Fact Finding Mission 21-31 August

Findings and recommended changes to TA: Bio-waste minimization and valorisation for low carbon production in the rice sector - Vietnam

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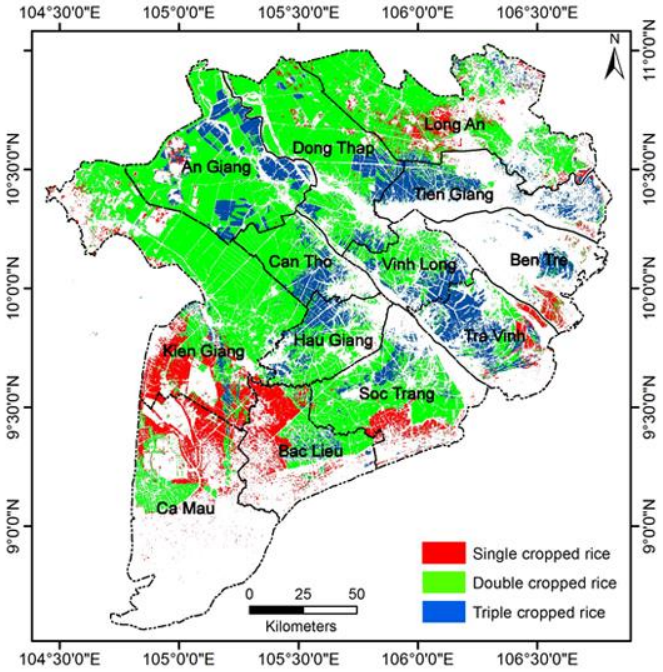
1. Fact Finding mission

The SNV team visited a number of mills and technology manufacturers in the Mekong Delta region from the 22nd to the 31st of August. The field visit was undertaken with the following objectives:

- Understand better the current development in the rice milling sector on rice husk resource availability and potential other resources such as rice straw
- Assess on the ground performance of various valorisation technologies; briquetting, pelleting, heat and power generation.
- Assess opportunities for optimal valorisation of husk

In this period Ho Chi Minh city, Tien Giang, Dong Thap, Can Tho, An Giang province was visited in the Mekong Delta Region (MRD) of Viet Nam. In Cambodia the province Takeo and Phnom Penh was visited. In Viet Nam, this covered the main rice producing areas, where 3 cropping season per year are common, see the figure below:



This fact-finding report includes observations from the field, discussions with millers, traders, technology producers, DARD (Department of Agriculture and Rural Development), discussions with experts, including follow up communication and literature review.

The overall aim of this report is to identify strategies and options to maximize the outcome of this technical assistance (TA) which eventually results in improving the economic performance of rice millers.

2. Main Findings

Rice mills

- There is a government push towards full-service mills that service a particular cropping area, including service provision to farmers and processing of rice from drying to polishing and whitening. Furthermore, mills that export rice should have a minimum installed capacity of 10 ton/hour in order to obtain an export licence.
    - In the past, dehusking was often done by small mills near the rice cultivation area and then transported to larger mills for further processing. This double milling system had several disadvantages as the practice made it difficult to control the quality of the rice.
- Most mills are medium or large size. Small sized mills are rapidly disappearing in favour of mills with more professional equipment.
- The electricity tariff for productive sectors[1] is applicable to mills and shown below:

Voltage level from 22 kV to under 110 kV	**VND/kWh**	**USD/kWh[2]**
a) Normal hours	1405	0.0630
b) Low hours	902	0.0404
c) Peak hours	2556	0.1146
Calculated weighted weekly (24/7) average	1485	0.0666
Calculated weighted normal and low hour average	1252	0.0561

- The peak hour is a period of 2 blocks of in total 5 hours, 2 hours in the morning and 3 in the afternoon on all days except Sunday. The exact time varies by province and allows EVN, the National Electricity Utility, to spread the load over a longer period. Low hours are 6 hours during the night (22:00-04:00) and normal hours the remaining hours.
- Milling during peak hours is much more expensive compared to the normal hours, 2556 compared to 1405 VND/kWh respectively.
- Private sector mills operate around 10 to 12 months per year and, except in the peak season, they try to avoid the peak hours.
- State owned mills operate as per milling quota set by the Government state owned company Vinafood 2. Accordingly, some may operate only 7 months per year until the quota is reached.
- The millers interviewed complained about high monthly energy bills. It was not possible to ascertain why the bill is high during the field mission; it is likely the combination of high milling throughput and milling equipment that is somewhat antiquated and not that energy efficient. Energy efficiency (EE) improvements and concurring energy savings may therefore be possible.

