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Abbreviations

CAPEX	Capital Expenditure
CHP	Combined heat and power
CH₄	Methane gas
COD	Chemical Oxygen Demand
CO₂	Carbon Dioxide
DoIT	Department of Industry and Trade
DoNRE	Department of New and Renewable Energy
ESCO	Energy Service Company
EU	European Union
EVN	Electricity of Vietnam
EUR	Euro
FDI	Foreign Direct Investment
FIT	Feed-In-Tariff
FO	Fuel oil
FS	Feasibility Study
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
LCOE	Levelized Costs of Electricity (equivalent LEC)
Kt	Kilo ton (1000,000 kilogram)
MoIT	Ministry of Industry and Trade, Vietnam
MoNRE	Ministry of Natural Resources and Environment
NDC	Nationally Determined contributions
OPEX	Operational Expenditure
PBP	Payback period
IRR	Internal Rate of Return
NPV	Net Present Value
VPPA	Vietnam Paper and Pulp Association
VCA	Vietnam Cassava Association
SNV	Netherlands Development Organisation

01

Executive Summary

1 Executive Summary

The pig-pork, the paper and pulp and the cassava-starch sub-sectors experience high growth rates and operate in a highly competitive environment. Bio-energy usage is a common practice in the cassava and the pulp industry but less in the paper industry and at pig farms. Bioenergy up-scaling opportunities exist in all sub-sectors, both for self-generation and ESCO models.

This report represents the outcome of the sub-sector analysis on utilizing bioenergy for heat and electric generation study executed by the Local Consultant Firm (SNV Netherlands Development Organisation in conjunction with the International Consultant (Eric Buysman). After work package (WP) 1 – the sub-sector review and selection study and WP 2 – the consultation workshop, 3 sub-sectors were selected (1) Pig-pork, (2) Paper and pulp and (3) Cassava-starch. In WP3 sub-sector data on sub-sector performance on bio-energy opportunities were collected through a mix of physical visits, telephone interviews and literature review. The outcome of WP1 to 3 are consolidated in this final report.

1.1 Introduction

Vietnam has a large bio-energy potential, but usage remains limited except in the sugar industry. Exploiting this source could help various industries not only to reduce energy costs, in combination efficient technologies such as cogeneration, but also reduce greenhouse (GHG) emissions.

1.2 Implementation

This study was executed in the period January to June 2021.

1.3 Key findings

1.3.1 Pig-pork sub-sector

- The sub-sector is undergoing structural changes resulting the economic impact of the Asian Swine Flu (ASF) epidemic and competition from pork imports. In response to this, the sub-sector is moving away from disconnected channels consisting of small-scale farms and cooperatives, towards channels in which all functions, from feed to meat, are controlled by a large company, such as contract farming sponsor companies or companies with 3F (Feed, farming, food) business models.

- While a significant portion of pig farms have waste treatment systems in which biogas is captured, gas utilization levels remain low, due to technical and financial barriers.
- A case study was prepared on the biogas-electricity generation potential of a large pig farm. The case study concluded that electricity generation from biogas is financially attractive for captive power purposes. The before tax levelized cost of electricity (LCOE) was estimated at 1243 VND/kWh and a simple pay-back period (PBP) of 1.89 years.

1.3.2 Paper and pulp sub-sector

- The paper and pulp sub-sector is a competitive sector attracting significant foreign direct investment (FDI). The sector produces mostly kraft paper (85%) and relies on imported pulp and scrap as input material, domestic pulp production remains limited. The sector is moving towards large mills with high capital investment.
- Fuel decisions are determined based on price and boiler specifications. Energy Service Companies (ESCO's) are relatively common source of steam for small and medium mills, but significant up-scaling potential remains.
- There are only 2 pulp mills. These mills have their own supply of biomass (residue from

plantations), produce a residue with high calorific value which is the black liquor, and can replace a significant amount of coal with plantation residues. Paper mills on the other hand, do not have an own source of bio-energy other than unused scraps and rely mostly on coal.

- The case study focused on the planned biomass combined heat and power (CHP) investment of the VINAPACO pulp and paper mill. The CHP will utilize bark and wood chips from their pulp-wood plantations (70%) and coal (30%) as fuel. This study recommends a CHP with a boiler operating at 510 °C and 100 bar to maximize electricity production. The proposed CHP was financially evaluated based on 5 quotations from companies received. The investment is viable at a maximum cost of around 828 billion VND resulting in a LCOE and levelized cost of steam production lower than both grid electricity and steam retail tariffs of ESCO's.

1.3.3 Cassava-Starch sub-sector

- Cassava is an import crop in Vietnam, second after rice in cultivation area. Cassava-starch sub-sector is export oriented and relies for a significant share of cassava roots on Cambodia. Vietnamese produces mostly native starch; some factories are investing in modified starch production lines to create higher value added.
- Biogas is captured from wastewater in almost all companies and used as a fuel for drying starch and pulp.
- Prior to 2015 pulp had little value and was not dried, in that period factories had excess biogas. Nowadays however, fueled by the growing animal feed industry, pulp is dried in drum and flash dryers fueled with biogas and sold to animal feed factories.
- A cassava factory in Tay Ninh was selected for the case study, this factory reported having excess biogas. The case study revealed that biogas for electricity generation is very attractive with a before tax LCOE of just 1124 VND/kWh and a simple PBP of 1.45 year. The study also

investigated a CHP scenario, but the LCOE was at 1478 VND/kWh which is less attractive. Similar biogas to electricity opportunities may exist in other large factories or may arise with improvements in energy efficiency and may further increase with improved mechanical pulp drying equipment.

1.4 Recommendations

This study relied on data collected from factories and secondary literature resources. However, limited data was available on key input data necessary to assess the exact bio-energy potential. Therefore, in all the case studies the potential was calculated using proxy data. A follow up-study should perform on-site measurements of key parameters (biogas produced, wastewater, chemical oxygen demand (COD), etc.) to validate the findings in this study.

Cost-effective points of entry with leverage potential are in the pig-pork sector channels with connection functions (in which a great number of farms can be reached), in the paper and pulp, working with ESCO companies could achieve similar results in the sub-sector. In the cassava-starch sub-sector there are no strong linkages between the factories. Working with large companies owning multiple factories is perhaps the least-cost mode of entry with leverage potential.

1.5 Conclusion

This study showed that significant bio-energy opportunities exist in the pig-pork sub-sector which are also financially attractive. Opportunities in the pulp and paper sector are limited to pulp mills, unless a stable supply of cost-competitive biomass can be secured.

Cassava-starch sub-sector is a bio-energy success story. Overall energy efficiency improvements are possible which could create opportunities for on-site power generation or CHP.

Chapter

01

Introduction

1 Introduction

This chapter provides background information on the assignment, the study objectives an overview of the activities implemented, study limitations and report outline.

1.6 Study background

The Climate Protection through Sustainable Bioenergy Markets in Vietnam project (BEM) aims to improve the preconditions for a sustainable use of biomass for electricity and heat generation in the country. The project supports Vietnam's efforts in climate protection by promoting the energy recovery of already generated biomass waste for power and heat production. As a contribution to reduce emissions, and thus to achieve the Vietnamese Nationally Determined Contributions, the BEM project is commissioned by the Ministry of Environment, Nature Conservation, and Nuclear Safety (BMU) through the International Climate Initiative (IKI). The BEM project promotes greenhouse gas (GHG) abatement capacities by improving the conditions for sustainable use of bioenergy in power and heat production, focusing more on the improvement of planning, technical and financial capacities of respective actors in the biomass energy sector in order to realize bankable investment projects.

As per the Terms of Reference, the study aims to identify the bioenergy¹ potential in three selected subsectors following a subsector approach². The ToR splits the assignment into four work packages. This document presents the final deliverable: the final report. The final report is based on the sub-sectors desk study (WP1), the consultation workshop (WP2) and the data collection package (WP3)

1.6.1 Study objectives

This study focuses on subsectors to identify potential for the energetic use of biomass waste via:

1. Describing the current structure of the subsectors, in terms of the activities, actors, and rules involved. Explaining why and how this structure arose.
2. Analyzing the implications of this structure for economic performance of the subsector. This will concern the current and future performance. Predictions about the future performance will consider what the analysts know about the evolving supply and demand conditions facing the subsector.
3. Analyzing possible forces of change for the utilization of bioenergy: the energy demand status (electricity and heat); the energy supply status; the business plans in upgrading and/or making new investment into combined heat and power (CHP) technology, the involvement of energy service companies (ESCO), the technology providers; the key barriers to bioenergy application.
4. Documentation case studies: the existing successful model of utilizing bioenergy in the studied subsectors and the most technical and economic potential actors of utilizing bioenergy in these studied subsectors.

Objective 4, in consultation with GIZ, focused on identifying and assessing new bio-energy opportunities in the sub-sectors instead of documenting existing successful models of utilizing bio-energy .

¹ 'bioenergy' refers to renewable energy sourced from materials derived from biological sources (organic matter). Examples of bioenergy include but not limited to biomass waste and biogas generation from biowaste.

² The description of the subsector analysis refers to an article made by John M. Staatz: "Notes on the use of subsector analysis as a diagnostic tool for linking industry and agriculture, Department of Agricultural Economics, Michigan State University, February 1997

1.6.2 Scope and sub-sector selection

In WP1 '23' sub-sectors were studied in the food processing (in both agriculture and aquaculture sectors), water treatment, pulp and papers, biomass boilers, brewery and textile sectors with regard to the application of bioenergy for electricity and heat generation.

Four sub-sectors were recommended: Food processing, pork, cassava starch processing and paper and pulp. During WP2, the consultation workshop, this was narrowed down to cassava- starch processing, pork and paper and pulp:

1. **Pig-pork sub-sector** – this was previously referred to as the pig farm sub-sector. However, the aim of this sub-sector is to produce pork. Thus, this sub-sector is referred to as the pig-pork sub-sector in this report. The bio-energy potential assessment, however, focusses on one participant in the sub-sector, the pig farms.
2. **Paper and pulp sub-sector** – in this sub-sector paper product are produced, either directly from imported pulp and scraps or by first producing pulp from woody biomass.
3. **Cassava- starch:** the whole cassava plant has value and roots can be processed into tapioca starch (as end-product or raw material for further processing), bioethanol and dried chips. The bio-energy potential assessment, however, focusses on one participant in the sub-sector, the cassava starch processing factories.

1.7 Data collection methods

1.7.1 Field visits

Table 1: Field visits by sub-sector, location and period

Sub-sector	Number	Province	Period
Pig-pork	5 (or 9)*	Phu Tho, Thai Nguyen, Bac Ninh	26 March – 15 April
Paper and pulp	5	Binh Duong, Bac Ninh	25 March - 26 April
Cassava - starch	6	Tay Ninh and Daklak	27-29 April

** 5 visited physically and 4 interviewed telephonically*

1.7.2 In-depth interviews for the case studies

In-depth interviews were held with sub-sector associations, ESCO providers, animal feed companies, technology providers, bio-energy fuel providers, provincial authorities (DoIT) to understand better the sub-sector performance and the bio-energy potential. A separate mission report is available of each sub-sector. Annex I contain the full list of interviews held.

1.8 Data analysis

A sub-sector level assessment was used to determine the potential for bioenergy. This approach sheds light on how the functions (enterprises) are organically connected horizontally and vertically with other enterprises and activities in the sub-sector. Understanding the dynamics of the various relationships is vital for the identification of bio-energy intervention opportunities.

Subsector assessment is a systems approach to the study of economic activity enabling a better understanding of the dynamics in the subsector. The objective of subsector assessment is to analyze all participants, their linkages, and influential factors in the agribusiness system in order to identify constraints and opportunities for growth. Subsector assessment is a powerful tool for project designers and decision-makers because it clearly illustrates where change can have the most significant impact on the subsector.

1.8.1 Study limitations

This study has several limitations:

1. **Selection bias:** The information obtained from the field visits are not representative for the whole sector. Due to time and budgetary constraints, only in a limited number of regions factories were visited. Data from the field visit however was triangulated with interviews held with other actors and branch organizations before drawing sub-sector wide conclusions.
2. **COVID-19 travel restrictions:** Due to COVID-19 travel restrictions the international consultant was unable to visit Vietnam and the factories. Also, due to the recent outbreak of COVID-19 in Vietnam, it was not possible to physically visit all the pig farms as planned, several interviews were therefore conducted telephonically.
3. **Case study data:** Factories often shared their data without restraints. However, few factories frequently monitor key parameters (COD in effluent, boiler efficiency, biogas production etc.) and in some cases actual processing capacity differed from capacity reported. This made it challenging to provide accurate estimates on the feasibility of a certain bio-energy intervention.

1.9 Report outline

In chapter 2 the first sub-sector is described, the pig-pork subsector. It starts with a general overview, the processes, the sub-sector map and sub-sector performance, results from the data collected, the case-study and a discussion/conclusion. The same set-up is employed in chapter 3 and 4 for the sub-sectors paper and pulp and cassava-starch respectively. In chapter 5 a general conclusion is provided.

Chapter

02

Sub-sector Pig-Pork

2 Sub-sector Pig-pork

The pig-pork subsector is developing rapidly and while the sub-sector is endowed with a large bio-energy source – biogas from waste (water) - biogas usage remains low. This chapter provides an overview of the sub-sector, the bio-energy usage and opportunities, and a case study on the financial viability of biogas for power generation and a conclusion on the leverage points for bio-energy intervention.

2.1 Sub-sector overview

2.1.1 Background

The livestock sector is a key component of the Vietnamese economy, contributing to 22 -24% of the agricultural gross value and continues to grow in response to increasing food demand driven by fast-paced economic growth (MARD 2020). The Ministry of Agriculture and Rural Development (MARD) has developed the Directive 1520/QĐ-TTg dated 6th October 2020 “Livestock Development Strategy for the Period 2021 – 2030, vision 2045” aiming to increase the national production of meat from 4.6 million tons of pork, beef and poultry in 2014, to 5 – 5.5 million tons by 2025 and 6 – 6.5 million tons by 2030. The increased production will require the industrialization and modernization of the livestock industry; particularly in developing intensive systems and large-scale production, which currently account for 45% of the farms nationwide and contribute to over 60% of the output (Department of Livestock Production (DLP), 2019).

The livestock sector consists of beef cattle, dairy cattle, pork, poultry, and other livestock. The sub-sector selected in this study in work package 1 and 2 is the pig-pork sub-sector. Pork is the most important meat in the Vietnamese diet with 71% followed by poultry (20.4%) and beef (8.6%) (MARD, 2019). In terms of pork consumption, Vietnam is the second highest pork consumer in Asia after China.

2.1.2 Pig farming

The average pig population is 27 million pigs, 45% are raised by household farms (including cooperatives) and 55% by small to large scale commercial farms (DLP, 2021). Farms are classified by the number of animals expressed in livestock units (LU), where 1 LU is 5 to 6 pigs (DLP, 2021):

Table 2: Farm scale classification

Farm scale	Livestock units	Number of pigs
Household	<10	<50
Small	10-30	50-180
Medium	30-300	180-1800
Large	>300	>1800

The concentration of pig farms varies in accordance with the geographical and socio-economic conditions. The Red River delta, the northern midland and mountainous zone and the central coast have a higher concentration of pig farms compared to the central highlands, the southeast, and Mekong river delta (Van, Son, Bao, Kuyama, & Cong, 2016).

The pig farming sub-sector is undergoing significant structural changes. There is a move away from household farming, cooperatives and pig farms towards large-scale companies and contract farming. This trend accelerated with the outbreak of the Asian Swine Flu (ASF) epidemic. Household pig farming decreased significantly from 1st of April 2019 to the 1st of April 2021 with around 30.8% or with almost 0.9 million pig farming households, the number of cooperatives dropped from 1,104 (2018) to 911

(2020), similarly, the number of large farms reduce from 14,481 farms (2017) to 9,924 farms (2020)³. Large companies in contrast, which own or contract multiple large farms, grew in size compared to before ASF. The largest 16 companies in the last 2 years increased fattening pig production by 71% and number of sows with 30% (DLP, 2021). These companies have made significant investment focusing on advanced technology, sanitary and closed value chains and on connecting markets for both domestic and export purposes. The 16 largest companies are the Charoen Pokphand (CP) group, Mavin, Dong Nai Food Industry Corporation (DOFICO), GreenFeed Joint Stock Company, DABACO Group, Hoa Phat Group, Deheus Group, Vinh Anh Food Company, Posco Deawoo (Korea), Tan Group Long, Vietnam Joint Stock Company, Tan Long, New Hope and KDI Holdings and are holding a cumulative of 5.5 million pigs.

2.1.3 Markets

Domestic pork production is mostly focused on the Vietnamese market and has an annual at \$8 billion⁴ turnover. In response to the ASF epidemic, Vietnam has opened its market for pork imports to address supply constraints. The imports have, as a result, grown rapidly. During the first 11 months of 2020, Vietnam imported 127,730 tons of fresh, chilled, or frozen pork, worth \$303.8 million entailing an increase of 416% in volume and 546.5% in value over the same period of 2019. In 2020, pork imports were mostly from Brazil (29.9% followed by Poland and Canada with 19.3% and 18% respectively (OEC, 2021). In the first 4 months 2021 most pork is supplied by Russian, reaching 22.14 thousand tons valued at \$60 million (VN Business, 2021), see below:

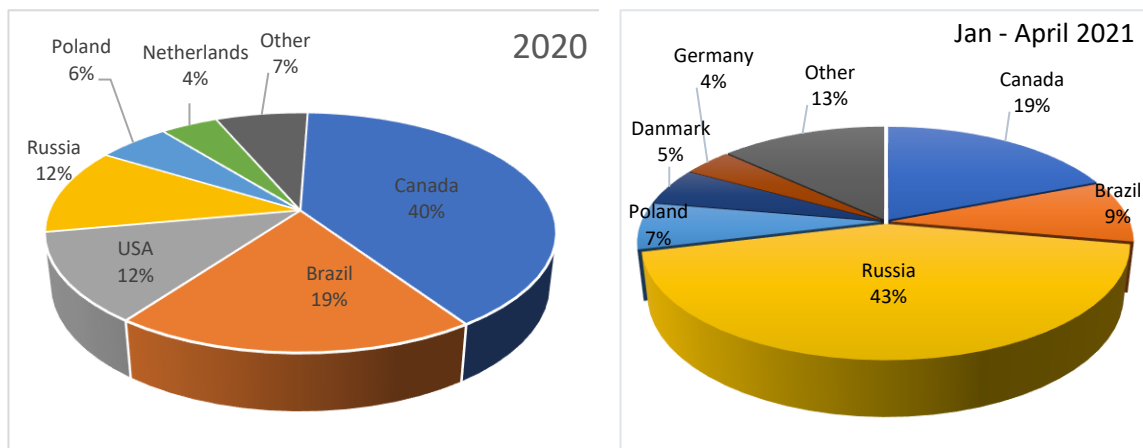


Figure 1: Market structure for imported pork 2020 (left) and the first 4-month 2021 (right)

Exports are just around 3.87 million ton in 2021 (Nhan Dan, 2021). Export of pork is estimated at \$66.9 million in 2019 of which most, 88.9%, is exported to Hong Kong.

MARD has signed an agreement with the World Organization for Animal Health (OIE)⁵ to support livestock production chains to meet quality standards for export. Vietnam will focus on supporting large enterprises and large corporations to find markets, and at the same time, increase domestic animal feed production. By 2025, Vietnam is expected to have 10 to 12 linked production chains meeting the requirements of importing countries. Accelerating exports will generate more benefits for enterprises and farmers, contributing to the rapid development of Vietnam's livestock sector.

2.1.4 Field visits

In the scope of study, the project team visited and interviewed three CP contract farms in Phu Tho, one farm in Thai Nguyen and one cooperative farm in Bac Ninh. An additional 4 farms were interviewed telephonically as COVID-19 restrictions prevented the team from travelling to the field.

³ Official MARD data

⁴ Author's calculations based on pork consumption and average pork value

⁵ Acronym used internationally is of the former name: Office International des Epizooties

2.1.5 Sub-sector performance

2.1.5.1 Sub-sector map

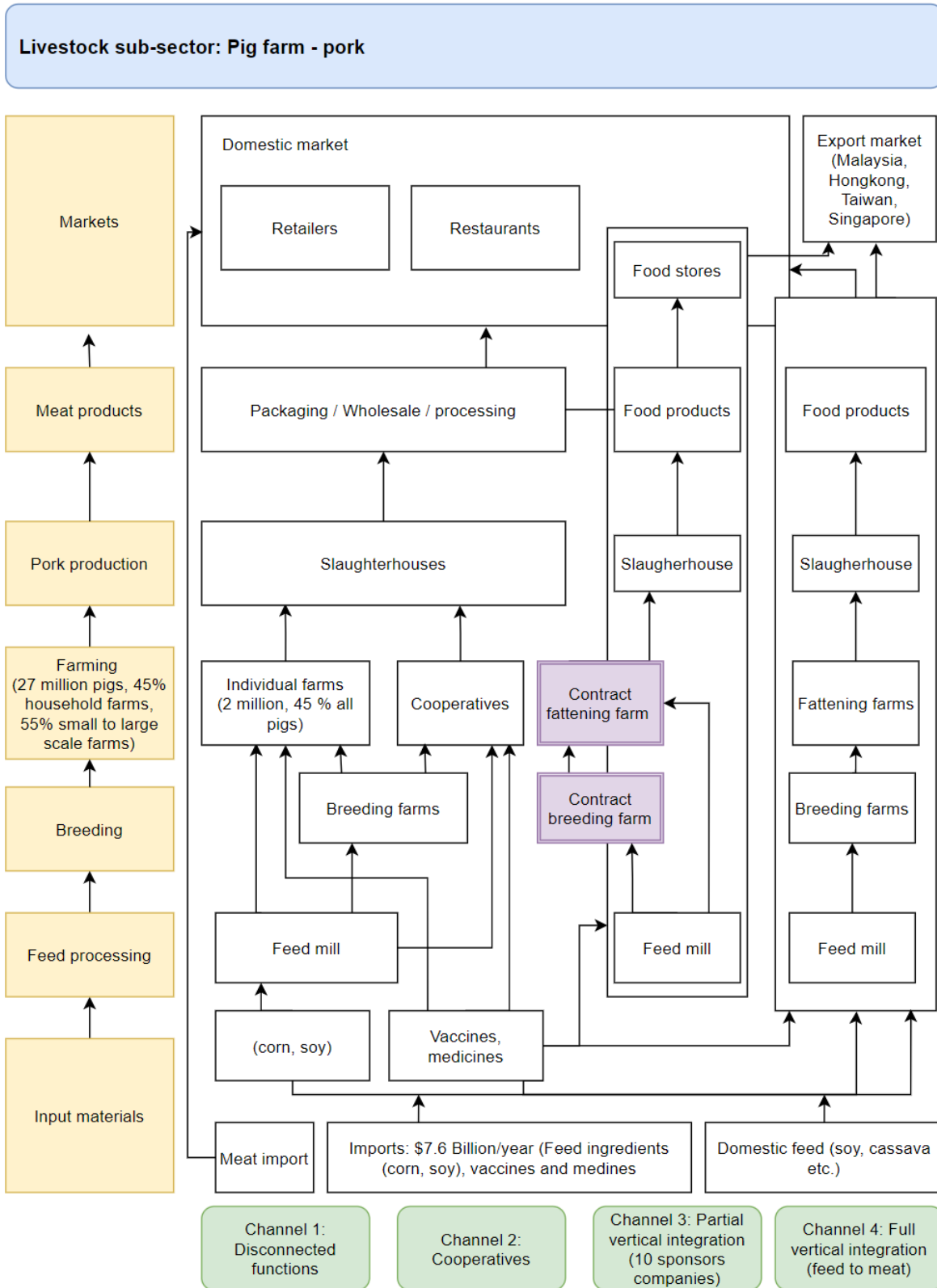


Figure 2: Pig-pork sub-sector map

There are 4 main channels in the pig-pork sector

1. **Disconnected functions.** In this channel the various functions rely on each other but without establishing a formal relationship or contract. The farms operating here are independent.
2. **Cooperatives:** in this channel one or more functions/participant cooperate with each other. Relationships can be formal and informal. The advantage of this channel is that these farmers as a group have more influence than individual farms enabling them to negotiate better contracts and their relationships facilitate sharing of information and expertise.
3. **Partial vertical integration:** These channels are controlled by sponsor companies working with farms in a contract farming agreement. The farms itself however are not owned by the sponsor company (highlighted in purple in the map). Some sponsor companies have their own retail channels (e.g., C.P. depicted in picture on the right). The sponsor companies take care of input, management of the main production processes as well as the output. Contract farms are responsible for the operation (breeding or fattening pigs), farm management, waste disposal and to arrange the necessary permits. The advantage of this model is that farmers have their inputs and outputs covered, benefit from technical assistance of the sponsor companies and stable predictable prices for their pigs. The main sponsor companies are C.P., De Heus, Hoa Phat Agricultural Development Joint Stock Company, Thien Long, Vina Agri, and others.
4. **Feed to meat:** In this channel one company controls all functions, sometimes even with their own retail channels (food shops). DABACO, Mavin (Meat Deli), C.P., Austfeed are the main companies in this channel.



