Potential Market Demand Study

Assessment of the market potential of FS treatment treatment products in Son La, Bac Ninh and Ba Ria

PURR – Partnership for Urban Resource Recovery

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Contents

1 Introduction

In Vietnam, 50 to 70 % of urban households in urban areas have septic tanks that produce faecal sludge (FS) (WHO and UNICEF, 2013). Management solutions for the accumulated FS are typically lacking. In this study, viable FS treatment in Vietnam based on resource recovery options were evaluated. Resource recovery is the treatment of wastes in valuable products that become a resource in industry or agriculture. This study was conducted in Bac Ninh, Son La and Ba Ria, within the PURR project and followed the Market Driven Approach for Selection of Faecal Sludge Treatment Products (Schoebitz et al, 2016 – available at www.sandec.ch/fsm_tools).

Son La province, located in the North West mountain region of Vietnam, covers a surface of 1,417,444 ha, of which about 20% is dedicated to agricultural land. The province, constituted of 1 city and 11 rural districts, is home of 12 ethnic groups with total population of more than 1.1 million (DARD Son La, 2015). Son La URENCO collects FS and operates a small pre-treatment unit, from which the treatment products are used as soil amendment for green areas of the city.

Bac Ninh province is located near Hanoi and covers a surface of 882,700 ha. It is comprised of 1 city, 1 town and 6 districts. In 2013, the total population of the province was 1.114 billion people (General Statistics Office of Vietnam). Bac Ninh Water and Sewerage Company collects FS, as also do several private companies. Currently, there is no FS treatment plant.

Ba Ria-Vung Tau is a coastal province located in the South East region of Vietnam. The province, covering a surface area of 198,950 ha has 1.053 million residents (General Statistics Office of Vietnam, 2013). Ba Ria – Vung Tau is comprised of 7 inland sub-districts and 1 island district. BUSADCO collects FS, as well as other private companies. One of these private companies operates a treatment plant.

To ensure recommended solutions are adequate for the local context, the Market Driven Approach evaluates the local demand for treatment products and resource recovery. Added benefits include that by first defining treatment products the treatment technology can be designed for adequate protection of public health, sales of treatment products can offset treatment costs, and a market demand will help to ensure sustainable operation of treatment plants. This study identified which FS treatment products have the highest local market attractiveness, and substitute products that are already currently used, which could be replaced by FS treatment products. The results are presented by city, with conclusions on FS resource recovery options and related treatment technologies.

1.1 Objectives of the study

The Market Driven Approach aims to:

1. Identify potential products and product applications in selected geographical areas that could be replaced by FS treatment products,
2. Identify relevant stakeholders and market participants related to FS products,
3. Evaluate the market volume and acceptance for FS products,
4. Analyse the market attractiveness (potential for market growth, market volume) for the products.

2 Methods

A glossary for terminology used in the Market Driven Approach is provided in Table 1 (Sandec 2016), and the main steps can be summarized as:

1. Literature review and expert interviews to identify potential products that could be replaced by FS treatment products in selected geographical areas, and their potential product application. Statistical data, annual province reports, and publications on research or development project were included in this step.
2. Expert interviews and contact with the local authorities to identify relevant stakeholders and market participants related to substitute products,
3. Interviews with the relevant stakeholders and visits to production, sale or enduse units were conducted to evaluate the market volume and market growth potential for substitute products,
4. Based on the results of the literature review, interviews and visits, calculations were made to analyse the market attractiveness (potential for market volume, market growth) for the substitute products.

Presented in this report are a summary of results from each of the steps for the study implementation in Bac Ninh, Son La and Ba Ria. The scope of analysis was limited to provincial boundaries of the three cities, as the potential uses of FS treatment products are widespread in the provinces. Only industrial applications or sales within these boundaries were considered for substitute products.

Table 1: Definition of terminologies (taken from Schoebitz et al., 2016)

Terminology	Definition
FS treatment product	Resulting solid and/or liquid forms that are produced from FS treatment technologies.
Product application	Type of industry, production unit or economic activity where the FS treatment product could be used and where current substitute products can be identified and assessed.
Substitute product	Existing relevant product that the FS treatment products would replace.
Market participant	Stakeholders that play a role in the supply chain and use of substitute products and/or FS treatment products, for example producers, wholesalers, retailers, and customers of products.
Market volume	Multiplication of number of units sold per available substitute product with the given price over a specific period. Provides estimates of the potential financial flows for one substitute product.
Market growth	Estimated future growth in sales for all identified substitute products for one potential FS treatment product. Historical growth of products can be used to extrapolate future growth.
Adjustment factor	A means of estimating the difference in future market attractiveness of a a FS treatment product, in comparison to the substitute product. An adjustment is necessary, as a substitute product (e.g. commercial synthetic fertilizer) may not have the exact same market attractiveness as a faecal sludge treatment product (e.g. nutrient amended FS pellets). In this report, the adjustment factor was estimated based on the willingness from interviewees to use FS treatment products, the price they would pay (smaller or equal to the substitute product, and the support from local authorities for use of this FS treatment product.

2.1 Potential FS treatment products and product applications

As shown in Table 2, a preliminary list of seven potential substitute products was identified based on the literature review. These are potential products that could be replaced by FS treatment products. In a second step, this list was validated trough experts interviews and field visits, and substitute products that are actually available were identified and assessed. In this case, product application means a centralized production unit, in contrast to households or geographically diverse units. Both small- and large-scale industries were targeted for potential application of FS treatment products.

Table 2: Potential FS treatment products and product applications (adapted from Sandec 2016)

No.	Substitute product	Form	Product application
1	Soil conditioner / fertilizer	Compost, Pellets, Digestate from anaerobic digestion, Black soldier flies residual	Agriculture, Horticulture, Flower industry, Forestry
2	Animal feed	Black soldier flies, Fish meal	Aquaculture, Livestock, bird farm
3	Animal fodder	Plants from drying beds, Dried aquaculture plants	Livestock and bird farm
4	Reclaimed water	Effluent from FS treatment	Agriculture, Horticulture, Flower industry
5	Solid fuel	Pellets, Briquettes, Powder	Energy through combustion
6	Liquid fuel	Biogas	Lighting, Heat, Cooking fuel
7	Electricity	Conversion of Biogas or gasification of solid fuel	Feeding into the grid

2.2 Substitute products and potential industrial applications in Vietnam

The list of potential substitute products was validated based on the existing situation in Bac Ninh, Son La and Ba Ria through interviews and site visits. The result was that four substitute products were eliminated based on:

1. It was assumed that biogas from anaerobic digestion would only be used directly at the FS treatment plant for energy recovery (e.g. temperature control of thermophilic digestion).
2. Electricity produced by gasification of is not yet well enough developed, and requires operational complexity.
3. An assessment of the market volume for fodder was not possible, as in these areas there is very limited purchase of fodder, as animals graze on grass supplied by the farmers raising animals.
4. It was determined based on the local climate and water availability that a strong market for reclaimed water does not exist.

The remaining three substitute products were further analysed, as detailed in

Table 3. The local potential for these substitute products was evaluated in a further step for each of the three cities, as described in the results.

Table 3: List of existing substitute products and investigated FS treatment products

Product	Existing substitute product	FS treatment product
1. Soil conditioner / fertilizer	Commercial bagged products such as soil amendment, compost and fertilizers available at the market that help to increase soil structure and fertility.	FS can be composted to produce an organic soil amendment. Nutrients could also be added (N, P, K) to treatment products to produce an organic fertilizer.
2. Animal Feed	There are a number of commercial bagged products that contain necessary nutrients for animal growth for different types of animals and for each stage of growth.	Protein can be produced in the form of Black Soldier Flies that are used for FS stabilization.
3. Solid fuels	Coal is used as a fuel for heating and cooking. In brick production, coal powder is mixed with clay and burned in the kiln. In cement manufacturing, coal is also used in the kiln. For cooking in households and restaurants, briquettes are used that are made from coal and charcoal.	Dried FS can be used for brick, cement production and charcoal briquettes, as an alternative fuel in the kiln, and by incorporating the ash resulting from FS incineration. Charcoal briquettes are used for cooking at households and restaurants.

2.3 Calculation scheme for market volume estimation

In this report, an exchange rate of 1 USD = 22,500 VND was used for estimations (from September 2015) to evaluate the best options for resource recovery of FS.

For fertilizers and animal feed, calculations were made as shown in Figure 1 and Figure 2, based on estimates provided by the Department of Agriculture and Rural Development (DARD), for 2014. There is a wide variety of animal feed products. Thus average feed expenditures for each animal category was based on the literature review, and the market volume was calculated based on the percentage of protein content in animal diets. Black soldier flies are considered as a protein source for livestock.

