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Proposed Budget and duration: USD **1,199,258** over three years (2011-2013)

2. Executive Summary

Eastern Africa countries are faced with similar development challenges including high population growth rate, low agricultural productivity, increasing number of agro-processing industries, pollution and contamination of water sources by agro-processing industrial wastes, inadequate energy supplies and climate change effects such as extreme drought and flooding. It is therefore imperative to address these challenges in an integrated and regional manner, in which key stakeholders including the public and private sectors are actively engaged. The goal of this *Consortium* is to contribute to climate change mitigation, environmental sustainability, and agricultural development by applying strategic waste management innovation systems in Eastern Africa (focussing on Ethiopia, Tanzania and Uganda). Specifically the project aims to: (1) Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa; (2) Develop and optimize innovative wastewater treatment processes integrating biogas production and water/nutrient reuse for enhanced industrial and agricultural productivity in Eastern Africa and; (3) Evaluate and disseminate the economic, environmental and social benefits of the integrated wastewater treatment bioprocesses. We will achieve our objectives by use of appropriate technologies that will be designed, developed and optimized to achieve: (1) better treatment of agro-process wastewaters (slaughterhouse, tannery and Banana wine processing wastewaters) in Uganda, Ethiopia and Tanzania, respectively and; (2) generation of useable by-products such as biogas, bio-fertilizers, and agricultural products (vegetables, flowers, animal feed/pasture grass) from wastewater treatment processes. Through this integrated wastewater treatment approach, we will contribute to environmental, social and economic development of Eastern African countries including reduction in pollution and contamination of water sources receiving agro-processing wastewaters, reduction in incidences of water related diseases such as diarrhoea, reductions in emission of greenhouse gases (GHG); generation of renewable energy source (biogas), slow down the rate of deforestation for firewood and charcoal, reduce indoor air pollution (IAP) and respiratory diseases since Biogas burns smoke free, and improve agricultural productivity by provision bio-fertilizers.

The proposed *Consortium* hinges on lessons learned from the successes and challenges of previous SIDA/SAREC projects in Eastern Africa, especially BIO-EARN programme phase 3 which carried out treatment of slaughterhouse wastewater at City Abattoir (Uganda) and tannery wastewater at Modjo Tannery (Ethiopia). Whereas the project treated these industrial wastewaters, they were not economically sustainable because they did not add-value to wastes by integrating hydroponic systems for vegetables and flowers cultivation, production of useable by-products such as biogas and bio-fertilizers into the treatment process to make it sustainable. The proposed *Environmental Innovation Project Consortium II* comprises of scientists from Waste Stabilization Ponds (WSP) & Constructed Wetland Research and Development group (University of Dar Es Salaam - UDSM), Department of Biochemistry (Makerere University - MAK), School of Graduate Studies University of Addis Ababa (Ethiopia - AAU), National University of Rwanda (NUR), and AKUT *Burkard and Partner* (Germany, www.akut-umwelt.de, AKUT). The private sector partners involved in this consortium include Bassajabalaba Hides and Skins - City Abattoir (Uganda), Modjo Tannery, Addis Ababa (Ethiopia), and Banana Investments Ltd, Arusha, (Tanzania). Each scientific partner contributes technical skills, experiences and synergies to the *Consortium*: UDSM has engineers with technical experiences in constructed wetland technologies; AKUT Partner has experience in designing and installation of industrial scale biogas digester plants; MAK and AAU have experiences in operation of reactors and constructed wetlands treating slaughterhouse and tannery wastewaters, respectively. On the other hand, Bassajabalaba Hides and Skins, City Abattoir (Uganda) and Modjo, Tannery (Ethiopia) both have over four years (2006-2010) experience in operation of integrated technologies treating high strength slaughterhouse and tannery wastewaters, respectively, under the SIDA/SAREC supported BIO-EARN project. Whereas Banana Investments Ltd, Arusha (Tanzania) have not participated in similar arrangements, they have committed strong technical, financial and in kind support towards the success of the proposed *Consortium* project. The proposed *Consortium* project is anticipated to run on budget of USD **1,199,684** over a period of three years (2011 -2013).

3. Background and rationale for the proposed project

3.1 Background

Agriculture and industrial processing are viewed as the main drivers of economic growth in Eastern Africa. On the contrary, they are also the main drivers of climate change because they are often accompanied by unsustainable utilization of land and water resources. There is now a growing regional interest in alternative energy sources as a result of increased demand for energy coupled with a rise in the costs of available fuels. A number of initiatives such as the Africa Biogas Partnership Programme (ABPP) which comprises a partnership between Hivos and Netherlands Development Organization (SNV) supports national programmes on domestic biogas in Ethiopia, Kenya, Rwanda, Tanzania, Uganda, Senegal and Burkina Faso, Heifer-International Uganda programme, AKUT Burkard and Partner-German, etc have started addressing the energy crisis at household level. There are also medium to large scale biogas plants operated in the region such as that operated by Kenya Meat Commission slaughterhouse, Athi River, and Katani Ltd, Tanzania (http://www.thebioenergysite.com/articles/308/tanzania-sisal-biogas). However, one linkage that has not been addressed in Eastern Africa is the integration of agro-processing, energy recovery and water reuse for economic activities (especially agricultural sector). The agro-processing sector generates a large quantity of effluents with high organic contents, which if treated suitably, can result in a perpetual source of energy and nutrient fertiliser (Rajeshwari et al., 2000). Despite the negative environmental impacts associated with agro-processing wastewaters (i.e, nutrient enrichment and oxygen depletion in aquatic systems, toxicity and greenhouse gas emissions) the effects can be minimized and energy and nutrients can be tapped by means of anaerobic digestion (Rajeshwari et al., 2000). The existing wastewater treatment methods in the region are not integrated and thus do not innovatively add value to the wastes by recovering nutrients (N&P) and bio-energy to improve agricultural productivity, contribute to the ever increasing energy demands in the region, and reduce GHG emissions. Furthermore, these wastewater treatment technologies often do not meet national discharge standards to protect the human population and the environment.

Most studies on the anaerobic treatment of slaughterhouse and tannery wastewaters for example have been conducted with fixed film reactors, up-flow anaerobic sludge blanket (UASB) reactors and anaerobic fluidized bed reactors (Borja et al., 1995; Rajeshwari et al., 2000). The UASB has relatively low investment requirements, can sustain high organic loading rates (OLRs) when the wastewater contains mostly soluble chemical oxygen demand (SCOD) (Borja et al., 1995) but requires long start-up periods and skilled personnel. In addition, granular sludge UASB reactors like fluidized bed technology provides an opportunity for higher loading rates and resistance to inhibitors (Rajeshwari et al., 2000). Raw slaughterhouse, banana wine process wastewater or tannery wastewater contains high concentrations of insoluble, slowly biodegradable solids, often representing over 50% of the polluting charge (Massé and Masse, 2000). This therefore makes treatment and recovery of biogas and nutrients from slaughterhouse, tannery and banana wine process effluents more feasible using continuously stirred tank reactors (CSTRs, Kaparaju et al., 2007), and also reduces GHG emissions. The anaerobically treated slaughterhouse and banana wine effluent contains essential nutrients (N&P) for plant growth which could be harnessed for vegetables, flowers and animal fodder (grass) cultivation under hydroponic or irrigation conditions. Thus, through an integrated innovative approach to agro-process waste treatment involving pollution reduction, biogas production and nutrient recovery/recycling for agriculture, this project will contribute to the attainment of the Millennium Development Goal No. 1 by contributing to eradication of extreme poverty and hunger through energy and nutrient recovery for agricultural production, as well as ensuring environmental sustainability and improved livelihoods (MGD No. 7) in the Region.

3.2 Problem statement

Although rapid expansion of agro-processing industries in Eastern Africa is viewed as an indicator of economic progress, they are greatly associated with environmental degradation, notably the discharge of untreated or partially treated wastewater and greenhouse gas emissions, and consequently climate change (EPA, 2003; Kyambadde, 2005). It is estimated that less than 60% of people in Eastern Africa have access to safe water supply or sanitation services (WSP, 2002; EPA, 2003). It is also predicted that by 2020 about 75-250 million people in Africa could face shortages of clean water and food and greater risks to health and life as a result of climate change (ECA,

2008). Furthermore, the unsafe release of greenhouse gases (GHGs) into the atmosphere through anaerobic bio-conversion of agro-process wastes to biogas that contains about 50% methane enhances climate change. One unit of methane has a global warming potential of 21 computed for a 100-year horizon or 56 computed for 20 years (Ayalon and Avnimelech, 2001; IPCC, 2007). Industrial process wastewaters such as those from slaughterhouses, tanneries and banana wine processing among others are highly recalcitrant and difficult to treat due to the high soluble and insoluble organic matter content, nutrients and metals. The few conventional agro-process wastewater treatment processes in Eastern Africa are either focussing on reducing pollution load alone or biogas production but not designed to integrate wastewater treatment, biogas and nutrients recovery. Thus they do not contribute to the energy supply or nutrient resources for improved agricultural productivity and climate change mitigation. This paves way for nutrient depletion from arable land, increased deforestation rates, increased GHG emissions and enhanced climate change. During the previous Sida-supported BIO-EARN programme, BIO-EARN Project 3 developed bioprocesses for the treatment of high-strength industrial wastewaters both at laboratory and field-scale levels (City Abattoir in Uganda and Modjo Tannery in Ethiopia). However, the project did not cater for bio-energy, water reuse and nutrient recovery/recycle processes yet these are pivotal for economic development. This project will therefore focus on optimising biogas production, water reuse and nutrient recovery from slaughterhouse and banana wine process effluents in Uganda and Tanzania, respectively by integrating anaerobic digesters, hydroponic systems, aerated sequencing batch reactors and constructed wetland units. This project will also focus on optimising biogas recovery from Tannery wastewater in Ethiopia and further treatment of the effluent in sequencing batch reactors (SBRs) integrated with constructed wetlands to reduce the pollution load and recycle the water for tanning processes.

3.3 Rationale

In Uganda, studies (Kyambadde, 2005) have shown that the City Abattoir significantly impacts on the ecology and water quality of Inner Murchison Bay of Lake Victoria from where drinking water supplied to Kampala City is drawn. The abattoir has a slaughter capacity of 500–600 cattle and 200–300 goat/sheep units per day, respectively, with an average wastewater production capacity of 400 m^3 per day. This highly polluted wastewater effluent (COD > 10,000 mg/L) significantly contributes to nutrient enrichment and oxygen depletion of Lake Victoria. In Tanzania, Banana Investments Ltd processes 25 metric tons of peeled ripe bananas per week to produce wine in a process that produces about 400 m^3 of high-strength wastewater (BOD, 3000 mg/L) per day. The enterprise unsustainably uses 3600 cubic meters of wood fuel per year costing the company USD 50,000 per annum (Njau, personal communication). On the other hand, more than 20 tanning industries are currently operational in Ethiopia (EPA, 2003). The Modjo tannery for example generates 4 500 m^3/day of wastewater with a COD content of 10 000 mg/L (Seyoum *et al*., 2003) which is discharged to Modjo river feeding into Lake Koka (Ethiopia). Downstream communities use this lake for irrigation and other domestic activities and this poses a health risk to these communities.

The current treatment processes in the region do not integrate pollution reduction, energy and nutrient recovery from agro-process wastewaters. Therefore, processes that add value along the waste treatment chain are necessary strategies to complement global climate change mitigation efforts. In this project, the value-addition chain encompassing anaerobic bio-conversion of agro-process wastes to produce biogas energy and nutrient-rich slurry, aerobic oxidation of anaerobic digestate to reduce organic and nutrient loading in the wastewater and generate nutrient-rich sludge, use of effluent from anaerobic digester and aerobic SBRs to cultivate vegetables, flowers and animal fodder in hydroponic systems and finally polishing of this effluent in constructed wetlands would be an innovative strategy and incentive to achieve sustainable waste treatment and environmental clean-up in the region. The use of the slurry (bio-fertilizer) and nutrient-rich pre-treated wastewater under hydroponic (soilless culture) conditions would mitigate climate change, increase agricultural productivity, food security and poverty eradication (Liu et al., 2009). The recovery of biogas from the agro-process waste feedstock will compliment energy needs of these industries. For example, Banana Investments Ltd anticipates a 75% reduction in wood fuel consumption when a biogas plant is built under this project. Similarly, City Abattoir operations in Uganda require large volumes of hot water to maintain high levels of hygiene which translates into high costs of electricity. The abattoir also uses large quantities of charcoal to prepare meals for over 2000 persons visiting or working at the abattoir on a daily basis. Recovery of biogas from slaughterhouse wastewater for local consumption will reduce charcoal usage by about 80% and which is a sustainable and environmentally friendly strategy. There is also a great potential to recycle treated and

disinfected wastewaters for industrial use such as cleaning slaughtering areas, animal storage facilities and public convenience facilities. Treated tannery wastewater could also be recycled back into the production system to reduce water consumption. Therefore, it is imperative to integrate and optimize biogas production and nutrient recovery from agro-process wastewaters as well as water reuse in the region. This would contribute to slowing down the rate of deforestation, improve soil fertility by using the slurry, protect freshwater resources, and reduce green-house gas emissions and mitigate climate change. By treating agro-process waste, this project will also contribute to the attainment of the Millennium Development Goal No. 7 by ensuring environmental sustainability and improved livelihoods in the Region.