Figure 3: C.P. food shop

The main functions in the sub-sector are:

Table 3: Description of the main sub-sector elements

Function	Description and channels
Input materials	Veterinary agents. Import of sow and piglets. Animal feed raw materials
Feed processing	In this function animal feed is produced. This is often a mix of domestic sources, but commercial feeds tend to rely mostly on imports. Cassava pulp, is one of the domestic ingredients used to produce animal feed (see chapter 4 how this affected the cassava-starch sector). Most pig farms rely on commercial feed (67%), but household farms often produce their own (33%)
Breeding	In this function piglets are raised to a certain weight. The piglets are then sold and transported to farms specialized in fattening. In mixed farms the breeding and fattening function are combined.
Fattening	In function pigs are fattened until a desired weight. Pigs are then aggregated and transported to the slaughterhouse by traders, cooperatives or purchased by the contract farm sponsor company.
Pork production/slaughtering	Pigs are slaughtered in formal and informal slaughterhouses. Contract farm sponsors often have their own slaughterhouses which allows them to control the quality and standards throughout the value chain. Feed to meat farm types all have their own slaughterhouses.

Meat product	In this step meat is aggregated, packaged and prepared for the markets. In the case of small slaughterhouses this step may be skipped, and offal and other meat are sold directly on the markets.
Markets	The main markets are the domestic market for direct consumption or used as ingredient in food products by food processing factories, i.e., noodle makers. Some pork companies have their own retail channels.

2.1.6 Policy environment

Waste management

The “Law on Animal Husbandry” 2018 (Directive 32/2018/QH14) states the requirements of on-farm livestock production to “collect and treat livestock production effluent to meet the national technical standards on livestock production effluent before discharging them into receiving sources” and to “treat waste gases from the livestock production activities to meet the national technical standards on livestock production waste gas”.

Environmental regulation

Vietnam National Standard No. 62 issued by the Ministry of Natural Resources and Environment (MONRE) in 2016. This national standard specifies wastewater discharge qualities of 6 parameters (potential of hydrogen or pH, biochemical oxygen demand or BOD5, COD, total suspended solids or TSS, total residue or TS and Coliform). According to a study of Van et al (2016), despite this regulation, the effluent quality is not always met, and therefore adequate waste treatment remains therefore a concern (Van, Son, Bao, Kuyama, & Cong, 2016).

Climate regulation

With increasing levels of industrialization, and the risk of environmental pollution due to animal waste generation, Vietnam aims to reduce the impacts of the livestock sector and comply with the national determined contributions (NDC) targets, through the development of sustainable and organic agriculture; improved effectiveness, competitiveness, and biosecurity in livestock production; as well as the deployment of waste management technologies (e.g., biogas) to curb GHG emissions (MARD, 2020).

2.1.7 Market outlook

Demand side

1. Price elasticity of pork demand

Studies have shown that pork, along with rice, vegetables, fruit and sugar are so-called normal foods. An estimated 11.4% of disposable income is spent on pork in Vietnam (Hoang, 2017). The income elasticity of pork in Vietnam is estimated at around 0.428 (Hoang, 2017). Thus, with doubling of income, it is estimated that pork consumption will increase with 42.8%. In the case of low-income households, the elasticity is much higher with 1.03. Thus, while pork is for most households a normal good, it is luxury good for the poorer segments. Currently, the per annum capita pork consumption stands at 22.22 kg.

2. GDP growth

Vietnam, being one of the most dynamic emerging countries in the East Asia region, has seen sustained GDP per capita growth of 270% in 2002-2018 reaching USD 2,700, and a decline in poverty from 70% to 6%, lifting more than 45 million out of poverty (WB, 2020). The GDP in Vietnam is forecasted to grow nearly five-fold by 2035 to \$1.59 trillion because of demographic trends and increased consumption of resources.

The demand for food also increases rapidly due to the increase in population and income, and the pattern of food consumption has also changed. The past decade has witnessed a rapid increase in the consumption of meat (especially pork), milk and eggs.

The forecasted rapid GDP growth coupled with the high price elasticity of pork predicts that pork demand will grow rapidly in the coming years and decades. With a predicate five-fold GDP growth by

2035, pig demand is expected to grow with $5 \times 0.428 = 2.9$ times. This would increase pork consumption to around 65 kg/capita/year. In comparison, annual per capita consumption in China and Germany stands around 41.3 kg and 62.6 kilogram respectively. Other studies estimate the growth to be around 4% per annum by 2035 (or 110% increase compared to 2016). Historical growth rate in the period 2006 – 2016 is 5% (Van, Son, Bao, Kuyama, & Cong, 2016). In sum, pork demand is expected to increase significantly in the coming years/decades.

Supply side

Vietnamese pork demand grew faster than production in the years 2013-2019 (see figure below) resulting in supply constraints and policies to open the market for imports to meet demand.

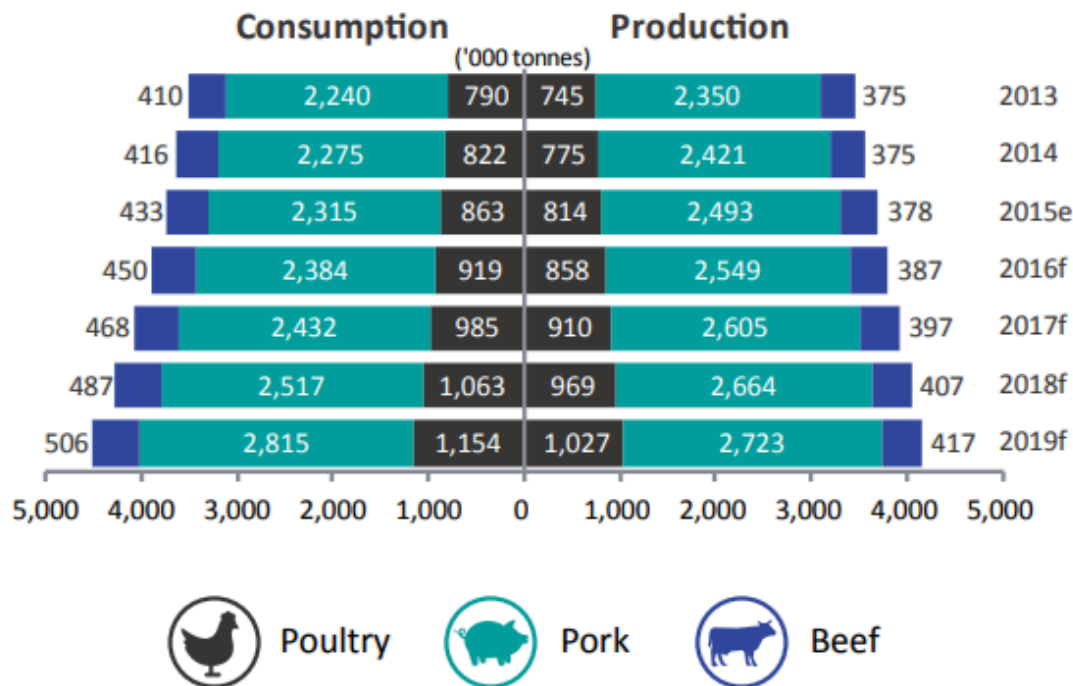


Figure 4: Consumption and production of poultry pork and meat (Ipsos business consulting, 2016)

Letters after the years: e= estimate, f= forecast

Vietnam's meat market is growing with the involvement of an increasing number of FDI companies and importers. Such changes pose a threat for local manufacturers, as the price of imports become more competitive when compared with locally produced meat. Foreign producers mainly rely on economies of scale and access to cheap feed which enable them to enter the market with low prices. At the same time, the dominance of small-scale farms hampers productivity gains of local producers, preventing them from competing successfully in the market (Ipsos business consulting, 2016).

Between 2019 and 2020, an epidemic of the ASF virus led to a severe impact on the productivity of pig farms in Vietnam and the region. According to the United States Department of Agriculture (USDA), over 6 million pigs were culled in the country, leading to a decline in pork production, with economic losses over \$570 million, and an unprecedented pork price crisis. The COVID-19 pandemic amplified an already complicated path of recovery for the livestock sector.

In response to the ASF epidemic, Vietnam has opened the market for live pig import and pork to address supply shortages⁶ resulting in more competition. Pork is multiple times cheaper to produce in the USA

⁶ <https://Vietnamtimes.org.vn/imported-pork-is-conquering-domestic-market-23077.html>

compared to Vietnam due to higher productivity (i.e., higher feed conversion ratio) and lower feed cost⁷. With trade liberalization policies this will pose an increasing threat to the Vietnamese pork industry.

In order to combat the wave of imported meat, some large-scale local companies have invested in feed to meat and contract farming channels with strict disease control. Dabaco Group (Dabaco) is a typical example that has successfully applied the “from breeds to table food” approach. Dabaco aims to develop a strong group in the agriculture industry, using modern technology and a closed 3F value chain – farming (breeding and farms), feed (producing livestock feed) and food (meat processing) – in combination with Dabaco’s supermarkets and fresh food shops. In 2015, the company reached a total revenue of nearly US\$269 million, an increase of 10% compared to 2014. Hoa Phat Group, one of the leading private industrial companies in Vietnam, is another example of a 3F value chain. The company aims to expand its pig production capacity to one million tons by 2020.

However, a weakness to further industrialization and sector growth is the reliance on imported feed. The dependence on imports, and the sharp increase in global prices of raw materials due to crop failures and China buying record quantities, means input prices have increased sharply (Industry and Trade news, 2021). This remains a challenge in the sector. Also, the threat of future epidemics in the livestock sector remains prevalent as it transitions towards intensive supply chains.

2.2 Bio-energy usage and opportunities

2.2.1 Bio-energy sources

At pig farms large quantities of animal waste, pig manure, is produced (DLP, 2018). The amount varies with the age of the growth stage and type of pigs but is around 2 kg/pig/day on average (SNV, 2021). There are no national estimates available on biogas production potential from fresh manure. In the table below a number of estimates are depicted from literature reviews:

Table 4: Specific biogas production by source

Source	Calculation parameters	Specific biogas production
IPCC 2006 revised guidelines (IPCC, 2019)	0.3 kg volatile solid excretion per pig/day ⁸ Specific biogas production 0.29 m ³ CH ₄ /kgVS Methane concentration 60%, methane density 0.67 kg/m ³	97 l biogas/pig/day or around 48.6 l/kg pig manure (an average pig produces around 2 kg pig manure (SNV, 2021))
SNV biogas handbook (SNV, 2021).	-	40 to 60 l/kg pig manure
GIZ Digest volume II (GTZ, 1999)	-	60 l/kg pig manure

All values are in the range of 40 to 60 liter. The average of 50 l/kg fresh pig manure is taken for the purpose of this study. Including an anaerobic stage with biogas capture can therefore generate large amounts of biogas. In the next table the theoretical biogas potential is calculated:

⁷<https://tieudung.vn/thi-truong/tai-sao-gia-thit-heo-o-my-re-hon-gap-5-lan-so-voi-viet-nam-43540.html>

⁸ At an average pig weight of 28 kg. The actual weight and thus the VS excretion is higher

Table 5: Calculated theoretical biogas potential

Variable	Unit	Value (averages)
Pigs	Million head	27.4
Daily waste	Kg/animal/day	2 (1.2-4)
Annual waste	million ton	20
Daily gas volume	Liter gas/kg manure	50
Biogas output	Million m ³ /year	1000
Electricity	GWh/year ⁹	2,300

2.2.2 Bio-energy utilization status

A significant number of livestock farms, 41.8% have as part of their waste management system a biogas plant, around a third compost their waste and remainder have either another form of treatment or none at all (table 5)

Table 6: Manure treatment systems of commercial farms in Vietnam¹⁰

Treatment method	%	Number	Comment
Anaerobic treatment with and without biogas recovery	41.80%	9115	Not all farms have biogas utilization equipment ¹¹
Aerobic treatment (composting)	32.40%	7065	-
Other forms of treatment	21.9%	4775	Vermi-composting, fish feed, sun-drying
None	3.9%	850	Discharge to land/water bodies / sewer
Total	100%	21,805	

Statistics are not available on the number of farms that utilize gas for electricity production, however, all the experts interviewed, and supported by the literature, generally agree that electricity production for captive power is not common. This means that biogas is either vented to the atmosphere or flared. Occurrences of venting is detrimental to the climate, methane, the main constituent of biogas, has a relative global warming potential of 86 compared to CO₂¹² in a 20-year period, thus a much stronger direct impact.

⁹ 1 m³ can be converted into 2.3 kWh with a generator with an efficiency of around 40%

¹⁰ MARD's Livestock Production Department (LPD) survey in 2018,

¹¹ Limited data is available on the number utilizing gas. The NAMA biogas for onsite power generation for Medium/Large pig farms assumes biogas is released <https://bit.ly/3xJmcmZ>

¹² IPCC fifth assessment report (AR5)

Reasons for not utilizing biogas for power generation vary (DLP, 2021):

- Lack of biogas feed-in-tariff
- Hydrogen sulfide (H₂S) filters are not always effective leading to low removal efficiency and low generator lifespan
- High investment and maintenance cost of existing generators (often converted secondhand diesel generators)
- Lack of suppliers with quality technology and biogas electricity generation success stories
- Insufficient quality after sale services

2.2.2.1 Findings from the field

Several farms in each channel were interviewed. Key findings of 4 CP contract farms interviewed are presented here below:

Table 7: Key data of 4 CP farms interviewed

Farm/collection data	Hau Bi farm	Thanh phat Farm	Mr. Tue-Mui farm	Dai Tu Farm
Location	Phu Tho	Phu Tho	Phu Tho	Thai Nguyen
Capacity (head)	4,000	3,500	3,000	5,000 fattening and 500 sow)
Type	fattening	fattening	fattening	fattening and breeding
Cycle per year	2 cycles, 5 months each	2 cycles, 5 months each	2 cycles, 5 months each	Continuously
Time off/year	2 months	2 months	2 months	0
Energy demand (kWh/month)	23,000	25,000	18,000	55,000
Electricity cost (VND/month)	45,000,000	50,000,000	35,000,000	80,000,000
Electricity consumption (kWh/pig/day)	0.2	0.25	0.25	0.3
Biogas digester volume (m ³)	2,000 + 1000	3000	7000	3500
Amount of biogas (m ³ /day)	Not monitored			1000 (estimate)
Wastewater (m ³ /day)	150	180	130	250
Generator capacity (kW)	40	40	flared	70
Generation operation (hrs/day)	15-16	10	-	16
Investment cost for biogas gen-set (million VND)	150 only cost for diesel engine conversion, filtering and installation	300 (125 for engine, 133 million for diesel engine conversion + 46 million for filter)	-	450, 200 for diesel engine conversion and biogas filter system 250 million VND for DO genset
Payback period (farmer estimate) (yr.)	1 – 1.5	1	-	1.5
Operation cost gen-set (VND/month)	3 million	3 million	-	4 million

The reported pay-back period is rather short. This is partly the result of the investment boundary, which only includes the energy usage equipment, not the biogas plant itself. The biogas plant itself is often mandated by the contract farm sponsors, e.g., in the case of C.P. for sanitary purposes.

Most farms reported that all biogas was consumed except in the case of Thai Nguyen farm, they claimed to have more biogas available. One farm does not use biogas for power generation; biogas is flared and used for cooking instead.

Three other farms were approached telephonically:

- Cam Giang cooperative farm (Hung Huy Breeding and Livestock Equipment Joint Stock Company) in Hai Duong (Value chain of Huong Que farm). This farm is a breeding farm supplying piglets to its cooperative members and other companies. The farm has 1,000 sows and produce sows and piglets. The farm is equipped with 3,000 m³ biogas in which biogas is captured and then flared, the solid separated from manure is sold as fertilizer instead.
- One fattening pig enterprise of DABACO was interviewed. The farm has a capacity of 1,800 sows and produces 40,000 piglets annually. Waste is treated in a biodigester, and the captured biogas is flared. Previously biogas was used for electricity generator, but the generator broke down after a short period. This experience discouraged the company to use biogas for electricity generation.
- Hoa Phat Agricultural Development Joint Stock Company has 10 farms, 6 farms owned by Hoa Phat and 4 contract farms. Among 6 owned farms, there was one farm using biogas for electricity generation but after the installation of a liquid solid separator, where solids were taken out of the waste stream and sold as fertilizer, the amount of waste fed into the digester reduced and therewith biogas decreased substantially.

Currently, biogas is either flared or used to burn dead pigs for sanitary purposes in all the 6 farms.

2.3 Sub-sector case study

2.3.1 Company description and structure

The Quang Tri high-tech agriculture farm is a new investment and is being constructed on a plot of 136 hectare of which 1.6 hectare is allocated for the power supply. This farm was selected for a case study into the potential using biogas for electricity generation.

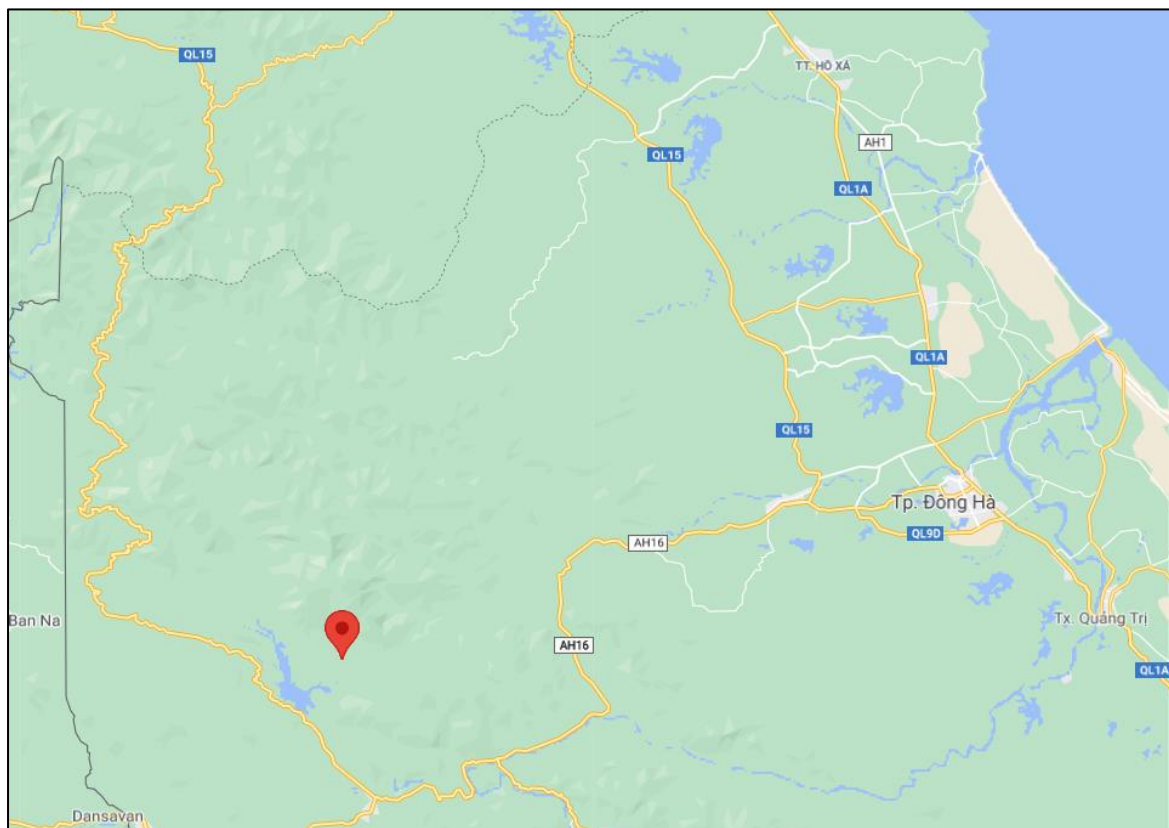


Figure 5: Location of the farm in Quang Tri province

The farm is located deep in the province in a sparsely populated area. The key investment components are:

Table 8: Quang Tri key investment components

#	Component	Details
1	3 barns	each barn has 2,500 sows and 24,000 pigs
2	10 MWp solar rooftop	in consideration
3	Cattle farm	1,000 breeding and beef cattle

The investment project has been prepared and approved. The first barn is being constructed and will be taken in use around September 2021. It is expected that from October 2021 to December 2022 the other barns will be constructed and that from 2023 the whole farm is in operation. The land, after a 50-year lease, will be handed back to the local authorities in December 2070.

2.3.2 Energy demand

Farm energy demand was taken from the feasibility study prepared for the farm:

Table 9: Estimated energy demand of the 3 pig barns

#	Consumables	Qty	Capacity (kW)	Total capacity (kW)	Usage time		Usage coefficient	Total usage capacity (kW)	Output (kWh/day)
					From /to	Total (hour)			
1	Water Heater	36	2.50	90.00	18h-19h	1	1	90	90
2	Light bulb	132	0.03	3.30	8h-18h	12	1	3	40
3	Heating lamp	3669	0.07	256.83	0h-24h	24	0.3	77	1,849
4	Pressure pump	3	1.20	3.60	8h-9h	1	1	4	4
5	Cooler pump	132	0.75	99.00	0h-24h	24	0.8	79	1,901
6	Sterilize pump	6	0.75	4.50	8h-9h	1	1	5	5
7	Sterilize zone pump	3	0.75	2.25	8h-9h	1	1	2	2
8	Lighting lamp	2706	0.02	40.59	8h-18h	12	1	41	487
9	Panasonic air condition 120000 BTU	15	3.52	52.76	9h-17h	8	1	53	422
10	Industrial washing machine Panasonic 9kg	3	2.00	6.00	18h-20h	2	1	6	12
11	Pressure sprayer	30	3.50	105.00	8h-9h	1	1	105	105
12	Exhaust fan	864	1.10	950.40	0h-24h	24	0.7	665	15,967
13	Ceiling fan	108	0.05	5.40	8h-18h	12	1	5	65
14	Wall fan	102	0.06	5.61	8h-18h	12	1	6	67
15	Wall fan	102	0.06	5.61	8h-18h	12	1	6	67
Total (kWh/day)									21,083

The total estimated electricity consumption is 21 MWh/day or around 7 MWh/day of 1 pig barn.

2.3.3 Bio-energy intervention

The 3 barns are not situated near each other, and therefore one barn is considered for the case study. The investment will include the following waste treatment system including a biogas plant:

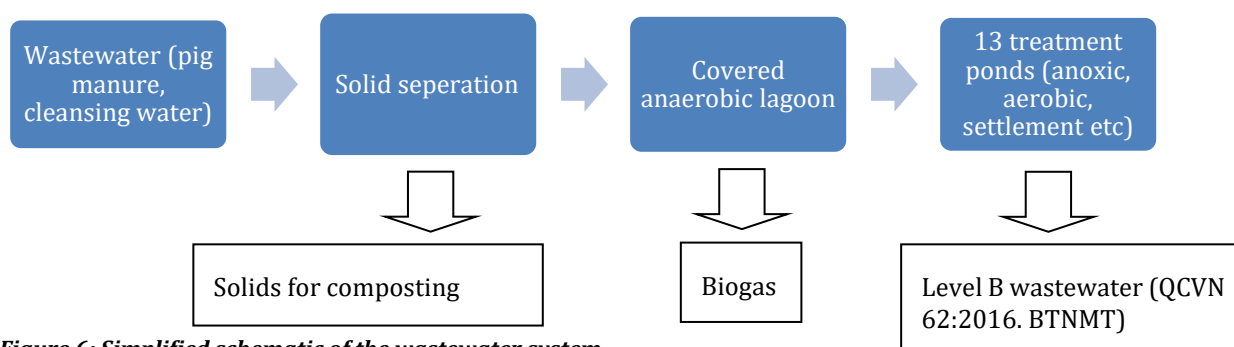


Figure 6: Simplified schematic of the wastewater system

Solids will be recovered from the waste stream and after composting sold as fertilizer. The remaining wastewater is fed into the digester, a high-density polyethylene (HDPE) covered anaerobic lagoon digester.

Normally, biogas production is calculated on the basis of VS (volatile solids), or by using an estimate on the biogas production per kilogram of manure. However, in this case the biochemical methane production will be less due to the separation of solids. There are no estimates available on the remaining biogas potential. According to Chinese manufacturer of manure solid separators around 60% of the COD remains in the wastewater (Zhehan, 2021). However, the COD content of pig manure wastewater is not known. An on-site measurement is necessary to examine the number of COD and biogas potential remaining. For the purpose of this study however, the China reference values are used as a proxy, and it is assumed that 60% of the biogas potential remains.

2.3.4 Financial assessment

2.3.4.1 Basic parameters

The table below shows the basic parameters used in the financial calculations.

Table 10: Basic parameters used for the financial calculation

Item	Unit	Value	Remark
Contingency rate	%	10	Assumption
Interest rate	%	12	Typical rate for business loans
Loan period	Year	10	Assumption
Discount rate	%	13.75	Reflecting the weighted cost of capital, assuming 75% debt-financing at 12% and 25% equity at 25% return on equity
Tax rate	%	N/A	Calculations are based on EBIDTA (Earnings Before Interest, Taxes, Depreciation, and Amortization)
Electricity price	VND	1827	Weighted average of off-peak, peak and normal rates for medium voltage connection (22 kV)

Although project financing is to be decided by the project owner, in the analyses a loan of 75% of the project costs is included at the indicated interest rate of 12%, with a repayment period of 10 years.

Technical data

Table 11: Anaerobic digester performance data used in calculations

Item	Unit	Value	Comment
Biogas recovery	l/kg manure	30	Biogas production is 40-60 l/kg of which 60% remains after solid separation (50*60%=30)
Waste-in	ton	53	2 kg/pig * 26,500 pigs

Biogas production	m ³ /day	1590	calculated
Total energy in biogas	MJ	33,390	1 m ³ = 21 MJ ¹³

2.3.4.2 Generator sizing

The pig farm will likely have a 22 kV connection and falls in the tariff category manufacturing industry. The EVN tariff is tabulated below:

Table 12: Electricity tariff for manufacturing industries with 22 kV connection

Tarif category	Period	Hours/day	Rate (VND/kWh)
Standard hours	Monday- Saturday 4 AM- 9:30 AM 11:30 AM – 5 PM 8 PM – 10 PM Sunday: 4 AM – 10 PM	13 (18 on Sunday)	1555
Peak hour	Monday- Saturday 9:30-11:30 5 PM – 8 PM	5 (none on Sunday)	2871
Off-peak	10 PM – 4AM	6	1007

Financially it is most attractive to generate electricity during the peak and normal hours. It is assumed that the generator will run on average 16 hours per day covering both peak and normal hours.

