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2015 RPD OR TPS PROJECT CALL FOR PROPOSALS

Complete project proposal form

Publication of the call: 30 January 2015
Deadline for submitting completed proposals: 28 August 2015
REVISED 15 September 2015, in red in the text

Research Projects for Development (RPD)

RENEWABLE PROJECT

Vietnam

EPPE Gauthier, North coordinator University of Liege
Le Hung Anh, South coordinator, Industrial University of Ho-Chi-Minh City

* Enter the right note: RPD or TPS



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SOMMAIRE

WARNING

To be considered, the completed project proposal must meet the formal criteria requested and be submitted to the North Coordinating University by **28 August 2015, at the latest**. The proposals will be sent to ARES by 4 September 2015 at the latest via an official letter from the project's North Coordinating University.

Please **observe the character font and size** stipulated for the different headings to be completed (Tahoma 9 - Tahoma 7.5 in tables). The maximum number of characters **includes spaces**.

The description of the overall context, of the issue, of current strategies, of the state of the art and of the intervention strategy must be **based on scientific references in the body of the document** (UK format) and covered thoroughly in Point 8.2.

Please avoid redundancies in the different sections of the form.

1 PROJECT DESCRIPTION

Project title	**RE**moval of **N**utri**E**nts in **W**astewater treatment via micro**A**lgae and **B**iofue**L**/Biomass production for **E**nvironmental sustainability in Vietnam, **RENEWABLE** project
Country of the Coordinating University South	Vietnam
Other country or countries of partner institution(s)	NA
Topic or concentration sector for the ARES-CCD in question	Priority thematic in the ARES-CCD document for Vietnam (country factsheets): management and protection of natural resources related to water issues with a strong emphasis in environmental protection
Budget	482768,98 €
Duration (in months, between 36 and 60 months)	48 months
Sector[1]	14081; 23070
Scientific fields targeted[2]	Applied Science and Environmental Sciences
If relevant, title of the activity or project for which the proposal is a continuation project and financing period	NA

1 Provide the 5-digit OECD-DAC purpose code (example: 32210) showing the specific field of the economy or the social structure of the beneficiary country in which the project proposal intends to stimulate development. For more information, see: http://www.oecd.org/fr/cad/stats/codes-objetclassificationsectorielle.htm et http://www.oecd.org/fr/cad/stats/documentupload/2012%20CRS%20purpose%20codes%20FR.doc for the list of purpose codes.

[2] Report here the scientific fields as they are mentioned in your pre-project proposal form.

2 STAKEHOLDERS

Please attach a statement of intent **for each coordinating and partner institution** using the form provided.

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3 PROJECT SUMMARY

The RENEWABLE project (**RE**moval of **N**utri**E**nts in **W**astewater treatment via micro**A**lgae and **B**iofue**L/**Biomass production for **E**nvironmental sustainability in Vietnam) aims to couple wastewater treatment and the production of microalgae-based biomass valorisation as an effective way to enhance inorganic nutrients removal (N and P) from aquaculture wastewater and to produce biofuel and animal feedstuff from biomass. The wastewater treatment is the first priority of the project. The **Ninh Thuan province** situated in South-central region of Vietnam has been selected to install a field pilot. The province has many valuable assets to achieve the specific objective (SO) of the RENEWABLE project. An advantageous climate (average temperature stable around 27°C), driest region of Vietnam and excellent sunlight intensity, all conditions favorable for microalgae production. It is one of four biggest fishing grounds of the country, with 50000-60000 tons of seafood produced each year. Moreover, Ninh Thuan waters have constant salinity and a rather clean environment, ideal conditions for high quality seed for shrimps. They produce and provide most of the seed shrimp (24 billions post-larvae of shrimps and prawns in 2014) for all the country. Aside the climate and the favorable environment, the RENEWABLE project will have support from the regional government (DOST, Department of Sciences and Technology) of the province. They will participate as partner in the project. Since 2007, the Belgium government is involved in cooperation programs mainly in connection with water resources (2007-2019) in Ninh Thuan. In addition, the province has a marine seed-breeding center with high technology facilities (people, large scale ponds, laboratories) where the field pilot of the RENEWABLE project will be installed.

The intended effect of the RENWABLE project, formulated as its SO, will consist to **ensure that the feasibility of the reduction of the pollution load of aquaculture wastewater discharged in coastal areas by using microalgae and their biomass valorization techniques is tested and results disseminated to regional government and aquaculture farmers**. Farmers, local authorities, shrimp producers and shrimp industry in general have been clearly identified as the end beneficiaries of the RENEWABLE project.

To achieve the SO, a consortium of academic **professors, scientists, local government and local farmer association, local research center and industrial partners** from the North and the South with diverse backgrounds and complementary skills have decided to join the project. In addition, a steering committee made of representatives of Ninh Thuan provincial authorities has been created to ensure the lobbying towards the adoption of the RENEWABLE technology developed. The RENEWABLE project is an interdisciplinary project that brings together biologist, geneticist and physiologist of microalgae, bio-engineer, chemical engineer, analytical chemist and economists in rural developments. We paid attention to select partners that cover the required skills in North and South consortia in order to ensure that the required competences will be available locally.

The four-years RENEWABLE project fits perfectly with the priority thematic of the ARES-CCD document for Vietnam highlighting management and protection of natural resources related to water issues with a strong emphasis in environmental protection and sustainable development. During this project, two Vietnamese PhD students and 5 master students will be financially supported and shared between the different research groups in the North and South partners. Investment and operating costs will allow supporting the research and the technical development of the project in Vietnam by installing a lab pilot at IUH and a field pilot in Ninh Thuan.

4 HISTORY OF THE PROJECT

The complex issue of wastewater in Vietnam was brought to the attention of Belgian academic partners by their Vietnamese colleagues as a topic related to the implementation of different joint initiatives.

Prof. Gauthier Eppe (North Promotor), Prof J-L Vasel (North Partner) and Prof. Le Hung Anh (South Promotor) collaborate since a couple of years in the framework of an International Executive Master in Environmental Sciences (IMES), which was launched between University of Liege (ULg) and the Industrial University of Ho Chi Minh City (IUH) in 2010. Every year, Gauthier Eppe and J-L Vasel spent two weeks in Vietnam teaching Environmental analytical chemistry and water and wastewater treatment, respectively. These modules are given in close collaboration with Prof. Le Hung Anh (South coordinator) and his team responsible to organize them locally.

Since 2011, Prof. G. Eppe and Prof. C. Remacle collaborate, through a FNRS-FRFC grant, in the investigation and understanding of the regulation of storage carbohydrate metabolism in *Chlamydomonas reinhardtii* by using genetic and metabolomics approaches. They study the influence of mutations affecting starch synthesis or content on algal metabolism as well as the identification of molecular and metabolic factors.

Prof. C. Remacle and Prof. S. Agathos collaborate through a Walloon-funded project in the investigation of the use of microalgae for bioenergy purposes. Microalgae with higher lipid content were isolated and their growth in photobioreactors was assessed in different culture conditions.

Prof. Agathos has a long-standing collaboration on bioremediation with the Institute of Biotechnology of the Vietnamese Academy of Science & Technology (VAST) in Hanoi since 2002.

Prof. J-L Vasel had several projects in Vietnam in collaboration with the Vietnamese Academy of Science and Technology (WBI and PIC). His local knowledge in the field and expertise is definitely an asset for the RENEWABLE project. He is collaborating with Prof. Le Hung Anh through PhD students exchange.

Dr Trinh Ngoc Nam is a expert of biotechnology. In collaboration with Prof. Le Hung Anh, Dr. Trinh Ngoc Nam is teaching the module Environmental Biotechnology of the master program of Institute for the Environmental Science, Engineering & Management (IESEM). Both scientists collaborate in several R&D projects and as senior adviser for the farmer and industry on applied biotechnology.

Prof. Ph. Lebailly (ULg) is Professor of Economy and Rural Development at Gembloux Agro Bio-Tech and has a long experience and collaborations with Vietnam.

Prof. K. Tran is lecturer at University of Economics in Ho Chi Minh City and head of the Department of Agricultural Economics and Rural Development. He used to conduct rural surveys and joint some Belgium-Vietnam cooperation projects; and study local agri-products' value chain analyses. He has many practical experiences on shrimp production in Southern Vietnam.

Prof. Ph. Lebailly and Prof. K. Tran collaborate since 1995, they had several research projects on value chain analyses for agricultural commodities in Southern Vietnam such as Competitiveness of rice value chain in Southern Vietnam; Improvement of shrimp products' quality exported to Europe through building up capacity of shrimp producers, private sector and local authority in Bac Lieu province.

This year, new academic (Prof. Ph. Lebailly and Prof. K. Tran) and non-academic Vietnamese partners from province government and association joined the RENEWABLE project (see chapter 14 for details).

All the partners of the RENEWABLE project have complementary skills and we have been paying attention that all the skills will be covered by the North and the South partners as the research part of the project will be part time in Belgium and in Vietnam while the pilots installation, the diffusion of know-how, training will be exclusively carried out in Vietnam.

5 GENERAL CONTEXT

The Vietnamese economy has grown rapidly over the last 25 years and is considered as one of the fast-growing economies in Asia. Their economic development largely relies on natural resources (agriculture, fisheries and forestry), placing stress on the environment as a result of deforestation, overfishing, water pollution, salinization and acidification of soils. Poor sanitation leads to economic losses of $780 million or 1.3 per cent of Vietnam's GDP every year, according to the report of the World Bank[1]. According to the Vietnam Environment Protection Agency (VEPA), the key environmental issues that the country has to face today are: the global climate change, the degradation of the main environment components (forest, biodiversity, water and air) and the problem of solid waste. The fourth Assessment Report of IPCC indicated that the impact of climate change will seriously affect developing countries, in which Vietnam with its exceptionally long coastline is cited as one of the top countries vulnerable to climate change leading to serious floods, frequency and intensity of tropical cyclones, and sea level rise impacting particularly agricultural regions of Mekong and Red river deltas. Against this background, the Vietnamese Government is taking a constructive approach to international climate policy. It has expressed its willingness for the country to pursue its own nationally appropriate GHG mitigation actions (NAMAs), in accordance with its development status.

Vietnam is relatively rich in water resources but the discharge of untreated wastewater released from both domestic and industrial activities into the river network has caused serious pollution problems such as eutrophication of surface water in many urban centers areas and agricultural regions. For domestic water, although 60% of households dispose of wastewater through a public sewage system, much of this went to the drainage system with only 10% of the water treated. Aquaculture and seafood processing are highly developed in Vietnam. The country has no fewer than 1000 food processing corporations and thousands of fish/shrimp-farming. Wastewaters from this type of industrial activities are characterized by a high content of ammoniacal nitrogen that can affect the aquatic environment if they are directly released in rivers. Low incomes, use of rudimentary techniques and the lack of information about the development of state-of-the-art technologies mean that, currently, only 4% of the overall companies operating in the fields are equipped with a wastewater treatment system. When installed, the treatment is mainly based on activated sludge and poorly operated. Currently, the coastal areas are being devastated by salinization as a result of higher tidal flooding and reduced drainage of fresh water. For these areas an innovative land use concept needs to be developed. Salt adapted food plants are a widely studied solution, but rising salt concentrations will limit the production of food plants (rice). Reutilization concepts for these areas to aquaculture can be developed. To achieve sustainable development in bio-economical areas it is vital for environmental pollution to be dramatically reduced through ecological and economically viable utilization of the organic waste and wastewater.

