THE SEEDS OF ENERGY
IN THE
SOWING SEEDS OF CHANGE PROJECT

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This publication is a compilation of several studies executed by SNV for the the Australian Government funded project, ***Sowing Seeds of Change: Community-based Climate Change Mitigation through Sustainable Rice Production***.

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Abbreviations and Acronyms

Acronym	
CAEM	Centre for Agricultural Energy and Machinery
DOST	Department of Science and Technology
IRRI	International Rice Research Centre
LHV	Low Heat Value
LPG	Liquefied Petroleum Gas
AFU	Agri - Forest University
RE	Renewable Energy
SHEER	School of Heat Engineering and Refrigeration
SNV	The Netherlands Development Organisation
SSC	Sowing the Seeds of Change
SRI	System of Rice Intensification
SRR	"Low Cost" in Vietnamese
VBARD	Bank for Agriculture and Rural Development
VBSP	Bank for Social Policy
VSBK	Vertical shaft brick kiln
WBT	Water Boiling Test

1 INTRODUCTION

The Australian Government funded project, *Sowing Seeds of Change: Community-based Climate Change Mitigation through Sustainable Rice Production* (SSC) supports a number of capacity building activities for smallholder rice producers and provincial agencies in Quang Binh and Binh Dinh provinces, Vietnam. The project helps communities adapt to climate change and farmers increase incomes and reduce GHG emissions.

The SSC project has four components. The Renewable energy from rice residues component (RE component) is the focus of this report and aims to create a more sustainable rice value chain through the utilisation of rice residues for renewable energy. The RE component, together with the System of Rice Intensification component and the Inclusive business – market linkages component, is the basis for the fourth component - Knowledge management advocacy (Figure 1).

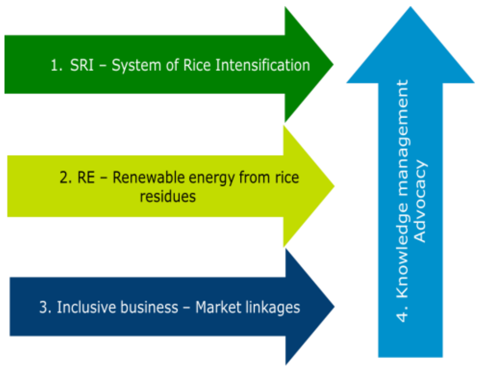


Figure 1: Structure of the SSC project

The implementation of the RE component took place from the start of the SSC project in mid 2013 to the end of 2014. The agriculture extension services in Quang Binh and Binh Dinh provinces were the local partners for the RE component and were closely involved in all project developments. A survey on rice farming and rice residues was undertaken in both provinces to access the availability of rice residues for energy production and other uses. This was followed by an independent review of technologies available for the reuse of rice residues. SNV than executed in-depth research on four of the identified technologies, of which three were introduced to the communities participating in the SSC through a pilot study (the paddy dryer was studied in depth but not implemented within the timeline of the project).

This handbook is divided into five main chapters, and is presented according to the five phases of the RE component (Figure 2). After an introduction, the next chapter focuses on setting the project baseline. Chapter 3 summarises the review of available technologies for the reuse of rice residues for renewable energy and other purposes. There are then three chapters for each of the technologies applied in the RE component of the SSC project: Gasifier stoves, Rice husk briquettes and Straw Baling Machines. These chapters summarise the technologies and pilot studies. This handbook is part of the last activity of the RE component - Communication and knowledge sharing.

Figure 2: Structure of RE component

2 SETTING THE BASELINE

A baseline survey was conducted in 2013 in Quang Binh and Binh Dinh provinces. The survey took place in the selected project communes of: Quang Ninh, Quang Trach, Tay Son and Tuy Phuoc (
Figure 3). The results of the survey served multiple purposes - not only did this data support the project team, in close cooperation with local stakeholders, to make decisions on the technologies that were implemented as part of the RE component, it also provided a clear view of the project communities before the SSC project intervention. This baseline data will enable measurement of the impact of the SSC at the end of the project.

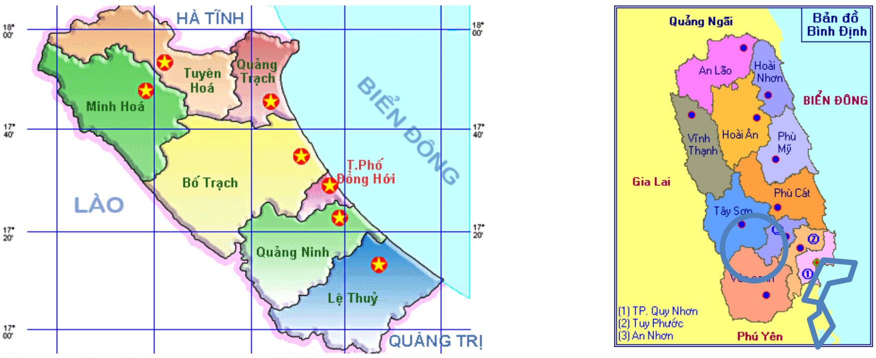


Figure 3: Project location

The aim of the survey in the SSC project area was to:

1) better understand the socio-economic situation of communities and households
2) get a clearer understanding of energy use and residue availability
3) get a full understanding of the rice sector, including market developments
4) gather baseline data to enable measurement of the impacts of the SSC intervention.

Topics studied included household income, income (including costs) from rice production, the local rice value chain (current and potential), rice residue and waste management and energy use.

Table 1 Project participants

Province	Quang Binh		Binh Dinh	
District	Quang Ninh	Quang Trach	Tay Son	Tuy Phuoc
Commune	An Ninh	Quang Hoa	Tay An	Phuoc Son
Total # of households participating	90	80	90	90
# households in treatment group	67	60	67	67
# households in control group	23	20	23	23

The survey was completed by the Hanoi University of Agriculture as part of the SCC project.[1] The survey started with a desk top study, followed by field interviews and visits. General information was collected from the local authorities, who were an important information source for the study. A total of 350 households from four communes (accounting for 10% of SSC project beneficiary households) were divided into treatment groups and control groups. Households from the control groups (accounting for 25% of surveyed households) were located at the same commune as households from the treatment groups but were not selected as direct beneficiaries of the SSC project. The treatment group were the households at which SSC project interventions were aimed. Focus group discussions (8-10 people) focused on current rice practices at the household level. During these discussions information on cropping seasons, rice varieties, average fertiliser application, production cost, rice yield, irrigation systems and markets was collected. Structured questionnaires were used to interview individual households for more in-depth information and statistical data.

2.1 HOUSEHOLD CHARACTERISTICS

Household land ownership highlights from the survey:

- households in the project area own on average 7.9 sao[2] land
- 29.1% of households are large rice producers with more than 0.5 ha
- large rice producers (1-3 ha) are only found in Quang Ninh and Tay Son districts
- 28% of households are working on rented land
- rice producers in Quang Ninh and Tay Son have access to 11.1 and 9.1 sao while those in Quang Trach and Tuy Phuoc have only 2.3 and 4.4 sao respectively.

Table 2 shows the area of rice paddy in each district. Both provinces have three rice seasons: a spring and summer season and one season around winter (the latter is different in each province due to climate). The winter season in Quang Binh only occurs in a small area in the south and results in yields of around 30 – 40 ton/ha lower than the yields of the other seasons. In Binh Dinh the yield varies significantly per district. On average, the difference between the yields in the spring and summer seasons in Binh Dinh is small, while there is a big drop in the winter season yields to around 44.7 ton/ha (compared to 62.4 and 59.5 ton/ha in the spring and summer seasons).

[1] The full report is available upon request in both Vietnamese and English.

[2] Survey results were measured in sao, a traditional unit of land area in Vietnam. The sao varies somewhat from province to province. It is equal to 360 square meters in the north, 500 square meters in the centre and 1000 square meters in the south.

Table 2: Planted paddy area (ha) in Quang Binh and Binh Dinh, 2011

	Average	Spring season	In-between season	Summer season
TOTAL Quang Binh	**52,679**	**28,553**	**9,073**	**14,482**
Quang Trach	10,651	5,598	n/a	4,950
Quang Ninh	8,332	4,938	876	2,433
TOTAL Binh Dinh	**112,329**	**47,790**	**22,176**	**42363**
Tay Son	12,005	4,950	2933	4,122
Tuy Phuoc	15,095	7,559	300	7,236

Source: Statistical year book of Quang Binh and Binh Dinh province, 2011

Table 3: Yield and yearly production in Quang Binh and Binh Dinh by district, 2011

	Average (Quintals/ha)	Spring season (Quintals/ha)	Recycled season (Quintals/ha)	Summer season (Quintals/ha)	Total production (tons)
TOTAL QB	**49.38**	**57.65**	**28.24**	**47.74**	**260,146**
Quang Trach	51.37	52.76	n/a	50.56	54,717
Quang Ninh	52.77	60.78	17.75	50.56	43,968
	Average (Quintals/ha)	**Spring season (Quintals/ha)**	**Winter season (Quintals/ha)**	**Summer season (Quintals/ha)**	**Total production (tons)**
TOTAL BD	**57.8**	**62.4**	**44.7**	**59.5**	**649,289**
Tay Son	57.9	62.5	49.1	58.7	69,537
Tuy Phuoc	65.5	68	45.3	63.7	98,853

Source: Statistical year book of Quang Binh and Binh Dinh province, 2011

In Quang Ninh and Tay Son districts (where hybrid rice is largely cultivated), the costs for paddy growing are roughly VND 18-20 million/ha, around VND 3-4 million higher than purebred rice in Quang Trach and Tuy Phuoc. While the total cost/ha is similar between the two provinces, the lower yield in Quang Binh makes production costs much higher than in Binh Dinh. On average, each ton of hybrid rice costs VND 3.8-4.0 million in Quang Binh and VND 2.9-3.0 million in Binh Dinh. In 2012, households in Quang Ninh district have to pay VND 0.8-1 million more for production for each ton of rice compared to households in Tay Son district. Meanwhile, the cost for each ton of purebred rice in Quang Trach district was VND 1-1.4 million more expensive than that in Tuy Phuoc district.

On average, surveyed households earned approximately VND 16 million/ha for spring rice and VND 14million/ha for summer rice. Rice can account for up to 70 – 75% of agricultural income, as demonstrated in Table 4.

Table 4: Household income from agriculture

Province	District	Type	Agriculture Income (million VND)	Rice Production (%)	Vegetable & Cash crop (%)	Livestock %	Aquaculture %
QUANG BINH	Quang Ninh	Control	22.03	74.38	0.75	21.91	2.96
		Treatment	23.36	75.30	1.06	20.00	3.64
	Quang Trach	Control	13.03	18.84	2.30	67.35	11.51
		Treatment	11.26	37.56	0	47.78	14.66
BINH DINH	Tay Son	Control	38.88	69.87	4.53	25.60	0
		Treatment	21.16	41.19	14.81	44.00	0
	Tuy Phuoc	Control	21.86	74.84	0	25.16	0
		Treatment	19.55	69.07	9.87	21.06	0
Overall			**20.38**	**60.96**	**5.69**	**30.53**	**2.82**

Formal credit from the Bank for Agriculture and Rural Development and the Bank for Social Policy is accessed by 33% of borrowing households that participated in the survey. Households in Quang Binh province have better access to bank credit than households in Binh Dinh province, demonstrated by a higher percentage of borrowing households and higher average credit volume. Formal credit is mainly used for livestock production or household off-farm investment, such as house reconstruction and/or higher education for children. There are some households in Quang Binh that have relatively large loans from the bank to invest in overseas labour migration.

Input suppliers such as agricultural cooperatives and agro-input retailers also play an important role in providing in-kind credit, which accounts for 25% of total household demand. This type of credit is largely used for rice production. Farmers borrow for agricultural inputs such fertiliser, pesticides and seeds at the beginning of each season and repay loans after harvesting. However, information on the interest charged for these loans is not clear because rice producers do not consider this in detail. In practice, repayment of loans is one of main motivations for farmers to sell their rice immediately after harvesting.

On average, the duration of in-cash credit in surveyed districts is nearly two years for VND 17.7 million/household. Households in Tuy Phuoc district have the lowest credit volume, equivalent to one-third of the average borrowed amount in other districts. Meanwhile, households in the treatment group in Tay son district have to pay a very high interest rate for their credit, nearly 24% per year (nominal rate). Details of household access to credit is provided in Tables 5 and 6.

