



# Development of biomass fuel chains in Vietnam

Arvo Leinonen | Nguyen Duc Cuong



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Arvo Leinonen

VTT

Nguyen Duc Cuong

Vietnamese Institute of Energy (IE)



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VTT  
PB 1000 (Teknikvägen 4 A, Esbo)  
FI-02044 VTT  
Tfn +358 20 722 111, telefax +358 20 722 7001

VTT Technical Research Centre of Finland  
P.O. Box 1000 (Tekniikantie 4 A, Espoo)  
FI-02044 VTT, Finland  
Tel. +358 20 722 111, fax + 358 20 722 7001

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## Development of biomass fuel chains in Vietnam

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### Abstract

The project 'Development and demonstration of multi-fuel supply chains for power plants and industrial boilers in Vietnam is a part of The Energy and Environment Partnership Programme in the Mekong Region (EEP Mekong). The project was carried out by the Institute of Energy (IE) from Vietnam together with Technical Research Centre of Finland (VTT) during 2011–2012.

The main objective of the project was to develop and demonstrate the effective and reliable biomass supply chain based on multi-fuel for the CHP plants and industrial boilers. The current supply technologies and costs were analysed in the beginning of the project in Vietnam. Five theoretical development studies, based on this analysis, were made to develop biomass supply chains. Three of the case studies were selected for practical demonstrations.

According to the data of 2010 of the EEP multi-biomass project, the total main solid biomass potential for energy production in Vietnam was about 104.4 million tons (374 TWh). A lot of biomass is utilised for energy and other purposes at the moment. The total surplus of biomass is 22.8 million tons. The share of agro-biomass of the surplus was 82%, the rest (18%) being wood fuel. The main biomass fuel resources are paddy straw, rice husk, maize trash, coconut shells, bagasse and wood residues.

In 2005, the total biomass used for energy production was 583.3 PJ (162.0 TWh) of which 366.3 PJ (101.8 TWh) was wood fuel (63%) and the remaining 217.0 PJ (60.3 TWh) different agro-biomass residues. Household sector accounted for 75.8% of the total biomass consumption. The remaining 24.2% was consumed by small industries in heat production and by sugar mills in their CHP plants. The share of biomass (583.3 PJ) from the total primary energy consumption in 2005 (2 182 PJ) was 27% which is a very high figure. The share of biomass of the total energy consumption has decreased during the last years because of the total energy consumption has increased rapidly during the last years.

At the moment biomass is economical in Vietnam in heat production of industrial companies. At the moment there is only one very small rice husk power plant in operation in Vietnam. There are many other power plants that are under developments phase in different parts of Vietnam. The main barriers for biomass plant investments are the low electricity price and lack of reliable biomass supply chains to the user.

Rice husk and bagasse are the most important biomass fuels in Vietnam. Rice husk is transported currently by boats (15 tons) to brick producers and other consumers. The loading of rice husk at rice mill and unloading of it at a power plant is normally carried out manually. The price of rice husk at power plant is 350–450 VND/kg (3.4–4.4 €/MWh). The rice husk price is increasing in Vietnam.

The new supply technologies developed in the case studies were demonstrated in three cases in Mekong River Delta region. In the demonstration of 'New effective biomass supply system' it was possible to decrease biomass supply costs by 15% using bigger boats (25 ton) and pneumatic unloading device. In the supply chain the unloading costs of the pneumatic device were 73% lower than those of manual unloading.

The objective of the demonstration of 'Multi biomass fuel supply and combustion in power plant' was to evaluate the extension of the operating time of CHP plants in sugar mills for year-round by using surplus bagasse with rice husk as a fuel. There were no problems in blending of bagasse and rice husk, or in combustion of them in the CHP boiler. Burning of rice husk together with bagasse for electricity generation during summer time at sugar mill is profitable if the price of rice husk is not too high.

The objective of the demonstration of 'Biomass pellet production and use in industrial boilers' was to investigate technology and economy of using biomass pellets in industrial boilers, in order to replace the utilization of fossil fuel (e.g. coal and oil). Production costs of bagasse pellets were the cheapest, 372 VND/kWh (13.0 €/MWh). The conclusion from the demonstration was that it is economical and technically feasible to use of pellets in industrial boilers. The fuel costs in steam production with the bagasse pellets would be about 40% lower than using traditional firewood.

**Keywords** Biomass , supply, development, Vietnam

## Preface

The project 'Development and demonstration of multi-fuel supply chain for power plants and industrial boilers in Vietnam' was a part of The Energy and Environment Partnership Programme in the Mekong Region (EEP Mekong). The programme is carried out during 2009–2012 and is funded by the Ministry for Foreign Affairs of Finland and the Nordic Development Fund. The main objective of the project was to develop and demonstrate the effective and reliable biomass supply chain based on multi fuels for CHP plants and industrial boilers.

The four main tasks of the project are 'Analysis of the current biomass supply technology' (1), 'Development and demonstration of biomass briquetting technology' (2), 'Case studies of new biomass supply technologies' (3) and 'Demonstration of the new supply technologies in practice' (4).

The project was carried out by the Vietnamese Institute of Energy (IE), and Technical Research Centre of Finland (VTT) during 2011–2012. IE was the leader organization of the project. VTT's role was to act as a partner in the project. The project has been carried out together with Mr. Nguyen Duc Cuong from IE and Dr. Arvo Leinonen from VTT. Mr. Nguyen Duc Cuong from IE has been the project leader.

The project has been carried out in close contact with the Vietnamese companies. Information on the current supply technology has been gathered with visits to rice mill, sugar mill, rice husk power plant, sawmills and wood processing plant and brick factories in Vietnam. Demonstration of the new technologies was also made in close contact with biomass companies.

We would like to thank all the company representatives for their kindness to make the project implementation possible. We will also thank Project manager Truong Dinh Hai from Dinh Hai Cogen Stock Company, Director Nguyen Thanh Son from Bentre Sugar Joint Stock Company, Director Cu Van Thanh from Luong Quoi Private Enterprise and Owner Nam Thanh Nga from Nam Nga for cooperation in the project. We would also like to thank the representatives of wood processing companies in Lien Ha commune in Hanoi city and Nam Vang and Hiep Luca brick and ceramics companies in Thuan Thoi commune in Mekong River Delta region and coffee processing companies in Central Highlands.

Arvo Leinonen and Nguyen Duc Cuong

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Appendix 1: Experiences of biomass production and supply in other countries

# 1. Introduction

*The biomass resources of Vietnam are large.* The highest biomass sources for energy production in Vietnam are crop residues and wood fuel. The crop residues can be classified in two categories – agricultural by-products (rice straw, corn leaves and cobs etc.) and agro-industrial by-products (rice husk, bagasse, peanut shells, coffee husks etc.). The total biomass production output in Vietnam in 2010 was about 104.4 million tons (374 TWh or 1 346 PJ) (Tran 2009). The main crop residue sources include paddy straw (37.6 million tons), rice husks (7.5 million tons), maize trash (15.0 million tons) and bagasse (7.2 million tons). The annual wood fuel potential is also high (31.7 million tons).

A lot of biomass is used for energy in Vietnam. The use of biomass fuels was 583 PJ (162 TWh) in 2005. The share of biomass fuels was 27% from the total primary energy consumption in 2005. Biomass is mainly used in households (76%), and the rest (24%) is used in small industrial boilers and CHP plants in sugar mills. The main energy consumption potential in Vietnam is in municipal and industrial co-generation power plants (CHP) in steam, heat and power generation. *One of the main problems of combined heat and power (CHP) plant investors* is the reliable delivery of biomass fuel all year round. The main reasons for this include: the seasonal production of biomass, many small, scattered biomass owners and undeveloped biomass production, collection and transport system.

*The main objective of the project was to develop and demonstrate* the effective and reliable biomass supply chain, based on multi-fuels for the CHP plants and industrial boilers. The project was divided into the six tasks. First in the project the current supply technologies and supply costs were analysed in Vietnam. The biomass briquetting technology was developed in the second task in order to intensify biomass transport. In the third task the new supply technology was studied theoretically in the case studies. In the fourth task the new technologies were demonstrated in practice, and in the fifth task the results of the project were disseminated. The sixth task consists of the project results reporting.

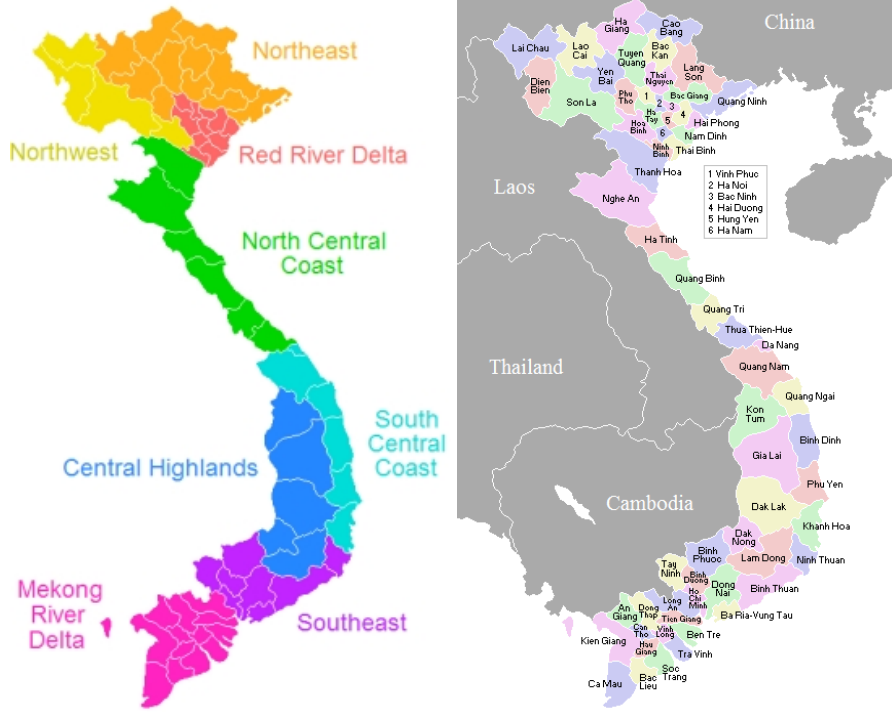
*The analysis of the current biomass supply technologies and supply costs* was made by visits to rice mill, sugar mill, rice husk power plant, sawmills and wood processing plant, and brick factories in Vietnam. The first trip was made in March 2011 to Mekong river delta region. During this trip the visits were made to Nam Nga rice mill, Ding Hai rice husk power plant, Ben Tre sugar mill and coconut processing plant (Fig. 1). The second visit was made in June 2011. During the sec-

ond trip visits were made to sawmill in Hanoi City, and to brick and ceramics production factories in Vinh Long province in Mekong Delta region. Information on the current biomass supply system and development needs were gathered during the visits. The results of the visits have been presented in this report.

*The target of the case studies* was to assess theoretically the potential to develop five new biomass supply technologies. The case studies for the study were selected on the basis on the results of the first phase. The analysis of the case studies covered technology and economical assessment. The case studies in task three were: New biomass transport system (1), Multi biomass fuel supply and combustion in power plant (2), Biomass pellet production and use in industrial boilers (3), Purchasing contract between biomass seller and buyer (4) and Buffer storing system for reliable biomass supply (5). Feasibility studies are based on the Finnish and Thai experience.

*Three most important case studies were selected for the demonstration* in the field. The first one was 'New biomass transport system and it was demonstrated together with Dinh Hai Cogen Stock Company. The second one was 'Multi biomass fuel supply and combustion in power plant', and it was demonstrated together with Ben Tre sugar mill. The third case study was 'Biomass pellet production and use in industrial boilers' and it was made together with the Chin Thi candy company. The target of the demonstrations was to assess theoretically the potential develop of five new biomass supply technologies. The target was also to verify the results of case studies made in task three in practice.

# 1. Introduction



**Figure 1.** Map of regions and provinces in Vietnam.

## 2. Biomass fuels in Vietnam

### 2.1 Description of biomass fuels in Vietnam

Biomass is organic matter available on a renewable basis. Biomass includes crop and wood residues, firewood and different kinds of waste biomasses. In this report the main focus is in agricultural and wood residue biomass. The crop residues can be classified into agricultural residues and agro-industry residues. The agricultural residues consist of rice straw, corn leaves and cobs etc. Agro-industrial by-products consist of rice husk, bagasse, peanut shells and coffee husks etc. The wood residues consist of sawdust, wood chips and bark. There is also a lot of firewood available.

The main biomass potential fuels in Vietnam are paddy straw, rice husk, maize husk, bagasse and coconut shells. Forest industry residues have also large potential.

*Paddy straw* (Fig. 2, Table 1) makes up about half of the yield of paddy. The outermost layer of the paddy grain is the *rice husk* (Fig. 4), also called rice hull. It is separated from the brown rice in rice milling.

*Maize trash* consists of the leaves and stalks of maize plants left in a field after harvest. Maize trash makes up about two and a half times the yield of a maize. *Maize husk* refers to the leafy outer covering of an ear of maize as it grows on the plant. *Corn cob* is the core of an ear of maize, to which kernels are attached.

*Bagasse* (Fig. 3) is the fibrous matter that remains after sugarcane are crushed to extract their juice. *Cane trash* consists of leafy leftovers of the sugarcane harvest.

*Coconut* fruit has three layers as other fruits – exocarp, mesocarp and endocarp (Fig. 5). The exocarp is the thin outermost layer (or skin) of the fruit. The mesocarp is a thick husk composed of coarse brown fibers (coir). The endocarp (shell) is the hard, but relatively thin woody inner layer of a fruit that contains the endosperm. The endosperm is partly solid (fibrous white coconut ‘meat’, which adheres to the inner wall of the endocarp) and partly liquid (coconut water).

*Wood fuel* consists of sawdust, bark and wood chips. *Sawdust* is a by-product of cutting timber with a saw, composed of fine particles of wood. Wood chips are also a by-product of forest industry. *Wood chips* are made from logs not suitable for further processing. Firewood is any wood-like material that is gathered and used for fuel in small fireplaces.

## 2. Biomass fuels in Vietnam

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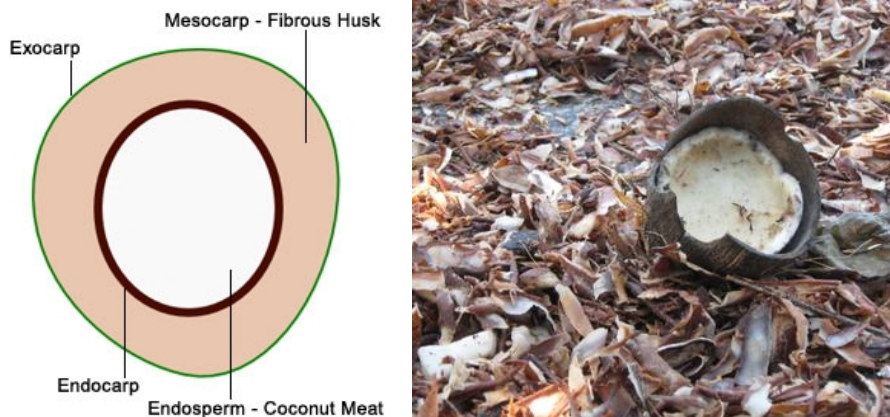
**Figure 2.** Straw left on the rice field after paddy harvesting (Photo by Arvo Leinonen).



**Figure 3.** Bagasse storage in Ben Tre Sugar -company (Photo by Arvo Leinonen).



**Figure 4.** Rice husk (Photo by Arvo Leinonen).



**Figure 5.** Coconut layers in Figure 5a (Anon. 2013) and coconut shell and 'meat' layer in Figure 5b (Photo by Arvo Leinonen).

**Table 1.** Residue to crop ratio of some crops (Tran 2011).

Residue/crop	Ratio
Paddy straw/Paddy	1.0
Rice husk/paddy	0.2
Bagasse/Sugar cane	0.3
Cane trash/Sugar cane	0.1
Maize trash/Maize	2.5
Cassava stem/Cassava	0.3
Peanut shell/Peanut	0.3
Coffee husk/Coffee bean	0.4
Coconut shell/Coconut fruit	0.15

## 2.2 Fuel properties of biomass fuels

The calorific value of woody biomass is higher compared to the agricultural biomass. The calorific value of dry wood ( $Q_{net,d}$ ) is about 5.3 kWh/kg (19.0 MJ/kg). From the agricultural biomass the calorific value ( $Q_{net,d}$ ) of rice husk and straw is lower (12.6–14.6 MJ/kg) than the calorific value of the other agricultural biomass fuels like bagasse, coffee husk and coconut shell (15.5–17.8 MJ/kg). The main reason for lower calorific value of rice straw and rice husk is the higher ash content (15–25%) compared to other agricultural biomass fuels (1–8.0%) (Table 2). The ash content wood biomass is low, 0.5–2.0%.

The moisture content while using biomass as a fuel is 40–55wt-% with bagasse and wood fuels. With other biomass fuels it is between 10–20wt-%. That is why the calorific value of bagasse and wood fuels ‘as received’ ( $Q_{net,as}$ ) is low being 2.1 kWh/kg (7.5 MJ/kg) compared to agricultural biomass fuels, 3.0–4.7 kWh/kg (10.8–16.9 MJ/kg).

With pelletizing it is possible to increase the calorific value of wet biomass fuels like wood and bagasse. In pelletizing process the biomass is dried up to 13wt-%. The calorific value of wood pellets ‘as received’ ( $Q_{net,as}$ ) is 3.9–4.9 kWh/kg (14.0–17.6 MJ/kg).



**Table 2.** Fuel properties of Vietnamese biomass. <sup>1</sup>Garivait et al. 2006, <sup>2</sup>Kargbo 2010, <sup>3</sup>Saenger et al. 2001, <sup>4</sup>Rice knowledge bank 2013, <sup>5</sup>Youshmione Co. LTd. 2013, <sup>6</sup>Vu et al. 2012, <sup>7</sup>DST Technology 2013, <sup>8</sup>ECN 2013, <sup>9</sup>Biomass energy foundation 2013, <sup>10</sup>Arrombee et al. 2011, <sup>11</sup>Ioannidou et al. 2008 and <sup>12</sup>Alakangas 2000.  $Q_{gr,d}$  is the gross calorific value of dry matter.  $Q_{net,d}$  is the net calorific value of dry matter.  $Q_{net,ar}$  is the net heating value of wet matter. 1 kWh is 3.6 MJ.

Fuel type	Moisture content % on wet basis	Ash content % on dry matter weight	$Q_{gr,d}$ kWh/kg (MJ/kg)	$Q_{net,d}^8$ kWh/kg (MJ/kg)	$Q_{net,ar}$ kWh/kg (MJ/kg)	Bulk density, wet (kg/loose-m <sup>3</sup> )
Paddy straw <sup>1,2,3,4</sup>	12–22	15–25	4.3 (15.3)	4.1 (14.6)	3.0–3.5 (10.9–12.6)	75 loose 100–180 baled
Rice husk <sup>1,2,4,5</sup>	8–12	17–26	4.9 (17.5)	3.5–3.7 (12.6–13.4)	3.0–3.4 (10.8–12.1)	70–110 loose
Bagasse <sup>6</sup>	50	1–4	4.4 (15.7)	4.3 (15.5)	2.1 (7.5)	120
Coconut shells <sup>3,7</sup>	10–20	4–5		4.6 (16.7)	4.1–4.7 (14.8–16.9)	
Coconut husks <sup>9</sup>	5–9	6		4.6 (16.7)	4.2–4.4 (12.9–14.8)	
Coffee husk <sup>3,8</sup>	10–12	1–4	4.5–5.1 (16.1–18.2)	4.9 (17.8)	4.3–4.4 (15.4–15.8)	185–300
Maize residues <sup>10</sup>	6–8	3–8		5.1 (18.2)	4.6–4.7 (15.0–15.5)	
Peanut shell <sup>11</sup>	9	5,7		5.1 (18,3)	4.6 (16.4)	
Forest chips <sup>12</sup>	40–55	0.5-2.0		5.1-5.6 (18.5–20.0)	1.9–3.1 (7.0–11.0)	250–350
Sawdust <sup>12</sup>	50–55	0.4-1.1		5.2–5.3 (18.9–19.2)	2.0–2.3 (7.2–8.4)	250–300
Wood pellets <sup>12</sup>	8–10	0.3-0.5		4.4–5.3 (15.8–19.2)	3.9–4.9 (14.0 -17.5)	640–690
Firewood <sup>12</sup> – Pine, spruce- and birch	20	1,2		5.1-5. (18.3-20.0)	4.1 (14.8)	240–320

## **3. Biomass fuel potential in Vietnam**

### **3.1 Total biomass production in Vietnam**

The total main solid biomass fuel potential of Vietnam is about 104.4 million tons in 2010 (Table 3), corresponding to about 1 346 PJ (374 TWh) of energy production potential every year. This is about 50 % of the total energy consumption (2 682 PJ or 745 TWh) in Vietnam in 2009 (IEA 2011).

The main biomass fuel resources are paddy straw (32.1% from the total potential), firewood fuel (30.3%), maize trash (18.5%), rice husk (6.6%) and bagasse (4.0%). Also there are available small amount of other biomass resources like cane trash (2.8%), cassava stem (2.6%), peanut shell (0.2%), coconut shell (0.1%) and coffee husk 0.5% (Table 3) (Tran 2011). All together agro-biomass residue potential was 72.7 million tons (69.6%) and the wood fuels was 31.7 million tons (30.4%).