[1] *Ministry of Industry and Trade's Decision No. 2256/QD-BCT dated March 12, 2015)*
[2] *Exchange rate is 22,301 VND/USD*

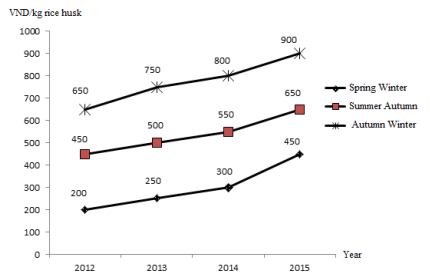
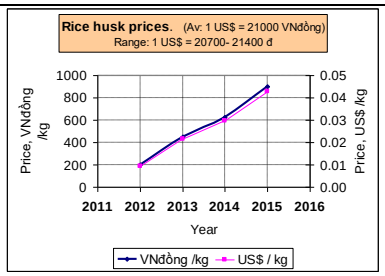
- Energy efficiency improvements is being addressed currently under the Resource Efficient and Cleaner Production (RECP) – a UNEP and UNIDO program by VNCPC. For example, VNCPC has executed an energy audit on the Song Hau mill, which included recommendations on LED lighting and variable speed motors etc. They are currently auditing 5 others state owned mills that belong to VINAFOOD 2 in the Mekong Delta Region (MDR).

Paddy drying

- Almost all medium and large rice mills have installed mechanical dryers, most often a flatbed dryer. More advanced drying technologies such a fluidized column dryer are becoming more common among larger mills.
- It is more difficult to ensure uniform drying of paddy in flatbed dryers compared to fluidized bed column dryers. In a flatbed dryer uniformity, within a certain range, is ensured by either turning over the paddy manually or, in larger mills, mechanically using an auger conveyor.
- Rice husk is the most common source of fuel for furnaces that supply heat to the dryer, in rare cases, coal is used.
- Around 20 to 40 kg of husk is required to dry one ton of paddy depending on the moisture content. In the rainy season, husk consumption per unit of paddy is therefore higher than the dry season.
- The share of husk used for drying varies considerably between the mills, reasons being:
  - Not all mills are full service mills, some focus on processing brown rice and do not require drying equipment.
  - Some mill offers paddy drying as a service to other millers or traders and are consequently using a large share of their husk for that purpose.

Rice husk use, price and availability

- In a full service mill (drying, dehusking, whitening and polishing), 10 to 20% of the husk is used for drying depending on the moisture content of the paddy. At those mills around 80 to 90% of the husk is available for other uses.
- In practically all cases rice husk is valorised. Common valorisation routes are included in Annex II and include:
  - Paddy drying
  - Briquetting/pelleting
  - Sale of raw husk to brick kilns, to companies that have fluidized boilers, to traders, to briquetting or pelleting companies
- The fact-finding missions was unable to confirm the basic premise of the ToR; husk is in neither of the visited areas dumped or under-utilized; the price of husk is relatively high and there is a competitive market for it. Discussions with experts in the field, i.e. professors from the Can Tho and Nong Lam University, confirmed this.
- The price of husk has been increasing significantly since 2010 when it was available for free or at low cost or was even dumped. This has drastically changed and husk has a high value currently, as exemplified in the table below:

		**From the fact finding mission:** In 2010/2011 price of husk was either 0 or very low (100 VND/kg) In most location it gradually increased, in some it peaked in 2012 with prices of up to 1200 VND/kg and then decreased but remained high In general, it is now around 500 to 800 VND/kg depending on the season
Truc et al (2015) - *Current uses and economic efficiency of rice husk uses of the rice millers in the mekong delta, vietnam*. Can Tho University Study among 85 millers in Can Tho, An Giang, Dong Thap and Tien Giang	Former professor Phan Hieu Hien of the Nong Lam University of HCMC. Study executed for the Seed of Change project of AusAID.	The price of husk is influenced by the price of coal and international oil market

- In 2010 the price of husk was very low. Professor Hien from the Nong Lam University, interviewed on 6 September, argued that this was because of the transition from small scale dehusking to large scale dehusking. Suddenly, in a short period, large amounts of husk became available at a point-source for which no market was available. That practice led to underutilization and dumping of husk in waterways.
- The low price of husk, in combination with the high oil and coal price in 2011 and 2012, led to a rapid development of various valorisation options; mostly as fuel (briquettes and pellets) and a great number of husk to power project have been proposed in that period as well. Only one materialized so far, the Dinh Hai steam project which started in 2010 but stopped production in 2012 after just over a year operation.

Rice husk as fuel

- Rice husk has a low volumetric bulk density making it expensive to transport as raw material. For that reason, husk is often densified in order to reduce transportation costs. Another reason is that raw husk cannot be used in traditional coal fired boilers, but with some small modifications to the grate rice husk briquettes and pellets can also be used as fuel in those boilers.
    - The most common densification method is briquetting. Pelleting is much more expensive and only installed at large mills.
    - In provinces that are well connected by water-ways, a significant part of the husk is nevertheless transported raw by boat. This mode of transportation is relatively inexpensive combined with the fact that both the mills and the kilns are often well connected by waterways.