In terms of legislation and environmental policy, the Decision No. 332/QD-TTg of March 3, 2011, approved by the Prime Minister, strengthen the scheme based on the economic development of aquaculture through 2020. With general objectives to rapidly develop aquaculture in the direction of industrialization, modernization, high effectiveness and competitiveness and sustainable development; to develop it into a major production sector to supply raw materials for export processing and domestic consumption, and concurrently create a lot of jobs, increase incomes for farmers and fishermen, thus assuring social security and contributing to hunger eradication of poverty alleviation and maintenance of security and defence in the country's seas and islands. Some specific targets are also described such as by 2020, the aquaculture output will reach 4.5 million tons and total area for aquaculture will reach 1.2 million ha; the aquatic product export value will reach USD 5 - 5.5 billion and jobs will be created for some 3.5 million laborers.

In this context, the RENEWABLE research project aims to contribute to the prevention of coastal surface and groundwater pollution from aquaculture farming in Vietnam by reducing its pollution load with the use of microalgae wastewater treatment approach. The biomass produced is a source of possible renewable energy for biofuel production and animal feedstuff production. The proposal is a constructive approach that tackles the environmental issues mentioned above. This project completely fulfills the priority guidelines described in the ARES-CCD document for Vietnam in terms of environmental protection and water pollution.

6 DEVELOPEMENT ISSUE

6.1 OVERALL ISSUE

The quality of surface water is affected in Vietnam. The pollution comes from different sources including the discharge of solid wastes, untreated wastewater released from both domestic and industrial activities into the river networks, but also the intensification of agriculture and food production. In this sector, wastewater from aquaculture is considered as an important environmental issue. Fish and shrimp farms are generally located in the vicinity of coastal regions and often directly connected to the sea or deltas (e.g. Mekong delta). The Vietnamese coastline is over 3,200 km long, offering great potential for marine fisheries to play an important role in Vietnam's emergent market economy. More than 400,000 people work directly in capture fisheries, and over two million people in support industries and related services. The raw materials for processed fish products come mainly from the southern part of the country, which accounts for 70% of total export value. Around 60% of factories are located in the south, mainly in coastal areas. The untreated wastewaters, rich in nutrients, are directly released into rivers but also into the sea and costal water. The global quality of surface and groundwater is currently a cause of concern in Vietnam. The main reasons that could explain the current situation are described in the problem tree attached in annex. A series of causes are highlighted in the diagram. As already mentioned in the previous section, the fast economical development of Vietnam put stress on the environment and led to unsustainable use of natural resources. Even if environmental legislations exist, texts are mainly economical based oriented, with little emphasis towards environmental protection of water resources and water treatment. In addition, there is a lack of application and compliance with these regulatory texts. One can also incriminate that there is a limited awareness about environmental issues and knowledge of the local population working in these economical sectors.

All these sources of pollution led to the deterioration of the quality of surface water in Vietnam. The problem is global and no region/province is spared; for instance, the Mekong delta is also affected where more than 400 thousand hectares are under shrimp production. Mekong Delta is the main shrimp-producing region in Vietnam with more than 10% shrimp productive areas are under intensive production specialized by high larvae density, high feedstuff and chemical application. The wastewater is directly discharged to canals and rivers systems and makes soil salinized. Besides, the nutrient loads can lead to water eutrophication and harms aquatic environment. In addition, discharged wastewater probably contains chemicals, bacterial- or viral diseases that easily and quickly spreads and infects other aquatic creatures when canal and river water is again pumped in shrimp ponds without appropriate treatment. By that way, the wastewater is likely serious problems if contamination problem is not solved. In addition, in order to avoid loss due to wastewater, underground water is highly exploited for shrimp production, leading to serious loss of un-renewable natural resource. The level of groundwater drops by roughly a meter/year in Southern Vietnam in Mekong Delta. That situation is not sustainable and will impact aquaculture farmer's income and livelihood.

An overview of the overall issues is depicted in the problem tree (figure attached with the proposal).

6.2 SPECIFIC ISSUE

Among the surface water pollution sources described in 6.1, which are various and diffuse, the RENEWABLE project will focus on wastewaters from shrimp aquaculture and more specifically on wastewater from intensive shrimp farming aquaculture in the Ninh Thuan province. Our project will work in close collaboration with the governmental South partner from the Department of Sciences and Technology of the Ninh Thuan province located in the middle-South of Vietnam at about 350 km North East from Ho Chi Minh City.

During the mission in Vietnam organized this summer, we visited a farm of intensive shrimp production during a field trip in Ninh Thuan province. Such farms encompass several open ponds (from 5 to 10) working in closed systems. The size of a pond is about 1000 m^3 as depicted in Figure 1. The bottom of the pond is covered with a waterproof cover. The production cycle from larvae to shrimp harvesting takes about 3 months. At the end of a cycle, the untreated wastewater is completely discharged in river or coastal water/soil and the empty pond is cleaned before being re-used. Frequently (several times a week), about 20% of the total amount of water is replaced in the pond during the 3 months cycle. Saline water directly pumped from the sea, after pretreatment, is used to refill the open pond.

Figure 1: Open pond from intensive shrimp farm in Ninh Thuan province.

The wastewater generated by this activity has high loads of organic and nutrients. The average BOD_5 generally ranges from 20 to 500 mg/L (COD = 100-1000 mg/L). In addition, the wastewater contains high levels of suspended solids and is rich in nutrients. Another important aspect of the wastewater discharged here is its high salinity (Na^+, Cl^-, SO_4^{2-}), caused by the seawater used by these farms. Saline wastewater has adverse effects to biological processes. High salt levels cause bacterial cells to dehydrate because of osmotic pressure. Saline wastewater discharge can pollute groundwater and the surrounding lands used for agriculture. Due to massive aquaculture development, lack of planning, rudimentary technology and use of many types of improper chemicals cause negative impacts on aquatic environment such as organic contaminants, pathogenic organisms, toxins (ammonia, nitrite, hydrogen sulfide)… Concentration of many pollutants in wastewater from shrimp/fish farming exceed effluent standard maximum limits. In addition, the use of antibiotics, if they are recirculated, could become either harmful for the fishes but also for microalgae itself when implementing algae wastewater treatment. Indeed, the risk of inhibition of algal growth is likely.

So far the fisheries hatcheries and shrimp ponds we visited are operating in open pond as depicted in Figure 1 and our project will focus on this type of intensive farming. Farmers and authorities are aware of the pollution generated by this economical activity and they are interested in treating wastewater reasonably in a sustainable manner. However, an important work of awareness raising, education and training is needed.

From discussion with stakeholders, it's very important that if wastewater problem caused by shrimp production is Ninh Thuan is solved, that experience can be widely applied in Mekong Delta to reduce environmental degradation and ensure international environmental standards for shrimp products.

6.3 TARGET GROUPS AND BENEFICIARIES

Target groups:

- Aquaculture farmers (hatcheries, fish and shrimp farmers) from Ninh Thuan Province (approx. 20000 framers)
- Biofuel industry: production of biodiesel for Vietnam's market (fish boots, vehicle in agriculture)
- (Animal feed industry : biomass produced from algae for animal feedingstuffs)

Beneficiaries groups:

- People using water from river (aquaculture, agriculture, using for drinking and household)
- Local authorities (reduction of environmental loss and mitigating activities)
- Shrimp producers in Mekong Delta (due to ensured source of postlarvae and experience in wastewater treatment)
- Shrimp industry in general (due to satisfied environmental standards in intertnational trading)
- People in general (due to ensured livelihood and fresh water supply)

6.4 RELEVANCE FOR DEVELOPMENT

Since the beginning of the years 2000, one can observe important changes in the traditional agriculture production of coastal areas in Vietnam. Farmers facing with low incomes from rice culture and salt marshes decided to use land surfaces for aquaculture. These changes have been done by farmers with the objective to increase the family incomes in agricultural areas where the rice production was relatively low. Shrimp production in Vietnam became an important aqua-cultural sector that helps the country earn hard currency through shrimp products' export. Shrimp production and processing also create rural employment, especially for women and young labors in processing plants and other jobs in input provisions, shrimp trading and on-farm activities. The activities also provide livelihood for million rural families living along the coastal areas.

These mutations had important economical impacts on coastal regions in Vietnam with pronounced modifications in labor organization and in creating jobs in food industry. This type of familial aquaculture has grown very fast to meet internal market demand but also exportation. With these spontaneous initiatives, the Vietnamese authorities had difficulties to regulate these new producers in environmental sustainability schemes either for fresh and saline water. Shrimp production in Vietnam has changed from extensive to intensive cultivation. Therefore, the application of feedstuff, chemical, and anti-biotic products increases year by year and leads to more discharged wastewater problem. Such increasing application causes more seriously environmental problems as described above and leads to social concerns. Without appropriate treatment, wastewater can create big failure of shrimp industry because high nutrient and disease contents. In addition, climate changes and sea level rise might impact those vulnerable areas situated very closely or directly connected to the sea.

If wastewater collected and treated appropriately, nutrient contents can be accumulated in useful forms and so discharged water is clean and does not harms aquatic and land environment. In that way, financial and economic benefits can be significantly created through commercialization of nutrient-contained biomass for feedstuff or bio-fuel purposes and reduction of environment loss. Shrimp producers can reduce their production costs including loss due to wastewater contamination and additional income for selling biomass. Feedstuff and/or bio-fuel industries can be directly beneficiaries when new products developed. Rural communities livelihood in Ninh Thuan province can be improved as environmental problems solved. Shrimp producers and other stakeholders of the value chain are ensured from satisfying environmental standards posed by importers for shrimp products' trading. Local authorities and government can avoid budget expenditure for environmental – mitigated activities.

Shrimp production in Ninh Thuan province and more generally in Southern Vietnam uses massive resources and contributes importantly to the region economy and livelihood. Cleaning discharged wastewater from shrimp production via microalgae is significantly contribute to sustainable development in Southern Vietnam. The RENEWABLE project submitted here will contribute to face these challenges.

7 SCIENTIFIC ISSUES

7.1 STATE OF ART AND BIBLIOGRAPHY

Microalgae are attractive biofuel sources because of their high photosynthesis efficiency and potential for biodiesel-compatible lipid content[2]. Another possible application for algae biomass in terms of energy is biomethane production[3]. Concerning biodiesel, in addition to the problem of the high cost of biodiesel production[4], wastewaters, especially from fisheries, are usually rich in nitrogen, a characteristic not typically suited for enrichment of algal biomass in lipids, as lipid accumulation is often resulting from nitrogen limitation[3]. On the other hand, although the market price for biomethane is lower than that of biodiesel, it does not require extensive biomass extraction[3]. When looking to the whole process, from algae to biomass products, several points need to be considered: algal species, type of growing systems (open ponds or closed photobioreactors), harvesting and processing of biomass for valorization. Choice of algal species is of primary importance: ideal algae should exhibit high growth rate in the presence of wastewaters under the Vietnamese climate, and high lipid content if biodiesel is envisaged for biomass valorization. These major challenges can be duly addressed via extensive bio-prospecting. On the basis of reviewing the literature published from 1983 to 2011, 651 species and subspecies of microalgae distributed in ponds, lakes, reservoirs and rivers have been found in some areas in Vietnam. Among these, several species display high potential for application in wastewater treatment and biodiesel production. The choice of the type of cultivation system is also of primary importance. The most common large-scale production systems in practice are high rate algal ponds (HRPs), also known as open ponds or raceway ponds. HRPs are relatively inexpensive to build and operate, provide a promising wastewater treatment method but often suffer from low biomass productivity due to contamination, poor mixing, dark zones, and inefficient use of CO_2[5]. HRPs are currently considered the most cost effective reactors for wastewater management and capture of solar energy for biofuel production. Closed systems used at large scale, such as tubular photobioreactors (PBRs), are only the type, which permits the monoculture growth of microalgae for extended periods[6]. Compared to HRPs, tubular PBR can give better pH and temperature control, better protection against culture contamination by other microflora and potential system failure, better mixing, less evaporative loss, and higher cell densities[7]. In wastewater treatment, tubular PBRs can significantly reduce both organic matter and nutrients present in wastewaters. Despite these benefits, tubular PBRs have not yet achieved significant use in full scale operating systems mainly due to material and maintenance costs[7]. Energy savings and a gain in photon-to-biomass conversion efficiency can be obtained with innovative PBR designs such as flat plate airlifts[8]. Moreover, PBRs can be an appropriate means of building up a significant biomass of inoculum to serve as seed culture for the wastewater treatment HRPs. Effective biomass production in wastewater treatment for biofuels requires separation of biomass from water. Harvesting, dewatering and lipid extraction from microalgal biomass are still challenging issues because they consume large amounts of energy. On the other hand, if biomethane is considered, biomass could be simply dried in open air before anaerobic digestion. Biomass can be separated from the broth by filtration, centrifugation, flocculation (spontaneous or aided) and other means[9]. The cost of biomass recovery can be significant because of the small cell size and relatively low biomass levels (dilute suspension). Research efforts are therefore needed for cultivation under higher cell densities, which poses engineering challenges with regards to cell accessibility to light and mass transfer[9]. Use of mathematical models can be useful to manage the bioreactor in optimal conditions to promote autofloculation conditions or at least to facilitate flocculation[10,11].