**Table 3.** Total main solid biomass potential in Vietnam in 2010 (Tran 2011). 1 TWh is 3.6 PJ.

	Type of biomass	Potential in 2010 (wet) mill tons	Energy content (as received) kWh/kg (MJ/kg)	Potential in 2010 (as received) TWh (PJ)	Share % (TWh)
1	Rice husk	7.52	3.3 (11.9)	24.8(89.3)	6.6
2	Rice straw	37.57	3.2 (11.5)	120.2 (432.8)	32.1
3	Bagasse	7.20	1.8 (6.5)	15.1 (54.4)	4.0
4	Cane trash	2.40	4.2 (15.1)	10.3 (37.2)	2.8
5	Maize trash	15.00	4.6 (16.6)	69.0 (248.4)	18.5
6	Cassava stem	2.28	4.2 (15.1)	9.6 (34.5)	2.6
7	Peanut shell	0.18	5.1 (18.4)	0.8 (3.0)	0.2
8	Coffee husk	0.40	4.3 (15.5)	1.7 (6.2)	0.5
9	Coconut shell	0.14	4.4 (15.8)	0.6 (2.2)	0.1
10	Firewood	27.60	4.1 (14.8)	113.2 (407.4)	30.3
11	Wood residues from sawmills	4.08	2.1 (7.6)	8.6 (30.8)	2.3
	<b>Total</b>	<b>104.37</b>		<b>373.9 (1 346.2)</b>	<b>100</b>

### Rice Straw

In 2010 paddy production was about 38 million tons in 2010. The main biomass source for fuel in Vietnam is paddy straw (433 PJ). The largest paddy cultivation area is Mekong River Delta contributing 54 % of paddy straw and rice husk production in Vietnam. The residues of paddy harvesting are paddy straw and stubbles. Normally paddy stubbles are left on the field. Only paddy straw is harvested for different use. In average it is possible to get one ton of straw from one ton of paddy. In 2010 the paddy production was about 38 million tons producing about 38 million tons of paddy straw (Tran 2011).

### Rice husk

The rice husk residue is generated at the rice mills. From one tons of paddy it is possible to get in average about 0.2 ton of rice husk. The total rice husk production was 7.5 million tons in 2010 (Tran 2011).

#### **Bagasse**

The total sugar cane cultivation area in Vietnam in 2002–2003 was 315 000 ha. The average yield of sugar cane is about 50 tons per ha. In 2010 the total sugar cane production was 24 million tons (Tran 2011). While pressuring one ton of sugar cane 300 kg of bagasse in 50% moisture content is received. The total bagasse output was 7.2 million tons in 2010. In Vietnam the average annual yield of bagasse is 12.5–15.0 tons of bagasse per ha, assuming that the sugar cane yield is 50 tons/ha.

In Vietnam there are 40 sugar mills (Institute of Energy 2009). The capacity of the mills varies from 4 450 to 51 000 tons of sugar cane per day. In the northern provinces the capacity of the sugar mills is 26 850 tons, in the central provinces 23 450 tons and in the southern regions 32 150 tons of sugar cane per day. All the sugar mills use bagasse in their CHP boilers to supply electricity and heat for their own use.

#### **Coconut shells**

The total coconut cultivation area was 130 000 ha in 2006. The coconut production of this area was 0.96 million tons. During the last years the cultivation area of coconut has increased. The average coconut yield is 7.3 tons per ha (Vinay chand associates 2011). The share of coconut shells of the coconut fruit weight is 15%. The total amount of coconut shell production in Vietnam in 2010 was 0.14 million tons. The main cultivation area of coconut in Vietnam is the Mekong River Delta region. About 74% of coconut in Vietnam is cultivated in this area (Vinay chand associates 2011).

#### **Maize**

Maize cultivation and processing residues has a big biomass potential. In 2005 the maize production was about 3.8 million tons and in 2010 about 6 million tons. Maize is harvested by picking and husking the maize cobs. The residues after harvesting include stalks, leaves and corncobs, which are usually collected for fuel and food for livestock. Maize is cultivated mainly on Central Highlands, North East, South East and North Central Coast regions. One ton of maize seeds produce 2.5 tons of maize residues. In 2010 the maize residue potential was about 15 million tons (Tran 2011).

#### **Coffee husks**

Vietnam is currently growing mainly Robusta coffee. In 2007, the total coffee growing area was over 500 000 hectares. Average coffee yield was 1.97 tons/ha in 2007. In 2007 the coffee production in Vietnam was about 1.0 million tons. Vietnam has 560 000 households growing coffee, generating steady jobs for over half a million people and offering millions of part time jobs during harvesting season. Coffee

plantations in Vietnam are usually small. From coffee plantations 99% are under 5 ha (Nguyen 2011). The total coffee husk production in Vietnam was 0.4 million tons in 2010.

#### **Wood**

The total domestic supply of roundwood in Vietnam was about 3 million solid-m<sup>3</sup> in 2006. The biggest wood producers are North-East, North central coast and Southern central coast regions. The total wood fuel production potential in Vietnam was very high (31.5 million tons) being nearly as large as the rice straw potential in 2010 (Tran 2011). A big share of wood fuel is utilized in households for energy purposes.

#### **Peanut shells**

In 2010 the peanut production was about 0.6 million tons. With an average shell to peanut ratio of 0.3, the total peanut shell generated in 2010 was 0.18 million tons.

### **3.2 Total biomass fuel potential in Vietnam**

The total biomass production in Vietnam in 2010 was 104.4 million tons. The total biomass potential in Vietnam was 22.8 million tons in 2010. The total biomass electricity production potential is evaluated to be at least 2 500 MW<sub>e</sub>. At the moment, mainly at the sugar mills, the installed power capacity is 150 MW<sub>e</sub> (Nguyen 2012 and Tran 2011).

The total agro-biomass residue production in Vietnam was 72.7 million tons in 2010 (Table 4). 42.3 million tons of agro-biomass residues were collected and 23.6 million tons were utilized for different purposes. The surplus of agro-biomass was 18.7 million tons in 2010. The energy content of 18.7 million tons of agro-biomass is about 262.5 PJ (72.9 TWh) of energy (Tran 2011).

The firewood surplus was about 3.5 million tons in 2010. Also there was a little bit surplus of wood residues in 2010. Wood residues can be also used for electricity production.

### 3. Biomass fuel potential in Vietnam

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**Table 4.** Biomass potential for energy (mill tons/year) in Vietnam in 2010 (Tran 2011).

<b>Crop residues</b>	<b>Total biomass potential (mill ton/a)</b>	<b>Biomass collected (mill ton/a)</b>	<b>Biomass utilized (mill ton/a)</b>	<b>Biomass surplus (mill ton/a)</b>
Paddy straw	37.57	18.8	7.8	11.0
Rice husk	7.52	4.5	3.0	1.5
Bagasse	7.20	5.9	4.3	1.6
Other crop residues	20.40	13.1	8.5	4.6
Firewood	27.6	24.8	21.3 <sup>1</sup>	3.5
Wood residues	4.08	3.7	3.1 <sup>1</sup>	0.6
<b>Total</b>	<b>104.37</b>	<b>70.8</b>	<b>48.0</b>	<b>22.8</b>

<sup>1</sup> Year 2005

## 3.3 Regional biomass potential

### 3.3.1 Potential of main agricultural residues

The main biomass residues in Vietnam are agricultural residues and wood fuel. From agricultural residues the most important are rice husk, rice straw, bagasse and maize trash. They cover about 57% of the total biomass resources and 93% of the agro-biomass potential in Vietnam.

The main biomass resources are at Mekong River and Red River Delta regions. The main rice husk and rice straw producers are the Red river delta and the Mekong river delta regions. The biggest bagasse producers are the Mekong delta, the North central, the Central coast and the South-East regions. Maize is cultivated mainly on Central Highlands, North East, South East and North Central Coast regions (Table 5).

*Mekong River Delta* region has about 47% of the main agro-biomass resources in Vietnam. The main biomass resources in Mekong River Delta region are rice husk and paddy straw accounting for 89% of all agricultural residues. The total rice production was 18.2 million tons in the region in 2007. Rice husk production was 3.8 million tons of rice husk and 13.8 million tons of rice straw in 2007. The other agricultural residue production was 2.0 million tons in 2007 (Thanh 2010). About 2.7 million tons of rice husk was used in households and brick kilns for heat production in 2007. There is still unused about 1.1 million tons of rice husk in 2007. The consumption of straw is very small (1.4 mill. tons) in the area. There is about 12.4 million tons of rice straw unused in the area (Thanh 2010 and Nguyen 2009).

Rice husk production in Mekong River Delta region changes during the year. Normally, peak season of paddy milling is from February until June. After this period the paddy milling capacity reduces slowly to October. In November, December and January nearly all rice mills operate periodically or top their working. There for, the supply of rice is not enough for rice husk power plants in those

months. Storing of rice husk is necessary. The average size of the rice mill is 10 000–30 000 tons of paddy per year. The average rice husk production of each mill is 2 000–6 000 tons per year.

The total coffee production in Vietnam was 1.26 million tons in 2011. Coffee is primarily grown in Vietnam in the Central Highlands region covering about 90 of the total coffee cultivation area in Vietnam. In the Central Highlands it was produced about 1.1 million tons of coffee, corresponding to about 0.33 million tons of coffee husks. The main provinces producing coffee are Dak Lak, Lam Dong, Gia Lai and Kon Tum provinces (Nguyen 2011).

The total forest area in Vietnam is 12.6 million ha. There are a lot of forestland in all Vietnamese regions except in Red river delta and Mekong river delta regions.

**Table 5.** Regional production of main agricultural residues in Vietnam in 2005 (Tran 2008).

Region	Rice husk mill. tons	Bagasse mill. tons	Straw and cane trash mill. tons	Total mill. tons
Northwest and Northeast	0.54	0.32	3.12	3.98
Red River Delta	1.30	0.04	5.19	6.53
North Central Coast	0.58	0.76	2.79	4.13
South Central Coast	0.35	0.67	2.83	3.85
Central Highlands	0.15	0.35	0.84	1.32
Southeast	0.33	0.76	2.78	3.87
Mekong River Delta	3.55	1.55	16.51	21.25
<b>Whole country</b>	<b>6.78</b>	<b>4.45</b>	<b>34.4</b>	<b>45.63</b>

### 3.4 Biomass use for energy in Vietnam

#### 3.4.1 Biomass use for heat production

Biomass is an important energy source in Vietnam, especially in rural areas. It is estimated that about 70% of rural population in Vietnam are currently relied on biomass as a daily cooking fuel. Biomass is also used to produce thermal energy in various industries and handicraft facilities such as the traditional brick, lime and pottery kilns, small sugar refiners etc.

In 2005, the total biomass used for heat production was 565.7 PJ (157.2 TWh), of which 366.3 PJ (101.8 TWh) was fuel wood (65%), 79.3 PJ (22.0 TWh) paddy straw (14%), rice husk 38.3 PJ (10.6 TWh) (7%), bagasse 11.1 PJ (3.1 TWh) (2%) and other agro-biomass 70.7 PJ (19.6 TWh) (12%). Household sector accounted for 78.1% of the total biomass consumption for thermal energy production. The remaining 21.9 % was consumed by the small industries (Tran 2011) (Table 6).

### 3. Biomass fuel potential in Vietnam

*Fuel wood and agricultural-forestry residues* are relatively important energy resources in Vietnam. About 60% of rural population use these resources as fuels for daily cooking. Biomass is also used in small industry companies for heat production. These companies use biomass for burning bricks and ceramics, and for processing food.

In the past, *rice straw* was used as fuel for daily cooking of households in the rural areas of the Northern region. In the Central and Southern regions, rice straws were not used as fuel but left in the fields and burnt out. The total amount of rice straws used as fuel is estimated of 7.8 million tons, accounting for 24% of total amount of rice straws. At present, people in the Northern region use small amounts of rice straws as fuel, and began flaring them out along the roads in crop harvesting season, causing pollution to the ecological environment.

*Rice husks* are partially used for burning bricks in the Southern provinces and as fuel for cooking in rural households. The amount of rice husks used as fuel is estimated of about 3.0 million tons, accounting for 40% of total rice husks generated annually.

*Coffee husks, ground nut husks, corn trunks and cobs, trunks of beans, tops of sugar canes, sawdust, and wood chips* are also used as cooking fuels. So far, about 40% of these types of biomasses are exploited and used. Total consumption of them is about 1.69 million tons.

About 24.4 million tons of wood fuels is used in Vietnam, of which 79% is used in households and the rest in small industries for heat production.

**Table 6.** Use of biomass for thermal energy production in 2005 (Tran 2011). 1 TWh = 3,6 PJ.

Biomass type	Use sector		Total biomass use by biomass source	
	Household TWh (PJ)	Small industry and handicraft TWh (PJ)	TWh (PJ)	mill. tons
Firewood and wood residues	80.74 (290.6)	21.03 (75.7)	101.76 (366.3)	24.4
Paddy straw	22.04 (79.3)	-	22.04 (79.3)	7.8
Rice husk	7.73 (27.8)	2.91 (10.5)	10.64 (38.3)	3.0
Bagasse	1.92 (6.9)	1.16 (4.2)	3.08 (11.1)	1.5
Other biomass (Cane and maize trash, cassava stem etc.)	10.35 (37.3)	9.28 (33.4)	19.63 (70.7)	8.5
<b>Total by use sector</b>	<b>122.78 (442.00)</b>	<b>34.38 (123.8)</b>	<b>157.16 (565.7)</b>	<b>45.2</b>



#### 3.4.2 Electricity from biomass

*The bagasse* is used for combined heat and power (CHP) production in about 40 sugar mills in Vietnam for a long time. At present, the total installed power capacity of these CHP plants is about 150 MW<sub>e</sub>. The sugar mills used 2.1 million tons (15.5 PJ) of bagasse for power and heat production in 2005. This is about 75 % of the total bagasse production (Tran 2011). The capacities of these power plants vary in the range of 1.5–24 MW<sub>e</sub>. Electricity and steam produced is mainly used by the sugar mills in their production processes. It has been estimated that about two million tons of bagasse is used annually by sugar plants in the steam boilers to produce about 450 GWh electricity and 4 million tons of steam (Institute of Energy 2009).

At present, only 3 power plants in sugar mills are selling their surplus electricity to the national power grid. The price of electricity sold to grid is 820 VDN/kWh (228 VND/MJ, 0.029 €/kWh) (Institute of Energy 2009). The demand for selling of surplus electricity from other power plants to the national power grid is big because of the electricity consumption in Vietnam is increasing. However, low electricity selling price is a barrier to electric capacity increase. On the other hand, because most of the equipment (steam boilers) in existing sugar plants are old, with backward technologies and low efficiency (low steam parameters) and surplus electricity is unsold, so combustion of bagasse and energy use at these plants are not effective. Therefore, technology renovation and capacity increase are issues raised for these cogeneration power plants.

Up to now, only one 50 kW *rice husk* fired cogeneration system has been installed as a demonstration plant in Long An province (at the Food Milling and Processing Enterprise No. 2) (Tran 2011). This project has been implemented in 1999 with the financial assistance from the Government of Australia (through the Australia-ASEAN Technical Cooperation Program, AAACP-III). The cogeneration system consists of a 2.5 ton/h fluidized bed boiler, a 50 kW steam turbo-generator, a heat exchanger and three paddy dryers. This plant stopped its operation because of low economic efficiency of the plant.

The Dinh Hai Cogen Joint Stock Company has built *the first steam power plant using rice husks* as fuel in Can Tho city in 2006 (Tran 2011). The power plant is producing steam used in the 8 industrial companies in the surroundings of the power plant. The power plant produces 25 tons of steam per hour. The pressure of the steam is 45 bar and the temperature 450 °C. The annual consumption of rice husks in the power plant is 37 500 tons (150 000 MWh or 540 000 GJ) with whole steam production capacity and the operation time of the power plant is 6 000 hours per year. The target of the company is to build a turbine of 7 MW<sub>e</sub> in the future.

Apart from the above mentioned rice husk power plant there are some other rice husk power plants under development phase in Mekong River Delta region.

#### 3.5 Total biomass use for energy production in Vietnam

The total biomass use for heat production in households and small industries (45.2 mill. tons, 565.7 PJ) and for power and heat in sugar mills (2.1 mill. tons, 17.6 PJ) was all together 47.3 mill. tons (583.3 PJ) in 2005.

Household sector (442.0 PJ) accounted for 75.8% of the total biomass consumption for energy production. The remaining 24.2% was consumed by the small industries in heat production and sugar mills in their CHP plants.

In 2005 the total primary energy consumption in Vietnam was 606 TWh (2 182 PJ) (IEA 2011). The share of biomass (583.3 PJ, 162.0 TWh) from the total energy consumption was 27% which is very high figure (Tran 2011). The total energy consumption has increased rapidly in Vietnam during the last few years. The total primary energy consumption in 2009 was 745 TWh (2 682 PJ) (IEA 2011). The use of biomass has not increased as fast as the total primary energy consumption. That is why the share of biomass of the total energy consumption has decreased during the last years.

Finland is one of the leading countries in renewable energy and biomass utilization for energy purposes. In Finland the share of renewables (390 PJ, 108 TWh) from the total primary energy consumption (1 392 PJ, 387 TWh) was about 28% in 2012. The share of wood biomass from the total energy consumption was about 23% in 2012.

#### 3.6 Development of biomass use for energy

The main potential of biomass fuels for energy in Vietnam includes wood fuels, rice straw, maize trash and bagasse. Large amount of bagasse is currently used for energy purposes. Rice husk is mainly used in households and small industries for heating purposes. There is especially a big potential to use rice straw and maize trash for energy purposes. However, these fuels are more challenging fuels than wood, rice husk and bagasse, but there is experience in the world in the utilization of these fuels.

At the moment biomass is economical in Vietnam in industrial heat production. The use of biomass in industrial boilers should be increased and supported.

There is currently only one very small *rice husk* power plant in Vietnam, but there are many other power plant projects under developments phase in different part of Vietnam. The main fuel in these power plants would be rice husk. The main barrier for biomass plant investment is the low electricity price. The main reason for this is the use of cheap coal for electricity production. There should be some subsidies for biomass use for energy purposes. In Europe there are different kinds of subsidies offered by states for renewable energy in order to stop the greenhouse effect.

In Vietnam there is potential to increase the use of bagasse for power production. The use of these boilers should be extended outside the sugar production season, but even there the main problem is the lower electricity price. However,

the electricity price depends on the region. In Mekong River Delta region the price of fuel for electricity is low but in Central Highlands region the price of fuel for electricity is high. This is the reason why the sugar mills in Mekong River Delta region are not selling electricity to national grid but sugar mills in Central Highlands are doing that.

## **4. Current biomass supply system in Vietnam**

### **4.1 General information**

The analysis of the current supply chain was made by visiting the power plants using biomass as fuel in Mekong River Delta region. During the visits it has been discussed with the operators of the power plants and information is gathered of the current supply system and development needs. The results of the visits are presented in this report.

The analysis of the current supply chain was carried out by visits to a rice mill, a sugar mill, a rice husk power plant, sawmills and wood processing plants, and brick factories in Vietnam. The first trip was made in March 2011 to Mekong River Delta region. During this trip the visits were made to Nam Nga rice mill, Dinh Hai rice husk power plant, Ben Tre sugar mill and coconut processing plant. The second visit was made in June 2011. During the second trip visits were made to a sawmill in Hanoi City, to brick and ceramics production factories in Vinh Long province in Mekong Delta region. Information on the current biomass supply system and development needs have been gathered during these visits.

Figure 6 presents the normal fuel supply chain of power plants in Vietnam. The supply chain varies from biomass to biomass. Bagasse is mainly used in sugar mills where it is produced. Rice husk is normally transported from rice mills to the power plants and other industrial boilers.

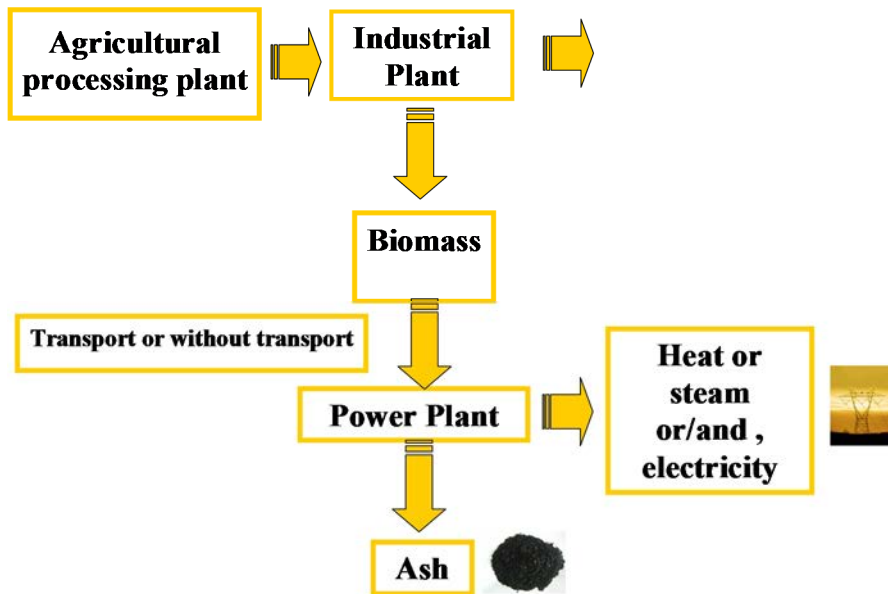


Figure 6. Schematic picture of the fuel supply chain.