- **Briquetting**:
  - Main technology: Extruder screw press (manufactured in Vietnam) and to a lesser extent piston press (imported technology). The most common briquette diameter is 90 mm.
    - Screw press:
      - Relatively inexpensive (~100 million VND for 400-500 kg/h), but requires routine maintenance on the screw and die.
      - The briquettes are formed by compression and heating of the outside which chars the briquettes surface area and the inside of the briquettes around the guiding rod. Without proper care, this could result in a fire hazard. This has happened to some mills.
    - Piston press (also known as ram and die technology):
      - Relatively expensive (~800 million for 1-1.2t/h) but requires less maintenance.
      - The briquette is somewhat brittle and not charred on the outside and looks like a very large pellet.
  - Briquettes are sold for around 1100 VND/kg at the factory gate and 1400-1500 VND retail. The price has been relatively stable since 2012.
  - The production cost is around 300-400 VND/kg
  - Briquetting is a common technology in the MRD because of its relative low investment cost and over 150 mills have installed briquetting machines.
  - Market: Domestic market only, mainly to industries that require steam.
  - Briquetting companies' profit margin is becoming smaller as the price of husk is increasing but the price of the briquette has not changed much since 2012. Some companies operate for that reason at low capacity, or even stop producing outside the rice milling season when the price of husk is high.
- **Pelleting**
  - Main technology: Rotary ring die, mostly from China and some from Europe. There are no domestic suppliers of the technology. The technology is relatively expensive, around 800 million VND for an installed capacity of 1 ton per hour (Chinese) and 1.5 to 2 times higher when sourced from Europe.
  - Most investment into pelleting machines was done before 2013 when the price of rice husk was low and because there was emerging export market for pellets.
  - Maintenance: The maintenance is more complicated compared to briquetting machines and required trained technicians. The ring die (mould) has to be cleaned after 40 hours

Figure 1: Rotary ring die

and has to be replaced after approximately 8000 ton of product and has to be ordered from abroad costing around $2,200 to $5,000.

- Pellet are sold for around 1300-1450 VND/kg at the factory gate and retails for around 1600-1700 VND/kg. The production cost is around 380-400 VND/kg.
- Market: mostly domestic and competing with briquettes. The export market is significantly smaller since South Korea stopped importing pellets in 2014. The reason behind it is not clear and may be related to a lack of consistent quality or lack of adequate laboratory facilities to test the product.
- The profit margins are narrow of pellet producers as they are currently competing with briquette producers on the domestic market.

- **Raw husk**
  - Fluidized bed boilers are able to use rice husk directly as fuel although some basic processing such as grinding it to finer particles may still be required. The higher thermal efficiency of those boilers combined with lower feedstock cost compared to briquettes/pellets, depending on the distance, makes this option attractive for many industries.
  - Brick kilns typically use husk raw and are for that reason located near waterways making it easy to transport the husk to the kilns. Traditional kilns however are closing or will close in the near future as per government directive to reduce air pollution.
  - Grinded husk is sometimes used as an additive to animal feed. It is not clear whether this would improve the quality of the feed (i.e. the digestive fibres of the husk could aid digestion) or if it is used to 'bulk up' the feed with a low cost additive with little nutritional value (cost reducing measure).

Heat and power generation

- **Steam**
  - Steam could be used through a heat exchanger to dry paddy. There are no mills however that do this in Viet Nam. Direct combustion of husk in a furnace to generation thermal energy for drying is the most common method.
  - There is one example of an energy service company that used rice husk to generate steam for industries – the Dinh Hai Enterprise.
    - They started in 2009 to supply steam (20 ton/h) from a 2 MW fluidized bed boiler fed by rice husk to sea food companies in the Tra Noc industrial zone in Can Tho through a 5 km long pipe.
    - Within one year they were able to recoup their investment; rice husk price was low, 100 to 200 VND/kg; selling price of steam was high, at 70% of the price of steam generation from oil
    - They planned to generate electricity as well from husk by converting the installation to a 7 MW CHP, but this never materialized. One of the obstacles faced was the low grid electricity tariff and the low feed-in tariff. In addition, in

2012 the company ceased operations as some clients switched to using their own boiler and others went bankrupt which diminished the demand for steam.
        - With current coal prices, generation steam from husk with a price of 1000 VND/kg is still interesting and cost competitive with coal according to the director of the company. However, companies may prefer to install their own steam boiler instead of relying on a centralized steam provider.

- **Combined heat and power (CHP) or power only generation**
    - There are no examples in Vietnam of CHP or power generation from rice husk with the exception of a small pilot CHP of 50 kWe in Long An a few decades ago.
    - In 2013, when the price of husk was low, many CHP plants were proposed, 169 in total, see Annex III.
    - The CHE Group (Malaysia) started in 2003 with studying the feasibility of CHP and announced in 2013 they are planning to construct 20 10 MW CHP plants in Viet Nam using an advanced technology from Torftech[3] (UK) that creates highly valued amorphous silica ash by the cement industry. The plants are multi-fuel and can accept both rice husk and rice straw.
        - Their business model is based on selling of the silica ash for $400-$500 per ton, they have secured a PPA (power purchase agreement) of $7.4/MWh with EVN and claim to have secured long term contracts with a number of rice mills for their first plant of 10 MW for only 200 VND/kg. That price was realistic in 2013 but low in 2016; it is not clear how that would affect the viability of their plan.
        - They ran into difficulties with financial closure which has stalled their programme of 20 plants.
    - The Sweden-An Giang Cooperation project is exploring CHP in An Giang province.
        - They trained students on biomass power projects, prepared a GIS database of milling plants and biomass power plants and prepared a number of business outlines include 2 business models ready for financing.
        - The biomass power plants however have limited viability. For example, one proposal prepared by ENERTEAM (Energy Conservation Research and Development Centre) and FA (Full Advantage, Thailand) won a grant from EEP Mekong. The proposal provides a good insight in the viability of rice husk to power
            - The project concept note submitted to EEP was about funding a 3 MW CHP with a total investment of almost 5 million euro
            - They were granted 0.7 million Euro grant contribution, which would lift the payback period (PBP) from 13.8 years to 12.2 years, the IRR would increase from 6.6 to 9.1%.