Figure 1: Calculation scheme to estimate the market volume for fertilizers

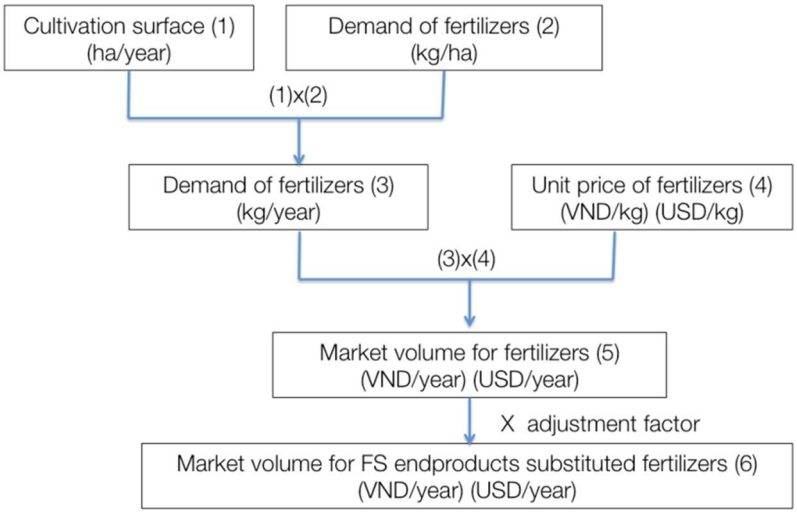
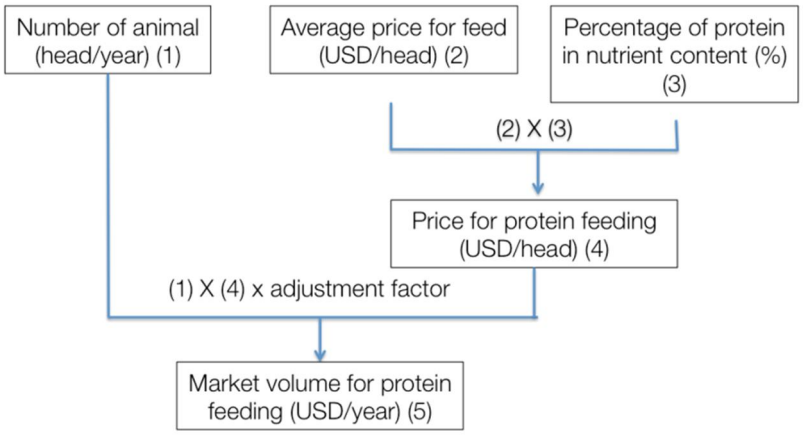


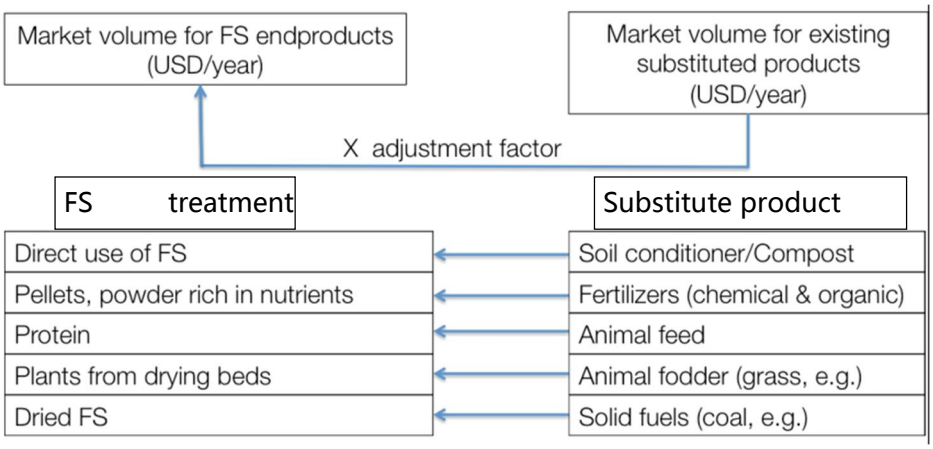
Figure 2: Calculation scheme of market volume of animal feed in livestock



First, the market volume for the existing substitute products was assessed, and then the potential market volume for FS treatment products calculated, applying the adjustment factor. The adjustment factor was set from 0.5 to 1.5, depending on the willingness of consumers to purchase FS treatment products at lower, equal or higher prices than existing substitute products. A factor of 0.5 was applied where willingness to use FS treatment products was observed to be low, or the collaboration with the relevant stakeholders was difficult. This factor was determined based on discussions with relevant stakeholders, and takes into account the investment costs required to use FS treatment product instead of the substitute product, their comparative efficacy/quality of FS treatment products, and social stigma.

The final calculation of the potential market volume for all FS treatment products in each province was carried out as shown in Figure 3.

Figure 3: Calculation scheme for market volume



The discussion about the market attractiveness of the different treatment products in the 3 cities is based on the calculations for 2014, as information on market growth is often missing.

2.4 Organization of the field studies

Relevant market participants that were interviewed included management boards from local authorities, and sellers and consumers for each product application, as shown in Table 4.

Table 4: Summary of market participants

Substitute product	Management board	Seller	Producer / consumer
Soil conditioner / fertilizer	Department of Agriculture and rural Development (DARD)	Fertilizers seller, FS emptier	Farmers
Animal Feed	DARD	Animal feed seller	Livestock & aquaculture farm
Solid Fuels	Department of Industry and Trade (DOIT)		- Briquettes workshop, - Brick enterprise, - Cement enterprise, - Restaurant, - Recycled paper mill

A questionnaire that is provided in Annex 1 was used for interviews to investigate market volume and market growth in each application. Plantation, perennial industrial plants, floriculture and forestry are all concerned with soil conditioner/compost and fertilizers. Therefore, the interviewees for these groups are the same.

It was considered that information provided by individual suppliers or consumers are not sufficiently representative of the situation at provincial scale. Therefore, where possible, official numbers provided by the management boards were considered for the calculations, and information cross checked and discussed with interviews.

3 Results

3.1 Son La province

In 2014 the economic growth rate of Son La increased by 11.18% compared to the previous year. There are three main sectors contributing to the local industrial economy, service and trade, industry and construction, and agriculture-forestry-aquaculture, with contributions of 42.3%, 26.65% and 31.05%, respectively (Son La People Committee, 2014). The quality of life has continuously improved, with a total annual income above 1000 USD/cap.year for the year 2013 (The Voice of Vietnam, 2015).

There are more than 257,000 ha of agricultural cultivation in Son La province, including plantation and horticulture, perennial industrial plants and floriculture. The principal plants are maize, tea and coffee plants, covering about 70% of total cultivation surface of the province (DARD Son La, 2015).

According to DARD, Son La province has a beneficial environment for livestock activities. Cow breeding for meat and milk and other livestock farms are strongly developed in Moc Chau Plateau, located 120 km far from Son La City (DARD Son La, 2015). There are also about 160,000 goats in the province, which are fed by natural grass, and hence expenditures for commercial animal feed were considered negligible.

According to Son La Aquaculture Division, the province has a wide water surface area, with the area dedicated to aquaculture estimated to 2,458 ha.

There are also cement, brick and charcoal briquettes industries in Son La.

Table 5: Summary of stakeholders interviewed in Son La province (in orange: management board, in purple, suppliers, and in green, consumers)

Substitute product → / *Application* ↓	**Soil conditioner / fertilizers**	**Animal Feed**	**Solid fuels**
Plantation	DARD 1 floriculturist 1 coffee farm 2 FS emptiers 2 sellers of fertilizers		
Perennial plants (e.g. coffee)			
Floriculture			
Forestry			
Aquaculture		2 sellers	
Livestock		2 sellers 1 cow farm	
Cement			DOIT 1 Cement Enterprise
Brick			DOIT 1 Brick Enterprise
Restaurant			1 Briquette workshop

3.1.1 Market attractiveness for soil conditioner/ fertilizers in Son La

As indicated by DARD and the Agricultural Materials Company of Son La Province, Branch Office in Son La City, farmers prefer to use fertilisers over compost or other soil conditioners.

Soil conditioner

Son La Urban Environmental Company (URENCO) produces its own soil conditioner. They collect FS in the city of Son La, which is then transported to a small treatment unit, consisting of a small settling tank followed by a gravel filter. The settled FS is then used as soil conditioner without further treatment for URENCO gardens. The plants are grown for the green areas of the city, for which URENCO is also responsible.

FS collected by private emptiers is often transported to nearby coffee farms for use as a soil conditioner, without treatment. This practice is not optimal for human or environmental health. The main concern of emptiers is to find a place for FS disposal, so the FS is typically provided for free to farmers. Sometimes, coffee farms pay the FS emptiers a small amount for transport cost, but this amount was difficult to determine. Therefore, market volume and market growth for untreated FS, as well as soil conditioner/compost could not be precisely calculated for the city of Son La.

Fertilizers

Chemical fertilizers are mostly used as farmers believe they allow a better control of yields than organic fertilizers or conditioners. Fertilizers, which are imported from other provinces, can be purchased at distribution agencies in every district.

According to DARD, DOIT and two large suppliers of fertilizers in Son La (see Annex 2) it is difficult to estimate the actual consumption of fertilizers in Son La territory. Although there is a guide from DARD on fertilizer application for each type of plant, it is commonly observed that farmers apply nutrients based on personal experience and financial availability. The interviews with floriculturists and coffee farms confirmed this.

