BRIQUETTE PRODUCTION BY THE INFORMAL SECTOR: THE CASE OF UCLA IN ILOILO CITY, PHILIPPINES

Dissertation

zur Erlangung des akademischen Grades

Doktor-Ingenieur (Dr.-Ing.)

an der Fakultät Bauingenieurwesen
der
Bauhaus-Universität Weimar

vorgelegt von

M. Eng. ARIES RODA DACALLO ROMALLOSA
aus
Republik der Philippinen

Weimar, 18.05.2017

Gutachter:

1. Prof. Dr.-Ing. Eckhard Kraft (mentor)
2. Univ. Prof. Dipl.-Ing. Dr. nat. techn. Marion Huber-Humer
3. Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Hans Wilhelm Alfen

ACKNOWLEDGMENT

This dissertation may not have been conceptualized without the prayers, help and support of the following persons and organizations. The author wishes to express her sincerest thanks and indebtedness to them who had been instrumental in the completion of this dissertation work.

To Bauhaus-Universität Weimar (BUW) especially to Prof. Dr.-Ing. Eckhard Kraft, Adviser and Head of Biotechnology in Resource Management under the Faculty of Civil Engineering, for his technical expertise and suggestions in the improvement and finalization of this manuscript. To the rest of his Team who is mostly comprised of fellow PhD students, for the knowledge shared and the technical and financial assistance provided during her stay in Weimar as well as facilitating the analyses of the briquette samples sent.

To the Faculty of Civil Engineering of BUW headed by the former Dean, Prof. Dr.-Ing. Hans-Joachim Bargstäd and the Professors and Staff, for allowing her to observe, experience and learn what Resource Management is on that side of the world. To her Co-Supervisors Univ. Prof. DI Dr. Marion Huber-Humer from the University of Natural Resources and Life Sciences in Vienna, Austria and Prof. Dr.-Ing. Hans Wilhelm Alfen who is now the Dean of the Faculty of Civil Engineering of BUW, for the knowledge and suggestions shared in helping improve this work.

To her employer, Central Philippine University based in Iloilo City, Philippines, through its President, Dr. Teodoro C. Robles, for all the academic and financial support provided through its Faculty Development Program and its University Research Center through its Director, Dr. Reynaldo N. Dusaran. To her mother unit the College of Agriculture, Resources and Environmental Sciences, through the leadership of its Dean, Dr. Jaime C. Cabarles, Jr., and to the rest of its Faculty and Staff especially to Prof. Hope G. Patricio, for their technical assistance, motivation, prayers, and moral support. Special mention is given to Mr. Diosdado “Babes” Aspa, Jr. of the CPU College of Agriculture Alumni Foundation, Inc. for his valuable help during her dissertation grant application.

To the German Government through its German International Cooperation (GIZ), its Embassy in Manila and especially to Dr. Johannes Paul, Engr. Klaus Hanuschke, and Engr. Voltaire Acosta, for their motivation and unselfish technical and scientific knowledge shared while conducting and writing this manuscript.

To the Philippines' Commission on Higher Education (CHED), for the Dissertation Grant provided in the conduct of the study. Special mention is given to CHED-OPPRI Director, Dr. Jean C. Tayag and Dr. Nancy J. Fajutrao of CHED Region VI, for their valuable support leading to the awarding of the grant.

To the University of Tokyo based in Japan headed by Professors Dr. Masahide Horita and Dr. Hide-Fumi Yokoo, and to Ms. Maki Ikuse, for partly financing the expenses incurred during the collaborative briquetting field tests conducted at the dumpsite of Iloilo City. To the General Services Office of the Iloilo City Government especially to Ms. Salome P. Villamor and Engr. Neil Ravena, for all the information, manpower, and expertise provided during the previous collaborative briquetting projects which led to this dissertation work.

To the members of Uswag Calajunan Livelihood Association, Inc. of Iloilo City, a registered group of informal sectors in this part of the Philippines and to all the wasteworkers of Calajunan Disposal Facility who joined, participated and shared their time, effort, ideas and skills during the formulation and conduct of this study. This paper is humbly dedicated to all of you! Special mention is also given to Ms. Lorelei Secatin, for her participation and valuable assistance in facilitating all the briquetting activities conducted at the UCLA Center.

To the author's Research Assistants for their valuable and countless help in all the technical and field-related work performed in this study. This achievement could not have been made possible without their never-ending support ever since she started working on biomass management.

To the different Colleges and Departments of CPU and private business establishments the author has dealt with, for their free provision of material resources needed in some aspects of the study.

To her parents Juan and Lolita, sister Kristine Marie and all her closely-related family members and closest friends, for their prayers, moral support, love and understanding while traversing this significant phase of her professional and academic life. Thank you for letting the author not miss the fun and opportunity to still travel and enjoy life despite all the busyness.

And above all, to God Almighty, her Source of everything, this work could not even have started without His provisions in various and countless forms, His guidance and the wisdom He has given her. TO GOD BE THE GLORY!

TABLE OF CONTENTS

PAGE

TITLE PAGE…………………………………………………………………… i

ACKNOWLEDGMENT………………………………………………………... ii

TABLE OF CONTENTS……………………………………………………….. iv

LIST OF TABLES……………………………………………………………… vii

LIST OF FIGURES…………………………………………………………….. ix

LIST OF ABBREVIATIONS………………………………………………….. xi

ABSTRACT…………………………………………………………………… xiii

CHAPTER

1 INTRODUCTION…………………………………………………... 1

1.1 Rationale…………………………………………………… 1

1.2 Significance of the Study ………………………………... 4

1.3 Objectives of the Study ………………………………….. 5

2 CONCEPTUAL FRAMEWORK…………………………………… 6

2.1 Study Area…………………….................................... 7

2.1.1 Iloilo City Profile……………………………………… 7

2.1.2 Solid Waste Management Profile………………………… 10

2.1.3 Integration of UCLA into the SWM System……………... 12

2.1.4 UCLA Center…………………………………………….. 14

2.1.5 Organization of UCLA…………………………………… 14

2.2 Briquette Production Technology………………………... 18

2.2.1 Briquetting…………………………………………….. 18

2.2.2 Utilization of Biomass and Urban Wastes……………….. 20

2.2.3 Preliminary Briquette Production Initiatives at UCLA….. 22

2.3 Socio-Economic Aspects………………………………… 23

2.3.1 Solid Waste Management in the Philippines…………….. 23

2.3.2 The Informal Sector in Developing Countries…………… 24

2.3.3 Involvement of the Philippine Government in the Informal Sector……………………………………….. 28

2.4 Technical Aspects………………………………………... 29

2.5 Feasibility……………………………………………….. 33

	2.5.1	Social Feasibility………………………………………….	33
	2.5.2	Technical Feasibility……………………………………...	34
	2.5.3	Economic Feasibility……………………………………...	35
	2.5.4	Environmental Feasibility………………………………...	35
3	METHODOLOGY…………………………………………………..		37
	3.1	Research Design…………………………………………..	37
	3.2	Data Collection……………………………………………	37
	3.2.1	Primary Data……………………………………………...	37
	3.2.2	Secondary Data…………………………………………...	40
	3.3	Technologies and Product Enhancement………………...	41
	3.3.1	Development and Description of Technologies Utilized……………………………………………………	41
	3.3.2	Principle of Operation…………………………………….	53
	3.3.3	Mixture Preparation……………………………………	54
	3.4	Briquette Production and Performance Evaluation……….	54
	3.4.1	Instruments and Equipment Used……………………...	58
	3.4.2	Data Gathered……………………………………………..	60
	3.4.3	Parameters Analyzed……………………………………...	61
	3.5	Data Processing and Analysis…………………………….	63
4	RESULTS AND DISCUSSION……………………………………..		64
	4.1	Socio-Economic Aspects of Briquette Production………..	64
	4.2	Technical Aspects of Briquette Production……………...	72
	4.2.1	Product Enhancement……………………………………..	72
	4.2.2	Briquette Quality Using the Enhanced Technology……....	83
	4.2.3	Potential Production and Earnings from Briquetting……..	88
	4.3	Feasibility of Briquette Production……………………….	95
	4.3.1	Social Feasibility………………………………………….	95
	4.3.2	Technical Feasibility……………………………………...	99
	4.3.3	Economic Feasibility……………………………………...	101
	4.3.4	Environmental Feasibility………………………………...	102
5	CONCLUSIONS AND RECOMMENDATIONS…………………..		105
	5.1	Findings…………………………………………………...	105
	5.2	Conclusions……………………………………………….	108

5.2.1 Enhancement of Briquette Production Technology……… 109
5.2.2 Quality of Briquettes Produced…………………………... 110
5.2.3 Potential Production and Income from
Briquette-Making………………………………………… 110
5.2.4 Feasibility of Briquetting………………………………… 111
5.2.5 Applicability of Briquetting to Other
Parts of the World………………………………………... 113
5.3 Recommendations………………………………………... 116
6 SUMMARY………………………………………………………. 118
7 REFERENCES…………………………………………………… 121
APPENDIX…………………………………………………………………... 133
A Production rate in pcs/hr and its analysis of variance………………. 134
B Production rate in kg/hr and its analysis of variance……………….. 135
C Boiling time and its analysis of variance……………………........... 136
D Cooking time and its analysis of variance………………………….. 137
E Bulk density and its analysis of variance……………………............ 138
F Survey instrument used……………………………………………... 139

LIST OF TABLES

TABLE		PAGE
1	Distribution of the respondents according to their personal profile (n=160)………………………………………………...........	65
2	Distribution of the respondents according to their civil status, number of children and household size (n=160)……………	66
3	Distribution of the respondents according to their highest educational attainment and monthly income (n=160)……………………………………………………...........	67
4	Distribution of the respondents according to their waste management/waste picking background (n=160)…………………..	68
5	Distribution of the respondents according to their housing conditions (n=160)………………………………………………….	70
6	Distribution of the respondents according to utilities available (n=160)……………………………………………………...........	71
7	Distribution of the respondents according to their kitchen/cooking devices (multiple response)…………..………....	73
8	Physical characteristics of the briquettes produced………………….	74
9	Production rate of the briquetting machines designed for improvement in pc/hr……………………………………………..	76
10	Production rate of the briquetting machines designed for improvement in kg/hr……………………………………………..	77
11	Operating performance of the briquettes produced in boiling water using the briquetting machines designed for improvement……………………………………………………...	78
12	Operating performance of the briquettes produced in cooking rice using the briquetting machines designed for improvement………………………………………………………	79
13	Bulk density of briquettes produced using the briquetting machines designed for improvement………………………………...	80
14	Heating value and proximate analyses of the briquettes produced using the improved briquetting technology………..........	84

15	Results of the heating value and proximate analyses of various raw materials from other studies……………………………	85
16	Ultimate analyses of the briquettes produced using the improved briquetting technology……………………………...........	87
17	Results of the heating value and proximate analyses of various raw materials from other studies……………………………	88
18	Distribution of the respondents according to familiarity and utilization of briquettes (n=160) prior to being introduced as fuel…………………………………………………………...	89
19	Utilization of the briquettes randomly provided to waste reclaimers in Calajunan disposal facility (multiple response)…………………………………………………............	91
20	Usefulness and willingness of the respondents to buy briquettes as substitute fuel for cooking (n=160)………………………………	92
21	Cost analysis in briquette production………………………………..	94
22	Potential daily production and earnings in the briquetting of wastes………………………………………………………..	95

LIST OF FIGURES

FIGURE		PAGE
1	Map of the Philippines and Iloilo City (Internet Reference [36])……	2
2	Flow of relationship between the parameters……	6
3	Location of the study area (Internet Reference [39])……	8
4	Map of Iloilo City showing its geographical districts (Internet Reference [39])……	9
5	UCLA Center……	15
6	Floor plan of UCLA Center……	16
7	Organizational structure of UCLA……	17
8	Handmade briquettes produced by some members of UCLA……	23
9	Hierarchy of waste recycling chain (Adapted from Wilson et al., 2006)……	27
10	Conduct of interview schedule on product acceptance of the technology developed……	39
11	The first hand-press briquette molder developed with briquettes produced……	42
12	The second hand-press briquette molder developed with modified support plate……	43
13	The second hand-press briquette molder with an extended handle……	43
14	Pillow-shaped briquettes produced using the hand-press briquette molder……	45
15	The first jack-driven briquetting machine developed for UCLA……	47
16	The hydraulic-type bottle-jack press briquetting machine in operation……	48
17	Removal of briquettes from the molder……	48
18	The second jack-driven briquetting machine developed for UCLA……	50
19	The final design of the hydraulic-jack driven briquetting machine to enhance briquette production……	51

20 The pulping machine utilized during briquette production………….. 52
21 Briquetting of wastes showing the placement of mixtures in the molder, compaction of the materials and removal of briquettes produced from the molders……………………………….. 53
22 The materials used in briquette production, namely from left to to right: waste paper, sawdust and carbonized rice husk…………….. 55
23 Summary of procedure for the production of briquettes..................... 56
24 The actual field production test at UCLA Center and the briquettes produced being dried……………………………………… 57
25 Briquettes produced using the three types of briquetting machine developed………………………………………. 73
26 Graphical presentation of the production rate of the different briquetting machines developed…………………............................. 77
27 Ranges of bulk densities of the different briquette molders developed…………………………………………………………….. 81
28 Summary of enhancements on the briquetting technologies developed leading to the final design…………………………....... 82
29 Integration of the socio-economic and technical aspects on briquette production leading to the improvement of the technology……………………………………........................... 83
30 Graphical comparison of the bulk density and moisture of the briquettes produced using the improved briquetting technology…….. 86
31 Graphical comparison of the heating value and the hydrogen content of the briquettes produced using the improved briquetting technology.………………………………………......... 87

LIST OF ABBREVIATIONS

ABBREVIATION	
AFR	Alternative Fuels and Raw Materials
BUW	Bauhaus-Universität Weimar
CARES	College of Agriculture, Resources and Environmental Sciences
CENRO	City Environment and Natural Resources Office
CO_{2eq}	Carbon Dioxide Equivalent
CPU	Central Philippine University
CRH	Carbonized Rice Husk
DENR	Department of Environment and Natural Resources
DIN	Deutsches Institut für Normung
DOE	Department of Energy
DOST	Department of Science and Technology
DTI	Department of Trade and Industry
EMB	Environmental Management Bureau
ESWM	Ecological Solid Waste Management
FPRDI	Forestry Products Research and Development Institute
GHG	Greenhouse Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSO	General Services Office
IPCC	Intergovernmental Panel on Climate Change
LGUs	Local Government Units
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goal
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
MSEs	Medium and Small Enterprises
NGO	Non-Government Organization
NSWMC	National Solid Waste Management Commission
Php	Philippine Peso

RDF	Refuse-Derived Fuel
SEC	Securities and Exchange Commission
SDG	Sustainable Development Goal
SLF	Sanitary Landfill
SWM	Solid Waste Management
SWM4LGUs	Solid Waste Management for Local Government Units
UCLA	Uswag Calajunan Livelihood Association, Inc.
USD	US Dollar

ABSTRACT

The construction and operation of a sanitary landfill (SLF) in the Philippines presents concerns on the regulation of the activities of the informal sector in the area. In anticipation of these directives, an association of informal waste reclaimers group called Uswag Calajunan Livelihood Association, Inc. (UCLA) was formed in May 2009. One option identified was the waste-to-energy activity through the production of fuel briquettes. With the availability of raw materials in the area, what was lacking then was an appropriate technology that would cater to their needs. This study, therefore, presented the case of UCLA on how socio-economic and technical aspects was integrated for the development and improvement of a briquetting technology needed in the production of quality briquettes as part of their income generating activities. A non-experimental posttest only design was utilized for the collection of descriptive information. Descriptions and discussions were also made on the enhancement of the briquetting machine from the first hand-press molder developed until the finalized design was attained.

Results revealed that the improved briquetting technology withstood the wear and tear of operation showing a significant ($P<0.01$) increase on the production rate (220 pcs/hr; 4 kg/hr) and bulk density (444.83 kg/m^3) of briquettes produced. The quality of cylindrical briquettes produced in terms of bulk density, heating value (15.13 MJ/kg), moisture (6.2%), N and S closely met or has met the requirements of DIN 51731. Based on the operating expenses, the briquettes may be marked-up to Php0.25/pc (USD0.006) or Php15.00/kg (USD0.34) for profit generation. The potential daily earnings of Php130.00 (USD2.95) to Php288.56 (USD6.56) generated in producing briquettes are higher when compared to the majority of waste reclaimers' daily income of Php124.00 (USD2.82). The high positive response (93%) on the usability of briquettes and the willingness of the respondents (81%) to buy them when sold in the market indicates its promising potential as fuel in the nearby communities. Results of briquette production citing the case of UCLA could be considered as potential source of income given the social, technical, economic and environmental feasibility of the experiment. This method of utilizing wastes in an urban setting of a developing country with similar socio-economic and physical set-ups may also be recommended for testing or replication.

1 INTRODUCTION

This chapter explains the rationale behind the conduct of this briquette production study citing one informal sector group located in Iloilo City, Philippines. It also details the significance and specific objectives of this study.

1.1 Rationale

The Philippines being an agricultural country generates a lot of biomass waste with promising potentials when properly utilized as renewable source of energy for cooking. These major abandoned biomass waste resources include rice husk, rice straw, sugarcane bagasse, coconut wastes, forestry residues and urban waste (Baconguis, 2007). When agricultural biomass wastes are converted to energy, they can substantially displace fossil fuel, reduce emission of greenhouse gases (GHG) while closing the carbon cycle loop and provide renewable energy to people in developing countries like the Philippines (from http://www.un.org/apps/news/story.asp?NewsID=15483&Cr=development&Cr1). As raw materials, biomass wastes have attractive potentials for large-scale industries and community-level enterprises. At a small scale, biomass is recognized as a form of renewable energy that is capable of meeting both heat and electricity demand most effectively in the form of combined heat and power, contributing towards international commitments to minimize environmental damage (Laryea-Goldsmith et al., 2011).

Being one of the highly urbanized cities in the Philippines, Iloilo City (Figure 1), which is the capital of the Province of Iloilo and classified under the Western Visayas Region, increasingly generates a lot of solid wastes. With a land area of 56 km^2 and a population of nearly half a million, a total of around 170 tons of solid wastes from the 300 tons daily generated domestic type wastes are presently delivered to the local dumpsite. Its dumpsite, which is around 5 km from the city center, is a controlled facility. The area of this facility represents about 0.29% of the city's land area. It is located in Brgy. Calajunan, Mandurriao with approximately 300 households of waste reclaimers who recover resources through collection and separation of specific wastes that can be sold to nearby junkshops (Gunsilius & Garcia, 2010. The signing into law of the Philippines' Republic Act 9003 (RA 9003) also known as the

Figure 1. Map of the Philippines and Iloilo City (Internet Reference [36])

“Ecological Solid Waste Management Act” in 2001 promoted the paradigm that waste is a resource that can be recovered. It determines that the local government units (LGUs), such as Iloilo City, are the primary institutions that should implement this act. RA 9003 mandates waste reduction at the source, recovery, recycling and reuse of wastes. While the law emphasizes the importance of these waste management techniques, it also prohibits waste picking in segregation areas or disposal facilities, unless the operator permits it. This is the case then of the waste reclaimers living near the vicinity of Iloilo City’s disposal site. They were given access to do waste recovery inside the facility. However, with the construction of a sanitary landfill (SLF) adjacent to the present controlled dumpsite, the usual activities of the informal sector, specifically that of the waste reclaimers, would become regulated.

The dynamic participation of the then unorganized itinerant waste workers in Iloilo City’s disposal site to the initiated activities and support to them by the private sector has led to their registration as an incorporated association called Uswag Calajunan Livelihood Association, Inc. (UCLA) in May 2009. This enabled them to sign official contracts with project partners. With UCLA’s integration and registration, the next challenge now is on how to sustain its association and members especially in terms of revenue. UCLA has to pursue new options in order to establish long-term economic activities as a company. In order to guarantee its sustainability, two major strategies have to be applied: improving the cost-benefit balance of the existing activities of UCLA and searching for new fields of activities to create additional income. One such option identified is waste-to-energy project through production of fuel briquettes (Gunsilius & Garcia Cortes, 2010), a processed biomass fuel that can be burned as an alternative to wood or charcoal for heat energy (Olorunnisola, 2007; Stanley, 2003).

To further strengthen the capacity development of UCLA members, training on basic skills development, awareness raising and integration were conducted between July to August 2010 in order to incorporate the members of the informal sector at the dumpsite into the solid waste management program of Iloilo City. One of the alternative livelihood opportunities presented was on briquette making through the utilization of biomass and urban wastes found in the dumpsite with the aid of a briquetting machine.

Preliminary research activities related to briquetting had already been introduced to UCLA in the past 5 years by the College of Agriculture, Resources and Environmental Sciences of Central Philippine University (CARES-CPU), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and Iloilo City's General Services Office (GSO) through their collaborative works (Romallosa et al., 2011a; Paul et al., 2009b). These previous studies on the identification and verification of recommended mixtures for briquetting and development of briquette molders allowed the waste workers/participants to learn the basic skills in briquette production.

This study focused on the continued introduction of briquetting in the waste workers association. This specifically presents their case as to how socio-economic and technical aspects were integrated until an acceptable technology was achieved when ease of use and the number and quality of briquettes produced were considered. UCLA, being a key player in the diversion of these wastes from the municipal waste stream, was studied and observed on how their manpower potential and skills would allow them to produce according to different possible work scenarios leading to potential source of income for them. This would also serve as basis when other similar groups would follow.

1.2 Significance of the Study

The integration of briquette production as one source of income for members of UCLA is a very effective way to upgrade their ability to add value to collected materials (Haan et al., 1998). In this case the collected waste paper would have an add-on value when converted into paper briquettes or when mixed with other biomass wastes to maximize its potential. As a legally registered organization, they can now transact or negotiate business with local authorities and/or private sector, hence, evading intermediate dealers. In this manner, their income can be significantly increased and their activities become more legitimized and socially acceptable (Medina, 2000).

Looking into the business side of briquette production as producers and sellers of this product, their involvement in this activity could elevate their rank in the hierarchy of informal sector recycling (Tirado-Soto & Zamberlan, 2013; Wilson, Velis & Cheeseman, 2006). From individual waste scavengers/pickers/reclaimers they could move up to the hierarchy as recycling medium and small enterprises (MSEs) and scavenger cooperatives. They could even become middlemen for industries looking into the possibility of utilizing briquettes for their industrial operations.

The livelihood option on briquetting of wastes may also address the focus of the Millennium Development Goals (MDGs) on poverty reduction now switched to Sustainable Development Goals (SGDs) which is to eradicate extreme poverty and hunger (from http://www.un.org/sustainabledevelopment/sustainable-development-goals). The production of briquettes could be instrumental in sustaining the life of the waste reclaimers association by providing them regular income through sales of these fuels and even reduce their household expenses through savings from buying or using the conventional charcoal, wood fuel or liquefied petroleum gas (LPG). The waste strategies on improving recycling or diversion rates may also be enhanced since these waste papers that cannot be sold as scrap paper can still be processed as briquettes.

The presence of UCLA in the community as producers and suppliers of briquettes could provide a permanent venue for people to have access to this kind of alternative source of fuel for cooking. This could open doors on the acceptability of briquettes as suitable replacement for conventional fuels for cooking like charcoal, wood, and LPG. The use of briquetting technology can even help the government in its drive to promote the limited development and widespread use of biomass resources through pilot testing, demonstration and commercial use of biomass briquetting for heat generation making it a renewable alternative source of energy (Uzun & Kanmaz, 2013; Primer on Biomass Briquette Production, 2010).

The case of UCLA in integrating the socio-economic and technical aspects in its operation could serve as a model on how an organization is able to address concerns about disposal of wastes by utilizing it as value adding material in creating a useful product like briquettes. This approach could be well documented and maybe replicated by other organizations for the same purpose.

1.3 Objectives of the Study

This study presented the case of Uswag Calajunan Livelihood Association, Inc. (UCLA), a registered group of informal waste reclaimers that produces briquettes from the utilization of abundant biomass and urban wastes in the area.

Specifically, this study aimed to achieve the following:

1. Enhancement of briquette production through development of an appropriate technology that would produce more quality briquettes;

2. Perform physico-chemical analyses of briquettes produced using the enhanced briquetting technology;

3. Assessment of the impact of utilizing abandoned wastes suitable for briquette production by members of UCLA as a potential source of income for them; and,

4. Exploration of the social, technical, economic and environmental feasibility of using the technology in producing quality and acceptable briquettes for the community and other areas with similar socio-economic and physical set-ups.

2 CONCEPTUAL FRAMEWORK

The research framework explains the existence of a problem. It served as basis for examining and analyzing the relationship between or among the study variables. These connections may be further explained and illustrated in concrete terms using a conceptual framework (David, 2005).

This unit describes first the background about the study area. These include the City Profile, SWM background of the area and the organization of UCLA.

The paradigm shown in Figure 2 serves as the working framework for this study. The figure presented summarizes the many considerations needed for the existing briquette production technology that had been developed for UCLA as an approach required in developing an improved version of the technology for the production of quality and acceptable briquette products. The paradigm explains how it is best to cooperate with the informal sector in terms of socio-economic and technical aspects in order to assist them in the improvement of their livelihood, working conditions and efficiency in recycling especially of biomass and urban wastes.

The figure draws the movement of the parameters considered in the study. The arrows within the framework are used to denote the movement of the influence of the parameters considered.

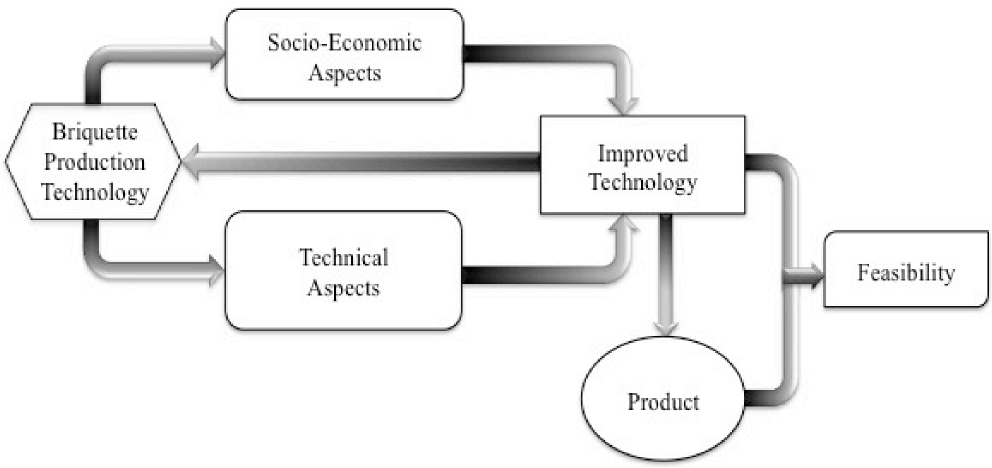

Figure 2. Flow of relationship between the parameters

Different aspects may have profound influence on the present briquette technology. When considered, they could have an effect on the improvement of the technology such as ease of operation or the increase in the rate of production. However, it would also be possible that the improved technology may still be unacceptable to the end-users; hence, further socio-economic and technical considerations may be applied until the results are incorporated for another improvement. Once acceptable to the stakeholder, products are fabricated and formed. These are then subjected for more verification to determine the feasibility of the product.

2.1 Study Area

The Philippines (Figure 3) is an archipelago of 7,107 plus islands located in the Southeast Asia. It has a land area of 300,000 km^2 with a total population of 92 million based on the 2010 Census of Population and Housing (from http://www.census.gov.ph). It is one of the fastest urbanizing countries in East Asia: fueled by in-migration and natural population growth. The country is divided into three island groups: Luzon, Visayas, and Mindanao. Metro Manila, the capital, is the 11th most populous metropolitan area in the world. As per capita in 2007, the Philippines is ranked as a low-middle income country (The World Bank Group, 2009). The country has 18 administrative subdivisions known as regions. Regions are generally organized to group provinces that have the same cultural and ethnological characteristics. The provinces are actually the primary political subdivision, however, they are grouped into regions for administrative convenience. Most government offices establish regional offices instead of individual provincial offices, usually (but not necessarily always) in the city designated as the regional center. Western Visayas, located in the Visayas, is one of the 18 regions of the country (from http://nap.psa.gov.ph/activestats/psgc/SUMWEBPROV-SEPT2016-CODED-HUC-FINAL.pdf).