## 4.2 Dinh Hai rice husk steam power plant in Can Tho city

The Dinh Hai Cogen Joint Stock Company has built a rice-husk steam power plant in Can Tho City in 2006. Can Tho City is located in Can Tho province in Mekong River Delta region. The power plant is located on Tra Noc II industrial park. The power plant is producing steam used in the 8 companies in the industrial park. The steam delivery pipeline is 5 000 m long. The power plant is producing 20 tons of steam per hour. The pressure of the steam is 45 bar and the temperature 450 °C. During the main season from November to July the plant is operating with full capacity using 270 tons of rice husk per day. During the season from August to October the plant operates with partial load using about 100 tons of rice husk per day. There is a plan to install a turbine at the plant in the future.

Rice husk for the steam power plant is transported from rice mills by boat through rivers and canals. The rice husk is stored for the winter months at the backyard of the power plant.

### Rice husk production

The steam power plant is buying the rice husk from the local trading company, and the trading company buys the rice husk from the local rice mills. One of the rice mills in Mekong River Delta region is Nam Nga in Tien Giang province. Nam Nga processes 20 000 tons of paddy per year. The total amount of rice husk generated in Nam Nga rice mill is about 4 000 tons per year. Nam Nga sells the rice husk to

#### 4. Current biomass supply system in Vietnam

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the local supplier, which has hired about 20 boat owners for rice husk transport. In 2011 the worth of the selling contract was 800 million VND. This is about 200 VND per kg or 61 VND per kWh (16.8 VND/MJ, 0.59 €/GJ) of rice husk. Nam Nga rice mill is not delivering rice husk to the Dinh Hai steam power plant. The customers of Nam Nga rice mill are located in Vinh Long province about 50 km away from rice mill.

##### **Rice husk transport to the power plant**

Rice mills in the Mekong River Delta are mainly located along rivers so it is convenient to transport rice husks by boat to the power plants. The boats are loaded with rice husk with conveyors (Fig. 7). The load of rice husk in the boat varies from 10–20 tons (100–200 loose-m<sup>3</sup>) (Fig. 8). The loading time is about 3 hours. The boats used for rice husk are original wooden boats. The price of a new boat is about 200 million Vietnamese dong. The average transport distance of rice husk to Dinh Hai power plant is about 40 km. By boat it takes about one day to deliver one load to power plant.



**Figure 7.** Loading of rice husk into the boat in Nam Nga -rice mill in Tien Giang -province in 2011 (Photo by Arvo Leinonen).



**Figure 8.** Boat loaded with Rice Husk in Nam Nga -rice mill in Tien Giang -province in 2011. (Photo by Arvo Leinonen)

#### **Unloading of rice husk from the boat at power plant**

The rice husk is unloaded and transferred from the boat with buckets into small truck trailers near the steam power plant (Fig. 9). Unloading of a boat takes about 8 hours. The volume of a truck trailer is about 12 loose-m<sup>3</sup> (Fig. 10). Rice husk is transported by the trailer to the power plant located about 300 m from the canal. At the power plant rice husk is stored at the backyard of the power plant. Storing of rice husk is necessary because rice husk is not available outside of rice harvesting season. From the store rice husk is feed by tractor to the conveyors transporting the material in the boiler.

#### **Purchase Contract of rice husk**

Dinh Hai steam power plant has a purchase contract of rice husk with the trading company. There are several rice husk traders from which rice husk can be purchased. The duration of the contract is only few months. In the contract there is specified the amount and delivery time for the rice husk at power plant. During the rice harvesting season the price of rice husk is low. That is the main reason to buy and store rice husk at power plant during harvesting season. Dinh Hai power plant is planning to increase the covered store area of rice husk at power plant (Fig. 11).

#### 4. Current biomass supply system in Vietnam

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**Figure 9.** Unloading of rice husk in Luong Quoi Private Enterprise in Ben Tre province in 2011. (Photo by Arvo Leinonen).



**Figure 10.** Truck trailer for short transport of rice husk at Dinh Hai power plant (Photo by Arvo Leinonen).





**Figure 11.** Rice husk storage at Dinh Hai power plant (Photo by Arvo Leinonen).

### **4.3 Bagasse fired power plant in Ben Tre sugar plant**

The Ben Tre Sugar Joint Stock Company has a sugar plant in Ben Tre province beside Ham Luong river in Mekong River Delta region. The sugar plant has started in 1998. The average capacity of the plant is 2 000 tons of sugar cane per day. The sugar mill is in operation 7 months (200 days) per year from October to April. The total designed capacity of the sugar mill is about 400 000 tons of sugar cane per year. The actual capacity is about 280 000 tons of sugar cane per year (2011). The sugar cane processing is generating a lot of side-product called bagasse. Bagasse is the fibrous matter that remains after sugarcane is crushed to extract their juice. Bagasse production amount in Ben Tre sugar mill is about 84 000 tons (176 000 MWh or 635 000 GJ) per year.

#### **The power plant**

The power plant consists of two boilers and sugar mill's side-product bagasse is used as a fuel in the power plant. Each boiler produces 20 tons of steam per hour. The pressure of the steam is 26.5 bar and the temperature is 400 °C. The steam is used for electricity production in a backpressure turbine and generator. After the turbine the low pressure steam is used for the sugar processing. The electricity

#### 4. Current biomass supply system in Vietnam

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production capacity of both of the turbines is 1.5 MW. The sugar mill sells a part of the surplus electricity (0.2 MW) to the company next door.

The bagasse consumption of each boiler is 12–15 t/h, so the total fuel consumption of the two boilers is about 76 000 tons of bagasse (160 000 MWh, 576 000 GJ) per year. This means that in each boiler it is used about 38 000 tons of bagasse. The surplus of bagasse (8 000 tons) in the sugar mill is used for pellet production.

##### **Sugar cane production and transport to sugar mill**

Sugar mill is buying the sugar cane from the farmers in the surroundings of the sugar mill. The output of the sugar cane cultivation on the farms is 75 kg/ha. The total sugar cane cultivation area is 5 300 hectares. The sugar cane is transported from the farms by wooden boats and truck trailers (Fig. 12). The capacity of the boats are about 20 tons. The maximum transport distance is 50 km.

##### **Sugar cane storage and use as a fuel**

After pressing the bagasse is transferred to the storage located at the backyard of the sugar mill (Fig. 13). Bagasse is not dried before burning in the boiler. The bagasse is transferred from the storage to the boiler. The production of bagasse exceeds the use of the sugar mill by 8 000 tons. The surplus of bagasse sugar mill is converted into bagasse pellets, which are used as animal feed and as fuel. The bagasse is first dried (Fig. 14) in the sun and crushed (Fig. 15) and after which it is pelletized (Fig. 16).



**Figure 12.** Sugar cane is transported to sugar mill by wooden boats or truck trailers at Ben Tre sugar mill (Photo by Arvo Leinonen).



**Figure 13.** Power plant and bagasse storage at the backyard of the sugar mill in Ben Tre sugar mill (Photo by Arvo Leinonen).



**Figure 14.** Bagasse is dried on the ground by solar energy for pellet production in Ben Tre sugar mill (Photo by Arvo Leinonen).

#### 4. Current biomass supply system in Vietnam

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**Figure 15.** Bagasse is crushed after solar drying with a crusher in Ben Tre sugar mill (Photo by Arvo Leinonen).



**Figure 16.** Bagasse is pelletized after drying and crushing in Ben Tre province (Photo by Arvo Leinonen).

### 4.4 Bagasse pellet boiler in Ben Tre province

There is a private company called Chinthi near Ben Tre sugar. The main product of the company is malt for candy production. The company has a boiler which uses bagasse pellets as a fuel. The boiler produces 1 ton of steam per hour. The steam pressure is 7 bar and steam temperature 100 °C. The fuel input of the boiler is about 1.0 MW<sub>th</sub>. The boiler has been constructed in the summer 2011. The investments costs for the boiler system were 650 million VND (22 755 €). The bagasse pellets are purchased from Ben Tre sugar mill (Fig. 17).



**Figure 17.** Bagasse pellet boiler in Ben Tre province (Photo by Arvo Leinonen).

### 4.5 Coconut shell and rice husk fired steam boiler in Ben Tre province

Luong Quoi Private Enterprise has a factory for processing coconuts for food in Quoi Commune in Ben Tre province next door the Bentre Sugar Mill. Luong Quoi enterprise produces annually 10 000 tons of upgraded coconuts. The side product from the process is coconut shell. The production of coconut shells in the plant is about 5 000 tons per year. The energy content produced coconut shells is about 22 000 MWh (79 000 GJ) (20 % moisture).

##### **The power plant**

The coconut company has two steam boilers producing steam for the process. The outputs of the boilers are 4 and 5 tons of steam per hour. The total amount of fuel used in two boilers is about 11 500 tons (50 000 MWh, 180 000 GJ). This means that the coconut shells produced at the plant is not enough to feed the steam boilers. By the side of coconut shells (5 000 tons), the company uses also rice husk of about 8 000 tons (26 000 MWh or 95 000 GJ) as a fuel. The coconut shells are crushed before burning in the boiler.

##### **Rice husk supply to power plant**

The nearest rice husk resource for Luong Quoi coconut plant is in Cai Be and Cai Lay districts in Tien Giang province, 40 km far from the plant. There are about 50 rice-milling plants in these two districts, the capacity of which is 2 tons/h each. The total paddy processing capacity is about 300 000 tons per year and rice husk capacity 60 000 tons (198 000 MWh or 712 000 GJ) per year.

The milling plants are located near canals, convenient for waterway transportation at low cost. From the milling plants, rice husks are transported through canals to the Tien river, located upstream from the Ham Luong river, then to sugar plant, located by the river. One boat can transport 15 tons of rice husks. Rice husk is unloaded by hand from the boat and transported by conveyors to the boiler (Fig. 18).

##### **Purchase contract**

At the moment there is buyer's market on rice husk in Mekong River Delta region. Luong Quoi coconut plant has a purchase contract of rice husk with the trading company. The duration of the contract is one year long. In the contract there is specified the amount and delivery time for the rice husk at power plant. The delivery price for rice husk is not specified in the contract.



**Figure 18.** Unloading of rice husk in Luong Quoi Private Enterprise in Ben Tre province in 2011 (Photo by Arvo Leinonen).

#### **4.6 Wood processing plants**

In Lien Ha commune near Hanoi city there is a wood industrial region having about 200 sawmills and 200 wood processing companies (Fig. 19). The sawing capacity of round wood by sawmills is about 200 000 solid-m<sup>3</sup>/a. The round wood is coming from Vietnam and abroad. The sawn timber is sold for the wood processing companies located nearby sawmills. Wood processing companies are making different kind of wood products from lumber, such as furniture and kitchen fixtures.

#### 4. Current biomass supply system in Vietnam

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**Figure 19.** A sawing machine in Lien Ha commune in 2011 (Photo by Arvo Leinonen).

The sawn timber is dried in two chamber dryers owned by different companies. The dryers are located in the industrial zone. The heat for drying is made in two boilers. The steam production capacities of the boilers are 500 kg/h and 1 000 kg/h. Wood chips, coming from the wood processing plants, are combusted in the boilers. The total consumption of wood chips in the boilers is about 10 000 loose-m<sup>3</sup> of wood chips per year assuming the dryers operating time as 6 000 h/a.

Side products, such as sawdust, bark and slabs are coming from sawmills and other lumber residues from wood processing plants and sawmills (Fig. 20). The total side product production in the area is about 100 000 solid-m<sup>3</sup> (187 000 MWh or 673 000 GJ, 50wt-%) assuming 50 % of round wood is enabled to process into wood products.





**Figure 20.** Slabs and packed sawdust in Lien Ha commune in 2011 (Photo by Arvo Leinonen).

At the moment some of the sawdust is transported in sacks by trucks to board factories outside the industrial area. Some of the slabs from sawmills are chipped and used in the dryer boilers. However, there are still huge amounts of wood side products available for energy production in the area. 200 000 MWh (720 000 GJ) of wood chips enough for 30 MW CHP plant.

### **4.7 Rice husk as a fuel in brick and ceramics production**

#### **Brick, ceramics and paddy production in Vinh Long province**

The two main industries in Vinh Long province in Mekong River Delta region are brick and ceramics production and rice cultivation and processing. Vinh Long province is the biggest brick and ceramics producer in Mekong River Delta region. About 630 million bricks and 13 million units of ceramics are produced annually in 1 300 factories. Brick and ceramics factories are owned by private companies. The paddy production is 900 000 tons of paddy in every year in Vinh Long province. The rice husk production is 180 000 tons per year. The second biggest brick and ceramics producer is Dong Thap province in Mekong Delta River region.

#### **Rice husk use as a fuel in Vinh Long province**

In brick and ceramics production the clay products are burnt in the kilns using rice husk as a fuel (Fig. 21). The annual rice husk consumption in brick production is 315 000 tons assuming that 0.5 kg of rice husk is used for every brick unit. The rice husk consumption in ceramics production is 3 250 tons assuming that 0.25 kg of rice husk is used for every ceramics units. The total rice husk consumption Vinh Long province is 318 250 tons of rice husk in brick and ceramics production. Because the rice husk production in Vinh Long province was only 180 000 tons the

companies must buy about 43 % of their rice husk consumption from neighbouring provinces like Tien Giang, Dong Thap, Hau Giang and Ben Tre provinces.

##### **Nam Vang and Hiep Luca private brick and ceramics companies using rice husk as a fuel**

Nam Vang is one of the ceramics producers in Vinh Long province. It is located in Mang Thit district in An Phuoc commune. The factory is beside the canal. The Nam Vang company produces 127 000 ceramics units annually for export and domestic markets. It is using 3 100 tons of rice husk in kilns of ceramics (Fig. 21). The rice husk is bought from the local rice mills and it is transported to the ceramics factory by boat (Fig. 22). The rice husk is unloaded and transferred by buckets manually into covered storages (Fig. 23). The Nam Vang company has three different storages. The capacity of the biggest storage is about 800 tons covering nearly 30 % of the whole annual rice husk consumption. The rice husk is used in the kilns to produce heat for ceramics burning (Fig. 24).

The Nam Vang company does not have any contract of rice husk purchasing from the rice husk supplier. The company is buying the rice husk when the price of rice husk low and when it is needed. The price of rice husk varies from 180–400 VND per kg (6.3–14.0 €/ton) depending on the season. The price of rice husk is low during the main paddy season and high out of the paddy season. The rice husk storages are made to balance the rice husk price and availability around the year. The availability of rice husk during out of paddy season is not good and the price is at that time high.

Another company in Thuan Toi village is Hiep Luca private company producing bricks and ceramics. It is also using rice husk as a fuel in kilns. The rice husk comes also by boat to the company and it is transferred by buckets to the storage.



**Figure 21.** Kilns in Thuan Toi village in An Phuoc commune in 2011 (Photo by Arvo Leinonen).



**Figure 22.** A boat loaded with rice husk in Thuan Thoi village in An Phuoc commune (Photo by Arvo Leinonen).

#### 4. Current biomass supply system in Vietnam

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**Figure 23.** Rice husk is transferred by bucket from the boat to the storage in Hiep Luca company in Thuan Thoi village in 2011 (Photo by Arvo Leinonen).



**Figure 24.** The kiln in Nam Vang private company in Thuan Thoi village (Photo by Arvo Leinonen).

## **4.8 Bagasse and coffee husk use as a fuel in Gia Lai province**

### **Gia Lai province**

Gia Lai province in Central Highlands region has many advantages to develop sustainable and effective agriculture. Climatic conditions and soil properties are favourable for agriculture. Currently, the province has 76 367 ha of coffee, 73218 ha of rubber, 20 568 ha of cashew trees and 5 050 ha of pepper plantations (Vietnam business forum 2011).

### **Gia Lai Cane Sugar Thermolectricity JCS**

In Gia Lai province there two sugar mills: An Khe sugar mill and Gia Lai Cane Sugar Thermolectricity JCS sugar mill. Gia Lai Cane Sugar Thermolectricity Joint Stock Company is a Vietnam-based company engaged in the food processing industry. It manufactures sugar and sugar-based products, such as syrup, confectionery products and beverages. It is also involved in the generation, transmission and distribution of thermal power and electricity.

The total sugar cane production area is 7 000 ha and the average yield of sugar cane is 65 tons/ha. The total sugar cane production is 420 000 tons per year. The sugar production is 45 000 tons per year. The total bagasse production in sugar mill is 132 300 tons per year. The Gia Lai sugar mill starts its annual operation during 1–25 May and stops 20–25 November. The sugar mill operation time is 160 days and 3 850 h.

There is a plan to increase the yield of sugar cane from 65 tons/ha up to 70 tons per hectare. This enables the increase of the sugar cane production up to 490 000 per year.

### **Power production in Gia Lai Cane Sugar Thermolectricity JCS**

There is a CHP plant in Gia Lai Cane Sugar Thermolectricity JCS. The power plant produces heat and electricity. Heat is used in sugar mill sugar production process. Main part of the produced electricity is sold to the national grid. Some of the produced electricity is used by the sugar mill itself. The steam output of the boiler is 75 tons per hour. The temperature of steam is 485 °C and the pressure 40 bar. The total bagasse production (132 300 tons) is used in the boiler.

The total energy amount of 132 300 tons of bagasse is 278 000 MWh (1 000 000 GJ) assuming that one ton of bagasse has 2.1 MWh (7.6 GJ) (50% moisture content). The annual operation time of the boiler is 3 850 h. The electricity output of the boiler is 12 MW<sub>e</sub> and the rest is heat used at the sugar plant. From the total electricity production (46.2 GWh) about 71 % is sold out to the local energy company. The rest is used is the sugar mill. The price for the sold electricity is about 700 VND/kWh (0.025 €/kWh).

##### **Coffee husk production in Gia Lai province**

Coffee is primarily grown in the highlands covering 90 % of the total cultivation area (Nguyen 2011 and Nguyen 2012b). About 960 000 tons of coffee was produced in the Central highlands. The main provinces producing coffee are Dak Lak, Lam Dong, Gia Lai and Kon Tum provinces. Currently Gia Lai province has 76 367 ha of coffee plantations. The total coffee production Gia Lai province is about 153 000 tons of coffee and 51 000 tons of coffee husk. At the moment the coffee husk is used mainly as fertilizer but also as a fuel for heat production in coffee beans drying.

## **5. Supply costs of rice husk to power plant**

Rice husk price is changed by market demand and season. During the main season from January to April, the rice husk price is fluctuated in the range of 30–40 VND/kg (1.1–1.4 €/ton) but from August to September, it is increased to 50–100 VND/kg (1.8–3.5 €/ton). Beyond the main rice season the milling plants are operated only at 50–70% of design capacity, and the rice husk price increases to 250–350 VND/kg. If transport costs from milling plants to power plant (100 VND/kg) are included, the rice husk price in the main paddy season is 150–250 VND/kg and beyond the main paddy season 350–450 VND/kg (12.3–15.8 €/ton).

## **6. Development of biomass supply technology in Vietnam**

### **6.1 Implementation of biomass supply development**

The current biomass use and supply technology in Vietnam was assessed in the task one of the EEP-project (Leinonen & Nguyen 2012b). The next phase in the project was to develop a biomass supply chain. Theoretical development study on the selected five selected topics of biomass supply technology (Biomass fuel system development – task three) was made first. After the development study three topics from feasibility study were demonstrated in practice (Biomass fuel supply demonstration – task four).

The project organised visits to rice mill, sugar mill, rice husk power plant and candy factory in Mekong River Delta region in September and December 2011. During this visit it was discussed about the development needs of biomass supply with the representatives of the companies. Based on this discussion it was selected five topics for the development study.

The selected topics (case in parenthesis) are:

1. New biomass transport system (Dinh Hai steam power plant)
2. Multi biomass supply and use in power plant (Ben Tre sugar mill)
3. Biomass pellet production and use in industrial boilers (Chin Thi industrial boiler)
4. Purchasing contract between biomass seller and buyer (Dinh Hai power plant)
5. Buffer storing system for biomass supply (Dinh Hai power plant)

The study was made as a case study. The development of the supply technology in the studies is mainly based on the Finnish and Thai experience on biomass supply technology. The topics that will be demonstrated in practice are presented at the end of the theoretical analysis.

The results of the development study are presented in the task report (Leinonen et al. 2012b).



## **6.2 Study on new biomass supply technology**

The main development needs in biomass transport in Vietnam are focused on biomass boat transport and unloading biomass from the boat at power plants. The share of boat transport of the total rice husk supply costs at power plants is high. Unloading at power plant is very time consuming and expensive working phase because it is carried out manually.

The target in the study was to evaluate the technology and economy to develop rice husk transport by using bigger boats and trucks and secondly to develop the biomass unloading phase at power plant by mechanical equipment. Technology and economic analysis was made in the study. The transport development study has been made as a case study in Dinh Hai rice husk steam power plant.

On the basis of the results of the study it is possible to reduce the rice husk transport cost by 20 % by using bigger boats (25 tons) and mechanical unloading system compared with the present 15 ton boat transport and manual unloading.

The truck transport is not competitive at the moment with boat transport. However, there is a lot potential to develop truck transport of rice husk. The payload of a truck trailer can be increased, and hence reduce the transportation costs. The truck trailer can also be equipped with a tipping device by which it is possible also to decrease unloading costs. With these new equipment the truck transport could be competitive with boat transport.

## **6.3 Study on multi-biomass fuel supply and consumption in power plant**

The sugar mills in Vietnam have CHP plants producing electricity and steam for the mill from processing by-product bagasse. The sugar mills in Vietnam are operating six months (from the end October to the end of April) every year, because of which the CHP plants are also closed for the summer months.