Table 13: Electricity gen-set size calculation

Item	Unit	Value	Comment
Running hours	h/day	16	16 hours generator running per day to consume all biogas
Engine efficiency	%	35%	Typical for medium-scale generators
Power production	kWe	203	16 hours/day at full load
Maximum installed capacity	kWe	290	Calculated at 70% average load. This is a load gen-set are able to sustain for longer periods

The farm load profile (blue line), the generator power generation (green line) and the electricity tariff as function of the hour of the days is shown below:

¹³ Typical calorific content of biogas from manure (60% methane)

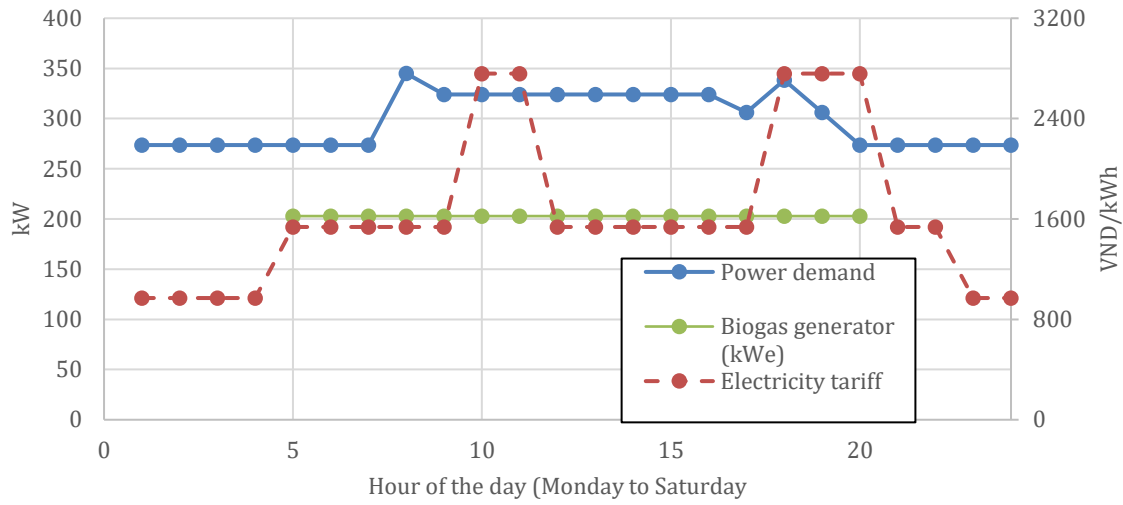


Figure 7: Farm demand, power generation and electricity tariff as function of hour of the day

The generator will produce around 60% to 74% of total power of the farm during the 16 hours period. In case there is a black-out, the generator can serve as a back-up generator during most hours of the day by increasing the load to 100% and all hours when certain non-critical equipment (air conditioners, lighting lamps, are turned off).

The farmer could also choose to increase the amount of electricity generated during peak hour tariff. This would yield financial benefits but will also reduce the lifespan of the generators due to the higher load. In a follow up study, it should be examined if it makes financially sense to install a larger gen-set allowing the farm to displace all peak hour electricity with electricity generated from biogas.

2.3.4.3 Investment costs

The minimum installed capacity is 290 kW at 70% load. This is a load that biogas generators normally can sustain over longer period. In the investment 2 generator of 160 kW, totaling 320 kW are considered. The average load is then 63%, which is advantageous for the lifespan of the generator. Two generators have an advantage over one, one can be maintained while the other is running and if one fails, the other generator can be used at a higher load or longer running period enabling the farm to convert all biogas into electricity. The main costs are based on supplier quotations. The investment costs are calculated below.

Table 14: Investment costs in biogas gen-set

Item	Total	Lifetime (years)	maintenance (%I)	Comment
2X 160 kW Prime Power Genset open type air cooled.	2x \$25,350	10	\$0.02/kWh	Gen-set from China Made of high-quality international brand components (Engine: Deutz/Cummings or equivalent)
Biogas Scrubber (H2S / Moisture removal)	\$13,900			Alternator: Stamford, Leyroy-Somer or equivalent)
Consumables (H2S filter material)	-	1000 hours	\$3.5/kW	

Grid Sync Panel	\$5,800	15	nil	Based on supplier estimate of 70 kW generator: 250 kg for 70kW installed capacity. 1 kg = 25,000 VND
Transport				
Sea freight China port to Hai Phong/HCMC	\$1,050	-	-	
Custom Clearance and transport to site	\$800	-	-	
Installation cost				
Civil works at site (concrete slab, simple shed for generator)	\$1,200	20	nil	
Installation cost	\$7,100	-	-	
Sub-total	\$ 75,985	-		
<i>Contingency / unexpected cost</i>	\$ 8,715	-	-	10%
Total (USD)	\$ 85,583	-	-	
Total (VND)	₫ 1.9 billion	-	-	1 USD = 23,000 VND

The biogas generator is an international brand generator assembled in China. Generators sourced from Europe have a much higher CAPEX. More study is required at which conditions European generators, often with a longer lifespan and lower OPEX, are financially viable.

2.3.4.4 Revenues

The total estimated daily energy demand is 7 MWh and the amount generated by biogas is around 3.2 MWh/day. Biogas electricity can therefore reduce the amount of grid electricity with 46%. In the next table the value of this is calculated:

Table 15: Estimated revenues from displacing grid electricity

Item	Unit	Units (units/a)	Unit cost (VND)	Revenue (VND/year)
Displaced grid electricity	kWh	1,184,881	1827	2,160 million (\$93,915)

2.3.4.5 Cash flow analysis

In the table below the cash-flow is shown for a 10-year period in kVND. There is a net positive cash flow from year 1 and a net cumulative cash flow from year 3 onwards.

Table 16: cash flow biogas plant (kVND)

Item	0	1	2	3	4	5	6	7	8	9	10
Equity	1,042										
Debt financing	3,126										
Short term financing											
Inflow from operations		4,083	4,083	4,083	4,083	4,083	4,083	4,083	4,083	4,083	4,083
Total inflow	4,168	4,083	4,083	4,083	4,083	4,083	4,083	4,083	4,083	4,083	4,083
Operating costs		1,333	1,333	1,333	1,333	1,333	1,333	1,333	1,333	1,333	1,333
Corporate tax		-									
Interest payable		375	338	300	263	225	188	150	113	75	38
Loan repayment		313	313	313	313	313	313	313	313	313	313
Total outflow	-4,168	2,021	1,984	1,946	1,909	1,871	1,834	1,796	1,759	1,721	1,684
Net cash flow	-4,168	2,062	2,100	2,137	2,175	2,212	2,250	2,287	2,325	2,362	2,400
Cumulative	-4,168	-2,106	-6	2,131	4,305	6,518	8,767	11,054	13,379	15,741	18,141

The next table shows financial indicators calculated from the cash flows. It shows a Levelized Cost of Electricity (LCOE) of 1243 VND/kWh, which is well below the standard and peak hours tariff.

Table 17: Financial indicators

Item	Unit	Value	Comment
LCOE	VND/kWh	1243	energy generation and costs are discounted with the same rate
IRR	%	60	10-year IRR
NPV	million VND	3,458	10 year period
	USD	\$150,322	
Simple payback period	year	1.89	-

2.3.5 Discussion and conclusion

There is a clear business case for biogas-electricity generation. The return on investment is high and the pay-back period is short. The LCOE is lower than the standard and peak hours tariff of EVN. It should be noted that the returns are high because the investment boundary only includes the gen-set not the biogas plant. This is reasonable as the biogas plant is installed regardless for environmental compliance reasons.

However, the calculation behind this conclusion is not based on actual COD-in and actual digester performance data. During the field visit, one farmer adopted a similar waste management system where the solid were separated before feeding into the digester and this resulted in significant less biogas production. While the team could not confirm why this happened, it does indicate that more study is required on the remaining biogas potential. In a follow-up study the remaining biochemical biogas potential should be determined and based on more accurate conclusions can be drawn. The follow up study should, at minimum, measure these parameters:

- Mass balance for solid separation process
- Total solids, suspended solids, COD inflow and concentration
- The treatment efficiency of AD
- The biogas potential (kgCH₄/kgCOD or kgVS)

Finally, if the farms install a 10 MWp solar plant, which is under consideration, the additional electricity demand during the day will be much lower. In that case, it might not be possible to consume all biogas during the normal and peak hours and the generator will be required to run during the off-peak hours. During that period however, the LCOE is higher than the EVN tariff and thus not financially attractive.

A follow up study should also assess the possibility of utilizing engine heat to warm water for stable heating. Since the generator runs mostly during the days, hot water should be stored for nighttime warming.

2.4 Stakeholder commitment to bio-energy utilization

2.4.1 Forces of change for the utilization of bioenergy

None of the farms interviewed have commitments to reduce GHG emissions or environmental commitments other than meeting wastewater discharge regulations.

At national level however, there is a target to reduce GHG emissions for agriculture sector. Decision No. 543/QĐ-BNN-KHCN on releasing an action plan to cope with climate change for 2011-2015, with a projection to 2050 in agriculture sector. One of the goals is to maintain the sector growth rate of 20 percent, reduce the 20 per cent poverty rate and reduce the GHG emissions rate of 20 per cent over 10-year periods. However, this policy target has not percolated to local or farm level.

A major challenge to utilization biogas for power is the poor experiences with generating electricity and the lack of quality equipment with adequate after sales services. This has undermined the trust of farms into biogas to electricity somewhat. However, the case study demonstrated that biogas-electricity generation is financially very attractive, thus the challenges are likely more technical than financial.

Possibly the promotion of ESCO models, which mitigate the technical risk could overcome this barrier. E-green company for example is working on an ESCO service model in which E-green takes care of the investment, operation and system maintenance and sells electricity for a fixed cost of 1500 VND/kWh. This tariff is around 17% lower compared to the average EVN rate during normal and peak hours (1800 VND/kWh).

2.4.2 Leverage and stakeholder commitment

The sub-sector map showed that channel 3 (contract farms) and 4 (feed to meat) manage or own a significant number of large farms. Working with these companies, can create leverage throughout their channels. CP for example already requires farms to install a covered anaerobic lagoon digester. Working with a company like CP and possibly with an ESCO provider like E-Green, could in a cost-effective manner reach, and inspire, a great number of farms.

2.5 Discussion and conclusion

The pork sub-sector is growing rapidly but remains oriented on the domestic market. Vietnam is self-sufficient in pork production, and this is not expected to change soon. However, there is a risk that Vietnam is becoming less competitive with increasing opening up the market unless the country manages to increase its domestic feed production and/or manages to source feed at lower prices globally and increases productivity.

The sub-sector is structurally changing, there is a trend towards vertically integrated channels including horizontal linkages with contracted large farms where one company controls the whole value chain. This has advantages in terms of scale, technology and dissemination of knowledge and information. Leverage points for interventions, therefore, are also more pronounced in those channels than others.

A significant number of farms have biogas plants, but gas utilization is low. At the same time, this study showed that generation of electricity from biogas is highly attractive. It appears that the challenge is not financially, but more of a technological nature and/or a trust issue. For those reason, it is recommended to work with strong trusted players in the sector that influence or control channels, such as CP, DABACO, Mavin and similar companies. These companies already provide technical assistance to the companies within their value chain and have environmental policies concerning waste management¹⁴.

Building upon this network and using it as a vehicle to demonstrate that biogas to electricity works, and is financially attractive, could and should motivate other farmers to follow.

¹⁴ CP has at head office level in Thailand GHG mitigation targets, but this is not yet translated to their operations in Vietnam

Chapter

03

Sub-sector: Paper and Pulp

3 Sub-sector Paper and Pulp

The paper and pulp sub-sector is rapidly developing with high growth rates and significant FDI. Bio-energy usage however is limited to pulp mills and paper factories when the fuel is competitive with coal. Bio-energy opportunities exist for self-generation and ESCO models.

3.1 SUB-SECTOR OVERVIEW

3.1.1 Background

Vietnam's paper industry is one of the key processing industries and contributes to the national economy with around \$1.6 billion or 1.5% of GDP in 2019. The paper industry creates jobs for directly and indirectly for millions of workers in the industry and other industries, such as packaging production, printing, afforestation, education and training, science and technology, and international integration (VVPA, 2021).

The industry has grown impressively with around 29% per year in the period 2015-2018 outstripping domestic demand growth (10%/year) (VVPA, 2021). In 2019, the domestic consumption of paper packaging was estimated at 4.2 million tons while exports reached 0.8 million tons. In the last 3 years, Vietnam's paper export has achieved remarkable growth with over 200% annually (SNV, 2021).

Paper is produced by an estimated 300 enterprises. Around 220 of those companies are small and medium enterprises producing around 10% of all paper products and 80 large companies produce around 90% of all paper. Major producers in Vietnam's paper industry are Chanh Duong, VinaKraft, Lee & Man, SGP, and Dong Hai Ben Tre which, in 2018, have cumulative capacity of 76% in the industry (Vietnam Economic times, 2021). There are two main geographical concentrations of mills, the south around HCMC and the north in Hanoi and bordering provinces. A small number of mills are scattered in other provinces (Thi & Anh, 2020).

Most of these companies are member of the Vietnam Pulp and Paper Association (VPPA). In terms of ownership form, there is 1 state-owned enterprise (Vietnam Paper Corporation, VINAPACO) and the remainder are joint-stock enterprises, limited liability companies, household businesses, joint ventures, and foreign direct investment (FDI) companies. FDI enterprises are primarily involved in packaging paper while local companies focus on other types of paper (Vietnam Economic times, 2021).

There are three types of paper mills in Vietnam:

1. Pulp and paper
2. Paper products (writing paper, tissue) kraft, corrugate paper).
3. Carton box and other packaging papers.

The paper mills are divided into three scales (Thi & Anh, 2020):

1. Large scale (capacity > 100,000 tons of product/year), 4% of all mills
2. Medium scale (capacity of 1,000–10,000 tons of product/ year), 50% of all mills
3. Small scale (capacity <300-ton of product/year, 46% of all mills

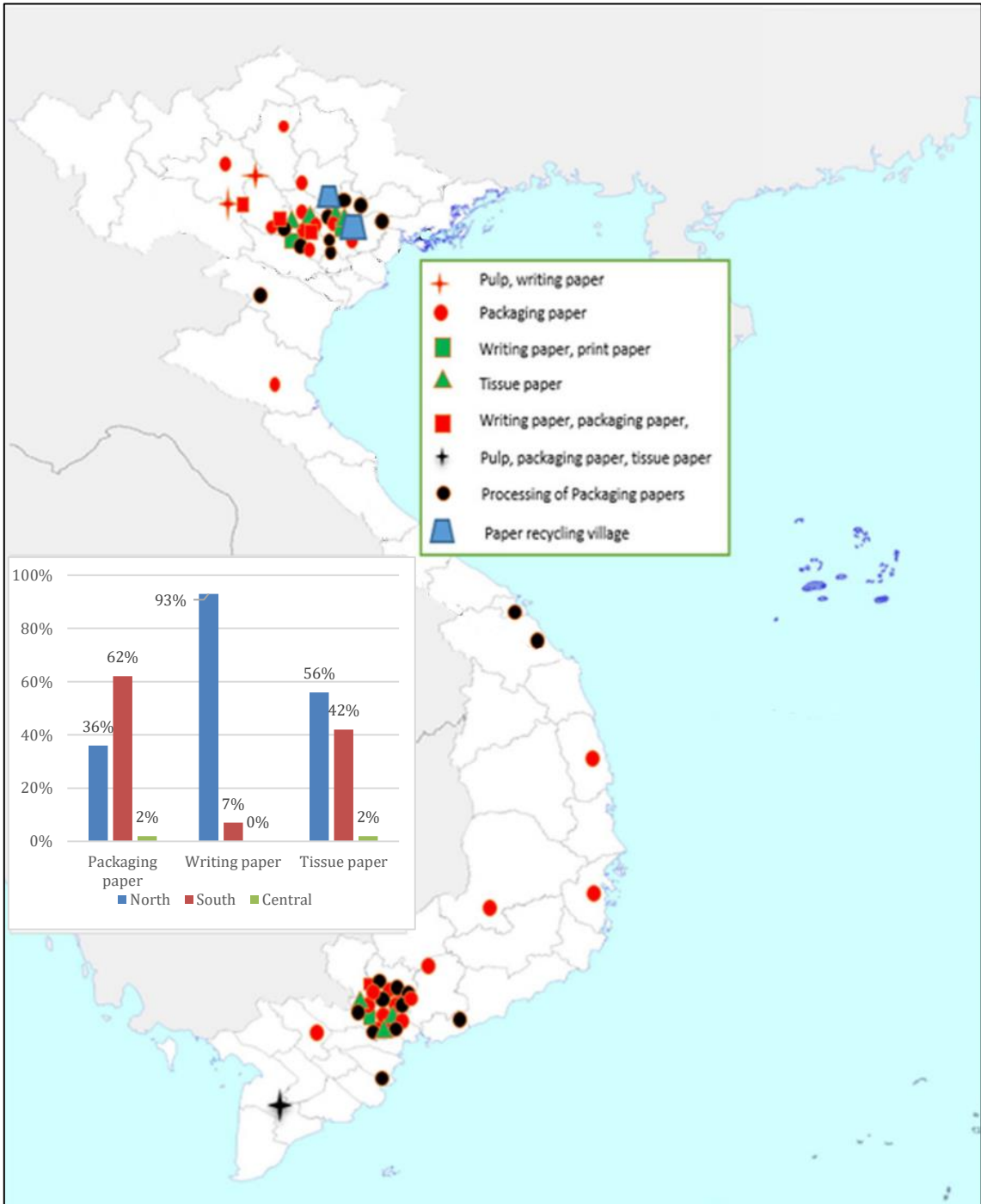


Figure 8: Geographical location of paper and pulp mills

The main products categories:

Printing/wiring paper	Special paper (Votive paper)	Industrial packaging	Tissue and toilet paper
			

3.2 Manufacturing process

3.2.1.1 Pulp production

Pulp is a lignocellulosic fibrous material prepared by chemically or mechanically separating cellulose fibers from wood, fiber crops, wastepaper, or rags. Mixed with water and other chemical or plant-based additives, pulp is the major raw material used in papermaking and the industrial production of other paper products (Mathews, Ayoub, Pawlak, & Gruden, 2013).

There are three main pulp types:

- 1 **Mechanical wood pulp:** also called grinding wood pulp, is a pulp made by mechanical grinding of fiber raw materials. It occupies an important position in the paper industry. It has a low production cost, simple production process, strong ink absorption, high opacity, soft and smooth paper. Mechanical pulps are used for products that require less strength, such as newsprint and paperboards.
- 2 **Chemical wood pulp** is produced by combining wood chips and chemicals in large vessels called digesters. There, heat and chemicals break down lignin, which binds cellulose fibers together, without seriously degrading the cellulose fibers. Chemical pulp is used for materials that need to be stronger or combined with mechanical pulps to give a product different characteristic. The kraft process is the dominant chemical pulping method, with the sulfite process second.
- 3 **Recycled pulp:** is also called deinked pulp (DIP). DIP is recycled paper which has been processed by chemicals, thus removing printing inks and other unwanted elements and freed the paper fibers. The process is called deinking. DIP is used as raw material in papermaking. Many newsprints, toilet paper and facial tissue grades commonly contain 100 percent deinked pulp and in many other grades, such as lightweight coated for offset and printing and writing papers for office and home use.

The Kraft process, which is the processes used in Vietnam (2 factories) to produce pulp is shown here below:

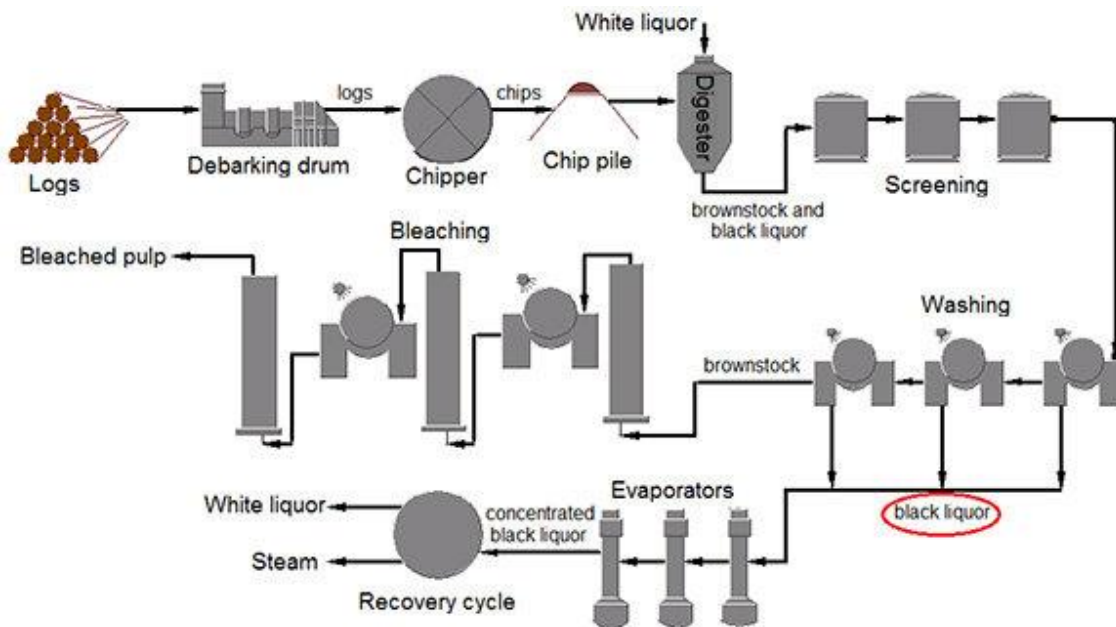


Figure 9: Flow diagram for a kraft pulp mill

The image depicts the processing of wood into pulp. The kraft process aims to separate lignin from its polysaccharide constituents in which wood is cooked in alkaline sulfate (white liquor) resulting in the production of bleached wood pulp and black liquor.

Approximately 7 tons of black liquor are produced in the manufacture of one ton of pulp (Biermann, 1993)¹⁵. Black liquor contains around half of the energy from the wood fed into the digester of a kraft pulp mill. It is normally concentrated to 65 - 80% by multi-effect evaporators and burned in a recovery boiler to produce energy and recover the cooking chemicals.

Domestically pulp is produced by 2 companies: VINAPACO and An Hoa Paper. The combined production of pulp is around 220 kilo ton (kt). Most pulp is imported, 339 kt, and generally has a higher fiber strength (VVPA, 2021). This is despite the fact that Vietnam exports around 10 million ton of wood chips/pellets annually suitable for pulp production. For various reason, this resource is not used, such as mills are not located near the wood production areas, lack of suitable technology, etc.

