fluctuations in abundance and distribution patterns of commercial fish species;
 - iii) fishery statistics analysis (i.e. change in CPUE) for both countries;
 - iv) intra and inter-specific relationships among species (predator-prey relationship);
 - v) sardine biology parameters including growth.
 - 4) Baseline monitoring:

The geophysical and geochemical properties of the lake stratification will change very slowly and therefore a continuous monitoring in the long-run is more important than a baseline survey, which is already done by the DRC/Belgium/Swiss cooperation at the moment. What would be most urgent is a baseline survey on fisheries (abundance; carrying capacity; fishing yield) and plankton-fish interaction. The fear is that the methane harvesting could change the nutrient fluxes in the lake and thereby the primary productivity and therefore the biological activity

5.3.3 Kabuno Bay specific monitoring

The working group recommends to:

1. monitor the temporal development of the gas concentrations and investigate the reasons for the changes observed;
2. develop, based on results of the studies, a separate plan for reducing gas eruption risk from Kabuno Bay.

²² Not in Kabuno Bay