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7.2 SCIENTIFIC ISSUE(S)

The treatment of wastewater from fisheries and more generally from food industry, is not a new question even if there is a technical and scientific gap between the theoretical knowledge of the technologies to be developed and the full scale facilities to be implemented in site. The innovative part of the RENEWABLE project is more related on the global approach to improve the sustainability of aquaculture farms in Ninh Thuan province of Vietnam, and even to initiate a green circular economy approach. In order to develop this approach, key questions are raised : what kind of algae can we cultivate and produce to treat wastewater from aquaculture in Ninh Thuan? How to collect the biomass and insure that the biomass produced has the required characteristics for valorization? Which quantity of energy is needed to reach an economical valorization? Those questions raised require interdisciplinary skills to propose adapted answers and solutions.

For instance, in collaboration with Vietnamese colleagues, we will define a set of microalgal species which will fulfill the criteria necessary for the project : robust strains with fast growth rate in saline wastewater from shrimp culture, and high lipid content. Preliminary results from a master thesis from IMES 3 carried out over the last 3 months and under the supervision of Prof. Le Hung Anh, Dr Trinh Ngoc Nam and Prof. G. Eppe showed very encouraging data at laboratory scale from shrimp ponds. For instance, the strain selected (*Chlorella vulgaris microalgae*) was able to eliminate more than 80% COD, 75% N-NH4+; 80% TKN and 66% TP. This clearly indicates the potential of microalgae for aquaculture wastewater treatment[12].

These species will need to be easily cultivated in open ponds and PBR and their downstream processing should also be easy and take into account the final use : for biodiesel, then in addition to the high lipid content, easiness for breaking the cell wall should be considered whereas if the biomass is used for fish feeding, the total amount of proteins and the ratio of the different amino acids as well as presence of long chain fatty acids is important. Thus intensive collaborations between biologists, analysts and bioengineers from North and South is required.

Another example is the use of mathematical models to describe the behavior of the bioreactors. It is not common to use such approach but we should be able to demonstrate how dynamic models can greatly help to manage the development of the pilot and to defined optimal conditions to increase the biomass productivity and to reach criteria for autofloculation and collect of the biomass. All the skills are available in our consortium.

In addition, the project will also require acceptance by the shrimp farmers of the cultivation of the algae and thus needs correct information to the targeted population and beneficiaries. The whole project is therefore challenging by many aspects because it requires the integration of factors of various nature : biological, chemical, physical and societal. The innovation compared to the projects usually conducted on microalgae mainly relies on the fact that the whole chain process from wastewater treatment, growth cultivation to biomass production and valorization should be made on site in Ninh Thuan province of Vietnam, and will thus be really depending on the Vietnam context and environment. We are strongly convinced that it could be achieved because as presented below we have already extensive collaboration both at the North and South levels and between South and North partners.

8 EXISTING STRATEGIES AND OTHER COOPERATION ACTIVITIES

Since 2007, the Belgium government is involved in cooperation programs mainly in connection with water resources in Ninh Thuan province.
From 2007 to date, the Government of Belgium has funded 22 millions Euros to the province, for four projects:
- Construction of Lanh Ra reservoir in Districts of Phuoc Vinh and Ninh Phuoc (2007 - 2012);
- Increase of capacity for assessment and management of water resources (CAPAS) (2009-2012);
- Increase of capacity for water supply and provincial public service (2010 - 2014)
- Water resources management and urban development in relation to climate change in Ninh Thuan province (in development, period 2013-2019)
The project to improve water management capacity and to provide public services in Ninh Thuan
The indicative cooperation program between Vietnam and Belgium signed on 8/3/2007, focusing the two areas:
- Capacity building, institutional policies strengthening
- Support programs for water supply and environmental sanitation.
The Belgian government expressed interest in supporting a number of districts in Ninh Thuan province, a southern central coastal province of Vietnam currently facing challenges in the water management sector.
CONTRIBUTION OF VIETNAM: 3,070,000 €
BELGIAN GOVERNMENT GRANTS: 10,000,000 €
Thus, the RENEWABLE project will have support from the regional government (DOST, Department of Sciences and Technology) of the Ninh Thuan province. They will participate as partner in the project because our project is completely in line with Belgium cooperation programs already established.

Existing activities of international cooperation

NOTE: a PRD has been assigned to Prof Kestemont in 2015 with Vietnam but it is not related to the thematic developed in the RENEWABLE project.

Professor Philippe Lebailly had a PFS project related to 'Master en économie et sociologies rurales' in Vietnam Cambodge and Laos (2009-2015). This project is in collaboration with Prof. Khai Tran, also member of the RENEWABLE project.

In addition Prof. Vasel had two projects in collaboration with Vietnam the last years in connection with wastewater treatments:
VALEAUTAQUA project PIC (Vietnam-Belgium, 2009-2011):
Conception, diagnostic, optimization of the management, rehabilitation of wastewater treatment plants with the objective of valorization of water in the framework of sustainable development in Vietnam
Project WBI (Vietnam VAST-Belgium, 2009-2012):
Development of cost effective technologies to wastewater treatments of effluents rich in N content (household, aquaculture, …)

At international level, Prof Le hung Anh is involved :
AKIZ project (Vietnam-Germany, 2009-2014):
The project aims to develop activities for the central sewage treatment plant of an industrial zone (Tra Noc). The German-Vietnamese joint research project develops an integrated wastewater concept for industrial zones ("AKIZ" = "Integriertes Abwasserkonzept für Industriezonen") to secure the efficiency and sustainable operation of the whole wastewater system including all its technical components. In addition to the combination of centralized and decentralized wastewater treatment solutions, the close connection of technical and financial planning is an important part of the integrative approach. This also includes adequate structures for wastewater tariffing and cost allocation.
Using containerized pilot plants for different branches in Tra Noc Industrial Zone, high-tech solutions for pre-treatment of wastewaters, generation of energy from wastewater and recuperation of valuable substances are adapted and verified by on-site pilot systems, taking into consideration the local conditions. Concepts for sewage sludge management are investigated. Monitoring surveys create the database for control mechanisms especially in terms of toxic wastewaters.

Biomass Town Project (Vietnam-Japan, 2009-2014)

The major objectives of the Biomass Town Plan in Cu Chi District are to reduce environmental burden, establish recycling-based society, and revitalize the local economy.
Cu Chi District's Biomass Town Plan aims to promote sustainable biomass utilization, improve hygienic conditions, and produce renewable energy through the introduction of advanced biomass utilization technologies and the dissemination of existing technologies.

Biogas Program for the Animal Husbandry Sector of Vietnam (Vietnam-Dutch, 2003-2014)

The project "Biogas Program for the Animal Husbandry Sector of Vietnam" is implemented by Livestock Production Department (under MARD) in cooperation with Netherlands Development Organisation – SNV.
Overall objectives of project are (i) exploiting effectively biogas technology and developing a commercial viable biogas sector in Vietnam; and (ii) contributing to rural development and environmental protection via provision of clean and affordable energy to rural households, improvement of community's sanitation and rural people's health, creation of job for rural labour and reduction of greenhouse gas emission.

The project has been started in 2003 and phased out in 3 periods:
- The phase I, (1/2003 - 1/2006): the project was implemented with a 2.5 Euro grant from the Netherlands government, and covered 12 provinces nationwide.
- The bridging phase, 2006: the preparatory year for phase II.
- Phase II (2007 – 2014), the project will be deployed nationwide.

FIRST (Fostering Innovation through Research, Science and Technology) Program (Vietnam-Worldbank, 2013-2019)

The South coordinator of our RENEWABLE project (Professor Le Hung Anh) will submit a project by the end of 2016 if the RENEWABLE project is accepted. The reason is simply related to the fact that FIRST will support only technology transfer and support to innovation. Then, it needs the research and development results from the RENEWABLE project. Thus, it can only be introduced if the RENEWABLE project is supported and it will contribute to the scale-up of pilots and valorization of the biomass. The results of RENEWABLE project are the key technology for application of FIRST program with a consortium of South and North partners.

9 COMPLEMENTARITIES AND SYNERGIES

Regarding the country factsheet for Vietnam and more specifically the guidelines of CIUF-CUD for the period 2014-2016, the RENEWABLE project is perfectly in line with the priority thematic of the management and protection of natural resources including aquaculture and water resources. We are aware that our project is not collaborating with the Agronomic University of Hanoi nor with the University Pham Ngoc Thach, where institutional support are established between Belgium and Vietnam but the thematic developed in the RENEWABLE project is a priority for Vietnam.

The Ninh Thuan province situated in South-central region of Vietnam has been selected to install a field pilot. The province has many valuable assets. An advantageous climate (average temperature stable around 27°C), driest region of Vietnam and excellent sunlight intensity, all conditions favorable for microalgae production. It is one of four biggest fishing grounds of the country, with 50000-60000 tons of seafood produced each year. Moreover, Ninh Thuan waters have constant salinity and a rather clean environment, ideal conditions for high quality seed for shrimps. They produce and provide most of the seed shrimp (24 billions post-larvae of shrimps and prawns in 2014) for all the country and large-scale production for export. The wastewater problem probably causes loss in shrimp larvae production and leads to deficit of larvae provision to all the country including Mekong Delta where an important part of the global production is performed there. Therefore, experience in wastewater treatment can be scaling-up to neighboring provinces and even to Mekong Delta. If succeeded, biomass production for feedstuff and/or bio-fuel can become a new and promised local economic activity.

10 RESPONSE STRATEGY

10.1 SYNTHESIS

The problem tree has been transformed in an objective tree where the global and specific objectives were defined and where 3 expected results were highlighted (see the objective tree in annex). Based on this objective tree, the logic intervention was validated (see attached logframe matrix).

The global objectives (GO) of our project are to contribute to improve surface water and coastal water quality in the broader frame of environmental protection and sustainability in Vietnam and to sustain the livelihood of aquaculture farmers.

The intended effect of the RENWABLE project, formulated as its specific objective (SO) will consist to **ensure that the feasibility of the reduction of the pollution load of aquaculture wastewater discharged in coastal areas by using microalgae and their biomass valorization techniques is tested and results disseminated to regional government and aquaculture farmers**. Farmers, people using water from river and local authorities have been clearly identified as the end beneficiaries of the RENEWABLE project. The stakeholders involved in the project are the aquaculture farmers (hatcheries, fish and shrimp) but also the industry of animal feedstuff and biofuel.