[3] http://www.torftech.com/

- Even with this grant component, according to the rice miller involved, Tuyen Phat, the project was deemed too expensive and risky. It could not compete with the grid and the PBP was deemed too long.

- In line with government policy to install 500 MW of biomass power projects by 2020, the government has created a more favourable environment for biomass projects by introducing grid feed -in-tariffs for biomass power projects. The grid feed-in-tariff (FiT) is $5.8/MWh for CHP and 7.4/MWh for biogas power plants. The FiT is in United States dollars ($) and the consequently the VND tariff can vary depending on the exchange rate.
- In Cambodia rice husk to power generation did take off aided by the much higher electricity tariff ($0.17/kWh).
  - In Cambodia a 2MW rice husk power plant was visited, the Angkor Kasekam Roongroueng co-generation plant.
    - This plant was the first of its kind to apply advanced technology from Torftech to produce amorphous silica ash from rice husk. The plant is largely grant funded through climate finance.
    - Their business model was to sell amorphous silica ash, selling of certified emission reductions (CERs under the Clean Development Mechanism and sell electricity to the grid ($14/MWh). Residual heat is not utilized.
    - They were able to produce ash with a high percentage of amorphous silica due to a tightly controlled temperature of combustion in the reactor of Torftech (Torbed fluidized bed reactor).
    - They produce typically around 1.5 MWe, of which 1 MWe is supplied to the mill, 200 kWe to the grid and 300 kWe is parasitic load of the co-generation plant. The parasitic load is relatively high but necessary to maintain the right conditions in the Torbed reactor for the production of amorphous silica
    - At the design of the plant, the aim was to sell ash to cement factories and several, mostly Vietnamese, expressed interest in this. According to the owner the ash is valued at around $600 per ton. They were however not able to produce the amounts required, a typical cement producer would need around 10,000 ton per year.
  - The CHE group, discussed on the pervious page, is planning to install the same technology in Viet Nam. They claim that another reason that Angkor Kasekam Roongroueng co-generation plant cannot sell the ash is due to the fact that the Torbed reactor is not running 24/7 because there is not enough husk and because of the relative short milling season in Cambodia. The quality of the ash is difficult to control with frequent shutting down of the process.
- Rice husk gasification (RHG) is a popular technology in Cambodia to produce power. As discussed in the inception report, the RHG market in Cambodia is contracting due to the availability of grid electricity, rising rice husk prices and operation and maintenance issues

with the technologies on the market (Ankur gasifiers and local manufacturers). Simple down draft gasifiers like in Cambodia are not economically feasible in Vietnam.

Song Hau food company

- The Song Hau food company was mentioned in the ToR as one of the state companies to be considered for business plan development and was specifically visited for that reason.
- Song Hau is a subsidiary of Vinafood 2 but is in process of becoming a joint stock company. This process will be completed in the coming months (September-October).
- In response to the government Decision No 606/QD-BCT dated 21 January 2015, promulgating the Roadmap for setting up raw material zone or implementing join production and consumption of rice by rice export traders in the period from 2015 to 2020, that requires mills that export to become a full-service mill, Song Hau intend to invest in a new mill closer to the rice production area. That mill, situated in Vinh district around 60 km from Tra Noc, would focus on drying and dehusking (20t/h) of paddy. The brown rice would then be transported to the Song Hau's main factory in Tra Noc district in Can Tho for further processing.
- The total investment is around $0.75 million; 30% equity and 70% loan. They did not make a decision yet on this and this is partly pending on the transition from being state owned to a joint-stock company and due to high interest rates on loans.
- Currently they also dry and dehusk paddy at their main factory in Tra Noc with an installed capacity of 10t/h. They share of husk that is not used for the paddy dryers is sold for around 600 to 700 VND/kg to industries nearby; a value that is quite satisfactory to them.
- Song Hau may need assistance to develop a business plan for valorisation of the husk at the new location, which is around 60 km from Tra Noc as they foresee some issues with the transportation of the husk. Their first use of husk would be for paddy drying but signification proportion of husk will remain available. Their ability to invest in rice husk valorisation seems rather limited, and the only options that seems applicable to them is the production of rice husk briquettes. It not certain whether they need assistance with that as it is a common technology with an established market for briquettes.

3. Discussion

The fact finding mission and also discussions with experts and literature review indicate that the premise on which the ToR is based, rice husk is underutilized and sometimes unused, is no longer valid. In contrast, rice husk has a high value and is being valorised on an increasingly competitive market. This has implications for the assignment and some of the components may need revisions. These are, inter alia, the valorisation tool and the scope in the opinion of the team.