Table 5: Percentage of households with access to credit and credit source

		Borrowed[3] (% HHs)	Credit source						
			Bank	Agro-input Retailers	Coops	Water company[4]	Other Retailers	Farmer Union	Relatives
Quang Ninh	Control	81.82	40.91	31.82	0	0	4.55	4.55	18.18
	Treatment	78.46	36.92	21.54	13.85	0	6.15	0	21.54
Quang Trach	Control	85.00	45.00	10.00	25.00	5.00	0	0	15.00
	Treatment	77.59	36.21	22.41	10.34	8.62	0	0	22.41
Tay Son	Control	86.96	47.83	21.74	8.70	4.35	4.35	0	13.04
	Treatment	83.58	25.37	26.87	8.96	10.45	10.45	1.49	16.42
Tuy Phuoc	Control	78.26	39.13	17.39	4.35	4.35	13.04	0	21.74
	Treatment	77.61	22.39	16.42	13.43	10.45	14.93	0	22.39
	Overall	**78.34**	**33.33**	**17.39**	**7.54**	**2.32**	**3.19**	**0.58**	**13.33**

Table 6: Average household loan size

Province	District	Type	Average amount/HH (VNĐ)	Average Duration (Month)	Average monthly interest rates (%)
Quang Binh	Quang Ninh	Control	19,200,000	18.18	1.00
		Treatment	33,000,000	29.50	1.05
	Quang Trach	Control	11,428,571	20.86	1.00
		Treatment	25,450,000	20.28	0.89
Binh Dinh	Tay Son	Control	20,750,000	25.14	1.36
		Treatment	17,762,963	34.29	1.93
	Tuy Phuoc	Control	7,678,571.4	14.25	0.98
		Treatment	7,047,826.1	13.43	0.71
Overall			**17,707,086.6**	**21.23**	**1.14**

2.2 Household energy consumption

LPG is used for everyday cooking in 60% of the households in each district. Due to its high price, households consume LPG in on a limited basis, most is used for quick meals such as breakfast or lunch. A tank of LPG (13kg) is used over five months in Quang Ninh district and at least three months in other districts. Surveyed households spend around VND 90,000 (around USD 4.4) per month for cooking with LPG.

Households mainly rely on wood and rice husk as energy sources for cooking over longer periods, such as preparing dinner, boiling water and making animal feed. Husk and wood are either combined or burned separately when used. Wood is used at the rate of at least 60kg/household/month in the project area. The

[3] Access to credit is understood as having loan from formal, semi-formal and informal sources (such as banks, mass and institutionalised organisations, input suppliers and relatives).

[4] This type of credit is under a sanitation program and used for fresh water only. It is given by the Bank for Social Policies and disbursed by local water companies.

average payment for biomass/household ranges from VND 45,000 to VND 85,000 (around USD 2.2 to 4.1).

The use of each type of fuel and household expenditure on energy is shown in Tables 7 and 8.

Table 7: Quantity[5] of fuels used monthly for cooking in the surveyed households

District	Group	Gas (tank)	Coal (kg)	Wood				Rice straw (sao)	Rice husk (kg)
				Kg	Handle	Pack	Small truck		
Quang Ninh	Control	0.18		122	0.08		1.00		21.4
	Treatment	0.18		90	3.50	3.50	1.40	1.00	38.4
Quang Trach	Control	0.27		110	1.70	5.75	0.21		35.5
	Treatment	0.21	20	104	4.64	6.00		2.00	41.7
Tay Son	Control	0.29		68		3.08	1.25		50.6
	Treatment	0.23	3	80.4		3.00	2.33		80.5
Tuy Phuoc	Control	0.26		64	1.50				32.1
	Treatment	0.28		60	2.00				72.4

Table 8: Average monthly expenditure for cooking fuel (VND)

District	Group	Gas	Coal	Wood	Biogas	Rice straw	Rice husk
Quang Ninh	C	74,162		42,000		-	0
	T	72,089		46.923		-	0
Quang Trach	C	106,166		84,825			6,000
	T	83,584	100,000	91,575	-		9,571
Tay Son	C	116,444		107,933		-	46,600
	T	93,244	24,000	67,956			53,750
Tuy Phuoc	C	96,971		65,393			0
	T	113,271		99,550			25,244
Overall		**91,633**	**62,000**	**85,365**	**-**	**-**	**37,913**

2.3 AVAILABLE OF ENERGY MATERIALS

2.3.1 Rice straw

Mechanical harvesting of rice is most common in Binh Dinh province, while in Quang Binh manual labour is the main harvesting tool used. About 68% of rice producers in the project area collect rice straw, which is equivalent to 56.5% of rice straw volume in the spring season, and 52% in the summer season. Rain is the main reason why smaller amounts are collected in summer.

Among the four survey districts:

- less than 40% of households in Tuy Phuoc collect rice straw, the total amount collected is between 26-28% of total production
- households in Tay Son district (where ruminant production is promoted) collect nearly all of the rice straw regardless of the harvesting method used

[5] Average volume for each type of fuel is calculated based on the households that used it

- between 65-75% of households in the two districts in Quang Binh collect rice straw.

Table 9: Percentage of rice straw collected from rice fields

Province	District	Group	By households	By volume	
				Spring rice	Summer rice
Quang Binh	Quang Ninh	Control	69.6	58.6	58.6
		Treatment	73.1	60.4	48.7
	Quang Trach	Control	65.0	43.8	43.8
		Treatment	70.0	43.7	37.3
Binh Dinh	Tay Son	Control	100.0	100.0	95.6
		Treatment	97.0	95.7	96.6
	Tuy Phuoc	Control	17.4	12.6	14.4
		Treatment	40.3	28.3	26.7
Over all			**68.3**	**56.5**	**52.9**

The use of rice straw as an additional source of energy (cooking) and nutrients (composting) was rare in all surveyed districts. Approximately 25% of households in Quang Ninh and 30% of the households in Quang Trach use rice straw for animal husbandry, for example to collect animal manure from chickens or pigs. Rice straw is being used for additional income generating activities such as mushroom growing in Quang Ninh (30-50% of households) and in Quang Trach (50% of households) as well as sales for cash by 30% of households in the treatment group and 52% in the control group in Tay Son district.

Table 10: Percentage of households that collect rice straw and its purposes

District	Group	Fodder	Cooking	Selling	Composting	Mushroom	Animal littering
Quang Ninh	Control	26.1	4.3	0.0	21.7	52.2	26.1
	Treatment	10.4	25.4	0.0	14.9	29.9	23.9
Quang Trach	Control	5.0	5.0	0.0	10.0	0.0	30.0
	Treatment	11.7	11.7	0.0	21.7	50.0	31.7
Tay Son	Control	43.5	8.7	52.2	13.0	0.0	4.3
	Treatment	65.7	4.5	29.9	6.0	0.0	3.0
Tuy Phuoc	Control	13.0	0.0	0.0	0.0	0.0	4.3
	Treatment	11.9	10.4	1.5	3.0	0.0	22.4
Overall		**24.6**	**10.9**	**9.4**	**11.1**	**17.7**	**18.9**

Uncollected rice straw is either burnt (Picture 1) or left in the field. This is a major health hazard, creating of pollution in many rice producing areas of Vietnam. Approximately 20% of households in Quang Ninh district and 6-7% of households in Quang Trach said that they gave part of their uncollected rice straw to other villagers as fodder. Details are in Table 11.

Table 11: Household treatment of uncollected rice straw

	District	Group	On site burning (%)	Left in the field (%)	Give away (%)
Spring season	Quang Ninh	Control	90.91	9.09	-
		Treatment	38.30	40.43	21.28
	Quang Trach	Control	78.57	14.29	7.14
		Treatment	60.00	33.33	6.67
	Tay Son	Control	36.36	63.64	-
		Treatment	43.48	56.52	-
	Tuy Phuoc	Control	66.67	33.33	-
		Treatment	81.08	18.92	-
Summer season	Quang Ninh	Control	63.64	36.36	-
		Treatment	36.17	42.55	21.28
	Quang Trach	Control	57.14	28.57	14.29
		Treatment	46.67	46.67	6.67
	Tay Son	Control	72.73	27.27	-
		Treatment	52.17	47.83	-
	Tuy Phuoc	Control	33.33	66.67	-
		Treatment	54.05	18.92	27.03

Picture 1: Rice straw burning

Only two households (one household in Tay Son and one in Tuy Phuoc) were currently selling their rice straw with approximately VND 150,000/sao and VND 80,000/sao respectively as prices (not represented in the Table 11). When asking people about their interest to sell and expected prices it became clear that approximately one third of the interviewed households in Quang Binh and Binh Dinh provinces were willing to sell their rice straw. However, due to labour availability it is not feasible for them to collect the straw and transport it to a central location (such as the commune centre). Instead, they were interested in selling it from the field. The expected selling price of rice straw from the field of VND 38,420/sao (the surveyed average of all districts), is much lower than the price from the communal centre (VND 103,106 /sao) due to the transportation costs. The transportation costs appear to be more than double the selling price from the field. Households in Tay Son can expect the highest selling prices, approximately VND 115,000-156,500 /sao for rice straw. The prices for rice straw are lower in Quang Ninh, Quang Trach and Tuy Phuoc, where rice straw is almost never sold. Many households strongly believe that nobody would buy the rice straw as it is at currently burned or otherwise wasted. Respondents only expect limited money for rice straw - households in the treatment group in Quang Ninh expect VND 7,500/sao and households in the control group in Quang Trach expect about VND 8,000/sao. The cheap price implies that rice straw can potentially be used for energy production.

2.3.2 Rice husk

62% of the interviewed households collect rise husks from the miller, mainly in Quang Trach and Tay Son district: 90% and 80% of households respectively. In contrast, only approximately 9% of households in the control group and 37% of households in the treatment group in Tuy Phuoc collect the rice husks at the millers.

Table 12: Household monthly rice consumption and husk collection

District	Group	Monthly milled rice/household (kg)	% households collected husk
Quang Ninh	Control	95.21	43.48
	Treatment	90.56	58.21
Quang Trach	Control	137.04	90.00
	Treatment	94.13	88.33
Tay Son	Control	146.96	82.61
	Treatment	169.58	77.61
Tuy Phuoc	Control	66.30	8.70
	Treatment	73.42	37.31
Over all		**108.42**	**62.29**

Households in Quang Ninh claim that rice husk is a waste product that millers struggled to dispose of due to its large volume (about 20% of total rice volume). It is interesting to note that there is one miller who pays approximately VND 120,000/day to dispose of the rice husk (often to be dumped in the natural environment, including rivers). This demonstrates the potential to reuse this product in renewable energy technologies.

The main use of rice husk is for cooking. A few households in Tuy Phuoc use their husk for poultry litter. Another use is the burning of husk to prevent or dispose of insects – which is done in some households in Quang Trach and Tuy Phuoc districts. More information is in Table 13.

Table 13: Use of husk by households

District	Type	Cooking	Selling	Compost	Poultry littering	Burn	Bedding for egg laying	Give away	Burn to prevent mosquito
Quang Ninh	Control	80.0	-	-	10.0	-	-	-	-
	Treatment	94.9	-	2.6	5.1	-	-	-	-
Quang Trach	Control	72.2	5.6	11.1	5.6	5.6	-	-	-
	Treatment	73.6	-	-	1.9	1.9	1.9	3.8	-
Tay Son	Control	94.7	5.3	-	-	-	-	-	-
	Treatment	84.6	3.8	1.9	1.9	-	-	5.8	-
Tuy Phuoc	Control	-	-	-	100.0	-	-	-	-
	Treatment	64.0	-	4.0	16.0	-	-	4.0	20.0

The average use of rice husk per household is 51 kg/month (Table 14). Household husk consumption depends a lot on local customs and habits. Rice husk usage in the Tay Son district is almost double that of Quang Ninh and Quang Trach districts.

In the project area, 95% of rice husk using households reported that their own milled rice is the main source of husk. However in Tay Son district, around 38% of households in the control group and 58% in the treatment group pay for extra rice husk because their own milled husks are not enough to meet their needs. Meanwhile, husk can be collected for free in the other districts, especially in Quang Ninh district.

Table 14: Monthly household husk usage

District	Group	Volume (Kg)	Source of husk (% households of total households)			Average price (VND/kg)
			Own milled	Free collected	Purchased	
Quang Ninh	Control	21.4	100.0	7.7	0.0	0.0
	Treatment	38.4	100.0	30.2	0.0	0.0
Quang Trach	Control	35.5	95.0	10.0	10.0	325.0
	Treatment	41.7	92.9	23.2	21.4	236.0
Tay Son	Control	50.6	95.2	0.0	38.1	532.4
	Treatment	80.5	100.0	0.0	58.3	532.0
Tuy Phuoc	Control	32.1	33.3	16.7	0.0	0.0
	Treatment	72.4	92.0	8.0	24.0	448.3
Overall		**51.4**	**94.8***	**24.6***	**13.4***	**469.6**

* one household can have more than one source of rice husks, for example they collect husk from the mill and buy additional husk

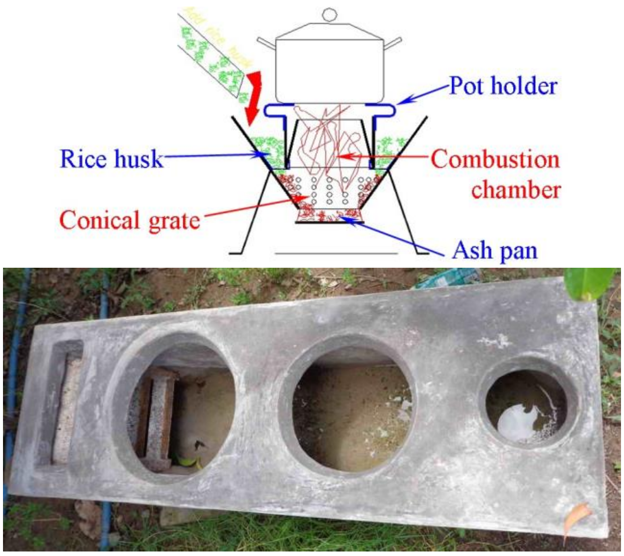
2.4 CONCLUSION

The findings from this survey give a good representation of the rice residue production and use in the two provinces of Quang Binh and Binh Dinh. Households in both provinces use rice husks for cooking with traditional cook stoves, which emit harmful smoke. A large amount of rice husk and rice straw is left in the paddy fields or at the rice millers because there is no economic reason for households to collect it. In both provinces, there are opportunities for the collection of rice residues and the application of renewable energy and reuse technologies related to rice straw and rice husks.