The rose farm in Chieng An Ward, Son La City, consumes 40-50 ton/ha of chemical fertilizers every 2-3 months. They confirmed their interest in using FS treatment products, if the product has equivalent quality and is less expensive. The owner of Tai Dam coffee farm in Son La City consumes about 2.5 tons of chemical fertilizers/ha.year. They stated that they do not use organic fertilizers due to higher prices and unclear efficiency on production yields. Similarly they expressed interest in using FS treatment products depending on their quality and price.

Since all interviewees were willing to purchase FS treatment products if they were less expensive than commercial fertilizers, an adjustment factor of 0.9 was selected. The prices for fertilizers are given in Table 6, and market volumes for FS treatment products substituting fertilizers in Table 7.

Table 6: Unit price of fertilizer in Son La province (DARD Son La, 2015)

	N	P	K	Mixed NPK	Organic fertilizer
Price (USD/kg)	0.47	0.22	0.60	0.22	0.04

Table 7: Market volume for fertilizers and FS treatment products substituting fertilizers in Son La province (DARD Son La, 2015)

			Market volume for fertilizers (USD/year)					Market volume for FS treatment products substituting fertilizers (USD/year)				
			Chemical fertilizer				Organic fertilizer	Chemical fertilizer				Organic fertilizer
		Surface (ha)	N	P	K	Mixed NPK		N	P	K	Mixed NPK	
Plantation and Horticulture	Paddy	54,300	5,068,000	5,031,800	5,864,400	-	15,445,333	4,561,200	4,528,620	5,277,960	-	13,900,800
	Maize	162,510	25,026,540	18,056,667	16,576,020	-	46,225,067	22,523,886	16,251,000	14,918,418	-	41,602,560
	Sugar-cane	5,213	486,547	-	312,780	-	370,702	437,892	-	281,502	-	333,632
	Vegetables	8,642	1,088,892	758,576	933,336	-	5,361,881	980,003	682,718	840,002	-	4,825,693
Perennial industrial plants	Mango	3,440	385,280	305,778	495,360	-	183,467	346,752	275,200	445,824	-	165,120
	Longan	7,569	883,050	672,800	1,135,350	-	-	794,745	605,520	1,021,815	-	-
	Tea (new)	1,201	-	133,433	-	-	213,493	-	120,090	-	-	192,144
	Tea (annual)	2,802	261,529	-	134,501	-	-	235,376	-	121,051	-	-
	Coffee (new)	3,389	237,216	753,067	203,328	-	1,204,907	213,494	677,760	182,995	-	1,084,416
	Coffee (annual)	7,907	1,014,757	-	1,423,296	-	-	913,282	-	1,280,966	-	-
Floriculture	Floriculture	34[1]	-	-	-	340,000	-	-	-	-	306,000	-
Total (1)			34,451,811	25,712,120	27,078,371	340,000	69,004,850	31,006,630	23,140,908	24,370,534	306,000	62,104,365
Total (2)			**156,587,152**					**140,928,437**				

1 Source: (Photographic Journal on Ethnic and Highland areas, 2015); interviews with local floriculturist

Hence, the market volume of FS treatment products replacing fertilizer demand in Son La province was estimated to be about 140,927,437 USD.

FS treatment products have a high potential for use in agricultural activities in Son La. The management board of DARD strongly encourages producing organic fertilizers or compost from FS and believes these will have a place in fertilizers market in Son La province.

According to DARD and the fertilizer sellers, it is difficult to predict the market growth of fertilizers, which is influenced by financial availability of farmers, and depends on the annual market fluctuation. However, given the planning of DARD, as well as observations during interviews and field visits, it is forecasted that the demand for fertilizers will increase in the next years.

FS treatment products could easily be introduced to floriculturists located in Chieng An Ward, Son La City. They have a stable and large demand for fertilizers over the year, and have shown strong interest to use FS treatment products. Further, they are located only 7 km from Son La City, where FS is produced, which would help to limit transport costs.

Figure 4: Rose floriculture in Ban Ca, Chieng An Ward, Son La City

3.1.2 Market attractiveness for animal feed in Son La

Livestock

Most animal feed products in Son La are imported from other provinces. There are 108 distribution agencies of animal feed in the province. There is a wide range of prefabricated products for each type of animal depending on the growth stage. According to Tuan Dzung distribution agency, there are about 4-5 primary distribution agencies in Son La City, which provide about 650 tons of animal feed per month for animal husbandry in Son La City and surrounding districts. There are secondary distribution agencies, which purchase animal feed from primary ones and deliver to husbandries. The current estimated market volumes for animal feed in Son La are presented in Table 8.

Table 8: Current unit price and market volume for protein feeding in livestock in Son La

	Price for feeding (VND/head)	Price for feeding (USD/head)	% Protein in nutrient content	Price for protein feeding (USD/head)	Number of heads	Existing market volume for protein (USD/year)
Pig	2,400,000[2]	106.67	20%[3]	21.33	514,360	10,971,299
Poultry	48,000[4]	2.13	17%[5]	0.36	5,250,000	1,890,000
Total						**12,861,299**

Both farmers and the management board of DARD had never heard about the potential for protein sources produced from FS treatment, and the possibility to use black soldier flies as animal feed. They would require a strong demonstration of effectiveness and public health safety before accepting to use black soldier flies.

Additionally, the husbandry producers currently have ready access to prefabricated animal feed products in the market, for which diets have been calculated specifically for each growth stage of the animal. Therefore, information would need to be given to the farmers concerning the amount of black soldier fly larvae to feed at the different stage in order to facilitate their commercialization. An adjustment factor of 0.7 is proposed for pig and poultry feed, to take into account these limitations. The market volume for protein feed from black soldier fly larvae was thus estimated to be 9,002,909 USD/ year. It is forecasted that numbers of cattle for the year 2020 will increase of 29% for pig and 23% for poultry farms.

Aquaculture

The production yield of aquaculture was 5,000 tons in 2014 (Communist Party of Vietnam Online Newspaper, 2015). Most of the fish are raised in household lakes and ponds. Only a small portion of fish is cultivated commercially in cages in Son La Hydropower Dam. Due to the lack of information on aquaculture activities, this study focused on sturgeon, a typical fish cultivated in Son La province. The market volume for animal feed in aquaculture was developed using a similar calculation scheme as for animal feed for livestock.

2 Source: (Animal Husbandry Association of Vietnam (AHAV), 2015)

3 Source: (VietDVM)

4 Source: (Hanh)

5 Source: (Ministry of Agriculture and Rural Development, 2014)

Table 9: Current unit price and market volume for protein in aquaculture in Son La province

	Quantity of animal feed (kg/kg product)	Price for protein feeding (VND/kg)	Price for protein feeding (USD/kg)	Production (ton)	Market volume for protein feeding (USD/year)
Sturgeon	1.10 [6]	35,000[7]	1.56	5,000	7,777,778

Similarly to animal feed, an adjustment factor of 0.7 is proposed for fish feed in Son La. There is no available information for future development of aquaculture activities.

The market volumes for black soldier fly larvae produced during FS treatment for livestock and aquaculture in Son La are respectively 9,002,909 USD / year and 5,444,445 USD / year.

Most livestock and aquaculture units are at small scale and fairly dispersed throughout the province, hence production of protein from black soldier fly larvae, or of fodder production from planted drying beds, do not appear to be optimal solutions in the Province of Son La.

3.1.3 Market attractiveness for solid fuels in Son La

Charcoal briquettes

Hanh Moc is the largest charcoal briquette workshop in Son La province. The current production is about 3,650,000 briquettes/year. The cost for coal is estimated at 2,200 VND/ briquette, equivalent to 0.098 USD/briquette. The charcoal briquettes are transported to 6-7 distribution agencies within the province for households and restaurants. Briquettes are made from coal and charcoal with additives and mould and dried 2-3 days.

Figure 5: Hanh Moc charcoal briquette workshop in Son La

6 Source: (http://www.baomoi.com/Phai-tu-chu-thuc-an-con-giong/c/11016609.epi, 2013)

7 Source: (http://www.baomoi.com/Phai-tu-chu-thuc-an-con-giong/c/11016609.epi, 2013)

Charcoal briquettes have long been considered as a cheap fuel. However their harmful gas by-products impact public health and air quality. For that reason, the Hanh Moc producer did not want to discuss further their production activities and the possibility of using FS. The adjustment factor for this product is proposed at 0.5, due to apparent low willingness to collaborate. The market volumes calculation are presented in

Table 10. For charcoal briquette production, the market growth cannot be assessed due to the lack of information on future market fluctuation.

Table 10: Market volume of charcoal briquette and dried FS treatment products in Son La

Production (briquette/year)	Price of coal (VND/briquette)	Price of charcoal (USD/briquette)	Market volume (USD/year)	Market volume for dried FS (USD/year)
3,650,000	2200	0.098	356,889	178,444

Brick production

According to Son La DOIT, the total brick production of Son La province was about 150 million bricks/year in 2014. The Mai Son Brick Enterprise produces about 20 million bricks/year, and consumes 0.3 kg of coal/brick. The coal is purchased locally and from Quang Ninh province at the price of 2.2 million VND/ton, (i.e. 98 USD/ton).