2.1.1 Iloilo City Profile

Western Visayas is designated as Region VI. It consists of five provinces, namely: Aklan, Antique, Capiz, Guimaras and Iloilo and 5 cities. The Region has a total land area of 12,828.97 km^2, which is approximately 4.28% of the total land area of the Philippines (from http://nro6.neda.gov.ph/?s=western+visayas+region).

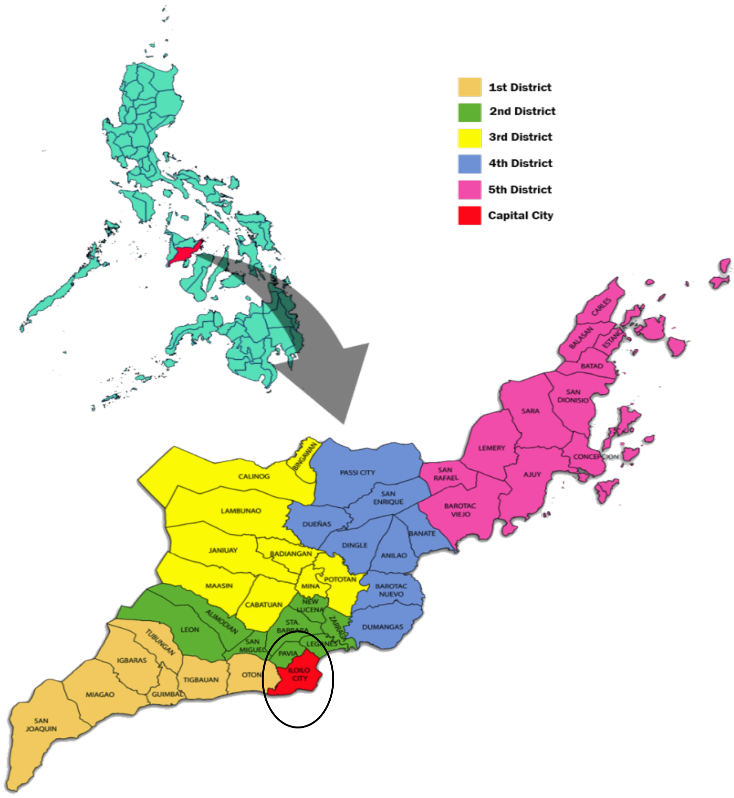

Figure 3. Location of the study area (Internet Reference [39])

Iloilo is one of the most progressive provinces in the Philippines. It occupies the southern and northeastern portion of Panay Island. As shown in Figure 3, it is bounded by the Province of Capiz on the north, Guimaras Strait on the south, Panay Gulf and Iloilo Strait on the east and Province of Antique on the west (from http://www.iloilo.gov.ph/homepage/location-map).

The capital of the Province of Iloilo is Iloilo City. It regained its cityhood status and was inaugurated as charter city on July 16, 1937 (from http://philippinelaw.info/statutes/ca158-iloilo-city-charter.html). It is classified as one of the two highly urbanized cities in Western Visayas. The city has a total land area of 70.34 km^2. More than 57.35% of the city's land area is considered residential. The city lies on a flat alluvial plain, reclaimed mostly from the swampy areas due to urbanization and industrialization in the late 19th century until the present. Ninety percent (90%) of the land mass has an elevation of 2.64 m above the main level water.

Ten percent (10%) of land mass has an elevation of 5.19 m. The slope category of the city falls between 0 to 3%, which means that for every 100-m distance, the rise is 0.5 m (from http://www.swm4lgus.net/partner-lgu/IloiloCity.php).

According to the 2010 census, Iloilo City has a total population of 424,619 (from http://www.census.gov.ph). As shown on the expanded map in Figure 4, Iloilo City is composed of six districts, namely: Jaro, Mandurriao, La Paz, Villa and Arevalo, Molo, City Proper and Lapuz. It has 180 urban barangays. Brgy. Calajunan, where the city's dumpsite facility is located has a population of 3,356.

Figure 4. Map of Iloilo City showing its geographical districts (Internet Reference [39])

The city is accessible by land through major arterial highways of the province and sea through its own national seaport. In general, the city's climate is considered as Type I based on Corona Classification characterized by two pronounced season: dry from November to April and wet for the rest of the year. Maximum rain period coincides with the peak of southwest monsoon from July to September. Temperature ranges from 22 to 32°C while the average humidity is about 77%. *Hiligaynon* is the local dialect spoken in Iloilo City while English is used as the language for business and education. Forty-three percent (43%) of the families are employed in non-agricultural areas and 20.5% are entrepreneurs.

2.1.2 Solid Waste Management Profile

The signing and approval of the Philippines' Republic Act (RA) 9003 or the Ecological Solid Waste Management Act of 2000 in January 26, 2001 was considered then as a timely solution to the emerging garbage problems in the country. This law promotes an integrated approach to solid waste management and sets out ambitious goals. Furthermore, it requires the LGUs to establish an ecological solid waste management program within their jurisdiction. Few implications of the law are establishment of a materials recovery facility (MRF) in every barangay or cluster of barangays; and the mandatory waste segregation and recycling at barangay level. This law emphasizes the importance of treating waste as a resource and promoting its recovery through avoidance, reduction or minimization, recycling and reuse (RA 9003, 2000).

The implementation of this law requires each LGU (like Iloilo City) and province to develop a ten-year SWM Plan, to be prepared by the respective SWM Board. They are to be submitted to the NSWMC for approval. Also, the law requires the LGUs to divert solid waste from final disposal at a minimum of 25% during the first five years of implementation and to increase that rate every three years thereafter. However, majority of LGUs are still unable to implement the minimum waste diversion requirement. Instead, it is mainly the informal waste sector consisting of waste reclaimers in the dumpsites, jumpers, itinerant waste buyers and junkshops that recover materials and divert solid waste materials from final disposal.

Iloilo City, on its part, also organized its Solid Waste Management Board that had been functional and providing policy guidance to the SWM activities of the city. The city's General Service Office (GSO) is tasked with the solid waste collection, street cleaning and the operation of the controlled disposal facility located in Brgy. Calajunan, Mandurriao. The GSO works closely with the City Environment and Natural Resources Office (CENRO), which is responsible for the waste management of the public market and perform monitoring of environmental problems of the city. Both offices are members of the Technical Working Group of the SWM Board. Iloilo

City drafted its 10-Year SWM Plan that covers a planning period from 2004 to 2013. This was submitted to the national government agencies DENR-EMB/NSWMC in 2006 for further review.

In May 2009, a Waste Analysis and Characterization Study (WACS) was conducted in urban and sub-urban barangays of the city. The city's municipal solid wastes (MSWs) primarily come from residential areas (56.46%), public market areas (4.45%), commercial districts (30.34%), and from other sources (8.75%). The average waste generation rate is 0.71 kg/capita/day, and as of 2009, estimated waste generation is approximately 300 tons/day.

The existing collection system of the city is contracted to a private company that covers all the 180 barangays utilizing 20 compactor trucks with specific routes and 11 trucks collecting specific types of waste from the public market. Currently, however, only 57% of the total generated waste (about 170-190 tons/day) is brought to the disposal site.

In 2006, with technical assistance from GIZ-AHT SWM4LGUs Project, Iloilo City drafted an integrated site development plan for the 22-ha Calajunan disposal site that included the closure and rehabilitation of the 10-ha old dump, operation of an improved transition disposal area within the old open dump and establishment of a 12-ha sanitary landfill (SLF). The Closure and Rehabilitation Plan was submitted to EMB 6 and was granted an Authority-to-Close (ATC) No. 10-0607 on June 15, 2007. At present, the financial allocations through a loan for the establishment of an SLF have already been approved.

In order to increase the recovery and recycling targets of the city and at the same time not to displace the informal sector who derive their livelihood and subsistence through waste picking at Calajunan dumpsite when the proposed SLF will be implemented, Iloilo City in collaboration with GIZ-AHT for the project SWM4LGUs integrated the waste reclaimers into the improvement plan of the disposal facility and made the waste reclaimers' socio-economic development plan. This initiative soon became in line with the NSWMC after the latter's adoption of the National Framework Plan for the Development of the Informal Sector in SWM. This plan acknowledges the role of the informal sector as critical actors in SWM; hence, they should be mainstreamed in the formal system. The Framework in summary calls for the integration of the informal sector in SWM by providing them with a favorable policy environment, skills development opportunities and access to secure livelihood, employment and basic social services.

As for the city's material resources recovery, recycling and composting, a building located at the disposal facility was constructed in 2004 to house the equipment needed for these activities. The in-house segregation units consist of input conveyor belt, drum screen and final conveyor units for combined mechanized-manual sorting that could process around 25 tons of the daily delivered 170-190 tons of waste at the disposal site. Recovery of sellable materials such as cardboard, metals and hard plastics is largely influenced by the activities of more than 300 waste reclaimers who obtain their livelihood by waste collecting in that area. Based on observations, a large fraction of valuable materials such as organic and alternative fuels and raw materials (AFR) are still disposed at the dump. These wastes are yet not fully recovered from the waste stream.

In line with AFR, Iloilo City was also the first LGU in the Philippines to start testing the recovery of these valuable materials since it was observed that the incoming wastes still contain a significant fraction of valuable materials. AFRs are waste materials that could still be used as substitute for fossil fuels such as coal or oil derivatives.

At present, the more than 20-year old dumpsite of the city is still being used for the disposal of MSW until such time the SLF is ready for operation. The city has provided a perimeter fence around the facility including access road for easy steering of garbage trucks during disposal. There is heavy-duty equipment including a weighbridge for better monitoring of the wastes delivered inside the area. There are also building facilities and amenities such as administrative building as office of the Manager and other staff employed by the city government.

2.1.3 Integration of UCLA into the SWM System

The integration of the waste reclaimers into the improvement proposals of the disposal facility and formulation of their socio-economic development plan provided them benefits and positive impacts in terms of improved income for the family, access to sanitary water supply and protection from occupation hazards and risks. As for Iloilo City, such benefit is in terms of increased recovery rates for wastes. Prior to achieving this, different interventions had been made in order to re-energize the involvement of the waste reclaimers located in Brgy. Calajunan and nearby areas. Since 2005, the LGU of Iloilo City together with GIZ implemented projects near the disposal site to encourage involvement of this sector. A group was formed to involve the 140 waste reclaimers in the initial activities intended for these collaborative projects by the city and GIZ. The workers were chosen according to their willingness to participate in the proposed association for waste reclaimers. The first group of participants was chosen among the waste reclaimers who were issued with an identification card or were already involved in common activities, like participating in informal organizational meetings and group discussions. Some of these initial activities introduced in the group included training on sewing of recycled design bags, and sorting out of AFR in cooperation with cement manufacturer Holcim. From there, several sub-groups were formed according to the activities introduced to them and then leaders were elected for each. In order to enable the informal workers to be active in SWM over a long period, the waste reclaimers organized themselves into a membership-based organization accountable to their members. The group then registered as a formal incorporated association in May 2009 known as Uswag Calajunan Livelihood Association, Inc. or UCLA for short. "Uswag" is a *Hiligaynon* word for progress; hence, the association conveys a message that it is for a progressive Calajunan livelihood association. The workers chose the stature of an incorporated body, with its own rights, privileges, and liabilities, because the registration process was simpler, cheaper and faster than for a cooperative. Furthermore, as an incorporated body, the group is able to sign official contracts with project partners – an important prerequisite in collaborating with private entities.

In order to cover the registration costs, membership fees were determined: first at Php100 per year and then, following a decision by the members in March 2010, it was made Php30 per month, a fact that demonstrates the improved income level of the members and the importance they now attribute to common activities. They also agreed on rules for joint work at the dumpsite. The formalized group opened a bank account to facilitate payment procedures. Data provided by UCLA revealed that they have now a total of 261 members. Out of this number, 77 members have not paid the membership fees yet. Despite the non-payment, they are still considered an official part of UCLA as decided by UCLA's Board Committee for Membership.

The association has initiated new income generating activities, one of which is briquette production utilizing the available biomass and urban wastes (discarded papers) found in the vicinity. Regular assemblies of all members and an annual Christmas Party served the purpose of maintaining and strengthening a common identity as a group and a consensus about the structure and activities of the organization. UCLA has established its own training center where researches and other activities are held. Social activities such as childcare and health checks are also conducted in the center.

2.1.4 UCLA Center

UCLA Center, as seen in Figure 5, is located in Brgy. Calajunan of Iloilo City. The lot, where the structure is built, being owned by the President (a Protestant Pastor) of the association is free of charge.

The center is approximately 100 m from across the disposal site. It was established to provide the group with a place for meetings, trainings and for developing new activities. This was also the location of all previously conducted field tests for briquette production.

UCLA Center has an estimated floor area of 110 m^2. It is constructed mostly of light materials. The roofing is made of *nipa* shingles with bamboo serving as rafters and braces. The posts are also made of bamboo. The flooring is elevated 0.80 m from the ground with concrete posts and foundations. It is laid with plywood as flooring. Majority of the structure is open except for the sewing area, stockrooms and two comfort rooms. The sewing area and stockrooms are properly secured since there are tools and other important items kept there. The floor plan of the center is presented in Figure 6.

2.1.5 Organization of UCLA

Based on the 2010 drafted UCLA Policy Manual, UCLA is a livelihood association created primarily to organize the waste reclaimers of Calajunan disposal facility together with its government and private partners in order to carry out its mission which is to develop the capacity of Calajunan waste reclaimers by providing livelihood options and to enhance their participation in the management of the SLF. It is an association whose membership is voluntary. The members for this association are either the waste reclaimers working at the disposal facility or private supporters having the same views with them. Presented in Figure 7 is the organizational structure of UCLA.

Figure 5. UCLA Center

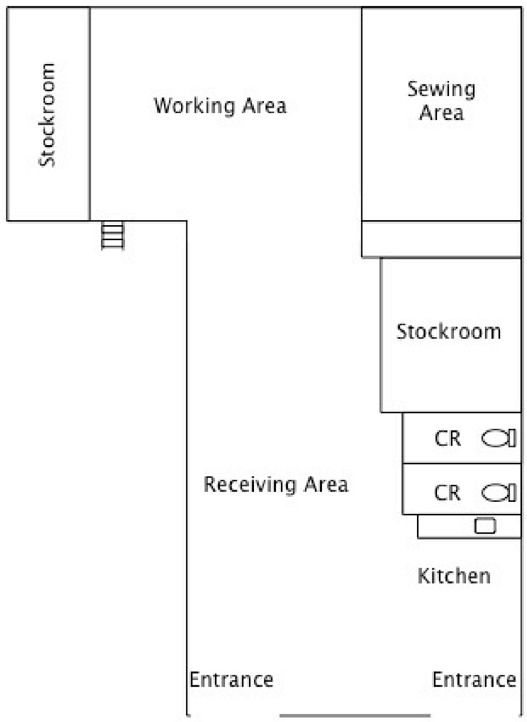

Figure 6. Floor plan of UCLA Center

As shown by the organizational structure in Figure 7, UCLA is headed by the Board of Directors in conjunction with the Partner Organizations and the different Board Committees. Its 13-member Board of Directors governs UCLA. These volunteers were responsible in determining the mission and purpose of UCLA, select and reviews the staff including their performances, ensure effective planning for the association, manage the resources effectively, and determine and monitor UCLA's programs and services.

The Board of Directors is headed by a Chairman who acts as the chief volunteer of UCLA. The Chairman provides leadership to the Board, sets the policy and to whom the Executive Officer (also known as the President) is accountable. Under the Chairman of the Board is the Vice Chairman, who takes over the job during the absence or as advised by the Chair. The remaining members of the Board are assigned as Board Secretary who serves as the Secretariat, Board Treasurer who is responsible for all fiscal matters, and Board Members.

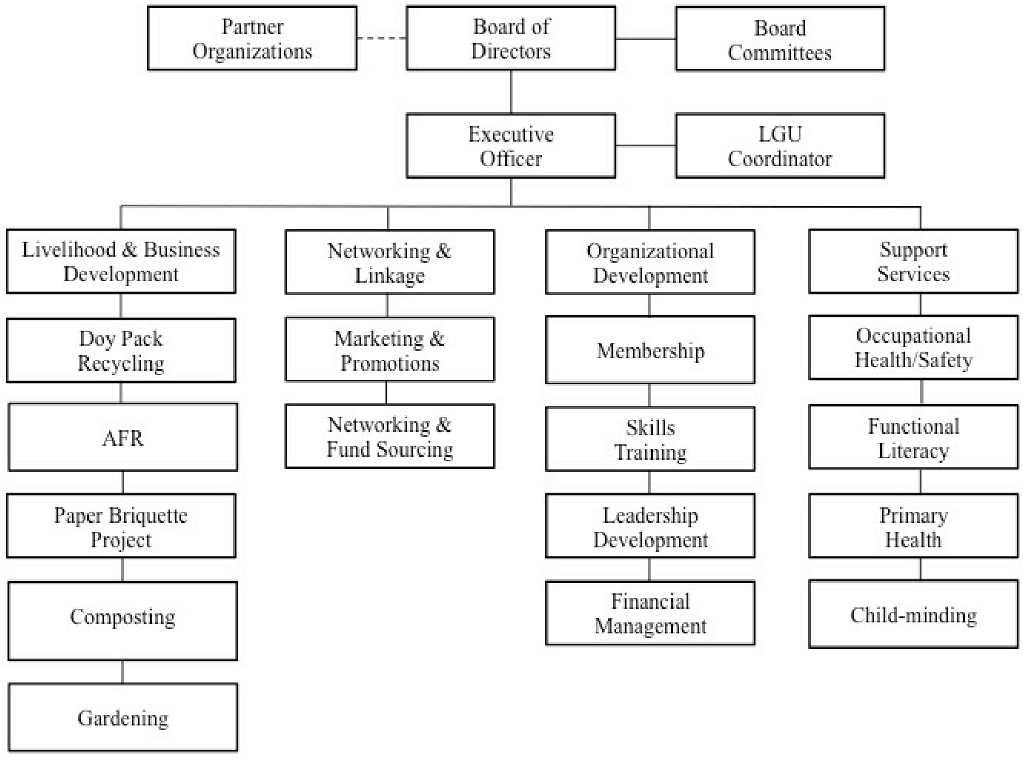

Figure 7. Organizational structure of UCLA

In order to perform its roles and functions more effectively, the Board created committees to carry out specific functions and concerns of the organization. Each UCLA Board Member is assigned to a specific committee of his interest and expertise. The association has Board Committees for Membership, Conflict Management, Finance, and Resource Generation/Fund Raising.

The Executive Officer (or President) of UCLA is primarily responsible to carry out the strategic plans and policies established by the Board of Directors. The Executive Officer is also working hand-in-hand with the LGU Coordinator who is directly under the General Services Office of Iloilo City LGU. Being a new organization, UCLA is still guided by the personnel of the LGU.

UCLA works on four major interests: a) Livelihood and Business Development, b) Networking and Linkage, c) Organizational Development, and d) Support Services. To sustain the activities and assure better income to the members of the association, UCLA has identified doy pack recycling, AFR, paper briquette production, composting, and gardening to be these sources of income for them. Among these livelihood projects, the doy pack recycling activity has so far set the most stable income. Other activities such as paper briquette production and AFR still needs more support especially on the technical side and on the establishment of supply and market for the briquettes. UCLA has identified networking and linkage as another key for a successful operation of their organization. Under this activity are marketing and promotions of their products including networking and fund sourcing. With the support of its Partner Organizations and the presence of the LGU, UCLA is introduced to many networks. This way, they get help in the marketing and promotion of their products. To encourage more waste reclaimers and other supporters, UCLA identified Organizational Development as another major interest for them. Although some members have not paid their membership dues yet, UCLA is there to represent this sector and become an example to the informal sectors that would want to be recognized for their role in the SWM system. The presence of UCLA in the disposal facility encourages stature, hence, showing the non-members the importance and stability of being in a recognized group. Lastly, UCLA recognized the importance of Support Services for their Organization. Through this, the members of the group would find support and security in terms of occupational/health safety, functional literacy or knowing their role and worth in an organization, and issues on primary health including child-minding. If a family of the waste reclaimer is out working in the facility, then their child or children may be temporarily left at the center where they could play or study instead of bringing them to the dumpsite and exposing these kids to risks and dangers brought about by exposure to wastes and harmful gases.

2.2 Briquette Production Technology

This parameter presents background about the principles of briquetting and its benefits, abundance of materials ideal for briquette production including preliminary initiatives of UCLA members on producing their own briquettes.

2.2.1 Briquetting

Briquetting is not a new technology. This industry started in the 20th century and is now making a comeback due to the diminishing resources for fossil fuels. Governments around the world endorse the advancement of this technology to address the increasing concern about waste disposal problems (Primer on Biomass Briquette

Production, 2010). Briquetting is also considered as one of the technologies included for biomass energy resources utilization and waste management together with the use of improved cookstoves, biogas, improved charcoal, carbonization and gasification (Omer, 2012). The end products from this process are called briquettes. As defined, briquettes are processed biomass fuels that can be burned as an alternative to wood or charcoal for heat energy. Often they are used for cooking and agro-industrial operations. This fuel source can offset the consumption of trees and help to decrease resultant desertification (Olorunnisola, 2007; Stanley, 2003). With briquetting, people especially the urban poor would be able to produce their own fuel through utilization of any appropriate combustible wastes like biomass and paper. Income can also be earned from briquettes if the household has access to an appropriate technology.

In a report presented by Baconguis (2007), the Philippine government agencies such as the Department of Energy (DOE), Department of Environment and Natural Resources (DENR), Department of Science and Technology (DOST) and other entities are currently promoting the development and widespread use of biomass resources through pilot testing, demonstration and commercial use of technologies such as biomass charcoal briquetting. The production and use of briquettes from abandoned resources like biomass and urban wastes are growing due to increasing fuel prices. Converting them, among others into briquettes, provides an opportunity for the disposal of cellulosic wastes and at the same time remove unwanted wastes, conserves the forest and reduces greenhouse gas (GHG) emissions, and provides alternative/additional livelihood to the urban and rural poor communities.

The process of briquetting involves the compression of a material into a solid fuel product of any convenient shape that can be utilized as fuel just like the use of wood or charcoal. The conversion of combustible materials found in the waste stream was found to be a better way of turning waste into wealth (Adegoke, 2002). If briquettes are produced at low cost and made conveniently accessible to consumers, it could complement firewood and charcoal usage for domestic cooking and agro-industrial operations, thereby reducing the high demand for the latter two (Olorunnisola, 2007). This is especially ideal in the Philippine setting wherein the main cooking fuels used include agricultural residues, fuelwood, charcoal, Liquefied Petroleum Gas (LPG) and kerosene (Samson et al., 2001). Based on the Philippine Annual Energy Sector Report, biomass together with solar and wind energy comprises 39.92% share of the energy consumption. Of this percentage for biomass, fuelwood has the highest share at 63.60%, while rice husk and charcoal have 6.90% and 5.70% shares, respectively (from http://www.jie.or.jp/pdf/19[1].Prof.Elauria.pdf). But due to many factors such as deforestation or dwindling of forest resources, other biomass wastes especially rice husks were considered.

2.2.2 Utilization of Biomass and Urban Wastes

Biomass is any organic matter that is available on a renewable or recurring basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes, wood wastes, aquatic plants, animal wastes, municipal wastes and other waste materials. It is recognized as one of the major potential sources for energy production (Sivakumar & Mohan, 2010; Psomopoulos, Bourka & Themelis, 2009; from http://www.epa.gov/sustainability/pdfs/Biomass%20Conversion.pdf). It is a renewable energy source that could dramatically improve our environment, economy, and energy security (Uzun & Kanmaz, 2013) and are considered the basic energy source in many developing countries (Balat, 2009). Its generation in the Philippines has never been a problem. However, most of these wastes are not utilized properly; oftentimes, these are just dumped at the back of the processing mills or along the roads. In worst cases, these wastes are openly burned, contributing more problems to the atmosphere. However, when these wastes are properly managed and utilized as briquettes for cooking operations, they could become a renewable alternative source of energy.

Almost any biomass can be briquetted. They can be formed individually or in combination without the aid of any binder (from http://www.lehrafuel.com/briquettes-manufacturing-process.html). In Nigeria, large quantities of agricultural and forestry residues produced annually are mostly underutilized. Yet, these residues are either burned or left to decompose (Olorunnisola, 2007). Previous studies, nevertheless, have shown the potential of these residues when processed into upgraded fuel products such as briquettes. One of the locally available materials briquetted for fuel energy production is sawdust (Olorunnisola, 1998; Ajayi & Lawal, 1995; Adekoya, 1989).

One important underutilized biomass in the Philippines is rice husk. As an agricultural country, one third of its agricultural lands are cultivated for crop production (FAO, 2000). With the country's increasing population, the demand for rice is also increasing. During rice milling, the outer covering of paddy, known as rice husk, has to be removed before it can be processed further for human consumption. Rice husk accounts for 20 to 25% of paddy's weight. According to data, the total rice husk potential of the country is estimated to be 3.14 million metric tons in 2005. The Province of Iloilo, which is the leader in terms of rice production in the Western Visayas region of the Philippines, generates about 165,000 metric tons annually (from http://www.aseanenergy.org/download/eaef/105-2004%20Project%20%20Summary %20for%20web.pdf). Rice husk, however, has to be converted in carbonized form before these can be made as pure material or mixture in briquette production. This can be attained by subjecting the materials to carbonization or pyrolysis process. The carbonized rice husk (CRH) can also be obtained directly as a by-product when it is utilized as fuel in direct combustion stoves, furnaces or from gasifiers.

Another important source of biomass waste in the Philippines is sawdust, which comes from logging and milling operations. The 2.06 million hectares of established forest plantation in 2005 is projected to even increase in the next ten years. Wood production from new plantations is also estimated to grow, thereby, increasing the generation of an abandoned biomass waste in the form of sawdust. This waste material, nonetheless, is seldom used as fuel in cookstoves because of its high moisture content, but it can be utilized further as an added material for briquetting.

Based on the 20-day segregation test run conducted by Paul et al. (2007), the volume of wastes brought daily to the materials recovery facility (MRF) of Iloilo City located in Brgy. Calajunan varied from 3.85 to 13.48 tons. These wastes were segregated mechanically at first. Then all materials of oversize fraction were further segregated manually by the local waste reclaimers. Results of the study further revealed that for the 20-day test, 4,554 kg of paper were collected or a daily production of 227 kg. These waste papers are presently sold by the waste reclaimers at Php1.50 (USD0.03) per kilogram. Based on this test, which sorted only around 20 tons out of the 170-ton wastes delivered daily to Calajunan, more than 2,500 kg of waste paper per day could theoretically be recovered. This recovered waste paper could be an alternative and viable material in binding the biomass residues for binder-less and perhaps smokeless briquette production (Grigorion, 2003; Demirbas & Sahin, 1998).

The high generation of biomass wastes like rice husks and sawdust including high-energy material like waste paper found in the waste stream is a significant way of properly utilizing them as fuel by converting them into briquettes.

2.2.3 Preliminary Briquette Production Initiatives at UCLA

Through the Deutsche Gesellschaft für Internationale Zusammenarbeit's (GIZ) project termed the Solid Waste Management for Local Government Units (SWM4LGUs) in collaboration with Iloilo City's local officials and its Social Development Program, the waste reclaimers of Calajunan were revitalized leading to a conduct of baseline studies on the informal sector's activities, living conditions and preferred income-generating activities. The 140 waste workers for the pilot activities were selected according to their willingness to enroll into the then proposed waste reclaimers association. And in May 2009, their group was registered as Uswag Calajunan Livelihood Association, Inc. (UCLA) allowing them to sign contracts with project partners.