3 TECHNOLOGY REVIEW

Dr Phan Hieu Hien from Nong-Lam University, Ho Chi Minh City and Mr Nguyen Thanh Nghi from the Centre for Agricultural Energy and Machinery, Nong-Lam University, Ho Chi Minh City undertook research[6] to further investigate reuse options for rice residues, including for renewable energy, in the SSC project areas. Eleven reuse options were investigated: ten using rice husks and one using rice straw. This chapter summarises this research, providing an overview of each reuse technology including design, use in Vietnam, costs, potential providers and an assessment of its suitability for use in the SSC project.

3.1 RICE HUSK FUEL STOVE



Picture 2: Portable and fixed rice husk fuel stoves

Topic	Information
Technology	This is a traditional cook stove in Vietnam and commonly has an inclined grate. It can portable or fixed. A portable stove has an inverted-cone metal sheet. The cost of this stove is approximately USD 3[7] with a lifespan of less than four years. If used indoors, it needs to be under a hood chimney or a ventilated area to prevent inhalation of flue gases with potentially toxic substances. Fuel is added from the top and debris are removed from the ash pan. A fixed stove is usually a single or dual concrete rice husk stove. The cost for a dual stove with two fire-rings and two concrete chimneys is approximately USD 35 with a lifespan of more than six years. This type of stove is not efficient - it is smoky and requires fuel supply every five minutes. The estimation of rice husk use for this stove is 1 kg/hour or 3 kg/day for the portable stove and 3.3 kg/hour or 10 kg/day for fixed stove.

[6] The report can be provided upon request.
[7] in 2012

Use in Vietnam	This stove is widely used throughout the Mekong Delta and areas far from the forest. The use of this technology has been declining due to increased income, resulting in people slowly moving away from the use of agricultural residues. However, as residues are still widely available at low cost, households often continue using these stoves for limited purposes, for example, for the outdoor cooking of animal feed. There are no clear figures on how many households are using this type of cook stove.
Suppliers	This stove is not branded. The stoves are made locally by welding workshops or masons or are home made.
Recommendation	This technology should not be used in the SSC project because of household air pollution and inefficiency.

3.2 RICE HUSK FUEL GASIFIER STOVE

Picture 3: Simple two-layer gasifier stove

Topic	Information
Technology	There are many different types of gasifiers in Vietnam, two primary ones being those with natural airflow and those with or forced airflow (i.e. with fan or without). The price varies widely from USD 10 to over USD 120. The operation time is 30 – 90 minutes.
Use in Vietnam	The total number of stoves in Vietnam is unknown. An SNV expert estimated that 1,000 stoves were sold in the northern provinces before 2013.
Suppliers	Distribution is mostly through door-to-door sales . Most of the stoves do not have an official brand and are locally made. At the national level, some central production is developing, but the supply chains and awareness raising/sales activities have not yet reached the (poorer) rural areas. Some brand names identified by SNV include: The He Xanh (Green Generation) stove, the SPIN project, Hi-tech stove, Thuan Phu stove and the Mr Viet stove. Rua village designs a stove (Picture 3) that has been produced widely over the last few years.
Recommendation	This technology is an option for use in the SSC project if tested for efficiency and emissions. Households with access to free rice husk, especially with frequent and long cooking tasks are likely to be interested improved technologies.

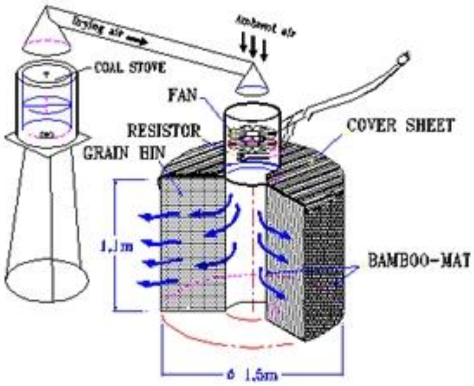
3.3 Larger rice husk stove for small scale food processing

Picture 4: Soya cake making using the larger rice husk stove

Topic	Information
Technology	This stove is similar to the fixed cook stove (3.1) but bigger, with an additional feeding basket and a larger stove/combustion chamber. It has many uses including for large and/or long cooking tasks like soya, rice-paper cakes or rice wine. The consumption of rice husk is over hundreds of kg/day.
Use in Vietnam	Processing agricultural products for local consumption, especially in the Mekong River Delta.
Suppliers	Most stoves are homemade or made with the support of local masons.
Recommendation	This technology is very inefficient. Large amounts of rice husk is used resulting in household air pollution. An improved version of this stove could be developed, however market potential is unknown.

3.4 Dryers for rice paddy drying

Picture 5: A 20-ton dryer in Cho-Gao (Tien-Giang Province), using loose rice husk as fuel

Topic	Information
Technology	Rice paddy driers use loose rice husk as fuel. There are two designs in Vietnam (FAO[8]): the flat-bed dryer and IRRI low cost SRR dryer developed by AFU. The flat-bed dryer typically has a batch capacity of 10 ton. It reduces the paddy moisture content from 26% - 15% in 7- 8 hours with rice husk consumption of 60 kg/hr, or approximately 50-60 kg of rice husk for one ton of paddy. The 3rd generation dryers, installed since 2009 include large-capacity recirculating towers (20- 40 tons per batch). They mostly use rice husk briquettes. The SRR dryer is based on research of eleven international technologies and is an adaptation of the Kongskilde model. This technology costs approxmitely USD 300 /machine and has limited customers.  **Picture 6 An SRR Dryer – air circulation through inserting forced air[9]**
Use in Vietnam	Approximately 1,500 flat-bed dryers were constructed in the Mekong Delta by the Centre for Agricultural Energy and Machinery (CAEM) and Nong Lam University (Agri – Forestry University) in Ho Chi Minh between 1980 and 1987. The average capacity is approximately 4 tons/batch. This increased to approximately 9,000 dryers by 2012, with an average capacity 10 tons/batch and an average price of VND 100 million (USD 4,500). They dry approximately 45% of the wet-season harvest. Most of the driers are located in the Mekong Delta. In 2012, approximately 350,000 tons of rice husk was used in flat-bed dryers, which is less than 8% of the annual rice husk produced in the Mekong Delta. The quality of rice will improve with the use of these driers - drying is consistent and efficient. These driers also help reduce the workload of households, often women. During the traditional drying process, which happens on the streets, pollutants contaminate the rice and when it starts raining or when there is not enough sun. This requires more work from the households. On average a batch of rice needs to dry for between four and five hours. The flat bed

[8] http://www.fao.org/docrep/x5427e/x5427e0d.htm#TopOfPage

[9] http://www.knowledgebank.irri.org/training/fact-sheets/postharvest-management/drying-fact-sheet-category/item/vietnamese-low-cost-srr-dryer-fact-sheet

	drier only requires one hour to dry an average batch of rice.
Suppliers	Suppliers include the Centre of Agriculture Energy and Machinery and small-scale workshops: Nam Nha private company, Nhat Phu Thai Ltd., Cuong Thinh JSC and Mr. Hai Hien in An Giang.
Recommendation	This is an interesting solution to increase the quality of the rice husk and reduce the workload of farmers (often women). This technology was recommended for use in the SSC project. However, for several reasons it was not implemented (including time pressure, lack of interest in investing in the technology).

3.5 RICE HUSK FURNACE FOR GRAIN DRYING

Picture 7: The automatic rice husk furnace for SRA-4 reversible flat-bed dryer

Topic	Information
Technology	Four rice husk furnaces were investigated: • box inclined-grate furnace • inclined grate furnace with cylindrical combustion chamber • automatic rice husk furnace (model AFU-IRRI-Hohenheim) • rice husk furnace using gasification. These technologies are in order off efficiency, the final one with the best performance and highest efficiency. On average a four tonne capacity machine consumes 25 kg rice husk/hour and has an efficiency of 70 – 75%. Six, eight and ten tonne capacity machines consume 40, 50 and 60 kg of rice husk/hour respectively, with an efficiency of 70 – 80%.
Use in Vietnam	The second model is the most known in Vietnam, with capacity of drying 4, 6, 8 and 10 tonnes of rice with limited smoke emissions. It is estimated that since 1995, there have been 3,000 installations of this model.
Suppliers	Often people develop their own design, similar to the design of the Processing Technology Centre of MARD. Alternatively, the technology can be imported via the Nhat Phu Thai company or Thien Nam company.

Recommendation	Grain drying results in higher quality grains, it saves time and supports drying independently of the weather conditions. This technology was recommended for the SSC project, and opportunities for piloting were explored. However at a later stage – mainly due to time pressure – this technology was not included in the project. Further scale-up of this technology is highly recommended.

3.6 Brick kiln

Picture 8: Brick kiln using rice husk as fuel

Topic	Information[10&11&12]
Technology	There are approximately 10,000 brick kilns in Vietnam, mostly in the south. There are six kilns: traditional brick kiln, Habla brick kiln, Verticle shaft brick kiln (VSBK), Hoffman brick kiln, Tuynel brick kiln and Thailand design. Kilns come in different sizes and with different levels of efficiencies.
Use in Vietnam	Brick kilns are one of the highest causes of pollution in Vietnam. This due to the use of coal, trash and agricultural waste (such as rice husk) as fuel, resulting in harmful emissions including black carbon.
Suppliers	Designs are developed and introduced mainly by Departments of Science and Technology. The Vietnamese Government has banned all traditional brick kilns and VSBKs by 2017.
Recommendation	There is a big opportunity for improvement of this technology. Further scoping of opportunities for design and industrial production of stoves with for higher efficiencies and better control of emissions is necessary. Such scoping was beyond the scope of the SSC project budget and timeline.

[10] Review of Vietnam Policy on Brick kiln (Hoang Anh Le, Ph.D – Faculty of Environmental Sciences, Vietnam National University, Hanoi, Vietnam)
[11] http://www.chrisquintero.com/2012/12/brick-making-in-Vietnam.html
[12] http://www.phudien.vn/kien-thuc/gach-tuynel/gioi-thieu-cac-cong-nghe-va-kieu-lo-nung-gach-tai-viet-nam.html

3.7 IMPROVED BRICK KILN (DESIGNED BY ENERTEAM)

Topic	Information
Technology	In response to social, economic and environmental demands, an improved brick kiln technology was developed by ENERTEAM (Energy Conservation Research and Development Centre), the four-chamber semi-continuous brick kiln. The kiln has four chambers to rotate brick drying, preheating firing and cooling in a semi-continuous operation. Two heating solutions can be included 1) direct-heating which means the application of traditional furnaces (in which the residues are combusted) and 2) gasification technology, in which a gas is produced which can lead to a more equal heat distribution. The direct heat pilot model has a production capacity of 4,000 – 4,500 pieces/day/chamber and costs VND 150 million. The gasifier pilot has double the production capacity in each chamber and costs VND 1,400 million.
Use in Vietnam	This technology is still in under development with no large scale uptake. The direct-heat technology was installed in An Giang in 2008 and the gasifier technology was installed in Dong Thap in 2010.
Suppliers	ENERTEAM, Ho Chi Minh City
Recommendation	A great potential solution for the problems as identified in 3.6, however there was not a perfect fit with the SSC project as brick making is not a main activity in the SSC project area.

3.8 RICE HUSK BRIQUETTING MACHINE

Picture 9: Briquettes coming out of the production line

Picture 10: A pile of husk briquettes

Topic	Information
Technology	A typical briquetting machine (powered by a 15- 20 kW motor) costs VND 50- 60 million (USD 2,500- 3,000) and can produce 200-250 kg of briquette/hour, with an electricity consumption of 80- 100 kWh/ton.
Use in Vietnam	There have been more than 100 installations of risk husk briquetting machines in the Mekong Delta. These were

	primarily smaller installations for medium sized rice mills, using two - ten briquetting machines of the above capacity. Larger installations in big rice mills or independent companies include 30- 100 briquetting units. When using the briquettes for household cooking, people used the same cook stove (with chimney) for rice husk briquette as they would for wood, without any modification. For industrial purposes in, for example Ho Chi Minh City, Binh Duong, and Dong Nai (making instant noodles, animal feed and processing heat) expensive coal can be replaced by briquettes. The average price of rice husk briquette is 1,500 VND/kg. Due to transportation cost, the market of this product limited to a 200 km radius from the production site.
Suppliers	Vietnam Research Institute Agriculture Machinery (RIAM), Vietnam Institute of Agriculture Engineering and Post-harvest Technology (VIAEP), Vietnam Pellet Machine (VPM) Ltd., Hatech Energy Corp., Hoang Phi Ltd.
Recommendation	Interesting for millers or places near millers where the rice husk is available and this technology has been introduced as part of the SSC project, see also Chapter 5.

