Integrated Renewable Energy Solutions for Aquaculture Processing; ENERFISH

Hidde Ronde, Aulis Ranne, Eric Peirano, Ian Byrne and Huy Le Duc

***Abstract*-- The European Union Framework Programme 7- ENERFISH project (** www.enerfish.eu**) aims to demonstrate a new poly-generation application with renewable energy sources for the fishery industry in Vietnam. From the energy viewpoint, the fish processing plant can be made energy self-sufficient, when the fish waste oil is processed in a biodiesel processor and further converted to electricity and heat in a CHP unit.**

The ENERFISH advanced CO_2 based freezing/cooling system requires optimization and control system planning of special high-pressure equipments. The high-efficiency cooling system can be tuned to be up to 14 % more efficient than conventional systems.

The economical optimization model shows that in the Vietnamese demonstration case the electricity production is, due to the low electricity tariff, uneconomical (except during electricity blackout), even if cogeneration heat can be utilized. This prompted a design of the plant (in this particular demontration case) whereby the necessary heat for the biodiesel process is taken from the waste heat produced by the compressors of the CO_2 cooling system. According to the calculations and assumptions presented in this article, the profitability of biodiesel production from fish cleaning wastes in Vietnam depends stronly on the market prices for fish waste and fish oil. Different business case scenarios are being described.

***Index Terms*-- Energy efficiency, biodiesel, business scenarios, cogeneration, environmental economics, distributed power generation, food technology, fuel technology, waste heat, waste recovery.**

I. Introduction

THE Enerfish process is well suited for fish processing units were there is a sufficient daily amount of wastes to produce biodiesel. Figure 1 puts forward a schematic chart of the Enerfish process with the main raw materials, by-products and outputs. This scheme suggests at least five different business models.

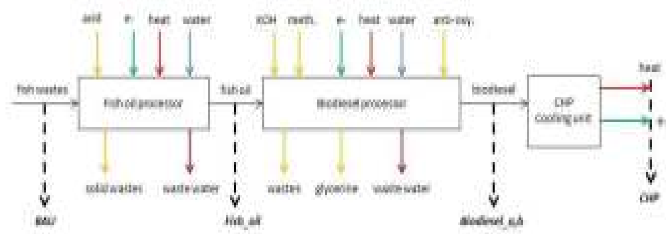

Fig.1. Schematic view of the Enerfish process. Dotted arrows: business models. Acid: formic acid, e-: electricity, KOH: potassium hydroxide, Meth: methanol, anti-oxy: anti-oxidant.

The different business models are given by the vertical dotted arrows.

- BAU: this is the business as usual scenario where fish wastes are sold to the market.
- Fish-oil: the company only invests in a fish-oil processor and sells fish oil to the market.
- Biodiesel_a: the company invests in both a fish-oil processor and a biodiesel processor and sells the biodiesel to the market (as well as the main by-product, i.e. glycerine).
- CHP: this is the "Biodiesel_a" business model with a supplementary investment in a CHP (combined heat and power) unit which produces electricity and heat. Electricity and heat can be sold to the market (to the grid for electricity and to a local heat network if any) and/or can be used to produce energy for the Enerfish process unit. If the production of biodiesel is sufficient, the surplus (part which is not used for combustion in the CHP unit) can be sold to the market.
- Biodiesel_b: the company only invests in the biodiesel processor, i.e. it sells its wastes to a fish-oil processor and buys back fish oil. Biodiesel and glycerine are sold to the market.

One of the main features of the Enerfish project is poly-generation: a cooling/freezing cascade based on CO2 is being installed. This investment is accounted for in a variant of the "CHP" business model where part of the produced electricity is used in the compressors of the cooling/freezing unit. A profitability analysis is going to be carried out for the Enerfish unit under operating conditions, i.e. mass flow rates and enthalpies, which are taken from the preliminary work performed in [1,2]. All prices and cash flows for these

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variables are computed in Euros, i.e. the risks inherent to fluctuations in currencies are not directly accounted for.