Prior to the introduction of the hand-press briquette molder to UCLA, some households of Calajunan had already been producing briquettes as their fuel for cooking using their hands due to the abundance of waste paper in their area (Figure 8). The hand-press technology refers to the first device developed in order to make use of the waste papers and other organic wastes for briquette making. This was documented during the UCLA training conducted in August 2010 for their skills development and awareness when some members showed their paper briquettes made by hand. This hand-made briquette production only strengthened their need for more capacity building since producing briquettes by hand was also grueling especially for women who found it tiring on the hands after many times of repeated production.

Figure 8. Handmade briquettes produced by some members of UCLA

2.3 Socio-Economic Aspects

The socio-economic aspects in this study emphasized the influence of both social and economic factors in the enhancement of the existing briquetting technology. This parameter also includes the role of the informal sector in the solid waste management system especially on the recycling of wastes for utilization in the production of briquettes.

2.3.1 Solid Waste Management in the Philippines

Solid waste management (SWM) is a global concern intensified by the volume and complexity of domestic and industrial wastes generated by society. Problems on the proper management of these wastes have been inevitable to many developed countries, more so, to developing countries like the Philippines. Over the last 10 years, the country has endeavored to improve its management and operation of solid waste generation through several national laws, rules, regulations, orders and memoranda pertaining to the environment, including resolutions and ordinances that are issued by the LGUs.

The most significant policy on SWM in the Philippines was the signing of then President Gloria Macapacal-Arroyo on January 26, 2001 of Republic Act (RA 9003), also known as the “Ecological Solid Waste Management Act of 2000.” Under this law, it is declared the policy of the government to "adopt a systematic, comprehensive, and ecological solid waste management program in the country."

The ecological solid waste management (ESWM) policy is based on the management of waste in the following hierarchy:

a. Source reduction (avoidance) and minimization of waste generated at source
b. Reuse, recycling and resource recovery of wastes at the barangay level
c. Efficient collection, proper transfer, and transport of residential wastes by city/municipality
d. Efficient management of residuals and of final disposal sites and/or any other related technologies for the destruction/reuse of residuals except incineration

The ESWM policy is supported by relevant laws enacted at the national level that affect the implementation of RA 9003. These include: Toxic Substances and Hazardous and Nuclear Waste Act of 1990 (RA 6969), Local Government Code of 1991 (RA 7160), Philippine Clean Air Act of 1999 (RA 8749), Philippine Clean Water Act of 2004 (RA 9275), Environmental Awareness and Education Act of 2008 (RA 9512), Renewable Act of 2008 (RA 9513), Climate Change Act of 2009 (RA 9729), and Organic Agriculture Act of 2010 (RA 10068).

2.3.2 The Informal Sector in Developing Countries

Informal sector is defined as individuals, families, and private sector (micro-) enterprises working in solid waste management services, whose activities are neither organized, sponsored, financed, contracted, recognized, managed, taxed, nor reported upon by governmental authorities (Gerdes & Gunsilius, 2010 as cited by Paul et al., 2012; Wiersma et al., 2008; Ali, 1999). Specifically, they are more engaged in the recovery of waste materials either on a full-time or part-time basis with revenue generation as the motivation. In Asia and Latin America, it is estimated that 2% of the urban population earn their livelihood through waste handling, picking, sorting, repairing and trading. The governments in developing countries are becoming aware of the economic, social and environmental benefits that waste pickers or reclaimers bring to their respective countries. Hence, they should change from an attitude of opposition, indifference or repression; they should be supportive (Medina, 2002).

In the Philippines, the members of the informal waste sector are usually migrants from the provinces and have only basic education. They live near the source of wastes or a buyer of recovered materials. Women and children are usually involved in waste picking; thus, they are prone to diseases as a result of unsanitary working conditions.

The way informal recycling activities are organized has important results for income generation, working conditions and social status. As a general rule, the less organized the informal recycling sector is, the less the people involved are capable of adding value to the secondary raw materials they collect, and the more vulnerable they are to exploitation from intermediate dealers. Hence, one of the major challenges in solid waste management in developing countries is how best to work with the informal sector to improve their livelihood, working conditions and efficiency in recycling materials found in the waste stream (Wilson et al., 2006).

The primary activities of the informal sector include the separation of organic and recyclable materials with variations from country to country on how the materials are extracted and utilized after (Wehenpohl, 2007).

Internationally, there are at least four main categories of informal collection for recycling especially in cities with a formal waste collection and disposal system (Wilson et al., 2006 as cited by Quiroga et al., 2011):

- Door to door – They are informal collectors who retrieve recyclables prior to the disposal of wastes they have recovered. They act as a private collection system; they segregate the mixed waste they have collected, after which, the residual parts are discarded. For this mode of collection, the vehicles used to carry the materials include pushcarts, animal-drawn carts, and bicycles among others.
- Municipal/formal transport – The workers get the recyclables while the garbage bags are being loaded to the collection truck. This practice is widespread in Mexico, Colombia, Thailand and the Philippines.
- Public spaces – The scavengers retrieve materials at the communal storage sites, including the commercial and residential containers placed on the streets. Recyclables are also retrieved on streets or public places, in vacant lots, canals or rivers or any place where waste is present.

- Final disposal places – Waste pickers collect wastes from areas or disposal sites that have given them permission to do so. These include composting plants, open dumps or landfills. Scavenging in these places occurs in cities throughout the economically developing world including Manila, Mexico City, Cape Town, Bangalore, Guadelajara, Rio de Janeiro, Dar es Salaam, Guatemala City and many others.

Depending on where and how materials are recovered, the informal waste sector in the Philippines are classified as follows (NSWMC, 2009):

- Itinerant waste buyers – They are waste collectors that go from house to house to purchase recyclables directly from the household-owners and/or domestic helpers. Usually, the junkshop owners provide them with a small operating capital and a pushcart to purchase the recyclables. They also recover materials from public bins and garbage bags that are left by waste generators at collection points.
- Jumpers – They are unauthorized persons (usually young men living near disposal facilities) who climb/jump up the garbage trucks during collection to recover the recyclables before it reaches the disposal facility.
- *"Paleros"* – Are garbage crewmembers who are employed by LGUs to collect garbage from the households and establishments. While the garbage trucks are en route to the disposal facility, one or two of the garbage crews start to separate the saleable waste materials and upon reaching a specific junkshop, they sell their collected wastes. Although prohibited by RA 9003, this activity is often tolerated by some LGUs because it augments the small income of the garbage crew. Then the income is divided among them.
- Waste reclaimers – Are persons who engage in waste picking activities in dumpsites, curbside, canals and waterways. Some of them settle near the dumpsites to minimize transportation costs.
- Illegal junkshop owners – Those buyers of the recyclables from the itinerant waste buyers, jumpers, garbage crew and waste reclaimers who operate without business permits. They, in turn, sell their recyclables to

consolidators who either sell the recovered materials to local recycling industries or to exporters of the said materials.

Figure 9 presents the hierarchy of the waste recycling chain from the least paid and vulnerable to those who benefit most in economic terms.

The waste reclaimers, which are at the bottom of the hierarchy, generate the lowest value in terms of income from recycling. They are the most vulnerable as they do not have an organized supportive network. Since there is no societal recognition of the importance of waste recycling to the economy, waste reclaimers usually have no concept of their work as being useful or worthy of regularization (Furedy, 1993). The waste reclaimers have limited capacity for processing or storing materials and are easily exploited.

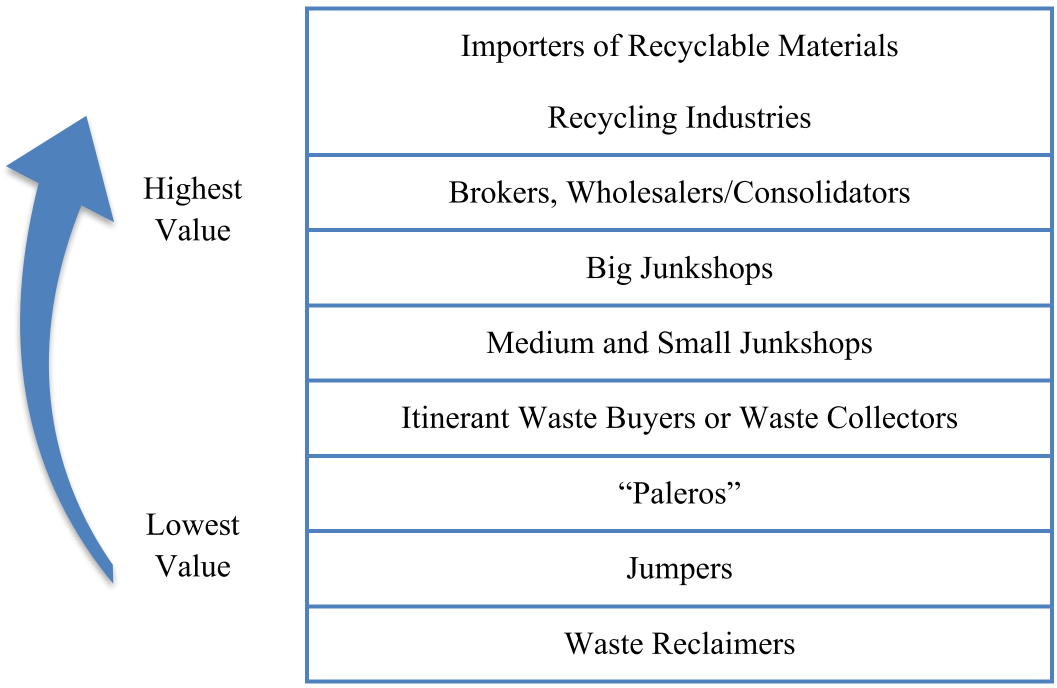

Figure 9. Hierarchy of waste recycling chain (Adapted from Wilson et al., 2006)

Organizing and training informal recyclers into micro and small enterprises is a very effective way to upgrade their ability to add value to collected materials (Haan et al., 2008 as cited by Wilson et al., 2006). By circumventing intermediate dealers, their income can be significantly increased and their activities become more legitimized and socially acceptable. Forming cooperatives and associations involving the informal sector can aid in the improvement of their position in the hierarchy of waste recycling chain. They can also negotiate as a discrete entity with the local authorities and/or the private sector and this legitimizes their activities and increase their income by circumventing or avoiding middlemen (Sanada & Yoshida, 2011; Medina, 2000).

Forming an organization and becoming a member offer a large number of advantages to the informal sector. Membership in such an organization allows the limitations and restrictions of individuals such as low level of schooling, lack of experience in collaborating and negotiating with business partners and public authorities to be overcome. Having an organization offers their members opportunities to improve their working conditions, increase their income and access services such as health insurance and micro-credit. These organizations are also important instruments for exchange of experience, coordination and increased sector "visibility" (Gunsilius et al., 2011).

An initial inventory of the organized groups among the informal waste sector in the Philippines shows that majority of these groups are mainly in Metro Manila. The government has recognized some of these groups either as associations or cooperatives. One of the largest organized groups of waste reclaimers is located in Payatas Disposal Facility in Quezon City, one of the districts of Metro Manila. The 2,000 waste reclaimers are organized in nine associations and one multi-purpose cooperative. In the inventory of 50 organized groups among the informal sector in the Philippines, 43 are located in Luzon, 3 are found in Visayas (where Iloilo City is located), and 4 are in Mindanao (NSWMC, 2009). UCLA is counted as one of the three groups in Visayas.

2.3.3 Involvement of the Philippine Government in the Informal Sector

The National Solid Waste Management Commission (NSWMC) established under the Office of the President is mandated to oversee the implementation of SWM plans and prescribe policies to achieve the objectives of RA 9003. The NSWMC is tasked to undertake the following activities, among others: (a) prepare the National SWM Framework; (b) approve, review and monitor implementation of local SWM plans; (c) provide technical and other capability building assistance and support to

LGUs; (d) develop a mechanism for the imposition of sanctions; (e) review the incentives scheme for effective SWM, etc. The Law also states that the Department of Environment and Natural Resources (DENR), through its Environmental Management Bureau (EMB), shall provide secretariat support to the Commission (RA 9003). The NSWMC is the only national government office directly involved in the development of a framework plan and national strategy to mainstream the informal sector in solid waste management. The other national agencies also work with the informal sector but on an indirect basis. In addition to the national government agencies, various church-based, private organizations and non-government organizations (NGOs) are also working for the welfare of the informal sector.

The Framework Plan, which was adopted through NSWMC Resolution No. 47, Series of 2010, hopes to empower the informal sector that is recognized as a partner of the public and private institutions, organizations and corporations in the promotion and implementation of the 3Rs (reduce, reuse and recycle) of solid waste management in the Philippines with the end view of alleviating poverty. The mission is to integrate the informal sector in the SWM system by providing them with a favorable policy, environment, skills development and access to a secured livelihood, employment and social services. More so, the NSWMC Resolution No. 48, Series of 2010 was also signed to create a multi-sectoral committee for capacity development of the informal waste sector, in which, it was agreed during the roundtable discussion with various stakeholders that the key to empowering the informal sector is to capacitate its members.

2.4 Technical Aspects

The technical aspects based on the conceptual framework explain related studies on existing briquetting technologies that have been designed or were adapted in other countries down to the Philippines. It also includes the importance of considering certain technical aspects such as shape of the briquettes to be produced, binding property of certain materials, and the mode and maneuverability of compacting materials to become briquettes.

Briquetting is one of several compaction technologies in the general category of densification. In densification, the materials are compressed to form a product of higher bulk density, lower moisture content, and uniform size, shape and material properties; making them easier to package and store, cheaper to transport, more convenient to use, and their combustible characteristics are better than those of the original waste material. There are two ways by which compaction can be accomplished in briquette production: with and without a binder. One must have something to make the materials stick together during compression. Otherwise, when the briquette is removed from the mold, it will crumble to pieces (from http://www.cd3wd.com/cd3wd_40/vita/briquette/en/briquette.htm). In fuel briquetting, paper may be used as partial binder material alone (Demirbas & Sahin, 1998). Cellulose, the main constituent of paper, is known to contain proteinaceous materials that tend to have excellent adhesive properties (Immergut, 1975). In a community-based energy briquette production project in an informal settlement in Nairobi, Kenya, paper served as binder for other materials used in producing doughnut-shaped briquettes. These materials include discarded coffee hulls, rice husks, charcoal particles, sawdust and wood chips (Njenga et al., 2009).

Making fuel briquettes out of rubbish takes the waste from the city and turns it into a source of energy. Materials identified that maybe turned into briquettes are waste paper and cardboard, agricultural residues, charcoal dust and sawdust. In producing briquettes, a hole at the center of the fuel is believed by many to improve the combustion characteristics of the briquette (Chaney, Clifford & Wilson, 2013). It encourages rapid drying, easy ignition and highly efficient burning due to the draft and insulated combustion chamber that the hole creates (from http://www.paceproject.net/UserFiles/File/Urban%20Living/make%20briquettes.pdf). Many parameters are also considered in the determination of the quality of briquettes produced from different agricultural and forest origin biomass. Some of these include production rate and economic analysis and thermophysical properties and chemical composition of the materials used for briquette production (Stolarski et al., 2013; Voicea et al., 2013; Vassilev et al., 2010; Chin & Siddiqui, 2000; Singh & Kashap, 1985).

Due to the abundance of biomass and other materials appropriate for briquetting, different technologies internationally and locally were developed and introduced to many stakeholders. Some different models of briquette presses that were designed and are used all around the world include wooden compound levers, hydraulic pistons, car jack presses, and solar or pedal powered versions (Stanley, 2003). Notably an organization called Legacy Foundation in America developed a low-pressure wet-briquetting process that uses a simple wooden press and has pioneered a successful training program for the production of briquettes from crop residues aimed at rural communities in developing nations (Chaney, Clifford & Wilson, 2013). Legacy Foundation and its partners in briquette production are working in Kenya, Nepal, Haiti, Peru, Southern Mexico, South Africa, Uganda and Malawi (from http://www.paceproject.net/UserFiles/File/Urban%20Living/make%20 briquettes.pdf). This machine developed by Legacy Foundation is classified under the wooden compound type, that is, the briquette press is built almost entirely out of lumber so the building materials are easy to find. The pressing is achieved through a simple lever mechanism and this design does not require special parts as opposed to screw presses and hydraulic jack presses. However, this briquette press is quite large and heavy so it is hard to transport and it requires two people to run it efficiently. This design could produce in one pressing about four cylindrical briquettes with a hole at the center. The mixed materials for one briquette is added in the cylindrical mold, after which, a spacer is inserted before the next mixture is placed. The process is repeated until the entire cylindrical mold is filled with mixed materials for compression using wooden lever. The cylindrical mold is designed to have many holes on the side to allow excess water to escape during compression (Stanley, 2003).

A technology similar with that of Legacy Foundation was also introduced by Enviro-Coal and Beaverton Rotary in Uganda to make fuel briquettes for their own use as well as to establish sustainable small businesses with a product that helps the producers earn a living wage, provide their customers with a less expensive cooking fuel and improve the environment by reducing deforestation. Their design called the Complete Peterson Press Model 3 Kit uses a hydraulic bottle jack positioned at the bottom in order to compress the materials in an upward manner. The machine can produce in one pressing two briquettes that are cylindrical with also a hole at the center (Beaverton Rotary Foundation, 2013).

In India, the briquetting industry started in 1981 with the introduction of low-density and high-density technologies. The former technology requires pyrolysis of the biomass followed by briquetting using a binder to maintain the structure. On the other hand, high-density briquetting technology compacts the biomass and holds the structure together without a binder. There are two types of high compaction technology: the piston press and the screw press. These technologies extrude the biomass through a die at a very high pressure. The briquettes produced also have a central hole (Grover, Mishra & Clancy, 1994).

In the Philippines, the then Office of Energy (now Department of Energy) conducted in 1990 the "Biomass Densification Research Project in the Philippines" for the University of Twente and the Dutch Ministry of Development Cooperation. The project investigated the status and extent of biomass briquetting in the country. Findings revealed that there is limited commercial production of biomass briquettes. The technology presents an opportunity to dispose unwanted waste and at the same time provides an alternative livelihood to communities (Primer on Biomass Briquette Production, 2010).

In addition, the researchers of the Philippine Forestry Products Research and Development Institute (FPRDI), based at the University of the Philippines - Los Baños, Laguna, fabricated a modified manual briquetting machine using steel plates, angle bars and round bars. It was patterned after an existing manual briquetting machine that weighs 55 kg. The modified unit made briquettes each measuring 3.8 cm high and 3.8 cm in diameter with 1.25 cm cavity (inner hole) diameter. It can produce 10 pieces of cylindrical briquettes with center hole in one pressing. The charcoal briquettes were produced from coconut shell and charcoal fines with cassava starch as binding material.

At the Philippine regional scene, other institutions and corporations also developed their own briquette machines. A visit to the campus of St. Paul University in Dumaguete City, Negros Oriental was an opportunity to observe the actual operation of their briquetting machine that utilized the waste paper generated in the campus. The technology employs the use of a hydraulic bottle jack positioned at the bottom. During the demonstration of the machine, it was observed that when the water drips from the molders during compression, it would make the hydraulic press wet. The machine can produce 20 cylindrical briquettes (with no hole) in one pressing. Another visit to the fabrication site of RU Foundry and Machine Shop Corporation in Bacolod City, Negros Occidental also revealed another low-density charcoal maker. The machine uses a car screw-type press principle in which compression is done by revolving the screw press in a downward manner. It can produce twelve no-hole cylindrical briquettes in one pressing.

Prior to the involvement with the informal sector in Calajunan, Central Philippine University (CPU), an institution of higher learning located in Iloilo City, also developed different briquetting technologies in the past years (Paclibar, 2002; Belonio, 2000). The technologies gave more emphasis on the use of purely biomass wastes (carbonized rice husk) including the use of binding materials such as cornstarch and animal manure. But with the increasing generation of urban wastes such as paper in Iloilo City (Paul et al., 2007), a more flourishing fuel for heat energy may be provided in the market. Hence, waste paper was considered as an add-on material for briquette production.

2.5 Feasibility

In the framework, the feasibility of briquette production by the informal sector of Calajunan dumpsite and the products they created is measured in terms of its feasibility on the social, technical, economical, and environmental considerations.

2.5.1 Social Feasibility

Integration of the informal sector in solid waste management activities proved that income, working condition and their social status could be improved even without putting them into waged positions. A variety of integration activities can assist informal sector actors get more regular income from the materials they collect. By the formation of a cooperative, the organization of the informal waste sector can be further improved. Integrating the informal sector through cooperatives or association can give them reliability especially in negotiating service contracts to industries and municipal authorities (Wehenpohl & Kolb, 2007). The lack of recognition by the formal system of the role of the informal sector makes the latter vulnerable to harassment, loss of secured access to post consumer materials and occupational hazards and risks.

The involvement of other sectors and groups on the plight of the informal waste sector is, therefore, instrumental in their organizational activities, decisions, and eventually in the success of the implementation of their projects. Some informal sector increasingly receives support and guidance from local non-government organizations (NGOs), sometimes in cooperation with international aid organizations. In some cases, the waste sector gets support from religious charity organizations. For example, the Zabbaleen in Cairo receives support from their Orthodox Christian Coptic Church; the waste scavengers at Payatas waste dumpsite of Manila receive support from the Catholic Church.

The organization of UCLA and its integration to the SWM system with support both from the government and private agencies could widen the way for this informal sector group to be socially accepted for their role in the society and their rank in the waste recycling chain.

The issue on lack of livelihood and opportunities, which is one of the main causes for increasing poverty in the Philippines (The World Bank Country Assistance Strategy, 2009), can also be addressed when briquette production by a group of informal sector is put in place. With UCLA's presence in the community and its gradual improvement as a legal institution, the lack of livelihood and employment can already be tackled, hence, the project can become instrumental in alleviating such issue in this part of the country.

2.5.2 Technical Feasibility

The availability of abundant biomass resources and urban wastes in Iloilo City and nearby areas makes briquette production possible. Iloilo, being a rice-producing province, generates a lot of biomass wastes. Sawdust is also generated by many furniture and lumberyards found in the city. Since the location of UCLA is only across the controlled disposal facility of Iloilo City, access to urban wastes in the form of paper is not difficult.

The equipment for production, as documented in many previous studies, have been continually improved through modification and had been tried by UCLA to suit on their needs. It is not complicated when operated and in case of unexpected damage due to wear and tear, a local welding shop near the center is available for immediate repair of the unit.

The briquetting process itself is not complicated as observed during the initial field production tests conducted in UCLA Center. The Center has enough working space allowing movement during production. Electricity line and availability of water supply are also not a constraint in the area.

The technology for briquetting in terms of recommended briquette material utilization and machine operation has been transferred already to the selected members of UCLA as part of their capacity-building initiatives.

2.5.3 Economic Feasibility

The informal sector handles large volumes of waste materials at no or marginal cost to the local governments and taxpayers. Their activities contribute to moderating the overall costs of municipal solid waste management and extending the life of disposal facilities. Various studies have also shown that the informal sector contributes to positive economic impacts on the overall solid waste management (NSWMC, 2009). By adding value to waste materials and creating new products, more materials will be diverted and the life of disposal facility will be further extended. Moreover, the informal sector can earn higher income than just recovering and selling recyclables.

Having completed the study of technical feasibility, the organization should then have sufficient information to determine the costs that are likely to be involved in production. Additionally, the market survey will have provided information about the selling price that could be achieved for the briquettes.

2.5.4 Environmental Feasibility

In a study made by Wehenpohl & Kolb (2007), activities of the informal sector like recycling and recovery of wastes in a solid waste management system in developing countries are associated with significant environmental benefits as they avoid negative extraction impacts when using primary sources. In all the six cities they have documented, the informal sector is the major force behind existing recycling efforts. As the informal sector provides processing industries with secondary materials, the damage to the environment associated with mining and refining virgin or primary natural resources is reduced, or in some cases avoided. The informal sector extracts and recovers more material at lower cost and uses much less fossil energy for doing so than the formal sector. It also keeps large amounts of recyclable materials out of disposal. Thus, the informal sector, as reported, produce a positive environmental impact provided that their work generally consumes less energy than the formal sector.

With the role of UCLA as producer of briquettes in the city, the consumers later on would be introduced to an alternative fuel for cooking replacing dependency on fuelwood, charcoal, and LPG. A production of 15,000 briquettes per year could lead to the replacement of 86,667 m^3 of fuel wood (from http://www.cleancookstoves.org/resources_files/feasibillity-and-impact.pdf). The 15,000 briquettes are equivalent to one-year supply of cooking fuel for an average household size having four members.

The substitution of briquettes for charcoal, fuelwood and LPG would also bring environmental feasibility through reduction in carbon dioxide equivalent (CO_{2equi}). Although the reduction in actual carbon released in the atmosphere would not really change significantly because combustion of wood and briquettes would release similar quantities, reduction is still attained since more trees are left standing to absorb more carbon instead of cutting them for fuel (from http://www.cleancookstoves.org/resources_files/feasibillity-and-impact.pdf).

3 METHODOLOGY

Methodology describes the research design, preliminary data collected and procedures used according to the scope and objectives of the study. The presentation of the approaches and methods used were divided according to the socio-economic and technical aspects of the study.

3.1 Research Design

Under the socio-economic aspect of the study, a non-experimental posttest only design was utilized for the structured interviews prepared to collect the descriptive information of the respondents like personal background, waste picking experience, housing condition, kitchen/cooking devices used, and acceptability and use of briquettes provided. The project site (Iloilo City) was described including the status of the SWM system in the City. The current situation including quantitative and qualitative scenario of the disposal site was also described. UCLA was described using initial information about its organizational structure, the physical/technical arrangement and location of its center.

3.2 Data Collection

There were different ways on how collection of data in the study was performed. Primary and secondary data collected were both used to gather the necessary information needed to establish the study.

3.2.1 Primary Data

Primary data are information collected directly from the subjects being studied, such as people, areas or objects (David, 2005). This method involves the gathering and updating of baseline data about the socio-economic demography of UCLA and the description of the center. In this study, primary data were collected through a structured interview and casual meetings/interviews with the members. Additional primary data were also obtained through the use of questionnaires. Actual visitations to the study site were done to observe how the association works in utilizing the floor space of the center during the field test of briquette production.

In gathering primary data, precise quantitative findings were generated and qualitative descriptive information were produced in the study. Quantitative data are information that can be counted or expressed in numerical values. Socio-economic data included baseline information on the socio-demographic background of the members of UCLA such as age, income and number of years in the dumpsite. Qualitative data, on the other hand, involve descriptive information that have no numerical value. Such included description of the organizational flow of UCLA, perception on certain issues raised pertaining to briquetting, including suggestions for the enhancement of technologies introduced to them.

- ***Structured Interview***

This method involves a face-to-face interaction between the data collector (the interviewer, and the source of information (the respondent). The interviewer directly asks the respondent questions from a prepared instrument, which is called an interview schedule (David, 2005).

An interview schedule was prepared and the interviewer explained and read the questions to the members of UCLA and other waste reclaimers found in the vicinity of Calajunan Disposal Facility on the use of the newly developed briquetting machine including their views on the utilization of briquettes as substitute fuel for cooking. Their answers were recorded verbatim by the interviewer in the instrument. Quantitative and qualitative questions in the interview schedule included queries about UCLA member's personal background, waste management/waste picking background, housing condition, and kitchen/cooking devices found in their households (Figure 10). A structured interview was also used in the assessment of the acceptance of briquettes as substitute fuel for cooking.

UCLA has 263 members living near the vicinity of the dumpsite; however, there are also non-UCLA members recovering wastes in the site. From this number, the sample size was determined using an online program (from http://www.raosoft.com/samplesize.html) at 0.95 reliability. The formula yielded a sample size of 157, however, 160 respondents were included in the survey. These respondents were identified using accidental sampling technique (Altares et al., 2003).