The target of the study was to evaluate the economy of expanding the operating time of CHP plants in sugar mills for year-round. The need for low pressure steam is not needed in the sugar mill during the summer time, because of which the target in sugar mill would be to sell electricity to the national grid and steam for the companies in the neighbourhood during the summer time. The study was made as a case study in Ben Tre Sugar mill. The study has concentrated on biomass availability, biomass supply and storage at power plant.

The objective is to expand the use of CHP plant in Ben Tre sugar mill for summer months from May to September. The total operation time for the CHP plants would be about 6 000 hours per year. At the moment the biomass boilers are operating about 4 000 h. The total biomass usage of two boilers would be 80 000 MWh (288 000 GJ) during the summer months. At the moment the surplus of bagasse is 20 000 MWh (72 000 GJ). The need for biomass from outside the mill is 60 000 MWh (216 000 GJ). The best option for the biomass outside the mill is rice husk.

There is a lot of rice husk available in Mekong River Delta region. That is why rice husk is the best additional fuel for the CHP plant to operate all year round. On the basis of the literature review there will not be any problems caused by the use of rice husk and bagasse together in the CHP boiler, even the properties of rice husk and bagasse are different. Rice husk is dry and the ash content is high. On the other hand bagasse is quite wet fuel, the ash content of which is low. While mixing bagasse and rice the moisture content and ash content of the mixed fuel will be decreased.

Based on the study there is not any obstacles to operate CHP plants as condensing mode to produce electricity during the summer time in sugar mills. Unlike in combined power and heat production, the heat energy left over after the turbine is not exploited in condensing mode operation. Instead, it is condensed with cooling water. This has to be solved somehow in the CHP plant of a sugar mill.

### **6.4 Study on biomass pellet production and use in industrial boilers**

Biomass is used in Vietnam mainly in households and industrial boilers. Rice husk and different kinds of agricultural residues are utilized in furnaces and boilers in industry to produce heat and steam for the company needs. The use of biomass in industrial boilers is going to increase in the near future because biomass consumption in heat or steam production is the most economic.

Biomass pellets is very good fuel alternative for the industrial boilers. The energy content of pellets is high, the transport costs low, and the feeding of pellets into the boiler is easy to automatize. There is a candy factory in Mekong River delta that is using bagasse pellets in the steam boiler.

The target in this development study was to investigate technology and economy to use biomass pellets in industrial boilers. The study contains the assessment of pellet production, supply and combustion technology and economy. In the study it was studied the use of bagasse and rice husk biomass for pellet production. The study is made as a case study in Chin Thi malt factory near Ben Tre sugar mill.

The pellet production costs were calculated in the study. The pellet production costs depend mainly on the capacity of the pellet machine and raw material price. The price of rice husks pellets is about 2 000 VND/kg (70 €/ton) and the production costs of bagasse pellets 1500 VND/kg (46 €/ton). The price of rice husk at power plant in the calculation was 800 VND/kg and the price of bagasse 300 VND/kg. The price of rice husk pellets is about three times higher than the price of loose rice husk. However, the transport costs of rice husk pellets are lower and also the combustion of rice husk pellets is more effective than those of loose rice husk.

Based on the study rice husk and bagasse pellets are very attractive fuels for industrial boilers, where the use of biomass is increased in the future.

## **6.5 Study on the purchasing contract between biomass dealer and buyer**

The biomass plant is designed to operate over 30 years, so the biomass supply for the power plant must be reliable from year to year in all circumstances. At the moment the purchase contract between biomass seller and buyer is made in general level.

The target of the study was to develop purchase contract in order to secure the biomass supply. The development of purchase contract was made based on experiences of purchase contract used in Finland. The study is made on the basis of the current contract used in Dinh Hai steam power plant.

In general it is important to start to create the quality and sampling standards for different biomass in Vietnam. This forms the basis for the biomass trade.

The Finnish contract model could form the basis for the contract used in Vietnam. The most important parts of the biomass purchase contract would be:

- The contract is made for one year, with an option for second year.
- The delivery season and different delivery batches in different periods within the season should be agreed.
- Agreement on the biomass quality in the contract.

## **6.6 Study on biomass buffer storage system for reliable biomass supply**

The main biomass fuels in Vietnam are agriculture-based fuels, so the biomass output of the fuels like rice husk and bagasse fluctuate periodically depending the harvesting season of the crops. On the other hand, the power plants are operating around the year. In order to deliver biomass fuels to power plant reliably around the year there must be buffer storages of biomass in Vietnam.

The target of the case study was to evaluate the buffer storage system for biomass reliable delivery to power plants around the year. The study is made as case study in Dinh Hai power plant.

Currently the biomass users have their own buffer storages at power plant and also at industrial boilers. The rice husk storages are covered with canvas or they are located in the constructed storage places having a roof. At sugar mills bagasse storages are not covered by anyway.

At Dinh Hai steam power plant rice husk buffer storage is 70 000 m<sup>3</sup> (7 000 tons as received) (Figure 25). If the store is not covered the moisture content of the upper layer of the store will get wet because of the rain. Based on the case study the covering costs of the buffer storage with canvas are 210 million VND (30 000 VND/ton). The energy loss of rice husk in the store is 5 500 GJ (1 530 MWh) and financial loss 185 million VND if the store is not covered. The covering costs and savings of the buffer storage are nearly equal but the quality of rice husk will

## 6. Development of biomass supply technology in Vietnam

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stay better if the buffer store is covered. This also means higher efficiency in the boiler. That is why the buffer storage is recommended to cover with plastic or canvas. In the costs calculation the rice husk price at the plant was 400 VND/kg (33.6 VND/MJ).



**Figure 25.** Buffer storage of rice husk at Dinh Hai steam power plant (Photo by Arvo Leinonen).

## **7. Demonstrations**

### **7.1 Implementation of demonstrations**

Feasibility studies on five topics on biomass supply technology in Vietnam have been carried out in the study. The topics included were: Development of biomass transport system (1), Development of multi-fuel supply system for power plant (2), Development of biomass pellet production and use in industrial boilers (3), Development of purchasing contract between biomass seller and buyer (4) and Development of buffer storage for biomass supply (5). The analysis was made as a case study (Vu et al. 2012).

Based on the results of the study three case studies have been proposed and selected for demonstration: 'Development of biomass transport system', 'Development of multi-fuel supply system for power plant' and Development of biomass pellet production and use in industrial boilers'. The biggest potential to develop biomass supply chain is in these topics.

Demonstrations in Mekong River Delta -region were made together with Scientists Vu Ngoc Duc and Scientist Nguyen Van An from Institute of Energy and Dr. Arvo Leinonen from Technical Research Centre of Finland. The demonstrations were made in close contact with the Dinh Hai steam power plant, Ben Tre sugar mill and Chin Thi malt factory.

The demonstrations were carefully followed, monitored and documented by the scientists. The time and capacity of the different working phases in the different operations during the demonstrations were measured. Samples from the raw materials and final products like pellets were also taken during the demonstrations. The energy and moisture contents, as well as the ash content of some samples were analysed. The measured technical results in the demonstrations have been presented in this report. The cost calculation of each demonstration has also been made and compared with the results got in the theoretical case study.

### 7.2 Demonstrations of new biomass supply technologies

#### 7.2.1 Introduction for the demonstration at Dinh Hai Joint Stock Company

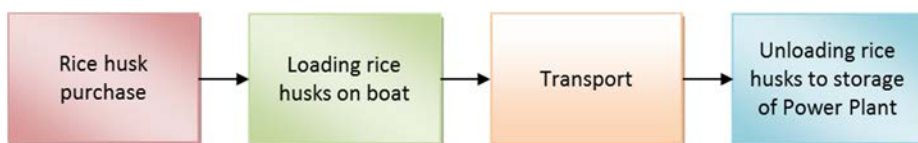
The demonstration of the new effective biomass supply system was made at Dinh Hai steam power plant. The target of the demonstration was to assess the use of bigger boats (25 tons) for rice husk transport to power plant, and secondly to assess the use of a new mechanical unloading device for rice husk unloading at power plant. The target is to decrease the transport cost by the new technologies. Currently the rice husk is transported by 15 tons boats to the Dinh Hai steam power plant and unloading is mainly carried out manually. The demonstration was carried out during 28–29 March 2012.

In the theoretical case study assessment it was calculated that with the use of bigger boats (25 ton) and with the mechanical unloading device it is possible to decrease transport cost by 12–26 % compared to the 15 tons boat and manual unloading (Leinonen et al. 2012b).

#### 7.2.2 Rice husk transportation and unloading at power plant

##### Rice husk transport process

There are four main activities in the biomass supply chain (Fig. 26), including purchase of rice husk from rice mill (1), loading the rice husk into the boat (2), transport of rice husk to the power plant (3) and unloading rice husk from the boat at power plant (4).



**Figure 26.** Diagram of transport and supply system of rice husks.

##### Purchase of rice husk

Rice husks were purchased from Phuoc Hung II paddy milling plant, located in An Thuan village, An Hiep commune, Chau Thanh district, Dong Thap province (Fig. 27). Phuoc Hung II paddy milling plant was established in 2006. The designed milling capacity of the plant is 270 tons of paddy per day and the designed operating time is 12 months per year. During the main season (from November to July) the plant is operated at the full design capacity. Operation time at that time is 24 hours per day. During the out-of-season (from August to October) the plant is operated with the capacity of about 100 tons of paddy per day.

Phuoc Hung II rice mill is located near to the Sa Dec river beside the Tien river, which makes the transport of the paddy, rice and rice husk by the waterways convenient. There are 15 other rice mills in the area with the same or smaller capacity.

The delivered moisture content of rice husk was low, 5.8wt-%, and the net calorific value as received 3.8 kWh/kg (13.5 MJ/kg).



**Figure 27.** Phuoc Hung II rice mill (Photo by Duc Vu).

Phuoc Hung II rice mill has a storage area of 1.5 ha for rice husk, there it is possible to store there 2 000 tons of rice husks (Fig. 28). In the recent two years the rice husk amount in the storage has been small because most of the rice husks are purchased by the traders. These traders usually sell rice husks to the brick and tile producers or for the animal feed. Rice husk price at the rice mill was about 100 VND/kg (3.5 €/ton). The price was low because it was the main milling season. During out-of-milling season the rice husk price at the mill was 200–300 VND/kg.



**Figure 28.** Rice husk storage yard of Phuoc Hung II paddy milling plant (Photo by Duc Vu).

### **Loading of rice husk into the boat**

Boat owner hires local workers at rice mill to load the rice husks into the boat. The number of hired workers depends on the size of the boat. In the demonstration there were all together seven men to load 25 tons boat with rice husk. The men in the demonstration were hired for the loading with 1 000 000 VND (35.0 €). The number of men used for loading smaller boats is five and the total costs about 700 000 VND (24.5 €). The hourly rate of the loading men was about 47 500 VND/h (1.7 €/h).

Loading of rice husk into the boat at Phuoc Hung II milling plant were started in March 28th 2012 at 9.45 am, and it was finished at 12.45 pm. So the loading time was three hours.

The transfer distance of rice from the milling plant storage to the boat were 15 m. Workers use bamboo baskets to carry rice husks into the boat. Each bamboo basket can contain about 20 kg of rice husk. That means that each bamboo frame (with two baskets) contains 40 kg of rice husks (Fig. 29 and 30). The real capacity of the manual loading (seven men) of rice husk was 7.9 ton/hour.





**Figure 29.** Manual filling of bamboo baskets with rice husk (Photo by Duc Vu).



**Figure 30.** Loading of rice husk by baskets into the boat (Photo by Duc Vu).

### Transport of rice husk by boat to the power plant

In the demonstration study rice husk were transported from Phuoc Hung II paddy milling plant to Dinh Hai steam power plant (75 km by water ways) by 25 tons boat (Fig. 31). The main parameters of 25 tons bigger boats are:

- Maximum load of the boat is 25 tons.
- Investment cost for a new boat is 450 million VND (15 754 €).
- Boat maintenance cost: Annual maintenance includes painting, waterproofing, sealing leakage. Periodical maintenance is made once in five years with the cost of about 12 000 000 VND (420 €). In addition, there are some costs for other small repairing. Estimated annual maintenance costs are 9 million VND (315 €).
- Registration cost is 1 500 000 VND per year (52.5 €).
- Diesel oil consumption of the engine without load is less than 5 litres in hour.
- Diesel consumption of the engine with the load is 6–7 litres in hour.
- Speed of the boat with no load is 15 km/hour.
- Speed of the boat with the load is 10 km/hour.



**Figure 31.** 25 tons boat for rice husk transport in the demonstration (Photo by Arvo Leinonen).

The topography in the area is characterized by many canals and ditches (Fig. 32). That is why the waterway transport is well developed in Cuu Long river delta. The average weight of rice husk transport boat is 15 tons according to the survey .

The tide plays important role in transportation of rice husks in Cuu Long river delta, which was also noticed in the demonstration. The boat had to wait for flood tide for three hours before it could leave (17.45 pm) the rice milling plant. The transportation distance of rice husk to the power plant was about 75 km and the transport time was about eight hours. The route of the boat from the milling plant to Dinh Hai steam power plant is presented in the Figure 32.



**Figure 32.** Route of transportation of rice husk to the power plant by bigger 25 tons wood boat.

### Unloading of rice husks from boat at Dinh Hai power plant

Rice husk was unloaded from the boat by a mechanical automatic unloading system. In the mechanical unloading rice husk is moved from the boat to the hopper by pneumatic suction. The unloading subsystem consists of a weighing machine connected to the belt conveying of rice husk to the hopper. With the help of weighing machine it was able to measure the rice husk amount transferred to the hopper. The measured weight of rice husk is the basis for the paying from rice husk to the paddy milling owner and for the transport of rice husk to the boat owner. The unloading system were operated with the electrical and hydraulic devices. The investment cost of the mechanical unloading device was about 400 000 000 VND (14 000 €).

Automatic loading-unloading system consists of five main parts (Fig. 33 and 34):

- System of suction pipe and nozzle equipped with rotary screw,
- Horizontal belt conveying system and vertical bucket belt conveying system,

## 7. Demonstrations

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- The hopper,
- The hydraulic device for opening the bottom lid of the hopper,
- Rice husk amount metering system (electronic scale) and
- Lifting device for raising and lowering suction pipe.



**Figure 33.** Rice husk unloading system at Din Hai steam power plant (Photo By Duc Vu).

Rice husk was loaded from the rice husk hopper to the truck by opening the bottom lid from the hopper by hydraulic cylinder (Fig. 35). The load in the truck trailer was 1.7 tons of rice husks. Distance from the river side to the storage of power plant is about 200 m.

Unloading of rice husk at the Dinh Hai power plant started at 8.40 am 29 March 2012. By 12.40 pm the whole 25 tons of rice husks were transferred to the plant storage. The unloading time lasted 4 hours.

The weight of rice husk in the boat was 23.6 tons measured by the weighing system in the unloading device. The mechanical unloading requires three men to operate the whole system. The total power demand of rice husk loading-unloading system was 35 kW.



**Figure 34.** Unloading of rice husk from the boat with the unloading device. The 25 tons boat (up and left) unloading device – suction pipe, horizontal belt conveyor, vertical bucket conveyor and the hopper (up and right), suction pipe (down and left) and suction nozzle (down and right). (Photos by Duc Vu and Arvo Leinonen).



**Figure 35.** Transport of the rice husk from the river side into the covered storage at power plant (Photos by Duc Vu and Arvo Leinonen).

### **The capacity of different working phases in rice husk supply**

In the demonstration the loading time of rice husks into boat was three hours and the real loading capacity was so 7.9 tons per hour by seven men. The boat had to wait flood tide for three hours. Transport time of rice husk by boat was eight hours. The speed of the boat in transport will full load was 9.4 km/h. The unloading time of rice husks from boat to the storage at the power plant were 4 hours and the real unloading capacity 5.9 tons/h. The whole journey lasted without delay 19 hours taking into account the return to rice mill. The boat transport capacity (including all working phases) in the demonstration was 1.25 tons/h.

Earlier in the project the measured loading capacity with the mechanical screw was 7.5 tons hour. The manual loading capacity with seven men is nearly the same, 7.9 tons per hour. The unloading capacity in the earlier studies (Task one and two) has been 0.5 tons/h with one man. The capacity of the mechanical unloading device (5.9 tons/h) was 12 times higher than that. We have to notice that two men are needed to operate the mechanical unloading device. The transport capacity of 15 tons boat is about 1.1 tons/h including two ways transport, loading and unloading working phases. In the demonstration the capacity with 25 tons boat were 14% bigger than with smaller boat (15 tons). The transport capacity depends on how many men are used for loading and unloading.

### 7.2.3 Rice husk transportation costs

#### Boat transport and unloading costs

In the supply costs calculation it has been used the same calculation model as in case study (task three). The initial figures have been checked on the basis of the demonstration results (Table 7). The calculated transport costs of rice husk using 25 tons boat with the mechanical unloading device are presented in Table 8. In the same table it has also been presented the transport costs using 15 tons boat and manual unloading.

Based on the cost calculation the rice husk transport costs are about 451 299 VND/ton (15.8 €/ton) by 25 tons boat and mechanical unloading. In the calculation the price of rice husk was 280 VND/kg and transportation distance 75 km. The share of rice husk purchasing costs are 62 %, the share of transport cost are 24%, the share of loading costs are 8 %, the share of unloading costs 5 % and the share of other costs 1% from the total costs.

The total supply costs are 451 299 VND/ton (15.8 €/ton) using 25 tons boat and mechanical unloading. They are 15% lower than the supply costs (528 318 VND/ton, 18.5 €/ton) using 15 tons boat and manual unloading. The transport costs (111 327 VND/ton, 3.9 €/ton) by 25 tons boat are only about 14 % lower than the transport costs (129 485 VND/ton, 4.5 €/ton) by 15 tons boat.

The unloading costs using the mechanical device are 21 825 VND/ton (0.8 €/ton). They are about 73 % lower than the manual unloading costs (80 000 VND/ton, 2.8 €/ton). Mechanical unloading costs are derived mainly from the labor costs, 13 559 VND/ton (0.5 €/ton). The investment costs for a mechanical unloading device are low, 5 888 VND/ton (0.2 €/ton). The investment costs are low because the capacity in mechanical unloading is high.

The rice husk price has a big impact on rice husk transport costs. At the moment rice husk price is increasing. The presented rice husk transport costs are calculated for the main paddy season. During out of the main paddy season the rice husk transport costs are lower because of the lower rice husk price.

## 7. Demonstrations

**Table 7.** The basic data for the calculation of rice husk supply cost in Vietnam. One € was 28 565 VND in March 2011.

	<b>Current system 15 tons boat Manual unloading</b>	<b>New system 25 tons boat Mechanical unloading</b>
<b>Basic data</b>		
– Price of the boat and diesel engine, VND	200 000 000	450 000 000
– Life time of the boat, a	10	10
– Price of the unloading device, VND	0	400 000 000
– Lifetime of the unloading device, a		20
– Workers work time, h/a	1 750	
– Worker's salary including overheads, VND/h	40 000	40 000
– Interest rate, %	20	20
– Diesel fuel price, VND/l	21 300	21 300
– Motor oil price, VND/l	300 000	300 000
– Depreciation degree, %	20	20
– Depreciation value of the boat, VND	21 474 000	48 318 000
– Depreciation value of the unloading device, VND		3 689 000
– Average boat speed, km/h	15.0	12.5
– Average fuel consumption of diesel, l/km	0.35	0.50
– Motor oil consumption, l/h	0.001	0.001
– Boat transport capacity, ton/a	4 861	6 731
– Boat transport time, h/a	5 250	5 250
– Transport distance, km	75	75
– Time for one load, h	16.2	19.5
– Insurance and registration for the boat, VND/a	4 000 000	6 500 000
– Administration (office etc.) costs, VND/a	12 000 000	12 000 000
– Repair and maintenance of the boat, VND/a (2.0 % from the investment)	4 000 000	9 000 000
– Repair and maintenance of unloading device (2.0 % from the investments), VND/a	0	8 000 000
– Manual loading capacity, ton/h/man	1.1	1.1
– Unloading capacity, ton/h	0.5	5.9



**Table 8.** The results from the calculation of rice husk supply costs by boat in Vietnam. Net calorific value of rice husk is 3.3 MWh/ton. One MWh = 3.6 MJ. One € was 28 565 VND in March 2011.

	<b>Current system 15 t boat Manual unloading</b>	<b>New system 25 t boat Mechanical unloading</b>	<b>Remarks</b>
<b>Rice husk price</b>			
– During the main season, VND/ton	<b>280 000</b>	<b>280 000</b>	
<b>Loading – working phase</b>			
– Loading costs, VND/ton	<b>36 364</b>	<b>36 364</b>	Seven men
<b>Transport – working phase</b>			
– Capital costs, VND/ton	3 673	5 968	three shifts/1 man per shift
– Interest cost, VND/ton	3 673	5 968	
– Diesel oil costs, VND/ton	74 303	64 083	
– Motor oil costs, VND/ton	2 990	1 805	
– Salary costs, VND/ton	43 200	31 200	
– Repair and maintenance, VND/ton	823	1 337	
– Insurance, VND/ton	823	966	
– <b>Total, VND/ton</b>	<b>129 485</b>	<b>111 327</b>	
<b>Unloading – working phase</b>			
– Capital + interest costs, VND/ton		<b>5 888</b>	7 men(15 ton)
– Insurance + maintenance, VND/ton		<b>2 378</b>	2 men(25 ton)
– Salary cost, VND/ton	<b>80 000</b>	<b>13 559</b>	
– Total, VND/ton		<b>21 825</b>	
<b>Overhead costs</b>			
– Administration costs (office etc.), VND/ton	<b>2 469</b>	<b>1 783</b>	
<b>Total costs</b>			
– Total costs of rice husk, VND/ton	<b>528 318</b>	<b>451 299</b>	
– Total costs of rice husk, VND/MWh	<b>160 096</b>	<b>136 757</b>	
– Total costs of rice husk, VND/GJ	<b>44 471</b>	<b>37 988</b>	

### Truck transport costs

In the demonstration the target was also to demonstrate the truck transport of rice husk to the power plant. This was not possible because the road regulations in the area did not allow to do this. However, the truck transport costs were calculated (Table 9 and 10). The total weight of the truck in the calculation was 40 tons. In the truck the trailer capacity is 55 m<sup>3</sup> and the rice husk transport capacity 5.5 tons. The price of the truck is 2.5 billion VND. Annual maintenance costs are about 50 million VND. The transport distance is 100 km.