The profitability of the different business models is investigated in terms of NPV, which is the sum of all discounted cash flows, including investments, during the economic period which is under investigation. This analysis is performed without accounting for taxation (EBITA) so that the outcomes of the calculations are independent from the financial strategy of the company or its taxation scheme. If a business model is found to be profitable with this preliminary analysis, a financial (taxes) framework, which depends on the business model, the country, etc., should be applied for further investigations.

The analysis is performed as for a regular investment project, with an initial investment, that generates positive (earnings) and negative (costs) cash flows during n years of operation. All cash flows are expressed in constant currency, i.e. free from any inflation which is supposed to be constant. These cash flows are then discounted with a weighted average cost of capital (WACC) and their sum gives the net present value of the project. The profitability index of the project, PI, i.e. the ratio PI = NPV/I, yields a measure of the discounted benefits per invested unit of currency.

II. Results

Today, according to ECC, fish wastes are traded at 244 Euros/ton, fish oil is traded at 680 Euros/ton and biodiesel at 687 Euros/litre (in Vietnam). These numerical values differ from the ones taken in [1], especially fish wastes, i.e. 100 Euros per ton instead of 244 Euros per ton.

Table 1 shows the different cash flows associated with each component of the Enerfish process computed from the ECC data and the economic variables displayed in Table 2.Table 2 puts forward the economic variables that have been chosen as a preliminary computation (inflation, equity, debt, investment and OM costs, etc.). Table 2 shows that there are no OM costs for the fish oil and Diesel oil processors as well as for the auxiliaries. No data was available and therefore it has been assumed that the cash flow generated by these costs do not influence too much the results. The sum of the cash flows displayed in Table 1 represents the total cash flow per day that could be expected from the "CHP" business model. Obviously no profitability can be expected. These cash flows show that the important economic variables are the market prices of the fish cleaning wastes, fish oil, and biodiesel. The market prices of electricity and heat are important for the cash flows generated by the CHP unit, but they are not first order terms for the overall cash flow values. Table1. Daily cash flow associated with the numerical values as given in text and [1] (OM: operating and maintenance costs).

Fish oil processor	€/d
fish cleaning wastes	-19764
acid	-1100
fish oil wastes	5040
fish oil	11560
electricity	-30
heat	-80
OM*	
Total	-4374

Diesel oil processor + tank	€/d
fish oil	-11560
potassium hydroxide	-1040
methanol	-750
water	0
electricity	-3
heat	-12
biodiesel	8931
glycerine	400
residues	0
Anti-oxidant	-240
OM	
Total	-4274

CHP/Diesel unit	€/d
gas oil	0
bio Diesel	-1098.67
electricity	298
heat	162.855
OM	-175
Total	-813

If a value of 100 Euros/ton is taken, as in [1], the cash flow for the fish-oil processor becomes positive (7290 Euros/day) and the overall cash flow as well. Profitability can be expected from the CHP business model with a lower price for fish cleaning wastes (profitability is generated by the fish-oil processor).

TABLE 2
ECONOMIC VARIABLES FOR THE COMPUTATION OF THE NPV OF THE BUSINESS MODELS.

Economic variables : cost of capital, duration of project, recovery factor, etc.			
i	inflation rate	0.02	
d_y	number of processing days/year	300	days/year
n	economic duration of the project	10	y
r_inv	investors' interest rate	0.1	
x_inv	investors' share	0.2	
r_loan	bank loan	0.06	
x_loan	bank's share	0.8	
Investment costs			
I_fop	fish oil processor	400,000	€
I_Dop	Diesel oil processor	450,000	€
I_CHP	Diesel/CHP unit	220,000	€
I_aux	auxiliaries, control system, etc.	100,000	€
si	subsidies (% of total)	0	
OM (operation and maintenance) and refurbishment costs			
vc_CHP	CHP unit	1.84	€/MWh

With the numerical values of Tables 2 and [1], (i.e. a fish cleaning waste price of 100 Euros/ton), the profitability of the project is extremely high, and i.e. a PI of 3.37 is reached after 10 years. For the lifespan of the CHP unit, an average value of ten years has been taken. Note that in the case of a minimum lifespan of 5 years for the CHP unit, the PI would still be 2.68. As a matter of fact, under these assumptions (110 Euros/ton for the fish wastes) the project is so profitable that one could invest in the cooling/freezing system as well (720,000 Euros in investment and 5.5 MWh of daily electricity consumption) and obtain a PI of 2.28. In such a case the PBT would be 2.6 years.