Figure 10. Conduct of interview schedule on product acceptance of the technology developed

- ***Informal Interviews***

Informal interviews offer a more flexible way of getting information. This is especially useful when little knowledge exists to obtain a general idea, or when certain details need to be clarified (Kajornboon, 2005). This method was used during workshops or activities conducted in UCLA Center where questions or clarifications were made by approaching certain members of the association. These questions pertained mostly on the feasibility of briquetting as a source of additional income for their organization. Questions were also asked on the simplicity or difficulty of adopting briquette production technologies introduced to them. Prior to the actual field operation of the final design of the machine for briquette production, many preliminary tests were performed at UCLA Center. The comments made during informal interviews while conducting preliminary tests were incorporated in the final design of the machine.

- ***Focus Group Discussion***

Focus group discussion (FGD) is an informal in-depth discussion in which a small number of participants (6-12), under the guidance of a moderator or facilitator talk about topics of special importance to a particular study. This method can provide relatively quick answers to specific questions. FGDs are increasingly used by researchers, practitioners and educators in the context of needs assessment and formative evaluation (David, 2005). Some of its uses are for the determination of group reactions to a certain program or intervention.

FGD was used during one of the annual gatherings and assessments of UCLA as an organization. One group considered under the briquetting team was met for discussion on how briquette production can be improved. Suggestions and recommendations especially on product enhancement and marketing were noted during the said workshop.

- ***Observations***

Observation is a method used to study social processes as they happen. By observing people and interacting with them, the researcher is able to avoid the artificiality of an experimental design and unnatural setting of a structured interview (Schutt, 1999). Direct observation can generate both quantitative and qualitative data. This technique is useful for studies that require description of operations, activities, or procedures (David, 2005). Another advantage of this method is the possibility of seeing the normal or regular functioning of any system (Steele & Taylor-Powell, 1996).

Throughout the conduct of the study, observations were made whenever the activities were performed at the center. In this method, the members of the association were observed on how they reacted to new technical interventions presented to them. Likewise, observations were made as to how they perceived the new technologies presented to them and how they acted as to whether they find the machines easy to operate or if they found the briquettes interesting for testing in their homes. This method was helpful on how they worked as a team or as an organization. Direct observations were made as to how they properly arranged the set-up of the machines used especially during the field test for briquette production. They were also observed on how they maximized the use of space of their building during the drying process of the briquettes.

3.2.2 Secondary Data

These are information collected from other available sources, like recent censuses, or data collected by large-scale national or worldwide surveys or data of completed studies (David, 2005). These also refer to data that were not personally collected; rather these are data obtained from books, articles, newspapers and magazines among others (Curran & Perecman, 2006).

Secondary data were utilized in describing the overview about Iloilo City including other data leading to the description of Brgy. Calajunan, where the city's disposal site is located and also that of UCLA. Data from other sources such as from previous studies, manuals and official and non-official documents were also cited in this study.

3.3 Technologies and Product Enhancement

The methodologies administered under this aspect were utilized in forming different approaches to enhance briquette production. This was done through the development of appropriate technologies that are acceptable to the needs of the stakeholders and can produce briquettes of good quality.

3.3.1 Development and Description of Technologies Utilized

The task to sustain the newly started livelihood activities for UCLA is of paramount importance to its future development. The UCLA board members are challenged to be more entrepreneurial in their approach and leadership. However, UCLA as an organization needs further technical assistance and support (Paul et al., 2012).

The following are the description of the different briquetting technologies that were developed and enhanced after the socio and technical considerations were integrated until the appropriate design for the waste workers was attained.

- ***Hand-Press Briquette Molder***

Exploration on the potential of producing briquettes as an identified alternative source of livelihood for UCLA members started with the very simple hand-press briquette molder presented in Figure 11. This was first developed in 2009 as an aid to explore options of value adding to materials that have been recovered as AFR by means of producing briquettes (Paul et al., 2009a; Paul et al., 2009b) and was evaluated during a 100-day recovery test. The materials mostly included light packaging materials and also organic materials like carbonized rice husk (CRH), sawdust and low quality waste paper from the dumpsite. The size of the briquettes produced were also considered in a way that it should be similar to that of charcoal so that the would-be users do not have to purchase a specific stove for this type of fuel.

Thus, the briquettes produced can be used for stoves intended for charcoal. Organic materials like sawdust and CRH and low quality waste paper were considered as materials for this type of production.

Figure 11. The first hand-press briquette molder developed with briquettes produced

One person can operate this machine and it was constructed using locally available materials. The machine is basically composed of the following major parts, namely: briquette molders, handle and frame. This first hand-press briquette molder was designed and constructed consisting of two symmetric half forms with five molders each. The bottom half is welded into a 0.3-cm (1/8-in.) thick metal plate. The resulting machine measuring 33 cm long by 32 cm wide, however, was found very heavy especially for women at the dumpsite. The flat surface of the frame does not allow any means for gripping on the machine specifically during transfer. The handle made from a 2.54-cm (1-in.) diameter galvanized iron (GI) pipe is welded only at the middle length of the five molders. During compression, it was observed that the pressure created during molding is not distributed evenly, hence, the need to brace the handle.

These limitations led to the development of the second hand-press briquette molder. The revised design presented in Figure 12 has the same parts, namely: briquette molders, handle and frame. The shape and dimensions of the briquettes produced are similar with those in the first design. Revisions made were on the frame, by using a 1-in. width metal square bar. The frame served as a grip during compression, lifting or transporting of the unit. Another revision was on the handle where it was braced on both ends of the molders in order to distribute the pressure during compression. During field production tests at UCLA, the members made additional improvement by extending the length of the handle to 55 cm for more force (Figure 13) during compression.

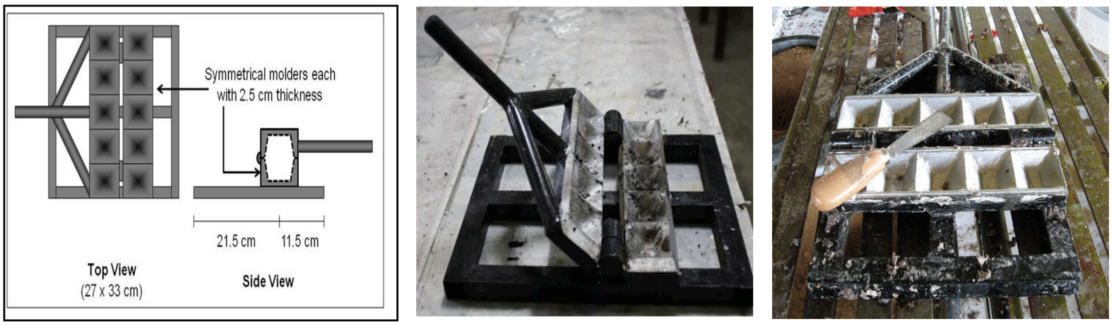

Figure 12. The second hand-press briquette molder developed with modified support plate

Figure 13. The second hand-press briquette molder with an extended handle

The hand-press briquette molders, in detail, are composed of the following parts:

1. Briquette molders – The hand-press machine has five symmetrical molders connected on both sides by a hinge creating a movable top for easy opening. They are used to contain the prepared mixture for compaction. Each molder measures 5 cm long, 5 cm wide and 2.5 cm high. A cutting allowance was provided giving a total length and width of approximately 27 cm by 6 cm, respectively. The molders are supported by the frame and hinged together to attain the pillow-shaped briquettes.

2. Handle – This is the part of the machine that maneuvers the movement of the upper half of the molder. This is also responsible in creating the pressure needed in the compaction of the mixtures. A 1.9 cm (3/4 in.) schedule 20 GI pipe with a length of 20.5 cm was welded at the center of the upper half of the molders and were braced to both ends with two similar pipes each having a length of 14 cm.

3. Frame – The first unit was made of a 0.3 cm (1/8 in.) thick mild steel (MS) plate while the second design was constructed out of a 0.3 cm (1/8 in.) thick by 2.54 cm (1 in.) wide square bar. One side of the frame was used as support during compression of the prepared mixtures while the handle was being pushed downward to create more pressure.

The operation of the briquette molder works on the principle of compacting the prepared mixture through the two symmetrical molders fastened together by two hinges on one side and with a handle on the other side. The movable upper half portion of the molder is opened while the fixed bottom part contains the mixture. Then these combinations are compacted by closing down the upper half molder. Pressure is created by pushing the handle down using one hand with the other hand holding the frame for stability. The pillow-shaped briquettes produced using this machine is presented in Figure 14. When the waste reclaimers used these briquettes in their respective homes, they observed smoke during the entire cooking operation. They noted that when they were then using briquettes produced manually by their hands (with a little hole at the center), less smoke was emitted. As part of the product enhancement of the technology, they suggested to produce briquettes with a hole.

- ***Jack-Driven Briquette Molder***

The limitations from the different commercial briquetting technologies developed internationally and locally including the recommendations made by UCLA members when they were using the previously designed hand-press briquetting technology were considered in the criteria for designing an improved version of the briquetting machine. Machines adopted in some parts of Africa (Beaverton Rotary Foundation, 2013; Chaney, Clifford & Wilson, 2013; from http://www.paceproject.net/UserFiles/File/Urban%20Living/make%20briquettes.pdf; Stanley, 2003) were very big and bulky, hence, limiting its portability during operation. Another consideration was the location of the jack at the bottom making it prone to water drips. Presence of water drips in the jack could hinder the efficiency of compression of the machine later on. Most of the machines developed can only produce about ten pieces of briquettes in one pressing, whereas, if the number of molders is increased, production can also be increased. Common denominator among these technologies was the shape of the briquettes produced which are cylindrical with a hole in the center. The briquettes produced were mostly dependent on the use of a binding material.

Figure 14. Pillow-shaped briquettes produced using the hand-press briquette molder

UCLA members also expressed feedbacks during the field-testing and operation of the hand-press briquette molder developed for them. These included the difficulty of compressing the materials since it was done by hand and the continuous production of smoke while using the briquettes as fuel for cooking.

These technical comments were considered as bases to further improve the design of the existing briquetting machine to enhance briquette production. Henceforth, the new technology would be portable and produce cylindrical briquettes with holes. The presence of a central hole in a briquette would aid in uniform and efficient combustion, with significant reduction in smoke (Grover, Mishra & Clancy,

1994) at the same time increasing the number of briquettes produced from five pieces per compression to sixteen pieces.

A screw-type scissor-jack placed on top of the molders was considered originally in the improved design to prevent water from dripping on the movable part of the machine (Figure 15). It was constructed to create fuel at a higher production rate and better compression strength as compared to the previously developed household hand-press briquette molder. The machine was also constructed using locally available materials and was fabricated at a local welding shop in Iloilo City making it easier for repair, maintenance and reproduction.

Preliminary test results using this design showed difficulty in maneuvering the handle for and during compression of materials. Rotating the jack is slow and tiring, delaying the production of briquettes. The constraints on this design steered into the replacement of a scissor-jack by a hydraulic bottle-jack that is easier to manipulate and which needs little effort during compression. As presented in Figure 16, the scissor-jack was removed and replaced with a hydraulic jack for easy management during briquette production. The spike responsible for creating the hole was also relocated at the upper cylinder so that while the solid cylinder is compressing, a hole is also made during the operation.

When this machine was introduced to the members of the Briquetting Team of UCLA for field testing, the main reaction was the heftiness of the molders. The female members of the association who operated the machine found it very hard to lift the upper cylinder after compression even if a spring was welded on both sides. It can be recalled that the purpose of the spring was to automatically lift the compressing cylinder. As observed during the procedure, the compressing cylinders have misaligned due to the wear and tear of operation. The weight of the briquette molders was another major problem especially for women UCLA members since they are the ones who are mostly involved in the production test. Another technical problem on the design observed was the difficulty of removing the compressed briquettes from the molders. The design needed correct alignment of the molder and presser (Figure 17) in order to remove the briquettes. This mode of removal further delayed the operation.

Figure 15. The first jack-driven briquetting machine developed for UCLA

Figure 16. The hydraulic-type bottle-jack press briquetting machine in operation

Figure 17. Removal of briquettes from the molder

Figure 18 illustrates the improvement of the machine incorporating all the suggestions made especially by the stakeholders. The machine was simpler in design and the heavy detachable molder was eliminated. Placement of mixed materials for molding, the mode of compression of materials and removal of briquettes became very simple and easy. A more durable spring was also used to prevent it from snapping off during operation. Lifting of machine parts was eliminated and after compression of the materials, the compressor was automatically pulled down once the jack was released. The improvement of the machine was done by incorporating all the suggestions made as part of the enhancement of the machine for better mobility, operation and ease of usage. As presented in the figure, the placement of the jack was transferred to the bottom. It was observed that jacks could better push and compress heavy objects up using its "neck" rather than pushing down the material for compression using its "bottom". The jacks were designed using that principle. To prevent the water drips, the upper metal plate was used as the catchment platter. The first improved hydraulic-type jack-driven machine was fabricated with only nine molders to initially make sure that the machine would function as designed. This whole unit weighed 45 kg including the jack.

With the improved design of the jack-driven machine, many briquettes can be produced in one press producing more fuels in a shorter time compared to the previously fabricated devices. This new development considered the limitations that were observed in the previous designs making sure that the briquettes produced were more acceptable to the end users.

The final design for a hydraulic-type bottle-jack press briquetting machine is presented in Figure 19. The machine consists of four major parts: briquette molders, cover, hydraulic jack and frame.

1. Briquette molders – The new machine was constructed with sixteen cylindrical holes. Each molder was constructed using a schedule 20 GI pipe having an inside diameter 5.7 cm (2-1/4 in.) and a height of 10 cm (4 in.). It was welded in the middle with a 1-cm diameter plain round bar to create the hole needed for the briquettes. Each molder was also drilled with twelve 0.5-cm (1/4-in.) diameter holes distributed evenly along its circumference. A 0.4-cm (1/8-in.) thick metal plate was inserted at the bottom and this is supported by 4 pieces of 0.8 cm diameter round bar welded to connect this sliding metal plate to another plate where the hydraulic jack

pushes it up during compression. The said sliding plate is responsible for holding the materials for compression.

Figure 18. The second jack-driven briquetting machine developed for UCLA

2. Cover – The cover of the machine held the materials when the hydraulic jack was compressing it up. It was made of a 1.3-cm (1/2-in.) thick metal plate. It was welded with three hinges to allow easy opening of the cover. During operation, it was locked by two bolts welded on the opposite side of the hinges.

3. Hydraulic jack – A 10-ton capacity bottle-type hydraulic jack was utilized for this machine. It was placed under the metal plate that supported the legs of the briquette molder. The jack was supported by a 1.3-cm (1/2-in.) thick metal plate braced by I-bars to withstand the forces created during compression. The metal plate was welded on the four legs of the machine that served as support.

Figure 19. The final design of the hydraulic-jack driven briquetting machine to enhance briquette production

4. Frame – The frame served as the legs and support of the machine. It was constructed from a 4.8 cm by 4.8 cm (1-1/2 in. by 1-1/2 in.) angle bar. The machine was 65 cm high. The cover measured 30 cm by 30 cm while the protruding leg measured 41 cm by 41 cm. It approximately weighed 65 kg.

- ***Pulping Machine***

Another important device needed for briquette production is the pulping machine. This equipment disentangles the waste papers making them homogenous. At times when there was no electrical supply during the field test, production continued even without the use of this machine. The quality of the briquettes was, however, not satisfactory. Voids were created during compression because the particle size of the waste papers was not even. To create better compression and solid product, the use of this equipment was emphasized to UCLA.

The pulping machine as shown in Figure 20 is driven by a 1 Hp capacitor-start single-phase electric motor. The machine was designed to have this size in terms of electric energy consumption so that it would not create heavy electrical load during operation. It can just be plugged to the common size of convenience outlets.

The device operates like a blender where the shredded papers or manually stripped papers are loaded inside the cylinder of the machine. The cylinder is then filled with water just enough to soak the papers loaded inside. The electric motor is turned on until a homogenous mixture is attained. The length of pulping operation depended on the volume of paper loaded inside the machine.

Figure 20. The pulping machine utilized during briquette production

3.3.2 Principle of Operation

The machine produced briquettes through the compressive force delivered by the hydraulic jack. The materials were first prepared separately, after which, they were placed into each of the cylindrical molders until these were totally filled. The molders were then closed and locked by the bolts. The hydraulic jack was pumped. While the materials were being pushed, excess water would come out of the holes of the molders. The metal plate that served as the molder support protected the jack from water drips during operation. The different legs that supported the molders were also responsible in distributing the load from the jack since these legs were also welded on the same metal plate pumped up by the jack. Once the materials had been compressed, the cover was oscillated to open position. Thrusting of the jack was continued until the briquettes were pushed out of the molders. After this, the jack was released forcing the two springs to automatically pull down the molder support back to the jack's normal position. This mode of operation eliminated any activities that would require the user to lift anything making it very easy to operate. The user would only require human power in driving the hydraulic jack. The use of the machine is presented in Figure 21.

Figure 21. Briquetting of wastes showing the placement of mixtures in the molder, compaction of the materials and removal of briquettes produced from the molders

3.3.3 Mixture Preparation

Prior to introducing the recommended mixtures for actual briquette production to UCLA, initial studies were made in finding the most viable mixture for the pressing of briquettes as household fuels (Paul et al., 2009b). Iloilo City, being an urbanized metropolis generates a lot of waste paper. The abundance of these materials generated in the city (Paul et al., 2007; Paul et al., 2009a) has led to its exploration as a potential alternative source of fuel. To maximize the potential of waste paper, the addition of commonly produced biomass wastes in the form of CRH and sawdust were considered as key ingredients in the formulation of mixtures for briquette production.

In summary, three materials were recommended for UCLA's briquette production; namely, paper, sawdust and CRH. During production, waste papers were recovered from the disposal facility and from particular colleges of CPU, whereas, the biomass wastes were derived from nearby rice mills and furniture shops within and outside of Iloilo City. The CRH used in the study was another form of waste that came from the by-products of direct combustion stoves that utilized rice husk as fuel for cooking. This type of stoves cannot totally convert the fuels into ash, only in carbonized form. Likewise, the sawdust utilized was directly obtained from nearby furniture shops that generate much of this waste from primary wood processing operations. Addition of biomass materials to waste papers can expand the maximization of the latter since literatures have already indicated that the heating values of rice husk and sawdust can sustain combustion (Romallosa et al., 2011b; Lee, 2007).

3.4 Briquette Production and Performance Evaluation

Production of briquettes by UCLA was performed in many installations through laboratory and actual field tests using the technologies developed. The process of undergoing field tests is necessary to achieve the improved technology necessary for the production of quality briquettes. New or modified versions of technologies developed were tested first on a laboratory scale at CPU.

All production tests utilized three materials. They were urban wastes in the form of waste paper and biomass wastes like sawdust and CRH. These materials were further processed using the briquetting machine for the following mixing proportions presented in Figure 22: Briquette 1: paper (100%); Briquette 2: paper (50%) +

sawdust (50%); and Briquette 3: paper (50%) + CRH (25%) + sawdust (25%). The dry weight of biomass and urban wastes and their combinations were all fixed to 3000 g. Then each mixture was processed until briquettes were produced. The same method of production was performed in every trial.

Figure 22. The materials used in briquette production, namely from left to right: waste paper, sawdust and carbonized rice husk

In the production of briquettes, all the materials needed were prepared first. The weighed materials were mixed manually in pure form or with add-on materials in a container based on the recommended mixing ratio. Once the mixture was homogenized, the materials were placed in the briquetting machine for compaction.

The briquettes produced were sundried to 20 to 30% moisture content making them ideal for further testing as household fuel when used for boiling water and cooking rice. The summary of the procedure in briquette production is presented in Figure 23. The same process flow was also followed during the actual field production test in Calajunan.

Performance evaluation of briquettes was done in four test runs on a laboratory scale. Boiling of water using the three different types of briquettes and charcoal as fuels were performed simultaneously using a 22-cm diameter concrete stove. During this test, the initial weight of fuel used, number of pieces of briquettes or charcoal consumed as fuel and the total length of operation were recorded and monitored. A 2,000 g or 2 li of water was used for the water boiling test. These tests determined which among the three types of briquettes including charcoal was ideal for boiling operation. After every boiling test, the weight of ash produced was measured. The same procedure was followed for the cooking test using 750 g of rice.

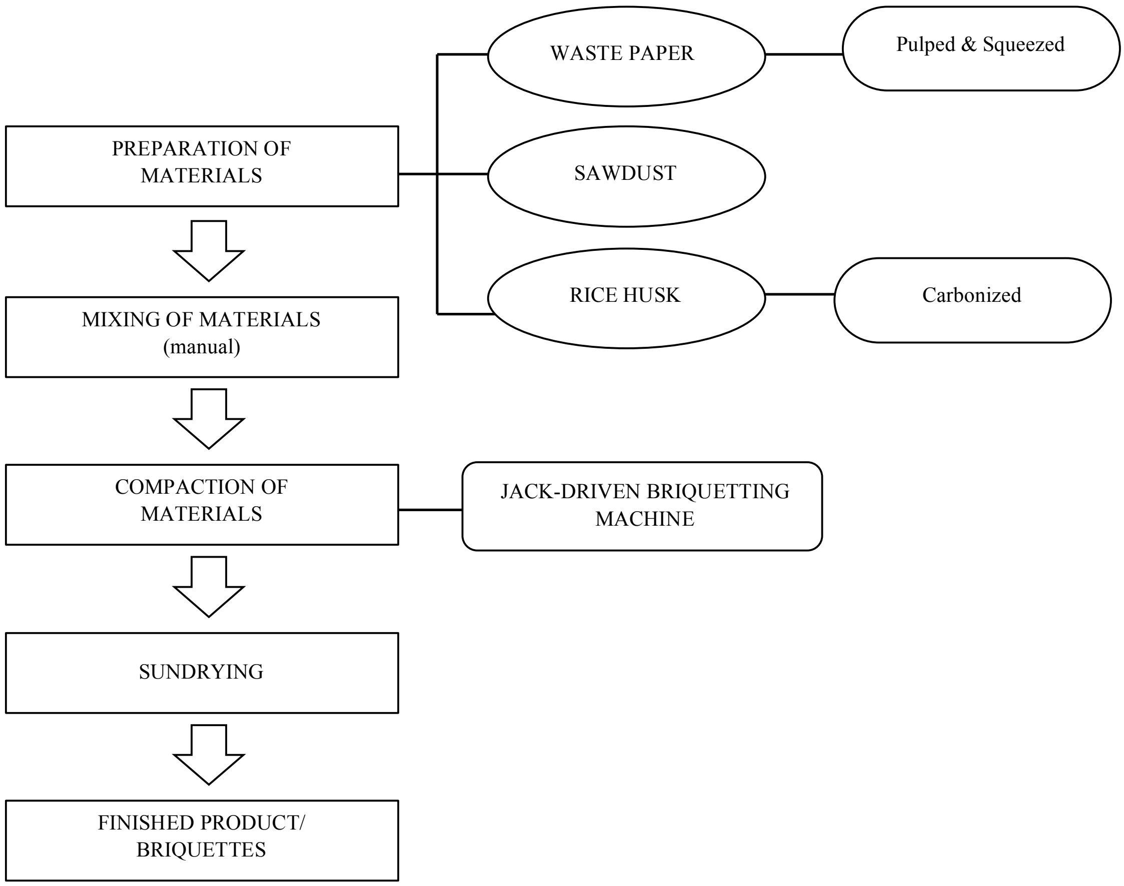

Figure 23. Summary of procedure for the production of briquettes

After the briquettes were sundried, samples were sent to Bauhaus-Universität Weimar (BUW) in Weimar, Germany for further physico-chemical tests. The identification and characterization of chemical and phase composition of a given solid fuel was the initial and most important step during the investigation and application of such fuel (Stanislav et al., 2010).

Verification of the performance of the machine was done through an actual field production test for 15 days (Figure 24). UCLA members who had been trained on briquette production through participation in previous studies or attendance in trainings conducted were commissioned for this test. Field production test was performed to determine the average volume of briquettes they could produce under simulated work conditions with each participant compensated based on the actual number of briquettes produced. The same mixture of materials as in the laboratory test was utilized for this field test.

Figure 24. The actual field production test at UCLA Center and the briquettes produced being dried

The actual field production test was performed at UCLA Center located just 100 m across Iloilo City's disposal facility. The Center has an approximate floor area of 144 m^2 and was made from light construction materials such as plywood for its flooring and nipa shingles for its roofing.

Eight units of the jack-driven briquetting machine were utilized for this test. Two persons working as a team operated each machine. On the other hand, two additional members were assigned for the pulping of waste papers. This set-up where a certain team is assigned to pulping and another one assigned only to briquetting indicates a specialized type of work. This manner is common in work places in order to attain higher production.

Production of briquettes was done in modes that represent different possible types of productivity. These included a team/worker who produced briquettes based on the following rates:

- Paid for every 4 pieces of briquettes produced per day
- Paid on a fixed rate by producing 150 pieces per day with bonus for every 4 additional briquettes formed
- Paid on a fixed rate with no required number of briquettes produced

These three different rates were representative of the three different possible productivities for workers, thus, the total production divided by the number of days and number of participants would indicate the average production rate per person. The first mode represented an output-oriented worker who can increase his income if he can produce more. The second mode represented a worker, who was willing to earn that much, and if he wanted to increase his fixed income, then he can produce more so that he can have a bonus. The third type represented a worker who does not really mind the volume he can produce as long as he is paid a fixed amount of money. The estimation of the fixed rate at 150 pieces per day was based on the average briquettes produced during previous briquetting tests conducted.

In summary, the activities performed by the UCLA members during the actual production tests started at around past 7 in the morning until around 5 in the afternoon. The start and end of production have all been at their pacing. They were observed as to how they organized and put their respective responsibilities in order. The arrangement of equipment and other necessary instruments used during production have also been arranged in a manner that would be safe for them and at the same time at a location that would not disrupt their work activities. Production started from the preparation of materials followed by pulping of paper. As the day progressed, they have become familiar as to the volume of materials they would only prepare, just enough for a whole day production.

The briquettes produced were then evaluated in terms of their performance when used for boiling water and cooking rice. The fuels produced were also subjected for laboratory analyses to determine their chemical properties. This method of evaluating the material characterization of briquettes is necessary in establishing more scientific proofs on the quality of briquettes produced by UCLA.

3.4.1 Instruments and Equipment Used

The following were the instruments and equipment used in this study:

1. Spring-scale balance. The 20-kg Fuji spring-scale balance was used in weighing the materials utilized in the study.

2. Compact scale. This 1-kg Silvano compact scale was used to measure the weight of smaller items/materials such as the individual briquettes produced.

3. Pocket spring balance. The 50-kg metallic pocket spring balance was employed to measure the weight of the hefty equipment such as the different briquetting machines developed.

4. Cooking pots. A 25-cm diameter aluminum cooking pot with approximately 0.1 cm thickness was used for the water boiling test. On the other hand, a 22-cm diameter aluminum cooking pot having a thickness of 0.3 cm was utilized for the cooking rice test.

5. Pail. A 56-cm diameter big pail was utilized for stocking pulped waste papers. The container is 71 cm high.

6. Wash basin. A 60-cm wash basin was also used for stocking pulped waste paper including other materials like sawdust and CRH. Hand mixing of materials for molding was also done in the wash basin. The wash basin has a height of 60 cm, making it ideal for easy mixing.

7. Thermocouple thermometer. An Oakton dual input J, T, E, K thermocouple thermometer was used in monitoring the temperature of the water during the water boiling test.

8. Moisture meter. This Extech instrument was used to monitor and measure qualitatively the range of moisture of the briquettes produced until dried.

9. Steel tape. The Stanley LeverLock steel tape having a maximum length of 5 m/16 in. was used in measuring the dimensions of the jack-driven briquetting machines developed.