4. Adding value to existing efforts (relevance and quality of content *of the proposal)*

The agro-processing sector of Eastern Africa region generates a large quantity of effluents with high organic contents, which if treated suitably, can result in a perpetual source of energy and nutrient fertiliser. Due to the ever increasing energy demands, depleting nutrient resources in arable lands and climate change resulting from GHG emissions, there is now growing interest in using agro-process wastes as alternative energy sources in the region. A number of biogas initiatives for example are currently running in the region to address energy needs at house hold and industrial scale level. The Africa Biogas Partnership Programme (ABPP) which comprises a partnership between Hivos and Netherlands Development Organization (SNV) supports national programmes on domestic biogas in Ethiopia, Kenya, Rwanda, Tanzania, Uganda, Senegal and Burkina Faso. Carmatec in Tanzania, KENFAP in Kenya and Heifer-International in Uganda, are implementing the Dutch initiative "Biogas for better life in Africa. In addition, UNEP / UNIDO have installed small scale Biogas plants at two Kenyan slaughterhouses, which are treating only part of waste water stream. AKUT in partnership with Kenya Meat Commission slaughterhouse, Athi River have installed a biogas plant using slaughterhouse waste as substrate. The German Technical Corporation (GTZ) has also supported the construction of an industrial Biogas plant at Kilife/Kenya. AKUT Burkard and Partner under its contract with GTZ PSDA (Promotion of private sector development in Agriculture) have also produced some biogas pre-feasibility studies for Kenyan agribusiness. Worth noting is that GTZs initiative in the Biogas sector will likely come to an end in June 2011 and thus the BioInnovate Programme might become a subsequent operator with a regional approach. Furthermore, Katani Ltd, a sisal growing company in Tanzania is operating a large-scale biogas plant and is used to run electricity generators which power the production machinery, with excess electricity supplied to out-growers/smallholders homes, schools and hospitals (http://www.thebioenergysite.com/articles/308/tanzania-sisal-biogas). In Rwanda large-scale biogas plants that use human excreta substrates are operational at six prisons. Therefore presence of such initiatives is evidence for demand-driven innovations in the energy sector and hence learning from practical experiences of these initiatives and industries operating large-scale biogas plants in East Africa shall be beneficial to achieving project success.

This project will further compliment regional efforts that address issues of waste management/climate change, energy supply and reduction in hunger and extreme poverty. These include municipal and industrial wastewater treatment by National Water and Sewerage Corporations and municipalities, and mitigation of pollution of Lake Victoria due to municipal and industrial effluents under the Lake Victoria Environmental Management Project. Other initiatives in the region include the UN-HABITAT funded "Sustainable Cities Initiative" which devotes its support towards capacity building in terms of manpower in waste management though it does not directly support activities involving the development of wastewater treatment technologies. The project will also innovatively add-value to the Sida-supported Bio-EARN programme, which focussed on Environmental and Industrial biotechnology projects to develop capacity to treat municipal and industrial wastewaters, by integrating biogas and nutrient recovery processes in the project design. The project shall also compliment initiatives that address hunger and poverty by producing nutrient-rich fertiliser (slurry) from waste treatment processes which will be fed into agricultural production systems and utilization of nutrient-rich wastewater in hydroponic system for vegetable and flower farming in the region. Such initiatives include the African Union's New Partnership for Africa's Development (AU/NEPAD) which coordinates and promotes socio-economic development, through different efforts such as Forum for Agricultural Research in Africa (FARA). The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA); FARA; Biosciences for East and Central Africa and International Livestock Research Institute (*BecA/ILRI*); Comprehensive Africa Agricultural Development Programme (CAADP); and

Economic Commission for Africa (ECA) which focus on boosting agricultural production in Eastern and Central Africa to reduce hunger and alleviate extreme poverty.

5. Potential for economic and social impact

The economy of East African countries heavily relies on the agricultural and industrial sectors whose current productivity is dependent on expensive non-renewable energy sources. The agro-processing sector generates large quantities of effluents with high organic contents which can be treated to produce energy and nutrient fertiliser. One of the technologies which can be used to treat various waste streams is the anaerobic digestion (AD). The AD has two main outputs: the biogas and the slurry. Biogas is source of energy which can effectively be used in many industrial processes to replace other costly energy sources (UN-ENERGY/Africa, 2008), while the nutrient-rich slurry is a good source of plant nutrients (N&P). Unfortunately, most agro-process wastes are discharged to the environment without recovering useful energy (biogas) and nutrients to enhance agricultural productivity. Therefore, by integrating wastewater treatment with energy and fertilizer production (nutrient recovery), and reuse/recycle of treated wastewater for industrial processing and agricultural production, this project will lead to outputs that are demand-driven and sustainable in the long run. This integration will also provide incentives to the agro-processing industry as value-addition will be realised at various stages of the waste treatment processes. Socially, a number of benefits will accrue from this innovation. For example, treatment of agro-process wastewaters that are discharged into Lake Victoria would save the USD 800 million fish industry in the region (Abila et al., Unpublished data). The fish industry creates employment opportunities, mostly rural-based, thereby helping to reduce rural-urban migration. Fish is also a rich source of animal protein for human consumption and provides raw material (fishmeal) for processing animal feeds. The industry also contributes to GDP and has continued to be an important source of foreign exchange earned from fish exports. The safe discharge of agro-process effluents into the environment also protects the economically productive human population from waterborne related diseases. Besides the three primary impacts (production of energy, treatment of wastewater, use of nutrients/ reuse of water) the project has secondary impacts which cannot be underestimated/disregarded. The recovery of bio-energy from agro-process wastes reduces greenhouse gas emissions (Fantozzi and Buratti, 2009), contributes to domestic and industrial energy requirements, slows down the rate of deforestation for firewood and charcoal, and reduces indoor air pollution (IAP) and respiratory diseases since Biogas burns smoke free. This project will therefore contribute to the eradication of extreme poverty and hunger (MDG No. 1) by fostering nutrient recycling into agricultural production systems, reducing illness that leads to decreased human capital building and economic mobility and enhance economic opportunity by creating jobs in the biogas sector. The project will also address MDG No. 4 (Reduce child mortality) by combating chronic diarrheal and parasitic infections due to untreated agro-process wastes; and ensure environmental sustainability (MDG No. 7) reducing pressure on local forests and biodiversity in protected areas, restoring nutrients to soil, reducing greenhouse gas emissions to mitigate global climate change, and providing and/or conserving clean freshwater resources in the region.

6. Regional and international collaboration

Eastern Africa countries are faced with similar development challenges including inadequate energy supplies for domestic and industrial use; high population growth rate, environmental degradation and low agricultural productivity caused by climate change (ECA, 2008; ASARECA, 2009; Hawkins et al., 2009). In order to effectively address these challenges and use the little available resources efficiently, international/regional networking amongst expert scientists based at research institutions and private sector organizations in the region to develop and support appropriate technologies that mitigate climate change and avoid duplication of efforts is necessary. This project is collaborative in nature and involves scientists from Makerere University (Uganda) and Addis Ababa University (Ethiopia) with expertise in environmental biotechnology. The University of Dar Es Salam brings in engineers with technical experiences in constructed wetland technologies while AKUT Burkard and Partner (Germany, www.akut-umwelt.de) backstops project activities with technical skills in designing and installation of industrial scale biogas digester plants. Line ministries of Energy and Mines Development and national biogas associations in partner countries, NGOs such as Forum for Environment, Environment and Development Action (ENDA) in Ethiopia, AGENDA and ENVICON in Tanzania and SNV, HEIFER International Uganda (HIU), Centre for Research in Energy and Energy Conservation (CREEC) in Uganda shall be involved in the project to harness their experience, resources and facilities for dissemination of technologies and hence contribute to the success of the project.

7. Project goal and purpose

7.1 **Goal:** Contribute to climate change mitigation, environmental sustainability, and agricultural development in Eastern Africa through integrated waste management innovation systems

7.2 **Purpose:** Integrate agro-process wastewater treatment with biogas production and water reuse/nutrient recovery in Ethiopia, Tanzania and Uganda

8. Project specific objectives:

1) Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa by 2013
2) Develop and optimize innovative wastewater treatment processes integrating biogas production and water/nutrient reuse for enhanced industrial and agricultural productivity in Eastern Africa by 2013
3) Evaluate and disseminate the economic, environmental and social benefits of the integrated wastewater treatment bioprocesses by end of 2013

9. Project outputs

1) An environmental innovation consortium II strengthened and supported to generate and use technologies for sustainable management of agro-process wastewater in E. Africa by the end of 2013
2) Integrated and optimized bioprocesses comprising wastewater treatment, biogas production and water/nutrient reuse installed and operational by end of 2013
3) Cost-benefit analysis reports of the integrated bio-processes produced for the three project subcomponents by end of 2013
4) Environmental and social benefits analysis reports of the integrated bio-processes produced for the three project subcomponents by end of 2013

10. Project outcomes

1) Pollution levels in water discharges at pilot test sites of partner countries in E. Africa reduced by up to 80%.
2) Biogas recovery, water and nutrient reuse from agro-process wastewater enhanced by 80% at partner pilot sites in Eastern Africa
3) GHG emissions from agro-process wastewater at pilot test sites of partner countries reduced by 80%
4) Human and infrastructure resources to integrate and sustainably manage agro-process wastewater developed
5) Increased investment, subsidies and adoption of integrated agro-process wastewater treatment technologies realized in partner countries in E. Africa

11. Methodology and description of project activities

11.1 Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa

In order to strengthen capacity to sustainably manage agro-process wastewaters in Eastern Africa, expertise in waste management shall be drawn from within the region (Ethiopia, Tanzania and Uganda) and outside the region to form an Environmental Consortium. Scientists from Universities, Research and Development Institutions (e.g AKUT Burkard & Partner) and local "Business Development Service Providers (BDSP)", NGOs important for marketing the technology, and lead environmental protection agencies shall form this consortium. Training and dissemination workshops shall be conducted targeting wastewater treatment managers, national regulatory organs (NEMA- Uganda, NEMC- Tanzania and EPA-Ethiopia), Local Government Authorities (LGAs), local private companies and local "Business Development Service Providers (BDSP)" important for marketing the technology beyond the life of the project. In addition, training of two master students from National University of Rwanda shall strengthen their capacity to manage wastewaters in Rwanda.

11.2 *Develop and optimize innovative wastewater treatment processes integrating biogas production and water/nutrient reuse for enhanced industrial and agricultural productivity in Eastern Africa*

11.2.1 Development and optimization of biogas production in anaerobic digester plants receiving slaughterhouse, banana process and tannery wastewaters

Agro-process wastewaters (slaughterhouse, tannery and banana wine process wastewaters) contain high concentrations of soluble and insoluble biodegradable organic matter, which when properly treated can yield energy and slurry fertiliser. Therefore, special emphasis will be given to hydrolysis of organic matter since it is a rate-limiting step in anaerobic digestion of insoluble organic waste. To add value to agro-process wastewaters, anaerobic digesters/reactors with volumetric capacities of 500, 300 and 400 m^3, respectively will be designed and installed at City Abattoir-Uganda, Modjo Tannery-Ethiopia, and Banana Investments Ltd-Tanzania to produce biogas from the wastewaters. Using biogas from the digesters, the reactors will be heated and operated at mesophilic conditions to increase gas yields and process stability as well as enhance the COD/BOD removal. Maximal COD/BOD removal is necessary to ensure that pre-treated effluent discharged to hydroponic systems does not result into methane generation or limit biological nitrogen and phosphorus removal in aerobic/anoxic SBRs. To start-up the biogas digesters, reactors will be seeded with anaerobic sludge either from existing plants treating similar wastewaters or municipal wastewater treatment plants and batch-fed periodically with wastewater. This will progressively increase the organic loading rate for the reactors by augmenting the volume of wastewater fed to the system until the system stabilizes and gas production maximised. To optimize the operational conditions of the digester system, various hydraulic retention times and organic loading rates will be studied and their impact on biogas production assessed. The slurry from the digester shall be recovered, dewatered on sand filters and processed for soil fertility improvement while the gas will be collected and used for cooking and boiling activities at the agro-processing facilities. The digester effluents shall be further processed in hydroponic, sequencing batch reactor (SBR) and constructed wetland (CW) systems (Figure 1) prior to discharge into the environment or recycle/reuse by the industries. To avoid toxicity of Cr on biological systems in the biogas digester, a segregation system installed at Modjo Tannery which separates chromium rich effluent from the rest of tannery effluent shall be used to deliver Cr-free effluent into a sedimentation unit located upstream of the anaerobic digester. Chromium that might come into the sedimentation unit shall either be precipitated due to the high pH level of the effluent and/or adsorbed by the system and thus not available to microbial actions in the anaerobic digester system. The chrome-rich effluents shall be processed by Modjo tannery wastewater treatment plant. Because the slurry from the digester treating tannery effluent may contain Cr, it will not be used as fertilizer but rather recovered and landfilled while the gas will be collected and used for cooking and possibly electricity supply to the tannery.