In brick production, coal powder is mixed with clay and fired in a tunnel kiln at 900 - 1050°C during 30 to 72 h. 1 kg of fired brick requires ~1.4 MJ (Greentech Knowledge Solutions Pvt Ltd., 2014).

Mai Son brick producer believes that FS treatment products could be a good alternative to replace coal in the heating process. Long transport distances of more than 450 km from Quang Ninh to Son La makes the coal price higher than in other areas, and the supply is sometimes interrupted. If the FS treatment product could meet the quality of currently used coal in terms of dryness and energy supplied, the brick producer would be interested in purchasing dried FS at a similar price to coal. Therefore, an adjustment factor of 1.0 was utilized. The market volume is presented in Table 11. According to the Son La DOIT report Master Plan of Industry and Trade for the period of 2016 - 2020, brick production could decline by -30% by 2020.

Table 11: Market volume for brick production in Son La province

Production scale (brick/year)	Consumption of coal (ton/year)	Unit price of coal (USD/ton)	Market volume (USD/year)	Market volume for dried FS (USD/year)
150,000,000	45,000	97.78	4,400,000	4,400,000

Cement production

Mai Son Cement Enterprise is the only cement producer in Son La province. They produce about 1 million tons of cement/year. The coal consumption is estimated at 130 kg of coal/ton of cement. Similar to coal in brick production, coal used in clinker heating is purchased from Quang Ninh province. The cement manufacturing process utilizes coal to heat cement clinker at the temperature of 1450°C. The cement producer had doubts regarding the combustible quality of dried FS. From their point of view, FS treatment products would not satisfy the strict requirements for clinker heating, in terms of maintaining temperatures of 1450^0C and low ash content. Even if the quality and efficiency of FS treatment products was proven, they were not interesting in using these substitute products. Therefore, the adjustment factor of 0.5

was used. The market volume is presented in Table 12. The cement production in Son La province is forecasted to reduce from 1 million tons/year in 2015 to 0.9 million tons/year in 2020, an equivalent reduction of 10% in 5 years.

Table 12: Market volume of coal in cement production and dried FS in Son La

Production (ton/year)	Consumption of coal (ton/year)	Unit price of coal (USD/ton)	Market volume (USD/year)	Market volume for dried FS (USD/year)
1,000,000	130,000	97.78	12,711,111	6,355,556

In total, the estimated potential market volume of dried FS substituting coal in Son La province is 10,934,000 USD for the year 2014 as shown in Table 13.

Table 13: Market volume and growth rate of solid fuels and FS treatment products in Son La

	Market volume for FS treatment products (USD/year)		Market growth (%)
	2014	2020	
Charcoal briquette production	178,444	178,444	-
Brick production	4,400,000	3,080,000.0	-30%
Cement production	6,355,556	5,720,000.0	-10%

Hence, only brick production or resource recovery of FS as solid fuel in Son La was considered, as the application does not change the current production process, the adjustment factor is high, and the production unit is centralized. However, this sector is expected to show negative growth.

3.1.4 Discussion and recommendations for Son La Province

The total market volumes and market growth for existing and FS substitute treatment products are summarized in Table 14.

Table 14: Estimated market volume and market growth of FS treatment products in Son La province

	Market volume for FS treatment products (USD/year)	Estimated market growth of FS treatment products (%)
Soil conditioner / Compost	-	
Fertiliser	140,928,437	Increased
Animal Feed	14,447,354	+25%
Solid Fuels	10,934,000	-20%
Total	**166,309,790**	

Among the five potential applications of FS in Son La province, fertilizer accounts for the largest potential, with 85% of total potential market volume. Both management authority and farmers have shown strong support on the fertilizers production from FS. FS could also be mixed with coffee husks, which are abundant around Son La City to produce a good compost. The floriculturists in Chieng An Ward, Son La City could be promising consumers for these products. The estimated positive growth rate for this sector would strengthen this conclusion. Another possible application would be in Mai Son brick production, but a negative growth is expected in this case.

3.2 Bac Ninh Province

In 2015, industry and construction, service and trade, and agriculture-forestry-aquaculture were estimated to contribute respectively to 76.3%, 18.7% and 5% of the economic industrial share in the province of Bac Ninh. The average income of Bac Ninh province was about 3,211 USD/cap.year for the year 2012, which is among the highest nationally (Tuy, 2013).

There are 91,000 ha of agricultural land in Bac Ninh Province, mainly comprised of rice paddies, accounting for 80% of plantation surface. The remaining fields are used for horticulture and floriculture. There are no perennial industrial plantations such as coffee or tea.

According to DARD, the aquaculture surface of Bac Ninh province in 2014 was about 5,457 ha, with a production reaching 34,200 tons. The main aquaculture products include red tilapia and carp fishes. The province is encouraging fish-cage cultivation in rivers.

Brick and charcoal briquettes are also produced in Bac Ninh, but there is no cement industry. Bac Ninh is the second industrial city in Vietnam, hence, a wide range of other application of FS as a fuel would be possible. Assessment of this potential is beyond the scope of this study, as it would require understanding the energy need of each company. A paper recycling industry was selected as an example calculation, based on discussions with DOIT.

Table 15: Summary of stakeholders interviewed in Bac Ninh province (in orange: management board, in purple, suppliers, and in green, consumers)

Substitute product → / *Application* ↓	**Soil conditioner / Fertilizer**	**Animal Feed (Protein)**	**Solid fuels**
Plantation	DARD 2 FS emptiers 1 floriculturist 1 horticulture farm		
Perennial plants			
Floriculture			
Forestry			
Aquaculture		1 seller	
Livestock		1 sellers 1 pig farm 1 poultry farm	
Brick			DOIT 1 Brick Enterprise
Restaurant			1 restaurant
Recycled Paper			1 producer

3.2.1 Market attractiveness for soil conditioner/ fertilizer in Bac Ninh

Soil conditioner

Farmers usually apply wood ash on cultivated land to increase soil fertility. They also sometimes mix poultry manure with enzymes and rice husk as a soil conditioner for vegetables, such as cauliflower, kohlrabi and cabbage. For example, interviewed farmers cultivating daisy flowers and vegetables said they prefer using wood ash and compost produced from poultry manure and rice husk. They said they would not be interested in using treated FS because these products are obtained free of charge. The dosage applied varies based on farmers' experience, which would make

quantitative assessment too difficult. Therefore, the market volume and attractiveness of soil conditioner / compost is not discussed for Bac Ninh.

Fertilizers

According to DARD of Bac Ninh, the farmers prefer chemical fertilizers as they think this ensures higher production yield. The unit prices of fertilizers for N, P, K, mixed NPK and organic fertilizers are presented in Table 16 and Table 17 presents the calculation for the market volume of fertilizers in Bac Ninh.

Table 16: Unit price of fertilizer in Bac Ninh province (DARD Bac Ninh, 2015)

	N	P	K	Mixed NPK	Organic fertlizer
Price (USD/kg)	0.44	0.13	0.53	0.44	0.22

During the interviews, an orchid farmer stated that they need a specifically high quality of chemical fertilizers and are not interested to use FS treatment products. The interviewed farmers think that bonsai and public-trees gardeners might be more interested in using FS treatment products, since these plants require a significant amount of organic fertilizers. Unfortunately, these stakeholders were not available for interviews during the field trips.

An adjustment factor of 0.7 is proposed for the market volume calculation, as the demand for fertilizers is good for tree or flower plantations, and represents limited public health risks since they are not consumable crops. However, no information about willingness to use products could be obtained as these market players were not interviewed. An information campaign on advantages of FS-fertilizers would potentially help raising interest from farmers.

Based on the calculation, the market volume of FS treatment products substituting fertilizers in Bac Ninh province was estimated at 143,025,588 USD. According to DARD, the cultivation surface will be 89,200 ha in 2015 that is about 2% less than the surface of 90,961 ha in 2014.