10. Vernier caliper. The stainless NSK Vernier caliper has a 200-mm by 0.05-mm specifications. This was used in measuring the dimensions of the briquettes produced.

11. Timer. The digital timer (KK-5853) was used in measuring the length of briquette production time including the time it took for the briquettes to boil water and cook rice until all fuels loaded were converted to ash. It also recorded the timer's lap time to measure specific activities in between the total operating time.

12. Pulping machine. This was used to pulp the waste paper used for briquette production. The machine has a 26-cm diameter by 40-cm high cylinder where pulping operation was performed. It is driven by a 1 Hp capacitor-start single-phase electric motor.

13. Concrete charcoal stove. A 22-cm diameter stove was where the briquettes were placed for boiling water and cooking rice tests.

3.4.2 Data Gathered

The following data were gathered for this study:

1. Total dry weight of materials. This refers to the dry weight of paper, sawdust and CRH that were utilized during the evaluation of the machine at the laboratory and actual test.

2. Pieces of briquettes produced. This refers to the number of briquettes produced per unit weight during the evaluation of the machine. This parameter was needed for rough estimation of the weight of briquettes produced. Knowing the number of briquettes produced per unit weight was also important in determining the briquettes needed for certain cooking applications, since it is easier to estimate the briquettes used by number instead of weight.

3. Pulping time. This represents the time required to produce evenly the disentangled soaked paper in the pulping machine.

4. Mixing time. Refers to the time required to hand mix the pure material or its combination in order to attain a homogenous mixture.

5. Briquetting time. This is the time needed in producing briquettes per type of mixing proportion from the time the mixtures were placed into the molders until they were removed from the machine as molded or briquetted material.

6. Fresh weight of briquettes. Refers to the weight of all briquettes for a particular mixing proportion per briquetting time immediately after production.

7. Dry weight of briquettes. Refers to the weight of briquettes per mixing proportion after the briquettes had been dried for at least 5 days under direct sunlight.

8. Dimensions of the briquettes. Refers to the diameter and thickness of briquettes produced.

9. Start-up time. This represents the time the flame was introduced to the briquette fuel until the briquette started to ignite.

10. Total operating time. This refers to the time required for the briquette to perform the boiling and cooking tests until all the fuel loaded in the stove were utilized and converted to ash.

11. Boiling time. The time needed for the briquettes to boil 2000 g or 2 li of water in the cooking pot.

12. Cooking time. Refers to the time it took the briquettes to cook the 750 g of rice in the cooking pot.

13. Temperature of the water. This refers to the initial and final temperature of water before and after the water boiling tests, respectively.

14. Distribution of respondents according to many parameters. This refers to the data gathered from the respondents through structured interview, informal interviews, FGD and observations. The parameters gathered included whether the respondent is an UCLA member or not; the type of cooking devices and fuels used including their source; familiarity with and production of own briquettes; and their willingness to buy the briquettes if sold in the market.

3.4.3 Parameters Analyzed

1. Production rate. Refers to the number of briquettes produced per hour. This was obtained by counting the number of briquettes produced within the allotted time.

2. Bulk density. Refers to the ratio of the weight of briquettes produced per unit volume. This is an important parameter in briquetting since it influences the transport, handling and storage of fuel (Voicea et al., 2013). The higher the density, the higher is the energy/volume ratio (Demirbas & Sahin, 1998). This was determined by dividing the weight of one briquette with its volume.

3. Quality of briquettes in terms of physico-chemical composition. The physical characteristics of briquettes included their dimensions and shape, bulk density, and heating value. On the other hand, the chemical characteristics included the proximate analysis and ultimate analysis of the briquettes. These were analyzed at Bauhaus-Universität Weimar (BUW) in Germany. Initial tests were done based on the international standards specified under DIN 19747:2009-07 (Investigation of solids – Pretreatment of samples, preparation and processing of samples for chemical, biological and physical tests) for the procedure in sample preparation. Further analyses were done based on different DIN standards. DIN stands for Deutsches Institut für Normung which means German Institute for Standardization.

4. Heating value. Refers to the amount of heat released during the combustion of a specified amount of fuel and considered as one of the most important routine analyses for exploiting agricultural wastes for energy conversion (Huang et al., 2009). The heating value, expressed in the study as high heating value of dry matter (HHV dm), refers to the amount of heat produced by the complete combustion of a unit quantity of fuel. Heating value is the most important properties of a fuel influencing the method of obtaining the thermal energy and compaction plant designing and implicitly of burning (Voicea et al., 2013). A heating value of about 5000 Btu/lb or greater is needed to sustain combustion (Lee, 2007; Yaws, 1999) and the higher its value, the better it is (Speight, 2008). This was analyzed based on DIN 51900-2 (Determining the gross calorific value of solid and liquid fuels using the isoperibol or static-jacket calorimeter, and calculation of net calorific value).

5. *Proximate analysis.* This is a standard compositional analysis conducted for the determination of fixed carbon, volatile matter, ash yield, and moisture. It is used to establish the rank of materials and to show the ratio of combustible to incombustible constituents. This study, however, covered only the ash yield and moisture of the briquettes produced. While the volatile matter (often comprising the moisture) generally accounts for the fraction that evolved by thermal decomposition, the fixed carbon, together with the ash, represents the theoretical solid residue (the char fraction) of a possible pyrolysis/gasification process (Galvagno et al., 2009). Moisture content was determined based on the methods of the German Federal Compost Quality Assurance Organization (Analysis Handbook of the Bundesgütegemeinschaft (BGK) Kompost e.V.).

6. *Ash yield.* This refers to the ratio of ash produced per unit weight of briquettes used in order to boil a specific weight of water. It also refers to the inorganic residue that remain after complete combustion of the feedstock. This is an important characteristic that influences the burning technology, emission of solid particle, and the handling and use of ash (Voicea et al., 2013; Vassilev et al., 2010; Speight, 2008). This was determined based on the methods of the German Federal Compost Quality Assurance Organization (Analysis Handbook of the BGK Kompost e.V.).

7. *Ultimate analysis.* This is considered as one of the most important routine analyses for exploiting agricultural wastes for energy conversion (Huang et al., 2009) and this refers to the standard analysis for determination of Carbon (C), Hydrogen (H), Oxygen (O), Sulfur (S), and Nitrogen (N). These are normally the five organic-forming elements in biomass (Vassilev et al., 2010). The study covered only the determination of H, N and S. Hydrogen was determined based on DIN 51732 (Testing of solid mineral fuels – Determination of total content of carbon, hydrogen and nitrogen – Instrumental methods) while nitrogen was determined based on the

methods of the German Federal Compost Quality Assurance Organization (Analysis Handbook of the BGK Kompost e.V.). The amount of sulfur, on the other hand, was analyzed based on the principles of DIN EN ISO 11885:2009-09 after fusion (Water surface – Determination of selected elements by inductively coupled plasma atomic emission spectrometry (ICP-OES).

3.5 Data Processing and Analysis

The average of all parameters analyzed under the technical aspects were computed using the arithmetic mean. Performance data of the different types of briquetting machine for fuel production using the three types of briquettes were statistically analyzed using the one-way analysis of variance (ANOVA). Significant differences between/among the means were determined using the Duncan's multiple range test (DMRT) to further compute the numerical boundaries that allow the classification of the difference between any two means as significant or non-significant. This was presented using the alphabet notation, *a* being the highest, followed by notations *b*, and *c* being the lowest.

4 RESULTS AND DISCUSSION

The results of the study citing the case of UCLA on how socio-economic and technical aspects were both integrated in the improvement of the technology for briquette production are presented and discussed under this chapter. The first part presents the profile of UCLA as a group of informal waste reclaimers that produces briquettes from the utilization of abundant biomass and urban wastes in the area. The second part presents the results of the enhancement of briquetting technologies for improved product output, its assessment as potential source of income and the exploration of using the technology.

4.1 Socio-Economic Aspects of Briquette Production

This part highlights the baseline of the different profiles of the respondents according to their personal background, household size, monthly income, waste management background, housing conditions, utilities available, and similar information. These records are necessary in answering the second and third objectives of the study.

The succeeding tables present the profile of the interviewed waste reclaimers found at the Calajunan Disposal Facility. Tables 1, 2 and 3 specifically present the respondents' personal background. In terms of their age, majority of the respondents (55.6%) were between 24 to 46 years old. This is followed by the older age group of 47 years old and above at 25.6%. The younger respondents with an age of 23 years old and below follow closely at 18.8%. The mean age of the respondents was 37.52 years old. Almost 60% of the waste workers interviewed were women indicating that gender is not an issue in this kind of source of living. The higher number of women waste reclaimers also showed reduction in gender inequalities in this field of work. It agrees that women, in this case, participate actively in the informal waste sector (Gunsilius et al., 2011). This result does not correspond with the study commissioned by GIZ indicating that 24 to 42% of the informal waste workers are female. In some places, waste pickers and traditional itinerant waste buyers are rather exclusively women, while in other regions men perform these first activities of the value chain, while women work at home sorting or pre-processing the collected wastes (Scheinberg, Simpson & Gupt, 2010 as cited by Gunsilius et al., 2011).

Table 1. Distribution of the respondents according to their personal profile (n=160)

Profile	Frequency	Percent
Age		
23 years old and below	30	18.8
24 – 46 years old	89	55.6
47 years old and above	41	25.6
Total	160	100.0
Mean Age = 37.52 years old		
Residence		
Brgy. Calajunan, Mandurriao, Iloilo City	143	89.4
Brgy. So-oc, Arevalo, Iloilo City	10	6.2
Brgy. Navais, Mandurriao, Iloilo City	2	1.2
Brgy. Pakiad, Oton, Iloilo	4	2.5
Brgy. San Isidro, Jaro, Iloilo City	1	0.6
Total	160	100.0
Gender		
Female	95	59.4
Male	65	40.6
Total	160	100.0

Most of the waste reclaimers interviewed were mainly residing in Brgy. Calajunan, Mandurriao, Iloilo City (89.4%) where the controlled facility is also located. Others reside in nearby areas that are located 3 to 6 km away from the facility. Ten of them (6.2%) reside in Brgy. So-oc, Arevalo, Iloilo City; 4 (2.5%) are from Brgy. Pakiad, Oton, Iloilo; another 2 (1.2%) live in Brgy. Navais, Mandurriao, Iloilo City. The other one or 0.6% resides in Brgy. Isidro located in Jaro district of Iloilo City.

Data in Table 2 reveal that the respondents found at the facility were mostly married (73.8%) with more than 50% having only 3 or below number of children. There were respondents having 4 to 6 children (23.1%) while 18.1% claimed to have

7 or more children. The mean number of children is 3.7. Almost 50% of the respondents has a household size of 5 and below followed closely by those having 6 to 10 household size (40.6%). Ten percent (10%) of the respondents live in a house having more than 10 members.

Table 2. Distribution of the respondents according to their civil status, number of children and household size (n=160)

Profile	Frequency	Percent
Civil Status		
Single	24	15.0
Married	118	73.8
Widow/widowed	3	1.9
Living together	15	9.4
Total	160	100.0
Number of Children		
3 and below	90	56.2
4 to 6 children	37	23.1
7 and above	29	18.1
No answer	4	2.5
Total		
Mean Number of Children = 3.71	160	100.0
Household Size		
5 and below	77	48.1
6 to 10	65	40.6
11 and above	16	10.0
No answer	2	1.2
Total	160	100.0

In terms of their highest educational attainment, almost the same percentage (27%) were elementary and high school undergraduates; although there were 11 waste reclaimers who were able to finish college (6.9%). They found waste reclaiming a momentary source of income while still looking for real jobs. From their educational attainment, only 38.8% are earning above Php151 per day (approximately USD3.43) followed by 33.1% of the respondents earning below Php100 per day (USD2.27). The rest were earning around Php101 to Php150 per day (USD2.30 – USD3.41). Based on the data shown in Table 3, their earnings at the facility were not extremely different from each other.

Table 3. Distribution of the respondents according to their highest educational attainment and monthly income (n=160)

Profile	Frequency	Percent
Highest Educational Attainment		
Elementary undergraduate	44	27.5
Elementary graduate	24	15.0
High school undergraduate	40	25.0
High school graduate	29	18.1
College undergraduate	12	7.5
College graduate	11	16.9
Total	160	100.0
Daily Income		
Php100 and below	53	33.1
Php101 – Php150	43	26.9
Php151 and above	62	38.8
No answer	2	1.2
Total	160	100.0

Presented in Table 4 is the distribution of respondents according to their waste management or waste picking background. Sixty-nine percent (69%) of the respondents were members of UCLA, while the remaining 30.6% were waste reclaimers who did not signify official membership with the group or were walk-in pickers in the area. Out of the 111 respondents who were members of UCLA, nearly half (44.4%) of them indicated involvement with the group for 3 years and below. Although UCLA was officially incorporated with SEC in May 2009, those who have indicated more than 6 years (21.9%) may have meant commitment by associating themselves with fellow members whom they have been working with at the dumpsite. In terms of level of involvement with UCLA, 59.4% claimed active membership. Active membership based on informal interviews with them means involving their selves with UCLA by attending regular or special meetings called, participating in trainings/seminars conducted, or paying their annual dues.

Table 4. Distribution of the respondents according to their waste management/waste picking background (n=160)

Profile	Frequency	Percent
UCLA Membership		
Yes	111	69.4
No	49	30.6
Number of Years with UCLA		
3 years and below	22	44.4
4 to 6 years	54	33.8
7 to 10 years	32	20.0
11 years and above	3	1.9
Total	111	100.0
Level of Involvement with UCLA		
No answer	49	30.6
Officer	7	4.4
Organizer	2	1.2
Active Member	95	59.4
Others	7	4.4
Total	160	100.0
Years of Waste Picking in Calajunan		
No answer	17	10.6
5 years and below	29	18.1
6 to 10 years	38	23.8
11 to 15 years	28	17.5
16 years and above	48	30.0
Total	160	100.0
Mean Number of Years = 15		
Number of Household Members Working in Calajunan		
No answer	41	25.6
1 person only	48	30.0
2 persons	26	16.2
3 persons	8	5.0
4 persons	5	3.1
5 persons	5	3.1
8 persons	3	1.9
Total	160	100.0

Other involvement includes being an officer or organizer (5.6%) of their association. The 49 respondents who indicated no involvement were the same respondents who specified no membership to UCLA. There were respondents though who were not sure (4.4%) of their own involvement; yet, they identified themselves with the group. More than 30% of the respondents have been waste picking in Calajunan for 16 years and above. Twenty-four percent (24%) have been doing it for 6 to 10 years followed closely by those doing them for 5 years and below (18.1%) and by those for 11 to 15 years. It can be noted that the then Calajunan dumpsite, now a controlled facility, has been existing for more than 20 years already.

More than half (56.9%) of the waste reclaimers as seen in Table 5 live in a small house having a 50 m^2 or below floor area. Thirty-eight percent (38%) of the respondents were able to build their house on a bigger floor area of 61 m^2 or more. Almost 94% of the respondents own the house they are living in. Some 4.4% reside in a government-owned house. The three other respondents reside either on a rented house, family-owned house or lives there as a caretaker. Seventy-two percent (72%) classified the condition of their place of residence as reasonably built while 22.5% live on a dilapidated or unstable house due to the way their house was constructed. Others (5.6%) were not able to identify the physical condition of their homes. The materials used as walls for their house were mostly made of bamboo (56.2%). Bamboo is a cheap alternative in constructing houses in the Philippines, yet, when properly constructed, could provide a decent home for households. Other respondents have wood (plywood) for their walls (16.2%). Around 13 to 14% utilized concrete or a combination of concrete and wood for the walls of their homes. It can also be noted that majority (57.5%) of the respondents live in a single room or studio-type home. They are followed by those whose house have 2 bedrooms (24.4%). About 14% have at least one bedroom while 4.4% have a house that can have or accommodate 4 bedrooms. A high majority (74.4%) of the homes of the waste reclaimers have a toilet with 45% of these located inside their respective houses. There were 47 respondents (29.4%) who indicated that their toilet is located just outside their home. Out of the 160 respondents, 41 or 25.6% reported that they no toilet. When asked about the details on this concern, others mentioned that they were sharing the use of the toilet with their neighbors or others were using the pit every time they defecate. The results

Table 5. Distribution of the respondents based on their housing conditions (n=160)

Profile	Frequency	Percent
Floor Area of House		
50 m^2 and below	91	56.9
51 – 60 m^2	8	5.0
61 m^2 and above	61	38.1
Total	160	100.0
Ownership of the House		
Owned	150	93.8
Rented	1	0.6
Government	7	4.4
Family-owned house	1	0.6
Caretaker	1	0.6
Total	160	100.0
Housing Condition		
Reasonably built	115	71.9
Dilapidated	36	22.5
Others	9	5.6
Total	160	100.0
Materials Used as Walls for the House		
Concrete	21	13.1
Concrete and wood	23	14.4
Wood	26	16.2
Bamboo	90	56.2
Total	160	100.0
Number of Room/Bedroom		
1 room only	92	57.5
1 bedroom	22	13.8
2 bedrooms	39	24.4
4 bedrooms	7	4.4
Total	160	100.0
Availability of Toilet		
Yes	119	74.4
No	41	25.6
Total	160	100.00
Location of Toilet		
Inside the house	72	45.0
Outside the house	47	29.4
No answer	41	25.6
Total	160	100.0

indicate that majority or more than half of the respondents own a reasonably built bamboo-made 1-bedroom house with toilet located inside their house.

It can be observed that the quality of life of the waste reclaimers is not that miserable due to the availability of and access to two important utilities, namely, electricity and water. Ninety percent (90%) of the respondents have available electricity in their homes while nearly the same figure (88.8%) have also an available water source. Water for their household use mainly comes from the installed individual or communal water pump (75%). Others derive their water from their neighbor (11.9%) while a minimal 1.9% can afford to be connected to the Water District. The 11.2% who gave no answer were getting their water from a deep well or from their neighbors. These data are all presented in Table 6.

Table 6. Distribution of the respondents according to utilities available (n=160)

Profile	Frequency	Percent
Availability of Electricity		
Yes	144	90.0
No	16	10.0
Total	160	100.0
Availability of Water Source		
Yes	142	88.8
No	18	11.2
Total	160	100.0
Water for Household Use		
Water District	3	1.9
Water pump	120	75.0
From the neighbor	19	11.9
No answer	18	11.2
Total	160	100.0

Prior to the introduction of briquetting technologies in Calajunan, some waste workers were already utilizing their hand-made briquettes (2.5%) as fuel for cooking. According to them, they use briquettes as substitute for charcoal. The use of charcoal stoves (72.5%) was ranked as the most common cooking device for majority of the waste reclaimers. The other commonly used device was wood stove as claimed by

58.7% of the respondents. Liquefied petroleum gas (LPG) stove, steel bars and the most primitive, which are the improvised stoves using stones were each used by 10% of the waste reclaimers. Apart from briquettes, which were utilized only by 4 respondents (2.5%), wood and charcoal were listed as the commonly used type of fuel for cooking by 86.8% and 68.7% of the respondents, respectively. In addition, LPG and rice husk were also utilized as other types of fuel. The dumpsite itself served as the main source of fuel by the majority (76.2%). The fuels that they found from that area included, among others, wood or any woody material and waste papers (corrugated paper, newspapers). Charcoal and LPG were mostly bought (52.5%) while rice husk and other wood fuels were obtained from nearby places (14.4%). When they were asked of the daily expenditure on fuel use, 30% said Php10 or below (USD0.23 and below) was being spent. This was followed closely by respondents (28.1%) spending about Php11 to Php20 (USD0.25 to USD0.45) and by those (25.5%) paying Php21 to Php40 (USD0.48 to USD0.91) for their fuel. Those who indicated spending Php41 (USD0.93) and above (11.2%) were found to be using the LPG as well. The introduction or access of households to regular supply of briquettes in the area would mean big reduction on the high dependence for wood and charcoal fuels. These data are presented in Table 7.

4.2 Technical Aspects of Briquette Production

The results of the technical aspect of the study shows how the products were enhanced through the improvement of the technology. The improved briquettes produced were then subjected for quality analysis.

4.2.1 Product Enhancement

The three types of briquettes produced using the three different briquetting machines are summarized in Figure 25 and Table 8. These briquetting machines were identified as HP for the hand-press briquetting machine, followed by JD4x4OD that pertains to the old or preliminary design for the jack-driven type with 4 by 4 (16 all in all) molders, and the final design (JD4x4FD) after the integration of the socio-economic and technical aspects. As seen in the figure and table, the briquettes produced varied in colors and shapes. Each machine was presented to have three different types of briquettes which represent the three types of mixing ratio used. In

Table 7. Distribution of the respondents according to their kitchen/cooking devices (multiple response)

Profile	Frequency	Percent
Cooking Device Used		
LPG stove	13	8.1
Wood stove	94	58.7
Steel bars	9	5.6
Stone	14	8.8
Charcoal stove	166	72.5
Type of Fuel Used		
LPG	13	8.1
Wood	139	86.8
Charcoal	110	68.7
Rice husk	2	1.2
Briquettes	4	2.5
Source of Fuel		
Bought	84	52.5
Dumpsite	122	76.2
Nearby places	23	14.4
Estimated Daily Expenses for Fuel Use		
Php10 and below *(USD0.23 and below)*	48	30.0
Php11 – Php20 *(USD0.25 – USD0.45)*	45	28.1
Php21 – Php40 *(USD0.48 – USD0.91)*	41	25.6
Php41 and above *(USD0.93 and above)*	18	11.2
No answer	8	5.0

USD1 = Php44

Figure 25. Briquettes produced using the three types of briquetting machine developed

Table 8. Physical characteristics of the briquettes produced

Parameters Measured	Types of Briquetting Machine		
	Hand-Press	Jack-Driven, 4x4, old	Jack-Drive, 4x4, final
Shape	Pillow-shape	Cylindrical with hole	Cylindrical with hole
Length, cm (≈)	4.83	-	-
Width, cm (≈)	5.13	-	-
Thickness, cm (≈)	4.20	3.10	1.95
Diameter, cm (≈)	-	5.43	5.46
Weight per Briquette, g	14	27	19
Volume per Briquette, cm^3	82.56	45.62	43.47

terms of briquette color, the three machines had similarities. The briquettes in the first column appeared mostly white because the waste papers were the only components of this fuel. On the other hand, the briquettes found on the second column for all machine type had light brown color with traces of white spots. This was due to the presence of waste paper and sawdust. The briquettes found in the third column represented the mixture of paper, sawdust and CRH. The presence of CRH in the mixture resulted in black being the dominant color of the fuels with specks of white and light brown. The isometric view of the briquettes can also be viewed from the figure where the difference in the thickness of the materials can be visually seen. The initial pillow-shaped fuels show a rectangular appearance when viewed from the top; these have an average length and width of 4.83 cm and 5.13 cm, respectively. When viewed on the side, the fuel curvedly protruded to an average thickness of 4.20 cm. On the other hand, the briquettes produced using the improved version of the briquetting machine with the aid of a hydraulic jack is cylindrical with a hole at the middle. The old version of the jack-driven 4x4 machine produced a slightly thicker material at 3.10 cm compared to the 1.95 cm produced by the final version. The difference in thickness was attributed to the improved efficiency of the final machine as a result of the proper alignment of the jack. This led to less friction during compression, thereby, maximizing the compressive power created during the maneuver of the 10-ton hydraulic jack. In terms of the diameter of the briquettes, the two jack-driven machines produced almost the same value at 5.43 and 5.46 cm, respectively.

Data in Table 8 also indicates that JD4x4OD produced, on the average, heavier briquettes at 27 g while the hand-pressed briquettes had the highest volume at 82.56 cm^3. The high volume was due to the fixed dimensions of the molders, unlike in the jack-driven machine, where the thickness varied depending on the amount of materials inputted and the compressive power of the jack as propelled by the operator. The values for the weight and volume per briquette are necessary data for the computation of the bulk density of the fuels.

The succeeding tables presented data on the operating performance of the three machines showing improvement from the manner it was compressed to the number of molders fabricated.

Each table highlights the results of the different molders developed alongside the three types of briquettes produced with their arithmetic means used in determining whether there was significant difference on the parameter measured or not. When the three machines were compared as to their production rate expressed in terms of the number of briquettes produced in an hour (Table 9), the mean production rate of the final design of the 4x4 jack-driven briquetting machine produced significantly ($P<0.05$) the highest at 220 pcs/hr. The production rates of the hand-press and that of the old design of the jack-driven machine were found to have no significant differences ($P>0.05$). In spite the fact that the old version can produce 16 briquettes at once while the hand-press can produce only 5 briquettes, the two were statistically similar because the former requires more effort and maneuverability due to the misaligned parts of the machine and the difficulty of removing the compressed fuels. These led to the interruption of its supposed non-stop operation. The final unit, on the other hand, was designed to integrate all the issues observed during its operation and field-testing by selected UCLA members. The moving parts had been properly aligned. The mode of removal of compressed briquettes was also redesigned to be a continuation of pumping of the briquettes until the fuels are pushed out at the top. The attachment of spring on each side allowed easy pull of the molders for another set of compression leading to more production of briquettes.

The results presented in Table 9 clearly show that the final design for the 4x4 jack-driven machine has significantly improved the rate of production in terms of the number of briquettes produced. The high rate of production of the final design is significant for UCLA especially because the association has plans of selling the briquettes per piece.

Table 9. Production rate of the briquetting machines designed for improvement in pcs/hr

Types of Briquetting Machine	Production Rate, pcs/hr			Mean (Machine)
	P	P + SD	P + SD + CRH	
Hand-Press	150	185	147	161 [b]
Jack-Driven, 4x4, old	172	206	177	185 [b]
Jack-Driven, 4x4, final	222	207	232	220 [a]

cv = 8.47%

[abc] Any two means on the parameter measured (in a column) followed by the same letter superscript are not significantly different at the 1% level of probability

When production rate was measured in terms of weight of briquettes produced per hour, results in Table 10 revealed that the old version of the jack-driven machine had statistically the highest ($P<0.01$) mean production rate value of 4.59 kg of briquettes per hour of operation followed by the final design of the jack-driven at 4 kg/hr and that of the hand-press at 2.17 kg/hr. The heavier briquettes produced in the older design was the thicker compressed briquettes formed. It can be noted that the net height of the molding cylinder for this unit is 4.5 cm while that of the final version is only 2 cm, thereby, producing a compressed fuel having an average thickness of 1.95 cm only. Although the hand-press briquette molder produced the thickest briquette (as can be viewed in Table 8), it cannot compete with the high compressibility of the jack-driven machines including the 11-briquette difference in the number of fuels produced in one press. The results under this parameter testify once again the improvement of the final technology in producing briquettes measured in terms of weight per hour production.

Figure 26 shows the graphical presentation of the production rate of the three briquetting machines developed. Each bar graph represents the hand-press (HP), jack-driven (4x4 old) or JD4x4OD and jack-driven (4x4 final) or JD4x4FD machines. The combination of a hydraulic-jack in the design and the increase in the number of cylindrical molders had clearly shown a significant increasing trend ($P<0.01$) in the production rate whether expressed in pcs/hr or in kg/hr. The improvement of the briquetting technology from a hand-press design to the addition of a hydraulic jack in its system has clearly improved production rate both expressed in pcs/hr and kg/hr of briquettes.