3.2.1.2 Paper production

Paper is produced from virgin pulp or recovered pulp (produced on-site from scrap). This process is partly mechanical and partly chemical and shown here below:

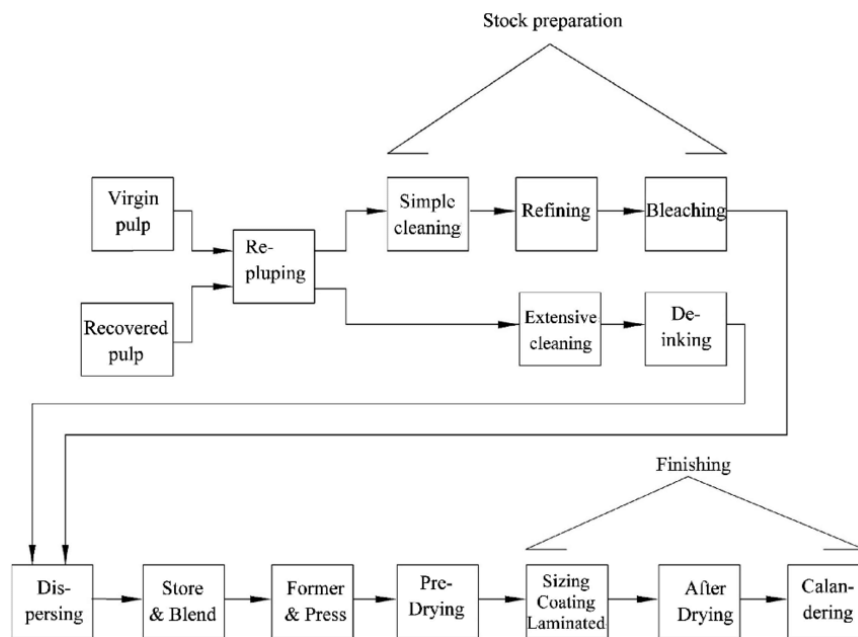


Table 18: Process flow diagram of paper production (Pandey & Prakash, 2018)

3.3 Sub-sector map

3.3.1 Material flow in Vietnam paper and pulp industry

The following paragraph presents the material flow in the sector:

¹⁵ This is likely similar in Vietnam – but could not be confirmed in this study

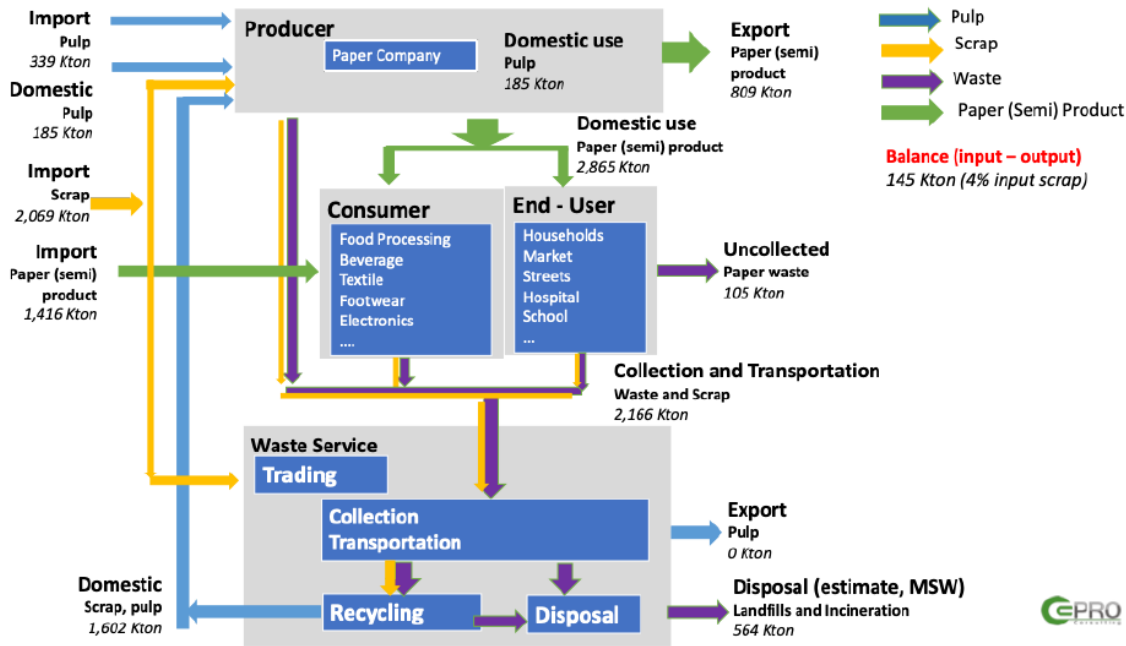


Figure 10: Overview of material flow in Vietnam plastic and paper sectors¹⁶

Most of the imports are scrap rather than pulp. Only particular pulps are imported, these are Bleached chemi-thermo mechanical pulp (BCTMP), bleached Kraft softwood pulp (BSKP) and unbleached kraft pulp (UKP).

1. Import

The biggest pulp suppliers are North America (accounting for 40.5%), Latin America (33%), and Europe (13.3%). The biggest used paper suppliers are the USA (accounting for 47%), Japan (29%), and Europe (17%) (Thi & Anh, 2020).

The Vietnamese Pulp and Paper Association (VPPA) projects that the amount of imported scrap will increase from 46% in 2015 to 60% in 2030. The reliance on important scrap can become a bottleneck for the sector. Circular 41/2018/TT-BCT for example lists categories of scrap to be terminated with trading, import and re-export, and its revision also mixed paper scrap is mentioned. Mixed paper scrap, however, is the main input for the paper sector (VBCSD, 2019).

- Domestic scrap:** Domestic used paper is classified at source and collected by retail collectors, transported to collection agents in the papercraft villages, and then transported to the pulp and paper mills.

¹⁶ Domestic pulp production has increased in 2021 to 220 kt – also other values may be slightly different

3.3.2 Sub-sector map

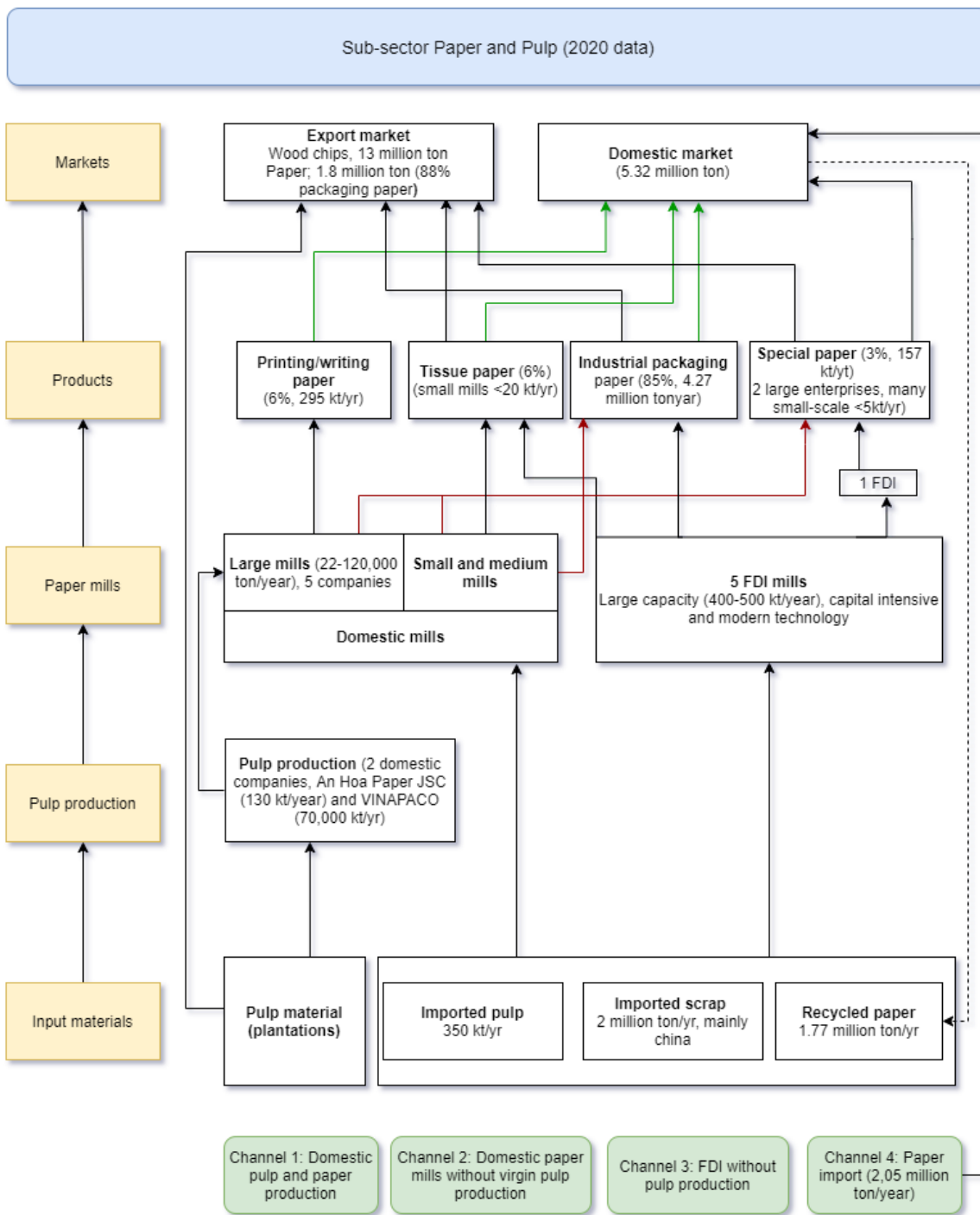


Figure 11: Sub-sector map

The main functions are:

1. Input materials: Acquiring raw materials for paper and/or pulp production
2. Pulp production: 2 domestic companies produce their own pulp from wood sourced from plantations
3. Paper mills: Production of the various types of paper
4. Products: 4 main types of paper are produced by the various enterprises
5. Markets: Main markets are domestic and export

There are 4 main channels:

1. **Domestic pulp and paper production:** Three companies specialize in producing pulp as input material for their production process. However, they also procure imported pulp and scrap as their own production is not sufficient
2. **Domestic paper mills without pulp production:** These mills rely on recyclables (scrap, imported pulp and recycled paper) to produce various paper products
3. **FDI companies.** FDI companies focus mostly on industrial packaging and tissue paper.
4. **Paper import:** This channel imports printing material for the domestic market.

3.4 Sub-sector performance

3.4.1 Market outlook

The average consumption per capita was 51 kg of paper in 2018 (Thi & Anh, 2020). The paper consumption market for packaging is expected to grow at an average of 9% until 2025. The total export turnover of Vietnam's paper and paper products in the first 10 months of 2017 reached US\$602.39 million, an increase of 45.7% over the same period in 2016 (VCCI, 2018). Despite such a high growth rate, the annual import volume is still expected to be 2 million tons. In general, Vietnam there is a trade deficit for paper and paper scraps (total imports are three times larger than exports), because the domestic supply is not enough to meet domestic production demand (Figure 12).

Global recycling rates of materials in the pulp and paper industry is now over 70%, namely: USA (70%), EU (73%), Japan (81.3%), Asia (51.5%), the average of the world (59%), and Vietnam (45%) (Thi & Anh, 2020). Therefore, there remains an opportunity to increase the domestic supply of paper and packaging materials by improve waste segregation and sorting of solid waste.

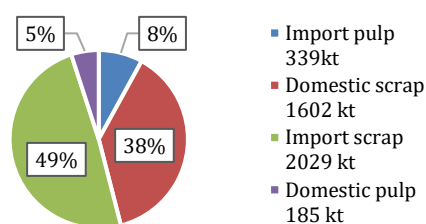


Figure 12: Material structure of the paper sector in kilo ton ((kt)

SGP and Dong Hai Ben Tre are the largest local enterprises while An Binh Paper, the third largest, has a capacity of just 80,000 tons per annum (Vietnam Economic times, 2021). Increasingly, foreign companies are investing in Vietnam's paper industry with high-capacity mills with integrated technology. The local competition, many of whom being small companies of less than 50,000 ton per annum risk losing out as they lack the investment capital required for a modern and competitive mill. (Vietnam Economic times, 2021).

3.4.2 Governance

Vietnam plastic and paper material flow is mainly under management of two ministries – the Ministry of Industry and Trade (MOIT) and the Ministry of Natural Resources and Environment (MONRE). MOIT is responsible for performing state management functions related to plastic and paper industry and trade development. MOIT has been assigned the task of management of production and quality for the business of these sectors. MONRE has responsibility for environment management and governance, including the environmental performance of all players. Institutional regulatory frameworks for environmental protection and waste management have, in general, been well established in Vietnam, but not in the case of the scrap specifically. While MONRE sees scrap as a waste, waste service providers and producers consider it as materials/inputs for their production. Vietnam allows the import of scrap only for final production. Importing of scrap is becoming a challenge for the Government of Vietnam (GoV) to control due to complexity in types and high volumes of scrap from the international market.

In 2018 the Vietnam became one of the alternatives ‘waste dumping sites’ when China stopped importing waste. MoNRE faced the difficult challenge of identifying and certifying import of scrap for production only, vis-à-vis mere dumping of waste. Circular 08/2018/TT-BTNMT) states that imported waste materials must not contain impurities greater than 2%, and moisture less than 20%. However, this is difficult to implement or to validate this for the company. VPPA recommends that imported paper scrap is seen as an opportunity rather than risk for the environment for various reason such as ensuring the quality of paper packing production and remaining competitive with other countries.

Solid waste management is a long-standing priority in Vietnam, and in 2018 the Government of Vietnam added the goal of establishing a circular economy as a national objective in Decision No.491/2018/QĐ-TTg on integrated solid waste management strategy to 2025 and orientation to 2030. Urbanization, as well as strong economic and population growth, are rapidly increasing waste volumes, with waste generation in Vietnam doubling in less than 15 years. The government’s National Strategy on Integrated Management of Solid Waste 2020 - 2050 seeks collection of 100% of urban solid waste, including targets for separating and recycling. These targets will be difficult to meet. With only 30% of the country’s 660 waste disposal sites classified as engineered sanitary landfills, waste disposal is causing serious land and water pollution as well as adverse human health impacts.

Energy regulation

Circular 24/2017/TT-BCT regulations on energy consumption in pulp and paper factories sets the norms for energy consumption in the sector by type of paper and capacity. The norms for the period 2021-2025 are:

Table 19: Energy consumption norm for paper products 2021-2025

No.	Type of products	Capacity (ton/year)	Norm (MJ/ton)
1	Packaging paper	> 50,000	6,713
		10,000 - 50,000	6,744
		< 10,000	5,482
2	Tissue paper	10,000 - 50,000	13,169
		< 10,000	14,572
3	Printing, writing and photocopying paper	> 50,000	13,649
		10,000 - 50,000	9.455

Norms are voluntary. The norms are a useful benchmark for companies to understand their energy intensity in comparison with other companies.

The Vietnam Pulp and Paper Association has been developing the Paper Industry Restructuring Project in 2020-2035 under the direction of the Ministry of Industry and Trade. This plan will address raw material input challenges, promotes local pulp production and restructure the paper production at craft villages to reduce the environmental pollution. The objectives are:

- Support development of paper industry, Vietnam need to focus on develop policies to regulate the investment orientation, avoid over-concentrated investment in one or more localities.
- Develop national standards for paper products, especially paper collection and recycling.
- Encourage the investment in production of imported products.
- Attract FDI investment in producing paper using high technology, especially for new types and high value products that never produced in Vietnam before (MOIT, 2020)

- Enhance social interest in the paper industry as a circular economy and important industry which highly associated with the development of many industries such as forestry and agriculture, chemicals, printing, packaging and mechanical engineering.

The sector is posed to continue to grow with a focus towards increasingly large scale and FDI investment. At the same time, provinces are restructuring the sub-sector by clustering small companies to industrial zones. Bac Ninh province for example, is one of the most industrial developed provinces in Vietnam with 66 industrial zones and 62 craft villages. In the craft villages 10,000s of household cooperate with manual paper production with a capacity in the range of 10 to 40 ton/year. The province started to restructure the paper industry from 2013 by relocating craft villages to industrial clusters and by replacing manual production with advanced technology which would also reduce environmental pollution.

3.5 BIO-ENERGY USAGE AND OPPORTUNITIES

3.5.1 Bio-energy sources in the sub-sector

Boilers and steam systems are important for the factories of subsector. Paper drying requires a large amount of steam at pressure of 3 – 8 bar. Small and medium enterprises consumed steam in the range of 5-25 TPH (tons per hour) while in large enterprise this can go up to 260 TPH (Vinakarft for example).

The main fuel used is coal and some biomass. Mills that produce their own pulp from woody materials produce a residue from pulp cooking, black liquor. Black liquor is used as fuel for steam generation in specially designed recovery boilers.

Generally, in the localities around the mill's sources of biomass area available such as wood chips, pellets, saw dust, tree bark etc. Many factories however continue to use coal as sourcing bioenergy from surrounding areas is not stable in quality and quantity.

Some mills also co-fire coal with scraps or industrial waste.

3.5.2 Energy demand in sub-sector

The paper industry is an essential but energy-intensive economic sector (Thi & Anh, 2020). The paper industry is one of the industries with the highest energy consumption; usually accounting between 20 up to 40% of the product's cost. Due to the low-level technology applied in the process, the energy consumption per unit of product in paper manufacturing enterprises remains 1.5 - 2.5 times higher when compared to other countries in the region. Energy efficient measures are therefore required to drive down energy consumption, lowering product costs, and ultimately increasing competitiveness in the sector. The main inputs, and sources of CO₂ emission are depicted in the table below:

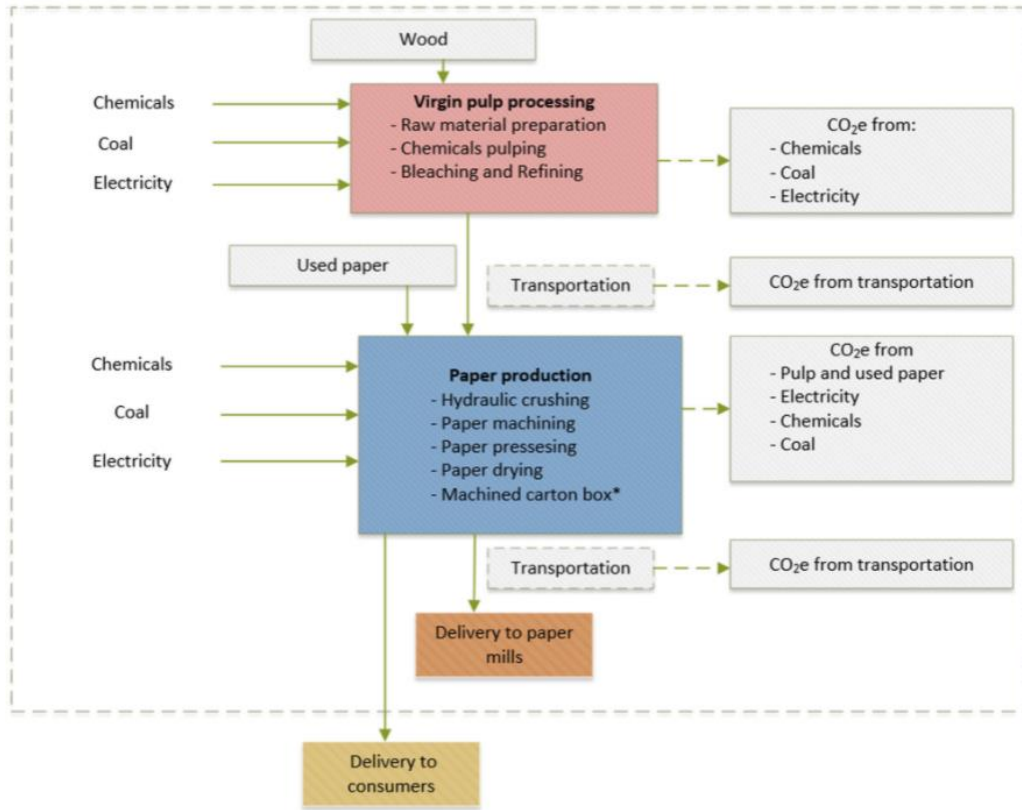


Figure 13: Inputs and outputs of the pulping and paper process (Thi & Anh, 2020)

A study on the energy intensity in the paper and pulp industry in north of Vietnam, conducted in 2020, is shown below:

Table 20: Energy intensity of 31 factories in the north of Vietnam (Thi & Anh, 2020)

Fuel	unit	Writing	Tissue	Corrugated paper	Kraft
Coal	Kg/ton paper	350	220	340	350
Electricity	kWh/ton paper	320	280	310	325

In comparison with other countries, the share of emissions from coal in total GHG emission is with 45.02% to 52.47% higher than other countries normally accounted for 20% to 25% of total GHG emissions. The reason is that other countries typically have a different fuel mix. Gas for example, is a much more important fuel in Europe: 43.9% biomass, 26.3% gas, 24% electricity, and 3.0% coal, the US: 43% biomass, 38.5% gas, 9.2% electricity, and 8.7% coal (Thi & Anh, 2020).

3.5.3 Factory visits

In addition to the literature review and meetings with key stakeholders, several factories were visited.

Table 21: Basic details of the factories visited

#	Factory	Province	Capacity (kt/year)	Website
1	Vinapaco (Bai Bang Pulp and Paper factory)	Tay Ninh	Pulp: 68 Paper: 100	https://vinapaco.com.vn/
2	Viet Phap Kraft paper factory – Phong Khe craft village	Bac Ninh	Kraft paper: 12	-
3	Viet My Kraft Paper factory – Dong Craft village	Bac Ninh	Kraft paper 36	-
4	Dong Tien Kraft Paper factory, Binh Duong	Binh Duong	50	https://dongtienpaper.com/eng
5	Vina Kraft Paper factory	Binh Duong	220	http://www.siamkraft.com/location/

In the table below the boiler types are describes and the fuel used in the visit factories

Table 22: Boiler, CHP and fuel use at the factories

Company	Source	Boiler (efficiency)	Fuel	Comment
Vinapaco (Vietnam paper company)	self-generation	145 TPH, fluidized bed (85%)	Blending of Bituminous coal from Australia and sub bituminous coal from Indonesia	Boilers are outdated and low efficiency (subcritical steam 450°C and 62 bar)
		36 TPH (80%)	Black liquor and fuel oil	
		20 TPH, reciprocating step grate	Wood chips and bark	
Viet Phap paper company	Steam	10 TPH step grate (68-73%)	Tree bark	Provide ESCO services to 5 small factories in craft villages
Viet My	Buys steam from ESCO	Step grate	50% tree bark 50% industrial waste	Saturated steam from at 385 kVND/ton, 8 bar. In 2024 company has to relocate to an industrial zone

	Thien Phuc ¹⁷			
Dong Tien	Buys steam from ESCO Tri Viet	20 TPH, step grate	Indonesian coal	Saturated steam 400 kVND/ton, 8 bar
		16 TPH, fixed grate	Biomass and paper production residues	
Vinakraft	CHP	130 TPH fluidized bed	25% biomass (including paper waste) 75% subbituminous Indonesian coal	Chinese boiler with good quality (130 TPH, 100 bar, 510°C)
	CHP	130 TPH fluidized bed	20% biomass (including paper waste, 80% subbituminous Indonesian coal)	Chinese boiler with good quality (130 TPH, 100 bar, 510°C)

Two out of the five visited companies rely on ESCO services for steam and 1 provides ESCO services next to producing paper. That company, Viet Phap, plans to focus exclusively on their ESCO business in the near future and stop producing paper.

Coal is the most important fuel in the sub-sector. Anthracite coal is the preferred coal and mined domestically. Domestic coal production however is decreasing resulting in higher imports from mainly Indonesia. Indonesian coal, subbituminous coal, however, has a lower heating value, and not all boilers are suitable for that type of coal.

Biomass is also used but is a minor fuel. The exact amount is not known and varies widely from factory to factory. In addition to this, paper waste and industrial waste (textile residues, plastic and other waste) is also used.

Relatively small quantities of biogas are also recovered from the waste treatment system in some of the factories. The amount recovered however, is minor. In the case of Vinakraft for example the contribution of biogas to the total energy demand is just 2-3% (2017 energy audit report)

In the next table electricity consumption is provided and the specific energy cost. The large factories visited, Vinapaco and Vinkraft have CHPs installed while the smaller factories only have steam boilers and rely on grid electricity.



Figure 14: Anaerobic digester at Dong Tien paper factory

¹⁷ For more see <https://tpeg.vn/>

Table 23: Electricity source, energy cost and specific energy consumption

Company	Electricity by source (MW)		Specific energy (kWh/ton)
	Own generation (CHP)	Electricity from grid	
Vinapaco	11.4	10.6	420 kWh/ton pulp 720 kWh/ton paper
Viet Phap paper company	0	0.9	450 kWh
Viet My	0	2	300 kWh
Dong Tien	0	4.16	420 kWh
Vina Kraft	43.6	3 ¹⁸	641 kWh ¹⁹

Energy share in production cost ranges from 20 to 41.16% in the factories and is therefore highly significant.

3.6 Case study – Vinapaco

Vinapaco, also known as the Vietnam paper corporation, was in consultation with GIZ selected for the case study. The company was formed in 1976 and has been running for almost 40 years since 1982. Vinapaco plans to use their existing lines for another 5 to 10 years. The CHP and auxiliary equipment however are outdated and need to be upgraded in line with the development strategy of the factory and energy norms of the government. The case study is focusing on replacing the existing CHP with a biomass (70%) and coal (30%) fired CHP using bark from plantations owned by the company.

3.6.1 Company description

Vinapaco is located in Pho Tho city in Phu Tho province.

¹⁸ 70-80 MWh/day

¹⁹ Calculated based on energy audit report 2017



Figure 15: Google satellite picture of the factory²⁰

1 = wastewater treatment, 2 = boilers, 3 = fuel storage, 4 = production lines

The company has one pulp production line and 2 paper production lines.

- **Pulp production line**

Raw material for pulping is sourced from 18 afforestation plantations of the company in Phu Tho, Tuyen Quang, Ha Giang and Yen Bai province comprising in total 30,000 hectares. Next to this, the company buys raw material from other companies/plantations. In addition, around 20,000 pulp is imported from the USA, Brazil, Canada, Sweden, Indonesia and Malaysia necessary to produce high quality paper products.

Around 2 ton of wood is required to produce 1 ton of pulp, the remainder is black liquor.

- **Paper production line**

The company produces writing and printing paper (300 ton/day) and tissue paper.

To produce 1 ton paper, factory consumes 800kg pulp (80%) + 200 kg additives such as calcium oxide (CaO) and others chemicals.

The main market for their products is the domestic market (98%). A minor percentage, 2% used to produce notebooks and other products by local partners (VPP, Hong Ha, Hai Tien) and exported to the USA and Japan. Paper can be FSC (Forest Steward Council) certified at an additional cost (100,000 VND/ton).

The main product produce is printing paper. Since 60-70% of all printing paper is imported, VINAPACO faces next to domestic competition with An Ha, also competition with pulp and Paper factories in China, Taiwan, Indonesia, Thailand (Double A, APP).