Table 17: Market volume for fertilizers and FS treatment products substituting fertilizers in Bac Ninh province (DARD Bac Ninh, 2015)

		Surface (ha)	Market volume for fertilizers (USD/year)					Market volume for FS treatment products substituting fertilizers (USD/year)				
			Chemical fertilizer				Organic fertilizer	Chemical fertilizer				Organic fertilizer
			N	P	K	Mixed NPK		N	P	K	Mixed NPK	
Plantation and Horticulture	Paddy	72,789	6,470,133	4,043,833	6,987,744	-	129,402,667	4,529,093	2,830,683	4,891,421	-	90,581,867
	Maize	3,673	538,765	244,893	333,055	-	6,530,489	377,136	171,425	233,138	-	4,571,342
	Peanut	809	30,543	50,666	51,744	-	898,333	21,380	35,466	36,221	-	628,833
	Bean	1,267	45,045	59,122	54,054	-	1,689,200	31,532	41,385	37,838	-	1,182,440
	Sweet potato	566	35,243	20,390	45,312	-	1,006,933	24,670	14,273	31,718	-	704,853
	Potato	2,082	259,106	152,687	199,882	-	5,552,267	181,374	106,881	139,917	-	3,886,587
	Vegetables	8,642	1,044,722	448,232	825,023	-	33,991,867	731,305	313,762	577,516	-	23,794,307
	Others	908	96,864	54,486	92,021	-	3,027,000	67,805	38,140	64,415	-	2,118,900
Floriculture	Floriculture	225	-	-	-	39,947	-	-	-	-	27,963	-
Total (1)		90,961	8,520,422	5,074,310	8,588,835	39,947	182,098,756	5,964,295	3,552,017	6,012,184	27,963	127,469,129
Total (2)			**204,322,269**					**143,025,588**				

3.2.2 Market attractiveness for animal feed in Bac Ninh

Livestock and birds

No estimates on the total consumption of animal feed in Bac Ninh province are available. The animal feed market is competitive, and farmers have a wide range of choices for products, quality and price.

According to the Suong Thuy distribution agency, the main animal feed products available in Bac Ninh market are for pig and poultry. In interviews with poultry and pig husbandry operations, they said the animal feed dosage is applied based on the guidelines on the animal feed packages. They sometimes also use food waste produced by the food industries located in the province.

Figure 6: Poultry farm in Phu Lam Commune, Tien Du District, Bac Ninh City

Similar to the situation in Son La province, livestock and bird farmers had never heard about the possibility to use black soldier fly larvae as a protein source for pig and poultry feed. They would need strong evidence proving its value to accept using the larvae from FS treatment. Thus, an adjustment factor of 0.7 was used in the estimation of the market volume shown in Table 18.

Table 18: Market volume for animal feed and FS treatment products substituting animal feed in livestock and bird activity in Bac Ninh province

	Number of heads	Market volume for protein (USD/year)	Market volume for FS - protein (USD/year)
Pig	410,678	8,761,131	6,132,792
Poultry	4,500,000	1,632,000	1,142,400
Total		**10,393,131**	**7,275,192**

Aquaculture

In interviews with FS emptiers, they said that application of raw FS in aquaculture ponds is common. This indicates that farmers would potentially accept to use black soldier fly larvae as a protein source. However, no information on the willingness to use the larvae could be gathered with aquaculture farmers due to time constraints.

Therefore, an adjustment factor of 0.8 was used. The calculation of market volume focuses on feeding expenditures for red tilapia fish.

Table 19: Unit price and market volume for protein feeding in aquaculture in Bac Ninh

	Dosage of animal feed (kg/kg production)	% Protein in food	Protein price (VND/kg)	Price for protein feeding (USD/kg)	Production (ton/year)	Market volume for protein (USD/year)	Market volume for FS-proteins (USD/year)
Red tilapia fish	1.50 [8]	25%[9]	8,250 [10]	0.37	34,200	12,540,000	10,032,000

In total, the market volume for protein in the form of black soldier fly larvae from FS treatment for livestock, bird and aquaculture activities was estimated to amount to 17,307,192 USD for 2014. According to DARD, the production scale of livestock, bird and aquaculture will remain the same in the next years.

Due to insufficient information on the willingness to use larvae, it is difficult to recommend resource recovery as an animal feed in one type of farm rather than another in Bac Ninh. Large aquaculture farms that are already with FS resource recovery would potentially be most interested, but they are spread around the province, which would involve higher transportation costs for FS treatment products. Smaller familial farms exist near to the city, for example in Nam Son.

3.2.3 Market attractiveness for solid fuels in Bac Ninh

Charcoal briquette

The demand for charcoal briquettes of the contacted restaurant in Bac Ninh was about 600 briquettes per month. The charcoal briquettes are supplied from a local workshop. However, the workshop refused to provide information on their production. Due to time constraints, no other charcoal briquette suppliers could be interviewed. Hence, information was not sufficient to estimate the market volume of charcoal briquettes in Bac Ninh.

Brick production

According to Bac Ninh DOIT, the total brick production of the province was about 360 million bricks in 2014. The Tan Son Brick Enterprise, which produces about 50 million bricks/year, stated that their coal consumption is about 0.3 kg of coal/brick. The coal is purchased from Quang Ninh province at the price of 1.5 million VND/ton, which is equivalent to 66.7 USD/ton.

8 Source: (DARD of Ho Chi Minh City, 2007)

9 Source: (DARD of Ho Chi Minh City, 2007)

10 (Aquaculture in Vietnam, 2014)

Figure 7: Brick production in Tan Son Enterprise

Similarly to the brick enterprise in Son La province, Tan Son Brick Enterprise showed a high willingness to use FS treatment products replacing coal. As they would accept to pay the same price as coal, and the adjustment factor of 1.0 was used. The market volume calculations are presented in Table 20.

Table 20: Market volume for coal and dried FS in brick production in Bac Ninh province

Production (brick/year)	Consumption of coal (ton/year)	Unit price of coal (USD/ton)	Market volume (USD/year)	Market volume for dried FS (USD/year)
360,000,000	108,000	66.67	7,200,000	7,200,000

Recycled paper production

Phong Khe commune is well known in Bac Ninh province for recycled paper production. The main products include kraft paper and tissues.

Figure 8: Recycled paper production in Phong Khe Commune, Bac Ninh province

There are 250 workshops in the province, producing about 10,000 tons of recycled paper per year (Doan, 2014).

Figure 9 shows the heating process in the steam generator where either coal or wood is used. The coal normally provides higher calorific energy than the wood. In Hien Hoa Paper Mill, coal is supplied from Quang Ninh province at the price of 88.9 USD/ton. The wood supplied from individual retailers is at the price of 17.78 USD/m^3.

Figure 9: Steam generator in recycled paper production using coal or wood

Due to the lack of information, the market volume of solid fuels in recycled paper production addresses only coal. It was considered that 0.24 kg of coal is needed to produce 1 kg of paper (Doan, 2014). The interviewed company owner was willing to use FS treatment products if they provide equivalent fuel/steam quantities at a lower price. An adjustment factor of 0.9 was thus used. The market volume estimates are presented in Table 21.

In total, the potential market volume of FS treatment products substituting coal in Bac Ninh province is about 7,392,000 USD for the year 2014. Both brick enterprises and recycled paper mills would be promising consumers for dried FS. There is no available data on future development of brick and recycled paper productions in Bac Ninh province.

Table 21: Market volume for recycled paper production in Bac Ninh province

Production (ton/year)	Consumption of coal (kg/kg of paper)	Unit price of coal (USD/ton)	Market volume (USD/year)	Market volume for dried FS (USD/year)
10,000	0.24	88.89	213,330	192,000

3.2.4 Discussion and recommendations for Bac Ninh Province

The total market volumes and market growth for existing and FS treatment products are summarized in Table 22.

Table 22: Total estimated market volume and market growth for FS treatment products in Bac Ninh

	Market volume of FS substituted treatment products (USD/year)	Market growth (%)
Soil conditioner/Compost	-	
Fertiliser	143,025,588	Increased
Animal Feed	17,307,192	0%
Solid Fuels	7,392,000	-
Total	**166,470,780**	

Among the three potential applications of FS products in Bac Ninh province, fertilizers accounted for the largest proportion with more than 86% of total market volume. Potential customers for FS-fertilizers could be bonsai and public-tree growing gardeners, who unfortunately could not be contacted. Based on available information, as brick factory and recycled paper mills are interested in using dried FS, solid fuels have a better resource recovery potential for FS in Bac Ninh.

3.3 Ba Ria – Vung Tau Province

The province is within the most active economic region of southern Vietnam, as a national leader in petrol exploitation, energy production, industries, tourism and coastal ports. In 2013, the economic shares of industry and construction, services, and agriculture-forestry-aquaculture were 69.9%, 24.4% and 5.7% respectively (Department of Planning and Investment of Ba Ria-Vung Tau, 2013). The provincial average income is high and in 2010, the GDP of Ba Ria-Vung Tau was 5,872 USD/cap.year (Ba Ria - Vung Tau People Committee, 2011).

The total surface of agricultural cultivation in Ba Ria-Vung Tau was about 113,650 ha 2014, including rice paddies, corn, vegetables, cassava and perennial commercial plants such as rubber, cashew and pepper (DARD Ba Ria-Vung Tau, 2015). No floriculture farm is registered in the statistics of Ba Ria-Vung Tau. According to Aquaculture Division, the province had an aquaculture surface of 7,852 ha in 2014. The main aquaculture products include prawn and fish, produced in fresh and saltwater. Livestock and bird farming activities are also important in the province.