Table 10. Production rate of the briquetting machines designed for improvement in kg/hr

Types of Briquetting Machine	Production Rate, kg/hr			Mean (Machine)
	P	P + SD	P + SD + CRH	
Hand-Press	1.92	2.28	2.31	2.17 [c]
Jack-Driven, 4x4, old	4.29	4.90	4.58	4.59 [a]
Jack-Driven, 4x4, final	3.35	4.11	4.55	4.00 [b]

cv = 8.07%

[abc] Any two means on the parameter measured (in a row) followed by the same letter superscript are not significantly different at the 1% level of probability

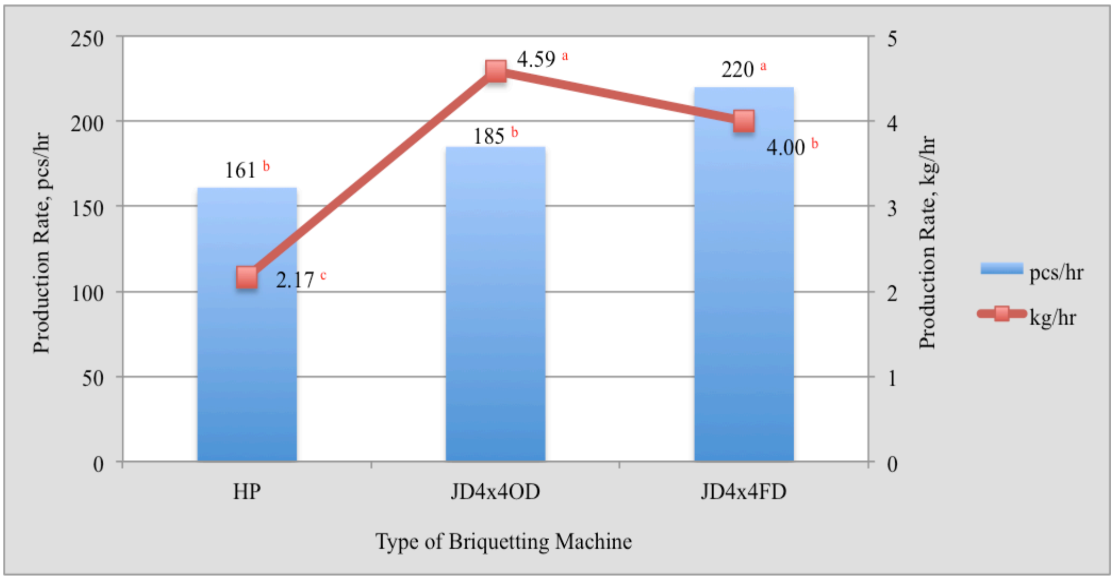

Figure 26. Graphical presentation of the production rate of the different briquetting machines developed

The quality of briquettes produced by the three machines when analyzed for their potential as fuel in boiling water and cooking rice are presented in Tables 11 and 12. These parameters are necessary in establishing the enhanced quality of briquettes when used as fuel for cooking operations. Data in Table 11 shows the results of the operating performance of the briquettes in terms of boiling 2,000 g (2 li) of water while that for Table 12 presents the results in cooking 750 g of rice. All tests for these parameters were done using the same size of the typical charcoal stove used by a typical household in the Philippines. The number of pieces of fuel used for each test was based on how much fuel the stove can contain in a single loading. On the average, 12 to 20 briquettes were used in order to perform the heat-related tasks. Results revealed a no significant difference (P>0.05) among the three machines according to their performance in boiling water. All the briquettes produced by the three briquetting machines performed just the same. No improvements were recorded because the briquettes produced, whether pillow-shaped or cylindrical, can boil 2 li of water at almost the same time (13 to 15 min).

Table 11. Operating performance of the briquettes produced in boiling water using the briquetting machines designed for improvement

Types of Briquetting Machine	Boiling Time, min			Mean (Machine)
	P	P + SD	P + SD + CRH	
Hand-Press	13.35	12.59	15.61	13.85 ^{ns}
Jack-Driven, 4x4, old	11.94	13.01	19.39	14.78
Jack-Driven, 4x4, final	12.47	12.53	16.55	13.85

cv = 6.50%

^{ns} Not significant

The briquettes were also tested for cooking 750 g of rice, an amount ideal for feeding 4 members of a usual household in the Philippines. Results presented in Table 12 show that the final design for the jack-driven and the hand-press machine significantly (P<0.01) attained the fastest cooking time (19 to 22 min). The cooking time for the old design of the jack-driven machine was the slowest at 28.23 min. This test indicated that enhancement was attained using the final design of the jack-driven machine.

It was observed during the boiling and cooking operations that the use of cylindrical briquettes with central hole emitted less smoke than the pillow-shaped briquettes produced by the previously developed hand-press molder. This result is supported by the findings and observations of Grover, Mishra & Clancy (1994).

Table 12. Operating performance of the briquettes produced in cooking rice using the briquetting machines designed for improvement

Types of Briquetting Machine	Cooking Time, min			Mean (Machine)
	P	P + SD	P + SD + CRH	
Hand-Press	17.33	18.37	22.67	19.46 [a]
Jack-Driven, 4x4, old	27.42	24.79	32.47	28.23 [b]
Jack-Driven, 4x4, final	19.87	22.55	22.47	21.63 [a]

cv = 6.21%

[abc] Any two means on the parameter measured (in a column) followed by the same letter superscript are not significantly different at the 1% level of probability

The old design of the jack-driven machine produced briquettes with significantly ($P<0.01$) the highest bulk density at 599.95 kg/m^3 followed by the improved jack-driven version at 444.83 kg/m^3. The hand-press briquetting machine clearly resulted in a low quality fuel as indicated by significantly the lowest bulk density of only 133.78 kg/m^3.

The results of the jack-driven machines paralleled to other briquetting technologies developed from other places that use the piston press creating very high pressure during operation (Beaverton Rotary Foundation, 2013; Grover, Mishra & Clancy, 1994). The high bulk density of the materials when compared to the hand-press technology was primarily due to the addition of a hydraulic-jack press that led to the increase in the pressure when molding the materials. The use of the hydraulic jack has improved the bulk density of the fuels by approximately 400%. It can be noted that the density of the briquettes increased with increasing pressure leading to improved quality of briquettes (Chin & Siddiqui, 2000; Singh & Kashap, 1985). This parameter is important in briquetting because the higher the density of the fuels, the higher is its energy/volume ratio. Briquettes with high-density makes them desirable during transport, storage and handling (Bhattacharya et al., 1990). The mean bulk density of briquettes produced using the old design of the jack-driven machine was significantly higher ($P<0.01$) compared to that of the new design since the thickness produced by the former was also thicker; hence, the briquette weight was also higher (Table 8). In addition, the higher density observed in the pure paper briquettes may be due to its homogenous nature, which may have enabled the material to form a stronger bond, resulting in denser and more stable briquettes (Olorunnisola, 2007).

The bulk densities of the briquettes (Table 13) produced using the jack-driven machines were numerically close with the results of the studies of Stolarski et al. (2013) and Demirbas and Sahin (1998) which produced fuels made from agricultural, forest origin biomass; and waste paper using a horizontal crank-and-piston briquetting press (bulk density ranged from 469 to 542 kg/m^3) and Shimadzu hydraulic press (bulk density reported to be 0.32 g/cm^3 or 320 kg/m^3). The comparisons are clearly illustrated in Figure 27.

Table 13. Bulk density of briquettes produced using the briquetting machines designed for improvement

Types of Briquetting Machine	Bulk Density, kg/m^3			Mean (Machine)
	P	P + SD	P + SD + CRH	
Hand-Press	100.82	100.45	200.07	133.78 ^{c}
Jack-Driven, 4x4, old	689.91	539.93	570.00	599.95 ^{a}
Jack-Driven, 4x4, final	485.41	390.06	459.01	444.83 ^{b}

cv = 4.16%

^{abc} Any two means on the parameter measured (in a column) followed by the same letter superscript are not significantly different at the 1% level of probability

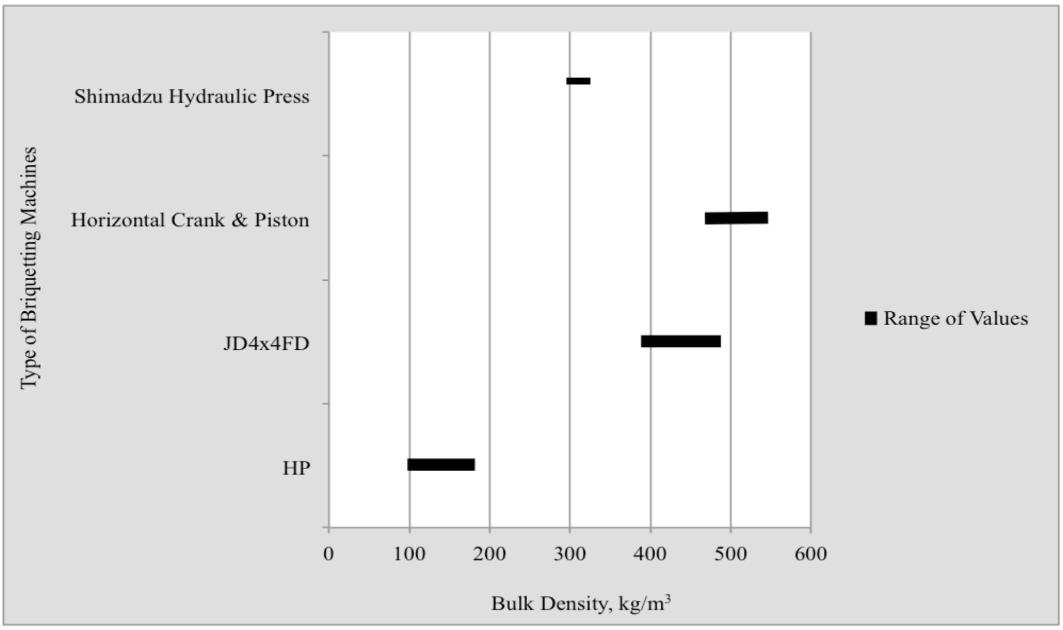

Figure 27. Ranges of bulk densities of the different briquette molders developed

The results of the different technologies developed as presented in the previous tables indicate that enhancement of briquette production through development of an appropriate technology that would produce quality briquettes was attained. These enhancements address the first objective of this study that is to produce more quality briquettes through development of an appropriate technology. The improvements are highlighted in Figure 28. The arrow in the figure indicates the enhancement of the technology. The first briquetting technology developed was a hand-press version wherein the compactness of the pillow-shaped briquettes produced is dependent on human power. The rate of production is very low since it can only produce five pieces in a single press. To improve the compactness and combustion characteristics of the briquettes, a jack-driven machine was developed and field tested by the UCLA members. The machine was able to produce cylindrical briquettes with a hole, thus, improving its combustion characteristics. Higher production rate was attained since 16 briquettes can be made in single press. The compactness of the fuels clearly indicated an improved bulk density leading to better fuel cooking quality. The old jack-driven machine, however, was difficult and complicated to operate. The placement of the jack above the molders limited the compressing power of the hydraulic device. Drips during compression were difficult to manage including the misalignment of the entire molder frame. These constraints led to the development of the final jack-driven machine addressing concerns found in the previous designs yet maintaining or even improving parameters that have been amended.

Continuous integration of both the socio-economic (includes acceptance and ease of use of the machine) and technical aspects (machine performance and product quality) was made from the first hand-press device until the final design for the improved appropriate technology was created leading to its fabrication (Figure 29). The performance of the machine in terms of production rate, combustion characteristics due to creation of central hole in the briquette and bulk density was documented to have enhanced. This was seen every time a new and improved technology is fabricated and after consolidating in the design the stakeholders' observations and recommendations after they were being field tested and utilized. Specifically, the final design of the 4x4 jack-driven briquetting machine was improved best in terms of production rate, and cooking time and bulk density of briquettes.

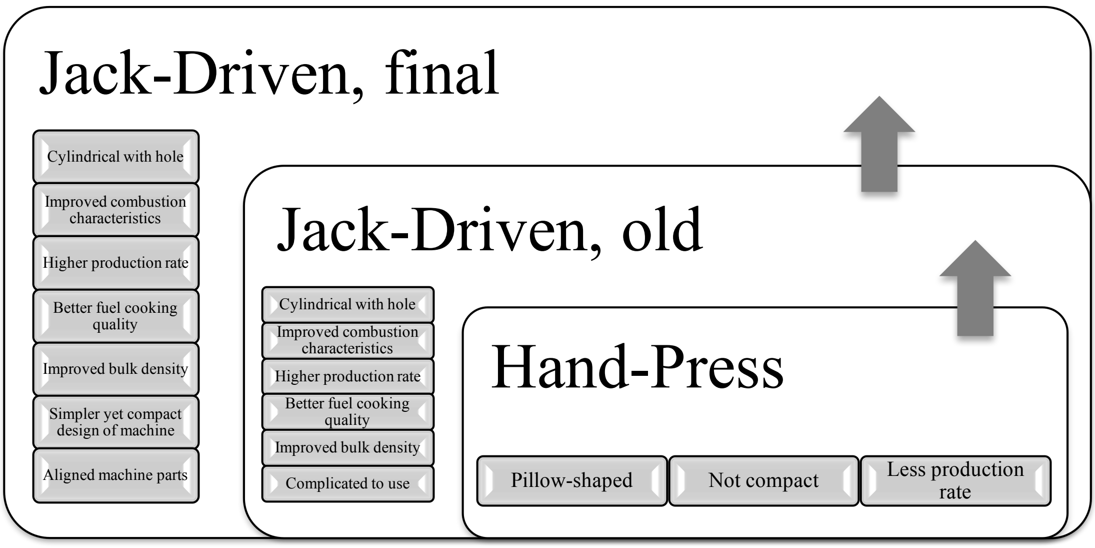

Figure 28. Summary of enhancements on the briquetting technologies developed leading to the final design

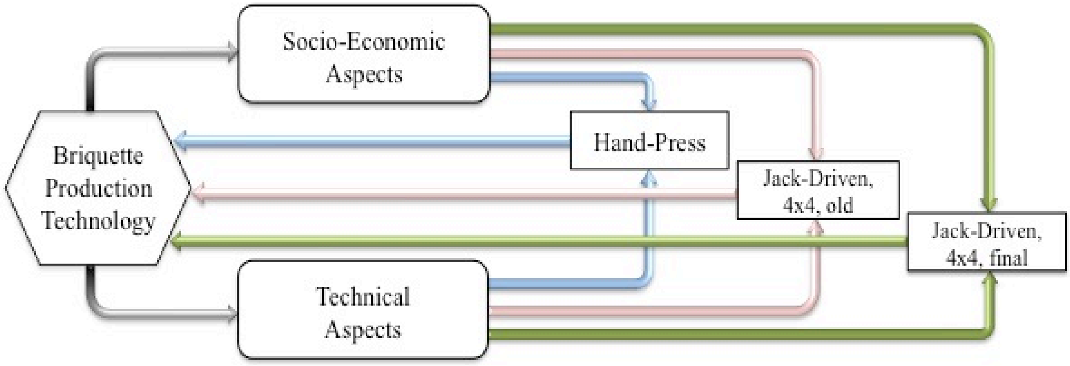

Figure 29. Integration of the socio-economic and technical aspects on briquette production leading to the improvement of the technology

4.2.2 Briquette Quality Using the Enhanced Technology

The subsequent results presented in the tables are the quality of the three types of briquette products formed using the improved jack-driven briquetting technology.

Heating value is a major quality index for fuels (Demirbas & Sahin, 1998). Fuels such as briquettes need a heating value of about 11.66 MJ/kg (5,000 Btu/lb) for it to be able to sustain combustion (Lee, 2007; Yaws, 1999). The heating values and proximate analyses of the briquettes produced using the improved technology are presented in Table 14. The waste paper mixed with sawdust briquettes numerically obtained the highest heating value at 16.68 MJ/kg (7,153 Btu/lb). The pure paper briquettes obtained 15.01 MJ/kg (6,439 Btu/lb) while that of paper mixed with sawdust and CRH was 13.69 MJ/kg (5,872 Btu/lb). All three recommended mixtures using the final design of the briquetting machine resulted in fuels that can sustain combustion (Lee, 2007; Yaws, 1999) making them ideal and feasible fuels for cooking and other heat-related applications. The calorific power or heating value of the material is influenced by the species and the moisture content (Voicea et al., 2013). The results of the physico-chemical analyses of this study, however, did not confirm that a lower moisture content may lead to higher heating value; the heating value of the briquettes was rather influenced more by the materials used especially sawdust since it has itself a higher heating value compared to pure paper and rice husk (Chin & Siddiqui, 2000; from http://www.igniss.pl/en/calorific_value_of_waste.php). When the heating value of the briquettes were compared to that of the German standards (DIN 51731) for compressed natural wood briquettes at 16.90 MJ/kg

(7,248 Btu/lb), results revealed that the paper and sawdust combination (P + SD) had the closest numerical value (16.68 MJ/kg; 7,153 Btu/lb).

Table 14. Heating value and proximate analyses of the briquettes produced using the improved briquetting technology

Parameters Measured	Type of Briquette			Mean
	P	P + SD	P + SD + CRH	
Heating Value, MJ/kg	15.01	16.68	13.69	15.13
Ash Yield, % dm	21.0	14.6	31.0	22.2
Moisture, %	5.6	7.1	5.8	6.2

The highest heating value measured from Briquette 2 compares fairly when associated with other fuels produced from other studies (Table 15). Cooking fuels like sawdust and bio-coal briquette, firewood and charcoal have heating values ranging from 18.65 to 27.98 MJ/kg (8,000 to 12,000 Btu/lb) while that of bituminous coal, a commonly used fuel in industries, ranges from 24.48 to 36.14 MJ/kg (10,500 to 15,500 Btu/lb) (from http://www.ket.org/Trips/Coal/AGSMM/agsmmtypes.html). The average value of the briquettes produced, likewise, was around 15.16 MJ/kg (6,500 Btu/lb). This indicates that this low-cost technology can create or form fuel briquettes that can closely meet the standards set for products that are mostly manufactured by companies using high technologies.

The proximate analyses of the briquettes covered in this study included the ash yield (percentage of dry matter, % dm) and moisture. Ash yield is the inorganic oxides that remain after complete combustion of materials (Speight, 2008). Results show that the third briquette (P+SD+CRH) had the highest ash content at 31.0% followed by Briquette 1 (P) at 21.0%. Briquette 2, which is a mixture of paper and sawdust, contained the lowest amount of ash at 14.6%. The higher ash yield for Briquette 3 is due to the presence of agricultural biomass like CRH, which contains higher ash yields, and thus, has much more ash-forming elements than most of forestry biomass like paper and sawdust (Stolarski et al., 2013; Vassilev et al., 2010). Rice husks when burned as fuel result in the oxidation of the carbonized ash to yield white ash that consists predominantly of silica (Ahmad Fuad et al., 1998); a major inorganic component of rice husk, which is about 20 to 30% of its weight (Saceda et al., 2011). This parameter is an important characteristic influencing the burning technology, emission of solid particle, and the handling and use of ash (Voicea et al., 2013). The ash yields of the briquettes produced were also found to have similar values as those of commonly used fuels in a household or in an industry (Table 15).

The moisture of the briquettes produced ranged from 5.6 to 7.1% of its dry matter (dm) weight. The use of a hydraulic jack in the compression of the briquettes and the presence of many holes at the side of the molders (Stanley, 2003) were instrumental in squeezing out excess water thereby decreasing the moisture content by almost 4% (Romallosa & Hornada, 2011). The moisture of the briquettes recorded also met the DIN 51731 standards that require fuels to have a moisture of less than 12%. The average moisture of the briquettes produced was numerically lower than most of the other fuel materials presented in Table 15. This indicates that the use of the hydraulic jack integrated to a properly designed briquette molder can evidently squeeze out excess moisture in the mixture.

Table 15. Results of the heating value and proximate analyses of various raw materials from other studies

Material	Parameters Measured from other Studies					Source
	Heating Value MJ/kg	Ash Yield % dm	Moisture %	Volatile Matter % dm	Fixed Carbon % dm	
Charcoal	28.35	11.3	14.9	-	-	Author
Firewood	26.84	3.70	NR	NR	30.65	ERDB, 2001
RDF	NR	26.1	4.2	73.4	0.5	Vassilev et al., 2010
Mixed waste paper	NR	8.3	8.8	84.2	7.5	Vassilev et al., 2010
Coal	20.64	18.27	7.64	43.44	NR	Onuegbu et al., 2011
Bio-coal briquette	19.00	17.96	7.42	NR	64.93	Onuegbu et al., 2011
Sawdust briquette	19.52	0.40	8.17	78.84	NR	Stolarski et al., 2013

NR = not reported

When the proximate analyses of the briquettes expressed in moisture (%) were graphically presented (Figure 30) against the respective bulk densities of the materials, the trend shows that the higher the bulk density of the fuel, the lower is its moisture. This is attributed to the compressive strength created with the use of a jack forcing out most of the moisture present in the briquettes during the molding process.

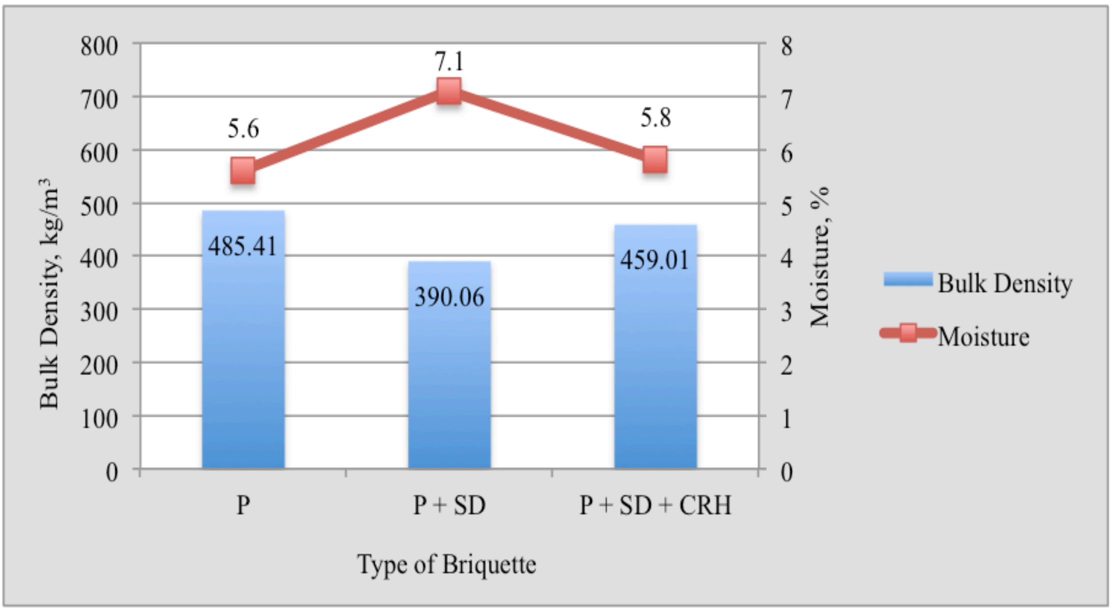

Figure 30. Graphical comparison of the bulk density and moisture of the briquettes produced using the improved briquetting technology

The ultimate analysis of a material covered the organic elements in biomass (Vassilev et al., 2010) and this includes hydrogen (H), nitrogen (N) and sulfur (S). The content of H in the three briquettes produced ranged from 4.8 to 5.9% with Briquette 2 (P+SD) having the highest value (Table 16). Voicea et al. (2013) mentioned that H is an important characteristic that influences the calorific power and the value should be high; hence, the higher H value in Briquette 2 also corresponded to higher heating value among the three mixtures (Figure 31). For the N content, which influences the emission of nitrogen oxides (NOx) and corrosion (Voicea et al., 2013), all three briquettes obtained the same value of less than 0.1% of its dry matter weight. The value obtained for S, which influences the emission of sulfur oxides (SOx) and corrosion were almost the same for the three briquettes ranging from 0.028 to 0.036% of the dry matter weight.

Table 16. Ultimate analyses of the briquettes produced using the improved briquetting technology

Parameters Measured	Types of Briquette			Mean
	P	P + SD	P + SD + CRH	
Hydrogen, % dm	5.1	5.9	4.8	5.3
Nitrogen, % dm	<0.1	<0.1	<0.1	<0.1
Sulfur, % dm	0.035	0.036	0.028	0.033

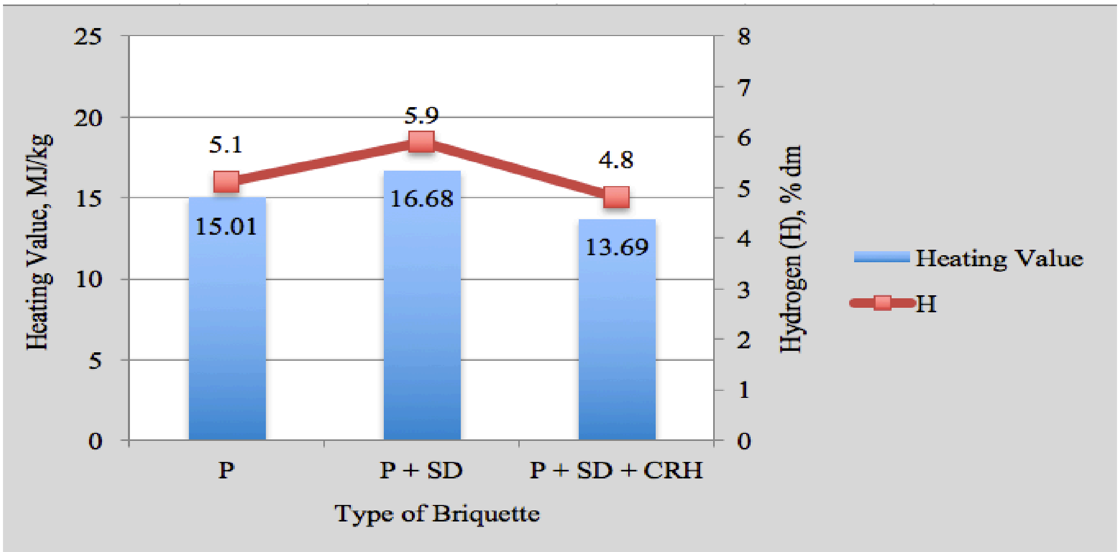

Figure 31. Graphical comparison of the heating value and the hydrogen content of the briquettes produced using the improved briquetting technology

As shown in Table 17, the briquettes produced contained lower N and S when compared to other biomass briquette fuels such as charcoal, waste paper briquette, refuse-derived fuel (RDF), mixed waste paper, and bituminous coal (Vassilev et al., 2010; Demirbas & Sahin, 1998). The results for N and S also conform with the values set under DIN 51731 standards of <0.3% and <0.08%, respectively. This implies that the briquettes produced, when used as fuel for heating operations, would emit less NOx and SOx which are pollutants in the atmosphere.

Table 17. Results of the heating value and proximate analyses of various raw materials from other studies

Material	Parameters Measured from other Studies H % dm	N % dm	S % dm	C % dm	O % dm	Source
Charcoal	2.25	ca. 1	0.04			Author
Waste paper briquette	6.1	0.4	NR	44.7	48.1	Demirbas & Sahin, 1998
RDF	7.8	1.1	0.47	53.8	36.8	Vassilev et al., 2010
Mixed waste paper	7.2	0.2	0.08	52.3	40.2	Vassilev et al., 2010
Bituminous coal	5.0	1.3	1.1	83.1	9.5	Vassilev et al., 2010
Pine sawdust briquette	5.37	0.10	0.007	52.15	NR	Stolarski et al., 2013

4.2.3 Potential Production and Earnings from Briquetting

One hundred sixty (160) respondents who are waste reclaimers at the Calajunan Disposal Facility were interviewed for their familiarity and utilization of briquettes prior to being introduced with fuels molded during the experiment. Results shown in Table 18 reveal that a great majority (88.1%) of the respondents were already familiar with the use of briquettes as cooking fuel. Seventy-five percent (75%) indicated that they learned about the briquettes through UCLA, 6.2% learned about it from seminars while 14.4% knew about it from other people. Seven (7) or 4.4% of the respondents did not give any answer to this specific question. The high percentage of familiarity through UCLA may be attributed to the posted list of activities and many actual field tests that were conducted and performed the past 4 years at the UCLA Center, which is just approximately 100 m away from the disposal facility. These activities may even have encouraged the 16.8% respondents to produce their own briquettes, although prior to the introduction of the project, 83.1% have indicated that they have not produced their own. Despite the low percentage of responses responses whether they produce their own briquettes or not, 44.4% of the respondents revealed that they have already started utilizing them while 55.6% claimed no usage or have not used the briquettes. This indicated that even though others are not producing their own fuels, yet, they were able to find a way of using this kind of cooking fuel in their homes. When asked further on this, some respondents mentioned that they were given briquettes after previous training activities at the center or they obtained them from neighbors who produce their own.