11.2.2 Development and optimization of hydroponic systems producing agricultural products using pre-treated nutrient-rich slaughterhouse and banana process wastewater in Uganda and Tanzania, respectively.

In order to utilise rich nutrients in process wastewater for gainful agricultural productivity, a series of hydroponic systems receiving treated effluent will be installed in Uganda and Tanzania, and planted with selected grasses for animal feed, vegetable crops, and flowers capable of growing in floating conditions. Rafts/mats will used to support the plants as they draw nutrients from anaerobically and/or aerobically treated process wastewaters. Various hydraulic retention times and organic loading rates, and oxygen concentrations in the water column will be investigated in order to optimize the operational conditions of the hydroponic systems.

11.2.3 Integration and evaluation of anaerobic digesters–hydroponics systems and constructed wetlands for biogas production, nutrient recovery from wastewaters

To sustainably treat agro-process wastewaters with value-addition along the treatment chain, integration of anaerobic digestion with hydroponic systems, aerobic SBRs and constructed wetlands is necessary to efficiently reduce pollutants to acceptable discharge standards while generating income from biogas and agricultural production. Therefore, integrated treatment systems consisting of continuously stirred anaerobic digesters, hydroponic systems, aerobic SBRs and a constructed wetland unit (Figure 1) will be operated for the treatment of slaughterhouse, banana wine and tannery effluents in Uganda, Tanzania and Ethiopia, respectively. The optimised anaerobic digester will be

linked to a hydroponic system where selected plants (vegetables, flowers capable of thriving in high-nutrient wastewaters) will be grown under soilless floating conditions to remove nutrients from the digester effluent wastewater. The treated effluent from the hydroponic system will then be further treated in aerobic SBRs to remove residual carbon, nitrogen and phosphorus. The resultant nutrient-rich sludge shall be dried and used as soil conditioner while the treated effluent will further be polished in subsurface flow constructed wetland to remove the remaining nutrients before discharge or recycle of the effluent to the processing plants. The performance of the integrated bioprocess shall be evaluated based on reductions in COD, BOD, suspended solids, electrical conductivity, nutrients, sulphides, metals (for tannery wastewater) and bacteria according to standard methods (APHA, 1998). Effluent water quality, yield and quality of plants in hydroponic systems, and quantity and quality of biogas and sludge/slurry produced from anaerobic digesters shall also be measures of process performance, nutrient sequestration into plant tissues as well as value addition along the innovation chain. The constructed wetlands in Uganda and Ethiopia will be upgraded to cater for increased volumetric flows while Tanzania will construct a new

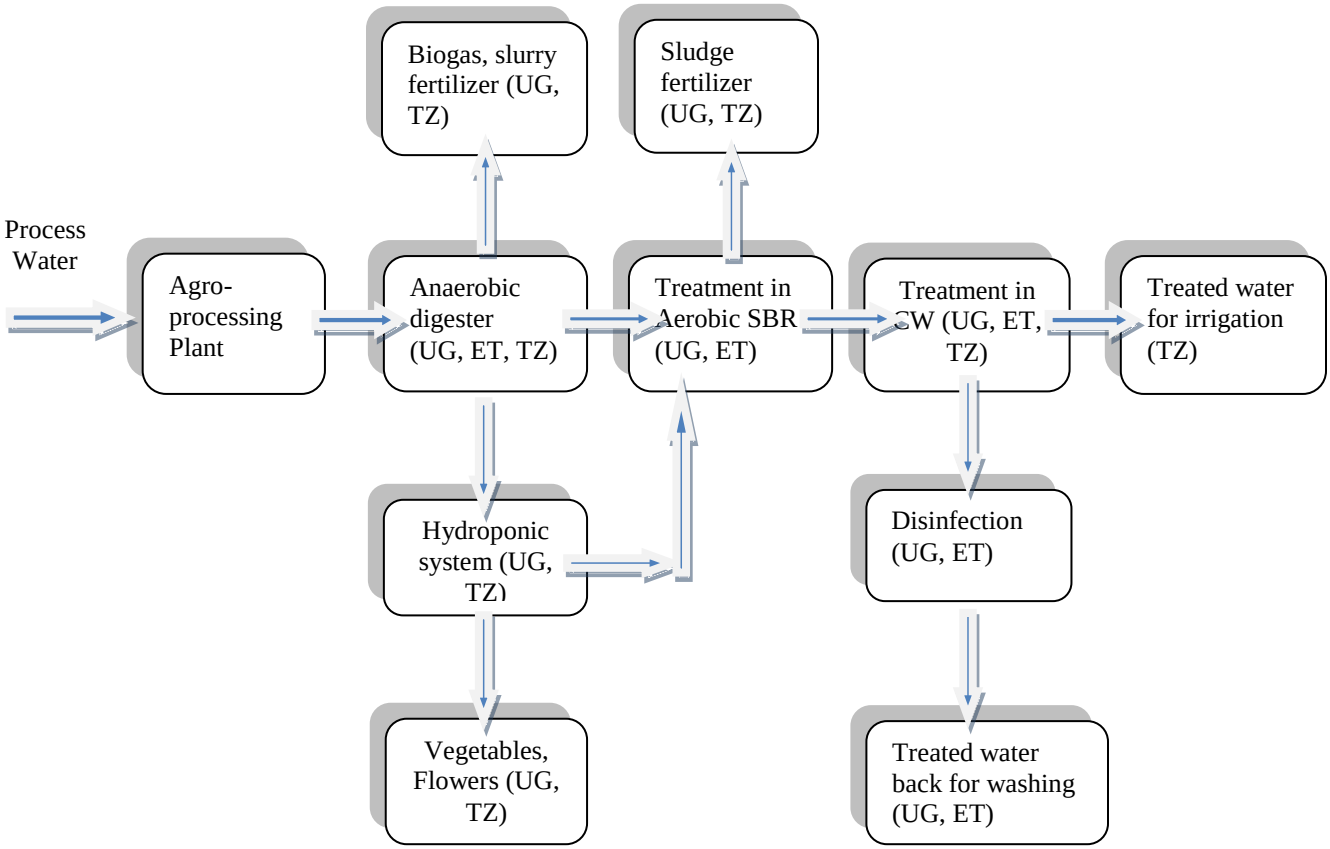

Figure 1: Process flow diagram showing innovation pathway and value addition to agro-process wastewater treatment. SBR: Sequencing batch reactor; CW: Constructed wetland; UG: Uganda; ET: Ethiopia; TZ: Tanzania

subsurface flow wetland. The constructed wetlands will be planted with selected plants with desirable traits such as high oxygen transfer capacity to the rhizosphere, high growth rate, and nutrient uptake and root development properties. The wetland design criteria for Tanzania shall be extrapolated from the banana wine process wastewater charactristics, macrophyte performance and the level of permissible national discharge standards. The impact of plant biomass harvesting on nutrient removal capacity of the wetland system and factors or mechanisms responsible for nutrient and bacterial removal from wastewater in the constructed wetlands will be elucidated during this project as described by Kyambadde (2005). In addition, mass balance studies will be conducted to elucidate the nutrient sinks

and the importance of the different steps/components in the integrated treatment process of agro-process waste so as to optimize the system treatment performance.

11.2.4 Determination of nutrient content of produced sludge from biogas digesters and SBRs and evaluation of its potential as a soil conditioner

Carbon, nitrogen and phosphorus are essential nutrients for plant growth. This activity will assess the potential of using the biogas digester slurry and sludge from aerobic SBR systems as a high nutrient organic fertilizer to increase overall crop yield and production, thereby augmenting income and restoring soil fertility in areas where soil degradation is prevalent. Organic carbon content will be determined after oxidizing dry powdered organic fertilizer with sulphuric acid and aqueous potassium dichromate mixture and subsequently titrating residual dichromate against ferrous ammonium sulphate (Nelson and Sommers, 1975). Nitrogen and phosphorus content will be determined as described by Mligo (2009). Sixteen plots will be demarcated and planted with selected local plants. Four of these will serve as controls without organic fertilizer added while 12 plots will be conditioned with the organic fertilizers from the treatment process and crop yields assessed over two growing seasons. The results shall be shuttled to NGOs and government agencies working in the agricultural sectors.

11.3 Evaluation and dissemination of the economic, environmental and social benefits of the integrated wastewater treatment bioprocesses

This activity is aimed at assessing economic, environmental and social benefits of the integrated wastewater treatment bioprocesses and consequently provide an advisory and enforcement tool to both regulatory agencies involved in environmental monitoring, and potential industries such as abattoirs, tanneries and banana processors, among others, generating the wastewaters as well as institutions (NWSCs) charged with wastewater management in the region. The report will also benefit financial institutions interested in funding waste management projects in the region. The economic (cost-benefit) analysis will among others include capital costing, fixed and variable operating costs, determining the modalities and delivery costs of getting the treated bio-fertilizers (sludge/slurry) and the generated biogas energy to end-users. Other costs involved in technology adoption/transfer and a critical analysis of financial parameters such as net present value (NPV) and internal rate of return (IRR) will also be considered during this assessment. An environmental and social benefits report will consider wood fuel conservation, GHG emissions, biogas as carbon neutral energy source, reversed soil degradation through slurry fertilizers, time and cost savings on wood fuel, cost savings on improved health conditions due to use of smoke free biogas energy etc. Therefore the findings of this activity will be shuttled to the local NGO's such as Forum for Environment, Environment and Development Action (ENDA) in Ethiopia, AGENDA and ENVICON in Tanzania, and SNV, HEIFER International Uganda (HIU), Centre for Research in Energy and Energy Conservation (CREEC) in Uganda for wider dissemination and technology adoption nationally, regionally and internationally.

12. Pathway to impact, applicability of the results in practice, potential impact and dissemination

The innovation pathway of the project shall involve digestion of the organic matter in wastewater to produce biogas. This biogas shall contain about 50% methane gas which is a green house gas (GHG) known to cause climate change. By capturing the biogas, there will be substantial reduction in its emission at project sites and therefore mitigating climate. This gas can be combusted to produce energy and CO_2, a gas which is less damaging to the environment than methane. The energy produced shall be used directly by the agro processing factory to supplement its energy requirements. For the Banana Investment Ltd a partner in this project the gas shall be replacing 75% of the wood they currently use in their processing. The biogas digester shall also give slurry that is reach in nutrients and this shall be processed to produce bio-fertilizers. The bio digester shall have also a liquid component that shall be treated in a Constructed Wetland in case of Banana Investments or in an SBR-Constructed Wetland combination in case of Modjo Tanneries and Kampala City Abattoir for further reduction of pollutants before the treated water is reused for agricultural activities.

In order to ensure successful uptake of the integrated bio process for agro process wastewater treatment, three level actors shall be involved at different stages of implementation. On the first level is the consortium partners/collaborators who shall be directly implementing the project. These partners are the research institutions (UDSM, MAK and AAU) responsible for technology development, the NGOs and the Agro-processing industries. The local NGO's such as Forum for Environment and Environment and Development Action (ENDA) in Ethiopia, AGENDA and ENVICON in Tanzania and SNV, HEIFER International Uganda (HIU), Centre for Research in Energy and Energy Conservation (CREEC) in Uganda shall be involved in the project to harness their experience, resources and facilities for dissemination and technology adoption and hence contribute to the success of the project. In the previous BIO EARN project, UDSM collaboration with ENVICON and AGENDA was very successful especially in working with the media, awareness raising and technology dissemination.

During construction phase, local private companies shall be involved in order to develop their capacities in design and construction of the integrated bio-process. They shall be the local "Business Development Service Providers (BDSP)" important for marketing the technology beyond the life of the project. The two entities (NGO, BDSPs) shall act as a link between the research and the end users of the integrated bio process.