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Calculation results indicate that when transporting rice husks by 40 tons truck supply costs are high, about 704 117 VND/ton (24.6 €/ton). The total supply costs by truck are about 56 % higher than the supply costs by 25 tons boat (451 299 VND/ton, 15.8 €/ton). However the transport costs by truck (363 941 VND/ton, 12.7 €/ton) are more than three times higher than the transport cost by 25 tons boat (111 327 VND/ton, 3.9 €/ton).

The 40 tons truck with a 55 m<sup>3</sup> trailer can transport only about 5.5 tons of rice husks because the specific weight of rice husks is low (about 100 kg/m<sup>3</sup>). This is the reason for high transportation costs. One point needed to be noted is that transport by water way in Cuu Long river delta is very convenient and transport distance by water way (75 km) is significantly shorter than by road way (100 km).

**Table 9.** The basic data for the calculation of rice husk supply costs by truck in Vietnam. One € was 28 565 VND in March 2011.

	Truck transport
<b>Basic data</b>	
– Price of truck (40 ton), VND	2 520 000 000
– Life time of the truck, a	10
– Truck volume, m <sup>3</sup>	55
– Truck payload with rice husk, tons	5.5
– Transport distance (one way), km	100
– Workers work time, h/a	1 750
– Truck average speed, km/h	70
– Manual loading capacity, ton/h/man	1.1
– Mechanical unloading capacity, ton/h	5.9
– Transport time including loading and unloading for one load, h	4.78
– Truck transport capacity, ton/h	1.15
– Truck transport capacity, ton/a	6040
– Worker's salary including overheads, VND/h	40 000
– Interest rate, %	20
– Diesel fuel price, VND/l	21 300
– Motor oil price, VND/l	300 000
– Depreciation degree, %	20
– Depreciation value of the truck, VND	89 000 000
– Fuel consumption of diesel engine, l/km	0.30
– Motor oil consumption, l/100 km	0.0005
– Insurance for the truck and registration, VND/a	50 000 000
– Repair and maintenance of the truck, 2.0 % from the investments, VND/a	50 000 000
– Administration, VND/a	12 000 000

**Table 10.** The results from the calculation of rice husk supply costs by truck in Vietnam. Net calorific value of rice husk is 3.3 MWh. One MWh = 3.6 GJ. One € was 28 565 VND in March 2011.

	<b>55 m<sup>3</sup> truck No tipping device</b>	<b>Remarks</b>
<b>Rice husk price</b>		
– During the season, VND/ton	<b>280 000</b>	
<b>Loading – working phase</b>		
– Loading costs, VND/ton	<b>36 364</b>	Manual, five men
<b>Transport – working phase</b>		
– Capital costs, VND/ton	37 257	Three shifts, one man per shift
– Interest cost, VND/ton	37 257	
– Diesel oil costs, VND/ton	232 490	
– Motor oil costs, VND/ton	5 458	
– Salary costs, VND/ton	34 783	
– Repair and maintenance, VND/ton	8 348	
– Insurance, VND/ton	8 348	
– <b>Total, VND/ton</b>	<b>363 941</b>	
<b>Unloading – working phase</b>		
– Unloading costs, VND/ton	<b>21 825</b>	Unloading costs are evaluated to be the same as in boat transport (25 ton)
<b>Overhead costs</b>		
– Administration costs (office etc.), VND/ton	<b>1 988</b>	
<b>Total costs</b>		
– Total costs of rice husk, VND/ton	<b>704 117</b>	
– Total costs of rice husk, VND/MWh	<b>213 369</b>	
– Total costs of rice husk, VND/GJ	<b>59 269</b>	

#### 7.2.4 Conclusions

At the moment it is economical to use boats for rice husk transport. The total rice husk supply costs by truck are about 56% higher than the supply costs by 25 tons boat. The transport costs by truck are more than three times higher than the transport cost by 25 tons boat.

It is more economical to use bigger boats (25 tons) for rice husk transport than the small boats (15 tons). The transport costs (111 327 VND/ton, 3.9 €/ton) using bigger boats (25 tons) are 14% lower than the costs with the small boats (129 485 VND/ton, 4.5 €/ton).

It is economical to invest for the mechanical unloading device at the power plant. The unloading costs using mechanical device are about 21 825 VND/ton (0.8 €/ton) and using manual unloading the costs are about 80 000 VND/ton (2.8 €/ton).

The total supply costs (451 299 VND/ton, 15.8 €/ton) using 25 tons boat and mechanical unloading are 15% lower than the supply costs (528 318 VND/ton, 18.5 €/ton) using 15 tons boat and manual unloading.

### **7.3 Demonstration of the combustion mixed biomass fuels in CHP plant**

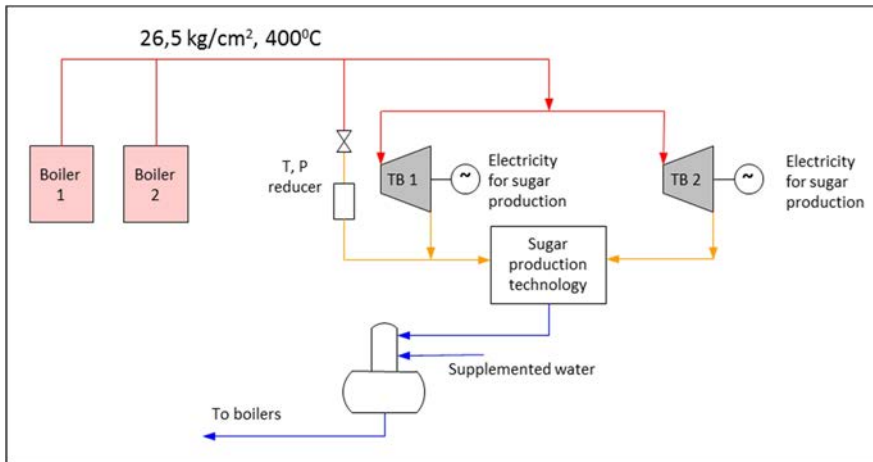
#### **7.3.1 Objective of the demonstration**

The sugar mills in Vietnam have CHP plants producing electricity and steam from processing by-product bagasse for the mill (Fig. 36). The sugar mills in Vietnam are operating six months (from the end October to the end of April) every year. That is why also the CHP plants are closed for the summer months.

The target in the demonstration study was to evaluate how to expand the operating time of CHP plants in sugar mills for year-round by using surplus bagasse with rice husk as a fuel. The need for low pressure steam is not needed in the sugar mill during the summer time. That is why the target in sugar mill would be to sell electricity for the national grid and steam for the companies in the neighbourhood during the summer time. This would need additional investments for the boiler and electricity system.

The demonstration was made at Ben Tre Sugar mill. The rice husk supply to the sugar mill, storage of rice husk at sugar mill, mixing rice husk with bagasse and combustion of rice husk together with bagasse were studied in the demonstration study. Two mixtures of rice husk and bagasse, that were combusted in a CHP boiler, were made in the study. The ratios of rice husk and bagasse in the mixture were 25 % of rice husk and 75 % bagasse and 50 % of rice husk and 50 % of bagasse. Pure bagasse was also combusted by the side of rice husk and bagasse mixtures.

The demonstration of rice husk and bagasse combustion at Ben Tre sugar mill was carried out on Saturday 5 May 2012. The day was at the bend of sugar production season and the sugar plant was not operating with full capacity, so the demand for steam was not high. The day at the end of the season was selected to avoid any possible disturbances in steam production in the plant.



**Figure 36.** Flow chart for steam and electricity production in the sugar mill.

### 7.3.2 The transport and handling of rice husk to CHP-plant

#### Rice husk supply to Ben Tre sugar mill

Bagasse for the fuel mixtures was obtained from the storage of the sugar mill. Rice husk for the test was transported by boat from Cai Be town in Cai Be district in Tien Giang province. The transport distance of rice husk was 50 km (Fig. 37). The rice husk price at that time of demonstration was 500–600 VND/kg.

The consumption of bagasse in each of the two boilers at sugar mill is 12–15 tons/h. The boilers were operating with 50 % capacity in demonstration. It was calculated that there is a need of 24 tons of rice husk for the demonstration.

Rice husk was transported from Cai Be town (point A on the map) by two boats to Ben Tre. One of the two boats were able to carry 16 tons load and the second one 8 tons. The boats were loaded in Cai Be city in 7.5 hours. The total transport time for the boats to come to Ben Tre was nine hours (01:00–10:00 am). The boats had to wait outside Ben Tre sugar mill three hours before they were able to come to the harbour in Ben Tre sugar mill. The Average speed of the boats was about 11 km/h. Rice husks were unloaded from the boat and transported manually to the bagasse storage yard. The storage area was about 100 m from the boat. The total transport time from Cai Be city was all together 15 hours. It took about eight hours for five men to unload the rice husk from the boat (Fig. 38).

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**Figure 37.** Route of rice husks transportation to the Ben Tre sugar mill.



**Figure 38.** Unloading and manual transfer of rice husks from the boat to the bagasse store areas (Photos by Duc Vu).

### Preparation of rice husk and bagasse mixtures

The bagasse consumption of one boiler is about 12.0 tons (90.7 GJ) per hour. The combustion test period was calculated to last about two hours with each three fuel types in two boilers. In the demonstration the need for each fuel type is about 360 GJ (100 MWh).

The rice husks from two boats (8 and 16 tons) were transported into two different heaps in order to help to make the blends of rice husk and bagasse. Eight tons heap of rice husk was used for the fuel blend where the share of bagasse was 75% of bagasse and the share of rice husk 25%. 16 tons heap was used for the blend where the share of bagasse and rice husk was 50%. The share of rice in husk and bagasse in the blends were made based on the energy content. The evaluated amount and energy content of three fuel types in the demonstration are presented in the Table 11.

The weight of full bucket of bagasse in the bulldozer was measured. Based on this weight it was possible to bring the right amount of bagasse (Table 11) into the rice husk heaps to achieve the right shares of rice husk and bagasse in the blends as presented in the Table 11. Finally, the different materials were mixed together thoroughly after all the bagasse and rice husk materials were first put in the same storage (Fig. 39). The mixtures were quite uniform.

The parameters from of the bagasse and rice husk and blends were analysed after the demonstration. The measured parameters from the fuel mixtures are presented in the Table 12. The parameters of rice husk and bagasse are quite the same as the parameters presented in the literature (Table 1). Only the ash content of rice husk (10.1%) is lower than the figure presented in the literature (17–26%).

**Table 11.** Calculated weight and energy content of bagasse and rice husks in the blends for the combustion tests. Net calorific value as received of bagasse was 7.6 GJ/ton (2.1 MWh/ton) and rice husk 11.9 GJ/ton (3.3 MWh/ton).

	Unit	Bagasse	Blend of 75% bagasse and 25% of rice husks	Blend of 50% of bagasse and 50% of rice husks
Weight and energy content of bagasse	ton/GJ (as received)	50.3/380	37.5/285	25.0/190
Weight and energy content of rice husk	ton/GJ (as received)	0/0	8.0/95	16.0/190
Total weight and energy content	ton/GJ (as received)	50.3/380	45.5/380	41.0/380

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**Table 12.** The measured heating values of different fuels used in the demonstration.

	Unit	Pure bagasse	Pure rice husk	Blend of 75 % bagasse and 25 % rice husks	Blend of 50% bagasse and 50% of rice husks
Gross calorific value (dry)	GJ/ton	15.7	14.6	15.5	15.5
Net calorific value (dry)	GJ/ton	15.5	14.5	15.4	15.4
Moisture	wt-%	51.1	6.4	43.7	36.3
Net calorific value as received (wet)	GJ/ton	7.5	13.4	7.6	8.9
Ash content	wt-%	3.1	10.1	4.6	5.3



**Figure 39.** Process of blending bagasse and rice husks (Photos by Duc Vu).



### 7.3.3 Combustion tests at Ben Tre sugar mill

#### Introduction

Three combustion tests were made with bagasse, and with rice husk and bagasse blends. The boiler and turbine parameters were monitored during the combustion test periods (1.5–2.5 h). The monitored boiler parameters were pressure and steam, boiler and flue gas temperature. The parameters were noted every 15 minutes. The combustion tests were made with two boilers and two turbines. The boiler was operating with low capacity during the combustion tests because the demand of the steam for sugar processing was low. The reason for this was the end of sugar production season. This caused difficulties to adjust the boiler capacity.

The mixed fuels were transferred with the bucket of a wheel tractor into the plant conveyor system feeding the fuel to the two boilers (Fig. 40). Results from the experimental combustion tests with three fuel types are shown in Table 13.



**Figure 40.** Feeding fuel to boilers (Photo by Duc Vu).

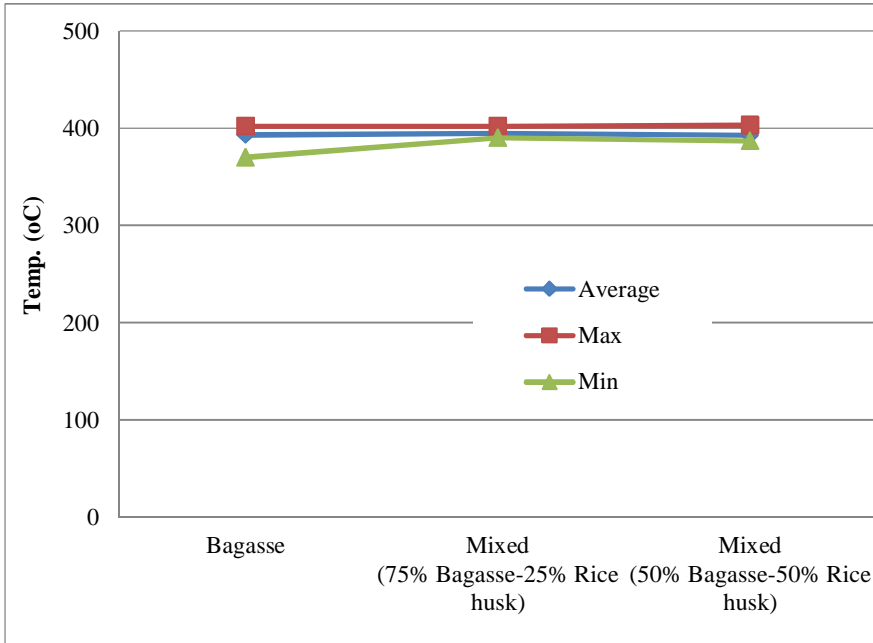
#### The results of the combustion tests

Information of the combustion tests in the boiler one is presented in Table 13 and Figures 41–43. The results from the combustion tests from the boiler two are quite the same as in the boiler one and that is why they are not included in the report.

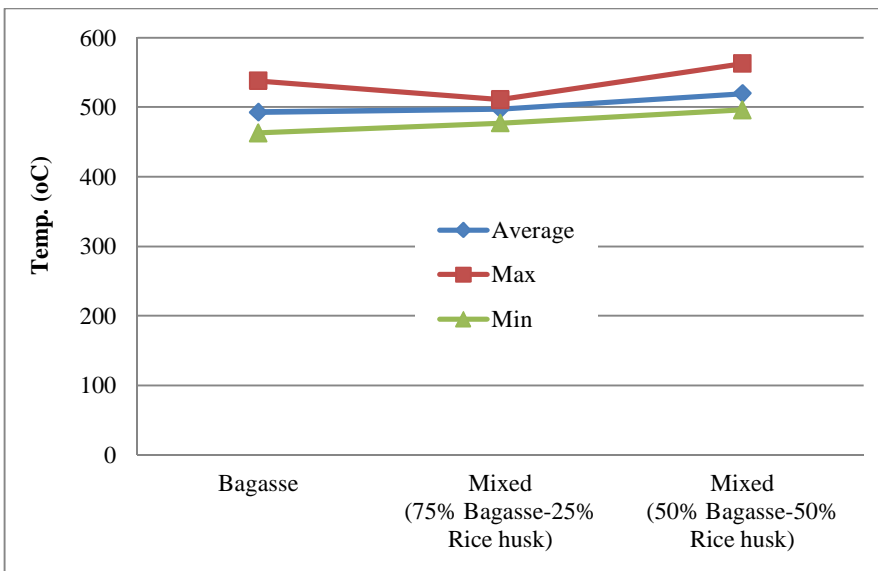
## 7. Demonstrations

**Table 13.** Parameters of the boiler one in the combustion tests.

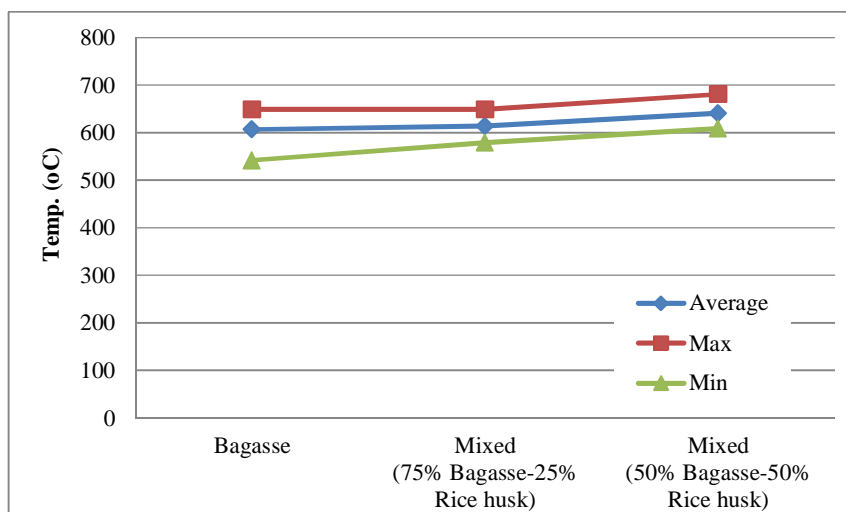
	Unit	Fuel one Bagasse	Fuel two 75% bagasse and 25 % rice husk	Fuel three 50% ba- gasse and 50 % rice husk	
Fuel consumption	ton	30.5	22.75	20	
Time	minutes	150	120	90	
Net calorific value	GJ/ton	7.5	7.6	8.9	
<b>Boiler</b>					
Produced steam	ton	29	21.6	18.9	
Steam pressure	Average	kg/cm <sup>2</sup>	26.7	26.9	26.9
	Highest	kg/cm <sup>2</sup>	27.3	27.3	27.3
	Lowest	kg/cm <sup>2</sup>	25.5	25.5	25.8
Steam temperature	Average	°C	393	394.8	392.6
	Highest	°C	402	402	403
	Lowest	°C	370	390	387
Temperature in furnace	Average	°C	492.8	497	519.6
	Highest	°C	538	511	563
	Lowest	°C	463	477	496
Temperature of flue gas	Average	°C	606.8	613.8	640.9
	Highest	°C	649	649	681
	Lowest	°C	542	579	609
Fuel consumption	t/h	12.20	11.38	13.33	
Steam output	t/h	11.6	10.8	12.6	
Fuel consumption for steam production	tons of biomass / ton of steam	1.05	1.05	1.06	
Fuel consumption for steam production	GJ of biomass / ton of steam	7.9	8.0	9.4	



**Figure 41.** Steam temperature of the boiler one with various biomass fuels.



**Figure 42.** Furnace temperature of boiler one with the various biomass fuels.



**Figure 43.** Temperature of flue gas of the boiler one with the various biomass fuels.

#### The analysis of the combustion tests

In order to ensure the safety for sugar production of the sugar mill, the demonstration of multi-fuel combustion test were carried out at the end of sugar season when steam demand for sugar production is low. Steam output was 10–13 ton/h and the boiler was operating with 50% capacity from the design capacity. Because the boilers were operated at partial load, the fuel consumption for steam production increased compared to the design load. The fuel consumption was in the range of 11–13 t/h in two boilers. The fuel consumption in tons per one ton of produced steam did not vary very much with different fuels, 1.05–1.06. But the fuel consumption in GJ per one ton of produced steam varied quite a lot with different fuels, 7.9–9.4. The lowest consumption was with bagasse and the highest with bagasse (50%) and rice husk (50%) blend.

The important parameters of the boiler such as temperature of superheated steam and furnace temperature are stable and they do not change very much during the tests with different biomass blends. Temperature in the boiler is the highest using bagasse (50%) and rice husk (50%) blend. The reason for this the higher volatile content of rice husk than bagasse. In addition, the situation of fly ash and slagging does not differ from the bagasse combustion. The aerodynamic regime of boiler is still secured.