III. Sensitivity Analysis and Discussion

A. CHP business model

As seen in the previous section, for the CHP business model, profitability mainly depends on the price of fish cleaning wastes and to some extent on the price of biodiesel. The cash flows in Table 1 clearly show that it is more profitable to sell the biodiesel directly to the market than to produce electricity. That is why, the number of hours at full load, for the CHP, has been set to 6.3 hours/day, i.e. it corresponds to an energy production (electricity and heat) which covers the needs of the Enerfish process.

Figure 2 displays the NPV as a function of the fish cleaning waste price in two different cases: with a cooling unit and a 5 year lifespan for the CHP unit and without a cooling unit and a 10 year lifespan for the CHP unit. Economic duration of project: 10 years. In both cases the price of the fish cleaning wastes must be below 120 Euros/ton in order to reach profitability (120.7 for the former case and 116.6 for the latter case). The supplementary investment costs for the cooling system (50% percent more) and the CHP unit (double investment) do not make a difference. As a matter of fact, if the fish cleaning wastes were to be bought at the market price (244 Euros/ton), a price for biodiesel of at least 1500 Euros per ton would be necessary in order to reach profitability.

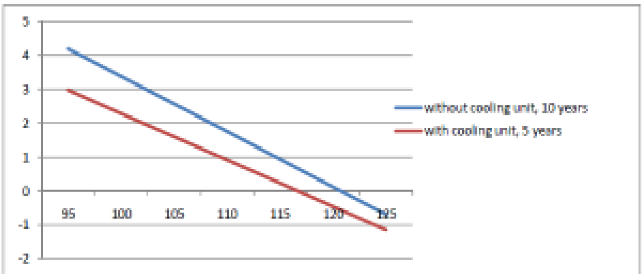

Fig. 2. CHP business model. PI as function of the fish cleaning waste price in two different cases: with a cooling unit and a 5 year lifespan for the CHP unit and without a cooling unit and a 10 year lifespan for the CHP unit. Economic duration of the project: 10 years.

B. Fish oil business model

In such a business model, an economic duration of 15 years is taken as it corresponds roughly to the lifespan of the equipment. In such a case, a maximum price of 188 Euros/ton can give profitability (it is the value which yields a zero NPV after 15 years).

For a market price of 244 Euros/ton for the fish wastes, the minimum price value of fish oil which gives profitability is 948 Euros/ton. Therefore, under current market conditions, such an investment could be profitable, i.e. fish oil is currently traded in international markets at 1500 US$/ton which is approximately 1100 Euros/ton. However, Figure 3 shows that such price levels are not likely to hold for a period of 15 years since they are correlated to crude oil price. One could argue that crude oil is going to keep its high prices, but such an assumption can be risky for the 'Enerfish' investor.

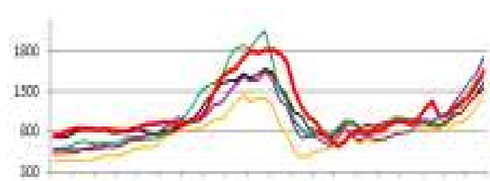

Fig. 3. Market prices for palm, rape, soya, sun, coconut and fish oils from January 2006 to December 2010 [3].

C. Biodiesel_a business model

Table 1 shows that this scenario is rather similar to the CHP one since the cash flows generated by the production of heat and electricity are much smaller than those generated by selling biodiesel to the market.

The limit values are roughly the same as in the CHP business model. A market price of 133 Euros/ton for the fish wastes is the maximum value for profitability for an unchanged price of biodiesel. If the price of biodiesel is the variable and the price of fish cleaning wastes is set at 244 Euros/ton, biodiesel must be sold at 1377 Euros/ton to reach a zero NPV.