²⁰ [Bãi Bàng - Google Maps](#)

3.6.2 Production process

VINAPACO’s production process is provided here below:

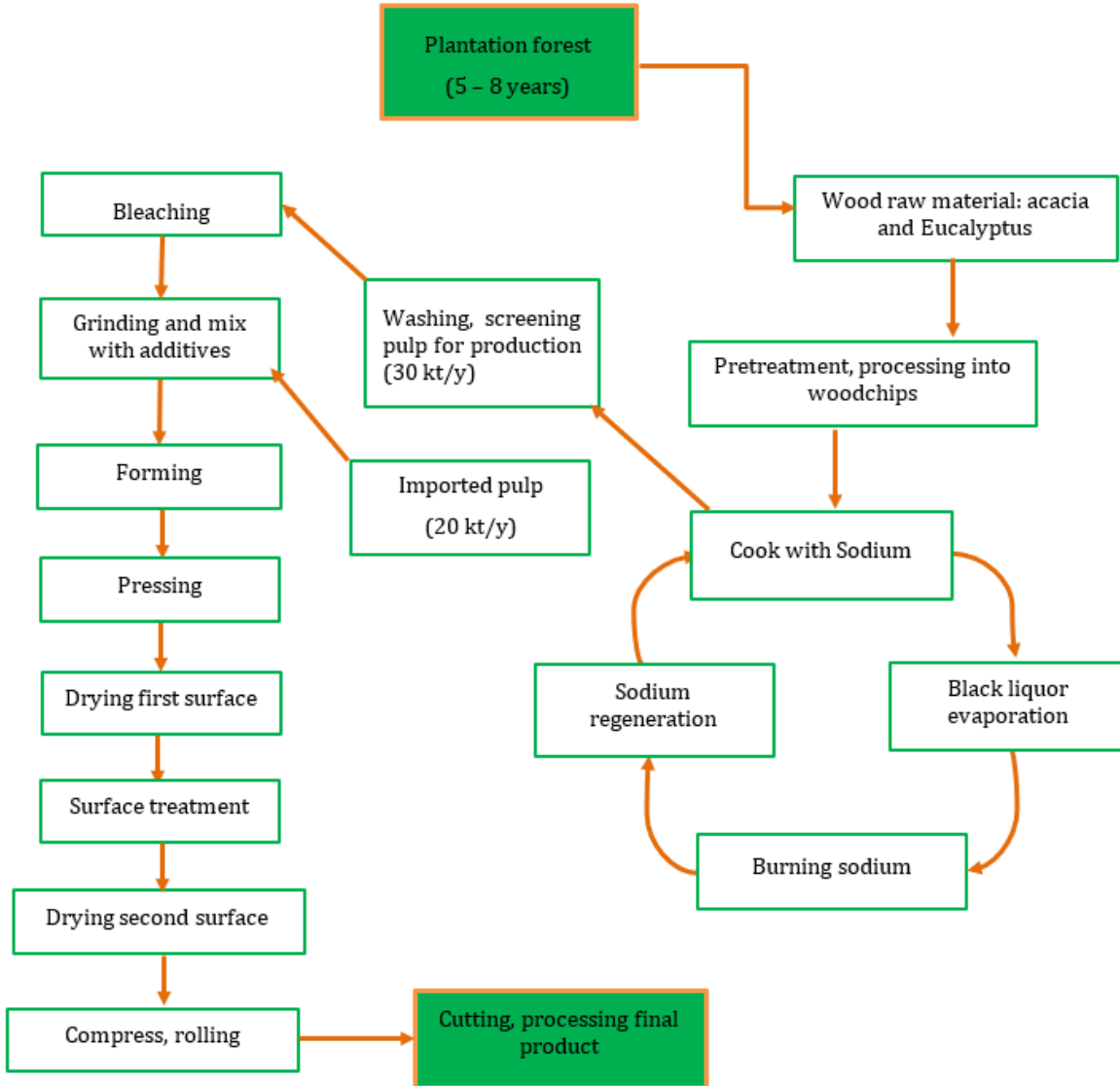


Figure 16: VINAPACO production process

3.6.3 Energy generation and demand

The following boilers are used in the factory

Table 24: Boilers and their specifications

Boiler	Fuel	Nominal/operated capacity TPH	Steam pressure and temperature	Comment
Fluidized bed	Anthracite coal	145/90	62/450°C	1970 technology
Black liquor recovery boiler	Black liquor	36/16-20	62/450°C	1970 technology
Biomass step grate boiler	Tree bark, wood chips	20/16	13 bar	2013 technology from Vietnam

The CHP system has 1 back pressure turbine with extraction grate and 1 condensing turbine. The specifications are depicted below:

Table 25: VINAPACO turbine specifications

Turbine	Unit	Back pressure turbine	Condensing turbine
Input steam flow (TPH)	Tph	95	85
Input steam temperature	oC	450	450
Input steam pressure	Bar	62	62
Extraction Pressure	Bar	13	-
Extraction flow	Tph	15	-
Outlet steam pressure	Bar	4.5	-0.85
Outlet flow	Tph	80	85

The main boiler, the coal fired CHP, has an efficiency of 76.27% according the 2019 boiler efficiency report when the boiler using domestic anthracite as a fuel. Recently, however, the company switched to using bituminous coal from Austria and sub-bituminous coal from Indonesia which increased combustion efficiency and the overall efficiency increased to 85%.

The boiler operates sub-critically, and significant higher pressure and steam temperature is possible resulting in a higher overall efficiency. In the sugar industry for example, steam with a pressure of 105 bar and 525°C are becoming common (Bosch holdings, 2021). Modern CHPs with back pressure turbine, should be able to reach around 87% combined efficiency (Gambini, Vellini, Stilo, Manno, & Bellocchi, 2019). Vinakraft for example already operates a boiler with a similar specification but with a condensing turbine with a pressure oof 100 bar and temperature of 510°C that can provide much higher power production.

The current condensing turbine of VINAPACO is only used for 1500 hours per year and only receives a limited amount of steam (8 TPH) during turbine maintenance and to use excess steam. The CHP is working at a lower pressure than originally designed, 62 versus 71, due to aging.

Energy costs take up a significant share of total production cost with around 20 to 30%. The total energy cost is estimated at 300 billion VND/year of which coals is around 70-80%. A new CHP could therefore help to reduce those costs.

Their current operation is energy intensive and above the norm of Circular 24/2017/TT-BCT.

Table 26: Energy intensity of VINAPACO and the Energy Norm

Product	Energy requirement	Specific intensity	energy Norm
Printing paper	MJ/ton paper	14,577	13,169
Pulp	MJ/ton pulp	9,572	N/A

Also, internationally, the factory of Vinapaco has a high energy intensity. Internationally, the norm is in the range of 7,380 to 10,800 MJ/ton²¹. Significant energy improvements are therefore possible.

3.6.4 New investment

VINAPACO is planning to replace the existing CHP system, a coal fired boiler with back pressure turbine, with a new CHP system with higher back pressure capacity with can adapt to the anticipated expansion in a tissue paper and wood board production line.

The CHP system considered by VINAPACO has similar operating parameters as the original. However, a system with higher pressure and temperature steam is advantageous as more electricity can be generated against a marginal higher fuel input.

In the next table the parameters of the current CHP, the proposed CHP and the CHP proposed by the team are tabulated:

Table 27: Steam flow for the 3 cases of VINAPACO

Description	Unit	Current CHP	Proposed new from Factory	Recommendation
Steam capacity supplied by main boiler	TPH	90	120	120
Pressure of steam supplied by main boiler	bar	62	62	100
Temperature of steam supplied by main boiler	°C	450	450	510
Steam capacity supplied by black liquor boiler (62 bar; 450°C)	bar	28	28	28
Steam capacity supplied by Biomass boiler (13 bar, saturated)	TPH	18	18	18
Steam entering the turbine	TPH	95	120	120

²¹ According to GIZ BEM international consultants.

Steam flow from turbine extraction at 13 bar	TPH	15	40	40
Steam exhaust from turbine to production process at 4.5 bar	TPH	80	80	80
13 bar steam demand for production process	TPH	33	58	58
4.5 bar steam demand for production process	TPH	103	108	108

Table 27 shows that the turbine extraction will increase from 15 to 40 TPH. This may affect to the efficiency of CHP system and electricity generation since a higher share of steam is not used for electricity production in the low-pressure part of turbine.

Table 28 shows the energy balance of the CHP. The first row depicts the total amount of energy input to the 3 boilers (black liquor, biomass, and the main boiler: existing, the proposed and the recommended investment to replace the main boiler).

Table 28: Current CHP, proposed CHP and the recommendation²²

Description	Unit	Current coal-fired CHP	Proposed CHP by VINAPACO	Recommendation
Energy input from fuel from 3 boilers	MJ/h	420,307	511,979	526,790
Fuel Energy used in CHP system	MJ/h	292,089	366,687	381,498
Energy of feed water into boiler of CHP system	MJ/h	65,353	87,137	87,137
Steam Energy out of boiler of CHP system	MJ/h	296,856	395,808	407,952
Energy for conversion from feed water to steam of CHP system	MJ/h	231,503	308,671	320,815
Gross Energy converted to Electricity in CHP system	MJ/h	45,638	54,696	68,251
Parasitic load	%	10	10	10
Parasitic power consumption	MJ/h	4,564	5,470	6,825
Net electricity production	MJ/h	41,074	49,226	61,426
Energy supplied to production process	MJ/h	201,820	254,280	252,592
Energy in condense water	MJ/h	64,959	85,716	85,716
Actual energy used in production process	MJ/h	136,862	168,564	166,876
CHP efficiency of main boiler	%	60.92	59.39	59.84
Electricity generation efficiency	%	14.06	9.61	11.66

²² All calculations by the BEM consultancy team obtained from interviews

Conclusion

- The table 28 shows the system efficiency of 3 cases. The recommended configuration has a slightly higher CHP efficiency and a much higher electricity generation efficiency
- The CHP system efficiency is lower than the original CHP configuration. That is because of the higher steam extraction flow for the anticipated new production lines.

The calculations are back-of-the envelop as not the calculations are based on several assumptions and the configuration of the new production line(s) are not known. In the next phase of this study, a detailed assessment is required to confirm the assumption in this report

3.6.5 Financial viability of recommended CHP investment

A financial evaluation of the recommended CHP was prepared. For this purpose, several CHP companies were approached to understand better the design of a CHP for VINAPACO and the investment cost. Details of the companies are tabulated in the table below:

Table 29: Companies approached

Company	Contact person	Email	website
Vyncke	Kevin Vandewalle	kyw@vyncke.com	www.vyncke.com
Enesco	Vu Trung Kien	kelvintk@gmail.com	www.enesco.com.vn
KPN Green	Kochaporn Krutkong	kochaporn.k@kpngreen.com	www.kpngreen.co.th
Thermax	Rajath Raj Prakash	Rajath.Prakash@thermaxglobal.com	www.thermaxglobal.com
Martech	Lau Duc Kim	kim.ld@martech.com.vn	https://www.martech.com.vn
Power Engineering Consultant Company No1. (PECC1)	Nguyen Thanh Tung	tungnt@pecc1.com.vn	http://www.pecc1.com.vn/

The companies were approached with a request for quotation. However, it is difficult for the companies to provide a quote without understanding the exact type of fuel, steam return pressure, electricity demand and other items. Furthermore, VINAPACO will upgrade its production lines in the coming years and implement various energy efficiency measures. An understanding of these changes is required before a CHP system can be designed. For this reason, detailed quotations were not possible.

Within the timeframe of the study, 4 quotes were received. All quotes should be interpreted as having a range of $\pm 20\%$.

Table 30: Quotations received for new CHP

Company	Billion VND	Million USD
ENESCO	541	23.5
PECC1	1028	44.8
MARTECH	828	36.0
Thermax	526	22.8

It was also attempted to calculate the OPEX and steam cost. However, this estimate is limited to the running cost of the CHP and maintenance. No data is available on other cost, such as insurance, taxation, installation cost, administration, and management cost, building cost etc. In the next table the operating costs are calculated with these limitations:

Table 31: Annual operation and maintenance cost estimate and data from VINAPACO

Cost component	Unit	Unit cost (mVND)	Number of units	Total (mVND/year)
				3,600
Human resources	Full-time salary	120	30	
				9,468
Maintenance	% Investment	378,700	2.5%	
				16,843
Electricity	kWh	1613 VND	10,442,421	
				60,992
Coal (30% all fuel)	ton	1.10	55,447	
Biomass fuel (70% all fuel)	ton	0.45	129,377	
				17,568
Water	Tons/year	0.02	878,400	
Total				166,689

The operation costs vary slightly between the suppliers as the maintenance cost is expressed as percentage of CAPEX. However, maintenance costs are, compared to fuel costs, minor, and consequently, all OPEX estimates are in the range of 166,689 (calculated in table 31) to 177,855 for the CHP with the highest CAPEX cost.

3.6.6 Financial evaluation

The table below shows the basic parameters used in the financial calculations.

Table 32: Basic parameters used for the financial calculation

Item	Unit	Value	Remark
Interest rate	%	12	Typical rate for business loans
Loan period	Year	10	Assumption

Discount rate	%	14.5%	Reflecting the weighted cost of capital, assuming 70% debt-financing at 12% and 30% equity at 25% return on equity
Tax rate	%	N/A	Calculations are based on EBIDTA (Earnings Before Interest, Taxes, Depreciation, and Amortization)
Electricity price	VND	1613	24/7 average electricity price for large industries
Steam cost	kVND/ton	390	ESCO average steam price – used to calculate avoided cost

In addition, it is assumed that parasitic load is 10%, average capacity factor is 85% and that around 92% of the boiler capacity is in use on average.

A cash flow has also been prepared and attached in Annex II of this report.

3.6.7 Results

Table 33: Financial indicators (10 year period)

Summary	NPV	IRR	Simple PBP
Enesco	\$17,438,208	33%	2.59
Martech	\$639,942	15%	4.64
PECC1	\$-15,059,014	3%	6.68
Thermax	\$18,523,409	35%	2.59

The quote received by PECC1 has an IRR lower than the calculated WACC of 3% and is under normal circumstances not considered viable, as also confirmed by the negative NPV. The quotation of Matrec show marginal viability, and those of ENESCO and Thermax show a reasonable return on investment.

It is not possible to calculate the LCOE as there are 2 outputs, steam and electricity. The LCOE therefore depends on the value of steam. The ginter triangle is a method to evaluate a CHP with 2 outputs. The CHP is viable steam and electricity can be produced at lower rate as the counterfactual scenario. The counterfactual scenario is grid electricity cost and ESCO steam retail price. These results are depicted in the ginter triangle below. Both electricity and steam have been discounted with 14.5% and the evaluation is based on a 10-year cash flow.

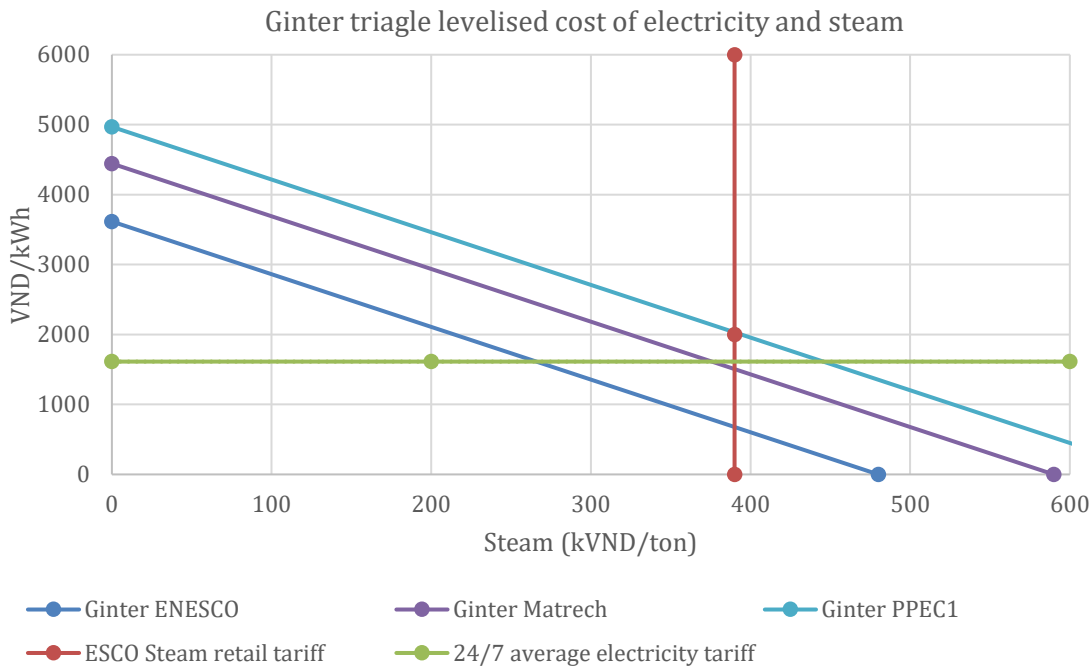


Figure 17: Ginter triangle of CHP performance

All combinations are viable at a y-axis value below the green line depicting the average grid electricity costs and all x-axis values at the left of the red line depicting the ESCO steam cost. The results of both Thermax and ENESCO were very close and therefore combined in one line.

The Ginter triangle of both ENESCO and Thermax have a number of viable steam and electricity cost combinations. Matrech on the other hand has a limited number of viable combinations and close the counterfactual scenario cost.

The PECC1 triangle on the other hand intersects the green and red line above the counterfactual cost level of both steam and electricity. The PECC1 CHP quote therefore is not viable as was previously also concluded based on the IRR and NPV based on a 10-year cash flow.

All triangles will shift to the left if the evaluation is conducted based on a 15-year cash flow, but that is likely beyond the time horizon of investors. Moreover, VINAPACO did not indicate what their investment horizon is.

3.6.8 Conclusion and discussion

The CHP system of VINAPACO is outdated and should be replaced with a modern CHP. A modern CHP will operate at a higher pressure and generate more electricity. The CHP proposed by VINAPACO will only have a marginally higher performance while a 'state of the art' CHP proposed will result in much higher savings.

The financial evaluation of various CHP quotes showed that a CHP system of Martech is just below breakeven of the counterfactual scenario, and therefore the CAPEX of a new CHP should be around the quote received from Matrec of 828 billion VND or lower.

A follow up study should focus on the planned investment of VINPACO, the energy demand after efficiency improvements, the fuel mix and fuel quality, and update the calculations accordingly. That study should also assess if it possible to improve energy efficiency and reduce steam demand to a level that the CHP can run on biomass only, without requiring coal.

3.7 Stakeholder commitment to bio-energy utilization

3.7.1 Forces of change for the utilization of bioenergy

Companies indicated that obtaining permits for new coal-fired CHP's are becoming more difficult. Certain companies for that reason consider investing in predominantly biomass fired CHP, i.e., VINAPACO, or may delay the investment in a new CHP and continue using their old boiler. Some of those companies, if they have to relocate to industrial zones, might be interested in contracting and ESCO, or could consider a biomass boiler if supply and pricing is guaranteed. This is however a challenge for paper mills which do not produce pulp and consequently do not have their own source of biomass.

Literature review indicated that many mills rely on outdated inefficient technology. Paper mills should improve production machinery systems such as installing inverters to reduce energy consumption and increase the durability of machinery, improving the convection systems to increase the boiler's efficiency. Moreover, the energy recovery systems should be modernized (Thi & Anh, 2020).

3.7.2 ESCO opportunities

Energy Service Company (ESCO) is a type of company using energy performance contracts as the basis for its remuneration in implementing energy efficiency project as business model.

There are 3 types of ESCO contracts for supplying ESCO service including

- **Guaranteed Savings contract** where an ESCOs guarantees a certain energy savings compared to the current business as usual (BAU)
- **Shared Savings contract** where as ESCOs will provide an energy saving solutions paid by the client. The energy saved compared to the BAU will be shared between client and the ESCO.
- **Guaranteed Rebate (Chauffage) contract** where as ESCO invests in the energy system and sells energy to the client.

In Vietnam the guaranteed rebate contract is the most common ESCO type.

ESCO's can provide unique leverage, in particularly those supplying steam to multiple factories or being the dedicated supplier in a particular industrial zone. To better understand the ESCO opportunities with regard to using biomass for steam/ electricity 6 ESCO's were interviewed, TPSSC, Kim Truong Phuc, Huynh Dang, Martech, Thuan Hai and Tri Viet Company. The main findings are:

- The ESCO value proposition is steam as a service with affordable prices avoiding the challenges related to maintaining and operating a steam system. ESCO companies have the expertise to maximize efficiency and thereby reduce costs and pass on some of those savings to companies.
- An estimated 20-30% of the factories use ESCO services, there is therefore a large potential to reach other factories. In particular, with the relocation of certain factories to economic zones new opportunities may arise and at larger scale.
- Few companies demand biomass powered steam, these are limited to international companies with strong corporate sustainable responsibility (CSR) agenda's/climate policies such as Adidas, H&M, Nike, Heineken
- Sourcing of biomass is a challenge due to seasonal fluctuations in availability and the coal price. Multifuel boilers are becoming more common giving user's flexibility in sourcing the cheapest source of fuel. With the low price of imported coal, coal remains popular.
- Most domestic ESCOs focus on steam services only, not cogeneration. Reasons are high investment cost as well as the complication of a CHP system. However, recently some ESCOs are cooperating with international companies with EPC contract for a CHP system.
- Ensuring stable biomass fuels for biomass boilers remains a difficult problem due to unstable supply chain.

An interesting ESCO is the Toshiba /Plant Systems and Services Cooperation (TPSSC). TPSSC is exploring the Vietnamese market and has as goal to reduce GHG emissions and cost-savings (10% savings) using exclusively biomass with a EPCC (Engineering, procuring, Constructing and commissioning) model. They are looking for large companies with at least 50 TPH steam and or 10 MW electricity. Their project will be registered under Joint Trading Mechanism (JCM) which would create additional revenue to

support their operations and to remain cost competitive with other ESCO relying on coal. Their mode of operation is well suited for industrial zones, where steam and electricity can be supplied to several factories.

A follow up study should focus on the industrial zones and the potential of inviting ESCO's like TPSSC with a biomass only ESCO model. This would create unique leverage as many companies are served at once.

3.7.3 Leverage and stakeholder commitment

Stakeholder commitment is limited to the focus on cost-savings and reducing energy intensity in line with government norms. Vinakraft, a joint venture company between SCG (Siam Cement Group), the biggest paper manufacturer in Thailand and Rengo (Japan) does not have GHG emission reduction targets, even though when SGP, at corporate level has clear sustainable development objectives and a goal to reduce GHG emissions with 28% in 2030 compared to 2007²³. Actions include increasing the share of biomass and clean energy in place of fossil fuels. However, this policy has not percolated into action in Vietnam.

ESCO models, as discussed in the previous section, can create unique leverage to a great number of factories within their domain, with or outside this sub-sector and should be explored in detail in a follow up study.

3.8 Discussion and conclusion

The pulp and paper sub-sector is developing and industrializing rapidly with significant FDI. The sector has as its main weakness reliance on imported scrap and pulp and a large number of small companies with improper waste management systems. National production of pulp production in Vietnam should be promoted instead of exporting raw woody materials like pellets and chips abroad. Also, in the interest of reducing environmental pollution relocating craft villages to industrial zones and promoting a shift from manual to mechanical production is necessary to maintain competitiveness.

Bio-energy usage is limited to black liquor recovery boilers and some biomass in multifuel boilers, however, most of the energy supplied is by coal. Without pressure from the government or buyers, coal will remain the predominant fuel as coal is, in many cases, cost-competitive compared to biomass. There are indications however that it is becoming more difficult to invest in new coal boilers as permits are not easily provided, this could lead to new investment in biomass boilers, but it could also delay investment in a new boiler.

The pulp and paper industry are an economic sector with a natural fit for the circular economic model. Therefore, making use of recycled paper sources and saving energy is especially important. To use recycled papers as a main material source in the paper mills, it is necessary to encourage paper recovery and recycling by legislating laws on recycling and saving resources as some developed countries have done. The pulp mills need to improve machinery to save energy and improve production efficiency by applying cleaner production and energy efficiency measures as well as using renewable energy.

The case study showed that a significant reduction in coal use is possible in the case of Vinapaco and generate electricity at an attractive tariff. However, additional energy efficiency measures are necessary to eliminate coal use entirely.

An intervention should therefore focus on improving energy efficiency alongside introducing biomass CHP models for large companies, while smaller companies, in particular those that have to relocate to industrial zones, will likely utilize an ESCO for their steam demand. Working with ESCO's therefore, can create leverage beyond the factory as often multiple factories are served.

²³ [Sustainable Development Strategy – SCG Sustainability](#)

Chapter

04

Cassava starch sub-sector

4 Sub-sector cassava-starch

Most cassava factories treat waste in several treatment ponds which includes an anaerobic stage from which biogas is captured. In most factories all biogas is used to generate heat to dry starch and pulp. A limited number of factories have excess gas which could be converted into electricity

5.1 SUB-SECTOR OVERVIEW

5.1.1 Background

Vietnam has made rapid technical progress in the selection and breeding of cassava. The combination of development and production of cassava as starch processing, animal feed and bioethanol has created more jobs, increase exports, attract foreign investment, and contributed to industrialization, and modernization of some rural areas (SNV, 2012).

Cassava production has increased significantly, from 2.3 million tons in 1994 to 9.9 million tons in 2011 and hovered around 10 to 10.9 million ton in the period 2012-2019. The dramatic increase in production results both from expanding cultivation (279,400 hectare to 519,360 hectare) and yield improvement (8.44 t/ha to 19.45 t/ha) between 1994 and 2019 respectively (FAOSTAT, 2021).