Thus, the specific objective (SO) of the RENEWABLE project will be achieved through three concrete visible outcomes, expected results ER1, ER2 and ER3 (NOTE: ER0 is related to the management of administrative tasks). To achieve the outcomes, the project requires a scientific consortium based on complementary skills between the North and the South partners. We paid attention to select partners in order to ensure that all the required skills will be covered in Belgium and in Vietnam. Industrial and governmental partners are also included to strengthen our group (see chapter 17).

As a preliminary, ER0 relates to the resources that are used efficiently and effectively for the RENEWABLE project. It relates to the administrative management of the project with a clear description and planning of the different activities and progress monitoring and reporting through out the 4 years project.

The scientific and technical strategy response to attain the specific objective comprised 3 expected results (ER1, 2 and 3). ER1, on which the project has been refocused, will consist to develop, at pilot scale installed in Ninh Thuan province famers, a fit for purpose-valorization technology for saline shrimp farming wastewater treatment. To achieve this result, 6 activities and related tasks are comprehensively described in the logical framework in annex. Briefly, it encompasses the characterization of organic and inorganic content of wastewater from shrimp aquaculture; the preparation of a list of potential Vietnamese microalgae strains; to install the laboratory wastewater treatment plant (lab pilot) at the IUH (laboratory of South partners coordinator and 1); to install the pilot in field (field pilot) at the research center for aquaculture at Ninh Thuan province (South partner 4); test the performances of nutrients removal with different wastewater characterized in the first activity according to the shrimp production period and seasons; and, finally to perform an economic evaluation of the wastewater treatment process. The objectively verifiable indicators will consist to evaluate if the pollution load of wastewater from shrimp farming treated through the (field) pilot is compliant with the legal standards used in Vietnam and in EU legislation.

ER2 will consist in ~~demonstrating~~ testing and documenting the valorization potential of the biomass produced ~~through animal feedingstuffs (source of proteins) and~~ through biofuel from saline shrimp farming wastewater treatment (priority highlighted by Vietnamese) and analysis of the remaining biomass after oil extraction for other valorization process (feedingstuff). ER2 core activities and tasks are to characterize the biomass produced from microalgae; to assess the valorization of the biomass for biofuel production; to assess the valorization of the biomass for animal feed production; to perform a socio-economical evaluation of the complete integrated approach; the handbook (technical, practical and economical data) will be provided to the stakeholders in order to prepare feasibility scale-up studies in the defined sectors. The objectively verifiable indicators will consist to scientifically tested valorization techniques for the biomass produced through saline shrimp farming wastewater treatment plant.

ER3 is dedicated to knowledge and know-how acquisition in aquaculture wastewater treatment and its biomass valorization through academic and applied researches but MAINLY to the dissemination of knowledge to the local government and targeted farmers of the Ninh Thuan province. One of the OVI for ER3 will be the achievement of two IUH PhD theses within the 4 years project. The PhD students will perform their research through ER1, ER2 and ER3 with the objective to publish articles in peer reviewed international journals. In addition, 5 master theses from the International Master in Environmental Sciences (IMES, joined master between ULg-IUH) will also be

carried out during the RENEWABLE project, including master theses in collaboration with the University of Economics HCMC to cover the socio-economical aspects of the project. In the second half of the project, the laboratory pilot installed at IUH will be devoted to master students and used in the framework of the executive IMES master for training and laboratory practical works in order to achieve academic sustainability. A minimum of 100 aquaculture operators and 500 farmers will be informed and trained about the potential performances of the field pilot tested in Ninh Thuan province. The RENEWABLE project will receive logistic support from Farmer's Union and the governmental department of Sciences and Technology of the province (South partners 3, 4 and 5). The dissemination of the information to the beneficiaries and stakeholders will be given through workshops, meetings organized through farmer's association, access to media and technical training in site.

To reach the SO, we decided to organize our budget in such a way that all the partners make financial efforts to give the opportunity to financially support two Vietnamese PhD students because the response strategy certainly requires two full time PhD students. One thesis will be oriented towards characterization with a strong emphasis in analytical chemistry and genetics under the supervision of Professors Eppe and Remacle. The second thesis will be related to the set-up of the pilots and simulation approaches to optimize the operating conditions under the supervision of Professors Agathos and Vasel, in close collaboration with our corresponding South partners for the two theses. In addition, an investment cost has been foreseen for our South partners (coordinator and partner 1) to install laboratory instruments and one lab pilot at IUH laboratory and one field pilot on site at the research center of fisheries at Ninh Thuan province (South partner 4). A description of the instruments needed is given in the detailed budget. It encompasses two growth chambers and a photobioreactor, a refrigerated centrifuge, an ultrasonic cell disruptor and a microscope equipped with a camera.

Source of means of verification are provided for each SMART-OVI associated with the SO, ER0, ER1, ER2 and ER3, respectively, as given in the logical framework. We highlighted a series of factors and conditions not under direct project control that could lead to the failure of meeting our set objectives and the delivery of expected results. Some of these external factors are treated more deeply in section 15 with proposals of preventive measures and corrective management measures to circumvent as much as possible these external risks. Finally, the activities and tasks are described in details in the following section 10.2

10.2 DETAILED DESCRIPTION OF THE ACTIVITIES

The first PhD thesis will mainly focus on characterization of aquaculture wastewaters, of algal strains, of biomass with the objective of water treatment and biomass valorisation as biofuel and animal feedstuff. This PhD will require using methodologies including lipidomics, genomics, and metabolomics to screen for and develop new strains that exhibit high growth and lipid content, broad environmental tolerances and the ability to produce high value by-products. This PhD thesis belongs to activities 1, 2 in result 1 and activities 1,2,3 in result 2. All the instruments required to perform these 'omics' researches are available at ULg. (Prof. Eppe and Prof. Remacle as supervisors).

The second PhD thesis will be more focused on bioengineering with the set-up of the PBRs, flat plate airlifts, open ponds at laboratory scale, and the design pilots in the laboratory at IUH and in the field at Ninh Thuan, optimization of operating conditions using simulation programs to demonstrate the usefulness of mathematical models. This PhD thesis belongs to activities 3,4,5 in result 1. All the pilots are available at UCl and will be constructed at IUH and Ninh Thuan with the investment costs of this project. (Prof. S. Agathos and Prof. J-L Vasel as supervisors).

PR = GE (North coordinator, including administrative staff of ULg)
PI = LHA (South coordinator, including administrative staff of IUH)

Result 0 N° – Result 0 **Ressources are used efficiently and effectively.**			
R0-A1	Activity 1 Ensure management (admin & finance) compliance with ARES procedures (yearly planning, disbursement and expenditure)	PR: GE PI: LHA	Month 1 to 48
R0-A2	Activity 2 Provide adequate project progress management and interdisciplinary exchanges	PR: GE PI: LHA	Month 1 to 48
R0-A3	Activity 3 Implement project visibility actions	PR: GE PI: LHA	Month 1 to 48

Description of the activities

Activity R0-A1: Activity R0-A1 Ensure management (admin & finance) compliance with ARES procedures (yearly planning, disbursement and expenditure)

PR: GE
PI: LHA
Timing: Month 1-48

Description :

The activity is divided in 4 tasks:

R0_A1_T1: Formalise project implementation arrangements through institutional conventions/partnership agreements based on grant agreement with ARES

R0_A1_T2 : Provide administrative support for procurement of equipment (procedures)

R0_A1_T3 : Ensure clerical daily administrative management and project accounting

R0_A1_T4 : Ensure consolidation of administrative and accounting reporting

Activity R0-A2: Activity R0-A2 Provide adequate project progress management and interdisciplinary exchanges

PR: GE
PI: LHA
Timing: Month 1-48

Description :

The activity is divided in 4 tasks:

R0_A2_T1: Hold 6-montly project review meetings among coordinators and partners

R0_A2_T2 : Prepare and submit annual project progress reports to ARES

R0_A2_T3 : Review project exit strategy at the begining of year 1

R0_A2_T4 : Prepare and submit final activity report

Activity R0-A3: Activity R0-A3 Implement project visibility actions

PR: GE
PI: LHA
Timing: Month 1-48

Description :

The activity is divided in 3 tasks:

R0_A3_T1: Project brochure (electronic version)

R0_A3_T2 : Project web-page (web site)

R0_A3_T3 : Link with ARES CCD

Result 1 N° – Result 1 **A fit to purpose - valorisation technology for saline shrimp farming wastewater treatment is tested at pilot scale.**			
R1-A1	Activity 1 Characterization of wastewater from shrimp aquaculture	PR:GE PI:CR, LHA, TN, NVD	Month 1 to 12
R1-A2	Activity 2 Preparation of a list of potential vietnamese microalgae strains	PR: CR PI: LHA, TN, JLV, GE	Month 6 to 24
R1-A3	Activity 3 Install the laboratory WWT experiment at IUH	PR: LHA PI: TN, CR, JLV, SA	Month 12 to 30
R1-A4	Activity 4 Install the pilot in field at the research center for aqualculture at Ninh Thuan Province	PR: TN PI: LHA, TH, NVD, JLV, SA	Month 24 to 36
R1-A5	Activity 5 Test the performance of nutrients removal with different wastewater characterized in R1_A1 according to the shrimp production period and seasons	PR: LHA PI: TN, TH, NVD, CR; JLV, SA, GE	Month 30 to 36
R1-A6	Activity 6 Economic evaluation of the wastewater treatment process according to the model proposed in 16.2 of the proposal	PR: TK PI: PL, LHA	Month 30 to 36

Description of the activities

Activity R1-A1: Activity R1-A1 Characterization of wastewater from shrimp aquaculture

PR: GE (North Coordinator)
PI: CR (North partner 1), LHA (South coordinator), TN (South partner 1), NVD (South partner 4)
Timing: Month 1-12

Description :

The activity is divided in 4 tasks:

R1_A1_T0: Capacity building of the south partners laboratories through training, equipment and exchange activities (IUH -IESEM and IUH-IBFT laboratories)

R1_A1_T1 : Sampling in site at the aquaculture research center in Ninh Thuan province and 10 other shrimp farms from the same Province at different periods (0 to 120 days) during dry and rainy seasons for basic in line parameters and complete analyses

R1_A1_T2: Analysis of water used for aquaculture (sea and groundwater) and wastewater every day (0 to 120 days) for in line basic parameter measurements (pH, salinity, Nitrogen content, DOC, NH_4^+, TOC, …)

R1_A1_T3: Analysis of water used for aquaculture (sea and groundwater) and wastewater at the beginning and the end of a shrimp pound production for parameters requiring laboratory analysis in IUH and ULg (Characterize organic and inorganic content including antibiotics). Evaluate quality of effluent wastewater to current environmental standards in Vietnam and European.