3.9 RICE HUSK PELLET

Picture 11: Rice husk pellet

Topic	Information
Technology	This is a similar technology to rice husk briquetting machines (3.8), turning loose rice husks into dense rice husks in the form of pellets. A 1.5 ton/hour pellet machine costs USD 150,000. The injection mould needs to be regularly replaced and costs USD 2,200. Replacement is necessary after every 1,000 tons of product.
Use in Vietnam	Demand for pallets is increasing. They are used by industry in Ho Chi Minh City and Binh Duong to replace coal in boilers, for example, by Acecook instant-noodle producer. The cost of rice husk pellet production is VND 1967,6 /kg[13]
Suppliers	Limited suppliers in Mekong river delta.

[13] (Nguyen Duc Cuong, Arvo Leinonen, 2013)

Recommendation	Interesting for millers or places near millers where the rice husk is available and was considered to be promoted as part of the SSC project. A comparison was made with briquetting machines and it was concluded that the business model and local demand for briquetting in the project area was higher at the time of the project.

3.10 RICE HUSK FOR GASIFICATION TO RUN AN ENGINE TO PRODUCE ELECTRICITY

Picture 12: The 5-kW continuous gassification system coupled to a diesel engine

Topic	Information
Technology	The technology gasifies rice husks to run engines for power generation. Due to increasing power prices and demand, research on this technology is of growing interest in Vietnam.
Use in Vietnam	In neighbouring countries where the electricity prices are more then double the price in Vietnam, these technologies are very common. In Vietnam however, the technology is less popular costs are not competitive with the electricity prices and with the availability of the electricity grid (97% of the country).
Suppliers	Currently no suppliers.
Recommendation	This technology could be used by rice millers once the technology available at a reasonable price or when the electricity prices increase.

3.11 STRAW BAILING MACHINE

Picture 13: The cubic-bale straw baler

Topic	Information
Technology	There are two types of straw baling machines in Vietnam: the cubic straw baler and the round straw baler. The cubic-baling machine creates two bales: one of 0.6 m x 1.2 m x 1.2 m (150 kg/bale) in size, suitable for forklift loading and another of 0.7 m x 0.5 m x 0.5 m (30 kg/bale) in size, suitable for manual loading. The price including the 8-HP diesel engine is VND 90,000,000 or approximately USD 4,500. The round-bale machine, with a production capacity of 2 ton/hr, creates approximately 100 22 kg bales of 0.5m x 0.7 m. The machine is powered through a tractor of at least 20 HP, which consumes four litres of diesel /hour. Bailers cost approximately VND 110,000,000.
Use in Vietnam	This technology is widely used in the south of Vietnam.
Suppliers	The two major suppliers are the Trading and Service Centre of Z755 and the Sub-Institute of Agricultural Engineering and Post-harvest Technology.
Recommendation	This technology was recommended for the SSC project site and more information can be found in Chapter 6.

3.12 Conclusion

After considering the baseline study and the renewable energy report, and within the scope of the SSC project budget, timelines and human resource capacity, four technologies were selected for application in the SSC project, of which in the end three were actually implemented in the project area; Gasifier stoves for domestic use, briquetting machines and Bailing machine (round-bale). The business case for a paddy dryer, including a willing purchaser, was not identified on time for the SSC project.

4 GASIFIER STOVE

Gasifier stoves is one of the energy technologies introduced by the project to help households improve quality of life, including their economic situation and the quality of their surrounding environment. After scoping the existing gasifier market, the five most popular gasifier stoves were selected for further investigation including technical testing (for emissions and efficiencies) and household preference testing. After testing, one stove made it to final dissemination stage.

This chapter will provide an overview of the process for testing the four models, selecting a model for piloting and the pilot process and conclusions. This process is summarised in the figure below.

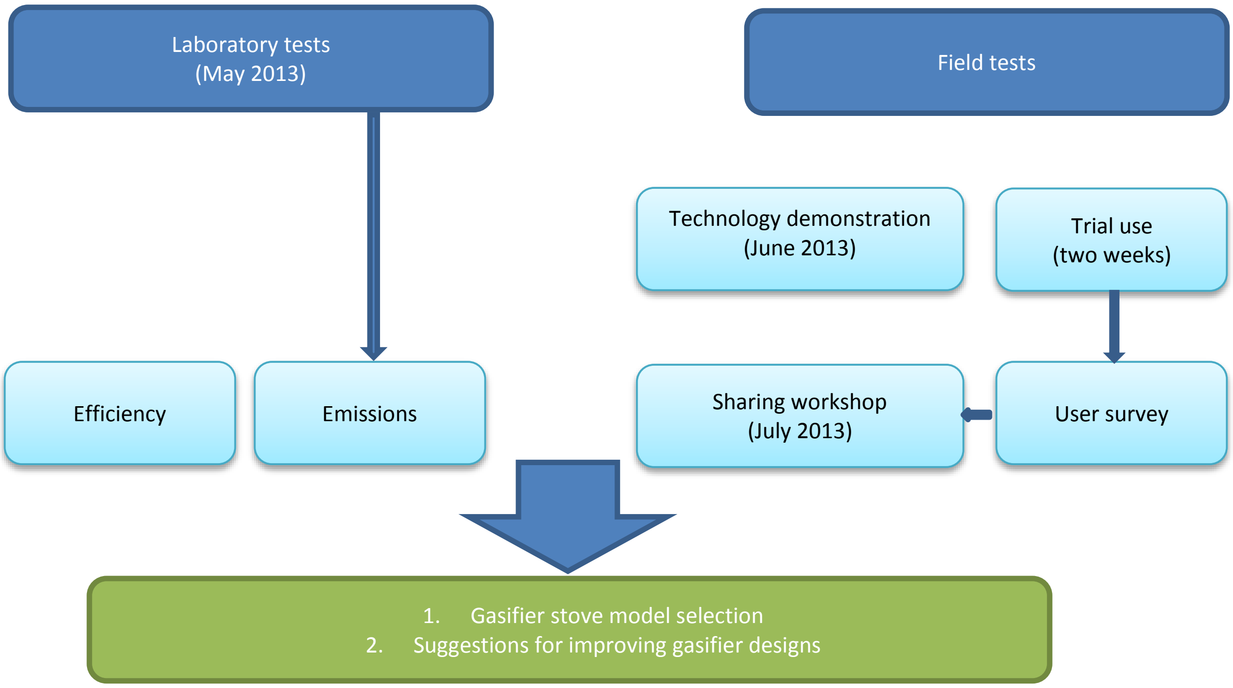


Figure 4: Gasifier technology process

4.1 IN-DEPTH INFORMATION ON THE TECHNOLOGY

The four stoves selected for testing were the:

- Rua stove, a design from Rua village (suburbs of Hanoi)
- Viet stove, a design from Mr Nguyen Ngoc Viet from Thai Binh province
- Thuan Phu stove, a design from Thuan Phu company
- SPIN, a design from the Sustainable Product Innovation Project [14]

[14] www.spin-asia.org

Table 15: Description of tested stoves

Stove model	Technical description
Rua Stove 	Material: Stainless steel, two layers Top-draft gasifier, 12V-DC fan (with adapter, 220V-AC supply required) Outer diameter: 30cm Inner diameter: 25 cm Height: 45 cm Load of rice husk (per batch): 1.3- 1.5kg Burning time: 30-45 minutes Market price: VND 150,000– VND 350,000 (based on size)
Viet Stove 	Material: Metal sheet stove Top-draft gasifier, 12V-DC fan attached (with adapter, 220V-AC supply required) Diameter: 18cm Height: 60cm Load of rice husk (per batch): 1.4-1.5kg Burning time: 30-35 minutes Market price: VND 150,000
Thuan Phu Stove 	Material: metal sheet and infrared burner Top-draft gasifier, separate burner, 220V-AC fan Diameter (reactor): 50cm Height: 80cm Burner width: 30cm Burner length: 60cm Load of rice husk: N/A Burning time: 2 hours Market price: VND 2,500,000
SPIN stove 	Material: stainless steel stove, two layers Top-draft gasifier, 12V-DC fan Outer diameter: 20cm Height: 60cm Load of rice husk: 1.36 kg Burning time: 30-45 minutes Market price: Not commercially available, estimated price per stove when made in small batches is VND 900,000– VND 1,000,000, estimated price for mass production is VND 600,000

4.2 Technical testing

4.2.1 Testing team

SNV collaborated with the School of Heat Engineering and Refrigeration (SHEER), Hanoi University of Science and Technology, to conduct the tests in the SHEER laboratory. The testing team was strong, with SNV members providing skills in testing[15] and SHEER members providing knowledge about heat.

4.2.2 Testing method

The project team faced a number of challenges when testing the stoves, including not having access to a testing centre or expensive emission measurements equipment, as used by professional testing centres. Despite these limitations, the team developed a number of methods to ensure testing was of high quality.

Tests were based on the Water Boiling Test Guideline (version 4.2.2), published by Global Alliance for Clean Cook stove[16] and developed collaboratively by alliance partners. The process of the Water Boiling Test Guideline is demonstrated in Figure 5.

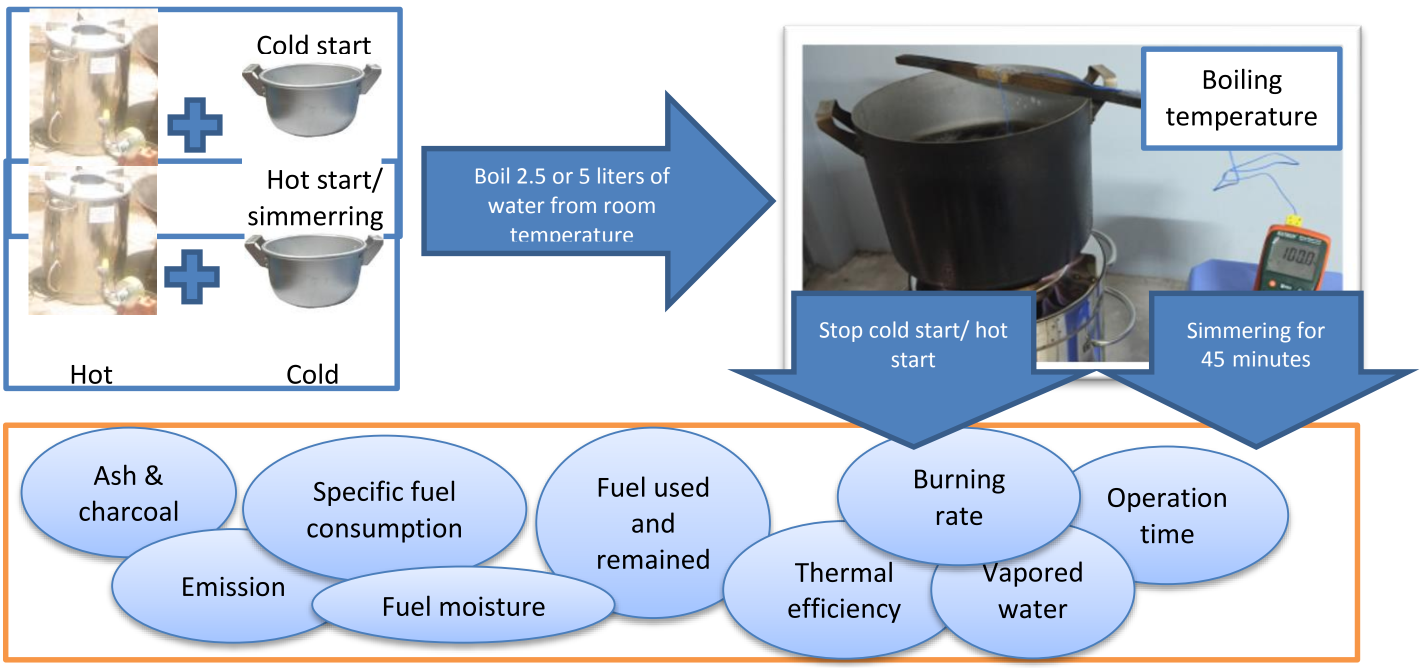


Figure 5: Water Boiling Test Guidelines

The Water Boiling Test Guidelines are designed for fuel-wood stoves, not for gasifier stoves. SHEER and SNV therefore adapted the tests for gasifier stoves.