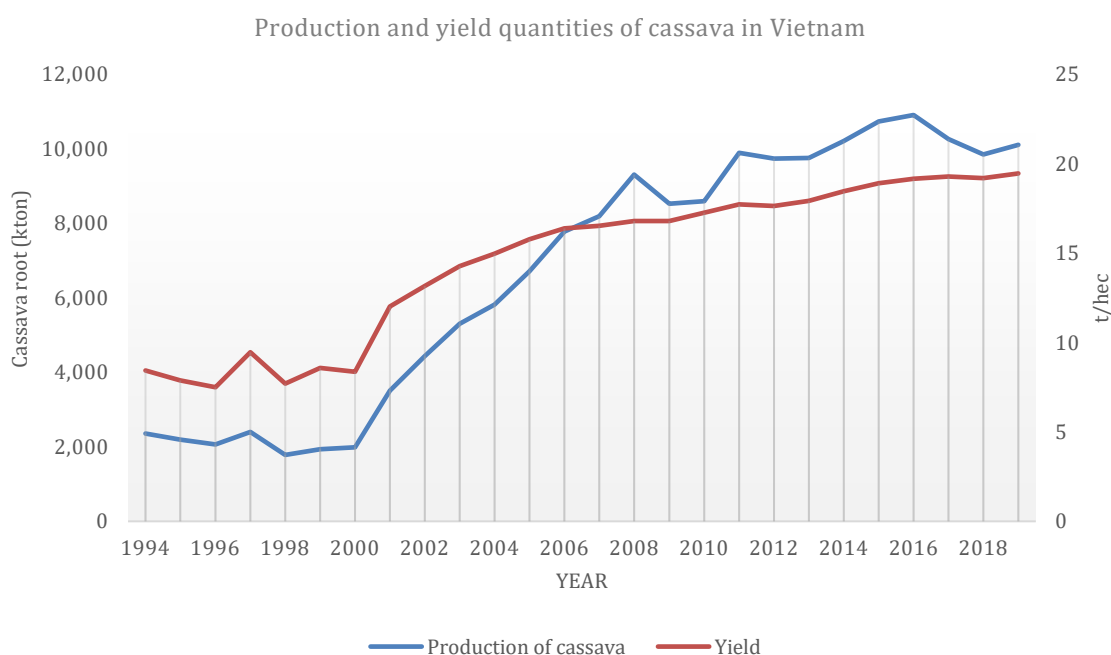


Figure 18: Cassava production and yield 1994-2019 (FAOSTAT)

Vietnam is the fourth largest producer of cassava in Southeast Asia, after Thailand, Indonesia and Cambodia and the 8th in the world. While the yield has improved in Vietnam, it remains lower than countries in the region. Cambodia and Thailand for example have an average yield of 21.1 and 22.3 t/hectare respectively, Lao PDR of 32.1 versus 19.2 t/hectare in Vietnam (ACIAR, 2019). Vietnam however has a competitive advantage over Cambodia in terms of processing capacity and energy prices, which resulted in significant import of cassava chips from Cambodia. In some provinces up to 70-80% of the produced cassava comes from Cambodia (ACIAR, 2019).

The gross production value is estimated at \$2.25 billion in 2019 (FAOSTAT, 2021) of which almost 1 \$1 billion (973 million) is exported in 2019 (Thaichinh, 2021). Of the exports, 85% is starch and 15% dried cassava chips and the main export market is China.

5.1.2 Cassava cultivation and processing

The cassava plant (*Manihot Esculenta Crantz*) is the only species in its genus that serves as a food crop. The plant is native to north and central-west regions of Brazil and brought by the Portuguese to Asia. It is a perennial shrub adapted to the hot conditions of tropical lowlands. Cassava copes better with poor soils than many other food plants.

Cultivation

Cassava farming in Vietnam is concentrated in two different geographies, the flat zones in delta areas and in hilly/mountainous areas with a degree of slope higher than eight percent (FAO, 2018).

However, in almost all provinces some cassava cultivation takes place (see the map at the right), but the bulk is grown in Tay Ninh, Gia Lai, Dak Lak, Phu Yen, Kon Tum, Binh Thuan, Son La, Dong Nai, Quang Ngai, Nghe An. Cassava starch processing factories are usually located near the cultivation fields.

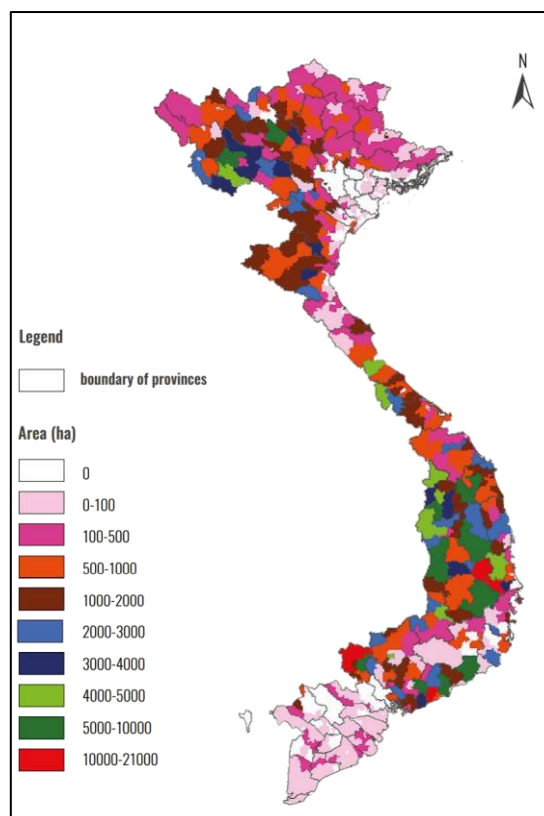


Figure 19: Cassava cultivation area by province

Yield by geography type and inputs required are tabulated in the table below:

Table 34: Cassava yield and inputs by region (FAO, 2018)

	Flat lands in the South	Sloping land in the North
Yield (ton/year)	25	14.5
Harvest residue (%)	15.5	12.07
Fertilizers (kg/hectare/year)		
Manure	39.2	50
N-fertilizer	138.5	36
P ₂ O ₅	115.5	50
K ₂ O	105.3	60
CaO	600	200
Pesticides	2	0
Seeds (kg/year)		
Cassava cuttings (stems)	750	875

The cassava planting season occurs 2-3 months before the beginning of the rainy season, in late February or March. In the South, cassava can be planted both in February and in September (FAO, 2018). The following table provides an overview of the cassava cropping season by region:

Table 35: Cassava planting calendar by region and month of the year

Region	1	2	3	4	5	6	7	8	9	10	11	12
North mountainous Region and Red River Delta												
North central coastal Region												
South-central coast and the central highlands												
Southeastern region												

Harvesting

Cassava harvesting is usually performed 7-11 months after the planting season. In the North, it is often still performed by hand, while in flat areas in the South mechanical harvesting is common (FAO, 2018).

Processing

Cassava is a versatile plant, and all parts have a use and value (Baguma, 2015):

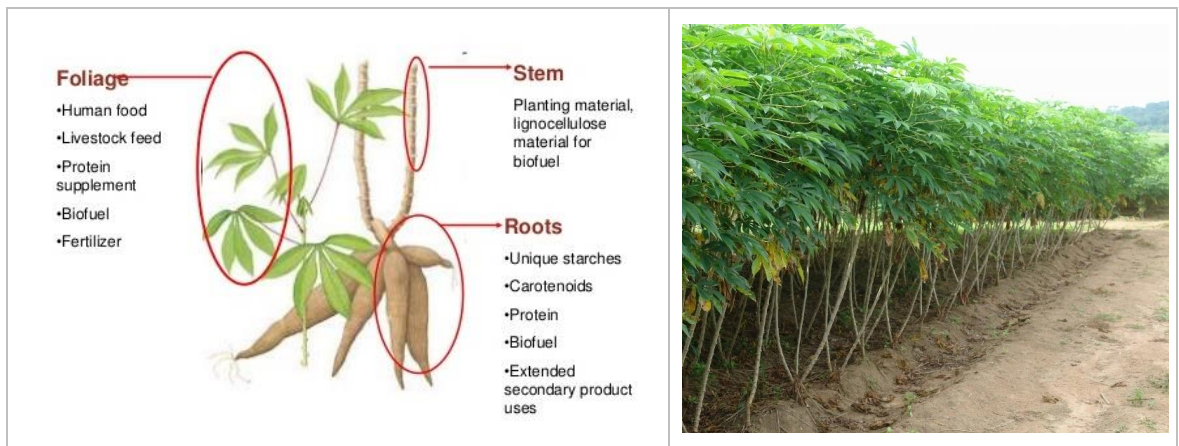


Figure 20: Left: Wholesome use of cassava plant. Right: cassava plantation

In the figure here below the various uses of the plant is depicted:

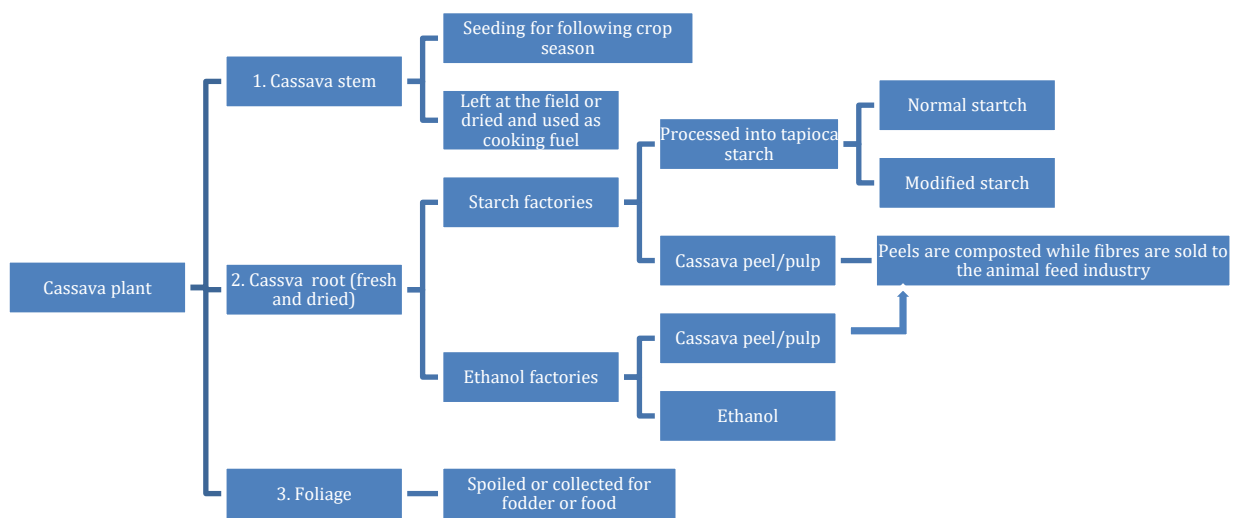


Figure 21: Cassava plant usage in Vietnam

Cassava stems (1 in the figure above), cassava root (2 in the figure above) and foliage (3 in the figure above) are discussed in more detail here below:

1. Cassava stems (also referred to as, shoots, stalks or cuttings) are after the cassava harvest selected and cut into stakes for storage and subsequent replanting (SNV, 2012). Stakes are planted mostly horizontally, but vertical planting, depending on the soil moisture or slated planted also occurs.

Excess stems are dried and used for cooking. However, stems also contain up to 15% of the starch in the stem can be extracted using simple water-based techniques (Wanbin, et al., 2015). This is however not practiced.



Figure 22: cassava root

2. Cassava root: The cassava root, dried or fresh, is input material to produce tapioca starch or ethanol

1. **Ethanol:** Cassava can be converted into ethanol in a number of processing steps. The conversion ratio of dried chips to ethanol is on average 2.3 kg/liter (FAO, 2018). Bioethanol as biofuel is promoted in Decision No. 177/2007/QĐ-TTg with the aim of replacing a part of fossil-derived fuels, contributing to ensuring energy security and environmental protection. In 2012, the Decision No. 53/2012/QĐ-TTg issued a roadmap to apply the ratio of mixing biofuels to traditional fuels and by 12 January 2015 E5 gasoline (5% bioethanol) is available in the market of 5 cities (ACIAR, 2019).

Vietnam has 7 biofuel factories, where ethanol (99.5%) is produced from dried cassava chips with a cumulative capacity of 410,000 m³ per year. The high cost of cassava-based ethanol; and a shortage of domestic production capacity due to technical and financial difficulties hampered ethanol production. As a result of the domestic production constraints, Vietnam imports significant quantities of fuel ethanol from the USA as well as from South Korea (probably transshipped from the USA) (ESI & NUS, 2020).

2. **Cassava starch:** commonly referred to as tapioca is a starch extracted from the storage roots of the cassava plant. Food grade cassava starch has a maximum moisture content of 13% CODEX STAN 176-1995: and less than 10 mg/kg HCN (Codex Standard for edible cassava flour). The nutritional profile of tapioca is limited. Tapioca provides only carbohydrate food value, and is low in protein, vitamins and minerals. There are 152 large scale cassava factories and many small-scale artisanal processing facilities²⁴. Small producers often supply their products directly to the local market for desserts, flour, and food dietary recipes.

Examples of tapioca starch are shown in the next table:

Table 36: Tapioca starch examples

Starch (off white powder with neutral odor and taste)	Typical supermarket package	Example a dish - Chè bột lọc (tapioca pearls in ginger syrup)

There are two types of starch produced:

- **Native starch:** are basically pure forms of starch – long-chain carbohydrates. This is the main product produced.

²⁴ Some sources estimate up to 4,000

- **Modified starch**²⁵: starch derivatives, are prepared by physically, enzymatically, or chemically treating native starch to change its properties (Vaclavik & Christian, 2007) Starches are modified to enhance their performance in different applications to increase their stability against excessive heat, acid, shear, time, cooling, or freezing; to change their texture; to decrease or increase their viscosity; to lengthen or shorten gelatinization time; or to increase their visco-stability. Few factories produce modified starch.

Table 37: Examples of industries using tapioca starch

Sub-sector	Uses
Food processing sub-sector	<ul style="list-style-type: none"> • Tapioca Starch works in a wide variety of cooking applications due to its unique characteristics of being gluten free, high viscosity, and bland taste. • Its high viscosity makes tapioca starch an excellent thickener to improve the texture of soups, creams, sauces etc. • It's often added to meat products to improve their moisture retention and firmness. • Improving the chewiness of confectionary and noodles.
Paper and pulp sub-sector	Paper production: improve resistance and strength of paper, and being waterproof, etc.
Textile sector	Minimizing breakage, splitting, improving the stiffness of fabrics, creating durability and brightness for the product.
Pharmaceutical industry & cosmetic industry	Bleaching agent, addition agent for soap, facial cream, and excipient.
Other	Other industries: Tapioca starch is often processed into adhesive material that is used as binders in many industrial applications such as the manufacture of plywood, detergent, plaster ceiling, animal feed, etc.

Residues: Residues are peel, pulp and wastewater.

The residue after starch extraction is a watery pulp. Cassava pulp contains about 50-70% starch on dry weight basis and 20-30% fibers which are mainly composed of cellulose and other non-starch polysaccharides (Edema, Sulaiman, & Rahim, 2013). After drying, this fibrous residue is sold as raw materials for livestock feed production.

Wastewater from cassava starch processing and ethanol production industries contains high COD/BOD levels and requires extensive treatment before it can be discharged.

²⁵ Modified starch should not be confused with genetically modified starch which is obtained from genetically engineered plants.

Table 38: Wastewater and cassava processing residues




Wastewater (example of wastewater pond)	Fibers	Peel
		

Figure 23: Residues; wastewater, fibers and peel

3. Foliage: Cassava leaves are edible and a common ingredient in certain dishes. Cassava leaves have a high protein content (20-25% of dry leaves). Cassava leaves are used as animal feed, processed into animal feed or for human consumption (see figure at the right). High yielding cassava plant however have high hydrogen cyanide (HCN) content and need to be dried first or ensiled before they can be used a food/feed source (Bien, Hoang, Ngoan, Howeler, & Wang, 2017)



Figure 24: Fried cassava leave and papaya flower - photo VOV.vn

5.2 Sub-sector performance

5.2.1 Sub-sector map

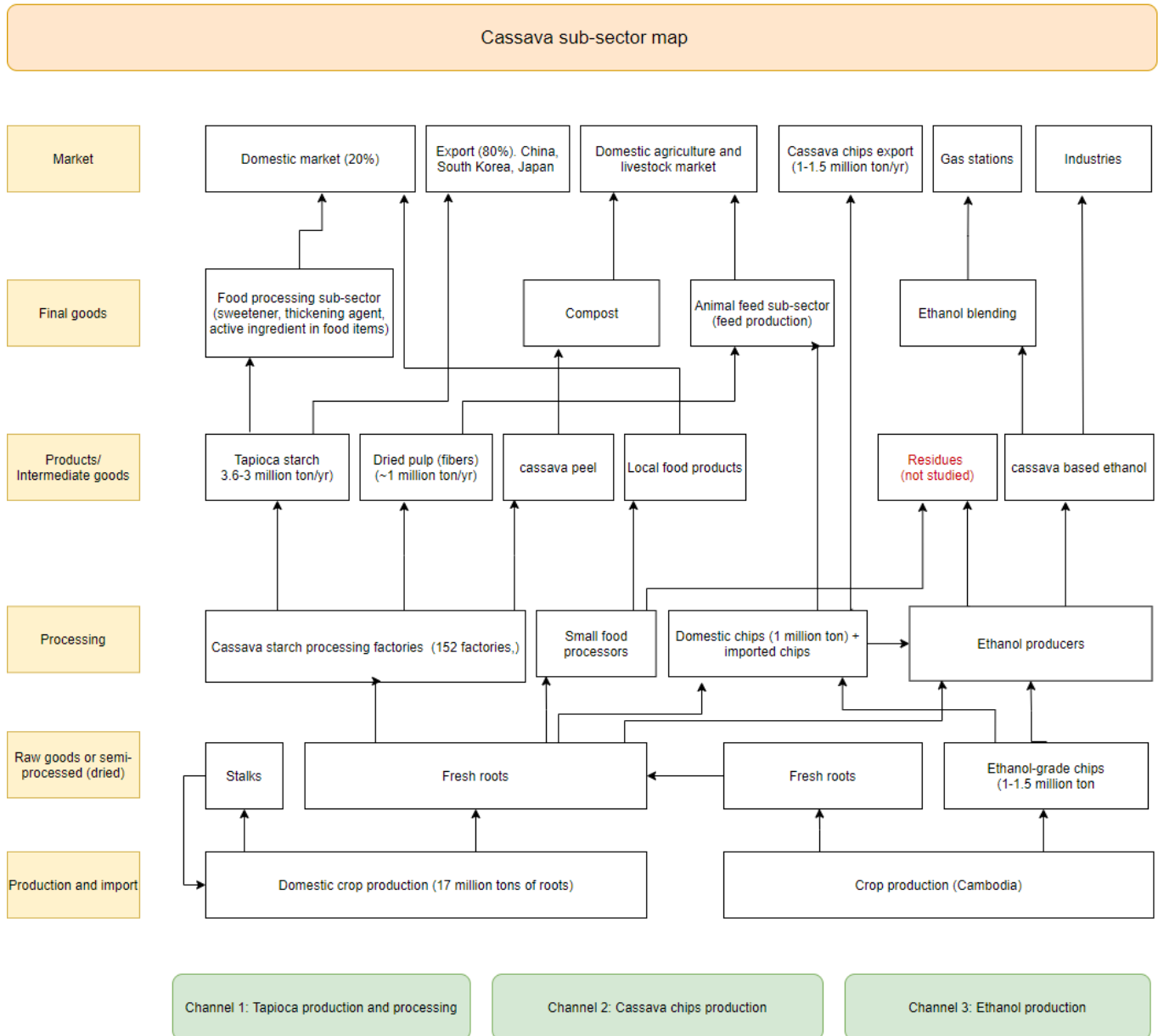


Figure 25: Cassava sub-sector map

The main functions are:

1. **Production:** cultivation of cassava in Vietnam and Cambodia
2. **Raw goods:** products from harvesting: Stalks – 20% are used the production function, fresh roots and ethanol grade chips (dried cassava cuttings)
3. **Processors:** steps where the products are processed into intermediary or end-products
4. **Products and intermediate goods** – in this step additional value are added by valorizing the waste products and/or utilizing starch for other products.
5. **Final goods:** the product produced ready for sales and distribution to markets
6. **Market:** These are the main markets, including the export market which is the dominant market for tapioca starch. This is partly because of high demand but also because the requirements are less strict compared to the EU, USA and Japan. These countries require high quality standards

conform the applicable ISO standards, and specific attention to preservations, product origin etc.) (VCA, 2021)

There are 3 main channels:

1. **Tapioca starch production:** The focus of this channel is to produce native starch. Modified starch is only produced in small quantities currently.
2. **Cassava chips production:** This channel produces chips for export or other sectors (animal feed and ethanol production)
3. **Ethanol production:** The focus of this channel is production of ethanol as fuel.

The map is simplified, within the sector it is possible to zoom in into more advanced production (modified starch) and starch used in other sub-sectors.

The relations between the various nodes are only depicted with lines ignoring the various transportation options and costs. Within the context of the study, it was not possible to assess the mode of transport and the costs.

Finally, the ethanol and the dry chips channel is not extensively studied, as the focus of this study was on cassava starch. The two channels were nevertheless mentioned as they are entangled with the cassava-starch activities.

5.2.2 Sub-sector performance

5.2.2.1 Market outlook

Procuring material competition

Cassava roots and chips originate both from Vietnam, but a substantial amount is also sourced from Cambodia. Cambodia exported in 2020 around 3.29 tons of cassava (dried and fresh) of which an estimated 46.5% is exported to Vietnam (OEC, 2021). Much smaller quantities are also imported from Laos and China. Factories in Tay Ninh which rely on 70–80% of their cassava from Cambodia.

There are only 7 factories in Cambodia processing cassava. Cambodia's National Cassava policy has a modest goal of increasing this to 17 in 5 years' time by 2025 but at the same time remains a large supplier of cassava raw materials for export to Vietnam and Thailand (MoC, 2020). Except in extraordinary situations, such as COVID-19 which led to the closure of the borders, cassava roots and chips arrived with a multiple delay which resulted in a lower starch quality and yield (VCA, 2021). Encouraging is that in Cambodia's national export strategy various actions are proposed such as negotiating with targeted export countries tax exemptions and reductions and trade facilitation to ensure a smooth export process from Cambodia. (MoC, 2020). Other policy action includes ensuring chips quality and addressing trade barriers.

Cambodia will however focus more on starch processing and in the long run, Vietnam will, face challenges procuring cassava. Also, the relationship between Vietnam and Cambodia is focused on selling only, without creating strong relationship through contract farming and extension services. In Thailand however, these relationships are established (Marshall, 2021). These relations could be strengthened by providing similar extension services and contract farming arrangements.

Prices have been fluctuating, due to procuring raw material, COVID-19 and diseases. In general, however, increased due to demand and competition, prices of cassava have increased significantly in the period 2002-2019:

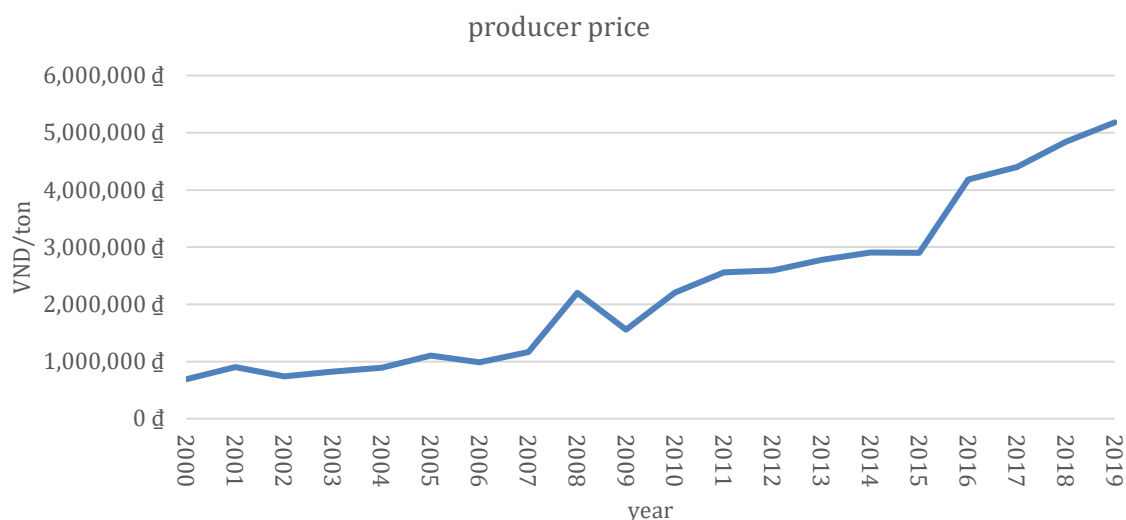


Figure 26: Producers price development 2000-2019 (FAOSTAT)

Plant diseases are regularly recording and often lead to input constrains and price hikes. In Vietnam, the cassava mosaic disease (CMD) outbreaks are a concern. Coordinated action on raising awareness, training of farmers, improve disease-free planting materials is lacking. In Thailand, the Thai Tapioca Development Institute²⁶ is addressing these issues, but such an institute is not available in Vietnam (ACIAR, 2019)

The Hung Loc Agricultural Research Center, an institute under MARD's jurisdiction, in Vietnam is introducing CWB disease resistant HLS11 varieties. This new variety has been brought to Dak Lak. There remains however much to be done on disease response strategies in Vietnam (Bien, Hoang, Ngoan, Howeler, & Wang, 2017).



Figure 27: Common cassava plant diseases (CBSD: Cassava brown streak virus disease, CMD: cassava mosaic disease)

Export market

The main market of tapioca starch is China. China imports around 49.20% share of all world imports followed by Indonesia with 16.15% in 2015. The tariff on imports is 12% in China and 9.5% in Indonesia (MoC, 2020). Worldwide the total trading value and amount is \$1.5 billion native starch and 3.5 billion modified starch. The average value of native starch (HS-110814) was \$372/ton while this is \$972/ton of modified starch (HS-350510).