#### The fuel costs in multi-fuel combustion

The steam production costs in the CHP boilers with different biomass blends used in the demonstration were calculated in the study. In the calculation the bagasse price was estimated to be 300 VND/kg (equal to price of bagasse sold to other

consumers) and the price of rice husks at storage yard 600 VND/kg. The results from the cost of steam production are shown in the Table 14.

The calculation results indicate that the production cost of one ton of steam while burning multi-fuel blend three (50% bagasse and 50 % of rice husk) were the highest, at level of 399 000 VND/ton of steam (14.0 €/ton of steam). The steam production costs are at the lowest while burning bagasse, 315 000 VND/ton of steam (11.0 €/ton of steam). The steam production costs using biomass blend two (75% bagasse and 25% of rice husk) are lightly higher than using bagasse as a fuel, 330 000 VND/ton of steam (11.6 €/ton of steam).

**Table 14.** Estimated fuel costs in steam production (one ton) by various biomass blends. The net calorific value of bagasse ( $Q_{net,ar}$ ) is 7.5 GJ/ton and of rice husk 13.4 GJ/ton. One € was 28 565 VND in March 2011.

	Unit	Fuel one Bagasse	Fuel two 75% bagasse and 25% rice husk	Fuel three 50% bagasse and 50% rice husk
Steam output	ton	1	1	1
Fuel consumption (Table 13)	GJ/steam ton	7.9	8.0	9.4
Energy content and weight of bagasse in the blend	GJ/ton	7.9/1.05	6.0/0.8	4.7/0.63
Energy content and weight of rice husk in the blend	GJ/ton	0/0	2.0/0.15	4.7/0.35
Price of rice husk	VND/ton (€/ton)	600 000 (21.0)		
Price of bagasse	VND/ton (€/ton)	300 000 (10.5)		
Fuel costs	VND/ton steam (€/ton steam)	315 000 (11.0)	330 000 (11.6)	399 000 (14.0)

### 7.3.4 Conclusions

The quality of rice husk and bagasse fuel blends were good. The rice husk and bagasse fuel blends were produced by bulldozer.

Technically rice husks can be burnt with bagasse at various ratios. In the demonstration the share of rice husk in the blend with bagasse was 25% and 50%. The boiler parameters remained stable and they were near while burning bagasse. There were not any sign of fly ash or slagging in the boiler.

Burning of rice husk together with bagasse for electricity generation during summer time at sugar mill is profitable if the price of rice husk is reasonable. The price of rice husk (600 VND/kg, 21.0 €/ton) is higher than the price of bagasse (300 VND/kg, 10.5 €/ton). This means that the fuel costs during summer time are higher than during the main sugar production season.

### **7.4 Biomass pellet production and use as a fuel in industrial boilers**

#### **7.4.1 The target and implementation of the demonstration**

Biomass is used in Vietnam mainly in households and industrial boilers. Rice husk and different kinds of agricultural residues are utilized in furnaces and boilers in industry to produce heat and steam for the company needs. The use of biomass in industrial boilers is going to increase in the near future because biomass consumption in heat or steam production is the most economic.

Biomass pellets are a very good fuel alternative for industrial boilers. The energy content of pellets is high, the transport costs are low and also the feeding of pellets in the boiler is easy to automatize. There is a candy factory in Mekong River Delta that earlier was using wood to produce steam for the malt process. Because of the benefits of the pellets Chinh Thi has constructed recently a new boiler using bagasse pellets as a fuel.

The target in the demonstration was to investigate technology and economy to use biomass pellets in industrial boilers. The study contains the assessment of pellet production, supply and combustion technology and economy. In the demonstration study it was studied three kinds of pellets: bagasse, rice husk and mixed rice husk and bagasse pellets. The pellets were produced in the demonstration at Ben Tre sugar mill using Hong Nhut company's pellet production equipment. The pellets were delivered to the Chin Thi malt factory where they were burnt in the grate boiler. Chin Thi malt factory is located about 5 km from Ben Tre sugar mill. The demonstration was carried out during 3–5 April 2012.

#### **7.4.2 Biomass pellet production**

##### **General information**

In the demonstration study it was produced three different kinds of pellets. These were bagasse, rice husk and blended pellets from bagasse and rice husk (50:50 of weight). Biomass pellets were produced in bagasse pelleting facility of Hong Nhut company (called as 'Hong Nhut') located in the area of Ben Tre sugar company (Ben Tre province) near the bagasse storage of the sugar mill. The working area of Hong Nhut pellet plant is about 200 m<sup>2</sup>. Five men are working at the pellet mill.

Hong Nhut bagasse pellet plant was constructed and put into operation in 2011. There is one pellet production line. At the moment the pellet plant is using bagasse as a raw material for pellet production. Bagasse is coming from the Ben Tre sugar mill. In the future the target is to increase the pellet production capacity if there is demand for the pellets at the market.

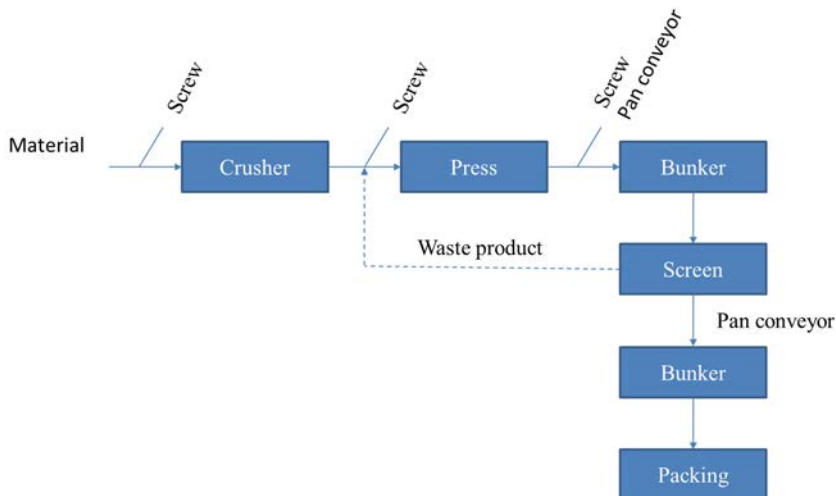
### Pellet production line

The moisture content and grain size of raw material must be suitable for pellet production. The moisture content must be low, 15–20wt-%. The grain size of the raw material for pellet production has to be small, under 5 mm. Hong Nhut is drying bagasse suitable for pellet production on the field outside the pellet facility.

The bagasse pellet production line system consists of many different working phases (Fig. 44). Bagasse must be crushed first for pellet production (Fig. 45). After crushing, bagasse is fed into the pellet press machine by a screw (Fig. 46). Raw material is pressed in the pellet machine into cylindrical pellets with diameter of about 8 mm. The average length of the pellets was 20–30 mm. Some small particles are also produced in the pellet production process.

After pelletizing the pellets and residues are transported into a screening device through the belt conveyor, bucket conveyor and intermediate hopper. Screening machine is a screen plate being in 15° declining angle. The diameter of the holes in the screen is 5 mm. Pellets and small particles from hopper fall on the screen surface, which is vibrated at high frequency (Fig. 47). Pellets are easily moving on declining surface and residues are separated from the pellets fallen down through the screen holes along the way of movement. Pellets which meet standard parameters are transferred by bucket conveyor into the final storage hopper and the residues are returned to pelleting machine. The volume of final storage hopper is about 1.5 m<sup>3</sup>. The pellets can be put into the packages from the storage hopper (Fig. 48).

The design capacity of the pellet machine is 1 000 kg/hour. The total electric capacity of electric motor is about 90 kW. The pellet machine in the demonstration was so called ring die pellet machine. There are small wheels in the centre of the ring ride on the die and force the raw material through the extrusion holes. The following figure illustrates operation principle of biomass pellet production line.



**Figure 44.** Principle diagram of biomass pelleting machine.

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**Figure 45.** Crushing of bagasse (left) and crushed bagasse (right) (Photos by Duc Vu).



**Figure 46.** Pellet press, screw, belt and bucket conveyors and intermediate pellet hopper in pellet production line (left) and ring die of the pellet machine (right) (Photos by Duc Vu).



**Figure 47.** Screening machine of pellets.





**Figure 48.** Packaging of pellets (Photos by Duc Vu).

### **Pellet production**

Bagasse for pellet production was taken from the bagasse store of Hong Nhut facility at Ben Tre sugar mill. The bagasse was dried by solar energy at the backyard of the pellet plant. The moisture content of bagasse before pellet production was 11.7wt-%. Bagasse was crushed before pellet production. All together it was produced about 400 kg of bagasse pellets in the demonstration. The pellet press was not in good condition during the pellet production. All the holes in the die were not totally open. That is why the capacity in bagasse pellet production was low.

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Rice husk pellets were produced like bagasse pellets. It was known that it is not possible to pelletize rice husk without grinding it into very small particles. The crusher located at the bagasse production plant was not suitable for the rice husk grinding. The grain size achieved with the crusher would have been too large. That is why the ground rice husk for the pellet production was bought outside the plant. The grain size of the rice husk was very small. It was like powder. The moisture content of rice husk was 16.1wt-%. The target was to increase the moisture content of rice husk over 20% for the pellet production. That is why it was added water into the ground rice husk. The adding was made by spraying water in the rice husk and mixing the water and rice husk together with the shovel (Fig. 49 and 50). The pellet machine was maintained before rice husk pellet production and the machine was in good condition while making rice husk pellets. It was produced totally 430 kg of rice husk pellets.

Ground bagasse and rice husk were blended manually for mixed pellets production. It was produced totally 313 kg of mixed rice husk and bagasse pellets.



**Figure 49.** Increasing moisture to ground rice husks (Photo by Arvo Leinonen).



**Figure 50.** Blending ground bagasse and rice husks (Photo by Duc Vu).

### 7.4.3 The pellet production results and evaluation

#### Productivity

The productivity in pellet production with all raw materials was good, 294–391 kg/h. The productivity of industrial pellet press in Europe is 650–1500 kg/h. The productivity in bagasse pellet production was 331 kg/h, in rice husk pellet production 294 kg/h and in mixed pellet production 391 kg/h. From the low productivity it can be seen the difficulty to make pellets from rice husk. The productivity in bagasse pellet production in the demonstration would have been bigger if the pellet press would have been in good condition. In bagasse pellet production all holes in the die were not open and that is why the productivity remained low. For the mixed pellet production the die holes were opened and that is why the productivity was the highest, 391 kg/h (Fig. 51 and Table 15).

#### Pellet quality

The quality of produced pellets was quite good. The most critical parameter in the International graded pellet standard for non-woody biomass (ISO 17225-6) is moisture. According the raw material classification based on International Standard ISO 17225-1 rice husk is classified under 2.1.1.4 and blend with bagasse

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under 2.1.1.5. In this standard the moisture content must be under 12wt-% for Class A and 15wt-% for Class B pellets. The moisture of bagasse pellets was 5.7wt-% and it meets the Class A limit. The moisture of rice husk (19.4wt-%), which exceeded Class B level and blended (rice husk + bagasse) pellets (13.7wt-%) meets the Class B level.

The ash content (A) of produced pellets was quite high. The ash content of bagasse pellets was 8.6 % (Class B). The ash content of rice husk pellets was 4.1 % (Class A). This is low compared to the ash content figures gathered from literature (17–26%). The ash content of blended (rice husk and bagasse) pellets were 12.7 % (Class B not met). This is more than the ash content of the pure rice husk and bagasse pellets. In Finland the ash content of straw pellets is 4–6 %. The ash content of rice husk used in eth demonstration is very low compared to the figures gathered from the literature (17–26%).

The bulk density (BD) of produced pellets were very good, 675–705 kg/m<sup>3</sup>. In the International graded pellet standard the density of Class A and Class B pellets must be over 600 kg/m<sup>3</sup>. The length of the bagasse pellets were 10–27 mm and the average length 17.9 mm. The length of the rice husk and blended pellets were quite same. Length can met A and B class requirements (< 40 mm).

The net calorific value of non-woody Class A and Class B pellets must be over 14.5 MJ/kg (4.0 kWh/kg). The produced pellets in the study did not meet this limit. According to the laboratory analysis the net calorific value as received ( $Q_{net,as}$ ) of bagasse pellets was 14.2 MJ/kg (3.9 kWh/kg), the net calorific value as received of bagasse and rice husk blended pellet and pure rice husk pellet was 12.2 MJ/kg (3.4 kWh/kg). These figures are quite the same as the net calorific value of straw in 15 % moisture content, 13.0 kWh/kg (3.6 kWh/kg).

In the ISO 17225-6 standard covers pellets produced from cereal straw, miscanthus and reed canary grass (three classes) and Class A and B for other grassy biomass like rice husk. There is mainly one normative (mandatory) threshold value for each property. The properties are not bound with each other. Also analysis methods to be used are listed in the standard. Most of the properties in the ISO 17225-6 standard are normative (mandatory) and only ash melting behaviours is informative (voluntary). In ISO 17225-6 the mandatory properties are diameter (D) and length (L), moisture (M), ash (A), mechanical durability (DU), fine particles (F), additives, net calorific value (Q), bulk density (BD), Nitrogen (N), sulphur (S), chlorine (Cl), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) and Zinc (Zn.) (Alakangas 2013). In ISO 17225-6 product standard of the A class pellets should be  $\leq 12\text{wt}\%$  B class pellets  $\leq 15\text{wt}\%$ . Additives and the amount in the pellets must be stated. Ash content in the pellets can be  $\leq 6\text{wt}\%$  (Class A) or  $\leq 10\text{wt}\%$  (Class B). The mechanical durability (DU97.5) should be  $\geq 97.5\text{wt}\%$  for Class A and DU96.0 ( $>96.0\text{wt}\%$ ) for Class B (Alakangas, 2013).

### Power demand

The demand for power for crusher in bagasse crushing in the demonstration was 0.069 kWh/kg. After crushing, bagasse was fed by the screw into the pellet press machine. The power demand in straw crushing in VTT's research was 0.16 kWh/kg (Hurskainen et al. 2011). The power demand for pellet press was in the demonstration 0.13 kWh/kg. In VTT's research the average power demand in pellet production is 0.083 kWh/kg.



**Figure 51.** Biomass pellets – Rice husk pellet (left), bagasse-rice husk mixture pellets (center) and bagasse pellet (right) (Photo by Duc Vu).

**Table 15.** Results of different biomass pellet production tests.

	Unit	Bagasse pellets	Bagasse and rice husk pellets	Rice husk pellets
Density of raw material	kg/m <sup>3</sup>	109.0	257	443
Moisture content of raw material	wt-%	11.7	13.7	16.1
Weight of produced pellets (not including residues)	kg	386.1	313	426.6
Weight of residues and loss	kg	72.3	75.1	73.4
Moisture content of pellets	wt-%	5.7	13.7	19.4
Net calorific value, dry	MJ/kg	15.1	14.5	15.7
Net calorific value as received	MJ/kg	14.2	12.2	12.2
Ash content of pellets	%	8.6	12.7	4.1
Bulk density of pellets	kg/m <sup>3</sup>	705	675.0	700
Pelletizing time	min	70	48	87
Pellet production capacity	kg/h	330.9	391.3	294.2

### 7.4.4 Pellet production costs

The investment costs of Hong Nhut company's bagasse pellet production line are about 900 million VND. Construction costs of the pellet plant were about 100 million VND. At present there are five permanent workers at the plant. Working time is eight hours per day and about 22 days per month. Worker's salary is about 7 million VND/month. In the calculation it assumed that all raw-material can be used for pellet production. The fine material sieved from the produced pellets can be used again for pellet production.

Bagasse for the pellet production is coming from Tre sugar company. The price of bagasse was 300 VND/kg (10.5 €/ton). As mentioned earlier Hong Nhut company has not produced rice husk pellets earlier. In the demonstration the ground husk was bought from a company located about 60 km away from the pellet factory. The price of rice husk in the demonstration was relatively high, 1 400 VND/kg (49 €/ton). The reasons for the high rice husk price were long transport distance and small supplied amount of rice husk. It was estimated that the grinding costs of rice husk at the Hiong Nhut pellet factory would be 200 VND/kg (7.0 €/ton). The rice husk price at that time of demonstration was 500–600 VND/kg (17.5–21.0 €/ton) at the plant. The total costs of ground rice husk would be 800 VND/kg (28 €/ton) at the pellet plant.

In the cost calculation it has been used the figures of capacity, power demand and heating values and etc. obtained from the demonstration (Table 16).

On the basis of the calculation, the production costs of bagasse pellets are the cheapest, 1 467 VND/kg (51.3 €/ton) (Table 17). The most expensive is to produce rice husk pellets, 1 968 VND/kg (68.9 €/ton). Rice husk pellete are 34% more expensive than the bagasse pellets. The mixed pellet production costs are between rice and bagasse pellets, 1 532 VND/kg (53.6 €/ton). The main reason for the high production cost of rice husk and mixed pellets is the higher price of rice husk. The price of rice husk is more than two times more expensive than bagasse.

The production costs of bagasse pellets are also the lowest if presenting the production costs per energy unit, 103.3 VND/MJ (3.6 €/GJ). In this case the production costs of rice husk pellets (161.3 VND/MJ) are about 56% higher than the bagasse pellets. The main reason for this the high moisture content of rice husk pellets (19.4wt-%). The moisture content of bagasse pellets were 5.7wt-%.

**Table 16.** The basic data for biomass pellet production costs calculation. One € was 28 565 VND in March 2011.

Expenses	Unit	Bagasse	Bagasse (50%) and rice husk (50%)	Rice husk
Pellet production capacity	kg/h	330.9	391.3	294.2
Operation time of the plant	hour/year	3500	3500	3500
Pellet output	ton/year	1158.1	1369.5	1029.7
Price of raw material	VND/kg	300	550	800
<b>Total raw material costs</b>	<b>VND million/year</b>	<b>347.4</b>	<b>753.2</b>	<b>8237.6</b>
Electric consumption - crushing and pelletizing	kWh/ton	199	164.5	130
Price of Electricity	VND/kWh	1304	1304	1304
<b>Electricity cost</b>	<b>VND million/year</b>	<b>300.5</b>	<b>293.7</b>	<b>174.5</b>
Investment costs of pellet production system	VND million	900	900	900
Investment costs for the plant (building and infrastructure)	VND million	100	100	100
Maintenance costs	VND million/year	20	20	20
Management	VND million/year	140	140	140
Insurance	VND million/year	20	20	20
Plant's lifetime	year	20	20	20
Machines' lifetime	year	10	10	10
<b>Labor cost</b>	<b>VND million/year</b>	<b>700</b>	<b>700</b>	<b>700</b>
Number of workers	person	10	10	10

**Table 17.** Estimated different biomass pellet production costs.

Expenses	Unit	Bagasse	Bagasse and rice husk	Rice husk
Production Capacity	kg/h	330.9	391.3	294.2
Pellet output	ton/year	1158.1	1369.5	1029.7
Heating value as received (wet)	MJ/kg	14.2	12.2	12.2
<b>Cost for the material</b>	VND million/year	347.4	753.2	823.7
<b>Electricity cost</b>	VND million /year	300.5	293.7	174.5
<b>Capital costs of pellet production system</b> – investment and interest	VND million /year	160.7	160.7	160.7
<b>Capital costs of the of plant</b> – Investment and interest	VND million /year	9.9	9.9	9.9
<b>Labor cost</b>	VND million /year	700	700	700
<b>Maintenance cost</b>	VND million /year	20	20	20
<b>Insurance</b>	VND million /year	20	20	20
<b>Management</b>	VND million /year	140	140	140
<b>Total cost</b>	<b>VND million/year</b>	<b>1 698.5</b>	<b>2 097.7</b>	<b>2 026.1</b>
<b>Pellet production costs</b>	<b>VND/kg</b>	<b>1 466.5</b>	<b>1 531.5</b>	<b>1967.6</b>
	<b>VND/MJ</b>	<b>103.3</b>	<b>125.5</b>	<b>161.3</b>
	<b>VND/kWh(€/MWh)</b>	<b>371.9 (13.0)</b>	<b>451.8 (15.8)</b>	<b>580.7 (20.3)</b>

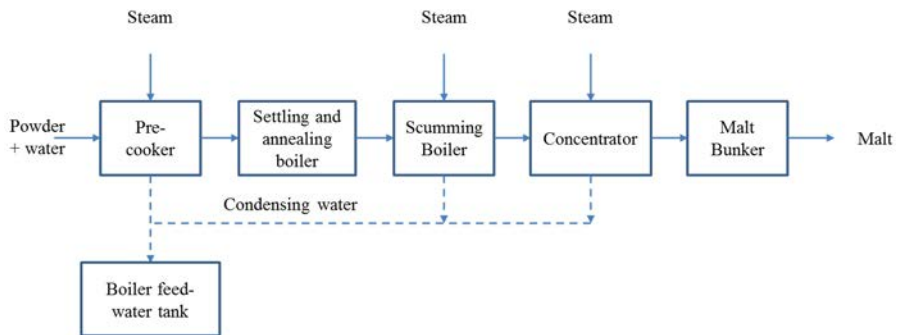
#### 7.4.5 Combustion of biomass pellets at industrial steam boiler

##### Basic information

The combustion tests with the pellets were made at Chin Thi malt plant in An Hiep -commune in Chau Thanh – district. The factory is about two km from Hong Nhut company. Chin Thi malt plant uses industrial steam. The steam is produced in eth boiler with the capacity of one ton steam per hour. The boiler is designed for burning biomass pellets as fuel. Boiler produces saturated steam in working pressure 7 kg/cm<sup>2</sup>. The designed pressure of the boiler is 10 bar. Saturated steam is used for cooking flour and solidification in malt production. Technological diagram of malt production is shown in the following Figure 52.