Activity R1-A2: Activity R1-A2 Preparation of a list of potential Vietnamese microalgae strains

PR: CR (North partner 1)
PI: LHA (South coordinator), TN (South partner 1), JLV (North partner 3), GE (North coordinator)
Timing: Month 6-24

Description :

The activity is divided in 5 tasks:

R1_A2_T0: Capacity building of the south partners laboratories through training, equipment and exchange activities (IUH -IESEM and IUH-IBFT laboratories)

R1_A2_T1 : Selection of microalgae from environment (sea, lake,..), from aquaculture ponds, from a bank research institute in aquaculture

R1_A2_T2: Test the strains with salinated wastewater from aquaculture characterized in R1_A1

R1_A2_T3: Testing and measuring the efficiency of nutrients removal in aquaculture wastewater

R1_A2_T4 Characterization of lipids (fatty acids) and proteins content of the remaining biomass in microlagae

Activity R1-A3: Activity R1-A3 Install the laboratory WWT experiment at IUH

PR: LHA (South coordinator),
PI: CR (North partner 1), TN (South partner 1), JLV (North partner 3), SA (North partner 4)
Timing: Month 12-30

Description :

The activity is divided in 6 tasks:

R1_A3_T1: Pre-treatment of wastewater (sedimentation and homogenization)

R1_A3_T2 : Install high-rate open pond for aquaculture wastewater. Evaluate batch versus continuous reactors (lab scale 200 to 500 L)

R1_A3_T3: Install harvesting system to collect microalgae (filtration and natural floating floculation)

R1_A3_T4: Install closed tubular photobioreactor for microalgae growth

R1_A3_T5 Install post treatment by sand filtration

R1_A3_T6 Mathematical modeling of the bioreactor installation. Dynamic models (using Matlab or others) will be tested to optimize conditions in open and closed photobioreactors. Simulation of scaling-up and feasibility studies will be performed

Activity R1-A4: Activity R1-A4 Install the pilot in field at the research center for aqualculture at Ninh Thuan Province

PR: TN (South partner 1)
PI: LHA (South coordinator), TH (South partner 3), NVD (South partner 4), JLV (North partner 3), SA (North partner 4)
Timing: Month 24-36

Description :

The activity is divided in 4 tasks:

R1_A4_T1: Install closed tubular photobioreactor for microalgae growth (tubular or plastic bags)

R1_A4_T2 : Install high-rate open pond for aquaculture wastewater in situ (10 m^3)

R1_A4_T3: Install harvesting system to collect microalgae (filtration and natural floating floculation)

R1_A4_T4: Install post treatment by sand filtration

Activity R1-A5: Activity R1-A5 Test the performance of nutrients removal with different wastewater characterized in R1_A1 according to the shrimp production period and seasons

PR: LHA (South coordinator),
PI: TN (South partner 1), TH (South partner 3), NVD (South partner 4), JLV (North partner 3), SA (North partner 4), GE (North coordinator), CR (North partner 1)

Timing: Month 30-36

Description :

Wastewater will be tested by measuring classical basic parameters of water quality but also organic and inorganic contents; compared with Vietnamese and International standards water quality

Activity R1-A6: Activity R1-A6 Economic evaluation of the wastewater treatment process according to the model proposed in 16.2 of the proposal

PR: TK (South partner 2)
PI: PL (North partner 2), LHA (South coordinator)
Timing: Month 30-36

Description :

The following ratios and appreciate questions below:

- Estimating input use, feed utilization coefficient, and waste volume discharged per ton live shrimp (or per 1.000 m2 of shrimp pond)
- Estimating scale and seriousness of wastewater pollution in Ninh Thuan due to shrimp wastewater
- Estimating financial loss due to such pollution at shrimp farm
- Estimating economic loss due to such pollution at local scale
- Estimating costs and benefits of water treatment using RENEWABLE solutions (microAlgae application)

Result 2 N° – Result 2 **The valorisation potential of products/biomass produced through saline shrimp farming wastewater treatment is ~~demonstrated~~ tested and documented (biofuel, animal feedstuff).**			
R2-A1	Activity 1 Characterization of the biomass produced from microalgae	PR: CR PI: GE, TN, TK	Month 18 to 30
R2-A2	Activity 2 Valorization of the biomass for biofuel production	PR: LHA, PI: CR, GE, TN, SA, TK, PL, GV	Month 24 to 42
~~R2-A3~~	~~Activity 3 Valorization of the biomass for animal feed production~~	~~PR: TN~~ ~~PI: CR, GE, JLV, TK, PL, GV~~	~~Month 24 to 42~~
R2-A4	Activity 4 Socio-economical evaluation of the complete inegrated approach according to the model proposed in 16.2	PR: TK PI: PL, LHA	Month 36 to 48
R2-A5	Activity 5 Handbook of operating system	PR: LHA PI: TH, NVD, JLV, SA	Month 42 to 48

Description of the activities

Activity R2-A1: Activity R2-A1 Characterization of the biomass produced from microalgae

PR: CR (North partner 1)
PI: GE (North coordinator), TN (South Partner 1), TK (South Partner 2), JLV (North partner 3), SA (North partner 4)

Timing: Month 18-30

Description :

The activity is divided in 3 tasks:

R2_A1_T1: Complete analysis of the biomass content

R2_A1_T2: Dewatering process (open air drying, other)

R2_A1_T3: Conducting an economic feasability assessment of the selected dewatering processes

Activity R2-A2: Activity R2-A2 Valorization of the biomass for biofuel production

PR: LHA (South coordinator)
PI: GE (North coordinator), TN (South Partner 1), CR (North partner 1), SA (North partner 4), TK (South Partner 2), PL (North Partner 2), GV (Industrial South partner)

Timing: Month 24-42

Description:

The activity is divided in 3 tasks:

R2_A2_T1: Test extraction techniques of fatty acids and lipids

R2_A2_T2: Synthesis of biodiesel from fatty acids extracted

R2_A2_T3: Conducting an economic feasability assessment of biodiesel production

R2_A2_T4: Analysis of the remaining biomass after oil extraction

~~Activity R2-A3: Activity R2-A3~~ ~~Valorization of the biomass for animal feed production~~

~~PR: TN (South partner 1)~~
~~PI: GE (North coordinator), CR (North partner 1) JLV (North partner 3), TK (South Partner 2), PL (North Partner 2), GV (Industrial South partner)~~

~~Timing: Month 24-42~~

~~Description:~~

~~The activity is divided in 2 tasks:~~

~~R2_A3_T1: Analysis of the remaining biomass after oil extraction~~

~~R2_A3_T2: Conducting an economic feasability assessment of animal feed production~~

Activity R2-A4: Activity R2-A4 Socio-economical evaluation of the complete inegrated approach according to the model proposed in 16.2

PR: TK (South partner 2)
PI: PL (North partner 2), LHA (South coordinator)
Timing: Month 36-48

Description:

The activity is divided in 2 tasks:

R2_A4_T1: Study of the socio-economic consequences of the decreasing water quality for intensive shrimp farming sector

R2_A4_T2: Study of the socio-economic motivation and constraints for the adoption of biomass WWT by intensive shrimp farms

Activity R2-A5: Activity R2-A5 Handbook of operating system

PR: LHA (South coordinator)
PI: TH (South Partner 3), NVD (South Partner 4), JLV (North partner 3), SA (North partner 4)
Timing: Month 42-48

Description:

All the technical and economical data will be centralized to prepare feasibility studies based on the results obtained for microalgae water treatment and the production of the well-characterized biomass for biofuel and animal feedstuff applications.

Result 3 N° – Result 3 **Aquaculture wastewater treatment and valorisation knowledge and know-how are increased by academic and applied researches and disseminated to the regional government and aquaculture farmers.**			
R3-A1	Activity 1 Increase academic biomass-based WWT know-how and knowledge	PR: GE PI: LHA, TN, CR, SA, TK, PL	Month 1 to 48
R3-A2	Activity 2 Dissemination of biomass-based WWT know-how and knowledge	PR: LHA PI: GE, NT, TH, TK, NVD MT	Month 1 to 48

Description of the activities

Activity R3-A1: Activity R2-A1 name

PR: GE (North Coordinator)
PI:
Timing: Month 1-48

Description :

The activity is divided in 3 tasks:

R3_A1_T1: Selection, recruitment and thesis supervision of two PhD students based on a short list prepared by IUH

R3_A1_T2: Supervision of MSc students from IUH and UEH.

R3_A1_T3: Strengthening of the existing modules of the International Master of Environmental Science regarding WWT and analysis of contaminants (applied courses & laboratory works)

Activity R3-A1: Activity R2-A1 name

PR: LHA (South coordinator)
PI:
Timing: Month 1-48

Description :

The activity is divided in 2 tasks:

R3_A2_T1: Participation to scientific symposiums to present the results of the project

R3_A2_T2: Organisation of technical workshops including steering committee meetings on site with the Department of Science and Technology (regional government) and farmer's union of the Ninh Thuan Province

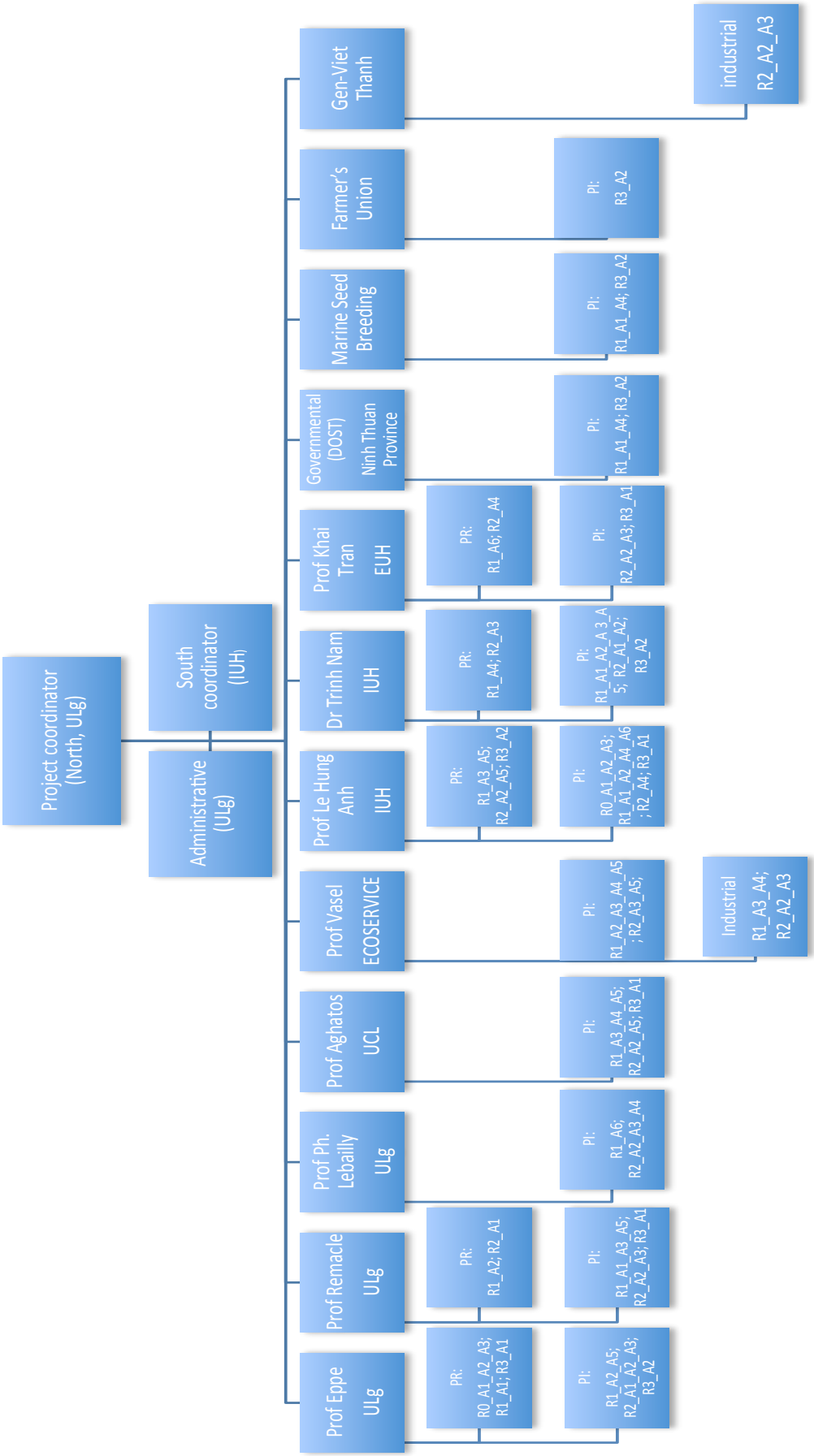
10.3 SCHEDULE

The scheduled model has been filled in and is attached with the proposal

11 PROJECT GOVERNANCE

The governance structure is depicted in the hierarchy chart in next page. The North project coordinator is responsible for the project. He will ensure the coordination of the project (ER0) and he is responsible for the administrative tasks. All the administrative parts will be managed by University of Liège. The South coordinator is responsible of the Vietnamese partners of the project, the administrative tasks in Vietnam are carried out by IUH. The South coordinator works in close collaboration with the project coordinator. The project work is organized around the intervention logic (see logical framework) and clear allocation of roles to each of the project partners at the level of activities and tasks. The Hierarchy depicted in the figure shows all the partners involved in the project; in the level below the partners, one can see all the responsible partners (PR) for the different activities. Each activity has an assigned responsible partner. Some partners can assume several responsibilities. The goal of the responsible partner is the achievement of all tasks within an activity. His role is to integrate proposed strategies to ensure that the workload is organized in a way that it fits with the corresponding results (see logical framework). Then, one level below is the involved partners (PI), where they can interact in many tasks within an activity by providing their expertise and skills to achieve the tasks. Finally, the last level of the hierarchy chart involves the industrial partners in the tasks where they can interact for valorization of the biomass produced.

