Bioenergy Generation from Rice Straw:
An Assessment in the Philippines

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Executive Summary

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1. Objectives

The main objective of this thesis is to assess the potential viability, for farmers and society, of using rice straw as a source of biomass for the production of renewable energy through anaerobic digestion. Central to this dissertation is the idea of sustainability as a criterion to assess production pathways. As such, a systems approach is used in order to assess the potential impacts and benefits of the components of a bioenergy value-chain at various potential scales of application.

A defining feature of the project is to provide a simple, yet robust and flexible approach to produce a limited set of indicators that can reliably inform decision-making and policy. It focussed on three complementary objectives:

1. To identify the components of biomass supply-chain in order to define a simple framework for analysing the viability of bioenergy production from rice straw at financial, energetic and environmental level. An overarching social outcome is also introduced in order to be consistent with the concept of sustainability.
2. To describe farmers' straw management practices and quantify energy needs, in order to identify potential drivers of engagement and suggest value-generating pathways.
3. To apply the framework to a case study in the Philippines in order to assess the potential value of possible business models at large, community and farm scale. The overall aim is to test the relevance of the framework.

1. Introduction

Rice is the staple food of more than half of the world's population. Around 91% of rice is grown and consumed in Asia and 29% produced in Southeast Asia. Rice is the third largest crop in volume behind sugarcane and maize, and its waste product also ranks as the world's third largest agricultural residue, behind sugarcane bagasse and maize straw.

For every tonne of rice grain, between 0.41 and 1.5 tonne of rice straw is produced, however this abundant by-product is rarely utilised. Traditional rice straw management practices are often hazardous to the ecosystem. Until today, open field burning is the most common practice of dealing with the straw, causing air pollution and health issues, while its incorporation into the soil delays land preparation for subsequent crops and causes methane emissions. On top of being costly to collect, rice straw has to be collected within a few weeks following the harvest to allow for re-seeding of the paddy fields for the next crop. In order to dispose of it as quickly as possible, most farmers, despite a regulatory ban, choose to incinerate their straw, often at night to avoid being fined.

Research on bioenergy production from agricultural wastes and co-products has gained momentum recently, partly due to the controversy regarding the use of traditional food crops as first generation feedstocks, and because of the relative availability of these residues. Further research is required, however, to explore the uncertainties about the energy and greenhouse gas balance of bioenergy pathways as well as the sustainability of large-scale applications. This is particularly the case for rice straw, which collection and transport are often cited as barriers to its use.

This thesis was completed in collaboration with the Rice Straw Project at the International Rice Research Institute (IRRI) in the Philippines and funded through the UK Department of Energy and Climate Change (DECC).

Rice straw as a source of biomass for anaerobic conversion

Strengths

- Widely available in South-East Asia at a low price and in abundant quantities.
- Agricultural residue. No competition with food and no additional land needed.
- High lignocellulose content.
- Environmentally positive compared to open-field burning or incorporation.
- Anaerobic conversion is a simple, cheap and proven technology.

Weaknesses

- Collection, handling and transport considered costly and impractical.
- Straw has a low degradability due to high C:N ratio and high silica content.
- Extraction of straw removes nutrients from the soil, which have to be replaced.
- There is virtually no organised supply-chain of straw, and only sporadic markets.
- Straw is considered by farmers as a waste, or at best as a low-value by-product.

Opportunities

- Underutilised resource.
- Increased regulatory focus on environmental impact of straw burning.
- Anaerobic digestion can be implemented at small scale and integrated in a cascading pathway, providing a great rural development opportunity.

Risks

- Non-energy uses of straw can compete with its use as energy feedstock.
- Low calorific value and low density of straw.
- Changing farmers' practices will require capacity building and sound economics.
- Application of anaerobic digestion to straw is still at an experimental stage.

2. Methodology

Objective 1: Modelling framework

- Desk-based review of modelling approaches, including state-of-the-art LCA guidelines
- Informal discussions with post-harvest experts, economists and social scientists at IRRI
- Excel-based modelling of a modular framework

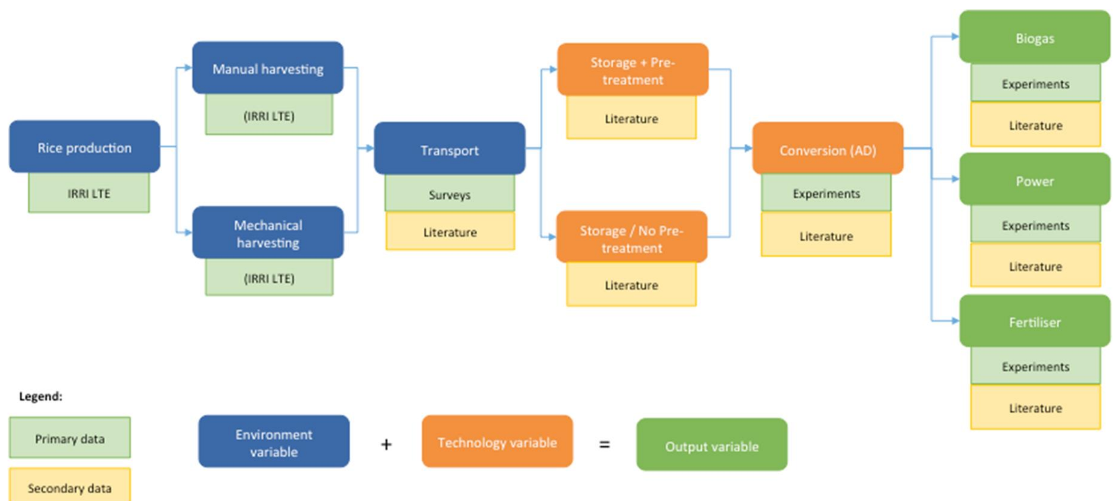
Objective 2: Farmers' needs and engagement opportunities

- Structured interviews with rice farmers
- Semi-structured interviews with other relevant stakeholders (eg. Labourers, village heads, etc.)