Bagasse pellets are used at the moment in the steam boiler at Chin Thi malt plant. The bagasse pellets are bought from the Ben Tre sugar mill. Earlier in the old boiler it was used firewood. The cost of firewood use for energy in Chin Thi malt factory was 4 000 000 VND per day. At the moment using bagasse pellet costs are about 2 500 000 VND per day.





**Figure 52.** Technological diagram of malt production.

Main parameters of boiler (Fig. 53):

- Boiler type: fixed grate
- Fuel type: biomass pellets (bagasse)
- Design capacity: 1 ton of steam/hour
- Designed pressure: 10 bar
- Working pressure: 7 kg/cm<sup>2</sup>
- Boiler efficiency: 85%.



**Figure 53.** Boiler burning pellets in Chin Thi malt plant (Photo by Duc Vu).

### Implementation of the combustion in the demonstration

The pellets produced in the demonstration were transported by truck to the malt factory (Fig. 54). The weight of the pellets was measured before feeding pellets into the hopper located under the boiler (Fig. 55 and Fig. 56). From the hopper the pellets were conveyed by bucket conveyor to the fuel hopper two. The fuel is automatically fed from the second hopper into the boiler according to the pressure of the boiler. When boiler's pressure has fallen to about  $5.5 \text{ kg/cm}^2$  the feeding of the fuel into the boiler started. Fuel feeding process ends when boiler's pressure reaches working pressure of  $7 \text{ kg/cm}^2$ .



**Figure 54.** The pellets were transported from the pellet factory to the Chinh Thi malt factory by the small truck (Photo by Arvo Leinonen).



**Figure 55.** Measuring the weight of pellets before burning (Photo by Duc Vu).



**Figure 56.** Feeding pellets to the first hopper (Photo by Duc Vu).

### Results from the combustion tests

Monitoring of the combustion tests with the pellets in the steam boiler was mainly carried out visually. Any measurements from the boiler were not carried out. During the tests it was burnt 87 kg of bagasse pellets, 146 kg of mixed pellets (bagasse and rice husk) and 152 kg of rice husk pellets (Table 18). The total combustion time with the pellets was about three hours. Because of the lower heating value of rice husk the specific fuel consumption with eth rice husk pellets and mixed pellets were higher than with bagasse pellets.

Length of the flame when burning rice husk pellets was the highest, and shortest with bagasse pellets. The flame of the rice husk pellet burning was whiter than in case of burning other pellets. This is due to the highest volatile content in rice husk pellets (Fig. 57).

The operator of the boiler has to remove ash from the boiler once an hour (Fig. 58). According to observation the ash forms big pieces on boiler's grates (Fig. 59). This hinders to supply air into the combustion chamber reducing heat exchange capability and reducing boiler's efficiency.

In rice husk pellet burning the ash forming happens fastest because the ash content in the rice husk pellet is higher than in the other pellets. Therefore while designing the boiler for rice husk combustion must be paid special attention to the ash slagging possibility.



**Figure 57.** Biomass pellets burning in the steam boiler (Photo by Arvo Leinonen).



**Figure 58.** Manual ash disposal from the boiler (Photo by Duc Vu).



**Figure 59.** Ash from biomass pellet combustion (Photo by Arvo Leinonen).

**Table 18.** Results of the combustion tests in steam boiler.

	<b>Unit</b>	<b>Bagasse pellets</b>	<b>Bagasse + rice husk pellets</b>	<b>Rice husk pellets</b>
Consumption amount	kg	87.4	145.8	152.4
Burning time	minutes	55	75	83
Specific fuel consumption	kg/h	95.3	116.6	110.2

### 7.4.6 Conclusions of pellet production and use in industrial boilers

It is possible to produce good pellets from bagasse, rice husk and from bagasse and rice husk mixtures. The most challenging material for pellet production is rice husk.

The rice husk pellets (161.3 VND/MJ, 20.3 €/MWh ) are more expensive than bagasse pellets (103.3 VND/MJ, 13.0 €/MWh). The most important factor for this is the higher price of rice husk raw material than the bagasse.

It is economical to use of pellets in industrial boilers. The fuel costs in steam production with the bagasse pellets are about 40 % lower than using traditional firewood.

Special attention has to be paid to design the boiler for rice husk.

## 8. Summary

### Project

The project 'Development and demonstration of multi fuel supply chain for power plants and industrial boilers in Vietnam is a part of The Energy and Environment Partnership Programme in the Mekong Region (EEP Mekong).

The main objective of the project was to develop and demonstrate the effective and reliable biomass supply chain based on multi fuels for the CHP plants and industrial boilers. First in the project the current supply technologies and supply costs were analysed in Vietnam. In the second phase five theoretical case studies were carried out based on the current supply technology analysis. The target of the case studies was to assess the potential in developing new biomass supply technologies. The analysis of the case studies covered technology and economical assessment. Altogether five case studies were analysed. In the third phase three case studies were selected for the practical demonstrations. The target of these demonstrations was to verify the results of the theoretical case studies in practice.

The project was carried out by the Vietnamese Institute of Energy (IE) with Technical Research Centre of Finland (VTT) during 2011–2012.

### Biomass resources in Vietnam

Based on the EEP multi-biomass project the total biomass potential for energy production in Vietnam is about 104.4 million tons in 2010. This means about 374 TWh (1346 PJ) of energy production potential every year. The main biomass fuel resources are paddy straw (32.1% from total energy potential) and firewood (30.3%). Also there are available many other biomass like rice husk (6.6%), maize trash (18.5%), bagasse (4.0%) and cane trash (2.8%), cassava stem (2.6%), peanut shell (0.2%), coconut shells (0.1%), coffee husk (0.5%) and wood residues from sawmills (2.3%). A lot of biomass is utilised for energy and other purposes at the moment. The total surplus of biomass was 22.8 million tons in 2010. The share of agro-biomass from the surplus was 82% and the rest (18%) is wood biomass.

### **Biomass use for energy**

In 2005, the total biomass used for energy production was 583.3 PJ (162.0 TWh) of which 366.3 PJ (101.8 TWh) was fuel wood (62.8%) and the remaining 217 PJ (60.3 TWh) different agro-biomass residues. Fuel wood consists of firewood and wood residues from wood processing plants. Household sector accounted for 75.8% of the total biomass consumption. The remaining 24.2% of biomass was consumed by small industries and by sugar mills in their CHP plants. The share of biomass (583.3 PJ) from the total primary energy consumption (606 TWh) in 2005 was 27% which is a very high figure. The total primary energy consumption in Vietnam has increased rapidly during the last few years. The total primary energy consumption in Vietnam was 2682 PJ (745 TWh) in 2009. The use of biomass has not increased as fast as the total energy consumption. That is why the share of biomass from total energy consumption has decreased during the last years.

### **Development of biomass use for energy**

At the moment biomass is economical in Vietnam in heat production in industrial factories. The use of biomass in industrial boilers should be increased and supported.

At the moment there is only one very small *rice husk* power plant in operation in Vietnam, and many other power plants that are under developments phase in different part of Vietnam. The main fuel in these power plants will be rice husk. The main barrier for biomass plant investment at the moment is the low electricity price in Vietnam.

In Vietnam there is also potential to increase the use of bagasse for power production. The use of these boilers should be extended outside the sugar production season. One of the main problems is the low electricity price.

### **The current rice husk supply technology to the power plant**

Rice mills in the Mekong River Delta are mainly located along rivers so it is convenient to transport rice husks by boat to the power plants. The boats are loaded with rice husk with conveyors. The load of rice husk in the boat varies from 10–20 tons (100–200 loose-m<sup>3</sup>). The loading at rice mills is normally carried out by mechanical conveyors. The loading time is about 2–3 hours using 15 ton boat. The boats used for rice husk are original wooden boats. The price of new boat (15 tons) is about 200 million dong. The average transport distance of rice husk to the user is about 40 km. By boat it takes 1–2 days to deliver one load to power plant.

The rice husk is unloaded and transferred from the boat by buckets. The unloading time is about 4 hours with seven men. If the boiler is not located near a canal, the rice husk must be transferred e.g. by trucks to power plant as it is made in Dinh Hai power plant. At the power plant rice husk is stored. Storing of rice husk is necessary because rice husk is not available or it is expensive outside of rice harvesting season.



The rice husk price in the main season is 150–250 VND/kg (5.3–8.8 €/ton) and beyond the main paddy season it is 350–450 VND/ton (12.3–15.8 €/ton) at the power plant.

### **Development of rice husk supply technology – case studies**

The target in *the first feasibility study* was to evaluate the technology and economy to develop rice husk transport by using bigger boats and trucks and secondly to develop the biomass unloading working phase at power plant by mechanical equipment. The study was made as a case study at Dinh Hai power plant in Can Tho province. Based on the cost calculations, the rice husk transport costs can be decreased by 20% using bigger boats (25 tons) and by using the mechanical unloading system compared to the 15 tons boat transport and manual unloading. The truck transport is not competitive at the moment with boat transport. However there is a lot potential to develop truck transport of rice husk.

The target in *the second feasibility study* was to evaluate the economy to expand the operating time of CHP plants in sugar mills for year-round. The study was made as a case study at Ben Tre Sugar mill in Ben Tre province in Mekong River Delta region. The study has been concentrated on biomass availability, biomass supply and storage at power plant. Currently there is not enough surplus bagasse at Ben Tre sugar mill to operate CHP plant in Ben Tre sugar mill over the summer time. While there is a lot of rice husk available in Mekong River Delta region rice husk is the best additional fuel for the CHP to operate year-round. Based on the literature review there will not arise any problems in co-firing rice husk and bagasse in the CHP boiler.

The target in *the third feasibility study* was to investigate the technology and economy of using biomass pellets in industrial boilers. The study was made as a case study in Chin Thi candy factory near Ben Tre sugar mill. Biomass pellets are a very good fuel alternative for industrial boilers. The energy content of pellets is high, the transport costs are low and also the feeding of pellets in the boiler is easy to automatize. In the study the pellet production costs were calculated. Based on the study rice husk and bagasse pellets are very attractive fuels for industrial boilers, where the use of biomass is increased in the future.

The target of *the fourth feasibility study* was to develop purchase contract in order to secure the biomass supply. The biomass plant is designed to operate over 30 years. That is why the biomass supply for the power plant must be reliable from year to year in all circumstances. At the moment the purchase contract between biomass dealer and the customer is made in general level. The development of purchase contract is made on the basis of experiences of purchase contract used in Finland. The study is based on the current contract used in Dinh Hai steam power plant. The Finnish contract model could be used as the basis for the contract used in Vietnam. It is important that the contract is long enough 1–2 years, to agree the delivery season and different delivery batches in different periods within the season and to agree about the biomass quality in the contract.

## 8. Summary

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The target of *the fifth case study* was to evaluate the buffer storage system for biomass reliable delivery to power plants around the year. The study is made as case study in Dinh hai power plant. The main biomass fuels in Vietnam are agriculture-based fuels. That is why the biomass like rice husk and bagasse are generated periodically depending the harvesting season of the crops. On the other hand, the power plants are operating around the year. In order to deliver biomass fuels to power plant reliably around the year there must be buffer storages of biomass in Vietnam. Currently the biomass users have their own buffer storages at power plant and also at industrial boilers. The rice husk storages are covered with canvas or they are located in the constructed storage places having a roof. At sugar mills bagasse storages are not covered.

### **Demonstrations**

Three case studies were selected for demonstration in practice. The target was to verify the findings of case studies in practice. The case studies were 'New effective biomass supply system', 'Multi biomass fuel supply and combustion in power plant' and 'Biomass pellet production and use in industrial boilers'. The demonstrations were made together with companies.

#### **Demonstration of new effective biomass supply system**

In the demonstration of 'New effective biomass supply system' the target was to assess the use of bigger boats (25 tons) for rice husk transportation to a power plant and secondly to assess the use of a new mechanical unloading device for rice husk unloading at power plant. The target was to decrease the transport costs by the new technologies. In the demonstration, one 25 ton load of rice husk was transported by boat to Dinh Hai steam power plant. The whole load was unloaded by pneumatic unloading device. The targets were achieved in the demonstration. Based on the cost calculation the rice husk supply costs with 25 tons boat and mechanical unloading are 15% lower than the supply costs using 15 tons boat and manual unloading. Especially unloading costs are 73 % lower than manual unloading costs. Currently truck transport is not competitive with boat transport of rice husk.

#### **Demonstration of Multi-biomass fuel supply and combustion in power plant**

The demonstration of 'Multi-biomass fuel supply and combustion in power plant' was made in Ben Tre Sugar mill. The target in the demonstration study was to evaluate to possibilities to expand the operating time of CHP plants in sugar mills for year-round by using surplus bagasse with rice husk as a fuel. Two mixtures of rice husk and bagasse were combusted the CHP boiler. The share of rice husk in the fuel mixtures were 25% and 50% of rice husk. In the demonstration it was burnt pure bagasse beside the rice husk and bagasse blends. All together 24 tons of rice husk was transported with two boats to the Ben Tre sugar mill. The fuel mixtures were made by bulldozer mixing the different fuels with each other.

The combustion tests showed that there is not any difficulty in using rice husk and bagasse together in the boilers. The boiler parameters were stable during the combustion. Burning of rice husk together with bagasse for electricity generation during summer time at sugar mill is profitable if the price of rice husk is reasonable. The price of rice husk is nearly two times higher than the price of bagasse. This means that the fuel costs during summer time are higher than during the main sugar production season.

### **Demonstration of biomass pellet production and use in industrial boilers**

The target in the demonstration of 'Biomass pellet production and use in industrial boilers' was to investigate technology and economy of using biomass pellets in industrial boilers in order to replace the using fossil fuel (e.g. coal and oil). The study contains the assessment of pellet production, supply and combustion technology and economy. In the demonstration study it was studied three kinds of pellets: bagasse, rice husk and mixed rice husk and bagasse pellets (50% rice husk and 50% bagasse). The pellets were produced for the demonstration at Ben Tre sugar mill using Hong Nhut company's pellet production equipment. The pellets were delivered to the Chin Thi malt factory where they were combusted in a grate boiler. From the results in the demonstration it can be seen that the productivity in pellet production and the quality of produced pellets were good. The production cost of bagasse pellets were the cheapest, 103.3 VND/MJ (13.0 €/MWh). The combustion tests with the pellets in the steam boiler were monitored. The conclusion from the demonstration was that it is economical and technical feasible to use of pellets in industrial boiler. The fuel costs in steam production with the bagasse pellets would be about 40 % lower than using traditional firewood.

### **The project results are disseminated largely**

The results of the demonstrations were presented to the biomass companies in a Biomass forum organised on 17<sup>th</sup> of August 2012. The seminar was organized together with the Department of Industry and Trade of HCM City. Many participants from agencies and companies from energy, electricity and biomass industry participated in the seminar. 20 biomass companies from the southern provinces also participated in the meeting. They were sugar companies, biomass investors and power companies.

The EEP project results have also been presented in the international ENEREXPO held on March 20<sup>th</sup>, 2012 and in the national workshop organised on the 20<sup>th</sup> of December 2012 in Hanoi, Vietnam. The policy makers, biomass traders and investors and energy companies were invited to the workshop. Also the project's new developed technologies were disseminated in the selected Mekong regional workshops and/or seminars in Laos, Thailand and Cambodia.

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# **Appendix 1: Experiences of biomass production and supply in other countries**

## **1.1 Rice husk and other biomass supply in Thailand**

### **1.1.1 Biomass resources in Thailand**

Biomass has been a traditional energy source in rural areas of Thailand for decades. Biomass fuel utilization has increased continuously in households together with country modernization. The domestic production of primary energy in Thailand during 2008 came up to 62 695 ktoe (729 TWh) of which renewable energy renewable energy was 806.4 PJ (224 TWh) (30.7%) (Asia biomass office 2011).

Two major biomasses in Thailand are agricultural side products and wood waste. At present, agro-industry is the most important source of the biomass. The main by-products from agro-industry are rice husk from rice mills, bagasse from sugar mills and fruit bundles, fiber and shells from oil palm mills. Wood industry is also a major source for biomass energy that includes residues from teak logs and rubber wood processing and eucalyptus plantations (Papong et al. 2005).

The total biomass potential is about 80.5 million tons in Thailand. The total agro-industrial residue production was about 74.7 million tons per year in 2004 consisting of bagasse (20.4 million tons), cane trash (21.2 million tons), rice husk (6.2 million tons), rice straw (12.0 million tons) and residues from palm oil mills (14.9 million tons). The total available unused agro-industrial residue is about 50 million tons per year. The total wood residue production was estimated to be about 5,8 million tons in 2000.

The unused agricultural and wood residue amount is estimated to be 51.7 million tons. The share of agricultural residues from this is 49.9 million tons and 1.8 million tons of wood residues (Papong et al. 2005).

### **Biomass use for energy**

The total consumption of biomass was 408.2 PJ (113.4 TWh) in 2003 accounting about 50% of the total renewable energy consumption in Thailand. The main biomasses used for energy are wood waste (36% from the total biomass use), bagasse (30%), charcoal (24%) and rice husk (10%).

It was used about 41.7 PJ (11.6 TWh) of rice husk for fuel (final energy) in Thailand in 2004. Rice husk is traditionally used as an energy source through direct combustion in the large rice mills (Papong et al. 2005). Most of the 40 000 rice mills located in Thailand are small and are not suitable to have their own heat production. The 3 MW power plant using rice husk should require at least 100 tonnes rice paddy/day. There are 360 potential rice mills in Thailand to develop small power plant from their owned biomass supply with a capacity of 100 to 2 000 tonnes of paddy per day.

There were five electricity power plants in Thailand using rice husk as a fuel and selling electricity to the grid in 2008. The average capacities of these power plants were about 11 MW of electricity (Finpro Region Asia 2009).

The consumption of *bagasse* for energy was 121.7 PJ (33.8 TWh) in 2004. The traditional use of *bagasse* is as a fuel in the sugar mill to produce steam for the process and electricity for mills. At the moment sugar mills can sell the excess electricity to the grid (Papong et al. 2005). There were 11 power plants in sugar mills in Thailand in 2008. The average capacity of these power plants was 25 MW (Finpro Region Asia 2009).

Wood residues include chips, bark and sawdust that is produced within various wood-processing industries. The consumption of wood fuels was 146.2 PJ (40.6 TWh) in 2003. The wood residues and charcoal (98.7 PJ) are used in households and small companies in rural area (Papong et al. 2005).

### **Biomass fuel chains in Thailand**

In Table 1/1 it is presented some information of the three rice husk power plants in Thailand. The capacity of the presented power plants is varying from 6–22 MW<sub>e</sub>. The biggest rice husk power plant (22 MW<sub>e</sub>) is using about 700 tons of rice husk per day.

Biomass is transported to the power plant by trucks (Fig. 1/1). There are two kind of trucks used for transport. The fuel consumption of GNG-fuel truck is 20 % lower than with diesel engine truck. Normally power plant does not have any signed contract with fuel supplier.

The rice husk price is 198.0–264.0 VND per kg. The price of rice husk is nearly the same as in Vietnam depending on the season.



**Figure 1/1.** Truck used for rice husk transport in Thailand.



**Table 1/1.** Information of three power plants in Thailand. 1 MWh = 3 600 MJ.

Power plant	Roi-Et Green Co. Ltd.	AT Biopower	Thai Seree
Location	Roi-Et province		
Fuel	Rice husk	Rice husk	Rice husk
Fuel consumption	About 250 tons/day	About 500 tons/day	160 tons/day
Fuel supply	Local rice mills	Local rice mills	Local rice mills
LHV of fuel	3.5 kWh/kg		
Water supply	Chi river	Nan river	Underground water
Connection	22 kW		
Installed capacity	9.95 MW	22 MW	6 MW
Contracted capacity	8.8 MW	20 MW	5.2 MW
Fuel storage	3 months storage - Indoor 18 000 tons - Outdoor 2 000 tons	1 month storage - Indoor 9 000 tons - Outdoor 3 000 tons	2 months storage - Indoor 9 600 tons

## 1.2 Harvesting and supply technology of reed canary grass in Finland

### 1.2.1 Introduction

In Finland the total energy consumption was 387 TWh (1392 PJ) in 2012. The main energy sources in Finland are wood (23%), oil (24%), coal (10%), nuclear energy (18%), natural gas (8%), peat (5%), hydro and wind power (5%), net import of electricity (5%) and some others (3%). The share on renewable energy was 30% in Finland in 2012. The target is to increase the use renewables in energy production. The most important renewable energy source in the future is biomass.

The use of logging residues but also the use of agro-biomass is increased in energy production. At the moment the share of agro-biomass in energy production is very small. The most important agro-biomass is reed canary grass (RCG) cultivated for energy purposes on the field. There is a lot of straw available for energy purposes. At the moment straw is not used as a fuel. The harvesting technology of RCG for fuel is presented in the following chapters. This harvesting technology can be used also for straw harvesting.

### Reed canary grass in Finland

Reed canary grass, RCG (*Phalaris arundinacea* L.) is a perennial grass, which grows wild in whole Finland. The natural habitats of RCG are shores of lakes, seas and rivers. It tolerates occasional flooding and also dryness. RCG suits to all soil types, but largest yields can be obtained from soils containing organic matter

and from peat soils (Pahkala et al. 2005). RCG produces harvest at least 10–12 years with one seeding, if RCG harvested in spring time, when aboveground parts of plant are dead. The height of the RCG growth is 1.5–2 m, and the maximum yields which are obtained in practice are 7–8 tonnes/ha. The yield depends on the fertilization.