On the second level are the policy organs namely the line ministries responsible for environment agriculture industry and energy. Similarly the national regulatory organs (NEMA- Uganda, NEMC- Tanzania and EPA-Ethiopia) and the Local Government Authorities (LGAs) shall be on this level. During execution of the project, these organs shall be informed of the project from inception and communication channels shall be established to have a formal exchange of information regarding the implementation of the project. Meeting involving the project partners/collaborators and these national organs shall be conducted at the inception of the project in the three countries.

On the third level are the technical skill institutions, other private business development service providers and financial institutions. These level actors shall be involved during the dissemination of project results and also during capacity building for design, construction operation and maintenance of the systems. This will be achieved through dissemination as well as training workshops.

Our project success plan draws on a partnership among multiple organizations with experience of working together on similar projects and with experts that will bring different experiences and expertise to build a strong foundation. In previous projects the University of Dar Es Salaam successfully collaborated with Makerere University of Uganda and Addis Ababa University in Ethiopia. Since completing the projects, members of the various institutions have maintained professional contacts, shared information about ongoing work, and explored other possibilities for collaboration. The University of Dar Es Salam brings in engineers with technical experiences in developing and implementing treatment technologies such as constructed wetland while AKUT Burkard and Partner (Germany, www.akut-umwelt.de) shall bring in technical skills in designing and installation of industrial scale biogas digester plants. AKUT Burkard and Partner (Germany) shall be responsible for planning, designing and overall supervision of biogas plant installation, start-up and operation while local construction firms shall be subcontracted to undertake construction activities of the biogas plants at the three partner industrial sites in the region.

Finally, all project activities will be in form of participatory decision-making arrangement and locally appropriate initiatives from within project teams and members and by seeking out local responses from participants and beneficiaries. This will not only ensure realization of desired outcomes but also enhance the likelihood of sustained community and policy engagement over the long term. With all these strategies and partnership in place, there is every reason to believe that the project will be successfully executed and results will help to achieve MDG's.

13. Quality and organization of the consortium

The partners in this consortium represent diversity of scientific disciplines and synergies. The lead partner Waste Stabilization Ponds (WSP) & Constructed Wetland Research and Development group based at University of Dar es Salaam has over 15 years of experience in research and application of constructed wetland technology for wastewater treatment. The group has built considerable expertise in the area of wastewater treatment and has placed itself as an authority in the area of Constructed wetland design in East Africa. The results achieved to date include development of holistic ecological model for the design of WSPs and a model for nutrient removal adopted by UNEP and the coupled model for wetland and ponds (Kayombo et al., 1999; Senzia et al., 2002; Kayombo et al,

2001; Mashauri and Kayombo, 2002; Njau et al., 2003 and Bilha, 2006). Considerable expertise has been built in utilization of integrated systems for improved effluent quality using both WSP and CW coupled to other wastewater treatment systems. The group has successfully introduced Constructed Wetland Technology for wastewater treatment to schools, prisons and colleges in Tanzania. Through various projects the group has managed to introduce the constructed wetland technology to Kenya (Shimo la Tewa Prison in Mombasa, Uganda (Kampala City Abattoir and Seeta High School wetland projects), Ethiopia (Modjo Tanneries) and Seychelles (Mahe). The group has also developed design, operation and maintenance manuals for constructed wetlands.

The WSP & Constructed Wetland Research and Development group shall also work with Dr. Innocent Mjema who is the Chief Biogas engineer with CAMARTEC, to provide biogas expertise. Dr. Mjema has been working on biogas systems since 2003, and has been involved in design, installation and quality control of biogas systems in Tanzania. Dr. Mjema has agreed to work with the proposed project.

The Department of Biochemistry, Makerere University in Uganda has over ten years research experience in environmental biotechnology and waste management. For the last 10 years, the Department has built capacity in monitoring and evaluation of environmental pollution, development and application of constructed wetland technology for domestic and industrial wastewaters, development and application of sequencing batch reactor technology for the treatment of high-strength agro-process wastewater, and characterization and determination of decay rate constants for municipal solid waste streams (Refer to CV of Co-PI, Uganda). The Department of Biochemistry together with WSP & Constructed Wetland Research and Development group installed a waste treatment system at City abattoir, Uganda with support from the Sida-funded BIO-EARN Programme. Being interdisciplinary, the department is also running a number of other projects addressing nutritional, diseases (malaria, sleeping sickness) and microbial enzyme technology with support from NUTRICIA, HarvestPlus, IAEA, AMANET and Bill & Melinda Gates Foundation among others. The Department of Biochemistry, Uganda shall lead the Uganda component of the proposed project and will be responsible for timely execution of project activities.

The Department of Biology and the school of graduate studies, Addis Ababa University in Ethiopia have research experiences in environmental biotechnology and waste management. For the last 10 years, they have built capacity in monitoring and evaluation of environmental pollution, development and application of sequencing batch reactors and constructed wetland technologies for treating industrial process wastewaters such as tannery effluents. The School of Graduate Studies, University of Addis Ababa shall be responsible for the execution of project activities in Ethiopia.

AKUT Burkard and Partner (Germany, www.akut-umwelt.de) have experiences in designing and installation of industrial scale biogas plants. Therefore, together with local engineering and construction firms, AKUT Burkard and Partner shall be responsible for planning; designing and installation of industrial scale biogas digester plants at partner industrial sites in this project (*see budgetary notes under 19.2*). AKUT Burkad and Partner shall undertake project activities after the tendering of system design and installation and shall utilize a budget line for this activity. The activity budget estimates reflected in this proposal have been provided by AKUT Burkad and Partner. The Department of Chemistry, National University of Rwanda shall provide two master students to undertake part of the project activities in order to build capacity in waste management in Rwanda.

Dr. K.N. Njau will be designated principle Investigator (PI) for the Project while Dr. Joseph Kyambadde and Dr. Mekibib David Dawit will assume the role of Co-PI in Uganda and Ethiopia, respectively. The PI shall be responsible for the overall project coordination and management, including liaison with BIO-INNOVATE and will be responsible for the ongoing staffing and monitoring of the Tanzanian team. The PI and Co-PIs will take responsibility for expenditures, reporting and accounting for all project component activities. Monthly team teleconferences will unite the entire key project participants to check on project progress in terms of the results based management expectations (expenses, reporting and logistics). The management structure to be put in place by WSP & CW research and development group at UDSM for the project will call upon systems and procedures used during the many projects completed in the past. The project will have a designated project administrator who is familiar with donor requirements and expectations, and who will ensure that all participants provide the information required to ensure proper fiscal management and management of resources. The structure will ensure that detailed project planning will be carried out jointly to ensure that the needs of all parties are met. Decision-

making will be collaborative, to the extent possible, recognizing the obligations and responsibilities to which all team members have agreed (**Table 1**).

14. Competence and skill track record of principal investigator

Dr. Njau, K.N-the Principal Investigator holds a Ph.D degree in Chemical Engineering from Technical University Eindhoven (TUE). During his 24 years as senior lecturer at the Chemical and Process Engineering, University of Dares Salaam (since 1986), Dr. Njau has supervised many research projects and published many papers in local and international journals. His main areas of research are Environment, Bio-fuels and Food Processing. His main area of expertise is reactor engineering. Dr Njau has also extensive international experience in water quality issues, Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP). He has worked extensively in the Lake Victoria basin on matters related to Lake Victoria Environment, also in the Zambezi River Basin on development of Integrated Water Resource Management (IWRM) Strategy. Dr. Njau has led several multinational teams working on consultancy and research issues. He was the Team leader for the Implementation Completion Report for the Lower Kihansi Environmental Management Project (LKEMP) and the Lake Victoria Environmental Management Project (LVEMP), a team leader for the Consultancy on Development of Applied Research Programme for Lake Victoria Basin. He was also a team leader for the team establishing Environmental Management System for Mtibwa Sugar Estates, Kigombe Sisal Estate and Karibu Textile Mill. He was the Chairman of a regional technical expert team (Kenya Uganda and Tanzania) for reviewing the World Bank funded project: Study on Toxic Chemical/oil products spill contingency plan for Lake Victoria. He was also the Chairman of a Regional Task Force (Kenya Uganda and Tanzania) overseeing the development of Lake Victoria basin Vision and Strategy Framework. Over the past 12 years Dr. Njau has extensively been involved in research and dissemination of Constructed Wetlands technology for wastewater treatment. He has supervised major constructed projects in Uganda, Tanzania, Kenya and Ethiopia and Seychelles where he participated in the planning, design, construction supervision, commissioning and monitoring of these wetland systems. Dr. Njau has published Design manual for Constructed wetlands (currently in print), Operations and Maintenance manual for constructed wetlands and Construction Instruction Manual for Constructed wetlands (currently in print)

Table 1: Collaborating Institutions, scientists and their roles

Research Institution and/or Partners	Responsible Person(s)	Expected Role
WSP & Constructed wetland Research Group, University of Dar es Salaam	Dr. K.N. Njau Eng. Prof. J. Katima Dr. Innocent Mjema Eng. Dr. W. Mwegoha	• Lead Partner for the Consortium and Principal Investigator (PI) • Overall Project Coordination and management • Liaison with BioInnovate Secretariat on behalf of the Consortium • Staffing and monitoring of activities in Tanzania • Coordinating project activities in Tanzania • Carrying out regional training on design, operation and maintenance of constructed wetland sys • Biogas system quality control • Procurement of project inputs,Production of manuscripts, Dissemination of project results
Department of Biochemistry Makerere University, Uganda & Department of Chemistry, National University of Rwanda	Dr. Joseph Kyambadde & Dr Nsengimana Hermogène Prof. F. Kansiime	• Co-Principle Investigators for Uganda & Rwanda, respectively • Coordination and management of activities in Uganda& Rwanda • Staffing and monitoring of activities in Uganda & Rwanda • Coordinating treatment systems start-up and monitoring in Tanzania, Uganda and Ethiopia • Procurement of project inputs • Production of manuscripts and supervision of MSc students, Dissemination of project outputs
Environmental Science Program Addis Ababa University Ethiopia & Department of Biology University of Addis Ababa, Ethiopia	Dr. D. D. Mekibib	• Co-Principle Investigator for Ethiopia component • Coordination and management of activities in Ethiopia • Staffing and monitoring of activities in Ethiopia • Procurement of project inputs • Production of manuscripts • Dissemination of project outputs
AKUT Burkard and Partner	Eng. Romas Radtke	• Designing and installation of anaerobic digesters in Uganda, Tanzania and Ethiopia
Agenda/ENVICON	Saada Juma Evody Ndumiwe	• Preparation of dissemination Plan for the Consortium • Carrying out dissemination activities in Tanzania
Centre for Research in Energy and Energy Conse-rvation (CREEC)		• Preparation of dissemination Plan for the Consortium • Carrying out dissemination activities in Uganda
Environment & Develop-ment Action (ENDA)		• Preparation of dissemination Plan for the Consortium • Carrying out dissemination activities in Ethiopia
City Abattoir, Uganda	Mr Mutebi Musisi	• Provision of experimental space, electricity, wastewater, and potential beneficiary of research outputs
Modjo Tannery		• Provision of experimental space, electricity, wastewater, and potential beneficiary of research outputs
NEMAs in Uganda, Ethiopia and Tanzania		• Dissemination of project outputs • Advising and persuading industrialists on the advantages of the developed technology based on the cost-benefit analysis report

Dr. K.N. Njau is the coordinator of WSP and Constructed Wetland Research and Development group which has been in existence since 2005 and has led the following major research projects:

1) Bio-EARN IF Project 8 "Transfer of Constructed Wetland Technology for Decentralized Wastewater Treatment" Sida/SAREC supported project. Status: Just completed.
2) Policy Innovation System for Cleaner Energy Security (PISCES) project working on Bio-energy access for rural areas. This is a five year DfID funded project which is ongoing (Assistant Coordinator).
3) Technology transfer in food and agro processing techniques: solar drying of fruits and vegetables. This is Rockefeller funded project which is ongoing
4) Peri-Urban Mangrove forests as potential phyto-remediators of Sewage in Eastern Africa (PUMPSEA). This was EU funded project involving 5 countries and 9 institutions. Status: Completed.

Referee: Prof Jamidu Katima, Principal, College of Engineering and Technology, University of Dar es Salaam, P.O. Box 35131, Dar es Salaam, Tanzania, Tel. +255 22 2410 753, Mobile: +255 754 265 864

15 Proposed consortium project management

15.1 Matching funds and commitment from host institution:

Banana Investments Ltd, Arusha, Tanzania has committed to contribute USD 150,000 to the project. Moreover the land for the proposed project has been set aside. Banana Investments shall also provide labour for the non-technical works such as site clearance and site security, utilities (water and power) at their cost during the execution of the project. Basajjabalaba Hides & Skins Co. Ltd (City Abattoir) has pledged to provide land for the construction of the proposed waste treatment system, gas and bio-fertilizer recovery, salaries for company staff and time to manage the proposed plants; security for project sites and other contributions as may be agreed with *BioInnovate programme.* Similar commitments have been pledged by Modjo Tanneries in Ethiopia. Modjo Tannery has pledged 300 m^2 land to be used by the project in addition to salaries for company staff and time to manage the proposed plants and security for project site.