Objective 3: Case study

- Scoring analysis based on relevant criteria to identify a pilot village
- Focus-group discussion with farmers
- Application of the framework

System boundaries and inventory data sources



Location of rice fields in the province of Laguna

3. Results & Discussion

3.1. Farmers' choice

Although differences between villages are sometimes very subtle, Tubuan stood out as the best candidate for further research on the feasibility of straw-to-bioenergy projects, thanks to simpler logistics, more homogeneous rice farms, as well as high energy spending and interest in alternative income sources. Moreover, the support from the Department of Agriculture of Pila (through subsidised chicken manure) is an opportunity.

The three potential scales of application were presented to 15 farmers from Tubuan and 2 members of the Department of Agriculture of Pila. Cascading options of mushroom production and duck bedding were also discussed. While farmers showed no interest at all for an industrial scale model in which they would act as simple provider of straw to the biomass plant, they did show interest for both the farm-scale and community-scale set-ups.

3.2. Economical drivers are scale-dependent

Anaerobic digestion is a simple, low maintenance technology which applications have been developed in many developing countries as a low-cost solution, notably in Asia including India and Vietnam. The choice of technology and additional feedstock (such as animal manure) is key to ensure efficient energy conversion as the resulting biogas yield, along with the price of output energy, is the biggest factor affecting the viability of anaerobic conversion. There is, however, no "one size fits all" solution and other factors affect the sustainability of straw to energy systems, depending on the environment considered and the scale of the project:

- **Farm-scale** applications should focus on the cost of the digester to ensure its affordability, as well as on the control of labour costs, which have the potential to make the whole process uneconomical. Consequently, farms where household labour is available are more likely to find value in straw-to-energy pathways.
- **Community-scale** applications, with increased technological complexity, should focus on selecting the technology that is best suited to the scale to avoid over scaling and to control costs. Transportation costs are not considered a significant factor yet due to the limited distance to cover in the cases considered.
- **Industrial-scale** applications, quite distinctly, are strongly dependent on both the price of output (power or gas) and the distance travelled for collecting straw. This is due to increased scale efficiencies that reduce the investment cost and labour requirements per tonne of straw, while increasing the area to cover in order to gather significant volumes.

3.3. Energetic and greenhouse gas considerations

In all cases considered in this study, the energy balances are positive thanks to the relative simplicity of anaerobic conversion as well as optimal use of animal manure. The greenhouse gas balance is, quite importantly, driven mostly by the savings from fossil-fuel displacement and very little by the actual scale or business-model chosen.

As such, the energetic and greenhouse gas aspects, although important in any sustainability appraisal, should be secondary factors in the design process as less significant overall.

3.4. Social development and farmers' engagement

Straw-to-energy applications have the potential to deliver additional income to farmers, either directly as owners of the energy system or indirectly as straw providers. The availability of a market price for straw is a first step in unveiling this value, and despite straw price significantly affecting the economics of the supply-chain, the study found that farmers could sell their straw at a reasonable profit. This should ensure consistent availability of straw on the one end, but may also incentivise farmers to become active stakeholders in the future and capture a bigger share of profits within the value-chain.

While the focus-group discussion highlighted a clear appetite from farmers to get involved, limited access to finance and lack of knowledge are barriers to overcome. As such, the leading support of international institutions like IRRI is much needed to prove the viability of straw-to-energy systems and for farmers to follow suit.

3.5. Cascading pathways

Several studies on integrated food-energy systems suggested that cascading pathways could deliver compounded benefits for farmers. This study found that synergies between duck raising and straw-to-energy systems can indeed increase the efficiency of the system as wastes from one agent is the input of the other (straw and manure).

Mushroom production, on the other hand, reduces the efficiency of anaerobic conversion due to significant carbon losses and increases the financial risk of the whole supply-chain. It should be considered as an alternative use of straw, rather than as a complement.

Finally, returning the residual fertiliser collected from the digestion process to farmers is a clear advantage, but care should be given to its processing and marketing in order to maximise adoption from farmers who are used to convenient synthetic fertiliser application.

3.6. Further research

This study is a first step in assessing the strategic business options available for developing rice straw to energy projects, with a particular focus on the Philippines. Farm-scale and community-scale applications were identified as the most promising applications, with community-scale offering the best potential to overcome non-technical barriers such as access to finance and limited knowledge in the region.

Further development of the framework could be useful to address tactical aspects, such as business model arrangements within the supply-chain itself for each operator.

Moreover, further data collection in other regions and rice-growing areas like India and Vietnam could broaden the scope of this study and provide additional insights before concluding on the future of rice straw anaerobic conversion.

Finally, dialogue with farmers identified the need for clear institutional leadership in order to build capacity but also to prove the technology within farming communities who cannot afford the costs of research and development.