- The moisture content and calorific value of rice husk (including the calorific value before and after burning) were measured in a research laboratory
- Thermal efficiency was measured

[15] Developed through the ICS testing training that was provided by the Aprovecho in 2011 (Lao PDR) and 2012 (in Vietnam)
[16] http://cleancookstoves.org/technology-and-fuels/testing/protocols.html

- Simmering time was cut to 30 minutes, as the operation time of most gasifier stoves is short
- The hot start was not executed
- The test system included a stove platform and an exhaust hood, which draw gases upward for sampling. A pipeline and fan were connected to the hood and emissions measurement equipment was inserted into the pipeline. CO & CO_2 were recorded manually. PM2.5 emissions were collected batch-wise and not continuously (during specific intervals sample sizes were taken that were analysed. Therefore the figures give an average of those samples and not of the total emissions throughout the test). The necessary equipment to do continuous measurements is not available in Vietnam at the moment.
- Water temperature, stove body temperature and fuel weight were measured and recorded in real time.

Repeated laboratory-based tests were undertaken to observe, compare and evaluate stove performance and quality in controlled settings. Five stoves were tested, the four designs described above (Table 15) and a traditional stove, for comparison.

4.2.3 Results

The results are summarized in the table below.

Table 16: Results of water boiling test

No	Parameter	Unit	Rua stove	Viet stove	Thuan Phu stove	Tradition al stove	SPIN stove
1	Efficiency and Fuel consumption						
1.1	CST Thermal efficiency (full power)	%	17.6	19.3	17.5	13.9	20.0
1.2	CST-SM Thermal efficiency (low power)	%	18.8	17.1	19.7	14.3	17.5
1.3	Fuel consumption at full power (CST)	g/min	44	48	38	36	44
1.4	Fuel consumption at low power (CST-SM)	g/min	30	33	26.5	33.6	25.3
1.5	Time to start up	min	<2	<1	<4	<2	<3
1.6	Time to boil 2.5 l water at full power	min	9	10	11	15	13
1.7	Burning time (at full fan speed)	min	35.6	30.8	80	-	30.8
1.8	Burning time (at low fan speed)	min	47	44	100	-	45
2	Emission						
2.1	CST CO	mg/m3	418	1581	426	375	956
2.2	CST-SM CO	mg/m3	206	1883	398	574	1059

2.3	CST-SM PM2.5	mg/m 3	13.1	12	2.5	37.9	9.45
3	Max stove body temperature	OC	125	325	85	220	75

Time to boil

The results show that the Rua stove, Viet stove and Thuan Phu stove are the fastest to boil water (Table 16 and Figure 6). The Rua Stove is the fastest, taking on average nine minutes to boil 2.5 litres of water. The traditional stove is the slowest to boil water, taking 15 minutes.

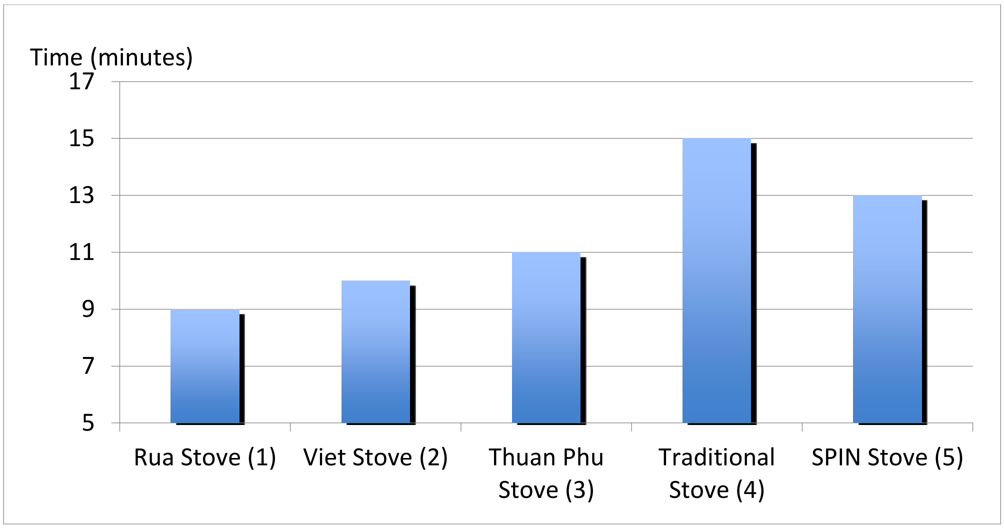


Figure 6: Time taken to boil 2.5 litres of water

(a) Thuan Phu stove

(b) Viet Stove

(c) Rua Stove

(d) Traditional Stove

Picture 14: Testing of four stoves at SHEER laboratory

Thermal Efficiency

Thermal efficiency is the ratio of the heat required to increase the water temperature and the latent heat of the evaporated water released as steam, to the total energy of rice husk consumption.

There is remaining energy in char. This was not taken into account in final calculations, as based on common household practices in Vietnam, the char is likely to be used as fertiliser. After analysing the mixture of char and husk of the Thuan Phu stove it was clear that remaining char should be reused as it is not fully combusted.

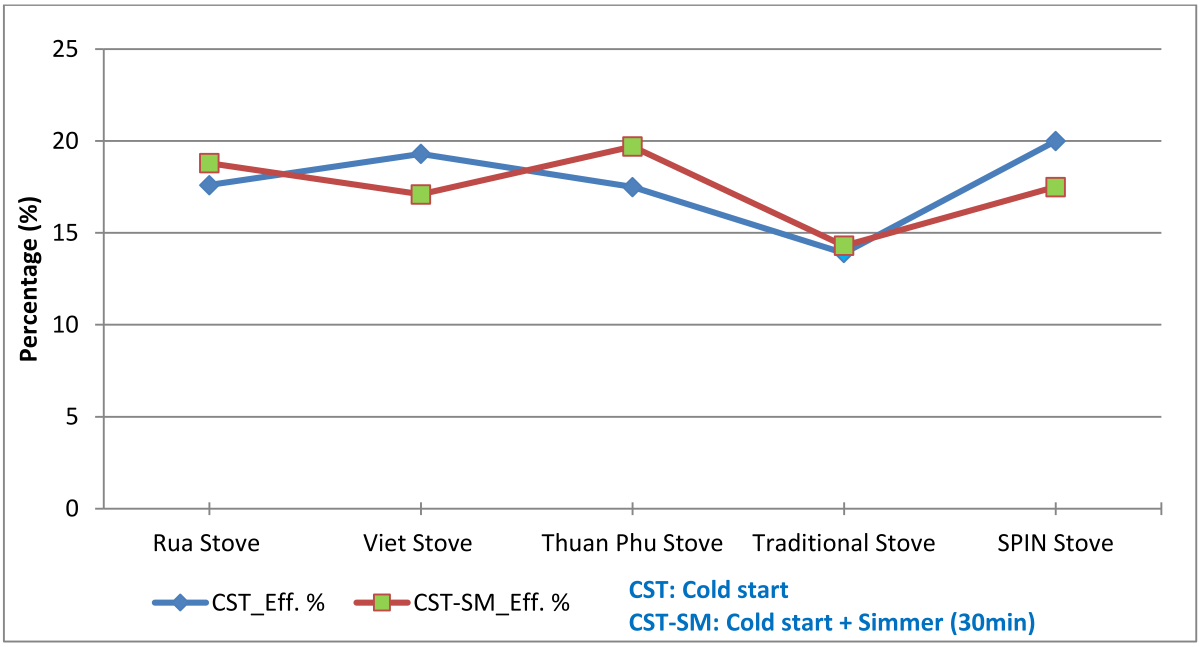


Figure 7: Thermal efficiency of the tested stoves[17]

[17] In order to compare stove performances, thermal efficiency has been calculated using the same method as the CST and CST-SM phases.

All of the selected gasifier models have higher efficiencies than traditional stoves. Thermal efficiencies of the gasifier stoves are similar and range from 17 to 20 % while a traditional stove has an efficiency of around 14 %.

4.2.4 CO emissions and PM2.5 emissions

PM and CO emissions are acknowledged to be silent killers in the kitchen by all scientists, the WHO indicates that due to cooking on biomass annually 4 million people die due to the concequences of lung diseases. It is especially women and children who are in and around the kitchen during times of cooking and therefore exposed to the risks. Measuring and taking into account these emissions is therefore of importance.

The CO concentration in the exhaust gases was measured for three minutes during CS and CST-SM intervals. The final value of CO concentration was calculated by averaging all of the recorded data shown in the figure below. In order to compare to the indoor emissions in the kitchen, stack CO concentration [mg/m3] was converted into CO emission rate as [g/MJ-del] and [g/min] by dividing total CO emission to total energy delivering to water pot and to total testing time, respectively.

The PM2.5 emissions were measured by sampling exhaust gases from the hood during the CST-SM phases, and then the PM2.5 dust was weighed using a Microbalance Metler-Toledo. The PM2.5 emission concentrations were calculated by dividing the collected dust content by the total cubic meter of exhaust gases during the CST-SM Test. To enable comparison, PM2.5 concentrations were also converted in to PM2.5 emission rate as [g/MJ-del] and [g/min], the same as CO emission conversion.

The Rua, Thuan Phu and traditional stoves have relatively good emission levels in both CST and CST-SM (Figure 8). Viet stoves are characterised by high CO emissions, which is evident by their poor performance on the CO emission metrics.

PM2.5 emission measurement has been only carried out for CST-SM operation. As the data in Figure 8 indicates, PM2.5 emission performance of most gasifier stoves are quite good. PM2.5 emission contents are lower than 230 mg/MJ-del. The Thuan Phu stove has the best PM2.5 emission performance - its content is only approximately 60 mg/MJ-del. This can be explained by the way the syngas passes to the burner. Syngas rises up through a rice husk layer, then goes into a plastic pipeline and finally passes through water pipeline before it rises up to the burner. Most particle mater and tar is absorbed by the rice husk layer and water. The worst PM2.5 performance is traditional stove, PM2.5 emission content is nearly 800 mg/MJ-del.

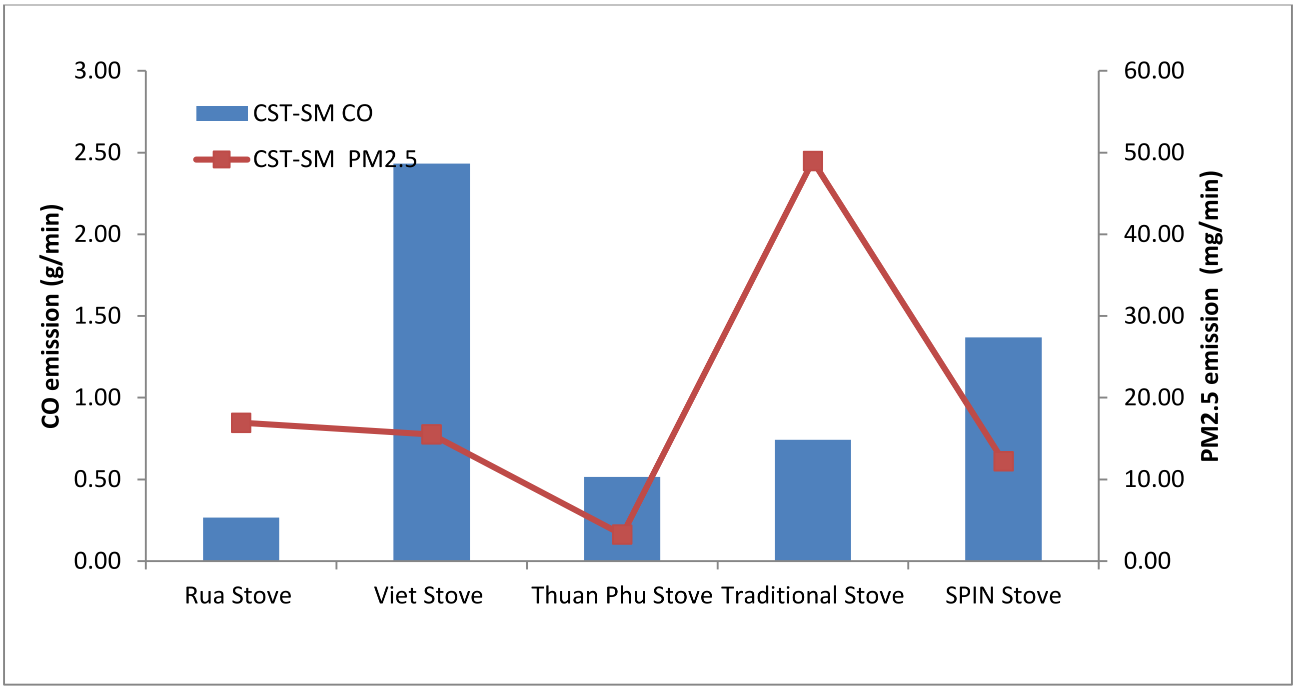


Figure 8: Emissions performance of five stoves the WBT during CST-SM

By observing both PM and CO emission levels (Figure 8), the greatest challenge for achieving the highest levels of performance will be reducing PM and CO emissions, to approach those achieved by Thuan Phu stove and Rua stove. Also evident in Figure 8 is the large range of emissions from the stoves, this variability is likely due to differences in operation and design.

Emission factor

The emission factor measures the amount of CO/PM emitted per 1kg of fuel burnt and is a good indicator to compare stove performance. Figure 9 shows the emission factors of the different stoves.