1. The valorisation tool

Most mills are aware of the various valorisation options and it is not likely that the tool has added value to them for the following reasons:

- There are many briquetting manufacturers that are actively targeting millers and can supply tailor made quotes. The tool in contrast can only provide a generic analysis.
- Pelleting of husk requires a careful on the ground analysis including a study of the various market opportunities. Given that export of pellet is for most millers not possible anymore, they are forced to compete on the domestic market with briquette producers. A valorisation tool will not be able to assess how viable pelleting is as it required a detailed on the analysis including a study of potential market linkages which are for millers difficult to assess as the export is often done through exporters.

In addition, given the competitive use and high value of husk; there are implications for power and or heat generation from husk. Power generation is not likely viable, because first of all, there are no examples of this in Viet Nam with husk and the power plant would be a first of a kind, with associated higher costs and secondly the price of husk, the low electricity tariffs and the relatively low grid feed-in-tariff, is severely limiting the viability, in particular because expectations are that the price of husk will increase; precarious conditions for any investor. The next table shows a simplified overview of the cost of producing electricity and the potential income stream based on the following assumptions:

- 1 MWe CAPEX: $1200/MW4
- Capacity factor is 75%
- The overall efficiency is around 20% (1.3 kg husk = 1 kWhe) which is the value commonly used in the literature and present the net amount of electricity produced after a share used for parasitic purposes.
- The variable costs, depreciation and operation cost are from IFC (2009) report on rice husk in Vietnam[4]
- Ash is sold as soil amendment and sold for $20/ton (~446 VND/kg)
- It is assumed that 50% of the electricity is consumed by the mill and 50% is supplied to the gird for $7.4 cents/kWh (1650 VND/kWh)

[4] IFC – Rice Husk Market Study

Table 1: Simplified calculation of the per kWh profit margin at 3 husk prices

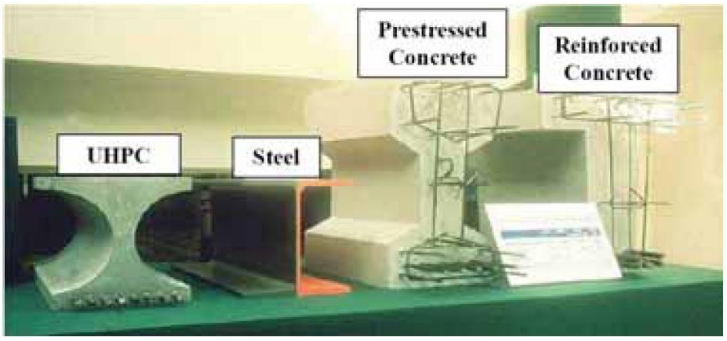
Rice husk price (VND/kg)		**500**	**750**	**1000**
Cost components				
	Fuel cost to produce 1 kWh @ 1.3 kg = 1 kWh	650	975	1300
	Variable cost ($0.01/kWh)	223	223	223
	Depreciation/kWh (10 year)	407	407	407
	Operation cost/kWh (5% CAPEX)	204	204	204
Costs excluding financing cost and contingency		**1484**	**1809**	**2134**
Income				
	Ash/kWh ($20/ton)	116	116	116
	Grid feed in (50%)	825	825	825
	Displacement of own electricity (50%)	742	742	742
Total income (exl. tax)		**1658**	**1658**	**1658**
Gross profit (VND/kWh**)**		200	-125	-450

- Based on the 'back of the envelop' calculation of the table above, rice husk power generation is not viable. Rice husk is commonly sold for prices higher than 500 VND and already at that price the profit margin is small especially given that taxes are not includes, financing costs, discount value and the CAPEX of $1200/MW is on the low side. IFC (2009) arrived at similar conclusions in 2009 while the rice husk price was at that time only $12/ton or 244 VND/kg.
- A potential way of making this viable, could be the valorisation of the ash by producing amorphous silica in a specialised fluidized bed boiler. The technology to do that is however still under development and the costs associated with it are higher due to more advanced technology, higher parasitic load and lower efficiency. The valorisation tool will not be able to assess this.

2. Valorisation opportunities

There are valorisation opportunities that cannot be assessed by the valorisation tool as these are not fully mature and because there is no market yet for the product.

The most prominent option is the production of amorphous silica ash which can be used as highly reactive pozzolan for Ultra High Performance Concrete (UHPC) instead of silica fume. UHPC has a much higher strength compared to normal concrete and thus beams and columns can be thinner which reduces both material requirement and space without comprising strength. As Pham Tuan puts it in his PhD thesis *"This makes it not only possible to design and to build gigantic structures and extremely slender, elegant and daringly designed structures, but also to make non-brittle ceramics for medical (implants and bone replacements) and industrial applications (tooling, pumps, and engines)".* See the figure blow on the properties compared to alternative materials.



Material	UHPC	Steel	Pre-stressed Concrete	Reinforced Concrete
Depth, mm	360	360	700	700
Weight, kg/m	141	110	466	528

Figure 2.11 UHPC, steel, pre-stressed, and reinforced concrete beams with equal moment capacities [Perry 2006]

This option requires a more detailed assessment which could be part of output 2: Development of business models.

Amorphous silica ash for the cement industry can be produced by installing an advance rice husk furnace for the paddy dryers (see figure 2) or by installing an advanced fluidized bed boiler for power and heat generation.