Governance and RACI (Responsible, Accountable, Consulted and Informed) matrix between partners through the different activities/tasks of the logical framework has been added in the proposal, see attached document.


Project coordinator (North, ULg)
South coordinator (IUH)
Administrative (ULg)
Gen-Viet Thanh
industrial R2_A2_A3
Farmer's Union
PI: R3_A2
Marine Seed Breeding
PI: R1_A1_A4; R3_A2
Governmental (DOST) Ninh Thuan Province
PI: R1_A1_A4; R3_A2
Prof Khai Tran EUH
PR: R1_A6; R2_A4
PI: R2_A2_A3; R3_A1
Dr Trinh Nam IUH
PR: R1_A4; R2_A3
PI: R1_A1_A2_A 3_A 5; R2_A1_A2; R3_A2
Prof Le Hung Anh IUH
PR: R1_A3_A5; R2_A2_A5; R3_A2
PI: R0_A1_A2_A3; R1_A1_A2_A4_A6 ; R2_A4; R3_A1
Prof Vasel ECOSERVICE
PI: R1_A2_A3_A4_A5 ; R2_A3_A5;
Industrial R1_A3_A4; R2_A2_A3
Prof Aghatos UCL
PI: R1_A3_A4_A5; R2_A2_A5; R3_A1
Prof Ph. Lebailly ULg
PI: R1_A6; R2_A2_A3_A4
Prof Remacle ULg
PR: R1_A2; R2_A1
PI: R1_A1_A3_A5; R2_A2_A3; R3_A1
Prof Eppe ULg
PR: R0_A1_A2_A3; R1_A1; R3_A1
PI: R1_A2_A5; R2_A1_A2_A3; R3_A2

12 CROSS-SECTORAL THEMATICS

According to the Belgian Law on Development Cooperation and the different items developed in the document, the RENEWABLE project integrates cross-sectorial dimensions as described in guidelines 5.2.1 and 5.3.1.

- The country factsheet for Vietnam and more specifically regarding the guidelines of CIUF-CUD for the period 2014-2016, our project is perfectly in line with the priority thematic of the management and protection of natural resources including aquaculture and water resources. This thematic developed in the RENEWABLE project is a priority for Vietnam.

- Synergies have been found with Belgian cooperation already supporting environmental sustainability and water resources in Ninh Thuan province (see chapter 8 and 9). The RENEWABLE project will develop its applied research in field in that province in close collaboration with the regional government and other local partners (farmer's union and fisheries research center).

- We have a specific attention to gender equality within our consortium and we will pay attention especially in the selection of the PhD students and master students where we will be ensure the gender equality.

- The environmental dimension of our project including protection of the environment and natural resources is obvious in our proposal and does not require any additional comments.

- Based on remarks from last year and the weakness of the South partners involved in the project, we strengthen our consortium. The South coordinator is the required person to manage a project as the RENEWABLE project in Vietnam. He is fluent in English and German. He knows European people and habits as he spent 10 years in Berlin during its master and PhD. He has already several national and international projects related to wastewater treatment and solid waste. He has a full support from its University for the RENEWABLE project. This was confirmed by a meeting between the Rector of IUH and Prof. G. Eppe during its mission organized in July 2015. The South partners have been further reinforced to cover all the thematic, activities and tasks in Vietnam. The major weakness is related to the management of the administrative part and the budget, as no information are available. We can only mention that existing connection with the administration of IUH in the framework of the executive master IMES works correctly between IUH and ULg.

13 CONTINUED PROJECT (IF APPLICABLE)

If the project extends an activity or a project financed by ARES or another donor, explain the fit between the two and the way in which the new project is based on the results of the previous one. If one or several evaluation(s) have been done, please provide their main conclusions and recommendations.

(4700 characters max, including spaces).

Not Applicable

14 PROJECTS ALREADY SUBMITTED TO ARES (IF APPLICABLE)

The project has been submitted last year. This new proposal has been completely revised in order to take into account the remarks from the reviewers. To summarize, new partners (Prof. Lebailly, North partner and Prof. Tran, South partner) joined the project to cover the socio-economical aspects, highlighted as a weak point in the previous submission. Based on a field trip mission organized mid-July with an expert in logical framework, all the objectives have been revised and reformulated, inducing a completely revised response strategy (see chapter 10). In order to better define the target population but also to demonstrate the feasibility of the project within 4 years, the South coordinator has undertaken to find new support and synergies in Vietnam (see chapters 8 and 9). Governmental South partners from Ninh Thuan province joined the RENEWABLE project. During the mission, we met the director and its team to formalize their participation in our project. This province has many positive arguments (see chapter 9) to develop and install pilots in-situ. We received a full support from the Department of Science and Technology of the Ninh Thuan province. With the president of the farmer's union of that province (assigned as South partner 5), they will help us to contact and diffuse the know-how to the aquaculture farmers of Ninh Thuan province. In addition, the province is equipped with a research center for fisheries and aquaculture. They mainly produce larvae for all the national aquaculture activities and production of shrimps in Vietnam. They are equipped with large size open ponds (1000 m^3) including technical staff and laboratory facilities on site. We visited the infrastructure and met the director who eagerly accepted to take part of our project (South Partner 4). A field pilot will be installed in that research center.

More specifically, responses to the major remarks of the experts have been summarized here below:

- The total duration of the project:

The project has been reduced 60 to 48 months as the master degree in Vietnam is now recognized by the Brussels Wallonia community to start a PhD. The one year additional 60 credits master program at ULg is not required anymore.

- Added value of the project compared to existing program in Vietnam and elsewhere; novelty offered in this context by this consortium

The scientific consortium is established (see history of the project) based on complementary skills in order to ensure that the objectives of the research and valorization will be achieved in Vietnam. We have paid attention that all the skills will be available either in Belgium and Vietnam. Regarding Scientific issues and novelty (see chapter 7.2). In addition, the technology proposed in the RENEWABLE project is in front research in this field with the developments of prototypes in Prof. Agathos and Prof. Vasel laboratories. The instruments, tools and expertise to characterize the micro-algae strains, wastewaters is also an asset for the project with state-of-the art instruments hat will be made available for the project and the PhD students. The added value is the total integration proposed from wastewater treatment to valorization of biomass produced for biofuel production and animal feedstuff installed in Vietnam.

- Integration between the FIRST project in Vietnam and also existing projects already running between Belgium and the Ninh Thuan Province and the RENEWABLE project presented here

The FIRST project (Fostering Innovation through Research, Science and Technology) (Vietnam Worldbank, 2013-2019) will be introduced by the end of 2016 if the RENEWABLE project is accepted. The essence of a FIRST project is related to economical development and support to innovation. The objective of a FIRST project will be to draw benefit of the RENEWABLE research development and to bring the technology into the market. By definition, the FIRST project will integrate the RENEWABLE project to value the results of the research performed within our scientific consortium and to scale-up the pilots. The industrials partners of the RENEWABLE project will be involved in the FIRST project.

In addition, since 2007, the Ninh Thuan province received financial support from Belgium (22 millions €) for projects including water resources. For instance, 'Increase of capacity for assessment and management of water resources (2009-2012)' ; 'Waters resources management and urban development in relation to climate change in Ninh Thuan province 2013-2019)' are projects that are managed in collaboration with our partner 3 (DOST, Department of Science and Technology from the Ninh Thuan province).

- Socio-economic approach of the project should be reinforced and should be included in addition to the

scientific skills already highlighted in the consortium.
The socio-economical aspects of the RENEWABLE project will be covered by the new North and South partners (Prof. Lebailly and Prof. Tran) see chapters 6 and 16.2

- How the companies involved in the project will transfer the technology.

The two companies, partners of the project, will have different tasks and objectives in the project (see response strategy). ECOSERVICE will provide its expertise to design and to implement microalgae photobioreactor in Vietnam. The company will support the project for the scaling-up of bioreactor and the technology (e.g. airlift flocculator) they can provide. ECOSERVICE will also define the methodology to develop and to fit a dynamic mathematical model of the open photobioreactor. GenViet Tat Thanh company is interested to collect the biomass produced for valorization through biofuel production and animal feed production.

- The needs of the targeted population, the farmers and fish industries, is not enough developed (only one task devoted to the beneficiaries, 7 tasks dedicated to research). For instance the farmers will not be asked during the project. How the beneficiaries, stakeholders will use the benefits of the results of the research

The project has been completely revised with new specific objective, new expected results, the targeted population has been clearly defined and identified (i.e. the shrimp farmers from the Ninh Thuan province). The Department of Science and Technology from the government and the Center of Rural Environment of Vietnam Farmer's Union from Ninh Thuan province will help us in organizing meetings, diffusion of know-how, to select farms where training or field pilot plants will be installed.

The budget dedicated to the organization of the diffusion of know-how has been revised and increased to ensure that this task will be implemented though out the 4 years project.

Revised September 15th 2015 (see note aux évaluateurs).

15 RISK ANALYSIS AND MANAGEMENT

Risk	Preventive measures	Corrective management measures
One or the two PhD students drop out during the 4 years project	Make a short list of several potential candidates from IMES IUH-	Adequate supervision of PhD students in Belgium and Vietnam research groups
Master students drop out	Make a short list of several potential candidates from IMES IUH and UEH	Adequate supervision of master students in Belgium and Vietnam research groups
Antibiotic content of fisheries wastewater inhibit algal production	Using recombinant DNA methods and gene transfer to create new strain algae which can resist to antibiotic	Treat wastewater (emerging bioactive contaminants pharmaceuticals, estrogenic compounds, antibiotic resistant genetic material etc.) by different techniques
Contamination of unicellular algae (not axenic algal), such as other species of phytoplankton, phytophagous zooplankton, or bacteria, during handling and poor temperature regulation	A sufficient number of agal strains will be made available by the project (Result 4) Two series of stocks are retained, one which supplies the starter cultures for the production system and the other which is only subjected to the handling necessary for maintenance	- Bacteria can be eliminated from the phytoplankton culture by washing or plating in the presence of antibiotics. - Sterilized culture medium by either physical (filtration, autoclaving, pasteurization, UV irradiation) or chemical methods (chlorination, acidification, ozonisation)
Impact on the sample during shipment from Vietnam to Belgium and from Ninh Thuan province to HCMC	Measure as much as possible basic parameters in situ with the collaboration of partner 4	Specific shipment protocol to maintain the physico-chemical characteristics of the samples
Negative impact of the medium of microalgae culture to environment	The media after harvesting of microalgae will be treated by HCl to convert NaOH into NaCl that is safely to discharge to the environment.	Testing of the medium composition after growing of algae will be tested. The toxicity of the medium of culture will be evaluated and compared to the level A of Vietnamese standard of industrial wastewater for aquaculture processing (QCVN 11: 2008/BTNMT)
Unrealistic productivities of biomass in theory	Exhaustive study of climate conditions of the South Vietnam, in particular Ninh Thuan province The issue of heterotrophy of algal species on metabolite production will be studied specifically within activities R2A2 and R2A3	Duration of photoperiod should be taken into account to get more realistic productivities Take into account the possible heterotrophy of some algal species that would reduce the net productivity of metabolites

16 SUSTAINABILITY

16.1 INSTITUTIONAL SUSTAINABILITY

Four universities are involved in the RENEWABLE project: University of Liège (Faculty of Sciences and Gembloux Agro Bio Tech); Catholic University of Louvain (Institute of Life Sciences); Industrial University of Ho-Chi-Minh City represented by the Institute for the Environmental Science, Engineering & Management (IESEM) and the Institute of Biotechnology and Food Technology and the Economic University of Ho-Chi-Minh City represented by the school of economics.