The total cultivation area of RCG in 2010 was 16 700 ha, which is 0.7% of all arable land area in Finland. In 2012 the cultivation area of RCG has decreased from these figures.

RCG is harvested in spring time in Finland. This has some favourable affects the combustion properties of RCG. During autumn the plant moves nutrients to roots before the aboveground parts of the plant die. Therefore the element concentration, which may be harmful on combustion, is reduced (Alakangas 2000). In spring the moisture content of growth is low, even 10%, and does not need separate drying. On the other hand, RCG is quite fragile causing losses on harvesting. Also the period for harvesting is not very long between melting of snow and the start of the new growing season.

### **Fuel properties of RCG and straw**

Fuel properties of RCG and straw are given in Table 1/2. Also fuel properties of wood chips and peat are given for comparison in table. Regarding the use of certain biomasses, the risk of high-temperature corrosion of superheaters has to be considered. The key elements on that process are sodium (Na), potassium (K) and chlorine (Cl). Na and K react with Cl producing KCl and NaCl, which attach to the surface of superheaters causing high-temperature corrosion. If there is sulphur (S) present, S reacts with Na and K producing less harmful substances, and risk of high-temperature corrosion decreases. If fuel contains calcium (Ca), this can react with S, leaving less S for reactions between S and K/Na. As a conclusion, the high ratio of S/Cl and low ratio of Ca/S reduces the risk of high-temperature corrosion. In this respect straw is more problematic fuel than RCG, if RCG is harvested during spring, because in autumn RCG moves nutrients (harmful elements) to the roots.

**Table 1/2.** Fuel properties of RCG, wheat straw, wood chips and peat (Alakangas 2000 & Lötjönen et al. 2011).

	<b>RCG spring harvesting</b>	<b>Wheat straw</b>	<b>Wood chips</b>	<b>Peat</b>
<b>Gross calorific value (<math>Q_{gr,d}</math>) kWh/kg (MJ/kg)</b>	4.8–5.2 (17.3–18.7)	4.9 (17.6)	5.1–5.6 (18.4–20.2)	5.6–6.4 (20.2–23.0)
<b>Moisture content wt-%</b>	10–15	20	40–60	40–50
<b>Energy density (<math>Q_{net,as/loose-m^3}</math>) MWh/loose-<math>m^3</math> (GJ/loose-<math>m^3</math>)</b>	0.3 (1.1)	0.3 (1.1)	0.7–0.9 (2.5–3.2)	0.9–1,3 (3.2)–(4.7)
<b>S (%) dry</b>	0.04 -0.13	0.15	0.01–0.05	0.1–0.3
<b>Na (%) dry</b>	<0.03	0.1	0.01	0.007
<b>Cl (%) dry</b>	0.02–0.1	0.8	0.03	0.02–0.06
<b>K (%) dry</b>	0.3 -0.5	0.8	0.1–0.2	0.02
<b>Ca (%) dry</b>	0.2	0.23		
<b>Ash content (%)</b>	1–6	5	0.5–3	2–12
<b>Ash melting point (°C)</b>	1100–1500	1050	>1150	>1100

### 1.2.2 Harvesting technology of reed canary grass

The following chapters describe the harvesting technology used in Finland for RCG. There is actually no difference whether these machines and work stages are used for RCG or straw, at least in Finnish conditions. Of course RCG must be cut by mowing before harvesting, but straw is already cut, and mowing is not needed.

There are two main options for harvesting. The most common method for harvesting is baling, transport of bales and crushing of them at appropriate point of the harvesting chain. Loose harvesting with precision-chopper given ready-made chaff, but transport of pure chaff is expensive due to low density of RCG. The situation is little different if chaff can be mixed with other heavier fuels, like with peat in Finnish conditions, if RCG is cultivated on the peat production area. If the share of RCG (or straw) in a mixture is relatively low, the load sizes are large enough, and transport costs low.

#### Mowing of RCG

Disc-mower conditioners (Fig. 1/2) are most common mowing devices on Finnish farms, and they can be used for cutting of RCG. Of course the conditioner part of the machine can crumble fragile RCG, so adjustment of it as loose as possible and removing counter-blades reduces harvesting losses. The other alternative is to use disc-mover, because it handles RCG more gently. The challenge of mowing is to get short stubble, because the growth is significantly flattened during winter by snow cover.



**Figure 1/2.** Disc-mover conditioner (Elho).

### **Ridging**

One reason for using ridging before harvesting of RCG or straw is to increase the mass of the ridge. This can increase the capacity of the harvesting machines, if heavy-duty or self-propelled precision choppers or large square balers are used. Especially with straw the mass of the ridge can be so small, that driving speed of machine can limit the harvesting capacity.

The other reason for using ridging is too wide ridges compared to width of the pick-up unit of the harvester. For example wide disc-movers produce wider ridge than width of baler intake.

### **Baling of RCG**

The most common baling device in Finnish conditions is round baler (Fig. 1/3). These are based on two alternative technologies: fixed-chamber and variable chamber technology. The variable chamber machines make little more dense bales, and the difference according to studies is about 9% (Paappanen et al. 2008). The diameter of the bales the fixed-chamber machines is 1.2 m, while with variable-chamber machines diameter can be adjusted between 1.2 and 1.8 m.

Better alternative for baling would be large square baler, but these are rare in Finland. The benefits of the square baler are at least as good density of the bales

than for round bales, and especially the empty space between bales on transport can be minimized. There are also indications that square bales can be crushed more easily than round bales.



**Figure 1/3.** Round baler.

### **Collecting of bales**

There are many possibilities to collect bales from the field. The selection of the machine depends on the size of the fields, transport distances and magnitude of the production volumes. One machine for bale collecting from the field is a *tractor equipped with bale spikes on a front-end-loader*. This machine is efficient method on small fields, if transport distance is not very long. Also a self-loading bale trailers can be used for collecting bales from the field. The idea behind these machines is that one tractor (employee) can collect the bales. Machines contain loading unit, which lifts the bales to trailer. This can happen even without stopping the tractor for loading of bale. There are models for round and square bales.

### **Storing of bales**

Bales are stored at the field side storage (Fig. 1/4), and from there they are transported to power plant according to fuel need. Bale stack usually have triangle shape cross-section. When covered with plastic foil, triangle shape form prevents

water to collect into pools on the plastic surface, because this water very probably penetrates into the stack at some stage of the storage. In Finland part of the bale storages are also applied with primer coat (insulating bottom), like wood or pallets), in order to prevent water rise from the ground.

The need to cover the bale storages and making an insulating bottom to them depends on the weather conditions, storage time and requirements of the power plant. If not covered or insulated from the ground, the moisture content of bale's surface layers can be 70–80%. The moisture is often on the surface layer, wet layer reaches into 20–30 cm depth, and the moisture content profile is not linear when going deeper into bale (Paappanen et al. 2011). In case of round bale, surface layers are more important, because similar thick layer on bale surface affects more on average moisture content of a bale than inner layers.



**Figure 1/4.** Bale storages. Storages should always have a triagle shape form, otherwise water collects into pools above the plastic cover.

#### **Harvesting with precision chopper**

Precision chopper (Fig. 1/5) is one option for harvesting, if transport distance to power plant is short. The density of RCG chaff in load is only about  $75 \text{ kg/m}^3$ , which about the half of density of bales. Precision chopper produces short chaff, about 20–30 mm (Paappanen et al. 2008). The chaff storages must be always covered with plastic foil, because loose chaff absorbs water easily.



**Figure 1/5.** Precision chopper and a trailer.

### **1.2.3 Supply technology of reed canary grass**

#### **Transport of RCG**

There are two different supply systems for RCG in Finland. One is to transport the bales directly to power plant, crush them and mix RCG to main fuels (Fig. 1/6). This is also the goal for the future, because it has some logistical benefits. This could be solution for power plants which aim to use RCG as much as possible and are willing to develop also the technology of the power plant, because there have been problems on handling the light RCG chaff at plants.

The other supply system is to transport mixtures of RCG chaff and main fuel. In Finland this means transport of mixture of milled peat and RCG. This supply system is preferred by power plants, which test the suitability of RCG to their plant, and are not willing to see additional trouble about handling of RCG bales. Conveyor systems designed for peat and wood chips suit also for fuel mixture, if the mixing is done thoroughly enough and there are not large pure lumps of RCG.

The average density of the RCG bales is 118–136 kg<sub>DM</sub>/m<sup>3</sup> for fixed-chamber bales and 129–148 kg<sub>DM</sub>/m<sup>3</sup> for variable-chamber bales (Paappanen et al. 2008). The load space volume of Finnish trucks is 120–140 m<sup>3</sup> (Fig. 1/6) Typical mass for round bale loads is 13–15 tonnes and for square bales 20–21 tonnes. The mass of chaff load is 9 tonnes. The bearing capacity of trucks is about 35 tonnes, and maximum length 25.25 m and maximum width 2.55 m.



**Figure 1/6.** Typical Finnish truck for transport of RCG.

### **Handling of RCG on power plant**

Many Finnish power plants are designed to use milled peat and wood chips and are constructed before RCG came part of the fuel assortment. Peat and wood chips are heavier and the grain size is smaller than those of RCG or straw chaff. These are the main factors affecting the handling of RCG on power plants. Different kind of blockages on sieves and conveyors are typical problems. Thorough mixing of RCG chaff with main fuels reduces these problems, but still the share of RCG can be limited by difficulties on handling.

Regarding bales, there are two main methods to feed fuel into the boiler. Many power plants use wood fuels, either logging residues or small diameter wood. In some cases this wood is crushed at the yard of the plant and is fed to conveyor system with front end loader. There are two possibilities to mix RCG with wood chips. Wood and RCG bales can be crushed simultaneously with mobile, heavy-duty crusher, which gives ready-made chaff. The other alternative is to crush bales separately and mix chaff with front end loader to wood chips before loading the mixture on the conveyor system.

Some power plants have stationary crusher, which is used for wood. These crushers can be used also for RCG bales. The capacity of the crusher is however higher with wood, and therefore RCG can be crushed if there is spare time. The capacity of the crusher can be limited by the capacity of the following conveyor system, so it cannot feed RCG faster without blockages and other typical problems.

Truck loads which are mixture of peat and RCG can be unloaded to conveyor system designed wood peat and wood chips, if mixing is thorough enough. Pure chaff loads cannot be unloaded to these conveyor systems.

The new concept for power plants is to build separate feeding line for RCG, which bypass the critical parts of the conveyor system. This could include slow rotating light crusher and for example pneumatic feeding line to the boiler. These



investments however require sufficient annual use volumes of RCG to be economically viable.

### Crushing of bales

The crushing of bales is an important work stage. In Finnish conditions the short chaff size is important, preferably under 5 cm. The ability to tolerate bale ties and bale nets is also important, because manual removal of these is expensive. The practice has showed that fast rotating hammer mills and tube grinders (Fig. 1/7) suit best for crushing of RCG. These crushers tear chaff from the bale surface. The chaff size of these machines is short, even under 3 cm.



**Figure 1/7.** Morbark 1200 XL tube grinder. Machine can crush wood and RCG simultaneously. The capacity of the crusher is about 20 tonnes/hour (Rinne et al. 2005).

The chapters above describe the mobile crushers, because they can be moved from one location to another. Danish Reka company manufactures stationery, light, slow-rotating crusher designed for straw. Crusher includes feeding line. The crusher and feeding line are automated, and they start and stop according to fuel need. The capacity of the crusher is 1–2 tonnes/hour.

Some power plants have stationery crusher (Fig. 1/8) for wood fuels. These crushers can be used also for RCG. Due to limitations of the feeding system, the capacity with RCG is lower than with wood, and therefore RCG can be crushed if there is spare time.

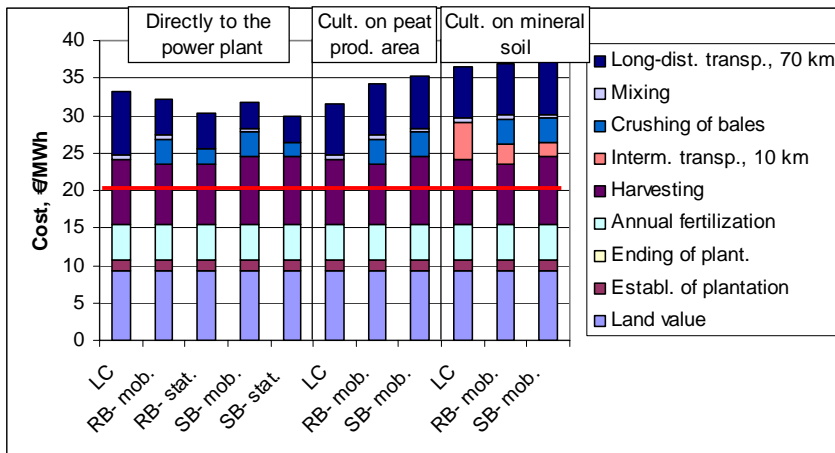


**Figure 1/8.** Heavy-duty crusher made by Raumaster from Finland at Jyväskylä power plant.

#### **1.2.4 Harvesting and supply costs of reed canary grass**

In Finland baling is the main harvesting method, but also precision choppers are used. Baling can be done with round baler or square baler. Produced RCG (bales or loose chaff) can be transported directly to power plant or transport can be done as mixtures. If fuel mixtures are transported, there are two options, either the RCG cultivation is on the peat production area or it is on surrounding farms, and intermediate transport of RCG from farms to peat production area is needed. These combinations of options give several harvesting chains, and the production costs of these chains are shown in Figure 1/9 (Paappanen et al. 2008). The figure includes legends, which show the machines and other conditions for which the costs are calculated. Figure also shows the level of farming subsidies (red line), which are granted to farmers cultivating RCG.

In general, the costs are lowest if bales are transported directly to power plant and are crushed there. Square baler chain is little better than round baler chain, mainly because transport costs of square bales are lower. The costs of stationary crusher can be lower than those for mobile crusher. The chains including a transport of fuel mixtures can compete with transport of bales, but only if RCG cultivation locates on peat production area. In this case loose harvesting with precision chopper is preferred, because why bale RCG, when bales must be crushed for transport. There is no significant difference on harvesting costs between precision chopper and baler. If RCG must be transported to peat production area for transport of mixtures costs increase, because even short additional transport increases costs.



**Figure 1/9.** Total costs of RCG harvesting and supply chain (LC=loose harvesting, RB=baling with round baler, SB=baling with square baler, mob.=mobile crusher and stat.=stationery crusher at power plant. 1 MWh = 3.6 GJ).

The production costs of straw in Finnish conditions are 12–14 €/MWh (3.3–3.9 €/GJ). Costs include harvesting, transportation of bales and crushing at the power plant, but exclude e.g. the land value and fertilizing, because these costs are allocated to main product which is grain.

### 1.2.5 Purchase contracts

In Finland RCG is used by large CHP power plants. The boiler capacity is up to 400 MW<sub>th</sub>. In Finnish conditions RCG can only be a supplement fuel, main fuels are peat and wood chips. One limit for RCG use is the energy share of RCG 20% with peat and 10% with wood chips. These limits are set in order to guarantee undisturbed functioning of conveyor system, sufficient energy feed and avoiding the problems in a boiler, like high-temperature corrosion and fouling. In practice, at the beginnings of RCG use, the annual share has been much smaller, even under 1%. This situation has created two kinds of contact models, which are called here Vapo model and Pohjolan Voima model, according to companies which use them.

Biomass company Vapo Oy makes contracts with farmers, according to which farmers cultivate RCG, fertilize, harvest and collect RCG to field side storage. Vapo buys the RCG from storages, and makes deliveries as needed. The main strength of this model is that Vapo can combine small streams of RCG and guarantee fuel supply to many large power plans. Power plants do business only with Vapo, and avoid making contracts with tens or hundreds of farmers. This may be important if the significance of RCG to power plant is not so great. In theory, farmers could get higher price from RCG without middlemen, but in any case someone has

to organize the fuel supply, and it costs. Vapo has also agreed to purchase all produced RCG, so farmers do not have to worry if they can sell their product or not.

*The Finnish power company, Pohjolan Voima Oy*, makes direct contracts with farmers. Farmers can decide if they also arrange the transport of RCG to power plant or is it left to power company. The price paid to farmer depends on who makes the transport. If power company arranges the transport, the price to farmer depends on the transport distance, according to distance classes.

The price paid to farmers depends on the transport distance from cultivation to power plant, and there are distance classes according to which price is determined. The contract period is five years, during which the contract cannot be cancelled. However, there is an unfairness clause which enables to negotiate the price again, if circumstances fundamentally change. Such circumstances are for example refund of electricity tax to power plants, some new support for renewable energy or significant rise of price paid by power plants. If there are significant changes on realized transportation and handling costs of power plant, the price paid to farmers can partially be compensated caused by savings. The agreement binds both parties, however the farmer has right to denounce the agreement without specific reasons during contract period.

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Title	<b>Development of biomass fuel chains in Vietnam</b>
Author(s)	Arvo Leinonen & Nguyen Duc Cuong
Abstract	<p>The project 'Development and demonstration of multi-fuel supply chains for power plants and industrial boilers in Vietnam is a part of The Energy and Environment Partnership Programme in the Mekong Region (EEP Mekong). The project was carried out by the Institute of Energy (IE) from Vietnam together with Technical Research Centre of Finland (VTT) during 2011–2012.</p> <p>The main objective of the project was to develop and demonstrate the effective and reliable biomass supply chain based on multi-fuel for the CHP plants and industrial boilers. The current supply technologies and costs were analysed in the beginning of the project in Vietnam. Five theoretical development studies, based on this analysis, were made to develop biomass supply chains. Three of the case studies were selected for practical demonstrations.</p> <p>According to the data of 2010 of the EEP multi-biomass project, the total main solid biomass potential for energy production in Vietnam was about 104.4 million tons (374 TWh). A lot of biomass is utilised for energy and other purposes at the moment. The total surplus of biomass is 22.8 million tons. The share of agro-biomass of the surplus was 82%, the rest (18%) being wood fuel. The main biomass fuel resources are paddy straw, rice husk, maize trash, coconut shells, bagasse and wood residues.</p> <p>In 2005, the total biomass used for energy production was 583.3 PJ (162.0 TWh) of which 366.3 PJ (101.8 TWh) was wood fuel (63%) and the remaining 217.0 PJ (60.3 TWh) different agro-biomass residues. Household sector accounted for 75.8% of the total biomass consumption. The remaining 24.2% was consumed by small industries in heat production and by sugar mills in their CHP plants. The share of biomass (583.3 PJ) from the total primary energy consumption in 2005 (2 182 PJ) was 27% which is a very high figure. The share of biomass of the total energy consumption has decreased during the last years because of the total energy consumption has increased rapidly during the last years.</p> <p>At the moment biomass is economical in Vietnam in heat production of industrial companies. At the moment there is only one very small rice husk power plant in operation in Vietnam. There are many other power plants that are under developments phase in different parts of Vietnam. The main barriers for biomass plant investments are the low electricity price and lack of reliable biomass supply chains to the user.</p> <p>Rice husk and bagasse are the most important biomass fuels in Vietnam. Rice husk is transported currently by boats (15 tons) to brick producers and other consumers. The loading of rice husk at rice mill and unloading of it at a power plant is normally carried out manually. The price of rice husk at power plant is 350–450 VND/kg (3.4–4.4 €/MWh). The rice husk price is increasing in Vietnam.</p> <p>The new supply technologies developed in the case studies were demonstrated in three cases in Mekong River Delta region. In the demonstration of 'New effective biomass supply system' it was possible to decrease biomass supply costs by 15% using bigger boats (25 ton) and pneumatic unloading device. In the supply chain the unloading costs of the pneumatic device were 73% lower than those of manual unloading.</p> <p>The objective of the demonstration of 'Multi biomass fuel supply and combustion in power plant' was to evaluate the extension of the operating time of CHP plants in sugar mills for year-round by using surplus bagasse with rice husk as a fuel. There were no problems in blending of bagasse and rice husk, or in combustion of them in the CHP boiler. Burning of rice husk together with bagasse for electricity generation during summer time at sugar mill is profitable if the price of rice husk is not too high.</p> <p>The objective of the demonstration of 'Biomass pellet production and use in industrial boilers' was to investigate technology and economy of using biomass pellets in industrial boilers, in order to replace the utilization of fossil fuel (e.g. coal and oil). Production costs of bagasse pellets were the cheapest, 372 VND/kWh (13.0 €/MWh). The conclusion from the demonstration was that it is economical and technically feasible to use of pellets in industrial boilers. The fuel costs in steam production with the bagasse pellets would be about 40% lower than using traditional firewood.</p>
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## Development of biomass fuel chains in Vietnam

The biomass potential in Vietnam is high. The main biomass sources for energy production in Vietnam are crop residues and wood fuel. A lot of biomass is used already for energy in Vietnam. The share of biomass fuels was 27% from the total primary energy consumption in 2005. Currently biomass is mainly used in households (76%) and in small industrial boilers and CHP plants in sugar mills (24%). In Vietnam there is a lot of potential to increase the use of biomass for energy production. The main energy consumption potential in Vietnam is in municipal and industrial co-generation power plants (CHP) in steam and power generation. One of the main problems of combined heat and power (CHP) plant investors is the reliable delivery of biomass fuel all year round. The main objective of the project was to develop and demonstrate the effective and reliable biomass supply chains based on multi-fuels. The current supply technologies and costs were analysed in the beginning of the project in Vietnam. Five theoretical development studies, based on this analysis, were made to develop biomass supply chains. Three of the case studies were selected for practical demonstrations.

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