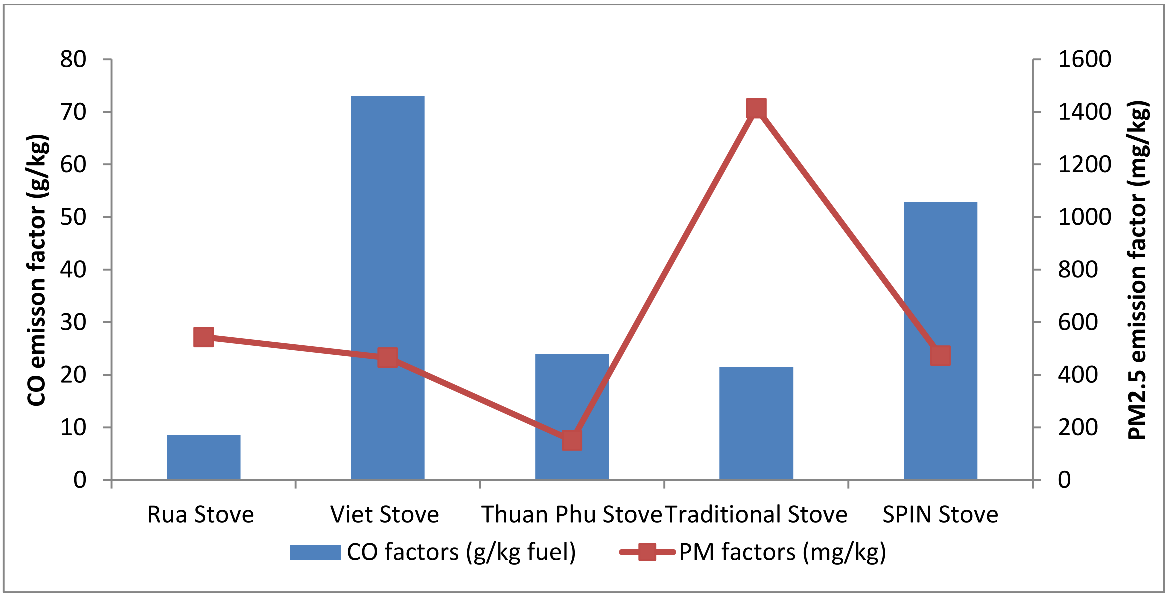


Figure 9: Comparison of emission factors (EF)

To get a better understanding of the CO emission factors, published data from Aprovecho[18] on the 3 Stone Fire stove and VITA stove was used. These stoves have a CO emission factor of 40g/kg and 90g/kg respectively.

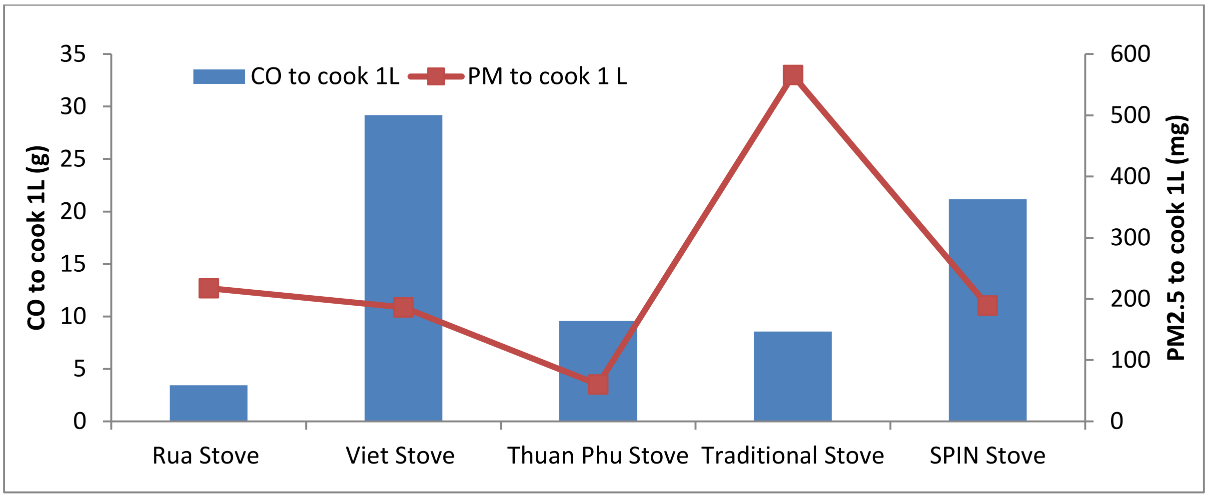


Figure 10: Relation of CO and PM for a cooking task under the emissions hood

Both All 3 domestic gasifiers have similar PM's, however the CO emissions of the Viet Stove are much higher.

In order to compare the performance of the stoves with international stove standards, a reference of the CO emission data series is presented below. The data was extracted from the Test Results of the Aprovecho Centre.

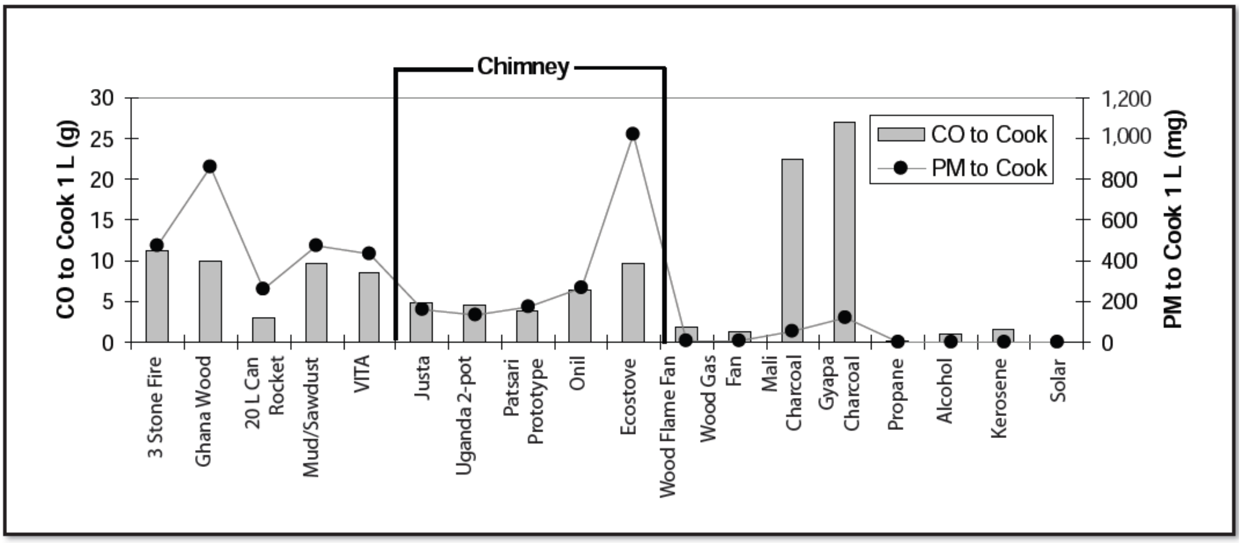


Figure 11: Relation of CO and PM for a cooking task under the emissions collection hood

18 Test Results of Cook Stove Performance, PCIA, Approvecho Centre. http://www.pciaonline.org/files/Test-Results-Cookstove-Performance.pdf

4.3 Trial use preference testing

In addition to laboratory testing, the stoves underwent user preference testing in the SSC project area. Below the results of this are shown.

4.3.1 Activities before evaluation

Two workshops were organised in each commune of the SSC project, Quang Binh and Binh Dinh. In total, 96 women took part (24 women per commune across 4 communes). The first workshop included indoor sessions in which the four stoves were explained as well as outdoor demonstration sessions, involving participation of the women in the audience.

After the workshop, participants used the gasifier stoves for two weeks. A user survey was conducted to gather information on user experience and marketing. The second workshop was then organised to gather in-depth feedback on participant experience.

4.3.2 Findings

Feedback from trial users indicates that quality of the stove is important (lifespan), as is the safety, the cooking and fuel consumption. Users who used stoves similar to the Rua stove in the past are particularly worried about quality. Their experience was that the quality of this stove was good in the beginning, but over time when demand increased, the quality quickly went down. Table 17 summerises user feedback of the four types of stove. The full report on the preference testing is available upon request.

Table 17: Advantages, disadvantages and suggestions for tested gasifier stoves

	Viet stove	Rua stove	SPIN stove	Thuan Phu stove
Advantages	• Portable, handy • Easy to operate • Fast cooking • Clean cooking • Fuel saving • No smoke	• Portable, handy • Easy to operate • Clean cooking • Fuel saving • No smoke	• Easy to operate • Clean cooking • Fast cooking • Fuel saving • No smoke • Suitable height (stable)	• Nice flame • Stable pot supporting structure • Easy to remove char/ash
Disadvantages	• Flame is too tall • Stove body is too hot • Not save • Fan is too strong	• Flame is too tall • Bad quality material • Fan is too strong	• Too high • Adapter easy to break • Pot handles are weak	• Difficult to operate • Takes long time to start (20-30mins) • High fuel consumption • Smoke has a bad smell • Smoky when adding more fuel during cooking
Suggestions	• Add one more outer layer to protect users from heat • Use better material quality • Reduce stove height	• Use better quality material	• Reduce stove height (-20cm) • Fan should be removable • Enlarge fuel chamber	• Convert to batch type (no need to add fuel during cooking)

Participants also provided suggestions for improvement of the stoves (Table 17) and an ideal stove (Table 18).

Table 18: An 'ideal stove'

Features of an ideal stove	Implication	Ideas for improvement
Portable, handy	Easy to remove char, easy to handle and move around the house	Stainless steel
Easy to operate	Simple lighting, fast firing	TLUD design, firing from top
Fast cooking	Powerful flame, able to run on high power	TLUD design, good fan
Easy to control fan	To control the flame for specific thermal need (e.g. boiling, simmering)	Use electronic adapter and a 12V DC fan from computer for better regulation
Clean cooking	No smoke, blue flame, no dust	Good burner (Belonio, Paul Oliver)
Stable pot supporting structure	Stable pot handles	Better handle welding (similar to LPG stove)
Not too high	A stable stove	Rua stove has most suitable height
Two layers (for the stove body)	Protection from the heat of the temperature of the stove body	Secondary air between two layers to cool the stove body, while utilising heat for gas combustion
High quality material	Long lifespan	Stainless steel
Long cooking time	Able to cook a full meal	Large fuel chamber, with controllable fan

4.4 Conclusion of the laboratory and preference tests

4.4.1 Selection of a stove for piloting

The analysis suggests that a design improvement of an available stove can meet participant expectations of an 'ideal' stove. The Rua stove was selected as the base version for design improvements for a number of reasons. The Rua stove has most of the features described above and can be easily adapted to meet additional features desired by households. The Rua stove has the lowest emissions among the stoves tested. Very importantly, the Rua stove has been produced and distributed on a large scale - thousands of Rua stoves have been produced and disseminated in the two years prior to testing. The market for Rua stoves has gone down due to the use of poor quality materials and short lifespan. Sellers have lost the trust of buyers - broken Rua stoves were found in the province after just three months of use. However as the Rua stoves have been in mass production, producers are available. Due to the economy of scale, the price can remain low.

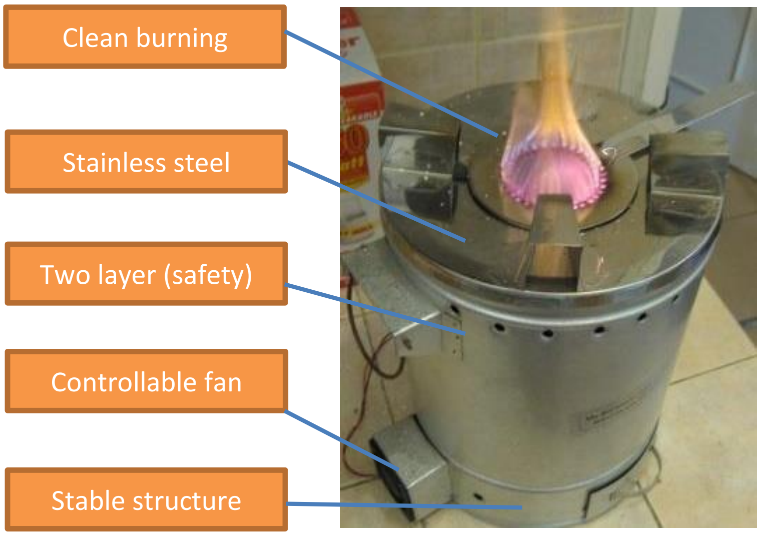
The SPIN stove is of high quality, however no mass production was be possible at the short term – and the price for small-scale production is too high for rural households. The Viet stove is made manually and there is limited capacity for production(one person runs the workshop). The Thuan Phu stove has a high cost and complex operations.

Incorporating some of the ideal stove features, with support from the EU-funded SPIN project and its partners, a new version of the Rua Stove was developed and selected for roll out in the SSC project. More details can be found in 4.4.2.