They are already collaborating through teaching programs and the embedment of the project within academic institutions of the south is key to institutional sustainability and can be illustrated by two examples:

1) ULg and IUH (through North and South coordinators) collaborate since 2010 in an executive master program entitled International Master in Environmental Sciences (IMES). Prof Vasel and Eppe teach two modules in connection with the RENEWABLE thematic: Treatment and management of liquid pollution and Analysis of environmental contaminants, respectively. This project will strengthen the professional relationships and collaboration between our two institutions. Benefits of this research project will have directly an impact in teaching programs of these two modules :

- With the treatment and management of liquid pollution module: Students will be taught about theory and practice in the field of wastewater treatment. A specific focus will be given to treatment of aquaculture, food processing by using algae, subject of primary importance for Vietnamese students interested in Environmental Sciences in regards to the economic activities of this sector in Vietnam. The Pilot installed in IUH laboratories and developed during the RENEWABLE project, will be directly used by students during practical work sessions.
- With the analysis of environmental contaminants module: The students will gain practice about analysis of algae components and biomass composition including the oil content of algae.

2) ULg and UEH (Prof. Ph Lebailly and Prof. Tran Tien Khai) collaborate for a long time and more specifically through a PFS project in a master in ' économie et sociologies rurales' in Vietnam.

The School of Economics of the University of Economics Hochiminh City, Vietnam has studies related to rural economy and environmental economics. RENEWABLE project connect both agricultural and environmental aspects. By the project, the UEH lecturers obtain more practical experiences to develop case studies for the related courses. The connection between the School and other provincial authorities, business sector and Belgian institution would be enhanced.

The RENEWABLE project will strengthen the collaboration between the universities involved for master programs already existing but also with the opportunity to start two PhD theses and 5 master theses related to the RENEWABLE thematics.

16.2 FINANCIAL AND ECONOMIC SUSTAINABILITY

The implementation of wastewater treatment techniques represents costs for entrepreneurs. They are far outweighed by the benefits to the reduction of pollution but in general and Vietnam in particular these externalities are never "paid" by operators. The 'polluter pays' principle is not easy to apply in Vietnam. It is therefore proposed from the start to set up a monitoring able to identify the costs of remediation of water. This will evaluate both the direct costs associated with the implementation of technology, but also the costs of labour. The analysis of these costs in the pilot station will be adapted to the situation faced by farmers.

Particular attention will also be given to economic analysis to quantify the benefit of the technology for pollution control. The aim here is to transpose into taxing the environmental benefits to the quality of the discharged water.

Finally and in order to enhance sustainability, we look for ways to enhance the commercial value for by products. For this, is scheduled to conduct a market study.

To ensure the financial sustainability of the proposed techniques (economic sustainability seems obvious), it is first proposed to establish a monitoring which will calculate the following ratios and appreciate questions below:

- Estimating input use, feed utilization coefficient, and waste volume discharged per ton live shrimp (or per 1.000 m2 of shrimp pond)
- Estimating scale and seriousness of wastewater pollution in Ninh Thuan due to shrimp wastewater
- Estimating financial loss due to such pollution at shrimp farm
- Estimating economic loss due to such pollution at local scale
- Estimating costs and benefits of water treatment using RENEWABLE solutions (microAlgae application and Biofuel/Biomass production;
- Conducting feasibility of technical model scaling up at firm level;
- Estimating costs and benefits of water treatment using microAlgae at larger scale, such as Mekong Delta

Once the data collected, it will be proposed to organize focus groups with various stakeholders to consider how to manage the additional costs associated with application of good environmental practices. All these aspects will be treated in the response strategy (see 10.2)

16.3 APPROPRIATION - SOCIOCULTURAL SUSTAINABILITY

We designed and wrote the RENEWABLE project in a manner to always promote appropriation of the project and its results by the local partners. First of all, we paid attention to associate the necessary and complementary skills in South partners to cover all the thematic of the RENEWABLE project. Second, we dedicated an important part of the budget to equip South laboratories and research centers with pilots and analytical instruments to develop all the applied research in Vietnam. Third, non-academic South partners joined the RENEWABLE project. We have support from the government of Science and Technology of Ninh Thuan province ; the farmer's union association and the research center for fisheries of the same province. All these partners are in daily contact with the beneficiaries of the project. We met all these South partners during the mission organized in July 2015 and they were very delighted to take part in the project. The new partners were recommended by our South coordinator. It clearly demonstrates the interest of the South partners to be active actors in the project. It is also important to note that the South coordinator has a full support from its academic authorities.

In addition, the provincial government of Ninh Thuan will be called to take policies to encourage the adoption of technology by farmers. So, to ensure the full cooperation of provincial authorities it is proposed to hold biannually meetings of provincial Steering Committee. The Steering Committee will include in addition to the project partners, the following representatives:

1. Head of steering committee: Mr. Tran Quoc Nam, Vice chairman of People Committee of Ninh Thuan province

Member:

2. Mr. Le Kim Hung, Director of Department for Science and Technology

3. Mr. Phan Quang Thuu: Vice Director of Department for Agriculture and Rural Development

4. Mr Truong Xuan Vy: Vice Director of Department of Planning and Investment

5. Mr. Le Tien Dung: Deputy Chief of the People Committee of Ninh Thuan province

6. Mr. Bui Anh Tuan: Director of Department of Natural Resources and Environment

7. Mr. Nguyen Hoang: Vice Director of Department of Finance

8. Mr. Nguyen Van Duc: Vice chairman of People Committee of Ninh Phuoc distric

9. Mr. Kieu Nho Bon: President of Farmer Union of Ninh Thuan province

10. Mr. Pham Thanh Hung: project coodinator in the Ninh Thuan province, secretary of the steering committee.

The objective of these meetings is to present the project results with particular attention to aspects related to the costs and ways to make the water process profitable economically. This will especially consider a mechanism taxes and / or subsidies to facilitate the adoption of technology.

Regarding the sociocultural sustainability of our project, it is addressed through two strategies. The first one is to disseminate information and training to target beneficiaries including relevant government. This task will be continuously delivered during the 4 years of the project. Tools such as steering committee meetings, seminars, workshops, website, contact through framers' association will be used to promote and explain the environmental issues. Government and associations (e.g. farmer's union) will take over the promotion and diffusion of know-how once the project has ended.

In order to ensure mid/long-term acceptance of the changes, the second strategy of the RENEWABLE project will focus on high education of young Vietnamese students through PhD Students and master programs. Two PhD students will have the opportunity to share their time (half-half) between Belgium and Vietnam and also master thesis will be devoted to the applied research of our project. In a broader view, it will have a positive impact to master and undergraduate students enrolled at the Industrial University of Ho-Chi-Minh City following Environmental topics by the reinforcement of knowledge in this field through teaching, instruments and pilot installed in laboratories and IMES collaborations. By this approach, we are convinced that our project could start a sociocultural sustainability related to the environmental thematic addressed here by the reinforcement of education of young Vietnamese students (linked with 16.1).

16.4 ENVIRONMENTAL SUSTAINABILITY

Inherently, the RENEWABLE project is oriented towards environmental sustainability. It fits perfectly with the priority thematic of the ARES-CCD document for Vietnam highlighting management and protection of natural resources related to water issues with a strong emphasis in environmental protection and sustainable development. No additional comments are added in this section, as environmental sustainability is addressed throughout the entire proposal.

17 HUMAN RESOURCES

The scientific consortium is based on complementary skills between the North and the South partners. All the skills and expertises are covered either in the North and in the South regarding the different research and application topics of the RENEWABLE project.

The expertise of the North promoter, **Prof. Gauthier Eppe** (ULg, Chemistry Department) is analytical chemistry and environmental chemistry related to the development of quantitative methods for the measurement of organic pollutants and metabolites in complex biological matrices using gas chromatography- mass spectrometry (GC-MS). Since 2010, he is collaborating with the Industrial University of Ho Chi Minh City (IUH) where he is teaching environmental analytical chemistry in an executive master in collaboration between ULg and IUH. Prof. G. Eppe and Prof. C. Remacle (ULg) collaborate for more than 3 years in the investigation and understanding of the regulation of storage carbohydrate metabolism in *Chlamydomonas reinhardtii* by using genetic and metabolomics approaches. They study the influence of mutations affecting starch synthesis or content on algal metabolism as well as the identification of molecular and metabolic factors.

The expertise of **Prof. C. Remacle** (ULg, Life Sciences Department) is genetics and physiology of microalgae. Her lab has a vast collection of strains of microalgae and of mutants affected in energetic processes (photosynthesis and respiration). It is fully equipped for axenic algae cultivation, for genetic and physiological analyses (O_2 exchanges, fluorescence measurements for evaluation of photosynthesis performances) and with multiple small phoobioreactors for control growth analyses in various conditions of light intensities and gas exchanges.

The expertise of **Prof. Ph. Lebailly** is agricultural economics and rural sociology and development. Prof Lebailly has a long standing collaboration Vietnam through teaching activities (PFS), research project, master and PhD students exchange programs with Vietnam. He received 'insigne pour l'œuvre de l'éducation' by the Ministry of Education in Vietnam in 2007.

The expertise of **Prof. J-L Vasel** (Emeritus Associate Professor ULg, currently consultant and private North partner in this project) is specialized in water and waste treatment including technical developments from pilot plant to scale-up systems. He develops mathematical models to optimize biochemical processes related to this topic. Prof. Vasel had several projects in Vietnam in collaboration with the Vietnamese Academy of Science and Technology (WBI and PIC, see section 6). His local knowledge in the field and expertise is definitely an asset for the RENEWABLE project, especially in the field of HRAP (High Rate Algal Pond) design, modelization and management..

The expertise **of Prof. S. Agathos** (UCL, Earth & Life Institute) is bioengineering. His laboratory (GEBI unit) studies bioprocess design and the application of cells and enzymes in bioreactors suitable for efficient production of high-value substances or for pollution control. GEBI has unique facilities combining analytical equipment and a complete pilot plant with bioreactors of various sizes and has particular experience in the technological exploitation and scale-up of fragile cells such as microalgae and animal cells. Prof. Agathos has a long-standing collaboration on bioremediation with the Institute of Biotechnology of the Vietnamese Academy of Science & Technology (VAST) in Hanoi since 2002.