Table 23: Summary of stakeholders interviewed in Ba Ria – Vung Tau province (in orange: management board, in purple, suppliers, and in green, consumers)

Substitute product → *Application* ↓	**Soil conditioner / Fertilizer**	**Animal Feed (Protein)**	**Solid fuels**
Plantation	DARD 1 seller of fertilizers3 FS emptiers 1 horticulture farmer		
Perennial plants			
Floriculture			
Forestry			
Aquaculture		DARD 1 seller 1 aquaculture	
Livestock and bird		DARD 1 seller	
Cement			DOIT 1 Cement Enterprise
Brick			DOIT 1 Brick Enterprise
Restaurant			1 Briquette seller

3.3.1 Market attractiveness for soil conditioner/ compost in Ba Ria

Soil conditioner

In interviews, DONRE Ba Ria-Vung Tau said that there is not large-scale production of compost or soil conditioner in Ba Ria-Vung Tau province. Most farmers use organic amendments that are produced locally on a smaller-scale with domestic wastes, cacao husks or chicken, pig and cow manure, mixed with commercial organic fertilizers. Such products are widely used in perennial tree plantations.

Figure 10: Horticulture farm using homemade composting in Tan Hai Commune, Ba Ria City

FS emptiers from BUSADCO and from Tan Thanh private company stated that FS collected by their companies is transported to the Dai Nam FS Treatment Plant in Toc Tien Commune, Tan Thanh District. The Dai Nam FS Treatment Plant currently does not produce any treatment treatment products for usage. FS emptiers from Le Gia Nhu private group also deliver untreated FS for free to rubber tree farms in Long Tan Commune, Dat Do District, where untreated FS is mixed with wood to produce good quality compost. No detailed information was gathered concerning quantities of compost. Thus, only market potential of fertilizers in Ba Ria is assessed.

Fertilizers

According to DARD, organic fertilizers are widely used since farmers understand their long-term efficiency and positive impacts on soil structure. There are 10 enterprises producing organic fertilizers and 3 enterprises producing chemical fertilizers, as well as 3 primary distribution agencies and 189 secondary distribution agencies in the province. Estimates of usage of fertilizers in the Province varies. This confirms that some farmers apply fertilizers based on their experience and financial availability and do not follow DARD recommendations.

Table 24: Unit price of fertilizer in Ba Ria-Vung Tau province (DARD Ba Ria-Vung Tau, 2015)

	N	P	K	Mixed NPK	Organic fertilizers
Price (USD/kg)	0.53	0.22	0.58	0.76	0.22

Local farmers greatly prefer using organic fertilizers over chemical fertilizers. The DARD informed that it is planned to modify the regulations concerning the quality of fertilizers. If good quality fertilizers could be produced with FS treatment products, for example, by amending compost or pellets with NPK, then the local market has the potential to rapidly integrate this FS treatment product. Interviewed farmers

expressed interest in using FS treatment products if they were less expensive than commercial fertilizers, hence, an adjustment factor of 0.9 was used.

Based on the calculation presented in Table 25 and the adjustment factor, it is estimated that the market volume of FS treatment products substituting fertilizers in Ba Ria-Vung Tau province is 190,272,706 USD. There is a strong competition among suppliers of fertilizers in Ba Ria – Vung Tau province, and the growth for this market is difficult to forecast. It is assumed that the demand will remain stable in the coming years.

FS-derived fertilizers could first be introduced or tested in horticulture farms in Tan Hai Commune, Tan Thanh District, Ba Ria City. These farms are cultivating different types of vegetables year round. Their fertilizer demand is high, and their location is only about 10 km from Ba Ria City, which could facilitate the transportation of FS fertilizers.

Table 25: Market volume for fertilizers and FS treatment products substituting fertilizers in Ba Ria-Vung Tau province (DARD Ba Ria-Vung Tau, 2015)

		Surface (ha)	Market volume for fertilizers (USD/year)					Market volume for FS treatment products substituting fertilizers (USD/year)				
			Chemical fertilizer				Organic fertilizer	Chemical fertilizer				Organic fertilizer
			N	P	K	Mixed NPK		N	P	K	Mixed NPK	
Plantation and Horticulture	Paddy	23,523	2,509,120	1,568,200	1,359,107	-	-	2,258,208	1,411,380	1,223,196	-	-
	Maize	15,051	321,088	150,510	130,442	-	6,689,333	288,979	135,459	117,398	-	6,020,400
	Vegetable	7,176	95,680	55,813	82,923	-	478,400	86,112	50,232	74,630	-	430,560
	Beans	1,319	17,587	10,259	15,242	-	87,933	15,828	9,233	13,718	-	79,140
	Cassava	8,919	380,544	396,400	669,916	-	10,901,000	342,490	356,760	602,924	-	9,810,900
Perennial industrial plants	Tobacco[11]	140	11,200	3,111	8,089	-	373,333	10,080	2,800	7,280	-	336,000
	Coffee	6,885	1,652,400	1,071,000	1,790,100	-	45,900,000	1,487,160	963,900	1,611,090	-	41,310,000
	Rubber[12]	23,061	1,844,880	5,124,667	1,332,413	-	51,246,667	1,660,392	4,612,200	1,199,172	-	46,122,000
	Cashew	10,652	1,193,024	615,449	467,741	-	9,468,444	1,073,722	553,904	420,967	-	8,521,600
	Pepper	9,074	2,032,576	-	2,201,957	11,517,931	28,230,222	1,829,318	-	1,981,762	10,366,138	25,407,200
	Fruits	7,851	1,046,800	348,933	567,017	-	17,446,667	942,120	314,040	510,315	-	15,702,000
Total (1)		113,651	11,104,899	9,344,342	8,624,946	11,517,931	170,822,000	9,994,409	8,409,908	7,762,452	10,366,138	153,739,800
Total (2)			**211,414,118**					**190,272,706**				

11 Source: Demand of fertilizers from (News on fertilizers, 2013)

12 Source: Demand of fertilizers from (DARD Son La, 2015)

3.3.2 Market attractiveness for animal feed in Ba Ria

Livestock and bird

There are 76 large-scale poultry farms in Ba Ria with 1,425 thousand birds, accounting for 41% of total poultry heads in the province of Ba Ria-Vung Tau. There are 152 large-scale pig farms with 195,346 heads, accounting for 57% of total pigs in the province (DARD Ba Ria-Vung Tau, 2015). In 2015, 242 primary and secondary agencies distributed animal feed in Ba Ria-Vung Tau province. Farmers purchase prefabricated animal feed, or produce it themselves by mixing different components.

Some livestock and bird farms have been using earthworms as animal feed, however no information about willingness to use black soldier fly larvae produced during FS treatment could be obtained during this study due to time constraints during the field trip. An adjustment factor of 0.8 is thus proposed. Table 26 presents the market volumes calculations. Large scale husbandry of pig and poultry has been increasing substantially in this province. A growth of ~4% is forecasted for this activity until 2020.

Table 26: Market volume for animal feed and FS treatment products substituted animal feed in livestock and bird activity in Ba Ria – Vung Tau province

	Number of heads	Market volume for animal feed (protein) (USD/year)	Market volume for FS - proteins (USD/year)
Pig	340,241	7,258,475	5,806,780
Poultry	3,474,000	1,259,904	1,007,923
Total		**8,518,379**	**6,814,703**

Aquaculture

For the city of Ba Ria, the study focused on prawn farms that account for about 50% of aquaculture surfaces of the province. DARD of Ba Ria stated that worms have also previously been used in aquaculture. Internet research confirmed that there is a good market potential for using worms as feed in Ba Ria. As DARD is supporting the use of worms in aquaculture and this practice is already existing in local farms, an adjustment factor of 0.9 is proposed for the calculations of the market volume as presented in Table 27. Some farms know the process of feeding with worms, and would accept to use Black soldier flies.

Table 27: Unit price and market volume for proteins in aquaculture in Ba Ria-Vung Tau

	Production (ton)	Quantity of animal feed (kg /kg product)	% Protein in food	Price for animal feed (VND/kg)	Price for protein (USD/kg)	Market volume for protein (USD/year)	Market volume for FS- proteins (USD/year)
Prawn	15,000[13]	1.50 [14]	21%[15]	35,500 [16]	0.33	4,998,400	4,498,560

13 Source: (DARD Ba Ria-Vung Tau, 2015)

14 Source: (DARD Thai Binh, 2010)

15 Source: (Luc, 2011)

16 Source: (Cong, 2012)

In total, the market volume of black soldier fly larvae as animal feed for livestock, bird and aquaculture activities is estimated at 11,313,263 USD for 2014 in Ba Ria.

Black soldier flies could first be introduced to aquaculture farms in Long Huong Commune, Ba Ria City. These aquaculture farms are already familiar with using worms as feed, and would accept to use black soldier fly larvae as feed. Their location is within Ba Ria City, so the transport cost could be limited.

Figure 11: Aquaculture farms in Long Huong Commune, Ba Ria City

3.3.3 Market attractiveness for solid fuels in Ba Ria

Charcoal briquette

During an interview, a retailer of charcoal briquettes in Ba Ria expressed low willingness to use FS treatment products. They distribute around 300 charcoal briquettes per day for households and restaurant kitchens at the price of 6,000 VND/briquette. The adjustment factor for this product is fixed at 0.5, due to low interest in testing FS treatment products for charcoal briquettes. Market volume and growth could not be estimated for the entire province, as the interviewed retailer was not willing to further collaborate, and no other retailer or producer was contacted due to time constraints.