15.2 Institutional support (letter of commitment):

The University of Dar es Salaam will contribute two Research Assistantships ($12000 each) and two work study students ($1 800 each) each year, as well as cash ($2000) and in kind ($13000) support for administration and communication. The UDSM shall also provide space for the UDSM team who are involved in the project, laboratory equipment and internet services for communications. The WSP & CW research Group based at UDSM as a lead institution and a core partner in Tanzania will designate Dr. K.N. Njau as the PI and Tanzanian team leader. The institution will grant infrastructure facilities including a vehicle estimated at $6,000 running costs per year.

Makerere University as project counterpart in Uganda will designate Dr. Kyambadde as Ugandan project coordinator. He will devote at least 50% of his available time for project coordination and execution. Department of Biochemistry, Makerere University (MAK), shall contribute to staff time and salaries and development of the technologies. Department of Biochemistry, Makerere University have strong research background in technologies related to wastes management. Some of the biotechnological equipment and consumables relevant to kick-start the proposed project were procured under BIO-EARN Programme. University staff trained under BIO-EARN programme will use their skills and time to execute the proposed project activities. Other forms of support to be provided by the institutions will include working space, internet services and administration of project funds. Infrastructure facilities are to be granted by Makerere University, estimated at $4000 per year. Dr. Kyambadde is also contributing one Research Assistant ($12,000), a work study student ($1800) and in kind support for administration ($1000).

The Addis Ababa University (AAU) as counterpart of the project in Ethiopia has designated Dr. Mekibib David Dawit as an Ethiopian team leader. He will devote at least 50% of his available time for project coordination and execution. Infrastructure facilities are to be granted by the University of Addis Ababa, estimated at $4000 per year. AAU will also contribute one Research Assistant ($12,000), a work study student ($1800) and in kind support for administration ($1000).

15.3 Monitoring and Evaluation, dissemination and communications plans:

Effective evaluation and monitoring of the results of the project are recognized as crucial to its success. Evaluation and monitoring components will be considered during the design of each project component to ensure that results are effectively and efficiently monitored and incorporated into further project design. With periodic review and redesign of future project elements, flexibility and resource reallocation may be necessary. Project results will be monitored on an ongoing basis using the performance indicators. The Tanzanian team based at the University of Dar es Salaam will be responsible for integrating all performance related data into a regularly updated performance measurement framework, identifying areas where performance needs to be improved, and disseminating this information to all members of the project team. The team visits to Uganda, Ethiopia and Tanzania for workshop will provide opportunities for face to face evaluation, decision making and reporting. These crucial meetings will permit important revisions to project components and plans and will provide for the significant mid-term and final evaluations. Feedback will be provided to project participants on several aspects of the project, including financial, schedule, technical and effectiveness at monthly teleconferences. Timelines and resources will be carefully monitored and regular reports will be issued to each participant tracking progress relative to the project plan. Technical materials developed by each team member will be reviewed by other team members and suggestions for clarification, correction or enhancement will be made and discussed amongst the team.

The main stakeholders in this project will be practitioners in the agro-processing sector, local government staff, central government staff at ministries and authorities related to agriculture, environment, industries, energy, climate change and waste management. Other stakeholders will be local farmers and graduate students. Moreover, the project is conceived in such a way that participants will act both as stakeholders and beneficiaries. To better communicate project outputs and results, there will be a series of training workshops and courses targeted at government staff (including planners, policy and decision makers as well as implementers), practitioners in the agro-processing sector, local farmers and graduate staffs. Project activities will also be accompanied by public engagement in the form of seminars at each University in partner country to publicize and engage the public, researchers, students and other relevant actors in the project work. Media work through the use of local and regional TVs, radios and newsletters will also be part of the communication plans. Finally, training and awareness materials to be developed i.e. brochures, flyers, posters, documentaries, manuals, reports, publications and books will also be used as vehicles to disseminate the project progress, outcomes and results to the wider community.

The PI and Co-PIs will meet once every year for purposes of planning and execution project activities as well as to review progress reports and project budgets. The Co-PIs will develop work plans and report their project activities to the PI on regular basis, and in particular submit progress reports every six months. The PI will report to *BioInnovate Africa* programme Manager

15.4 Intellectual property and other policy issues:

Each partner has an Intellectual property policy, and these will guide the IP issues. However, as a general rule, knowledge generated within the consortium will be property of the consortium. This does not automatically mean that all partners become the owner of the information generated by a single team or a limited number of teams. However, the aim is that all teams, for the duration of the project, should be able to use this knowledge for the scope of the project under the umbrella of the confidentiality agreement. In principle, the partner who is responsible for an invention will protect this knowledge by a patent application. In the case of joint inventions, all involved partners will be recognized as the inventors. If one of the teams does not intend to apply for a patent, the other inventors should have the first right to do this. In the case of granted patents, based on the results of the project, the other project partners should have the first right for taking a licence on the patent, if the inventor intends to licence the patent. If none of the consortium partners intends to patent an invention then the knowledge may be commercialized to third parties through the exploitation plan.

16. Milestones and time frame

1. An environmental innovation consortium II strengthened and supported to generate and use technologies for sustainable management of agro-process wastewater in E. Africa by 2013
2. Development and optimization of biogas production in anaerobic digester plants receiving wastewaters at partner agro-processing companies completed by 2012
3. Development and optimization of hydroponic systems producing agricultural products using pre-treated agro-process wastewaters completed by 2012
4. Integration and evaluation of anaerobic digesters–hydroponics systems and constructed wetlands for biogas production, nutrient recovery from wastewaters completed by 2013
5. Determination of nutrient content and potential application of sludge fertilizer from integrated bioprocess completed by 2013
6. Economic, environmental and social benefits report of the integrated wastewater treatment bioprocesses ready and disseminated by end of 2013

17. Indicators of progress towards results

17.1 Number of human resource with skills and knowledge to operate and maintain the integrated process in partner countries by 2014

17.2 At least three innovative integrated technologies encompassing wastewater treatment, biogas production and water/nutrient reuse installed and operational by end of 2013

17.3 Number of agro-processing industries, NWSCs, municipalities and regulatory agencies (NEMAs) and S&T Councils/Commissions in Eastern Africa using the economic, environmental and social benefits analysis reports increased by 2014

17.4 Number of financial institutions willing to fund waste management investments increased by 2014

18. Project Activity Plans

Activity	Time Line	Participating Institutions	Participating Scientists	Role(s)
1. *Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa* • Mobilization of inputs • Project planning meetings • Recruitment of staff & students	Jan – Jun 2011 Jan – Jun 2011 Jan – Jun 2011	• UDSM, Tanzania • MUK, Uganda • AAU, Ethiopia • City Abattoir • Modjo Tannery • Banana Investments Ltd	• Dr K.N. Njau • Dr. J. Kyambadde • Dr. D. D. Mekibib • Mr Mutebi Musisi • Mr. A.R. Olomi	• Coordinate activities in Tanzania • Coordinate activities in Uganda • Coordinate activities in Ethiopia • Coordinate activities at City Abattoir • Coordinate activities at Banana Investments Ltd
2.1 *Development and optimization of biogas production in anaerobic digester plants receiving slaughterhouse, banana process and tannery wastewaters* • Digester design • Installation • Start-up and Optimization	Jan – Jun 2011 Jan – Jun 2011 Jun – Dec 2011	• UDSM, Tanzania • MUK, Uganda • AAU, Ethiopia • City Abattoir • Modjo Tannery • Banana Investments Ltd • AKUT Burkad & Partner	• Dr K.N. Njau • Dr. J. Kyambadde • Dr. D. D. Mekibib • Mr Mutebi Musisi • Mr A.R. Olomi • Eng. Roma Radtke	• Coordinate activities in Tanzania • Coordinate activities in Uganda • Coordinate activities in Ethiopia • Coordinate activities at City Abattoir • Coordinate activities at Banana Investments Ltd • Coordinate digester design and installation in Uganda, Tanzania and Ethiopia
2.2 *Development and optimization of hydroponic systems producing agricultural products using pre-treated nutrient -rich slaughterhouse and banana process wastewater in Uganda and Tanzania, respectively* • Hydroponics design • Installation • Start-up and Optimization	Jan – Jun 2012 Jan – Jun 2012 Jun – Dec 2012	• UDSM, Tanzania • MUK, Uganda • AAU, Ethiopia • City Abattoir • Modjo Tannery • Banana Investments Ltd • AKUT Burkad & Partner	• Dr K.N. Njau • Dr. J. Kyambadde • Dr. D. D. Mekibib • Mr Mutebi Musisi • Mr A.R. Olomi • Eng. Roma Radtke	• Coordinate activities in Tanzania • Coordinate activities in Uganda • Coordinate activities in Ethiopia • Coordinate activities at City Abattoir • Coordinate activities at Banana Investments Ltd • Coordinate hydroponic systems design and installation in Uganda, Tanzania and Ethiopia
2.3 *Integration and evaluation of anaerobic digesters–hydroponics systems and constructed wetlands for biogas production, nutrient recovery from wastewaters* • System integration • Performance evaluation	Jan – Jun 2013 Jun – Dec 2013	• UDSM, Tanzania • MUK, Uganda • AAU, Ethiopia • City Abattoir • Modjo Tannery • Banana Investments Ltd • AKUT Burkad & Partner	• Dr K.N. Njau • Dr. J. Kyambadde • Dr. D. D. Mekibib • Mr Mutebi Musisi • Mr A.R. Olomi • Eng. Roma Radtke	• Coordinate activities in Tanzania • Coordinate activities in Uganda • Coordinate activities in Ethiopia • Coordinate activities at City Abattoir • Coordinate activities at Banana Investments Ltd • Coordinate integration of digesters, SBRs, hydroponics and CWs in Uganda, Tanzania and Ethiopia

2.4 *Determination of nutrient content of produced sludge from biogas digesters and SBRs and evaluation of its potential as a soil conditioner*	• Jun – Dec 2013	• UDSM, Tanzania • MUK, Uganda • AAU, Ethiopia	• Dr K.N. Njau • Dr. J. Kyambadde • Dr. D. D. Mekibib	• Coordinate activities in Tanzania • Coordinate activities in Uganda • Coordinate activities in Ethiopia
3. Evaluation and dissemination of the economic, environmental and social benefits of the integrate wastewater treatment bioprocesses	• Jun – Dec 2013	• UDSM, Tanzania • MUK, Uganda • AAU, Ethiopia • City Abattoir • Modjo Tannery • Banana Investments Ltd • AKUT Burkad & Partner • Agenda/ENVICON • CREEC • ENDA	• Dr K.N. Njau • Dr. J. Kyambadde • Dr. D. D. Mekibib • Mr Mutebi Musisi • Mr A.R. Olomi • Eng. Roma Radtke • Saada Juma • Evody Ndumiwe	• Coordinate activities in Tanzania • Coordinate activities in Uganda • Coordinate activities in Ethiopia • Participate in evaluation & dissemin-ation of technologies • Participate in evaluation & dissemin-ation of technologies • Carry out dissemination international • Carry out dissemination in Tanzania • Carry out dissemination in Uganda • Carry out dissemination in Ethiopia

19.2 Detailed budget for Environmental Innovation Project Consortium II (US Dollars for Three Years)

Activity	YEAR 2011 Budget Catagories	MAK	UDSM	AAU	Total
A	Equipment	-	240,000	18,000	258,000
B	Consumables	-	1,400	-	1,400
C	International Travel	4,800	-	4,400	9,200
D	Local Travel	12,780	12,499	13,500	38,779
E	Field Costs	135,200	13,528	105,100	253,828
F	Local training/dissemination workshops	4,000	4,800	4,000	12,800
G	Subsistence in EA	6,000	4,170	-	10,170
H	Tuition within the Region	6,350	15,300	-	21,650
I	Management/coordination Costs	9,900	2,000	9,900	21,800
J	Unforeseen	2,000	23,496	2,000	27,496
K	Overheads-(10%; 8%*; 5%)	18,103	(130,000)	7,845	(104,052)
	Total	**199,133**	**187,193**	**164,745**	**551,071**