Vietnam's main export market is China accounting for 89.2% market share in 2019 followed by South Korea with 3.1%, Taiwan 1.5%, Malaysia 1.2%, Philippines 1.2%. Exports of cassava starch in 2019 reached 2.1 million tons and \$895 million, equivalent to an increase of 23% in volume and 11% in value compared to 2018. (Thaichinh, 2021). The average export price of cassava chips reached \$208.5/ton,

²⁶ See [Welcome to Tapioca \(tapiocathai.org\)](http://Welcome to Tapioca (tapiocathai.org))

down 3% compared to the previous year (Thaichinh, 2021). Tapioca's export price is around 12 million VND/ton and domestically 11 million (VCA, 2021).

Within South-East Asia, cassava starch exports from Thailand and Vietnam continue to grow in value, while there has been a significant decline in chip exports, reflecting a changing market structure. Since the first quarter of 2018, Thai starch has been cheaper than starch produced in Vietnam and Indonesia, but more expensive than cornstarch from the United States (ACIAR, 2019). This led to an increase of Indonesian imports of cornstarch and syrups instead of tapioca.

The prospects for the cassava trade are favorable, as cassava still competes with corn and other substitute crops as a source of starch. In China and the Asian region there is a carbohydrate shortage, which is alleviated by a well-functioning cassava regional supply chain. The future of cassava will depend on its ability to maintain its competitiveness with corn and other substitute starchy crops grown in different areas in the world, in terms of starch quality, cost, special properties and reliable supply.

5.2.2.2 Position in the value chain

Vietnam is in the middle of the value chain, while Cambodia is at the beginning. Most value however is created when converting native starch into modified starch. Few factories in Vietnam are producing modified starch at the moment.

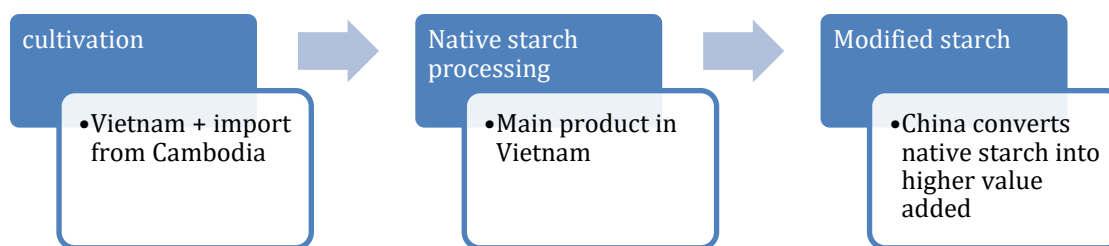


Figure 28: Tapioca value chain

There is increased interest and investment in the post-processing of starch to produce modified starch (VCA, 2021). The Hung Duy company in Tay Ninh for example has already set-up a production line for modified starch. Quang Ngai Argo-food Production company has invested in 3 modified starch factories. Other companies are also exploring this market.

5.2.2.3 Yield

Yields are relatively low in Vietnam compared to neighboring countries partly owing to climate and soil conditions. In Tay Ninh for example, with favorable climatic conditions, the yield reaches 40 ton/ha, which is much higher than in Dak Lak, 25 ton/ha. Some studies claim that yield increases of up to 50%, to 45–60 t/ha, achieved in field demonstrations are possible. Although the direct focus is on improving cassava productivity, there are cross-cutting goals related to improving the environment and achieving gender equality (ACIAR, 2019).

5.2.2.4 Policy environment

Circular QCVN 63:2017/BTNMT of 2017 on National Technical Regulation on effluent discharged from the cassava starch processing factories set discharge norms for zone A and B areas is the main policy regulating the environmental impact in the sector.

5.3 BIO-ENERGY USAGE AND OPPORTUNITIES

5.3.1 Bio-energy sources in the sub-sector

As per work-package 1 report, the following bio-energy sources are available in the sub-sector:

Table 39: Bio-energy sources in the cassava sub-sector (SNV, 2021)

Type of crop residues	Bio-energy type	Amount (t/t cassava root)	Amount kiloton	Lower heating value (MJ/ton or MJ/m ³)	Theoretical potential (TJ/year)
Cassava stems	Fuel for combustion	0.30	3000	17	51,000
Cassava peels	Biogas or dried as fuel	0.12	303	8.4	2,545
Wastewater	Biogas capture	10-18 m ³ wastewater/ton	232-310 million m ³	23 MJ/m ³	2,545

Peels (for rubber tree, not useful for other crops, due to high HCN, toxic component) and fibers are well valorized and used for animal feed purposes (animal feed factory) or given away for free (Dak Lak). Cassava stems are used for seedling in the next cropping season. Therefore, the focus on this study is on wastewater treatment and biogas recovery.

Information sources used in this chapter are based on-site visits, physical and remote meetings with key stakeholders and literature review.

5.3.2 Factory visits

Basic details of the factories are provided in the table below.

Table 40: Basic details of the factories visited

#	Factory	Province	Capacity (ton/day)	Website
1	Lien Phong	Tay Ninh	180	-
2	Hung Duy	Tay Ninh	250	https://www.hungduy.vn
3	Hao Nhai	Tay Ninh	200	-
4	Madrak Cassava	Dak Lak	100	http://apfco.com.vn/?sj=1025 ²⁷
5	Eapal	Dak Lak	150	-
6	Mdrak	Dak Lak	140	-

²⁷ Apfco has in total 16 cassava-starch factories

5.3.2.1 Operation

The factories in Tay Ninh operate around 9 to 10 months per year (300 days), which is made possible by favorable year-round conditions for growing cassava and the factories import significant quantities of cassava from Cambodia where the cultivation season is slightly different. In Dak Lak, the factories operate around 7 to 8 months per year (200 days).

In the most northern provinces this is even shorter, around 6 months per year from September to February (VCA, 2021).

5.3.2.2 Process description

The next figure shows the stages involved in the processing of cassava roots into tapioca starch with its mass balance. Actual values can vary depending on the starch content and the process technology, i.e., if treated process water is recycled.

Large amounts of solid and liquid wastes are produced along with tapioca starch. The liquid wastewater is produced in much greater amount i.e., more than 3 times of cassava roots mass (Virunanon et. Al., 2012).

The liquid wastewater usually contains about 1% solids and is generally treated in series of anaerobic with biogas capture, anoxic and aerobic ponds.

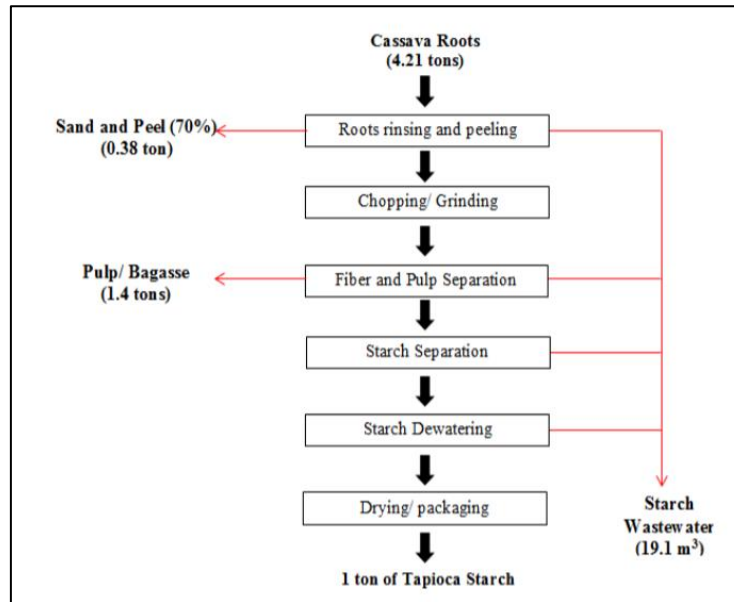


Figure 29: processes involved in tapioca starch production and mass balance (Edema, Sulaiman, & Rahim, 2013)

5.3.2.3 Products

All factories produce native starch. The factories in Tay Ninh tend to focus on the domestic market while those in Dak Lak on the export market. Hung Duy is in process of setting up production line to produce modified starch including a new waste treatment system.

Cassava pulp has become an important source of additional revenues for the factory as it is in high demand by the estimated 800 animal feed factories in Vietnam. In those factories it services as input material and is mixed with other feed.

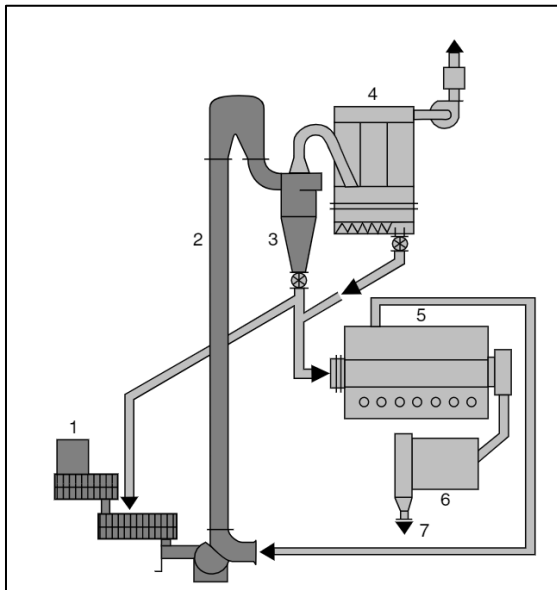
5.3.3 Energy usage and costs

5.3.3.1 Energy

Thermal energy

The moisture content of starch and pulp after separation is around 30 – 35% and 65% respectively and has to be reduced to around 13%. All 6 visited factories use a one-step flash column dryer for starch and a two-step column dryer for pulp. Flash drying works on the principle of pneumatic transport using hot air. Wet product is introduced into a high velocity air stream through a special venturi feeder. Highly turbulent airflow generates an intense gas-solid thermal exchange and disaggregates the product.

One-stage flash dryer



1. Wet product, 2 flash dryer, 3 cyclones, 4, fabric filter, 5 indirectly heated rotary calciner, 6 cooler, final product discharge (Borde & Levy, 2006)

Picture of flash dryer taken during the field visit

Figure 30: Flash dryer technology commonly used

Starch is dried by air heated from a biogas fired thermal boiler through a heat exchanger. Before air is fed into the dryer, the air is filtered to avoid possible contamination with pollutants. In Tay Ninh all boilers run on 100% biogas while in Dak Lak these are multifuel. Two factories in Dak Lak consumed around 200-300 ton of coal per year and 150 ton of wood in addition to biogas (biogas covered 70-80% of all energy demand). A typical boiler size is 6 million kCal/h or 25,116 GJ/hour in Tay Ninh while in Dak Lak the boilers are 50% smaller

Pulp is dried by direct exposure to hot flue gas. This is possible because the quality requirements are lower and minor contamination with impurities is acceptable. The initial moisture content is higher of pulp, around 90%. Dewatering first occurs with an extruder press to 65-70% moisture content and then pulp is dried in 2 stages, a drum dryer to reduce the moisture content to around 30-40% followed by a flash dryer to 13% as final product.

Pulp drying is a recent activity²⁸. Prior to 2015 this generally did not occur as there was no demand for the product by animal feed companies. However nowadays, fueled by the rapid growth in the livestock sector (see chapter 2) pulp is dried and sold to animal feed companies. In other countries, i.e., Thailand pulp is also sold fresh to animal feed companies, which would save biogas which could be used to produce electricity. Inquiry into the potential of selling fresh pulp was not possible according to the factories interviewed, pulp spoils quickly and it can only be stored dried. Only in certain locations, pulp is sold fresh to small farms which use it directly as animal feed.

Electricity

Electricity consumption varies between 210 to 305 kWh/ton (table 41). Factories on the higher side typically are all located in areas for which discharge has to meet the A norm and thus more intensive

²⁸ Animal feed survey among 3 animal feed factories- JAPFA group, Marvin Austfeed, DaBACO animal feed production and 2 cassava starch factories Quang Nhαι Cassava company and Hoa Nhαι cassava company

treatment is required. This is the case in Tay Ninh, energy consumption is lower in Dak Lak where wastewater has to meet discharge norm B.

Table 41: Electricity consumption and costs in the visited factories

No	Factories	Capacity (ton starch /day)	Electricity consumption	electricity (kWh/day)	Electricity cost (VND/month)
1	Hung Duy	250	305 kWh/ton	76,250	4 billion
2	Lien Phuong	180	295 kWh/ton	53,100	2.5 – 3 billion
3	Hoa Nhai	200	330 kWh/ton	66,000	3.4 – 3.6 billion
4	Madrak Cassava	100	240 kWh/ton	24,000	< 1 billion
5	Ea Pal Cassava	150	170 kWh/ton for only production process 210 kWh/ton for all consumption (production, water and wastewater treatment,)	31,500	< 1 billion
6	DakLak Cassava	140	230 kWh/ton for only production process 260 kWh/ton for whole factories consumption	36,400	1 – 1.2 billion

5.3.3.2 Water consumption

The main use of water is process water during peeling, grinding and washing roots. Water consumption is around 10 to 18 m³/ton starch. Factories in Tay Ninh have the lowest water consumption, this is because discharge has to meet standard A and that water is sufficiently clean for reuse. In Dak lak on the other hand, water is not sufficiently clean for reuse, and this explains the higher water consumption.

Process wastewater is collected and treated in a number of steps. Typically, this consists of a collection tank, covered anaerobic lagoon, anoxic ponds and several aerobic ponds followed by flocculation steps and a sterilization pond.

5.3.4 Energy production – biogas recovery

Wastewater from the refining stage has a high concentration of organic pollutants from which biogas can be generated. Most cassava factories capture biogas by including an anaerobic stage in their wastewater treatment system. The Vietnam Cassava Association (VCA) estimates around 95% of the factories recover biogas.

Biogas digesters are fed with wastewater pumped from a storage pond. In that pond effluent from the factory is retained and mixed with wastewater from the previous days. In this pond first decomposition takes place, resulting in a drop in pH (due to acidification) and a reduction of COD. From the storage pond, the



Figure 31: Biogas plant of Hung Duy Tapioca Starch factory

waste is pumped into the biogas plant. In all the factories visited, the wastewater is not neutralized by adding sodium hydroxide. This may affect biogas productions as a low pH inhibits methanogenic activity. In Thailand neutralizing the pH is common practice (Wattanaslip & Khompatraporn, 2021). However, the actual need of neutralizing the wastewater may depend on the residence time in the pond, the longer the lower the pH will become. A follow up study should assess this.

Biogas plants of the visited factories are all one-stage HDPE covered anaerobic lagoons with full hydrological isolation without active mixing or temperature control. The hydraulic retention time of anaerobic treatment process at visited factories are reported high at 40 – 60 days. A typical plant cost around 10 billion VND/system (depend on the capacity), which is small amount compared to vast investment of setting up whole factory. In Thailand more advanced technologies such as upflow anaerobic sludge blanket (UASB) digesters in a two-stage configurations are more common. It can be expected that these types of digesters have a higher COD removal efficiency and better process stability.

Factories visited were unable to provide reliable estimates on COD-in and out. However, there are a number of Vietnamese cassavas CDM projects and one of the monitoring requirements for compliance with the applied methodology is to measure in COD-in and -out on an annual or more frequent basis. There are 6 projects that are verified for 1 or more monitoring periods. These tabulated in the table below:

Table 42: Studied CDM projects

CDM project	Capacity (ton/day)
VN08-WWS-05, Methane Recovery and Biogas Utilization Project, Quang Tri Province, Vietnam	200
VN08-WWS-03, Methane Recovery and Biogas Utilization Project, Yen Bai Province, Vietnam	200
AVN08-S-02, Methane Recovery and Biogas Utilization Project, Nghe An Province, Vietnam	200

AVN08-S-01, Methane Recovery and Biogas Utilization Project, Nghe An Province, Vietnam	200
Wastewater treatment with Anaerobic Digester at Truong Thinh starch processing plant in Tay Ninh, Vietnam.	112
Wastewater treatment with Anaerobic Digester at Viet Ma starch processing plant in Tay Ninh, Vietnam	110

Next to these projects there a great number which are registered but did not initiate monitoring. Of those plants accurate ex-post data is not available and therefore not used in the analysis. The averages of the monitored projects were analyzed and compared with the information obtained from the fields visits in the table below:

Figure 32: Wastewater characteristics

Item	Unit	Reported by factories	Review of CDM projects (13 monitoring reports)
COD-in	mg/l	9,000-15,000	17,740
COD-out	mg/l	500-1200	620
Biogas recovery	m ³ biogas/kgCOD	N/A	0.47
	m ³ biogas/m ³ waste water	N/A	8.03
Wastewater	m ³ /ton	10-18	N/A

The findings from the CDM project are in line with literature values in Thailand (Wattanaslip & Khompatraporn, 2021).

The COD in and out estimates of the factories are not used because of the following reasons

- COD-in data is not measured, and it is unclear how valid the data is as the value is likely only collected during the design stage of the biogas plant
- COD-out data, this is more regularly measured for environmental compliance purposes – however the COD value measure is taken at the last stage in the treatment system, not the effluent of the biogas plant.

The reviewed CDM project are required to measure COD-in and COD-out and are therefore considered more reliable. However, it is not reported how many tons of starch these factories process during the monitoring periods.

5.4 CASE STUDY: Hung Duy

The Hung Duy factory is located in Tay Ninh, a google satellite image of the factory:



Figure 33: Duy hung cassava factory (google maps)²⁹ 1= wastewater treatment system of new investment in producing modified starch, 2 = wastewater collect tank 3 = two parallel biogas plants, 4 = biogas plant effluent treatment (settlement tank, anoxic tanks, anaerobic treatment and sterilization tanks)

Hung Duy Group was established in 1994 with business focus on tapioca starch manufacturing with two factories: the 1st factory (250 ton/day) in Hoa Hoi Industrial Zone, Chau Thanh District, Tay Ninh Province; the 2nd Factory (250 t/day) in Ninh Dien Industrial Zone, Ninh Dien Commune, Chau Thanh District, Tay Ninh Province.

Hung Duy operates the factory 300 days around year, produce 250-ton starch per day and 60 tons dried fiber. The product is high quality and meets the requirements of the fastidious markets such as the United States, Japan, Europe. Product of company also achieved certificates of ISO 9001: 2008, ISO 14000, ISO 22000: 2005 and Halal certificate. In-progress certificates: High Quality Vietnamese Goods, Non-GMO, Kosher Certificate and FSSC 22000.

Table 43: The quality of Hung Duy tapioca product

No.	Specifications	Unit	Standard
1	Starch	%	≥ 85
2	Humidity	%	< 14
3	pH	%	5 – 7

²⁹ <https://goo.gl/maps/cECyU18bFCu9LGKT8>

4	Whiteness	%	90 – 96
5	Viscosity	cP	8000 – 14000
6	Smoothly	%	96 – 99
7	Impurities	%	≤ 0,2
8	SO2	mg/kg	≤ 2

Wastewater is reused in the system and sludge is composted and sold to farmers. The factory located on an area of 0.515 km² or around 0.73 * 1.45 kilometers³⁰. Hung Duy operates 10 months per year. Wastewater is treated in 2 HDPE covered anaerobic lagoon biogas plants connected in parallel with 60 days hydrological retention time. Biogas is exclusively used for drying starch and pulp.

More biogas is produced than consumed according to the company. The company is therefore exploring the potential of generating electricity from the excess biogas – the case study.

5.4.1 Biogas surplus

The company does not have data on the amount of excess biogas other than the observation that not all biogas is used. Therefore, it is not possible to accurately estimate the potential of using excess gas for electricity generation.

Nevertheless, an attempt was made to estimate excess biogas production through:

1. Determine potential biogas production by using the CDM project as a proxy for biogas recovery and COD-in and removal efficiency
2. Estimate heat required to dry starch and pulp

The difference between both (1-2) will yield an estimate on the amount of biogas not used and available for other purposes.

Table 44: Anaerobic digester performance data used in calculations

Item	Unit	Value	Source
Biogas recovery	m ³ biogas/kgCOD	0.47 ³¹	Based on 13 monitoring reports of 6 CDM projects
Methane concentration	%	67	
COD-in	%	17740	
COD-out	%	62	
COD removal efficiency	%	89	
Thermal oil boiler efficiency	%	77	Expert opinion

³⁰ Author's own measurements using Google maps

³¹ The maximum methane production is around 0.35 m³ methane/kgCOD (Frederiks, 2016), which is around 0.52 m³ biogas/kgCOD at 67% methane

Pulp dryer efficiency	%	77	Expert opinion
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The calorific value of biogas at a methane concentration of 67%³² is around 23 MJ, this is slightly higher than the value used in chapter 2. In chapter 2 the default value of 21 MJ/m³ was used, while in this chapter it was possible to use the measured methane content from the CDM projects.

In the next table the factory energy balance is calculated

Table 45: Factory energy balance

Source	GJ/day	Comment
Biogas production	501	Calculated based on the CDM project for COD-in and biogas recovery (77ffice77. 25,000 m ³ /day)
Starch drying	245 (220 to 275)	Calculated based on Mollier diagram ³³ with air of 30 ⁰ C 70% RH heated up to 150 ⁰ C and end up with air 51 ⁰ C relative humidity (RH) 60% Average and range based on 11 to 13% moisture content of the project.
Pulp drying	141	Calculated based on Mollier diagram with air of 30 ⁰ C 70% RH with 2 step of drying. In first step air is heated up to 400 ⁰ C and end up with air 70 ⁰ C RH 60%; in second step, air is heated up to 250 ⁰ C and end up with air of 60 ⁰ C RH 60%.
Surplus	46 (11 - 80)	The surplus depends on the moisture content of the starch product. The average value is used in the calculations

Surplus biogas is estimated at, on average, 46 GJ/day, which is roughly equivalent to 2,013 m³ biogas. The calculation shows that the energy required for pulp drying is quite high due to the initial moisture content of 65%. One of the key improvements possible is installing an improved mechanical drying to reduce the moisture content which reduce the energy requirements for drying. This could further increase the surplus of gas and therewith the power generation potential.

5.4.1.1 Generator sizing

The factory will likely have a 110 kV connection and pay the tariff of the manufacturing industry. The costs are depicted in the table below:

Table 46: Electricity tariff for manufacturing industries with 110 kV connection

	Period	Hours/day	Rate (VND/kWh)
Standard hours	Monday- Saturday 4 AM- 9:30 AM 11:30 AM – 5 PM	13 (18 on Sunday)	1536

³² Average methane concentration as reported in the cassava factory CDM monitoring reports

³³ The Mollier diagram is a graphic representation of the relationship between air temperature, moisture content and enthalpy - and is a basic design tool for building engineers and designers

	8 PM – 10 PM Sunday: 4 AM – 10 PM		
Peak hour	Monday- Saturday 9:30-11:30 5 PM – 8 PM	5	2759
Off-peak	10 PM – 4AM	6	970

It is assumed that the generation will run during standard and peak hours. In the next table the biogas gen-set capacity is calculated.

Table 47: Electricity gen-set size calculation

Item	Unit	Value	Comment
Running hours	h/day	16	16 hours generator running per day (Peak + normal hours)
Engine efficiency	%	35%	Typical for medium-scale generators
Power production	kWe	281	for 16 hours/day
Minimum installed capacity	kWe	402	calculated at 70% average load. This is a load gen-sets normally can sustain for a longer period

5.4.2 Investment analysis

5.4.2.1 Basic parameters

Table 41 shows the basic parameters used in the financial calculations.

Table 48: Basic parameters used for the financial calculation

Item	Unit	Value	Remark
Contingency rate	%	10	Assumption
Interest rate	%	12	Typical rate for business loans
Loan period	Year	10	Assumption
Discount rate	%	13.75	Reflecting the weighted cost of capital, assuming 75% debt-financing at 12% and 25% equity at 25% return on equity

Tax rate	%	N/A	N/A, calculated as EBIDTA
Operating days	day	300	Factory operates 10 months/year
Grid electricity tariff during electricity generation	VND	1864	Weighted average of 5 hours peak rate week + 11 hours normal rate for 6 days per week + 16 hours normal rate on Sunday. Medium voltage connection (22 kV to 110 kV)

Although project financing is to be decided by the project owner, in the analyses a loan of 75% of the project costs is included at the indicated interest rate of 12%, with a repayment period of 10 years.

5.4.2.2 Investment costs

The minimum installed capacity is 402 kW at 70% load. This is a load that biogas generators normally can sustain over longer period. In the investment 2 generator of 250 kW, totaling 500 kW are proposed. The average load is then 56%, which is advantageous for the lifespan of the generator. Two generators have an advantage over one, one generator can be maintained while the other is running and if one fails, the other generator can be used at a higher load or longer running period enabling the factory to convert all biogas into electricity. The main costs are based on supplier quotations. The investment costs are calculated below.

Table 49: Investment components

Item	Total	Lifetime (years)	OPEX	Comment
2 x 250 kW Prime Power Genset open type air cooled.	2 x \$35,500	10	\$0.02/kWh	Gen-set from China. Made of high-quality international brand components (Engine: Deutz/Cummings or equivalent) Alternator: Stamford, Leyroy-Somer or equivalent)
Biogas Scrubber (H2S / Moisture removal)	\$13,900.00	10	-	
Consumables (H2S filter material)	-	1000 hours	Consumables (H2S filter material)	Based on supplier estimate of 70 kW generator: 250 kg for 70kW installed capacity. 1 kg = 25,000 VND
Grid Sync Panel	\$5,800.00	15	nil	Estimate
Transport				
Sea freight China port to Hai Phong/HCMC	\$1,050	-	-	Estimate
Custom Clearance and transport to site	\$800	-	-	Estimate
Installation cost				
Civil works at site (concrete slab, simple shed for generator	\$1,200	20	nil	Estimate

Installation cost	\$7,100	-	-	Estimate
Sub-total	\$ 100,850	-	-	
Contingency unexpected cost	/ \$ 10,085	-	-	10%
Total (USD)	\$ 110,935			
Total (VND)	2.5 billion			1 USD = 23,000 VND

5.4.2.3 Revenues

It is assumed that the generator runs for around 16 hours per day and would produce 4.5 MWh/day. This amount is relatively small compared to the total demand of 76.125 MWh per day, just 6%.