Brick production

There are 5 brick producers in the province with a total production of 124 million bricks/year (Ba Ria-Vung Tau People Committee, 2014). The Long Huong Brick Enterprise produces 20 million bricks/year and consumes more than 300 tons of coal/month. The coal is purchased at the price of 1.8-2.2 million VND/ton from Dong Nai province, but the source of origin is Quang Ninh Province. Prices are similar to those in Son La province.

The coal supply source of Long Huong Brick Enterprise is stable. They are interested in using dried FS if it has the same fuel quality and is less expensive than coal. Therefore, an adjustment factor of 0.9 is proposed for the calculations of the market volume as shown in Table 28. According to the Master Plan on Construction Materials of Ba Ria-Vung Tau Province to 2020 and 2030, brick production in the province could reach 180 million bricks/year, corresponding to an increase of 45%.

Table 28: Market volume dried FS sold for brick production in Ba Ria-Vung Tau province

Production scale (brick/year)	Consumption of coal (ton/year)	Unit price of coal (USD/ton)	Market volume (USD/year)	Market volume for dried FS (USD/year)
124,000,000	37,200	97.78	3,637,333	3,273,600

Cement production

There are 2 cement-production plants in Ba Ria-Vung Tau province, Thi Vai and Cam Pha. The cement production and kiln are in Kien Giang Province, which is outside the defined scope of this study, thus, the market volume was not analyzed.

In total, the market volume for dried FS substituting coal for brick production in Ba Ria-Vung Tau province is estimated at 3,278,953 USD for 2014. Application of dried FS in the brick enterprises located in Tan Thanh District is possible for trials.

3.3.4 Discussion and recommendations for Ba Ria-Vung Tau Province

The total market volumes and market growth for FS treatment products substituting existing products in Ba Ria – Vung Tau are summarized in Table 29.

Table 29: Total market volume and market growth of FS substituted products in Ba Ria-Vung Tau province in 2014

	Market volume of FS substituted treatment products (USD/year)	Market growth (%)
Soil conditioner/Compost	-	
Fertilizers	190,272,706	negative
Animal Feed	11,313,263	4%
Solid Fuels	3,278,953	45%
Total	**203,129,570**	

The market volume for fertilizers accounts for nearly 94% of total estimated market volume in Ba Ria – Vung Tau. This alternative is strongly encouraged by DARD. Application of FS derived fertilizers would be possible in farms nearby Ba Ria City. Black soldier fly larvae could also be supplied to aquaculture farms in Long Huong Commune as prawn and fish feed. Dried FS could also be used at brick enterprises to replace coal in heating process. Implications of these results are discussed in the conclusions section.

4 Concluding remarks

Among the FS treatment products and product applications initially considered in this study, 3 types of treatment products could be quantitatively assessed and compared in the 3 studied cities. They were fertilizers, black soldier fly larvae, and dried FS as solid fuels. For these treatment products, the product applications that were studied include agriculture (horticulture, floriculture and perennial plantations), husbandries (livestock, birds and aquaculture), charcoal briquettes, bricks, cement and paper recycling factories.

Table 30 summarizes the market volume, market growth and adjustment factor for the studied treatment products in the 3 cities for 2014.

Table 30: Summary table of the market volume and growth and adjustment factor for the FS treatment products in the three cities

	Product	Market volume	Adjust. factor	Comment	Market growth
Son La : Total 166,309,791 USD/year					
1	Fertilizers	140,928,437	**0.9**	Support from DARD & interest from farm	+
2	Livestock & bird	9,002,909	0.7	Limited interest to use FS products (need proofs)	+
3	Aquaculture	5,444,445	0.7	Limited interest to use FS products (need proofs)	nd
4	Briquettes	178,444	0.5	No interest to use FS products	nd
5	Bricks	4,400,000	**1**	High interest to use FS products	-
6	Cement	6,355,556	0.5	No interest to use FS products	-
Bac Ninh : Total 167,724,780 USD / year					
1	Fertilizers	143,025,588	0.7	No information on interest to use FS products	-
2	Livestock & bird	7,275,192	0.7	Limited interest to use FS products (need proofs)	0
3	Aquaculture	10,032,000	0.8	No information on interest, good potential	0
4	Briquettes	nd	nd	No interest to use FS products	nd
5	Bricks	7,200,000	**1**	High interest to use FS products	nd
6	Paper	192,000	**0.9**	High interest to use FS products, lower prices	nd
Ba Ria : Total 204,859,569 USD / year					
1	Fertilizers	190,272,706	**0.9**	Support from DARD & interest from farm	nd
2	Livestock & bird	6,814,703	0.8	No interest to use FS products, good potential	+
3	Aquaculture	4,498,560	**0.9**	Support from DARD & interest from farm	nd
4	Briquettes	nd	0.5	No interest to use FS products	nd
5	Bricks	3,273,600	**0.9**	High interest to use FS products, lower prices	+

In all 3 cities, there is a good potential for resource recovery from FS, and the cultural acceptance for the use of products is high. From a quantitative point of view, the market volumes for FS treatment products are in the same range in the 3 cities, with a greater market volume in Ba Ria, especially for fertilizers.

The selection of optimal treatment products was different for each city, depending on the willingness to use these products by industries or farmers. The best options for treatment products in each of the cities are:

Son La

1. Fertilizers, with potential sale to the floriculturists in Chieng An Ward, Son La City.
2. Solid fuels for brick production, with potential sale to Mai Son Brick Enterprise, in Mai Son District.

Bac Ninh

1. Solid fuels for either brick production, with potential sale to Tan Son Brick Enterprise, in Tien Du District, or for recycled paper production by Hien Hoa Paper Mill in Phong Khe Commune.

Ba Ria

1. Fertilizers for horticulture farms in Tan Hai Commune, Tan Thanh District, Ba Ria City,
2. Black soldier fly larvae, for aquaculture in Long Huong Commune,
3. Solid fuel for brick production in Long Huong Brick Enterprise, in Kim Dinh Ward.

All these FS treatment products have a potential for other Vietnamese cities with similar situations than Son La, Bac Ninh and Ba Ria. However, further assessment in is recommended prior to implementation. Indeed, the geographical and economic context of each city influences the optimal solutions. For example, Son La is a mountainous province, where transportation is complex. Thus, proximity between treatment plant and user might be more influential than elsewhere. Ba Ria is in Southern Plateau, and more representative of port cities. Bac Ninh, situated in the Red river Plateau, is more industrial. Therefore, collaboration with neighboring brick or paper industry can be facilitated.

Black soldier flies seem to have a greater potential in aquaculture, and among the 3 studied cities, this option could be tested in Ba Ria. Indeed, this was the only city where interviewees showed interest for black soldier flies as animal feed. In the other 2 cities, first tests could be done with fertilizers and solid fuels.

In the framework of future tests concerning FS management plan, the following FS treatment technology are feasible to produce the described FS treatment products:

- Treatment with Composting is well known to be efficient, low cost, and has a history of implementation in Vietnam. This solution is particularly interesting for Son La, as a composting plant is already being implemented for organic wastes. Co-composting of FS with household organic wastes could enhance the process and produce high quality compost. If compost is used for edible crops, the compost process needs to be closely monitored to ensure adequate pathogen reduction. Otherwise, compost should be used for non-edible crops or tree-plantations to protect public health. In Son La, the floriculturist in Chieng An ward appears to be a promising enduser of compost.
- Dried FS pellets can be produced by mechanical dewatering followed by pelletizers. This option is not space intensive, is especially promising if pellets can be used in nearby industries to limit transport costs. Where more land is available, less energy demanding options such as drying beds can be used for dewatering. These are more advantageous where space is available, and operational budget related to electricity is limited. The selection of drying technologies should be based on the local context (e.g. space availability, energy demand, and market for enduse). Brick industries showed interest in using dried FS the three cities. In Bac Ninh, Tan Son Brick company expressed high interest in using FS treatment products. To test various resource recovery options, an assessment could also be conducted with the Hien Hoa paper mill factory in Bac Ninh.

- Animal feed in the form of black soldier larvae could be piloted in Ba Ria. This seems promising based on the high number of aquaculture farms in this area. Pilots could be operated in Long Huong commune, collaborating with a local farm.

Depending on the level of development of different technologies, pilot scale treatment technologies should be run prior to implementing larger scale treatment plants in collaboration with emptiers, endusers and local authorities. Contacts for all referenced industries and farms are provided in Annexes 2, 3, and 4. During the pilot phase, additional research should be done on available quantities of FS, optimal pricing, packaging and storage of treatment products, required investment costs.