Activity	YEAR 2012 Budget Catagories	MAK	UDSM	AAU	Total
A	Equipment	15,000	93,000	-	108,000
B	Consumables	10,000	14,000	10,000	34,000
C	International Travel	8,200	4,320	7,400	19,920
D	Local Travel	12,780	12,499	13,500	38,779
E	Field Costs	55,400	13,528	45,300	114,228
F	Local training/dissemination workshops	9,000	-	9,000	18,000
G	Subsistence in EA	12,000	-	-	12,000
H	Tuition within the Region	13,200	15,300	-	28,500
I	Management/coordination Costs	9,300	1,500	9,300	20,100
J	Unforeseen	1,500	12,332	1,500	15,332
K	Overheads-(10%; 8%*; 5%)	14,638	(10,000)	4,800	9,438
	Total	**161,018**	**156,479**	**100,800**	**418,297**

Activity	YEAR 2013 Budget Catagories	MAK	UDSM	AAU	Total
A	Equipment	-	-	-	-
B	Consumables	-	-	10,000	10,000
C	International Travel	7,600	4,320	7,400	19,320
D	Local Travel	12,780	12,499	13,500	38,779
E	Field Costs	27,400	13,528	24,400	65,328
F	Local training/dissemination workshops	10,000	9,530	10,000	29,530
G	Subsistence in EA	6,000	8,520	-	14,520
H	Tuition within the Region	6,850	15,300	-	22,150
I	Management/coordination Costs	9,300	1,500	9,300	20,100
J	Unforeseen	1,500	5,216	1,500	8,216
K	Overheads-(10%; 8%*; 5%)	8,143	(10,000)	3,805	1,948
	Total	**89,573**	**60,412**	**79,905**	**229,890**
	Total	**449,724**	**404,084**	**345,450**	**1,199,258**

Budget notes:

- [1]Student research and training include: tuition fees, functional fees, student stipend, accommodation, book allowance, publication and thesis write up.
  Average cost per year of 1 MSc Biochemistry International student is USD 13,850 (Makerere tuition fees USD 5,000; functional fees USD 350; Student stipend USD 3600; Student accommodation 2400; Books USD 1000, publications and thesis writing USD 1500).Year 1 cost of training the 2 MSc students is less by USD 2000 because thesis writing is done in Year 2. The 2 MSc students will be registered with Makerere University and fully trained under the supervision of the scientists shown in table 1 (Participating Institutions and their roles). MSc students will be recruited from the National University of Rwanda.

- [2]Inception meeting budgeted for in Year 1 (USD 5000) shall bring together stakeholders and partners in waste management

- [3] Biogas digester system design, construction and training of digester operators shall involves designing of Biogas plant (set of technical drawings and technical description), evaluation of tender documents

- [4] Minor equipment such as pH meters, gas blowers & meters, and laptop computers for student use etc shall be bought under this project during year 2 when digester system is ready for monitoring and students ready to start collecting data.
- [5]Consumables such as chemicals and reagents, glassware are needed for analysis of water and slurry samples to evaluate system treatment performance and nutrient content of sludge samples
- [6]Field work costs shall include per diem for research scientists, student supervision allowances, extra (casual) labour costs during monitoring and evaluation of the integrated treatment systems, and other activities that may require extra technical support e.g laboratory analyses at Eastern Africa Institutions.
  - Salaries for participating scientists are covered by the host institutions, and are therefore not included in this budget.
- [7]Local travel includes costs for fuel and vehicle hire (maintenance) to the project sites
- [8]International travel costs include costs for airfare to attend meetings/workshops/conferences and per Diem. It also includes return travel costs for the international MSc students to be trained at Makerere University
- [9]Commissioning of the integrated agro-process waste treatment facility is essential to share experiences with potential industrialists that will adopt the developed technologies as well as policy makers that facilitate technology adoption and policy enforcement
- [10]Coordination costs include costs to be incurred by the PI and Co-PIs such as stationery, communication, organising local planning meetings/workshops, ICT equipment etc
- [11]Insititutional overhead costs (10%) for Makerere are required as a matter of policy. The policy requires 15% but this drains the budget and affects the operations of the project. Therefore, it has been reduced to 10%.
- [12]Economic, [13]Environmental, social and benefits analyses studies shall be conducted in Year 3 (see 18: Project Activity Plans above) after installation and evaluation of integrated agro-process waste treatment process, and study reports/findings disseminated in Year 3. This activity shall be contracted to competent organizations/individuals and estimated to cost USD 10,000 for studies and USD 10,000 for [14]dissemination of study findings.

19.3 Detailed Budget for Department of Biochemistry, Makerere University, UGANDA

Department of Biochemistry, Makerere University, UGANDA				
Project Activity	**Budget cost elements**	**Year 1 (2011)**	**Year 2 (2012)**	**Year 3 (2013)**
2. Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa	• [1]Student training (2 MScs)	12,350	25,200	12,850
3. Develop and optimize innovative wastewater treatment processes integrating biogas production and water/nutrient reuse for enhanced industrial and agricultural productivity in Eastern Africa	• [2]Stakeholders inception planning meeting	5,000	0	0
	• [3]System design and construction			
	• [4]Equipment			
	• [5]Consumables	130,000	41,000	0
	• [6]Field work expenses			
	• [7]Local travel	0	15,000	0
	• [8]International travel	0	10,000	0
	• [9]Commissioning workshop	15,760	20,000	15,000
	• [10]Coordination (6%)	6,000	10,000	8,000
	• [11]Institutional overhead costs (10%)	5,000	8,400	7,000
	• Unforeseen	0	5000	0
				0
		10,000	9,000	9,080
		20,600	17,700	6,660
		2,000	1,500	1,500
4. Evaluation and dissemination of the economic, environmental and social benefits of the integrated wastewater treatment bioprocesses	• [12]Economic benefits analysis	0	0	5,000
	• [13]Environmental & social benefits analysis			
	• [14]Dissemination of analyses reports	0	0	5,000
		0	0	10,000
Sub-Total		**206,710**	**162,800**	**80,090**

Budget notes:

- [1]Student research and training include: tuition fees, functional fees, student stipend, accommodation, book allowance, publication and thesis write up.

Average cost per year of 1 MSc Biochemistry International student is USD 13,850 (Makerere tuition fees USD 5,000; functional fees USD 350; Student stipend USD 3600; Student accommodation 2400; Books USD 1000, publications and thesis writing USD 1500).Year 1 cost of training the 2 MSc students is less by USD 2000 because thesis writing is done in Year 2. The 2 MSc students will be registered with Makerere University and fully trained under the supervision of the scientists shown in table 1 (Participating Institutions and their roles). MSc students will be recruited from the National University of Rwanda.

- [2]Stakeholders inception planning meeting budgeted for in Year 1 (USD 5000) shall bring together stakeholders in waste management (i.e Research scientists, NEMA, NWSC, Kampala City Council, Directorate of Water Development, Industrialists (City Abattoir etc), NGOs involved in waste transformation and technology dissemination and UNCST) so that project activities and technology developments can be embraced and in the long run adopted by industrialists and also enforced by policy makers (NEMA and DWD).

- [3] Biogas digester system design, construction and training of digester operators is estimated to cost USD 130,000. This activity involves designing of Biogas plant (set of technical drawings and technical description), evaluation of tender documents (USD13, 000); Supervision of construction works that are to be done by local construction firm (USD 13,000); construction of Biogas plant by sub-contracted local construction firm (purchase of materials e.g feeder, pump, pipes, valves, concrete, membrane, import of selected material, labour costs, permission and approval if required; USD 100,000); and training of biogas plant operators (instructional manual, training on site, USD 4,000).

- Year 2 (2012) system design and construction involves designing of hydroponic systems and upgrading of constructed wetland (set of technical drawings and technical description), evaluation of tender documents (USD 3,000); and supervision of construction works undertaken by local construction firm (USD 5,000); Training of operators (instructional manual, training on site; USD 3,000); Construction of hydroponic systems and upgrading of constructed wetland by local construction firm (purchase of materials e.g pipes, valves, concrete, import of selected material, labour cost, permission and approval, USD 30,000). This totals to USD 41,000.

- [4] Minor equipment such as pH meters, gas blowers & meters, and laptop computers for student use etc shall be bought under this project during year 2 when digester system is ready for monitoring and students ready to start collecting data. It will cost USD 15,000
- [5]Consumables such as chemicals and reagents, glassware are needed for analysis of water and slurry samples to evaluate system treatment performance and nutrient content of sludge samples, respectively and are budgeted at USD 10,000 in year 2 when digester is ready for monitoring
- [6]Field work costs shall include per diem for research scientists, student supervision allowances, extra (casual) labour costs during monitoring and evaluation of the integrated treatment systems, and other activities that may require extra technical support e.g laboratory analyses at Eastern Africa Institutions.
    - Salaries for participating scientists are covered by the host institutions, and are therefore not included in this budget.
- [7]Local travel includes costs for fuel and vehicle hire (maintenance) to the project sites
- [8]International travel costs include costs for airfare to attend meetings/workshops/conferences and per Diem. It also includes return travel costs for the international MSc students to be trained at Makerere University
- [9]Commissioning of the integrated agro-process waste treatment facility is essential to share experiences with potential industrialists that will adopt the developed technologies as well as policy makers that facilitate technology adoption and policy enforcement
- [10]Coordination costs (6%) include costs to be incurred by the PI and Co-PIs such as stationery, communication, organising local planning meetings/workshops, ICT equipment etc
- [11]Insititutional overhead costs (10%) for Makerere are required as a matter of policy. The policy requires 15% but this drains the budget and affects the operations of the project. Therefore, it has been reduced to 10%.
- [12]Economic, [13]Environmental, social and benefits analyses studies shall be conducted in Year 3 (see 18: Project Activity Plans above) after installation and evaluation of integrated agro-process waste treatment process, and study reports/findings disseminated in Year 3. This activity shall be contracted to competent organizations/individuals and estimated to cost USD 10,000 for studies and USD 10,000 for [14]dissemination of study findings.

19.4 Detailed Budget for Environmental Science Program, & Department of Biology, Addis Ababa University, ETHIOPIA

Integrated process for sustainable agro-process waste treatment and climate change mitigation in Eastern Africa		**Applying institution**		
		Environmental Science Program, College of Natural Sciences, Addis Ababa University		
Project Activity	**Budget cost elements**	**Year 1 (2011)**	**Year 2 (2012)**	**Year 3 (2013)**
1. Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa	[1]Student training (PhD)	0	0	0
2. Develop and optimize innovative wastewater treatment processes integrating biogas production and water/nutrient reuse for enhanced industrial and agricultural productivity in Eastern Africa	• System design and construction	**80,000**[2]	**60,000**[3]	0
	• Equipment *GC/ Gas monitors* *BOD sensor* *Pumps*	**18,000** *15000* *1000* *2000*	0	0
	• Consumables	**10,000**	**10,000**	
	Reagents for physicochemical analysis	*8000*	*8000*	
	Protective wear	*2000*	*2000*	
	• Field work costs	**20,000**	**20,000**	**8,000**

[1]Student research and training tuition fees, student stipend and accommodation are covered by AAU; however other expenses are included in both local and international travel, field work and consumables

[2] For design: 15,000 and construction, Phase I: 65,000

[3] Completion of construction, Phase II and start up, 60,000

- Extra labour will be required during field work activities of the integrated treatment systems, and other activities that may require extra technical support at Eastern Africa Institutions.
- Salaries for participating scientists are covered by the host institutions, and are therefore not included in this budget.