In the next table the value of this is calculated:

Table 50: Estimated electricity cost savings

Item/year	Unit	Units (annual)	Unit price	Total savings
Grid electricity savings	MWh	1,135	1864	2.5 billion VND (\$109,389)

5.4.2.4 Cash flow analysis

Item/year	0	1	2	3	4	5	6	7	8	9	10
Equity	637,876										
Debt financing	1,913,629										
Short term financing											
Inflow from operators		2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347
Total inflow	2,551,505	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347	2,302,347
Increase current assets											
Operating costs		741,564	741,564	741,564	741,564	741,564	741,564	741,564	741,564	741,564	741,564
Corporate tax											
Interest payable		191363	172227	153090	133954	114818	95681	76545	57409	38273	19136
Loan repayment		191363	191363	191363	191363	191363	191363	191363	191363	191363	191363
Total outflow	-2,551,505	1,124,290	1,105,153	1,086,017	1,066,881	1,047,744	1,028,608	1,009,472	990,336	971,199	952,063
Net cash flow	-2,551,505	1,178,058	1,197,194	1,216,330	1,235,467	1,254,603	1,273,739	1,292,876	1,312,012	1,331,148	1,350,284
Cumulative	-2,551,505	-1,373,447	-176,253	1,040,077	2,275,544	3,530,147	4,803,886	6,096,762	7,408,774	8,739,922	10,090,206

The financial returns are calculated Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA). It shows a Levelized Cost of Electricity (LCOE) of 1142 VND/kWh, which is well below the normal and peak EVN tariff. The other indicators also show that the investment is attractive.

Table 51: Financial indicators

Item	Unit	Value
LCOE	VND/kWh	1142
IRR	%	53.6%
NPV	Billion VND	4.3
Simple pay-back period	Year	1.45

5.4.3 Additional scenario: CHP

A biogas gen-set generates electricity with around 35%, thus 65% of the energy, mostly heat, is lost. Utilizing this heat as thermal energy is possible in a combined heat and power (CHP) system. This would improve overall efficiency as next to generating electricity, heat can be used for the assist the drying processes. Consequently, the amount of energy required from the thermal oil boiler will reduce resulting in biogas savings. These savings could in turn be utilized in the CHP to generate even more electricity and heat. Given that the quality of flue gas is of sufficient quality for pulp drying, it is possible next to generating electricity and using cooling water for the drying processes, to use the thermal energy in the flue gas for drying pulp.

This scenario was studied, but the results are less reliable than the other scenario where biogas is used for electricity generation only. The reliability is less because:

- Heat recovery depends on the type of gas turbine, internal combustion engine (IGE) and its actual specification varies between each supplier.
- A detailed thermal energy audit is necessary to estimate the actual and precise demand for heat in the various processes
- Hung Duy indicated that actual production is higher than indicated – this should be confirmed in a follow up study.

A basic lay-out of a CHP scheme and the use of thermal energy, both flue gas and hot water is:

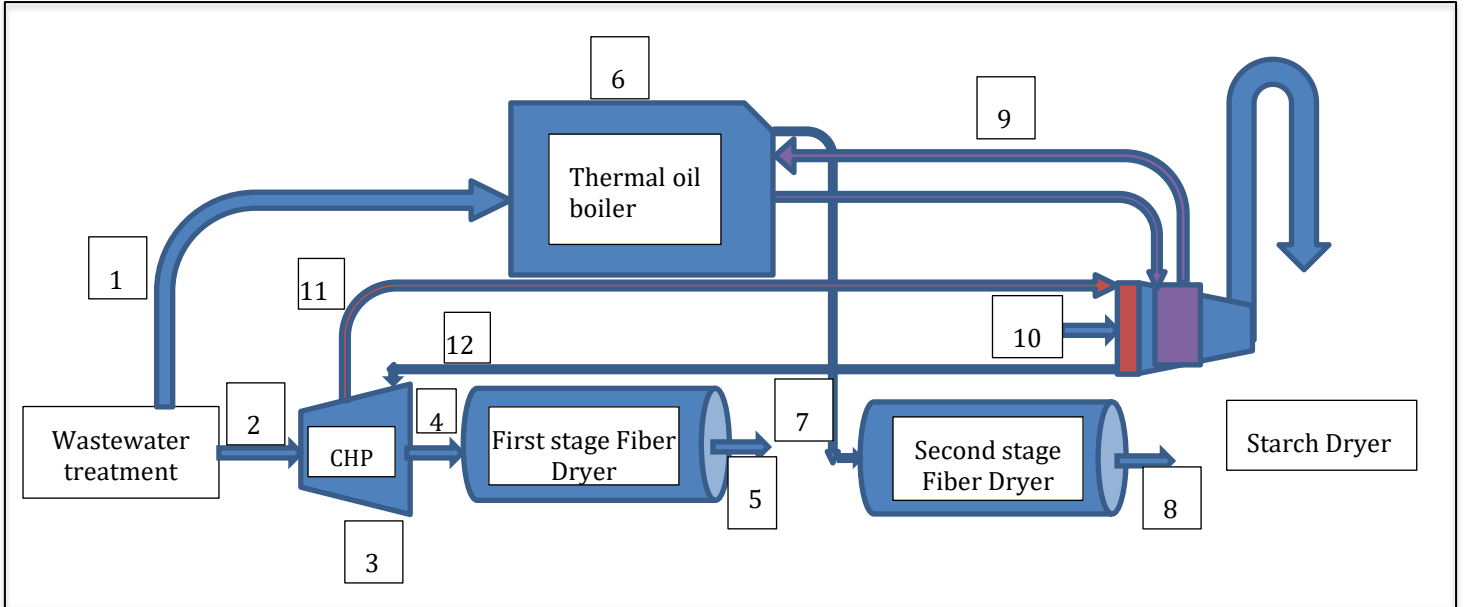


Figure 34: CHP system with heat recovery

The legend of the figure – including rough energy calculations

#	Description	GJ/day biogas
1.	Biogas consumption of the thermal oil boiler for drying:	197-312
2	Biogas going to CHP	111-260
3	CHP – Reciprocating Engine, 35% efficiency)	39-91
4	Energy in flue gas from CHP ~ 400°C	34-78
5	Flue gas from first fiber drying step 60°C and relative humidity (RH) 60%.	33-78
6	Thermal energy from biogas combustion transferred to thermal oil (79% efficiency)	156-247
7	Flue gas from thermal oil (200°C) could be recovered and introduced in the second fiber drying step	39-63
8	Flue gas from second stage fiber dryer 60°C and RH of 60%	39-63
9	Thermal oil going to starch dryer with temperature of 250°C and back with temperature of 220°C to supply heat for air.	156-247
10	Ambient air entering the starch drying is heated from 30 to 150 °C by the thermal oil, air departs at 51°C and 60%	-
11	Pre-heating of air entering the starch drying with engine cooling water with 90°C temperature	28-65

12	Recirculation of cooling water to the engine, 75°C	-
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5.4.4 Financial analysis

The same input parameters were used as with the first scenario (electricity generation only). The CAPEX and OPEX are however quite different.

- CAPEX is around \$627/kWe³⁴ for a gen-set in China, turnkey CAPEX is assumed
- OPEX: \$9/MWh³⁵

The financial returns are calculated Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) for a 10-year period:

Table 52: Financial indicators

Item	Unit	Value
LCOE	VND/kWh	1478
IRR	%	24.9
NPV	Billion VND	9.7
Simple pay-back period	Year	3.37

The LCOE is close to the average EVN price, and the IRR and other financial indicators show financial viability. However, due to the complexity of this system, more study is required on how to retrofit a CHP into the existing energy system

³⁴ Typical turnkey CHP in China: <https://www.oecd-nea.org/upload/docs/application/pdf/2019-12/7279-proj-costs-electricity-2015-es.pdf>

³⁵ OPEX from

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Overview_of_CHP_Technologies.pdf

5.4.5 Discussion and Conclusion

The case study showed that in situations with biogas surplus it is financially attractive to convert this into electricity, the LCOE is 1142 VND/kWh, the payback period is 1.45 year for an investment on 500 KW biogas generator for Hung Duy cassava factory. However, it should be stressed that the calculations are based on proxy data and not based on factory data. A follow-up study should therefore confirm the actual amount of excess biogas. Co-generation on the other hand, is also feasible, but required more study on how to retrofit this system

A challenge is the high heat demand of cassava factories in Vietnam. In Cambodia and Thailand this is much lower. In Thailand this is because pulp is not dried but sold fresh (Wattanaslip & Khompatraporn, 2021). This frees up biogas for electricity generation for captive use or grid feed-in, which is rather attractive at \$10.44/MWh³⁶. The situation is similar in Cambodia, where the electricity price (~\$18/MWh) is in the order of 2 to 3 times higher than in Vietnam. Electricity generation from biogas, instead of using it to dry pulp, is therefore more attractive. In a factory just across the border in Tay Ninh for example, 100,000-ton roots are annually, pulp is sun-dried and then sold as animal feed. All biogas is used for a steam boiler and in an electricity generator (Guascor, imported from Vietnam). Another 1 MW generator will be added to consume all the surplus biogas (Buthong, 2021).

The situation in Vietnam is different, electricity tariffs are comparatively low and the demand for pulp/fibers by animal feed factories is high. Thus, the most financially attractive option is using biogas for thermal energy to dry both starch and pulp.

5.5 Stakeholder commitment to bio-energy utilization

5.5.1 Forces of change for the utilization of bioenergy

Bioenergy is well utilized in this sub-sector, and this is a success story. The potential to utilize more bioenergy are therefore limited to factories with excess biogas. Anecdotal evidence is that larger factories have excess biogas at production capacity over 250 tons starch per day.

With technological advancement, i.e., two-stage biodigester systems, active stirring and advanced digester systems such as up-flow anaerobic sludge blanket (UASB) combined with production efficiency improvements could increase the number of factories with excess gas. Also in potential, increases in biogas production could be increased by omitting the intermediate storage – partially or completely – and feeding the digester directly with wastewater. An additional advantage could be that less sodium hydroxide (NaOH) would be required for neutralizing the pH of the wastewater before anaerobic treatment, as the fresh wastewater is substantially less acidic than the water coming from the storage lagoon (Frederiks, 2016).

Moreover, there are indications that biogas requirements for pulp drying can be reduced by improving mechanical drying of the pulp before the thermal drying stage. This could open up opportunities not only at Hung Duy to produce power and heat but also in other factories.

5.5.2 Leverage and stakeholder commitment

Most factories are standalone and the association focusses on the marketing of the products, not biogas recovery. However, working with APFCO, a company which owns over ten cassava factories or FOCOCEV with 11 factories could allow for better dissemination of knowledge and create leverage.

³⁶ https://www.eria.org/uploads/media/6_Distributed_Energy_System_in_Thailand.pdf

5.6 DISCUSSION and CONCLUSIONS

The market outlook for starch is generally favorable. However, disease risk and climate change and therefore input constraints remains significant threats. Also, in the mid to long term future it is expected that Cambodia will process cassava to starch which may lead to input constraints especially in the case of factories in the south of Vietnam. There is a need to develop a more coordinated approach to cassava value chain development to reduce disease risk and improve relations with farmers in Cambodia to secure supply.

Bioenergy, in the form of biogas, is well valorized in the cassava sector, albeit with relatively simple technologies, HDPE covered anaerobic lagoons which have a large footprint and are not the most efficient. Biogas is only used for heat and some factories continue to require supplemental fuel. Larger factories in the South (>250 ton/day capacity) appear to have a surplus, and electricity generation is financially attractive.

Pulp dryer however is a good source of income aided by the rapid developed in the livestock sector. As concluded in chapter 2, the reliance on imported feed is a weakness in the sector and using in-country resources a necessity. Thus, selling dried pulp as feed instead of energy production, is not only more financially attractive but will also reduce import requirements.

In some studies suggestions have been made to feed pulp to a stirred reactor, recover the energy and sell the dried effluent to animal feed factories (Frederiks, 2016). Biogas recovery will reduce the starch content but will likely leave dietary fibers intact. However, this requires a detailed assessment, not only the potential to recover biogas but also on the requirements that animal feed factories have.

Also, there are opportunities to reduce thermal energy requirements by introducing improved mechanical pulp dryers, this would enable ore factories to invest in (co-) generation.

Thus, in conclusion, bio-energy usage is common in the sector. Excess biogas has become less common due to the drying of pulp and where there is an excess, biogas to electricity generation is the most attractive option.

Chapter

05

Conclusion and discussion

6 Conclusion and recommendations

Three sub-sectors were studied, pig-pork, paper and pulp and cassava-starch. The sub-sectors are independent of each other but are also connected. Both pork and starch for example are key ingredients for the food processing sector, starch is also an ingredient used for paper processing and paper is used as packing material in all sub-sectors.

A significant number of pig-farms have biogas plants, but biogas usage is not common resulting in high GHG emissions. This study showed that power generation from biogas is financially attractive, but also that there are technical barriers preventing farmers from investing in power generation. ESCO models are being developed in this sector which could alleviate these technical barriers.

The paper and pulp sector is a rapid developing sector in terms of technology and scale. There are thousands of small manual paper production at craft villages in Vietnam, of which many have to relocate to industrial zones. This will create opportunities to introduce biomass based ESCO models.

Large mills rely predominantly on coal and a shift to biomass is challenging due to the requirement of having access to a long-term stable supply of biomass in terms of quantity, quality and price. Pulp mills on the other hand often have their own wood plantations necessary for pulp production. Residues from the plantation, such a bark, and twigs, can be used as boiler fuel.

Bio-energy usage in the cassava sector is a success story as fuel for drying starch and pulp. Limited biogas remains for power or CHP. However, there are indications that biogas could be saved with improved mechanical pulp dryers and utilizing heat from a CHP to assist in the thermal drying processes. A detailed follow up study is required to assess this, including how to increase process efficiency, and CHP opportunities.

None of the sub-sectors have CSR policies aiming to reduce GHG emissions. The main motivator to utilize bioenergy is cost, quality and reliable supply. Only certain multinational companies, purchasers (i.e. H&M in the garment industry), or FDI companies such as Heineken, or international ESCO companies such as TSSP, demand or only supply bio-energy.

8 Bibliography

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9 Annex I - Interviews held

No	Stakeholders	Respondent	Title	Methodology	Subsector
1	DLP – MARD	Dr. Tong Xuan Chinh	Deputy Director	Face to face (DLP office)	Livestock
2	VPPA	Dr. Dang Van Son	Vice Chairman, Secretary General	Face to face (VPPA office)	Pulp and paper
		Mr. Le Huy Du	Chief Officer		
3	Vietnam Paper Corporation (VINAPACO)	Mr. Ngo Tien Luan	Head of Technical Department	Visiting factory and interview	Pulp and paper
		Mr. Ha Duy Dang	Electrical Technician		
4	Hau Bi Farm (3600 pigs)	Mr. Vinh	Farm owner	Visiting farm and interview	Livestock
5	Thanh Phat Farm (4000 pig)	Mr. Nguyen Van Ly	Farm owner	Visiting farm and interview	Livestock
6	Mr. Tue – Mr. Mui farm (3000 pig)	Mr. Nguyen Ngoc Nghiep	Farm owner	Visiting farm and interview	Livestock
7	Dai Tu Farm (5500 pig) – Thai Nguyen	Mr. Thinh	Farm owner	Phone interview	Livestock
8	Vietnam Food Science and Technology Association	Prof. Dr. Ngo Tien Hien	President	Face to face (SNV office)	Food/Casava
		Dr. Nguyen Manh Dung	Deputy Secretary General		
9	Vietnam Cassava Association (VICAAS)	Mr. Nguyen Hung Manh	Deputy Chief of Head Office	Face to face (VICAAS office)	Cassava

10	DOIT Bắc Ninh	Mr. Nguyen Van Binh Mr. Nguyen Hoang Phuong Mr. Nguyen Viet Duc	Local government	Face to face	Pulp and paper
11	Việt Pháp Paper Company (Phong Khe, Bac Ninh city)	Mr. Phap	Boiler operator	Visiting factory and interview	Pulp and paper
12	Việt – Mỹ Paper Production and Trade Company (Phu Lam Industrial Zone)	Mr. Tam	Technical Manager	Visiting factory and interview	Pulp and paper
13	Huong Que cooperative farm – Hien Van – Tien Du, Bac Ninh	Mr. Thang	Farm owner	Visiting farm and interview	Livestock
14	Biomass fuel production and trade	Mr. Bao	Wood pellet Producer and Trader	Face to face	Biomass value chain
15	DOIT Bình Dương	Mr. Nguyen Thanh Toan – Director Mr. Tran Trung Hieu Mr. Dang Hoa Phong Mr. Nguyen Thanh Long	Local government	Face to face (DOIT Binh Duong office)	Pulp and paper
16	Dong Tien Company	Mr. Tien	Deputy Director	Visiting factory and interview	Pulp and paper
17	Vina Kraft Paper Company	Mr. Dao Trong Tam	Chief of Steam and Power Department	Visiting factory and interview	Pulp and paper

18	Tay Ninh DOIT	Mr. Doi – DOIT Deputy Director Ms. Hang Mr. Nguyen Huyen Cuong Mr. Nguyen Khac Cuong Mr. Nguyen Thanh San Mr. Nguyen The Phuong Ms. Phuong	Local government	Face to face (DOIT Tay Ninh office)	Cassava
19	Hung Duy Tapioca Starch Factory	Mr. Trung	Environmental Officer	Visiting factory and interview	Cassava
20	Lien Phuong Cassava Factory	Mr. Nguyen Thanh Tam	Factory Manager	Visiting factory and interview	Cassava
21	Hoa Nhai Cassava Factory	Mr. Nguyen Chi Minh	Factory Manager	Visiting factory and interview	Cassava
22	M’Drak Cassava Factory	Mr. Duong	Deputy Director	Visiting factory and interview	Cassava
23	Ea Pal Cassava Factory	Mr. Tuan	Technical Manager	Visiting factory and interview	Cassava
24	Dak Lak Cassava Factory	Mr. Son	Director	Visiting factory and interview	Cassava
25	BLH Agro-food processing Son La, 300 ton/day	Ms. Nhung	Deputy director	Phone interview	Cassava production and exporting company

26	Dragon Food (4 factories, 1 in Nghe An, 1 in Son La @ 320 ton/day; 2 factories in Lao 200 ton/day)	Mr. Hoang	Deputy director	Phone interview	Cassava production and exporting company
	UNDP Cambodia on Cassava policy		UNDP economist	Phone interview	Cambodia cassava policy
27	31 May	TPSC	Technical Team based in Japan and Ms. Le Mai Chi (Hanoi)	Project Coordinator	online interview ESCO company
28	– 2 June	Kim Truong Phuc	Mr. Tuan	Technical manager	Phone interview ESCO company
29	2021	Huynh Dang	Mr. Quoc	Director	Phone interview Boiler and ESCO company
30		MARTECH	Mr. Kim	Business Department	Phone interview Boiler and ESCO company
31		Thuan Hai Company	Mr. Nghia	Business Department	Phone interview ESCO company
32		Tri Viet/ APOLYTECH	Mr. Nga	Technical Manager	Phone interview Boiler and ESCO company
33	5- Jun- 21	JAPFA Group	Ms. Chau	Communication Officer	Phone interview Animal Feed company
34		Mavin Austfeed	Representative	Feed Department	Phone interview Animal Feed company

35	DABACO animal feed production	Mr. Cuong	Material Department	Phone interview	Animal Feed company
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10 Annex II: Cash flow ENESCO, MATRECH and PPEC1 CHP

ENESCO CHP

Cash flow analysis

	0	1	2	3	4	5	6	7	8	9	10
Equity	4,704,348										
Debt financing	18,817,391										
Short term financing											
Electricity savings	<u>7,322,829</u>	7,322,829	7,322,829	7,322,829	7,322,829	7,322,829	7,322,829	7,322,829	7,322,829	7,322,829	7,322,829
Steam savings	12,995,339	12,995,339	12,995,339	12,995,339	12,995,339	12,995,339	12,995,339	12,995,339	12,995,339	12,995,339	12,995,339
Total inflow	23,521,739	20,318,168	20,318,168	20,318,168	20,318,168	20,318,168	20,318,168	20,318,168	20,318,168	20,318,168	20,318,168
increased fixed assets	23,521,739										
Increase current assets											
Operating costs	8,696,843	8,696,843	8,696,843	8,696,843	8,696,843	8,696,843	8,696,843	8,696,843	8,696,843	8,696,843	8,696,843
Corporate tax											
Interest payable	9	188173	5	169356	1	150539	7	131721	3	112904	
							940870	752696	564522	376348	188174

		188173	188173	188173	188173	188173	188173	188173	188173	188173	188173
		9	9	9	9	9	9	9	9	9	9
Loan repayment											
Total outflow	-23,521,739	12,460,321	12,272,147	12,083,973	11,895,799	11,707,625	11,519,451	11,331,278	11,143,104	10,954,930	10,766,756
Net cash flow	-23,521,739	7,857,847	8,046,021	8,234,195	8,422,369	8,610,543	8,798,717	8,986,891	9,175,065	9,363,238	9,551,412
Cumulative	-23,521,739	-15,663,892	-7,617,871	616,324	9,038,693	17,649,236	26,447,952	35,434,843	44,609,907	53,973,146	63,524,558

MATREC CHP

Cash flow
analysis

	0	1	2	3	4	5	6	7	8	9	10
Equity	10,800,000										
Debt financing	25,200,000										
Short term financing											
Electricity savings		7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829
		12995339	12995339	12995339	12995339	12995339	12995339	12995339	12995339	12995339	12995339
Total inflow	36000000	20318168	20318168	20318168	20318168	20318168	20318168	20318168	20318168	20318168	20318168
increased fixed assets	36000000										
Increase current assets											
Operating costs		8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886
Corporate tax											
Interest payable		2,520,000	2,268,000	2,016,000	1,764,000	1,512,000	1,260,000	1,008,000	756,000	504,000	252000
Loan repayment		2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2520000
Total outflow	36000000	13998886	13746886	13494886	13242886	12990886	12738886	12486886	12234886	11982886	11730886
Net cash flow	(36,000,000)	6,319,282	6,571,282	6,823,282	7,075,282	7,327,282	7,579,282	7,831,282	8,083,282	8,335,282	8,587,282
Cumulative	-36000000	-29680718	-23109436	-16286154	-9210872	-1883590	5695691	13526973	21610255	29945537	38532819

PECC1 CHP

Cash flow analysis

	0	1	2	3	4	5	6	7	8	9
Equity	13,406,315									
Debt financing	31,281,401									
Short term financing										
Electricity savings		7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829
		12886957	12886957	12886957	12886957	12886957	12886957	12886957	12886957	12886957
Total inflow	44687715	20209786	20209786	20209786	20209786	20209786	20209786	20209786	20209786	20209786
increased fixed assets										
Increase current assets										
Operating costs		9,279,413	9,279,413	9,279,413	9,279,413	9,279,413	9,279,413	9,279,413	9,279,413	9,279,413
Corporate tax										
Interest payable		3,128,140	2,815,326	2,502,512	2,189,698	1,876,884	1,564,070	1,251,256	938,442	625,628
Loan repayment		3,128,140	3,128,140	3,128,140	3,128,140	3,128,140	3,128,140	3,128,140	3,128,140	3,128,140
Total outflow	44687715	15535693	15222879	14910065	14597251	14284437	13971623	13658809	13345995	13033181
Net cash flow	(44,687,715)	4,674,092	4,986,906	5,299,720	5,612,534	5,925,348	6,238,162	6,550,976	6,863,790	7,176,604
Cumulative	-44687715	-40013623	-35026716	-29726996	-24114462	-18189113	-11950951	-5399974	1463816	8640421

Thermax CHP

Cash flow analysis	0	1	2	3	4	5	6	7	8	9	10
Equity	10,800,000										
Debt financing	25,200,000										
Short term financing											
Electricity savings		7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829	7322829
		1299533	1299533	1299533	1299533	1299533	1299533	1299533	1299533	1299533	1299533
		9	9	9	9	9	9	9	9	9	9
Total inflow	36000000	2031816	2031816	2031816	2031816	2031816	2031816	2031816	2031816	2031816	2031816
increased fixed assets	36000000										
Increase current assets											
Operating costs		8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886	8,958,886
Corporate tax											
Interest payable		2,520,000	2,268,000	2,016,000	1,764,000	1,512,000	1,260,000	1,008,000	756,000	504,000	252000
Loan repayment		2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2,520,000	2520000
Total outflow	36000000	1399888	1374688	1349488	1324288	1299088	1273888	1248688	1223488	1198288	1173088
Net cash flow	(36,000,000)	6,319,282	6,571,282	6,823,282	7,075,282	7,327,282	7,579,282	7,831,282	8,083,282	8,335,282	8,587,282
		-	-	-				1352697	2161025	2994553	3853281
Cumulative	-36000000	29680718	23109436	16286154	-9210872	-1883590	5695691	3	5	7	9

Sub-sectors analysis to utilize bioenergy for electricity and heat generation

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