D. Biodiesel_b business model

Again, in that case the prices of fish oil and biodiesel must reach values that are far from the market values in order to reach profitability.

IV. Preliminary conclusions

A market study has been performed for a biodiesel based poly-generation process (electricity, heat, cooling) where fish wastes are used to produce fish oil, which is transformed into biodiesel. The process under investigation is built upon the "Enerfish"demonstration project in Vietnam where every day an aquaculture farm and its fish processing plant produce 80 tonnes of catfish wastes.

The study shows in a first part that aquaculture farms are the main niche market for this technology; aquaculture has a very high efficiency in terms of waste processing since there are almost no losses. Waste processing can be performed on site, thus avoiding logistics and GHG emissions generated by the transports. The main markets for aquaculture will be Asia, with China representing already today two third of the world's aquaculture production; Europe is a rather small market, aquaculture is mainly focused on cultured salmons.

There is no specific demand today for fish wastes or fish oil to produce biodiesel. The main uses of fish wastes are the production of fishmeal and fish oil (which is a by-product of fishmeal production) mainly for diets for aquaculture and farmed animals. Two sectors have increased their pressure on fish oil supply: the human food industry which needs omega 3 fatty acids (fish oil) and the pharmaceutical industry which generates high-added value products from fish wastes.

The market prices of these two commodities (fish wastes and fish oil) exhibit large variations. Economic modeling shows that under current market conditions, profitability can only be expected for the production of fish oil (and value added proteins) from fish wastes. Enerfish-like processes are likely to remain technical solutions for niche markets where fish wastes are not valorized and/or where there is no organized supply of fuels. This might be the case of remote territories such as islands or regions in developing countries.

These preliminary findings show that as for biodiesel produced from vegetable oil, biodiesel produced from fish oil must be subsidized at the moment in order to reach profitability

V. References

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VI. BIOGRAPHIES

Hidde Ronde, Doctor of Chemistry (Utrecht, 1977), former docent at the University of Technology at Delft (the Netherlands) and former Programmed Officer Environmental Chemistry and Physics at UNEP /GEMS (Global Environment Monitoring System, Nairobi, Kenya).

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Aulis Ranne, B.Sc. in Mechanical Engineering (1970), M.Sc. (1976) and Lic.Tech. (PhD) (1982) from Department of Mechanical Engineering, Helsinki University of Technology. His specialization focuses on energy systems and energy economics: analysis, innovation, optimisation and management of energy systems covering the whole energy chain: fuel supply, energy production, distribution, end-use, and environmental impacts, e.g. at the present, he leads the VTT teamwork in EU SYNERGY and GREENERGY projects.

Eric Peirano graduated in 1990 from ENSAM Paris in mechanical engineering and in 1991 from California State University in computer simulation. From 1991 to 1993, he occupied various R&D positions in the field of real-time simulation, in particular thermo-hydraulic applications. In 1992, he moved to Sweden where he obtained a Ph.D. in Energy Conversion at Chalmers University (1998). From 1997 to 1998, he was a consultant in several industrial fields (process, energy and transport). In 2000, he joined INRIA in Sophia-Antipolis as guest researcher where he developed probabilistic numerical methods for problems in industrial fluid mechanics. In 2002, he entered ADEME as an expert in charge of the development of R&D activities in the renewable energies sector as well as smart grids. In 2006, he became Deputy Head of the Renewable Energies Department at ADEME. After obtaining a Master's degree in finance (Risk and Asset Management) from Edhec Business School in 2009, he joined Technofi as executive Vice-President where he currently develops a commercial offer in the field of new materials and eco-manufacturing.

Ian Byrne MA Mathematics (1978) University of Oxford, Fellow of the Institute of Chartered Accountants in England & Wales (1981), Member, Energy Institute (1990). Ian is the Deputy Director of the NEF; his knowledge base is in energy efficiency, energy policies & strategy, analysis of carbon saving opportunities. He has been involved with the Carbon Trust's Energy

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Mr. Le Duc Huy obtained his B.Eng. degree in Electrics from the Technical University of Ho Chi Minh City (Vietnam). He has been acting as a project coordinator for several energy efficiency projects in food processing.