Figure 2: Advance rice husk furnace

The first option could be retrofitted with existing paddy dryers and may comprise a cost effective solution provided that the produced amorphous silica ash meets the requirements of the cement industry. The Malaysian CHE group is currently installing these type of furnaces in Cambodia for example.

Combined and heat generation (CHP) from rice husk can also yield amorphous silica ash under controlled combustion conditions. The TORBED technology of Torftech Group is one of the few technologies[5] that can produce amorphous silica. The ash could make the production of power and heat viable despite the low grid FiT and electricity tariffs.

Interviewed experts estimate the value of amorphous silica between $400 to $600 per ton, which translates itself to a value of $72 (1.58 million VND) to $108 (2.4 million VND) per ton of husk (assuming 90% of the ash is amorphous silica). Husk currently retails at 0.5 to 0.9 million VND, and thus it may be

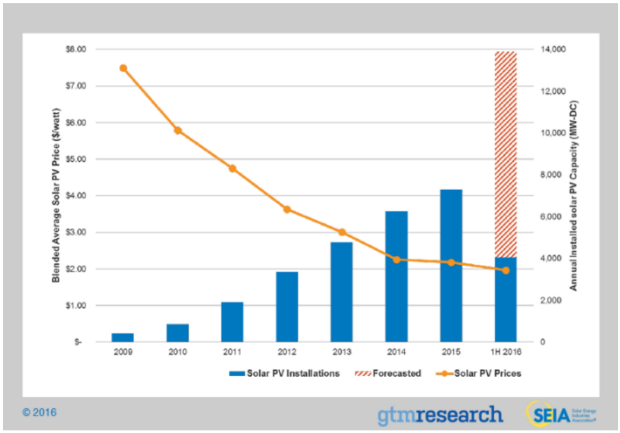
[5] http://www.torftech.com/index.php

possible to double or even triple the value of husk with this valorisation route. More study is required however to confirm this.

3. Enlarging the scope to solar energy

Potential other options of improving the economic performance of mills could be the introduction of Photo-Voltaic (PV) power for rice mills. PV faces the same challenges as power generation from husks, i.e. the low FiT, the low electricity tariffs but PV has a bright future for the following reasons:

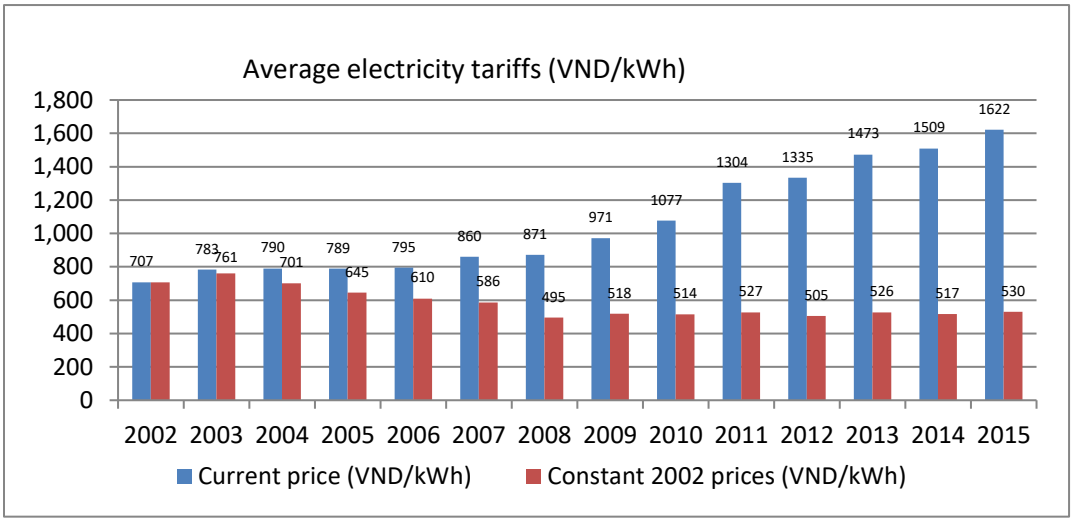
- PV (photovoltaic) or solar energy is becoming increasingly competitive and in many countries grid parity[6] has already been reached. For example, recently in the United Arab Emirates (UAE), a bid was won by ACWA Power and TSK with a ground-breaking tariff of $0.058 per kWh based on a power purchase contract of 25 years for a utility scale 260 MWp (Megawatt peak) solar power plant, outcompeting fossil fuel based power companies.
- PV prices are dropping every consecutive year. This has been branded the Swanson's law[7], who observed that PV costs half every 10 years. The figure on the right shows a dramatic decline in PV installation costs in the period 2009-2016 and the increase in installed PV power (from SEIA 2016).