	For PhD student *For CO PI and other team members* • Local travel *For PhD student* *For CO PI and other team members* • Coordination • Planning/dissemination workshops • International travel *For PhD student* *For CO PI and other team members* • Unforeseen	*15,000* *5000* **5,000** *3000* *2000* **9,000** **5,000** **5000** *2000* *3000* 2000	*15,000* *5,000* **10,000** 7000 3000 **14,000** **5,000** **15,000** *6000* *4500* 1,500	*6000* *2000* **10,000** *7000* *3000* **14,000** 0 **11,500** *6500* *5000* 1,500
3. Evaluation and dissemination of the economic, environmental and social benefits of the integrated wastewater treatment bioprocesses	• Economic, Environmental & social benefits analysis • Dissemination workshops	**5,000** 0	0 0	**5,000** **10,000**
	Total	159,000	129,500	57,500
Less direct financial support		0	0	0
Total request from Sida		159,000	129,500	57,500
Grand Total request from Sida				**346,000**

19.5 Detailed Budget for WSP & Constructed wetland Research Group, University of Dar es Salaam, TANZANIA

	Budget Element	Details	2011	2012	2013
1. Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa	Student training		**0**	**0**	**0**
2. Develop and optimize innovative wastewater treatment processes integrating biogas production and water/nutrient reuse for enhanced industrial and agricultural productivity in Eastern Africa	System design and construction	preliminary treatment system (Screen and grit chamber, and primary clarifier), Biogas system (buffer tank, bio-digester, Gas holder)	110,000	0	0
		Civil construction	60,000	0	0
		Horizontal subsurface flow constructed wetland	70,000		0
		Biogas boiler and gas holder	0	78,000	0
		Irrigation system and sludge processing	0	15,000	0
	Equipment	Laboratory equipment		14,000	0
		Computer	1400	0	0
	Consumables	Laboratory analysis (120 USD/sample x 72 samples)	0	4,320	4,320
		Stationery and office equipment	1,000	1,000	1,000
	Field costs	Per Diem for researchers (75 USD/day x 100 man-days/year)	7,500	7,500	7,500
		Field supervision fees (resident engineer)	12,000	12,000	7,000
	Local Travel	Field transport	7,500	7,500	7,500
	Coordination	Cost of PI for stationery, communication, organising project meetings, preparation of progress reports, etc	8,000	13,000	13,000
	International Travel		5,000	5,000	5,000
3. Evaluation and dissemination of the economic, environmental and social benefits of the integrated wastewater treatment bioprocesses	Economic, Environmental & social benefits analysis		5,000	0	10000
	Dissemination workshop		0	0	10,000
	Unforeseen		1,000	1,000	1,000
	Institutional fee (8%)		**23,072**	**12,666**	**5,306**
	Total		**311,472**	**170,986**	**71,626**
	Less direct financial support		130,000	10,000	10,000
	Total request from Sida		**181,472**	**160,986**	**61,626**

20. Log frame Analysis for the Environmental Innovation Consortium II Project

Title of consortium Project: **Integrated process for sustainable agro-process waste treatment and climate change mitigation in Eastern Africa**

Project Goal: Contribute to climate change mitigation, environmental sustainability, and agricultural development in Eastern Africa through integrated waste management innovation systems

Output	**Outcome**	**Performance Indicator of Outcome**	**Data Source**	**Collection Method**	**Assumptions - Assessment of Progress/Achievements**
Project specific objectives					
Objective # 1: Strengthen capacity to sustainably manage agro-process wastewater in Eastern Africa by 2013					
1.1 An environmental innovation consortium II strengthened and supported to generate and use technologies for sustainable management of agro-process wastewater in E. Africa	• Human and infrastructure resources to integrate and sustainably manage agro-process wastewater developed • Innovative integrated processes developed and operational in 3 Eastern Africa countries	• Number of human resource with skills and knowledge to operate and maintain the integrated process in partner countries by the end of 2013 • At least three innovative integrated technologies developed and operational by 2013	Program reports Project reports User/training manuals	Project reviews	• Partner companies in the region remain operational during the project life • Stakeholders remain committed to project activities • Donor/matching funds are available • Political stability
Objective # 2: Develop and optimize innovative wastewater treatment processes integrating biogas production and water/nutrient reuse for enhanced industrial and agricultural productivity in Eastern Africa by 2013					
2.1 Integrated and optimized bioprocesses comprising wastewater treatment, biogas production and water/nutrient reuse installed and operational in Eastern Africa	• Pollution levels in water discharges at pilot test sites of partner countries in E. Africa reduced by up to 80%. • GHG emissions from agro-process wastewater at pilot test sites of partner countries • Biogas recovery, water and nutrient reuse from agro-process wastewater enhanced by 80% at partner pilot	• At least three integrated technologies installed lead to 90% decrease in pollution by 2013 at partner agro-processing locations in Eastern Africa	• Program reports	Commissioning report	• Partner companies in the Region remain operational during the project life • Stakeholders remain committed to project activities • Donor/matching funds are available • Stable political environment

	sites in Eastern Africa • Biogas usage from agro-process wastewater enhanced by 80% at partner pilot sites in Eastern Africa				
Objective # 3: Evaluate and disseminate the economic, environmental and social benefits of the integrated wastewater treatment bioprocesses by end of 2013					
3.1 Cost-benefit analysis reports of the integrated bioprocesses for the three project subcomponents produced	• Increased investment, subsidies and adoption of integrated agro-process wastewater treatment technologies in partner countries in E. Africa	• Number of agro-processing industries, NWSCs, municipalities and regulatory agencies (NEMAs) and S&T Councils/Commissions in Eastern Africa using the report increases by 2014 • Number of financial institutions willing to fund waste management investments	• Program and project reports • Economic development statistics	• Project review	• Partner companies in the Region remain operational during the project life • Stakeholders remain committed to project activities • Donor/matching funds are available • Stable political environment
3.2 Environmental and social benefits analysis reports of the integrated bioprocesses for the three project subcomponents produced	• Integrated agro-process wastewater treatment technology adoption enhanced by 10% in partner countries in E. Africa by 2015 • Funding for integrated waste management in Eastern Africa increased by 5% per annum by 2015	• Number of industries and environmental regulatory agencies (NEMAs) using the report by 2015 • Number of financial institutions willing to fund waste management investments	• Program and project reports • Economic development statistics	Project reviews	• Partner companies in the Region remain operational during the project life • Stakeholders remain committed to project activities • Donor/matching funds are available • Stable political environment

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APPENDICES
A1. CVs of the Consortium Leadership
A1.1 CURRICULUM VITAE: KAROLI NICHOLAS NJAU

Name of Staff:	Karoli N. NJAU
Profession:	Environmental Engineer
Date of Birth:	4 November 1958
Nationality:	Tanzanian

Membership in Professional Societies:
Board Member – College of Natural and Applied Sciences (CoNAS)

Key Qualifications:

Dr. Njau holds a Ph.D. degree in Chemical Engineering. During his 19 years as lecturer with the Chemical and Process Engineering University, Dr. Njau has supervised many projects and published many papers in local and international journals. His main areas of research are Environment, Bio-fuels and Food Processing. His main area of expertise is in Reactor Design. Dr Njau has also extensive international experience in water quality issues, Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP). He has worked extensively in the Lake Victoria basin on matters related to Lake Victoria Environment, also in the Zambezi River Basin on development of Integrated Water Resource Management (IWRM) Strategy.

Dr. Njau has led several teams working on consultancy and research issues. He was the Team leader for the Implementation Completion Report for the Lower Kihansi Environmental Management Project (LKEMP) and the Lake Victoria Environmental Management Project (LVEMP), a team leader for the Consultancy on Development of Applied Research Programme for Lake Victoria Basin. He is also a team leader for the team establishing Environmental management system for Mtibwa Sugar Estates, Kigombe Sisal Estate and Karibu Textile Mill. He was the Chairman of a regional technical expert team (Kenya Uganda and Tanzania) for reviewing the World Bank funded project: Study on Toxic Chemical/oil products spill contingency plan for Lake Victoria. He was also the Chairman of a regional Task Force (Kenya Uganda and Tanzania) overseeing the development of Lake Victoria basin Vision and Strategy Framework. Over the past 8 years Dr. Njau has extensively been involved in the research in Constructed Wetlands for pollution control. He has supervised four major Constructed Wetlands Projects in Tanzania, Kenya, Uganda, Ethiopia and Seychelles where he participated in the planning, design, construction supervision, commissioning and monitoring of wetland systems. Dr. Njau has been leading the following research projects: Transfer of Constructed Wetland for Decentralized wastewater treatment; Peri-Urban Mangrove forest as potential Phyto-remediators of domestic Sewage in East Africa (PUMPSEA).

Education:

- PHD, Environmental Engineering–Topic of research: Electrochemical Treatment of Process Water from
- Galvanic Industry - University of Technology, Eindhoven, The Netherlands (1998).
- MSc. (Chemical Engineering)-Norwegian Institute of Technology (NTH) Trondheim, Norway (1987).
- BSc. (Process Engineering)- University of Dar es Salaam, Tanzania (1984)

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5. K.N. Njau, W. Mwegoha and Anesi Mahenge “Operations and Maintenance Manual for Constructed Wetlands ISBN: 978-9976-60-508-2”, Dare es Salaam University Press (DUP), 2010
6. K.N. Njau, N.Chacha and S. Pamba “Construction Instruction Manual for Constructed Wetlands” The manual is currently in print by Dare es Salaam University Press (DUP)

A1.2 CURRICULUM VITAE: JOSEPH KYAMBADDE– Co-PI UGANDA

BSc., MSc (Makerere University); PhD (Royal Institute of Technology – KTH, Stockholm)

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Research Interest/Specialization: Environmental Microbiology and Biotechnology

Academic Leadership: 2007 todate: Head, Department of Biochemistry, Makerere University

Current Research Activities:

July 2006- June 2010: Collaborating Scientist BIO-EARN Project 3, entitled “*Development of Efficient Technologies for the Sustainable Treatment of High Strength Wastewater in Eastern Africa*”, a project sponsored by SIDA/SAREC. Under this project we have set up a pilot scale integrated bioprocess comprising of anaerobic-aerobic sequencing batch reactors and constructed wetland treatment system treating slaughterhouse wastewater onsite at City Abattoir, Kampala.

Selected publications

1. Kyambadde, J., (2005). Optimizing processes for biological nitrogen removal in Nakivubo wetland, Uganda. PhD Thesis, Universitetsservice US AB, Royal Institute of Technology (KTH), Stockholm, Sweden, ISBN: 91-7283-962-7
2. Gumaelius, L., Kyambadde, J., Dalhammar, G., (2001). Variation in Cadmium and dichlorophenol (DCP) toxicity and lack of genetic correlation between inhibition and toxicity among efficient denitrifying bacteria in activated sludge. PhD Dissertation ISBN: 91-7283-097-2
3. Kyambadde J., Kansiime F., Dalhammar G., (2006). Distribution and activity of ammoniumoxidizing bacteria in Nakivubo wastewater channel and wastewater treatment wetland, Uganda. *Acta Hydrochimica et Hydrobiologica* 34 (1–2): 137–145.
4. Kyambadde J., Kansiime F., Dalhammar G., (2005). Nitrogen and phosphorus removal in substrate-free pilot constructed wetlands with horizontal surface flow in Uganda. *Water, Air, and Soil Pollution* 165(1–4):37–59.
5. Kyambadde J., Kansiime F., Gumaelius, L., Dalhammar G., (2004). Hydraulic loading, stability and water quality of Nakivubo wetland, Uganda. *African Journal of Aquatic Science* 29(2):213–220.
6. Kyambadde J., Kansiime F., Gumaelius, L., Dalhammar G., (2004). A Comparative study of Cyperus papyrus and Miscanthidium violaceum-based constructed wetlands for wastewater reatment in a tropical climate. *Water Research* 38(2):475–485.
7. Kyambadde J., Hawumba JF., Nyanzi SA., (2006). Municipal Solid Waste Composition and Decay Rate Constants. Study of Discards in Ten Municipalities of Uganda. Report Submitted to National Environment Management Authority, Kampala, Uganda.

A1.3 CURRICULUM VITAE: MEKIBIB DAVID DAWIT – Co-PI ETHIOPIA

Personal

Name: Mekibib David Dawit
Date of Birth: 17- 06 -1970
Nationality: British
Address: Environmental Science Programme, College of Natural Sciences, Addis Ababa University, P O Box 1176, Addis Ababa, Ethiopia
Telephone: Tel. +251 (0) 116551910 (work); 251(0) 913727786 (mobile)
E-mail: mekibib1@hotmail.com

Qualifications:

PhD: - Biogeochemistry of organic nitrogen in inter-tidal sediments. Middlesex University, July 2007.
MSc. (with Merit) -Integrated Pollution Control: - Middlesex University, London, Feb 2000.
Bachelor of Science degree in Chemistry: - AAU, July 1990.

Research projects undertaken

1. Analysis of PAHs, TPH and VOCs in soil and water samples from the Olympic Park site in Stratford using GC and GC-MS; 2007-2008.
2. Identification and characterisation of *allelopathic* semio-chemicals in a variety of wheat seedlings; 2003-2005.
3. Characterisation of climate induced organic nitrogen mineralisation in benthic sediments, Middlesex University; 2000 - 2003.
4. Development of novel ion-selective electrodes using liquid crystal materials,
5. Kingston University, London; 1995 - 1996.
6. Characterisation of flavonoids from indigenous plants in Ethiopia, NAPRECA, Addis Ababa University; 1989-1990.