4.4.2 Technical design

The design of the Rua stove needed improvement before the pilot. The main improves include:

- a controllable fan with a suitable air flow rate and a good dimmer
- a clean burner with blue flame
- better quality material to ensure lifepsan of the stove is at least one year
- to ensure safe use, two layers for the stove body are introduced. Another advantage of having two layers is that the secondary air flow can be taken along the gap between the layers for utilising the excess heat of the fuel chamber, and cooling down the outer layer.



Picture 15: Concept of a perfect gasifier

4.4.3 Stove cost

The new design meant an increase to the cost of stove production, which was carefully managed to ensure the product was still suitable for use in the SSC project areas:

- Improvement of the quality of the materials increases costs. The new DC fan with electronics and an adapter cost more than the original low quality fans. However, cost increases were minimal, computer fans and adaptors are widely available in the market and electronics circuits ordered in large quantities are reasonably priced.
- Some structures of the burner had to be modified, requiring investment in new moulds. In addition, more manufacturing steps were required because of the need for additional parts and more detailed work. These costs were minimised through mass production, increasing the economy of scale.

A normal quality Rua stove, which lasts for three months, has a price of USD 15-17. The SPIN stove, when mass produced, will last for one year and has a price of USD 45-50. Based on current materials and improvements, SNV predicted the remodelled Rua stove would have a price of approximately USD 30 when mass produced.

4.5 Financial Benefits of the gasifier stove

To ensure households benefited from the new stoves, the costs of changing from old stoves to the new model were estimated.

In terms of fuel cost, switching from an LPG stove or fuel wood stove to a rice husk stove will save user's money. Each stove has a different efficiency and each fuel has different low heat value (LHV), so the heat available for cooking is different. To be able to make comparisons about fuel use some calculations are necessary:

> *Amount of subject fuel = amount of alternative fuel x (useful heat of alternative fuel/useful heat of subject fuel)*

The stove efficiency and the LHV of LPG stoves, fuel wood stoves and rice husk gasifier stoves are listed in Table 19.

Table 19: Thermal efficiency, LHV and useful heat of fuels tested

Fuel	Stove Efficiency	LHV	Useful heat
	%	MJ/kg	MJ/kg
LPG (reference)	60	47.3	28.38
Wood (reference)	13	15.6	2.028
Rice husk gasifier (SNV lab testing)	20	14	2.8

According to the baseline survey, on average one household uses 3kg LPG (1/4 tank of 12kg) and 100kg of wood/month. These fuels cost on average USD 5 for LPG, and USD 5 for wood, making the average fuel cost per household per month USD 10. There are three possible scenarios for replacing LPG/wood with rice husk for cooking.

Scenario 1: Only free rice husk replaces the purchase of wood.
Amount of saved wood = 20kg of husk x useful energy of rice husk/ useful energy of wood = 27kg.
Each month each household saves = 27kg/month x 0.05USD/kg = USD 1.
Saving cost per year = USD 1.3 /month x 12 months = USD 15.6

Scenario 2: Only free rice husk is replaces the purchase of a 12 kg LPG bottle – price: USD 20.
Amount of saved LPG = 20kg of husk x useful energy of rice husk/ useful energy of LPG =2kg.
Each month each household saves = 2kg/month x (USD 20 /12kg) = USD 3.3 /month.
Saving cost per year = USD 3.3 /month x 12 months = USD 39.6

Scenario 3: All free rice husk and some purchased rice husk replaces 80% of LPG consumption and 50% of wood consumption. Purchasing price of rice husk is USD 05 cents/kg (highest price found in the field in pick season). The principle of this calculation used in scenario 1 and 2. The details of this calculation are in Table 2.

Table 20: Calculation on saving cost by switching fuel from LPG and wood to husk

	LPG		Wood		Husk		Total cost
	Use	Cost	Use	Cost	Use	Cost	
Baseline without gasifier	3kg	5USD	100kg	5USD	0kg	0	10USD
With gasifier	0.6kg (20%)	1USD	50kg (50%)	2.5USD	60kg	2USD	5USD
Monthly saving							5USD
Annual saving							**60USD**

With the price of VND 700,000 (equivalent to USD 30) for one stove under the SSC project, it will take 6 to 24 months to payback the stove. If this calculation is applied to Rua village model, it will take 3 months to nearly 10 months to payback the stove.

4.6 The Pilot in Quang Binh

It was decided to engage the Viet Stove company run by Mr. Viet, to assemble and distribute the improved Rua Stove in Quang Binh, as the company was able to work within project timelines. Marketing materials were developed including banners and demonstration stands to help retailers introduce the stove to users. Lessons learned from other SNV large scale improved cookstove programs were transferred and localised. The Agriculture Extension Centre of Quang Binh supported the selection of retailers. Retailers were continuously encouraged to sell the stoves – resulting in additional business for them and cleaner solutions for the end-users. A transit location for distributing stoves was developed, with the aim of developing this agent in the future. Training on the sales of the gasifier stoves was delivered in eight shops. During a six month period in which this pilot took place, over 50 stoves were sold.

Picture 16: Marketing materials of Vietstove

Picture 17: A local shop with Viet Stove product

An evaluation was conducted SNV in cooperation with Agriculture Extension Canter of Quang Binh in December 2014. One of the conclusions was that people were uneasy about the new stoves after bad experiences with other improved stoves in the past. Time is needed to introduce a new stove into communities, allowing people to observe its use and durability and make their own assessment on quality. This may take six to eight months.

The evaluation also revealed issues with the inner combustion chamber and the small fan (which supplies air). The first batch of stoves made were significantly higher in quality than the second batch. The company that made the stoves in the Rua Village was not providing the service and quality that had been agreed upon. The problems were mainly due to bad welding practises and unnecessary savings on the quality of the materials used. This can be corrected, as only two batches of stoves were produced in the pilot. After the evaluation results the issue has been immediately addressed with the producers of Viet Stove, so he can ensure the delivery of high quality stoves.

The limited timeline of the pilot restricted options for stove production and distribution. However the pilot did demonstrate that there is an appetite for gasifier stoves as a cleaner option for cooking. Recommendations for follow-up activities and/or pilot:

- include a commercial distribution company at the start of the project (who should also participate in all R&D phases and activities)
- a period of at least 1.5 years is required for implementation, ideally more
- the stoves should be trialled at least three months before sale
- more guidance is necessary for the sales of the stove, including how to differentiate a new stove from other stoves

- there is demand for a stove for long cooking tasks, which could be developed as a separate product
- VietStove or any producer needs to be able to control the production better in case of out of house production, or needs to decide to make the stoves in house so that quality can be controlled directly.
- Marketing is important- the combination of attractive advertisements and customer consultation can help convince potential buyers.

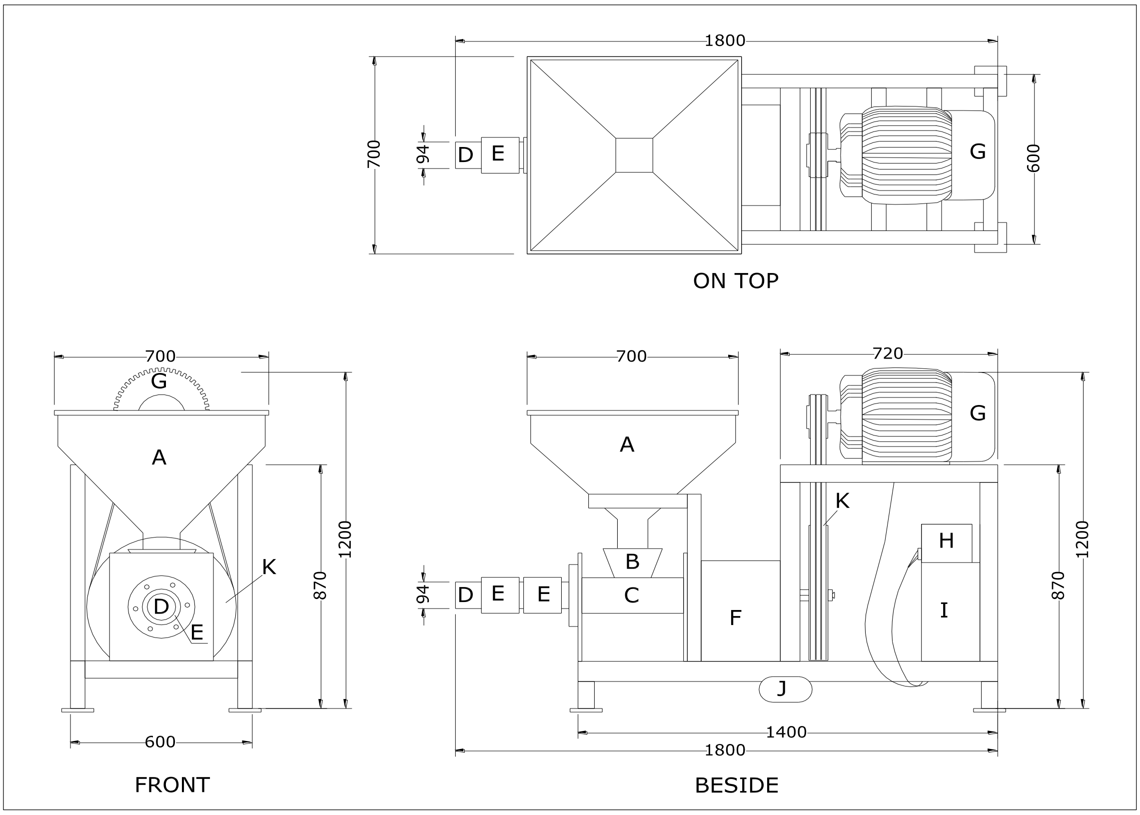
5 Rice husk briquette machine

Rice husks can be processed into briquettes, which in turn can be used as fuel for boilers in the industrial sector or for household cooking. In the SSC project areas, large amounts of rice husk stay at the rice mill and only small amounts are used for cooking. In the past, excess rice husks were typically burnt or dumped into rivers. This is practice is decreasing, as outdoor burning of rice husks is no longer permitted. This chapter will describe the process for manufacturing briquettes, demonstrate their potential to replace coal as an energy source, and provide an overview of the pilot of this technology in Quang Binh province.

5.1 In-depth information on the technology

SNV contacted several briquetting machine suppliers for participation in the SSC project pilot. The information below was provided by the selected supplier (selected based on quality and price comparisons), the Hoang Phi Company.

Picture 18 Briquette producing machine



The main parts of a rice husk briquetting machine	
Engine frame	Made of iron L73, L50, and L40 Outside dimensions of 700*1800 mm
Engine	3-phase motor (G) 22 KW Motor Starter Panel (I) Power input (Cu 3*35mm2) Power input for motor (Cu 3*25mm2)
Conveyor belt	Buley 4B200mm (Attached with the motor (G)) Buley 4B700mm (Linked to the motor) Curoa band size B (4 bands)
Motor (F)	Flange fixing the motor frames of (A) and (C) Inner motor (B) Outside flange (D) Ball-bearing sets keep the motions of the motor (3 tapered ball-bearings + 1 thrust ball-bearing)
Feeder part	Feeder (A), Feeder line (B), Fixed flange (A) and (C)
Briquette press	Coil (E) 3*2.6kW, Pressing mould (D), Flange mould

The process for producing briquettes is not complicated. The rice husk is manually fed into the feeder and is then transported by a screw conveyor into a mould (this takes approximately five minutes). The inner part of the mould is surrounded by three rounds of coils, which increase the temperature to 200 - 300°C. The heat causes the rice husks to expand causing friction. The screw continues to put pressure on the rice husks, and at the top of the screw the rice husks are grinded into a powder. The friction and the heat of the coils causes the silicon components in the husk power stick together. Rice husk briquettes reach a density of 1.1 to 1.2 compared to water.

Due to high temperature at the top of the screw and the wear and tear at this point, the screw conveyor needs to be removed every 30 hours of operation. GG33 cast-iron-welding rods or Weld Rod Cobalarc can be used to compensate. The propulsive force of the screw conveyor is relatively large so the ball bearings must be of high quality and heat resistant. In this machine, ball -bearings used must have parameters of 29412, 13, 14. Rice husk briquetting machines need lubrication regularly because they operate under high temperature and hard conditions. The oil should be regularly checked and changed every six months (equivalent to about 1,500 hours of operation). The coils operate with high capacity - each coil has a capacity of approximately 2.6 KW. The heat of the coil sometimes melts nearby extension cords, causing dangerous short circuits. Extension cords need to be checked and replaced when necessary.

Additional requirements for smooth operation of the machine include:

- The humidity of the raw materials to be less then 10% - normally, rice taken to millers is already at a suitable moisture content.
- Power supply must be stable, the power load cannot fall more than 8%. The transmission line should fit with the load capacity.
- People operating the machine should have safe working conditions including for management of dust - large amounts are created by the husks. High skill levels are not necessary but operators need to be able to recognise when to adjust the temperature and the input materials to meet machine requirements.