Table 18. Distribution of the respondents according to familiarity and utilization of briquettes (n=160) prior to being introduced as fuel

Profile	Frequency	Percent
Familiarity with Briquettes		
Yes	141	88.1
No	19	11.9
Total	160	100.0
How Briquettes were Known to Them		
UCLA	120	75.0
Seminar	10	6.2
From other people	23	14.4
No answer	7	4.4
Total	160	100.0
Use of Briquettes Prior to Introduction		
Yes	71	44.4
No	89	55.6
Total	160	100.0
Production of Own Briquettes		
Yes	27	16.8
No	133	83.1
Total	160	100.0

The same respondents were later on provided, on the average, with 3 kg of one type of briquette for them to use as cooking fuel in their respective homes.

Selected participants produced these briquettes during the 15-day actual field test experiment held at UCLA Center. As can be seen in Table 19, 45.6% of the respondents had the pure paper briquettes followed by the paper and sawdust combination at 32.5%. The three combination briquette materials (paper + sawdust + CRH) were utilized by 35 respondents (21.9%) for testing in their homes. More than 83% indicated that they were using them for cooking rice and food and for boiling water. Others (31.2%) claimed that they were using them in cooking food for their animals. The 11 to 15 pieces of briquettes utilized per cooking by 56.2% of the respondents also corresponded to the same amount when these briquettes were tested on a laboratory scale. Almost 22% of the respondents have used 10 pieces and below or 16 pieces and above per cooking. The latter utilization of briquettes may be associated to the cooking operation for animal food since this entails longer operation time, hence, more cooking fuels are needed. More than half of the respondents (56.2%) were able to utilize their 3-kg briquettes in 7 days while 17.5% used the fuels in 3 days. Less than 10% of the remaining 42 respondents utilized them in 2, 4, 5 or 14 days.

In terms of acceptability of the technology, a great majority (93.1%) of the respondents signified its usefulness as substitute fuel for cooking (Table 20). There were 111 respondents (69.4%) who indicated having no problems in using briquettes as cooking fuels while 49 respondents (30.6%) claimed to have encountered problems. Of these 49, almost 18% found the briquettes to produce too much smoke while 13.1% observed the fuels to burnout faster. Should these fuels be introduced in the market, 81.2% are willing to buy them as cooking fuel. According to the 63 (39.4%) respondents, the briquettes are much cheaper compared to charcoal. Others (23.8%) found it very useful and easy to handle while 11.2% considered it convenient during the rainy season when cooking fuels like dry wood are difficult to find. Eleven (11) or 6.9% of the respondents would prefer briquettes since it is tidy or clean in the hands when used compared to charcoal. The outcome of this interview with the waste reclaimers found in the vicinity of the disposal facility in Calajunan is a positive indicator of the potential of briquettes as substitute fuel for various cooking and heat applications.

Table 19. Utilization of the briquettes randomly provided to waste reclaimers in Calajunan disposal facility (multiple response)

Profile	Frequency	Percent
Types of Briquette Provided		
Pure paper	73	45.6
Paper + sawdust	52	32.5
Paper + sawdust + CRH	35	21.9
Total	160	100.0
Utilization of briquettes provided		
For cooking rice	149	93.1
For cooking food	144	90.0
For boiling water	134	83.7
For cooking animal food	50	31.2
Estimated number of briquettes utilized per cooking		
10 pieces and below	35	21.9
11 – 15 pieces	90	56.2
16 pieces and above	35	21.9
Total	160	100.0
Days utilizing the briquettes provided		
2 days	11	6.9
3 days	28	17.5
4 days	7	4.4
5 days	15	9.4
7 days	90	56.2
14 days	9	5.6
Total	160	100.0

Table 20. Usefulness and willingness of the respondents to buy briquettes as substitute fuel for cooking (n=160)

Profile	Frequency	Percent
Usefulness of briquettes as substitute fuel		
Yes	149	93.1
No	11	6.9
Total	160	100.0
Finding problems with the use of briquettes		
Yes	49	30.6
No	111	69.4
Total	160	100.0
Problems encountered in using briquettes		
No answer	111	69.4
Faster to burnout	21	13.1
Too much smoke	28	17.5
Total	160	100.0
Willingness to buy briquettes		
Yes	130	81.2
No	4	2.5
Not sure	26	16.2
Total	160	100.0
Reasons for Using/Buying Briquettes When Sold		
No answer/Not sure	30	18.7
Very useful and easy to handle	38	23.8
Much cheaper compared to charcoal	63	39.4
Useful during rainy season	18	11.2
Tidy in hands compared to charcoal	11	6.9
Total	160	100.0

The cost analysis in producing briquettes is presented in Table 21. These computations were made based on the laboratory and field testing of briquette production involving the selected members of UCLA. With the supplement of using a pulping machine during production, the total cost of investment was Php37,000.00 (USD840.91). The fixed cost which covered depreciation, interest on investment, repair and maintenance and insurance gave the same value (Php42.91 or USD0.97) for the three types of briquette. The production of pure paper briquettes, however, entailed a higher variable cost of Php229.12 (USD5.21) per day when compared to the other two briquettes which needed Php214.56 (USD4.88) per day. This was mainly due to the higher cost of electricity needed for pulping operations. Considering all the costs incurred at an assumed 8-hour operation per day, the cost of producing any of the three recommended briquettes ranged from about Php32.00 (USD0.73) to Php34.00 (USD0.77) for every hour of operation or Php0.13 to Php0.16 (USD0.003 to USD0.004) for every briquette produced. The design and development of this briquetting technology can be an answer to the limited commercial production of biomass briquettes in the country that would help convert combustible materials found in the waste stream turned into wealth (Primer on Biomass Briquette Production, 2010; Adegoke, 2002).

Data in Table 22 shows the computation of the potential earnings in making briquettes based on the production rate presented in Tables 9 and 10, and the operating cost in Table 21 with all data converted on a daily basis. When briquettes are sold after mark-up at Php15.00/kg (USD0.34) multiplied by the production rate for each briquette, the sales or revenue that may be generated would range from Php402.00 (USD9.14) to Php546.00 (USD12.41) per day. Subtracting the earned revenue with the cost of operation would give the producer potential daily earnings of Php130.00 (USD2.95) to Php288.56 (USD6.56), a value quite significantly higher when compared to majority of waste reclaimer’s surveyed daily income of Php124.00 (USD2.82) (Ikuse et al, 2014). When computed on an annual basis, one person may earn Php31,200.00 (USD709.09) to Php69,254.40 (USD1,573.96) just by producing briquettes. Higher earnings may be realized if members of an organization would work together for their income-generating project.

The integration of UCLA waste workers in the briquette production test corroborated the claim of Haan et al. (2008 as cited by Wilson et al., 2006) that organizing and training informal recyclers into micro and small enterprises is a very effective way to upgrade their ability to add value to collected materials. In this case, from PhP1.50/kg (USD0.03) of waste paper, this may become Php15.00/kg (USD0.34) of paper briquettes.

Table 21. Cost analysis in briquette production

Parameters Measured	P	P + SD	P + SD + CRH
Investment Cost, Php (USD)	37,000.00 (840.91)	37,000.00 (840.91)	37,000.00 (840.91)
Fixed Cost, Php/day (USD/day)			
Depreciation [1]	30.41 (0.69)	30.41 (0.69)	30.41 (0.69)
Interest on Investment [2]	8.11 (0.18)	8.11 (0.18)	8.11 (0.18)
Repair & Maintenance [3]	3.38 (0.08)	3.38 (0.08)	3.38 (0.08)
Insurance [4]	1.01 (0.02)	1.01 (0.02)	1.01 (0.02)
Total	42.91 (0.97)	42.91 (0.97)	42.91 (0.97)
Variable Cost, Php/day (USD/day)			
Labor Cost [5]	200.00 (4.55)	200.00 (4.55)	200.00 (4.55)
Cost of Electricity [6]	29.12 (0.66)	14.56 (0.33)	14.56 (0.33)
Total	229.12 (5.21)	214.56 (4.88)	214.56 (4.88)
Total Cost, Php/day (USD/day)	272.03 (6.21)	257.47 (5.85)	257.47 (5.85)
Operating Time, hrs/day	8	8	8
Operating Cost, Php/hr	34.00 (0.77)	32.18 (0.73)	32.18 (0.73)
Php/pc [7]	0.15 (0.003)	0.16 (0.004)	0.14 (0.003)

USD1 = Php44

[1] Straight-line method with 10% salvage value and life span of 3 years

[2] 24% of investment cost (IC)

[3] 10% of IC

[4] 3% of IC

[5] The average daily earnings by waste picking is Php123.80 (USD2.81) (Ikuse et al., 2014)

[6] 1.12 kW/hr @ 2 hrs pulping operation/day for Briquette 1 and 1 hr for Briquettes 2 and 3 @ Php13.00/kW-hr (USD0.30/kW-hr)

[7] Operating cost divided by production rate in pcs/hr from Table 9

Table 22. Potential daily production and earnings in the briquetting of wastes

Parameters Measured	P	P + SD	P + SD + CRH
Production Rate [1], kg/day	26.80	32.88	36.40
Operating Cost [2], Php/day **(USD/day)**	272.00 (6.18)	257.44 (5.85)	257.44 (5.85)
Sales [3], Php/day **(USD/day)**	402.00 (9.14)	493.20 (11.21)	546.00 (12.41)
Potential Earnings:			
Php/day [4] **(USD/day)**	130.00 (2.95)	235.76 (5.36)	288.56 (6.56)
Php/yr [5] **(USD/yr)**	31,200.00 (709.09)	56,582.40 (1,285.96)	69,254.40 (1,573.96)

USD1 = Php44

[1] Obtained from Table 10 multiplied by 8-hr production per day

[2] Obtained from Table 21 multiplied by 8-hr operation per day

[3] Revenue for briquettes when sold at a mark-up price of Php15.00/kg (USD0.34/kg) or @ Php0.25 (USD0.006) per briquette after mark-up)

[4] Sales less operating cost

[5] Potential earnings in Php/day (USD/day) multiplied by 20 days production per month for 12 months in 1 year

4.3 Feasibility of Briquette Production

This part of the results of the study answers the fourth objective, which is to explore the feasibility of briquette production citing the case of UCLA, in manufacturing quality and acceptable briquettes for the community. These include the social, technical, economic and environmental considerations.

4.3.1 Social Feasibility

Briquette production helps UCLA organize themselves as an association by identifying skilled members or those who have been trained already to pursue this type of livelihood venture for their association. The identified project, by integrating the utilization of waste papers found at the disposal facility and incorporating it with other materials found nearby, adds value to their wastes. They move up the hierarchy making them involved in enterprising rather than just waste picking or reclaiming (agrees with Wilson et al., 2006). The involvement of members of UCLA since 2005 to 2015 in different projects and researches conducted in the area (Tamura et al., 2015; Ikuse et al., 2014; Romallosa et al., 2011a; Romallosa et al., 2011b; Paul et al., 2012; Paul et al., 2009a; Paul et al., 2009b; Paul et al., 2007) have given them knowledge and information and capacitated them in many social aspects. These include, among others, conflict management, sanitation and first aid, basics on business accounting and marketing with focus on existing and targeted livelihood options such as briquette production. Members have been introduced to the use of technologies such as briquetting and pulping machines giving them additional skills and confidence in terms of expressing their ideas for the improvement of the technologies introduced.

In a study conducted by Aparcana and Salhofer (2013) about the application of a methodology for the social life cycle assessment (sLCA) of a recycling system, one of the approaches considered was on the social impacts produced due to the activities of the stakeholders within the scheme. Although their study focused on the use of sLCA in the formalization of the informal sector in low income countries specifically in the case of Peru, and, indicators were identified in the same way, this study also used quantitative and qualitative guides. Among the social issues they considered which were also tackled in this study included employment and basic social needs, favorable environmental policies, skills development opportunities, access to secure livelihood, occupational/health safety, functional literacy, physical working conditions, and fair wage among others. These indicators were also noted during the conduct of structured and informal interviews under the socio-economic aspect. Observations related to these indicators were likewise considered during field testing.

The association having its own constructed center located just across the controlled disposal facility provides them with a sense of existence in the area. Specifically, the Policy Manual of UCLA drafted in 2010 highlights the reality of a socially organized group where members have to adhere to the mission, purpose and all other policies set by the association. The fact that UCLA has its own organizational structure means solid foundation for the operation of the association.

The conduct of the actual field operation for briquette production represented the “Paper Briquette Project” under UCLA’s unit on Livelihood and Business Development. When this field testing was undergoing, it was observed that somebody from the association would come-out as the “leader” or someone that would take charge of the operation. This is a clear manifestation that the waste workers could follow orders or instructions from that person whom they think has a command over them. Lorelei or nicknamed “Gipos” came out as the team leader during the entire briquette production test. This mode of hierarchy is necessary to keep the relationships among members, including the operation, become harmonious and sustainable, just like in any organization or work place. Integrating the members to work together as one association showed that they can be relied upon should an undertaking such as briquette production be arranged for them. This observation on how participants/members handled the simulated field production agreed with the observations of Wehenpohl and Kolb (2007) that integrating the informal sector through cooperatives or associations would give them reliability. This is necessary especially when the association would start negotiating contracts to industries, municipal authorities or other interested entities.

The actual briquette production test, which was conducted for 15 days paved the way for the determination of the average volume of briquettes produced based on the simulated work conditions. This specific part of the study further allowed analyses of the cost of producing the briquettes, hence, allowing them to mark-up the price for a value in which the people in the nearby areas can afford to buy. The determination of the ceiling of market price for briquettes was also done through informal interviews with UCLA members.

As observed throughout the simulated test, briquette production may be considered as socially feasible for UCLA or similar associations given the encouraging performance the waste workers have displayed. The workers themselves exhibited consistent harmonious relationship while working together with the aim of earning more based on the agreed compensation scheme.

The support UCLA gets from the government and private agencies (both local and foreign) widens their network providing more venues to introduce their product like the briquettes. The recognition of UCLA by the LGU and its integration to the recovery of recyclable wastes from the controlled disposal facility has boosted their role in the society.

The briquette production test conducted by UCLA as livelihood is an answer to reducing poverty in the Philippines (The World Bank Country Assistance Strategy, 2009) specifically on financially alleviating the lives of the waste reclaimers in Iloilo

City. Production of briquettes by the informal sector using a low-cost jack-driven briquette molder can provide alternative/additional livelihood to the urban and rural poor communities giving them a more stable income. Stable income means gradual rise from poverty. With this livelihood option, such as briquetting of wastes, another Millennium Development Goal (MDG) now switched to Sustainable Development Goal (SDG) is addressed on poverty reduction. It may enable them to change their daily work place from the open dumpsite to a more organized and presentable place with access to sanitation and water facilities. Waste picking undoubtedly poses health hazards to the workers. The waste workers are exposed to bad odors and diseases from dealing with mixed wastes in the dump. Women are especially more vulnerable to waste picking under unhealthy conditions at dumpsites or by sorting and washing collected materials. Working in briquette production will eliminate all these direct effects that may be caused by high exposure to wastes. By strengthening women entrepreneurs in the informal sector such as the case of UCLA, they would be empowered to carry out more independent activities and to establish more self-contained livelihoods. Through this, the third MDG now switched to the fifth SDG that is to Promote Gender Equality and Empower Women, is addressed.

Since 2006, the government of Iloilo City located in the Philippines with the help of GIZ and a local NGO supported livelihood initiatives to waste workers found in Calajunan Disposal Facility (Paul et al., 2012). The objective of those programs was to support the poor workers at the dumpsite, helping them to gradually stop waste picking by providing livelihood opportunities. Results of this study indicated that, indeed, briquette production can be considered as having economic potentials. Since the waste workers was organized last May 12, 2009, it was easier for them to be officially formed as the briquette production team. The more organized they become, the higher would be their involvement in adding value to the biomass and urban wastes.

Involvement of the informal sector in briquette production is in congruence with the Philippines’ SWM Framework Plan, which hopes to empower through their promotion and implementation of the 3Rs of waste management with the end view of alleviating poverty. Briquette production through the use of a machine where the stakeholder themselves have been instrumental in the development of the technology is also responsive to the mission of the Framework. The mission is to integrate the informal sector in the solid waste management system by provision of favorable policies, environment, skills development and access to a secured livelihood, employment and social services. In addition, all the previously conducted briquette production field tests in UCLA with the participation of selected members have translated capacity building from their end. According to the NSWMC Resolution No. 48, Series of 2010, the key to empowering the informal sector is to capacitate its members.

The construction of a sanitary landfill adjacent to Calajunan Disposal Facility means uncertainty of livelihood for UCLA members and non-members who still do waste reclaiming. But with briquette production, once the Association can put everything in place, this improbability of sourcing income may be addressed.

4.3.2 Technical Feasibility

Results of the study suggested feasibilities both on the availability of raw materials needed for briquetting, the practicality of the design and operation of the jack-driven molder and the good quality of briquettes produced. These three important requirements are necessary for an organization such as the case of UCLA to sustain this kind of livelihood.

As mentioned by the Philippines' Department of Environment and Natural Resources (DENR), the example of UCLA in briquette production can be considered as an opportunity to properly manage the disposal of biomass wastes like rice husk and sawdust. Being an agricultural country, the Philippines has unlimited source of biomass wastes needed for briquette production. With an estimated 3.14 million metric tons of rice husk in the Philippines, 165,000 metric tons of it is generated in the province of Iloilo. This makes the area abundant in rice husk, an important yet underutilized biomass waste product which when carbonized, could be used as one ingredient in briquetting. The 2.06 million hectares of forest plantation in 2005, in turn, is projected to increase. This would impact high generation of sawdust when these forest products are processed into lumber. In the case of waste paper, the 20-day test conducted by Paul et al. (2007) in Iloilo City was able to collect 4,554 kg of paper or a daily recovery of 227 kg from the delivered 170 tons/day of waste to the city's sorting area (MRF). These three major ingredients clearly indicate technical feasibility as per availability of raw materials.

Using the data collected in this study, it is computed that one person operating the machine per day can utilize approximately 24 kg of waste paper, 16 kg of sawdust and 8 kg of CRH. If computed based now on the 6 existing available briquetting machines in UCLA Center, daily production of briquettes would lead to an estimated utilization of 144 kg of paper, 96 kg of sawdust and 48 kg of CRH. When converted to an annual rate, production would lead to the utilization of 34,560 kg of paper, 23,040 kg of sawdust and 11,520 kg of CRH. The conversion of 144 kg of waste paper means 63% utilization from the 227-kg paper waste recovered from Calajunan Disposal Facility. When the 144 kg of paper is sold at a prevailing rate of Php1.50/kg (USD0.03), it would only earn Php216.00 (USD4.91). But when these wastes are processed and sold as briquettes, the 144-kg waste paper may be able to generate an income of Php480.00 (USD10.91) increasing it more than 100% of its original value. An increased trend is also expected in the utilization of sawdust and CRH since these two materials typically have lesser selling value. In the Philippines, these biomass wastes are mostly dumped along the roads. The informal sector, therefore, could play a significant role in the recovery of these reusable waste materials from the waste stream and can add value to them as alternative fuels and raw materials (AFR) for household energy supply using an appropriate technology.

The fabrication of the machine, in order to convert those materials into briquettes, is also very feasible since the construction materials used were all procured from the local market. Two persons can fabricate the device using fundamental machine shop tools and equipment like welding machine, acetylene, drills and grinders.

The development of the jack-driven briquetting technology indeed produced briquettes of higher bulk density and lower moisture content. It also molded materials having uniform size, shape and properties. The development of briquette molder with good compressive ability accomplished the use of papers as a reliable binding material for briquette production (Demirbas & Sahin, 1998; Immergut, 1975). The case of UCLA in utilizing biomass and urban wastes with paper serving as the binding material can also be likened to the community-based energy briquette production in an informal settlement in Nairobi, Kenya. The materials produced utilized paper as binder with other mixtures coming from discarded materials like coffee hulls, rice husks, charcoal particles, sawdust and wood chips. The size and shape of briquettes are identified as doughnut-shaped (Njenga et al., 2009). They are also cylindrical with a hole but the size is like those of doughnuts.

The simple design and operating mechanism of the briquette molder does not need high technical know-how for it to be operated. A brief orientation on the operation of the machine may be done as experienced during the 15-day field test conducted in UCLA Center.

4.3.3 Economic Feasibility

Various studies have shown that the informal sector contributes to positive economic impacts on the overall solid waste management system (NSWMC, 2009). Briquette production could create job opportunities; specifically, it can promote job changes to waste reclaimers in Calajunan area. This study proves truly that there is money in garbage and that—waste is a resource.

In terms of economic feasibility, the most important impact of producing briquettes is the steady/above average income based on the 15-day field test conducted for this study with selected UCLA members. Based on computations, the marked-up price for briquettes when sold is Php0.25 or 25 cents per piece or about Php15.00/kg (USD0.34). When sold at this low price, a potential of Php402.00 (USD9.14) to Php546.00 (USD12.41) maybe generated per day per person. Subtracting all other operating expenses computed during the simulated field test, the waste worker may earn a daily profit of Php130.00 (USD2.95) to Php288.56 (USD6.56). The value is quite significantly higher when compared to majority of the waste reclaimer's surveyed daily income of Php124.00 (USD2.82). The difference in the amount between the average potential income from the surveyed daily earnings is significant that the change in peso can already allow them to buy one complete modest meal for an average household having four family members. Assuming that they produce 20 days in a month for 12 months in one year, the annual profit may range from Php31,200.00 (USD709) to Php69,254.40 (USD1,574). The computation clearly shows better employment opportunities for the workers. This also indicates that the test participants can be elevated more than 4 times over the statistical poverty line of USD2 per day as formulated with the MDG, now the SDG of the United Nations (Eradicate Extreme Poverty and Hunger). The introduction of briquette production in UCLA would also serve as an alternative option in order for them to establish long-term economic activities as an organized association of waste reclaimers.

Since the waste workers would be working in a weather-protected work place and not under the sun most of the time, as compared to waste reclaiming before, better working conditions are then set and achieved at UCLA Center since they can be found working now in an acceptable and presentable working area. Working with the existing 6 units of briquetting machine present in UCLA would also mean working together as one team on regular hours or output-based performance, thereby, providing them a sense of pride as workers. Although team work was not forced upon the workers during the field test, it was observed that the interest to earn more at the end of the day prompted them to work harmoniously and more efficiently. The scenario in allowing 18 waste reclaimers to work altogether under the same roof enhanced work-related communication and skills development amongst them. When the waste workers were offered job change to do briquette making, a compensation scheme of pay per performance with once in three days attracted the most for them as compared to the daily payment (Ikuse et al., 2014).

If briquettes are made accessible to households and consumers through UCLA, then the use of these fuels could substitute or complement firewood and charcoal for domestic cooking and agro-industrial operations. This study agrees with Olorunnisola (2007) that when this happens, briquettes would be able to reduce the dependence on the latter two fuels. Informal recycling systems such as briquette production can also bring significant economic benefits to developing countries (Wilson et al., 2006). With briquette production using biomass and urban wastes, it would stimulate the manufacture of low-cost, affordable products made from recycled materials.

4.3.4 Environmental Feasibility

The substitution of briquettes over the use of traditional cooking fuels like wood and charcoal can help conserve the forest from being denuded and help reduce emission of GHGs by avoiding the burning of biomass and urban wastes without purpose. For example, the recycling of biomass and urban wastes by the informal sector into fuel production would allow the conservation of resources such as charcoal. It would also prevent further exploitation of primary resources like trees as wood fuel. The process of briquette production can successfully recover these waste materials and return or convert them into productive use, which otherwise would have ended up at the back of rice mills, roadsides or in disposal facilities. According to Wehenpohl and Kolb (2007), this recovery and recycling of wastes in a solid waste management system can be associated with significant environmental benefits. UCLA is instrumental in obtaining and recovering biomass and urban wastes at lower cost and uses much less fossil energy during briquette production. They are also helpful in keeping large amounts of recyclable materials like paper out of disposal. Since the technologies (pulping and briquette molder) utilized by this group of workers are very simple, with only one single-phase electric motor consuming electrical energy, it is convincing to say that their production process brings positive environmental feasibility because it consumes less energy than the formal sector.

It can be mentioned once again that production of 15,000 briquettes per year could lead to the replacement of 86,667 m^3 of fuelwood (from http://www.cleancookstoves.org/resources_files?feasibility-and-impact.pdf). These 15,000 briquettes are equivalent to one-year supply of cooking fuel for an average household size with four members. If UCLA goes into full-swing production of briquettes, a unit of briquette molder can produce 220 pcs/hr. When computed in an annual rate at 8 hours of operation per day for 20 days in a month, this would lead to a production of 422,400 pcs (roughly 8,018 kg) of briquettes per year. This volume of briquettes would be able to supply 28 households with alternative cooking fuel every year. In an experimental study conducted by Foroughbakhch, Hernández-Piñero & Carillo-Parra (2014), the computed mean of the fuelwood volume per plant of the 12 wooden plant species after 20 years of plantation is 0.01443808 m^3. Utilization of this estimated annual briquettes produced would help save the cutting down of 169 million of trees or 89,000 hectares of land established for fuelwood production. The utilization of 314 kg of briquettes per household per year, after further analyzed, would help replace the consumption of 324 kg or 18 sacks per year of charcoal and approximately 8 tanks (at 11 kg/tank) of LPG per year.

The utilization of briquettes showed low CO_2 equivalent (CO_2eq) emissions compared to that of charcoal, fuelwood and LPG. CO_2eq is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO_2eq signifies the amount of CO_2 which would have an equivalent global warming impact. Using the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC Guidelines, 2006), computations revealed that the use of the briquettes produced may lead to an emission of 1,160,000 kg CO_2/Gg fuel. This is numerically low compared to that of charcoal at 3,304,000 kg CO_2/Gg fuel, fuelwood at 1,747,200 kg CO_2/Gg fuel, and LPG at 2,984,630 kg CO_2/Gg fuel. These data, once again, have proven the positive environmental feasibility of these alternative fuel to the low emission in the atmosphere of a greenhouse gas like carbon dioxide.

Material recovery of biomass and urban wastes from the dumpsite instead of letting them decompose provides a significant contribution to environmental sustainability and resource efficiency by making secondary raw materials available. This activity helps address MDG 7 in the local context that is to ensure environmental sustainability now switched to SDG 7 which is to provide affordable and clean energy.

The discussions presented above have shown that briquette production by the informal sector is socially, technically, economically and environmentally feasible.

5 CONCLUSIONS AND RECOMMENDATIONS

The major findings as to the status and background of UCLA as the informal sector being cited are presented below. These include the validity of briquette production when adapted to other parts of the Philippines or in other similar parts of the world. Conclusions were drawn based on the findings for every objective made. Recommendations were included on how to further go on and improve briquette production field of work in the future. This chapter discusses the results with consideration on the general and specific objectives of the study.

5.1 Findings

Based on the data gathered and analyzed from the methodology used, the following are the major findings of the study:

1. UCLA as a SEC registered livelihood association of waste reclaimers since May 2009 is still existing and sustaining its operation starting with 140 members during its initial activities and now with 261 members. Out of this number, 77 members have not paid the membership fee at Php30 (USD0.68) per month.

2. UCLA has established its own Center located approximately 100 m from across Iloilo City's controlled disposal facility located in Brgy. Calajunan, Mandurriao. The Center, with an estimated floor area of 110 m^2, has been serving as a place for meetings, assemblies, and venues for trainings and researches intended for new activities. This was also the area for the entire field test conducted related to briquette production.