- The economics of PV will eventually become so compelling that many businesses will install solar. For example, it is expected that the cost of electricity of new PV power plants in India, a comparable country when it comes to Global Horizontal Irradiation (GHI), is in 2025 between $3.5 to $5/MWh.
- An EEP Mekong project in Cambodia is offering solar packages to businesses of 100 kW with a LCOE (Levelized cost of electricity) of $0.10/kWh and $0.036/kWh over a 10 and 20 years' period respectively with 25% subsidy[8]. The LCOE without subsidy would then be around $0.13/kWh and $0.05/kWh calculated over a 10 and 20 year period respectively.
- An enabling environment is being created by MoIT. A draft Decision, subject to approval by the prime minster (circulated draft No: xxxx/2015/QD-TTg), stipulates $0.15/kWh for solar rooftops of up to 500 kW and $0.112/kWh for solar power plants of up to 100 MW for power purchase agreements (PPA) of 20 years with EVN and tax exemption for imported goods that cannot be manufactured in Viet Nam and exemption or reduction of business income tax for solar projects. The estimated LCOE, based on the example above from Cambodia with a similar GHI, is already lower than the estimated LCOE-10 year for rooftop solar.

[6] Grid parity occurs when an alternative energy source can generate power at a levelized cost of electricity (LCOE) that is less than or equal to the price of purchasing power from the electricity grid
[7] http://onlinelibrary.wiley.com/doi/10.1002/pip.709/abstract
[8] EEP mekong grant to Solar Partners Asia

- Preparing a solar business model for rice mills, i.e. rooftop solar, can create opportunities once the Decision is approved. Not only it can improve their economic performance but also shield millers from potential higher electricity tariffs in the future which are likely to occur, i.e., these have been rising gradually over the last decade, see below[9]:



[9] Policy discussion paper UNDP (2015)

4. Conclusion and recommendations

The fact finding mission revealed that there is a need to reorient the assignment given that husk is valorised on an increasingly competitive market. It also revealed that certain valorisation routes, such as power generation, are not viable under current conditions. A generic tool to assess valorisation optimization options will therefore have limited value and for options that can be assessed, such as briquetting, a well-functioning market is already established. The tool will therefore not have added value to millers.

Based on the findings, the team recommends to reorient the assignment towards options for which valorisation is still possible or to promising renewable energy options, see below:

#	Activity as per ToR	Proposed activity	Rationale/comment
1	List of indicators Valorisation tool	List of indicators	The list of indicator is almost finalized and will help with assessing business opportunities
2	2-3 business models	1. Production of amorphous silica ash 2. PV power for rice mills 3. To be confirmed	Business model 2 will be developed by reallocating the resources used otherwise for the valorisation tool. The team has expertise on solar energy.
3	Business plan development	Proposed is to work with Song Hau, provided	They are investing in a new location and may need assistance with assessing the valorisation optimization options for their husk. This it to be confirmed
4	Financing options for 2-3 business models	As proposed in the inception report, 2 models for private sector parties and 1 for state-owned	

Note that the use of husk for paddy drying is not an option per se, it is the most logical use of a share of the husk as there are few if any competitive fuels for drying. The drying operation itself is intrinsic to a well-run milling company.

Finally, small mills are rapidly disappearing, not only because of the government push towards consolidation in the sector but also because they are less economic and unable to compete on cost and quality with larger mills. For that reason, it may be worthwhile to focus on only on medium and large sized mills.

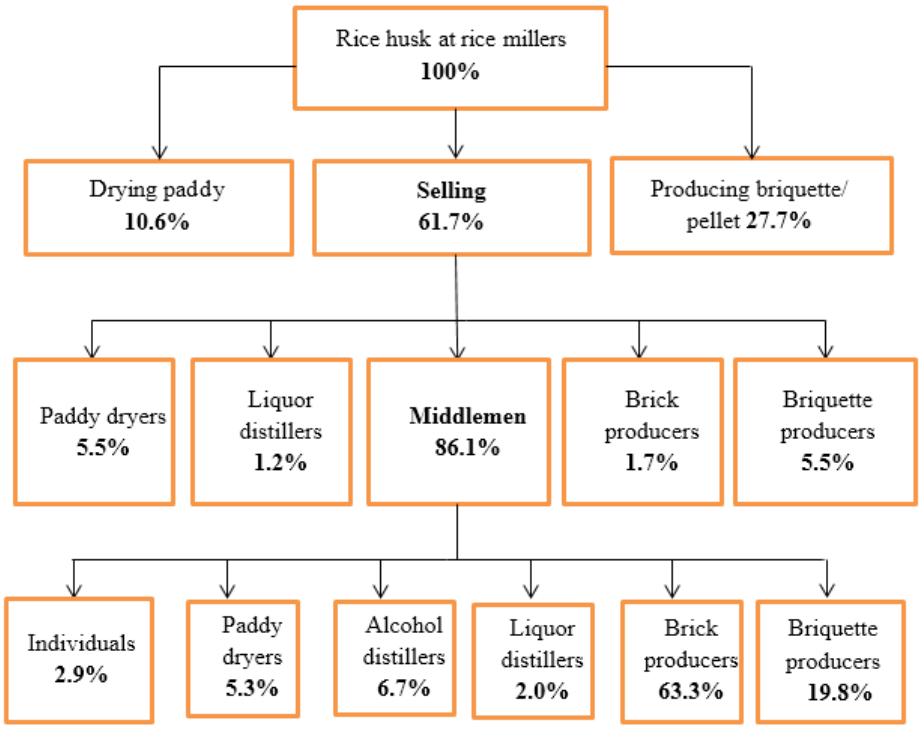
Annex I: Field trip schedule

AGENDA FOR FIELD TRIP TO MEKONG DETAL AND CAMBODIA

Biowaste minimization and volarizatoin for low carbon production in rice sector in Vietnam _UNIDO
23 - 31 August 2016