The expertise of the South promoter, **Prof. Le Hung Anh** (IUH, Institute for the Environmental Science, Engineering & Management) is environment technology and WtE (waste to energy). His institute has labs for wastewater treatment, solid waste treatment, exhaust gas treatment. He is the coordinator for several international R&D projects in Vietnam. In international master course on environmental science (IMES) between ULg and IUH he is the co-teacher for Prof. Vasel in module Treatment and management of liquid pollution. He is the one of the founder of Asian Network for Environment and Energy (ANEE). His recent research focuses on wastes and biomass to energy.

The expertise of **PhD. Trinh Ngoc Nam** (IUH, Institute of Biotechnology and Food technology) is molecular biology of plant and plant developmental genetics. His institute has laboratories for microalgae isolation, selection and classification using molecular biological techniques. It is full equipped for microalgae cultivation, nucleic acid extraction from microalgae and PCR system for analysis effect of abiotic factors to gene expression in microalgae.

The expertise of **Prof. Tien Khai Tran** (UEH, School of Economics) is agricultural economics and rural development. His department studies on value chain of agricultural products and ways to upgrading the value chain. Valuation of environmental loss due to inappropriate techniques in value chain's production is his interest. Khai has long collaboration to Belgian partners, especially Prof. Lebailly through educational and study activities.

Five non-academic partners (4 from Vietnam, one from Belgium) from government, association and private companies are also involved in the project to support the project in terms of giving access to aquaculture farms and the marine seed breeding facilities to install a field pilot in Ninh Thuan province, access to the target population through association and private company interested to create new market from biomass valorization (biofuel and feedstuff for animals from microalgae).

18 BUDGET BY LINE ITEMS

18.1 RESOURCES REQUESTED BY ARES

Provide an exact, detailed breakdown of the expenses planned by budget item. The total initial budget requested is the maximum budget the project can expect to receive even if, after budget verification by ARES, it becomes apparent that some items were forgotten or underestimated. The only changes authorised are to items contained in the maximum budget envelope.

In the event that a proposal is received with a budget that doesn't comply with financial standards, ARES reserves the right to correct the information provided to ensure conformity with the standards.

18.1.1 Budget preparation

Please complete the budget sections in the order below, **detailing the items and calculations** and referring to the attached vade-mecum.

a) Preparation expenses

Include:

- Travel expenses: (ticket price X the number of assignments)
- Per diems
- Lodging costs

Refer to the "applicable amounts" document for per diem amounts and lodging expenses
http://www.cud.be/images/stories/docs/DOCS-REFERENCE/ARES-CCD-Montants-applicables.pdf

b) Investment costs

#	Equipment	Model	Manufacturer	Quantity	Value per Each (EURO)	Amount (EURO)
1	Growth chamber	High illumination, F230	Taiwan Hipoint, Taiwan	2	2.992,33	5.985
2	Ultrasonic cell disruptor	SONICS Vibracell VCX1500 Ultrasonic Cell Disrupter	USA	1	11.282,04	11.282
3	Microscopy with camera system	Leica DMI3000 B	Leica, Germany	1	24.503,71	24.504
4	Refrigerated centrifuge	SIGMA 3-18KS High Speed Refrigerated Centrifuge	Sigma, Germany	1	6.732,44	6.732
5	photobioreactor	DASGP® Parallel photobioreactor System for Phototrophi	Eppendorf	1	55.055,00	55.055
					Total Amount	103.558

Investments justification:

1 : The growth chambers will be installed in IUH laboratory and in field in Ninh Thuan province at the research feed breeding center for algal culture studies and optimisation process related to activities R1_A2, R1_A3 in the project.

2 : Disruptor will be installed in IUH laboratory (Vietnam) for disrupting the algae cell in analysis of lipid content or DNA isolation study. The use of this instrument is not available in the laboratory IUH and is necessary to achieve the objectives of activities R2_A1, R2_A2, R2_A3.

3 :Microscope system will be installed in IUH laboratory (Vietnam) for microalgae isolation, determination properties of cell structure morphology and classification microalgae strain related to activities R1_A2

4 : Refrigerted centrifuge will be installed in IUH labolatory (Vietnam). This instrument will be used for collection microalgae biomass and related to activities R2_A1, R2_A2, R2_A3.

5 : Photobioreactor will be installed in IUH labolatory (Vietnam). This instrument is used for microalgae culture studies and seeding related to activities R1_A2, R1_A3

c) Operating costs

- In Belgium (**exceptional)** and in relation to analyse wastewater, microalgae for biofuel and feedstuffs composition (R1_A1, R2_A2 and R2_A3) performed at ULg and applied research on pilots at UCL, that cannot be performed in Vietnam (see Vade mecum). Thise activities requires state-of-the-art techniques. It includes the use of a GC/MS, an ICP/MS and HPLC-MS, mutli-cultivator nitrogen tank, spectroscope dedicated to fluorescence analysis and a camera, oxygraph for oxygen measurement. All together, these instruments cost much more than 1 million € and they are not available in Vietnam. Prof Eppe and Remacle will offer the possibility to the PhD students to use these instruments during the RENEWABLE project. The use of these instruments is necessary. Research and framing costs per PhD student will not cover the running cost of those instruments regarding the number of samples to analyze. We ask the project to partially (50%) contribute to the running costs of the analytical instruments. The remaining 50% will be in charge of the North partners. Running costs of the instruments: 6000 €.
- In addition to classical laboratories supplies and consumables that will be covered by the research and framing costs, additional costs related to equipment and accessories to run the photobioreactors PBR (electrodes and cables for CO2 and O2 monitoring, thermocouples, accessories of PAM florometer, tubing, cables, brackets, pumps, valves, manifolds, pipes, heat exchanger/water bath accessories for PBR temperature control, magnetic stirrers, hot plates and heating jackets/sheets, rotary shaker trays and clamps, glassware for sampling and synthesis, cylinders, syringes, beakers, glass-blowing service for PBR accessories, supplies for HPLC, FPLC or GC [cartridges (C18, C8, ...), pre-columns and HPLC columns, GC capillary columns, degasser line filters , filtration of the mobile phase, pressure drop regulator, filters for syringes, stainless steel fittings, accessories and septa, capillary tubes, , ...], optical fibers for PBR, glassware-baths-racks for molecular characterization (PCR, electrophoresis, etc), especially to run the prototype pilot flat plate airlifts PBR, only available at UCL during R1_A2 and R1_A3 : 6000€

- In Vietnam
- Disposables (Consommables)
- Operation in Laboratory: 48 months x 250 € = 12000 €
- Operation in Pilot : 12 months x 500 € = 6000 €
- Fuel : travels from HCMC to Ninh Thuan province (about 750 km for a return travel : 5000 € for 48 months
- Communications:
- A budget is allocated to ER3 of the project regarding the dissemination of know-how
- Years 2016, 2017,2018 : 5000 € per year. Years 2019 and 2020 : 10000€ per year with the objective to reinforce the activities related to information, training of the beneficiaries at the end of the project.

d) Staffing costs

1 administrative staff x 48 months x 250 € = 12.000 €

The staff will be in charge of administrative tasks related to the organisation of meetings in Vietnam for the dissemination of information towards beneficiaries, website, collection of data, writing reports and translation in Vietnamese.

e) Scholarship expenses

Doctorate scholarship **for 2 PhD students** :

- Travel expenses 1000€ x2 x 5 = 10000€
- The number of scholarship recipients : 2
- The length of each recipient's scholarship 4 years
- A detailed calculation of the scholarship amounts

48 mois	2016 (8 mois)	2017	2018	2019	2020 (4 mois)
Frais de mission	150 €	150 €	150 €	150€	150
Allocation de subsistance Belgique	2*1600 =3200 €	6*1600 =9600 €	6*1600 =9600 €	6*1600 =9600 €	4*1600=6400 €
Allocation de subsistance Vietnam	6*250 = 1500€	6*250 = 1500 €	6*250 = 1500€	6*250 = 1500 €	0
Installation (1 fois la première année)	550€				
Inscription	100€	100 €	100 €	100€	Pas nécessaire
Frais de retour et thèse (1 fois la dernière année)					700€
Frais d'encadrement	2x500 = 1000 €	6 x500 = 3000 €	6 x500 = 3000 €	6 x500 = 3000 €	4x500=2000 €
Frais de recherche	2 x1000 = 2000 €	6 x 1000 = 6000 €	6 x1000 = 6000 €	6 x1000 = 6000 €	4x1000= 4000 €
Déplacement des boursiers	1000 €	1000 €	1000 €	1000 €	1000 €
Frais de gestion	1431	2654 €	2654 €	2654 €	1715 €
Total for **2 scholarships**	20431 €	45354 €	45354 €	45354 €	30215 €

In 2016, 8 months (2 months in Belgium and 6 months in Vietnam). In 2020, 4 months in Belgium

- If applicable, the institution where the recipient is registered : The two PhD students will be enrolled at ULg.

f) Travel expenses

Belgium partners :3 partners in 2016, 2 partners in 2017, 2 partners in 2018, 2 partners in 2019, and 2 partners in 2020

Vietnam partners: 2 partners to Belgium for short stay for years 2016, 2017, 2018, 2019.

The cost of a trip 1000 €

In total 19 x 1000 €= 19000 €

g) Stay expenses

GE : 4 stays, 5 days, 120 € per night = 2400€
LHA: 4 stays, 5days, 125 € per night = 2500€
CR : 2 stays, 5days, 120 € per night =1200€
AS : 2 stays, 5days, 120 € per night =1200 €
JLV :2 stays, 5days, 120 € per night = 1200€
PL : 1 stay, 5 days, 120 € per night = 600 €
TN : 3 stays, 5days, 125 € per night =1875 €
KT : 1 stay, 5 days, 125 € per night = 625 €

Per diem
GE : 4 stays, 5 days, 49 € per day = 980€
LHA: 4 stays, 5days, 75 € per day = 1500€
CR : 2 stays, 5days, 49 € per day =490€
AS : 2 stays, 5days, 49 € per day =490 €
JLV :2 stays, 5days, 49 € per day = 490€
Pl: 1 stays, 5days, 49 € per day = 245€
TN :3 stays, 5days, 75 € per day =1125 €
KT : 1 stay, 5 days, 75 € per day = 375€
Refer to the "applicable amounts" document for per diem amounts and lodging expenses
http://www.cud.be/images/stories/docs/DOCS-REFERENCE/ARES-CCD-Montants-applicables.pdf

h) Shipping costs

- Shipping all equipments is estimated to 20000 €

i) Margin for insufficient budget forecast

See the detailed budget attached

j) Administrative costs

See the detailed budget attached

18.1.2 Summary budget table

Budget item	Amount (in €)
Preparation expenses	0€
Investment costs	103558€
Operating costs	70000€
Staffing costs	12000€
Scholarship expenses	186708€
Travel expenses	19000€
Stay expenses	17295€
Shipping costs	20000€
Margin	21428,04€
Administrative costs	32780,09€
TOTAL	**482768,98€**

18.1.3 Detailed budget table

Attach a detailed budget table in euros for the total project period using the MS Excel spreadsheet model provided.

18.2 CONTRIBUTION FROM THE LOCAL PARTNER(S) AND OTHER DONORS (CO-FINANCING)

Indicate the contribution made by the local partner(s) and by other donors for the budget items below.

Enter an overall amount for each budget item with a breakdown of the amount (e.g. staff expenses equal to X FTE for Y months). Repeat the table for each partner and donor.

Refer to the attached vade-mecum for information on what is covered by each budget section.

a) Staffing

b) Infrastructure

c) Equipment

d) Operations

e) Others

18.3 OTHER PROJECT FINANCING REQUESTS

Has this proposal or a similar proposal already been submitted to another donor? If yes, to which one(s) and what was the outcome, if known?

Not applicable