5.2 THE USE OF BRIQUETTES TO REPLACE COAL

In Vietnam, coal is used to generate steam for industrial processes, usually through a boiler. A simple boiler is demonstrated in Figure 16. Fuel will be combusted in the furnace, and through heat exchange, steam will be produced.[19]

[19] http://www.lenntech.com/applications/process/boiler/boiler-feed-water.htm

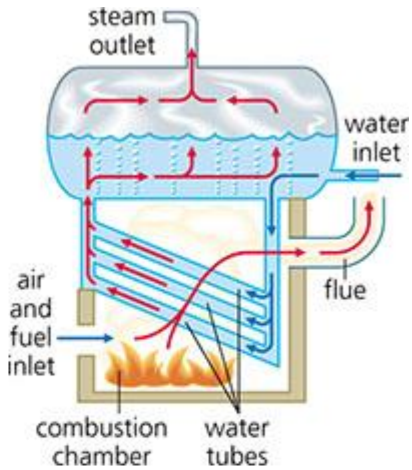


Figure 12: Simple boiler system

The relationship between the type of fuel used and heat transfer surface is demonstrated in the formula:

$$D = D_0 \times Stn$$

D = Steam quantity, kg/h
D_0= steam rate, kg/m2/h
Stn= heat transfer surface, m2

The calorific value of fuel is converted into the steam rate for quicker calculation and comparison.

Table 21: Steam rate of selected fuels

Fuel type	D_0 value (kg/m2/h)
Fuel Oil	25 – 37.5
Distillate Fuel Oil	15 – 20
Coal	10 – 15
Biomass (wood, rice husk briquette)	5

The introduction of briquetting machines as part of the SSC project is build around a business case of the replacement of traditional fuels as represented in table 22. To be able to develop a good business model it is important to estimate what it is that you are replacing and if this is financially interesting. Table 23 indicates the potential annual savings when using rice husk briquettes to replace coal in a steam boiler of a certain size. It can be concluded that the pay back periods are extremely low and often less than one year – under the assumption that the husks are available for free.

Table 22: Economic estimation of rice husk briquette machines[20]

No	Steam generation capacity, kg/h	Cost for replacement, million VND	Annual saving, million VND	Payback time, year
1	500	320	258	1.2
2	750	390	387	1.0
3	1000	445	516	0.9
4	2000	543	1.032	0.5
5	5000	1.230	2.580	0.5
6	6000	1.450	3.096	0.5
7	7000	1.697	3.612	0.5
8	8000	1.914	4.128	0.5
9	10000	2.150	5.160	0.4

5.3 Pilot in Quang Binh

SNV visited rice mills in Quang Binh and Binh Dinh to identify the use and access to rice husks and also discuss the potential interest from the millers and/or cooperatives for a briquetting machine. Furthermore SNV actively supported the development of a business model for the potential purchaser, identifying potential buyers of the briquettes and supporting partnerships. As investment in the equipment for briquette production is significant, potential buyers did need to commit to own investments and therefore also needed to have a minimum guaranteed amount purchased by the market. This was quite a significant activity as the discussions showed that there was no local knowledge on the production and/or use of briquettes. People are not aware of the opportunity.

A training manual for the rice husk briquetting machine was developed to increase the capacity of local authorities and rice mill owners to better understand briquette machines and the benefits of reusing rice husks. SNV also organised a study tour to the south of Vietnam for Binh Dinh and Quang Binh SSC project partners to see how the briquetting machines operate.

SNV approached eight companies in Quang Binh province as potential briquette customers. Two were already using rice husk briquettes to fuel boilers and one additional company intended to replace their coal boiler with a rice husk briquette boiler. Rice husk briquettes constitute 95% of the total fuel used by the Ha Noi – Quang Binh Beer company (5% of coal), while Long Giang seaweed starch company uses rice husk briquettes for 20% of their fuel supply. Both companies get fuel from other provinces. For several reasons, the other five companies were not interested in briquettes. Reasons included: special temperature requirements that are not met by

[20] The formula already indicated that when switching from coal to briquettes the steam quantity (with a same amount of fuel) will be reduced by half. Assumed prices of rice husk briquette are VND 2,000 /kg and for coal is VND 5,000 /kg, another assumption is the production of 8 h/day and 300 days/year.

briquettes, a source of free fuel (biomass) was available for use instead and small scale operations limited briquette benefits.

The rice mill of Ms. Tran Thi Quynh in Ta Phan village, Duy Ninh commune, Quang Ninh district decided invest in a rice briquetting machine. The rice mill invested 85% and the SSC project provided the other 15%. The miller was requested to develop a (simple) business plan to make the case and ensure commitment. Two briquette machines were purchased, details are in Table 23.

The SSC project supported the development of sales channels and advisory work – mainly on the technological side, for example through technology transfer trainings. The rice mill was linked to the two potential buyers of briquettes. This relationship created up a win-win situation - the briquette users saving on transport costs and stimulation of the local market.

Table 23: Budget for rice husk briquette machine investment with support from SNV

	Items	Contributed by SSC (VND)	Contributed by the miller (VND)
A	**Investment costs:**		
1	Purchase of two rice husk briquette machines	65,250,000	79,750,000
2	Cost for training on use of rice husk machine for local authorities and demonstration of rice husk machine, cost for AEC staff to monitor the model	19,330,000	
3	Promotion of 03 metric tons of rice husk briquettes for 3 potential/first buyers	2,250,000	2,250,000
	Total	**86,833,000**	**82,000,000**
B	**Annual Operational cost:**		
1	Electricity cost (88.000đ/hour x 7h x 25day/month x 10month)		308,000,000
2	Contribution of human resources	33,512,960	250,000,000
	Total (A+B)	**120,342,960**	**640,000,000**
	Percentage contributed to TOTAL YEAR 1	16%	84%

During installation of the machines, there were two major challenges:

- By own choice Ms. Tran Thi Quynh decided to not construct the workshop as indicated by the briquette machine seller and their design. This unfortunately resulted in a situation in which smoke could not leave the workshop. This issue was solved by enlarging the chimney to have a better flow out of the workshop.

- Due to a natural learning curve the briquettes were too loose initially, however through additional guidance of both SNV and the briquette machine deliverer this problem was overcome.

After thes initial challenges the machines have been operating well and when rice husk is available the household is making and selling the briquettes.

In conclusion, to get markets working it is very important to match demand and supply. During contact with the rice millers it became clear that burning or dumping of the rice husks is preferred to setting up a small briquetting business (see also the chapter with baseline information). Lack of knowledge on briquette production and use, lack of access to sales channels and the upfront investments are the main challenges identified that had to be overcome by the project. However all of them are relatively easy to address, and could easily be replicated for scaling up purposes. There is a big potential for this product, both on the supply and demand side in Vietnam.

6 STRAW BALING MACHINE

SNV introduced straw bailing machines to Quang Binh and Binh Dinh provinces to reduce the open burning of the rice straw and increase its value through central collection and linkages with potential end-users.

6.1 INFORMATION ON THE TECHNOLOGY

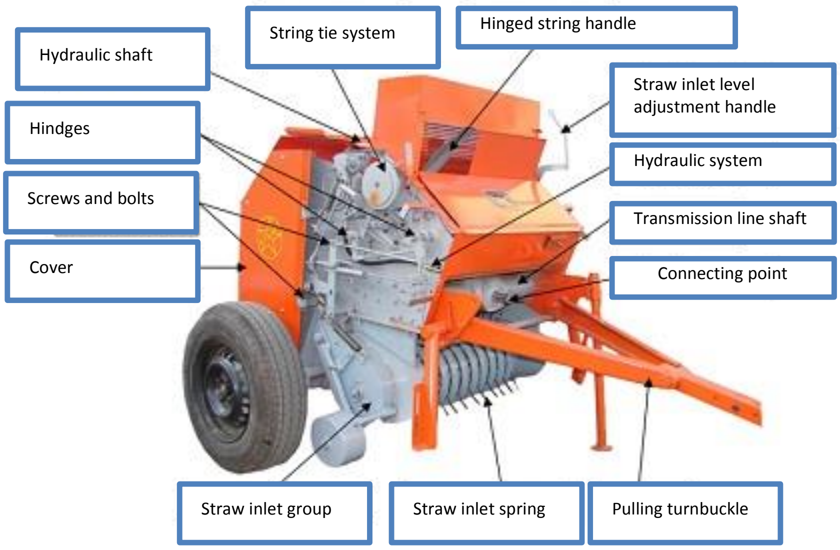
Rice straw is used for many purposes such as construction, combustion and feed. Straw has a large volume but low density making transportation costs high. Straw baling machines significantly reduce the volume of the straw enabling efficient collection, storage and transportation. In the south of Vietnam, the use of bailing machines has had positive environmental and economic affects.

Two types of straw balers are available Vietnam, those that create the box shape and cylinder shape bales.

Picture 19: Rice straw bales (box shape – left and cylinder shape – right)

Straw bailing machines are connected to a tractor which is driven through the rice fields collecting rice straw. When the rice straw inside the machine reaches a certain amount, the straw is tied and pushed out of the machine.

The information below is taken from the Z755 company website, the supplier of the machines in the SSC project. Most baling machines are similar to the one provided by Z755 company. [21]



[21] http://www.z755.com.vn/7569-may-cuon-rom-z755.html

Figure 13: Rice straw bailing machine structure

The operational principles of rice straw baling machines is to transmit the rotation of the outlet shaft of the tracker through the cardan shaft to the rotation for baling rice straw.

- The height of the machine can be adjusted to suit the length of the rice straw.
- Baling machines need to be connected to a tractor, which should be driven at a speed of 5 km/hour.
- The spring system of the rice straw inlet group will collect the rice straw and feed it into the rolling shaft, which rotates the rice straw in a cylinder shape.
- When the required quantity straw has been collected, the driver will be notified and will manually pull the hinged string handle for tightening. The hydraulic handle will then be pulled and the hydraulic piston will and push the rice straw bale out of the baling machine.
- After the rice straw is released, the direction of hydraulic valve will be changed, tractor moved and driving resumed.

Table 24: Components of rice straw bailing machine[22]

No	Description
1	Straw inlet reel
2	Wheels
3	Slope
4	Roller
5	Straps
6	Machine body
7	Speed box
8	Cutting shaft
9	Hydrauic cylinder
10	Curve bar

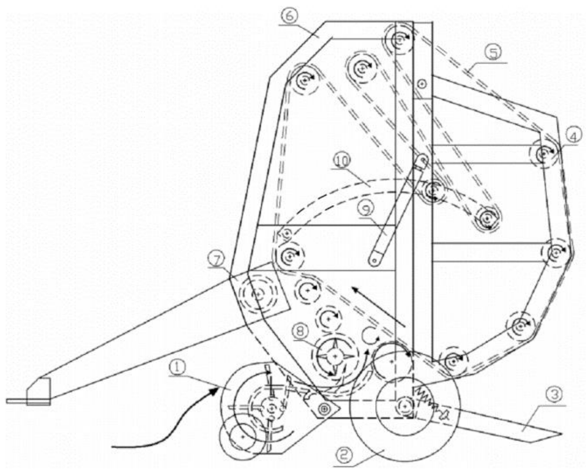


Figure 14: Inside rice straw bailing machine

Viscid oil should be changed in the places identified by the red arrows in Figure 17. The strain of the chains inside the machine should be rregularly checked – the maximum being approximately 3 mm. If this value is higher than 3 mm, the chain eye should be increased by tightening two wrenches that strain the pressure wheels (red circle in the picture below).Chains need to be oiled with viscid oil to ensure the smooth operation and increase the lifespan of the machine.

[22] crd.ctu.edu.vn

Figure 15: Maintenance positions of the rice straw bailing machine

6.2 THE PILOT IN QUANG BINH AND BINH DINH

Even though the investment in this technology is high (VND 150 million for a baling machine and VND 112 million for a tractor), two organisations decided to invest: the Phuoc Hung commune co-operative in Binh Dinh and the Livestock Breeding Center in Quang Binh. The straw bales are sold to animal farms in both provinces, and in Binh Dinh they are also sold to mushroom farmers. The payback period for the total investment is expected to be around one year.

In Binh Dinh, Phuoc Hung co-operative bought both the tractor and the baling machine with a total investment of VND 262,000,000. The Agriculture and Fishery Extension Centre supported 28% of the investment, SNV supported 42% of the investment and Phuoc Hung co-operative invested the remaining 30%. In Quang Binh, the Livestock Breeding Centre bought the baling machine with an investment of VND 150,000,000. SNV supported 70% of the investment and the centre invested 30%. Two operation and maintianence trainings were given by the technology provider with financial support from SNV.

The use of the machine in project areas has been extremely successful. The local government of Binh Dinh has shown interest in this equipment and is planning to purchase two more machines. Picutre 19 shows the operation of one baling machine in Phuoc Hung commune, Tuy Phuoc district. The capacity of this machine is 500 bales per day.

Picture 20: Operation of straw baling machine in Phuoc Hung, Tuy Phuoc, Binh Dinh

Picture 21: Storage of rice straw before and after using straw bale machine

Picture 22: Feeding cows with straw bales

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