Time	Company/technology	Location
23rd August		
8:30 AM - 10:00AM	Small scale rice husk gasification (experimental scale) and other systems	Center for Agricultural Energy and Machinery (CAEM), Nong Lam University - Thu Duc District, Ho Chi Minh City
10:30 - 12:00	An Nhon briquetting machine manufacture Company	No 47/13 Street No 11 - P16 - QGV - TP HCM (0837010105 - Mr. Hoang 0903731416)
10:30 AM- 2:00 PM	Travel from HCM to Tien Giang	HCH - Tien Giang
2:00 PM - 3:00 PM	Tan Tai rice processing enterprise with flatbed dryers	Tan Huong Ward, Chau Thanh District, Tien Giang Province
3:30 PM- 5:00 PM	Binh Minh Group, a rice straw trader	My Tho City, Tien Giang ProvinceTien Giang
Night	Stay overnight at My Tho, Tien Giang	
24th August		
9:00 - 10:00	Green Energy Co., a rice husk pelleting producer in	Tien Giang Cai Lay Town, Cai Lay District, Tien Giang Province
10:00 - 12:00	Travel from Tien Giang to Dong Thap	
2:00 - 3:00	BCD rice husk briquetting system	Chau Thanh District, Dong Thap Province
3:30 - 5:00	Tan Phat rice processing enterprise, the capacity? Size of rice mill?	Lo Vap, Dong Thap
Night	Stay overnight at Sadec, Dong Thap	
25th August		
9:00 - 10:30	Ngoc Dong Co., a rice misll with collumn dryer and flatbed dryers	Lap Vo District, Dong Thap Province
13:00 - 14:00	Lam Hieu briquetting machine manufacturer	Lap Vo District, Dong Thap Province
14:00- 17:00	Travel from Dong Thap to Can Tho	
Night	Stay over night at Can Tho	
26th August		
9:00 - 11:00	Meeting with NGO THI THANH TRUC, Ph.D. Vice head	Departmetn of Environmental and Resource Economics -Can Tho University
2:00 - 4:00	Song Hau Food Co. in Can Tho	Lô 18 Khu Công Nghiệp Trà Nóc 1 - Quận Bình Thủy – TP. Cần Thơ +84 (071) 841179 – 841418- 842284
Night	Stay overnight in Can Tho	
27th August		
8:00 AM - 5:00 PM	Team meeting in Can tho	Can Tho
Night	Stay overnight at Can Tho	Can Tho
28th August		
8:00 AM - 10:00 AM	Travel from Can tho to An Giang	
10:00 - 12:00	TUYEN PHAT TRADING CO., LTD	An Thanh Village, Hoa An Commue, An Giang Province
2:00 PM - 4:00 PM	Free	
Night	Stay overnight at An Giang	
29th August		
9:00 AM - 11:00AM	AN GIANG FOODSTUFF COMPANY LIMITED - Chau Phu rice mill	Vinh Thuan village, Vinh Thanh Trung Commune, Chau Phu
2:00 PM - 4:00 PM	AN VIET RICE CO., LTD, (rice mill and pelleting)	Binh Duc 5 Hamlet, Binh Duc Ward, Long Xuyen City, An Giang
Night	Stay overnight at Can Tho	
30th August		
7:00AM -12:00 AM	Travel to Sok Keo Rice mill in Cambodia with 850 kW Ankur gasifier	Takeo, Cambodia
1:30PM- 4:00PM	Visit to Angkor Kasekam 2 MW Co-generation plant	Phnom Penh, Cambodia
4:00 - 5:30 PM	Travel to hotel and check-in	
6:00 PM- 8:00 PM	Network meeting with experts	
31st August		
9:00 AM - 12:00 AM	Visit local rice husk gasifier manufacturer	
1:00 PM - 6:00 PM	Travel to the Phnompenh (Airport), back to Vietnam	

Annex II: Common valorisation routes



Annex III: List of planned rice husk-fired power plants to be constructed up to 2025

Location	No. of plants	Total installed capacity (MW)	Net electricity generation (GWh/yr)	Total investment cost ($US million)
Steam Turbine Power Plants				
An Giang province	2	22	96.14	36.25
Kien Giang province	1	5	21.12	9.00
Dong Thap province	2	15	64.32	26.00
Long An province	1	10	43.20	17.00
Soc Trang province	1	5	21.12	9.00
Tien Giang province	1	10	43.20	17.00
Can Tho city	3	24	103.90	43.20
Tra Vinh province	1	5	21.12	9.00
Hau Giang province	1	5	21.12	9.00
Vinh Long province	1	5	21.12	9.00
Bac Lieu province	1	5	21.12	9.00
North Central Coast	5	25	105.60	45.00
Red River Delta	5	25	105.60	45.00
Integrated Gasification Gas Engine Power Plants				
Mekong Delta River	8	8	32.64	8.00
Total	33	169	721.32	291.45

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