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7 Annex

Annex 1: Questions for MDA in Bac Ninh, Son La and Ba Ria – PURR project - July 2015

Industry description

1. Please describe the agricultural production scale, including:
    - Quantity (surface/head)
    - Production scale
    - Yield
    - Location of yours and the others in the province
    - How much is your benefits (in VND/year)

For the following industries applications:

- Plantation and horticulture
- Perennial industrial trees
- Flower industry
- Forestry
- Aquaculture
- Livestock & bird
- Brick industry
- Restaurant / Canteen
- Cement industry
- Paper recycling industry

Market volume

2. Please describe your main input investments (users of products) / benefits (sellers of products):
    a. For users of fertilizer (organic & chemical) / soil conditioner (organic & chemical) / compost
        - Kind of products used
        - Dosage: total amount/ amount per crops
        - Price/ Fees
        - Name/location of distribution agencies
    b. For users of animal feed (commercial 6 organic) / livestock feed (fodder)
        - Quantities needed
        - Kind of products
        - Name/location of distribution agencies
        - Price
    c. For users of solid fuel (charcoal, wood &husk)
        - Kind of fuel used
        - Quantities of fuel used per year, for each kind
        - Quantities per ton of product
        - Name/location of distribution agencies
        - Price of fuel for each kind
    d. For users of inorganic material (ashes)
        - Quantities of fuel used per year, for each kind
        - Quantities per ton of product

- Name/location of distribution agencies
- Price

e. For sellers (all products: fertilizers, soil conditioner, compost, animal feed and livestock feed, solid fuel and inorganic material)
    - Kind of products provided by themselves
    - Estimated (other and total?) supply sources in the province
    - Sources of products
    - Who are customers?
    - What are their purchase capacity and their location?
    - What are the quantities sold for each kind of product / customers?
    - Price for each kind of product / customers?

Market growth

3. Please describe the past trends and prevision in the next 5 years:
    - Production scale increased ? in % the past years
    - Production scale increased ? in % the next years
    - Input sources increased ? in % the past years
    - Input sources increased ? in % the next years
    - Prevision of gain/benefits
    - Prevision of challenges/opportunities

For the following products (both users and sellers):

- fertilizers,
- soil conditioner,
- compost,
- animal feed,
- livestock feed,
- solid fuel,
- inorganic material.

Adjustment factor

4. Potential to replace existing products by FS (for all product application, both users and sellers)
    - Willing to do, what would be the constraints?
    - Willing to pay (for users)?
    - Extra costs (in investment (e.g. to buy a new kiln), transport, equipment, etc.) ?
    - Extra cost of time needed (e.g., in operation and maintenance, if one more product is managed)
    - Cultural issues (e.g., if need to have communication with customers to make them accept the product is from FS, if there is a social stigma with using FS product).
    - Aspects related to variability over the year (e.g., as FS products may not be delivered at a constant rate)
    - Aspects related to lower or higher quality if this is made of FS (e.g. for chemical / organic fertilizers, maybe good organic fertilizer can be produced with FS… maybe not)
    - Aspects related to price (e.g., maybe products made from FS are cheaper, and therefore more attractive)

Annex 2: Stakeholders contacted for the study in Son La

Stakeholder	Application	Name	Address
Management board	Agricultural activities	Department of Agriculture and Rural Development of Son La	182 Nguyen Luong Bang Street, Son La City, Son La Province Tel: 022 3852133
Seller	Fertilizers	Agricultural Materials Company of Son La Province, Branch Office Son La	8 Tran Dang Ninh Street, Son La City, Son La Province Tel: 0903 485 769
Seller	Fertilizers	Tuan Thao Distribution Agency	Central Market, Son La City, Son La province Tel: 0223 855 656
FS emptier	Soil conditioner	Mr Ky, Urban Environmental Company of Son La (URENCO)	7 Ban Co Street, Chieng Le Ward, Son La City, Son La Province Tel: 0987 131 396
FS emptier	Soil conditioner	Mr Cuong Private emptier	Son La City, Son La Province Tel: 0977 258 789
Consumer	Perennial plants	Mr Luu, Tai Dam Coffee Farm	Nong Nua Commune, Chieng Ban Ward, Mai Son District, Son La province Tel: 0948 377 555
Consumer	**Floriculture**	**Ms Huong, rose floriculturist**	**Ca Village, Chieng An Ward, Son La City, Son La Province** **Tel: 0964 285 729**
Seller	Animal feed	Tuan Dzung Distribution Agency	413 Chu Van Thinh Street, Son La City, Son La Province Tel: 0169 500 961
Seller	Animal feed	Tuyen Lieu Distribution Agency	Moc Chau District, Son La province Tel: 0976 678 094
Consumer	Livestock	Ms Thuan Son, cow-milk breeding	26/7, Moc Chau District, Son La province Tel: 0946 265 200
Management board	Industry and Trade	Department of Industry and Trade of Son La	Unit 3, Chieng Le Ward, Son La City, Son La Province Tel: 022 852 268
Consumer	Charcoal briquette	Hanh Moc workshop	Unit 1, Chieng Xom Ward, Son La City, Son La province
Consumer	Brick	Mai Son Brick Enterprise	Mai Son District, Son La Province Tel: 0988 586 456
Consumer	Cement	Mai Son Cement Enterprise	Mai Son District, Son La Province Tel: 0988 586 456

Annex 3: Stakeholders contacted for the study in Bac Ninh

Stakeholder	Application	Name	Address
Management board	Agricultural activities	Department of Agriculture and Rural Development of Bac Ninh	Ly Thai To Street, Bac Ninh City, Bac Ninh Province Tel: 0241 3855 737
FS emptier	Soil conditioner	Mr Hung, Urban Environmental Company of Bac Ninh (URENCO)	4 Nguyen Dang Dao, Tien An Ward, Bac Ninh province Tel: 0944778162
FS emptier	Soil conditioner	Mr Tiep, Private emptier	Bac Ninh City, Bac Ninh Province Tel: 0972746665
Consumer	1 floriculturist (orchid)	Ms Do Thi Mo	Gioi Te, Phu Lam Commune, Tien Du District, Bac Ninh province
Consumer	1 horticulture farm	Mr Hop	Vo Cuong District, Bac Ninh City, Bac Ninh Province Tel : 0984 891 946
Seller	Animal Feed	Suong Thuy, distribution agency of DABACO corporation	Tam, Phu Lam Commune, Tien Du District, Bac Ninh province Tel : 0975 271 969
Consumer	1 poultry farm + pig farm	Mr Nguyen Van Luu	An Phu, Phu Lam Commune, Tien Du District, Bac Ninh province Tel : 0126 6059543
Management board	Industry and Trade	Department of Industry and Trade of Bac Ninh	Ly Thai To Street, Bac Ninh City, Bac Ninh Province Tel: 0915 179 524
Consumer	Restaurant		Pho Moi, Dang Nguyen, Tu Son District, Bac Ninh Province
Consumer	**Brick**	**Tan Son Brick Enterprise**	**Tien Du District, Bac Ninh Province Tel: 0241 350 1402**
Consumer	**Recycled paper**	**Mr Vi Van Cao, Hien Hoa Paper Mill**	**Phong Khe Commune, Bac Ninh City Bac Ninh Province Tel: 0964 480 000**

Annex 4: Stakeholders contacted for the study in Ba Ria

Stakeholder	Application	Name	Address
Management board	Agricultural activities	Department of Agriculture and Rural Development of Ba Ria	9 Huynh Ngoc Hay Street, Phuoc Hiep Ward, Ba Ria City, BR-VT province Tel: 064 382 9891
Seller	Chemical & organic fertilizers	Thuy Nga Distribution Agency	Hoa Long District, Ba Ria City, BR-VT province Tel: 064 382 6117
Consumer	**Horticulture farmer**	**Mr Long**	**Tan Hai Commune, Tan Thanh District, BR-VT province**
Seller	Animal Feed	Anh Nguyen Distribution Agency	Hoa Long District, Ba Ria City, BR-VT province Tel: 0986 795 456
Consumer	Aquaculture farm	Mr Tam	BR-VT province Tel: 0983 857 554
Management board	Industry and Trade	Department of Industry and Trade of Ba Ria -Vung Tau	No 1 Pham Van Dong Street, Phuoc Trung Ward, Ba Ria-Vung Tau province Tel: 064 3542677
Consumer	Charcoal briquette	Ms The, retailer	Ba Ria City Tel : 0982 406 977
Consumer	**Brick production**	**Mr Thin, Director of Long Huong Brick Enterprise, DIC group**	**Km 61, PL 51, Kim Dinh Ward, Ba Ria City, Ba Ria-Vung Tau province** **Tel: 0908 878 103**
Consumer	Cement production	Mr Hoa, Environmental Supervisor of Thi Vai Grinding Plant, Holcim Cement Group	Phu My 1 Industrial Zone, Tan Thanh District, Ba Ria-Vung Tau province Tel: 0973 632 646
FS emptier	Soil conditioner	Mr Trong, Ba Ria – Vung Tau Urban Sewerage and Development One Member Limited Company (BUSADCO)	No 6, 3/2 Street, Ward 8, Vung Tau City, BR-VT province Tel: 0908 870 198
FS emptier	Soil conditioner	Mr Hung, Le Gia Nhu private emptier group	Ba Ria City, BR-VT province Tel: 0919 741 698
FS emptier	Soil conditioner	Mr Nam, Tan Thanh private emptier group	Ba Ria City, BR-VT province Tel: 0902 456 279