Selected publications

1. Fitzsimons M.F., Millward G.E., Revitt D.M. and Dawit M.D (2006). Desorption kinetics of ammonium and methylamines from estuarine sediments: Consequences for the cycling of nitrogen. *Mar. Chem.,* **1:** 12-26.
2. Fitzsimons M.F., Dawit M.D., Revitt D.M. and Rocha C.S (2005). A study of the effects of early tidal inundation on the cycling of methylamines in inter-tidal sediments. *Mar. Ecol. Prog. Ser.,* **294:** 51-61.
3. Dawit M., Williams I.D. and Fitzsimons M.F. (2001) Determination of 1-aminopropan-2-one, a dissolved sewage component, in water samples, *Water Res.,* **35:** 1151-1156.
4. Fitzsimons M.F., Kamhi-Danon B. and Dawit M. (2001). Distributions and adsorption of the methylamines in the inter-tidal sediments of an East Anglian estuary. *Env. Exp. Bot.,* **46:** 225-236.
5. Dawit M. and Fitzsimons M.F. An improved method for the determination of aliphatic amines in marine sediments (In preparation).
6. Fitzsimons M.F., Dawit M.D. and Revitt D.M. Organic nitrogen release from resuspended sediments in the Thames Estuary (in preparation).

A1.4 CURRICULUM VITAE: HERMOGÈNE NSENGIMANA, PhD

Nationality: Rwandese
Date of Birth: 25 Dec 1974
Cellphone: +25008416745
E-mail: nhermo@yahoo.fr, nhermo@gmail.com, hnsengimana@nur.ac.rw

PROFESSIONAL EXPERIENCE

Currently: Vice Dean in Charge of Research, Consultancy and Postgraduate Studies

	Senior Lecturer, National University of Rwanda, Faculty of Science, Chemistry Department
October 2007:	President of PHI (Programme hydrologique international) in Rwanda
June 2007:	December 2007: Postdoctoral fellow at the Witwatersrand University-Johannesburg (South Africa): Method development for mercury speciation.
June 2003 – Dec. 2006:	Tutor and Demonstrator (Wits University)
2002 - to date:	Member of Environmental research group at National University of Rwanda
2001 – 2002:	Attaché of the RADMASTE center (Wits University): Microscience program in Rwanda.
1999-2000:	Faculty of Science- NUR Student representative and secretary of BCCR-AGEUNR

FORMATION

1995-2000:	Licence– Physical Chemistry (National University of Rwanda). Dissertation : Contribution aux paramètres physico-chimiques des Eaux du bassin du Nil et du Congo au Rwanda.
2003 – 2007:	(graduated 27 June 2007): PhD in Analytical and environmental chemistry (University of the Witwatersrand). My thesis was entitled ***Speciation of Organometallic of tin, lead and mercury in environmental samples***

Languages:	Fluent in French, English, Swahili, Kinyarwanda

Selected Publications

1. Ewa Cukrowska, Luke Chimuka, Hermogène Nsengimana, Valerie Kwaramba, Application of supported liquid membrane probe method for Extraction and preconcentration of organotin compounds in Environmental water sample, *Analytica Chimica Acta* 523 (2004) 141 – 147
2. Hermogène Nsengimana, Ewa M Cukrowska, Andy Dinsmore, Luke Chimuka Speciation of alkyllead in aqueous samples with Application of Supported Liquid Membrane Probe for extraction and preconcentration, *Journal of Separation Science*, 30(16), 2007,2754-9
3. Erasmus Chauke, Ewa Cukrowska, Mary-Jane Thaela, Luke Chimuka, Hermogene Nsengimana, Hlanganani Tutu, Fatty acids composition in South African fresh water fish as indicators of food quality for human consumption, *Water SA*, 2008, vol. 34, no1, pp. 119-125
4. E. M. Cukrowska , H. Nsengimana, J. Lusilao-Makiese, H Tutu and D. Amouroux, E. Tessier: Mercury and tin speciation in the environment affected by old tailings dumps in the Central Rand, Johannesburg, South Africa, Proceedings of Mine Closure 2008, Johannesburg, SA, pp 673-676.

A2. Letter of commitment – University of Dar es Salaam

UNIVERSITY OF DAR ES SALAAM

DIRECTORATE OF RESEARCH

P.O. Box 35091 ■ DAR ES SALAAM ■ TANZANIA

***Tel**: 2410500-8 Ext. 2087,2077,*
2410743, 2410727
***Mobile:** 0754 270789*
0784 767247

Fax: 255 022 2410743
255 022 2410 023
***e-mail:** research@udsm.ac.tz*

Ref. No AB3/31

28th September, 2010

The Programme Manager,
Bioresouces Innovations Network for Eastern Africa
Development (BioInnovate),
C/o ILRI,
P. O. Box 30709,
Nairobi 00100,
KENYA.

Re: COMMITMENT OF THE UNIVERSITY OF DAR ES SALAAM TO SUPPORT BIOINNOVATE PROJECT

I have been informed that the application for funding of a project titled "**Integrating agro-process wastewater treatment with biogas production and water reuse/nutrient recovery for sustainable agro-process wastewater management and climate change mitigation**" that has been prepared by the WSP & Constructed Wetland Research Project of the University of Dar es Salaam in collaboration with Department of Biochemistry, University of Makerere, Uganda and School of Graduate Studies- University of Addis Ababa, Ethiopia is being submitted.

I wish to state our commitment to this project. We at the University of Dar es Salaam have been carrying out various projects in the environmental area and our WSP & Constructed Wetland Research group has developed a lot of experience in the design and implementation of wastewater treatment systems in particular constructed wetlands.

I wish to state that we are in full support of the envisaged project. The University of Dar es Salaam shall contribute research staff and also support administration and communication for the envisaged project. The UDSM shall house the UDSM team, who are involved in the project, provide laboratory equipment and internet services for communications.

Sincerely

Prof. D. Mfinanga
Ag. DIRECTOR OF RESEARCH

A3. Letter of commitment – Banana Investments Ltd

Banana Investments Ltd.

P. O. Box 10123 Arusha - Tanzania, Tel: +255-27-2506475, Fax: +255-27-2501549, E-mail:banana@banana.co.tz

September 30, 2010

Dr. Karoli N. Njau
WSP and Constructed Wetlands Research and Development Group
University of Dar Es Salaam
P. O. Box 35131
DAR ES SALAAM

Dear Sir,

RE: WASTER TO ENERGY PROJECT

Banana Investments Ltd is involved in producing Banana Wine and Alcoholic beverages, mainly from ripe banana. We, in BIL, process approximately 5 tons of Bananas per day to produce the alcoholic beverages. Our main source of energy to boil banana is firewood and IDO. We have discussed project of generating biogas form the Effluent generated from the company to substitute firewood / IDO and to use the treated effluent for irrigation of banana farm surrounding the processing plant. The sludge from the bio digester shall also be processed into bio fertilizer for farming.

The project consists of:

1. Construction of Oil Separator, Equalization Tank and Primary Clarifier.
2. Construction of Upflow Anarobic Sludge bed Bio reactor.
3. Bio gas holder and Boiler with Biogas burner.
4. Constructed Wetland for secondary treatment.
5. Collection of treated water for irrigation and surrounding banana farm.

The cost of the total project is bifurcated into: -

1.	Primary treatment and Anaerobic Digester	USD	118,000
2.	Civil Construction	USD	88,000
3.	Lab Equipment	USD	16,000
4.	Constructed wetland	USD	80,000
5.	Irrigation system and sludge processing	USD	20,000
6.	Bio gas holder and Boiler with Biogas burner	USD	78,000
	Total	**USD**	**400,000**

Producers bottlers and distributors of Banana Wine

BIL is in the process of accumulating the fund for the above project and is committed to invest USD 150,000.00 from its own internal funds.

We hope that the proposal will be approved for matching grant so that the same can be completed successfully.

Yours sincerely,
BANANA INVESTMENTS LTD.

Banana Investments Ltd.
P O. Box 10123. Tel: 2506475
Arusha - Tanzania

Adolf R. Olomi
MANAGING DIRECTOR

A4. Letter of commitment – City Abattoir

BASAJJABALABA HIDES AND SKINS - CITY ABATTOIR

Old Port Bell Rd. Plot 1, 2 & 3, P. O. Box 20000 Kampala Tel: 041 233220/1/2

Our Ref:.....

Your Ref:.....

BASAJJABALABA HIDES & SKINS CO. LTD.
CITY ABATTOIR,
PLOT 1-3 OLD PORT BELL ROAD,
P.O. BOX 20000, Kampala, Uganda,
TEL: 256 414 233 220/1/2
FAX: 256 414 233 221

DATE: 1/10/10

THE PROGRAMME SECRETARIAT
BIOINNOVATE AFRICA
C/O ILRI
P O BOX 30709
NAIROBI, KENYA,
Email: bioinnovate@cgiar.org

Dear *BioInnovate* Programme Manager,

RE: PARTICIPATION IN THE PROPOSED ENVIRONMENT INNOVATION PROJECT CONSORTIUM II IN EASTERN AFRICA

City Abattoir, managed by Basajjabalaba Hides & Skins Co. Ltd is the oldest and largest slaughterhouse in Uganda. On average, we slaughter about 500-600 cows; 200-300 sheep & goats and 100-200 chicken daily. During the process of slaughtering and washing our animals and operational surfaces, we generate about 400 m^3 of organic and nutrient rich wastewater daily. This wastewater comprises of blood, pieces of meat, undigested stomach contents and pieces of hair/feathers.

Through funding by SIDA/SAREC under BIO-EARN phase 3, in collaboration with the Department of Biochemistry (Makerere University) and Makerere University Institute of Environment and Natural Resources (MUIENR), we set up a pilot scale wastewater treatment plant which is currently fully operational. The plant comprises of anaerobic-aerobic sequencing batch reactors and a constructed wetland unit. This system is operating efficiently and we have been able to substantially reduce the pollutant loadings emanating from our factory. Since our drainage channel connects to Nakivubo channel which drains into Murchison Bay, Lake Victoria, efficient treatment of our wastewater contributes to overall pollutant reduction into Murchison Bay, a source of drinking water for Kampala city and neighbouring towns.

However, the system we have currently performs only wastewater treatment without any generation of income from the process. Apart from meeting the wastewater treatment discharge

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standards set up by the Government of Uganda, there are no economic incentives for treating the wastewater. Through discussions with Dr. Joseph Kyambadde (Department of Biochemistry, Makerere University), who spearheaded the construction of our wastewater treatment plant, we agreed that we can invest in modification of the present treatment plant and generate biogas and manure in large quantities that can sustainably be commercialised.

We therefore write to your office to inform you of our willingness and interest to participate in the proposed ***BioInnovate Africa*** programme to be funded by the Swedish government through SIDA/SAREC. We very much appreciate the assistance offered to us in the previous programme of BIO-EARN Project 3, also funded by SIDA/SAREC. In the proposed project we are willing to contribute funds to enable modification and improvement of the existing treatment plant into an integrative system generating biogas and manure for sale. Our contribution will also include offering our land for the proposed project, our staff to manage the plant, security to the plant, and packaging and selling generated biogas. We believe that integrating wastewater treatment and generation of biogas will ensure self sustainability of wastewater treatment and contribute to reduction in environmental pollution.

Once again we thank SIDA/SAREC for the technical and financial assistance offered to us through BIO-EARN Project 3 and kindly request to be considered as a ***Private Sector Partner*** in the proposed ***Environment Innovation Project Consortium II.***

Sincerely yours,

Mr. David Mutebi Musisi
Quality Control Manager

01/10/0

A5. Letter of commitment – Makerere University

MAKERERE UNIVERSITY

P.O Box 7062 Kampala Uganda
URL: http://www.sci.mak.ac.ug
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Phone: +256 414 532401
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FACULTY OF SCIENCE

OFFICE OF THE DEAN

30 September 2010

The Manager
BioInnovate Africa Programme
Nairobi, Kenya

Dear Sir,

RE: INTEGRATED PROCESS FOR SUSTAINABLE AGRO-PROCESS WASTE TREATMENT IN EASTERN AFRICA

I am writing in support of the BioInnovate-Africa Environmental Innovation Consortium II project proposal entitled "**Integrated Process for Sustainable Agro-process Waste Treatment in Eastern Africa**" which aims at protecting the environment, mitigating climate change, and adding value to agro-process wastewaters by generating energy (biogas), organic fertilizers, and using nutrients in the wastewaters to produce agricultural products such as vegetables, flowers, and animal feed. The efforts are key pillars for national and regional economic progress and environmental protection and climate change mitigation

Makerere University is committed to these efforts and has for the past ten years worked on similar projects with support from Sida under the BIO-EARN Programme. We would like to further emphasise our commitment by participating in this project and committing out staff, salaries, office space, equipment, Internet connectivity and any other support that will facilitate the achievement of the consortium objectives.

Makerere University therefore strongly supports this proposal as we strive not only to promote sustainable industrial processing but also ensure environmental sustainability, improved livelihoods and mitigate climate change in the region as required by the Millennium Development Goals.

Yours sincerely

Prof. J.Y.T. Mugisha
DEAN, FACULTY OF SCIENCE

DEAN, FACULTY OF SCIENCE
30 SEP 2010
MAKERERE UNIVERSITY