3. The Association has a drafted Policy Manual. The 13-member Board of Directors in conjunction with the Partner Organizations and the different Board Committees heads it. UCLA works on four major interests: a) Livelihood and Business Development, b) Networking and Linkage, c) Organizational Development, and d) Support Services. It is under the Livelihood and Business Development interest that the paper briquette project was identified.

4. A survey of the personal profile of the 160 waste reclaimers interviewed for the study revealed that a great majority (89.4%) reside in Brgy. Calajunan, Mandurriao, Iloilo City where the disposal facility is also located. Their average age is 37.52 years and many of the respondents are women (59.4%).

5. Most of the reclaimers found at the facility are married (74%) with more than 50% having 3 or more children. Almost 50% of the respondents have a household size of 5 and below followed closely by those having 6 to 10 members (40%).

6. In terms of their highest educational attainment, almost the same percentage (27%) of respondents are elementary and high school undergraduates; although there are waste reclaimers with college degrees (6.9%) who are still doing waste reclaiming at the site. Almost 39% of the respondents interviewed shared that they earn Php151.00 (USD3.43) or more daily. Thirty-three percent (33%) earn Php100.00 (USD2.27) and below while 27% earn between Php101.00 to Php150.00 (USD2.30 to USD3.41).

7. The study revealed that out of the 160 respondents, 69% were members of UCLA while the remaining 31% were either waste reclaimers who are not official members of the group or were just walk-in pickers in the area. Out of the 111 respondents who were UCLA members, nearly half (44.4%) indicated involvement with the group for 3 years and below. Although UCLA was officially registered in 2009, respondents who have indicated more than 6 years of membership may have meant commitment by associating themselves with fellow members whom they have been working with at the dumpsite. Fifty-nine percent (59%) of the respondents implied active membership with UCLA. Involvement includes attending regular or special meetings called, participating in trainings/seminars conducted, or paying their monthly or annual dues. More than 30% were waste reclaiming in Calajunan for 16 years and above.

8. In terms of the waste reclaimers' housing conditions, more than half (56.9%) live in a small house having a 50 m^2 or below floor area. Almost all (94%) of them own their house. The houses they live in are reasonably built (72%) having bamboo (56.2%) as the major material used for its walls. It can also be noted that 57.5% of the respondents live in a single room only/studio-type home. They also have a toilet (74%), which is located inside (45%) the house.

9. The quality of life of the waste reclaimers is not that miserable due to connectivity with electricity (90%) and water source (89%). However, 75% of them get their water from a dug water pump. The water table may have been contaminated already by the leachate of wastes coming from the dumpsite.

10. Prior to the introduction of briquetting technologies in Calajunan, some waste workers were already utilizing their own hand-made briquettes (2.5%) as substitute for charcoal in cooking operations. However, wood (87%) and charcoal (69%) obtained mostly at the dumpsite or bought somewhere else were the common fuels used for cooking. On the average, 25 to 30% of the respondents spend about less than Php10.00 (USD0.23) to Php40.00 (USD0.91) daily on their fuel use.

11. Under the technical aspect of the study, the initial briquettes produced using the hand-press molder were pillow-shaped. The final design of the briquetting machine can now produce briquettes that are cylindrical with a hole at the middle, the weight of which ranged from 14 to 27 g per briquette. The briquettes formed slightly vary on thickness because this is dependent on the amount of materials loaded in the molder and the power exerted by the operator.

12. The development and enhancement of the briquetting machine from hand-press to jack-driven has significantly ($P<0.01$) improved when evaluated in terms of production rate both in pcs/hr and kg/hr. The enhanced design can specifically produce, on the average, 220 pcs/hr or 4 kg/hr of briquettes. The final design for the jack-driven machine has also attained significantly ($P<0.01$) the fastest cooking time for rice at 19 to 22 min. It was likewise clearly shown in the study that the continued enhancement of the machine has significantly ($P<0.01$) improved the bulk density of the fuels by approximately 400%.

13. When the briquettes of the final jack-driven briquette molder were subjected to physico-chemical analyses, results revealed that the heating values ranged from 13.52 to 16.55 MJ/kg (5,800 to 7,100 Btu/lb). The paper and sawdust combination obtained the highest value (16.68 MJ/kg or 7,153 Btu/lb) while briquettes mixed with CRH had the lowest at 13.69 MJ/kg (5,872 Btu/lb).

14. Results of the proximate analysis in terms of ash yield revealed that briquettes mixed with rice husk in carbonized form contained higher ash at 31% and, thus, have more ash-forming elements than most of forestry biomass like sawdust. The use of a hydraulic jack in compressing briquettes and the presence of many holes at the side of the molders resulted in briquettes with lower moisture at 5.6 to 7.1%.

15. Results of ultimate analysis in terms of H content in the three briquettes produced ranged from 4.8 to 5.9% with Briquette 2 (P+SD) having the highest. All the three types of briquettes produced have less than 0.1% N of its dry matter weight. The value obtained for S ranged from 0.028 to 0.036% of the dry matter weight.

16. Briquette 1 (Pure Paper) generated the highest operating cost per hour at Php34.00 (USD0.77) due to the additional expense on longer pulping operations for paper. Further computations revealed that all types of briquettes would generate an operating cost of Php0.14 (USD0.003) to Php0.16 (USD0.004) per piece.

17. Briquette production using biomass and urban wastes may give one member potential daily earnings of Php130.00 (USD2.95) to Php288.56 (USD6.56). On an annual basis, the amount would translate to Php31,200.00 (USD709.09) to Php69,254.40 (USD1,573.96).

18. Prior to the introduction and distribution of briquettes in the area, 88.1% specified familiarity with its use as cooking fuel. The majority (75%) got to know about the briquettes through UCLA's activities that had been conducted and performed the past 4 years at UCLA Center. The waste workers maybe familiar with the briquettes, however, only 44.4% are already using them as fuel even prior to the introduction of the fuels in their community. There were even 16.8% of respondents who produce their own briquettes at home.

19. The 3 kg of briquettes distributed to respondents were mostly utilized for cooking rice and other food (90%). Others are using them for boiling water and for cooking animal food. A little more than half (56.2%) of the respondents utilized the 3 kg of briquettes as alternative cooking fuel in one week.

20. In terms of acceptability of the technology, 93% signified its usefulness as substitute fuel for cooking; 69% indicated having no problems in using them but others found it to burn faster (13%) and emitted too much smoke (17%). Should these fuels be introduced in the market, 81.2% are willing to buy them since it is much cheaper compared to charcoal (39%) or very useful and easy to handle (24%).

5.2 Conclusions

The objectives of this research have been achieved. In line with the findings of the study, the following conclusions are drawn.

5.2.1 Enhancement of Briquette Production Technology

In answering the first objective of the study, results have clearly shown an enhanced briquette production after modifications of the briquetting technologies were developed. The integration of both the socio-economic and technical aspects of briquette production led to the gradual enhancement as per observation of the constraints in the design and results of operation of the previous machines developed. From a small hand-press briquetting machine to a 4x4 jack-driven briquette molder, all feasible suggestions and recommendations during the fabrication and evaluation stages of the units were considered until the improved version was finally acceptable to the would-be users. Acceptability refers to both the operating performance of the machine and the quality of briquettes produced as against the technologies that have already been developed. The improved briquetting technology has enhanced the ease and simplicity of operation. The jack-driven machine has significantly ($P<0.01$) increased the production rate expressed in pcs/hr by almost 37% as compared to the hand-press design. The integration of the hydraulic jack has obviously improved product quality. The improved technology was able to withstand the wear and tear of its use after it was subjected to actual field operation and production for 15 days. This is an indicator that the machine can perform well once the technology is adopted not only by UCLA but also by other similar stakeholders. In terms of production rate expressed in weight of briquette produced per unit time, the results of study have clearly implied enhanced quality of briquettes. This is evidenced by the production of heavier (more compressed) briquettes despite having less thick fuel as compared to that of the previously developed hand-press molder. More than 80% enhanced product quality was attained when rated according to this parameter.

From a smoky pillow-shaped briquette, the product was enhanced by changing the shape of the fuel into cylindrical with a hole, thereby, improving its combustion characteristics and air-movement as observed and recorded during the boiling and cooking tests. Less smoke was also observed. The use of a hydraulic jack in producing briquettes likewise significantly ($P<0.01$) improved the bulk density of the fuels by 400% against the hand-press design making them desirable for transport, storage and handling. The enhancement of the bulk density parameter made the briquettes numerically comparable to other briquettes made from agricultural, forest origin biomass and waste paper which were produced using the more complicated to operate and bulky hydraulic press and horizontal crank and piston technologies developed.

The final design of the 4x4 jack-driven briquetting machine was enhanced best in terms of production rate, cooking time, and bulk density of briquettes.

5.2.2 Quality of Briquettes Produced

Results of the physico-chemical analyses further revealed that the net heating value of the three types of briquettes produced using the enhanced technology is more than 11.6 MJ/kg (5,000 Btu/lb), the recommended value needed to sustain combustion. These made the briquettes produced and field tested by UCLA an ideal and feasible fuel for cooking and other heat-related applications. As cited, when agricultural wastes are converted to energy, such as fuel briquettes, it can provide renewable energy to people in developing countries like the Philippines and other countries alike that have high generation of biomass wastes. It agreed with Laryea-Goldsmith et al. (2011) that on a small scale, biomass is recognized as a source of renewable energy that is capable of meeting both heat and electricity demand most effectively in the form of combined heat and power, contributing towards international commitments to minimize environmental damage.

The paper and sawdust mixtures had the closest numerical value to the DIN 51731 standards. The moisture of the briquettes produced also met the DIN 51731 standards requiring fuels to have moisture of less than 12%. The higher value of elemental hydrogen (H) obtained from the paper and sawdust combination corresponded also to a higher heating value when compared to the biomass and paper mixtures. The quality of briquettes in terms of N and S were lower when compared to other biomass fuels like mixed paper, RDFs and bituminous coal. These values all conform to the DIN 51731 standards of $<0.3\%$ and $<0.08\%$, respectively. These imply that the briquettes produced when used extensively as fuel for heating operations and when sold in the market, would emit less NOx and SOx which are pollutants in the atmosphere.

5.2.3 Potential Production and Income from Briquette-Making

A person operating the briquette molder per day can help eliminate approximately 24 kg of waste paper, 16 kg of sawdust and 8 kg of CRH from the waste stream. Based on the operating expenses, the briquettes produced may be marked-up to Php0.25 (USD0.006) per piece or Php15.00/kg (USD0.34) for profit generation. Higher earnings may be realized if more members of an organization such as UCLA would work together in the production of briquettes using the developed jack-driven briquetting machine. In addition, the potential daily earnings of Php130.00 (USD2.95) to Php288.56 (USD6.56) generated in briquette production is higher when compared to majority of waste reclaimer's daily income of Php124.00 (USD2.82). This means that producers of briquettes can be elevated more than 4 times over the statistical poverty line of USD2 per day. The results of this study have shown that the briquette production field tested by UCLA could be considered as potential source of income for them given the economic viability of the identified project. It is an alternative option for them to be able to establish long-term economic activities as an organized association of waste reclaimers. Integration of the informal sector in Calajunan in the SWM system through their participation in the utilization of wastes to produce briquettes agrees with Sanada and Yoshida (2011) that integrating them can be realized by organizing and empowering the waste reclaimers in good cooperation with NGOs and the local government. This undertaking mentioned in this study was experienced in Phnom Penh City, Cambodia wherein the waste pickers organized a self-help group and supported by NGO for acquiring knowledge and skill for manufacturing various recycling crafts from used papers and plastics. In the case of UCLA, they were also supported in terms of technology use, knowledge transfer and capacity building for them to be able to go into briquette production. Their activities can greatly contribute to the reduction and reuse of the wastes generated in the area.

5.2.4 Feasibility of Briquetting

The high positive response (93%) on the usability of briquettes and the willingness of the respondents (81%) to buy them when sold in the market indicates the promising potential of briquettes as fuel in the nearby communities. The development of the improved design of the briquette molder is an answer to the limited commercial production of biomass briquettes in the Philippines. Production done specifically by UCLA in utilizing the abundant biomass and urban wastes found on this part of the world has also denoted positive impressions on the social, technical, economic and environmental side. The utilization of the wastes by recycling them into improved fuel will make UCLA members enterprisers rather just waste pickers or reclaimers. It enters them into new service roles and niches through their separate collection of paper and other biomass wastes and recycling them into cooking fuels. Being producers and sellers of their own products elevates their rank in the hierarchy of informal sector recycling. UCLA's participation during the design and evaluation process of continuously developing the technology has empowered them in decision-making and increased their confidence level knowing that their suggestions and recommendations are considered. The simulated field production of briquettes has provided them additional skills and capacitated them of many social capabilities like conflict management, work harmony, discipline and initiative, among others. Aside from the jack-driven briquette molder's aid for income generation, some UCLA members who were already utilizing hand-made briquettes can also utilize the machine. This time, however, the laborious method of compressing materials by hand will be replaced by a user-friendly gender sensitive technology that is affordable and can provide them economic returns in the long run. Material recovery of biomass and urban wastes from the dumpsite instead of indiscriminately burning them provides a significant contribution to environmental sustainability and resource efficiency by making secondary raw materials available. Production of briquettes as substitute fuel for charcoal and wood can help save a lot of trees from being cut down and protect forested areas from becoming denuded. Likewise, the utilization of briquettes has been computed to have low CO_{2eq} emission compared to those of charcoal, fuelwood and LPG. The presence of UCLA in the community as producer and supplier of briquettes for heat applications could provide a permanent venue for the people to have access to this kind of alternative fuel. The case of UCLA as being integrated both in the socio-economic and technical aspects in the enhancement of briquette production technology serves as an example on how a waste reclaimer's association could add value to waste materials in making useful products like briquettes.

The high participation of women waste reclaimers in the briquette production test suggests the extent to which urban women can have access to this kind of work opportunity. In general, waste workers do not have to labor under the sun for a long time just to earn income. With briquette production, they are provided with safe working area reducing their vulnerability to the many risks that may be caused while working in an open dump.

5.2.5 Applicability of Briquetting to Other Parts of the World

Briquette production using biomass and urban wastes by an organized association of waste workers upgrades the role of the informal sector in an SWM system. UCLA's organization and training background made the selected 18 members in the briquette production test more participative and suggestive in enhancing the technology used (Jack-Driven, 4x4, final) to produce quality briquettes made from paper, sawdust and CRH. Their familiarity with the technology allowed them to produce 220 pcs/hr or 4 kg/hr of briquettes, that when sold in the market for a marked-up value of Php15.00/kg (USD0.34), would provide them a net daily earnings of Php130.00 to Php288.56 (USD2.95 to USD6.56) which are higher than majority of the waste reclaimer's daily income of Php124.00 (USD2.82). This earning from briquette production is also higher when compared to the earnings from other countries. In Dhaka City, Bangladesh, the computed average daily income of the informal sector is BDT87.97 (USD1.14). With an average family size of 5 people, the income of the workers is not always enough to provide meals but they manage it somehow by living marginally (Alam, 2012).

According to Medina (2000), there are social benefits associated with informal recycling. The results of the study proved that briquette production could provide employment and livelihood for impoverished, marginalized and vulnerable individuals or social groups such as UCLA. This is shown by the potential production rate and earnings generated from this field-tested research work. The lack of education of some waste workers would not hinder their ability to participate in this endeavor since the briquette production technology introduced is not complicated. The livelihood opportunity introduced and observed from the operations of UCLA has similarities with the case of Zabbaleen in Cairo. As cited from the paper of Gunsilius et al. (2011), the Zabbaleen are a Coptic Christian minority, who have been active in collecting, sorting and recycling of a substantial portion of waste in Cairo since the 1930s. A Coptic church helped established their association and an environment and development program was initiated later with assistance from international funding agencies. Some opportunities introduced to them were new business prospects related to their trade and income generation project. There was parallel focus on improving livelihoods by introducing technologies to add value and on the education/social initiatives.

Tirado-Soto and Zamberlan (2013) concluded that the formation of networks of waste pickers is a process of social relations, by nature "popular" that requires support from other actors. However, there must be an economically viable project. The economic viability for UCLA's briquette production has involved already physical infrastructure such as the Center, machineries and technical training.

The activities conducted in UCLA in line with the production of briquettes had resemblances on the briquette production initiatives introduced at Kahawa Sowento Informal Settlement in Nairobi, Kenya (Njenga et al., 2009). One major problem experienced by the urban poor in cities of Sub-Saharan Africa including Kahaw Sowento Village is inaccessibility of affordable cooking fuel. With this, the Soweto Youth in Action (SOYIA) group in collaboration with Green Towns developed an initiative on making fuel briquettes from urban solid waste with an aim of generating income and providing employment to the urban poor while contributing to environmental management. The results of the community-based energy briquette production conducted in the capital city of Kenya became valid as experienced also in UCLA. Training courses were conducted especially on the technical side of fuel briquette production; the briquettes were made from common waste materials and quality was evaluated in a participatory manner. The doughnut-sized briquettes were sold at Ksh3 to Ksh5 (USD0.04 to USD0.06) per piece.

Similar initiative on biomass briquette efficiency in Malawi validated the briquetting production research performed in UCLA. Ndirande Nkhuni Project of Blantyre City in Malawi integrated income generation, provision of an alternative source of energy, and waste management as key areas for intervention. Women were given a chance to choose the type and design of the briquetting technology to allow them to acquire equipment that is easy to maintain because the spare parts are easy to get and are inexpensive. The machines designed for women producers require only a small capital investment, have an acceptable production capacity using minimum physical effort, can be locally maintained, and are financially and technically appropriate. These were similar approaches made with UCLA in which the briquetting technologies were enhanced a few times in order to address the needs and requirements of the waste reclaimers who would be producers of briquettes in the area. More women have also joined in the field production test making the introduced technologies gender-sensitive.

The size of the briquetting machine with roughly 30 cm by 30 cm x 65 cm dimensions and with an approximate weight of 65 kg makes the unit portable. This technology may be brought and introduced to places and countries where briquettes are used as fuel for cooking and biomass wastes are utilized as main ingredient for production. This may include Bamako Mali, Lilongwe Malawi, Kenya, and Haiti. These countries produce cylindrical briquettes with a hole using sawdust, rice husk, charcoal fines, carton board and waste paper. In Southeast Asia and nearby regions, the enormous availability of biomass wastes like rice husk and sawdust including the commonly generated municipal solid wastes from paper makes it valid to explore briquetting technology transfer. The results of introducing briquette production in UCLA in the Western Visayas part of the Philippines makes it feasible if applied also in Thailand, Vietnam and Nepal since these countries are well endowed with renewable energy resources (Shakya et al., 2014; Bhattacharya et al., 2002; Toan et al., 1998;). Just like the Philippines, these countries are rice producers with forestland covers. Previous projects and studies have also indicated the presentation of briquetting in these areas highlighting the potential of re-introduction and demonstration of the technology; a practical alternative to wood fuels (Toan et al., 1998). On the technical side of briquette production such as the machine utilized, the results are also applicable in India. This is indicated in the study of Grover, Mishra and Clancy (1994) which revealed that the machine developed competed well in terms of results when compared to the piston press and screw extruder technologies. The briquette production performed by UCLA members may even address the major shortcomings in hindering the wider dissemination of briquetting technologies in India. The results of the briquette making study may address these shortcomings on production rate, maintenance procedures, wear cost, and expertise.

In conclusion, results of the physico-chemical tests have shown that quality briquettes can be created from biomass and urban wastes, making them a renewable source of fuel with minimum cost. The enhanced briquetting machine introduced is inexpensive and production rate is high compared to the commercially available units in the Philippines. An enterprise on briquette production can be considered profitable for would-be small businesses and communities consuming other conventional fuels like charcoal and woodfuel as demonstrated by a waste reclaimers group in Iloilo City, Philippines.

5.3 Recommendations

To further improve and guide UCLA in its briquette production activities, the following are recommended.

As an association of waste reclaimers, of which most of the members have not attained college education, it is recommended that UCLA's production operation be always regularly supervised especially by Iloilo City's GSO. This is the same office that supervised them when they were initially formed. Record-keeping of their production process, raw materials utilized, operating expenses, revenues and other operation-related activities should be properly reviewed and monitored to see to it that the operation is still efficient. Members who had been trained or participated in the field tests before should be re-oriented of their interest in joining the briquetting team of UCLA to assure commitment from their end once the project is fully operational.

The operators of the briquette molder should be briefed not only about its operation but also of safekeeping in order to prolong the lifespan of the machine.

UCLA should also be assisted by other organizations whether government, private or educational institutions, and society at large on the proper packaging and marketing of briquettes to the necessary consumers and industry. Packaging of the fuels produced may be referred to the regional office of the Philippines' Department of Science and Technology (DOST). The marketing aspect, in turn, may be coursed through the Department of Trade and Industry (DTI) and a Marketing Team for UCLA be intensified for this specific task. Both these regional offices are located in Iloilo City. These possible offices and institutions should also assist UCLA in regularly monitoring especially the technical side of the operation such as the continuous improvement of briquette molders and pulping machine.

It is also recommended that the UCLA Center be refurbished as a working area for briquette production and at the same time a display area for the marketing of their packaged products.

Once UCLA has started generating sustainable profits, it is recommended that they invest in a small-scale dryer to facilitate uninterrupted drying of briquettes especially during the rainy season.

It is also recommended that additional ultimate analysis test be done on the quality of briquettes in terms of their total carbon and oxygen content; and proximate analysis test for the fixed carbon and volatile matter. These parameters are important especially when briquettes are used for higher industrial heat applications.

6 SUMMARY

The construction of a sanitary landfill (SLF) near the location of the existing controlled disposal facility in Brgy. Calajunan, Manduarriao, Iloilo City in the Philippines presented concerns on the regulation of the activities of the waste reclaimers in the area. In anticipation of these directives, an association of informal waste reclaimers group called Uswag Calajunan Livelihood Association, Inc. (UCLA) was formed in May 2009. The Association initially started with 140 waste workers until it rose now to 261 members. As a new organization, UCLA has to pursue many options for them to establish long-term economic activities. In order to guarantee its sustainability, two major strategies have to be applied: improve the cost-benefit balance of their existing activities and search for new fields of activities to create additional income. Based on the results of meetings, FGDs and other informal activities conducted with the members of UCLA, one option that was identified was the waste-to-energy project through production of fuel briquettes.

Production of briquettes came in the picture due to the obvious availability of raw materials that may be used in the project. As an agricultural country, the Philippines generates a lot of biomass wastes. Being a rice granary province of the country, Iloilo generates a lot of rice husks. Sawdust is also produced in high volume due to the presence of forested areas in Panay Island (where Iloilo is located) including the presence of many wood and handicraft industries. As indicated in many studies conducted at Calajunan, the disposal facility itself could reclaim significant volume of waste paper. Waste paper according to literature has a good binding property. With all these available waste resources, what was lacking then was an appropriate technology that would cater to the needs of the members of UCLA. This is where the College of Agriculture, Resources and Environmental Sciences of Central Philippine University (CPU) came in the picture. The University collaborated with UCLA through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in the development of many briquetting technologies which are suited for UCLA's preferences.

This study, therefore, presents the case of UCLA, an association of waste reclaimers found near the vicinity of Calajunan Disposal Facility located in Iloilo City, Philippines on how socio-economic and technical aspects could be integrated together to improve the briquetting technology needed for the production of quality briquettes as part of their income generating project. Specifically, the study aimed to enhance briquette production through the development of an appropriate technology that would produce more briquettes of good quality. The study also aimed to assess the impact of utilizing abandoned wastes that are suitable for briquette production to be adopted by members of UCLA as their potential source of income. It also sought to explore the feasibility of using the technology in producing quality and acceptable briquettes for the community.

The framework used in the study explained how it is best to cooperate with the informal sector in terms of socio-economic and technical aspects in order to assist them in the improvement of their livelihood, working conditions and efficiency in recycling especially of biomass and urban wastes. Different aspects may have profound influence on the present briquetting technology. When considered, they would have an effect on the improvement of the technology such as ease of operation or the increase in the rate of production. However, it would also be possible that the improved technology may still be unacceptable to the end-users; hence, further socio-economic and technical considerations were applied until the results were incorporated for another improvement. Once acceptable to end-users, products were created. The briquettess produced were then subjected to more verification in order to determine their feasibility socially, technically, economically and environmentally.

Under the socio-economic aspects of the study, a non-experimental posttest only design was utilized for the collection of descriptive information. The study area, respondents and the status of the SWM system were described using primary and secondary data through structured interviews, informal interviews, FGD and observations.

For the technical aspects, descriptions and discussions were made on the enhancement of the briquetting machine from the first hand-press molder developed until the final design was attained. The principle of operating the technology was included in the study. Technical considerations were also integrated in the development of the briquetting machines utilizing the recommended mixtures, namely: pure paper; paper (50%) and sawdust (50%); and paper (50%), sawdust (25%) and CRH (25%). The operating performance of the briquetting machine was done in four test runs and the briquettes produced were subjected to laboratory and field-testing in order to determine its usability, quality and applicability to the would-be users. The laboratory testing of the machine and of the briquettes produced as fuel for boiling and cooking was performed at the Appropriate Technology Center of CPU – CARES while the field production test was accomplished at UCLA Center in Brgy. Calajunan, Mandurriao, Iloilo City. Briquette samples were sent to Bauhaus-Universität Weimar in Weimar, Germany for further physico-chemical analyses. Some parameters analyzed were further tested using the one-way analysis of variance (ANOVA). Significant differences between/among the means were determined using the Duncan's multiple range test (DMRT) to further compute the numerical boundaries that allow for the classification of the difference between any two means as significant or non-significant.

Results revealed that the improved briquetting technology was able to withstand the wear and tear of operation showing a significant ($P<0.01$) increase on the production rate and bulk density of briquettes produced. The quality of cylindrical briquettes produced in terms of bulk density, heating value, moisture, N and S closely met or has met the requirements of DIN 51731. Based on the operating expenses, the briquettes may be marked-up to Php0.25/pc (USD0.006) or Php15.00/kg (USD0.34) for profit generation. The potential daily earnings of Php130.00 (USD2.95) to Php288.56 (USD6.56) generated in producing briquettes are higher when compared to majority of the waste reclaimer's daily income of Php124.00 (USD2.82). The high positive response (93%) on the usability of briquettes and the willingness of the respondents (81%) to buy them when sold in the market indicate its promising potential as fuel in the nearby communities.

The study has shown that integration of both the socio-economic and technical aspects of briquetting have led to a feasible briquette production activity as documented in the field tests performed by UCLA. Quality briquettes can be created from biomass and urban wastes, making them a renewable source of fuel with minimum cost. The enhanced briquetting machine introduced in the study is inexpensive and production rate is high compared to the commercially available units in the Philippines and even in some parts of the world. An enterprise venturing in briquette production can be considered profitable for would-be small businesses and communities consuming other conventional fuels like charcoal and woodfuel as demonstrated by a waste reclaimers group in Iloilo City, Philippines.

7 REFERENCES

Books, Journals and Proceedings:

Altares, P.S., Copo, A.R.I., Gabuyo, Y.A., Laddaran, A.T., Mejia, L.D.P., Policarpio, I.A., Sy, E.A.G., Tizon, H.D., & Yao, A.M.S.D. (2003). *Elementary statistics: A modern approach.* Manila: Rex Book Store.

A Primer on Biomass Briquette Production. (2010). Philippines: Foundation for Resource Linkage and Development, Inc.

Adegoke, C.O. (2002). *Energy as veritable tool for sustainable environment*. Inaugural Lecture Series 31 of the Federal University of Technology, Akure, Nigeria.

Adekoya, L.O. (1989). Investigation into the briquetting of sawdust. *The Nigeria Engineer, 24*(3), 1-10.

Ajayi, O.A. & Lawal, C.T. (1995). Some quality indicators of sawdust/palm oil sludge briquettes. *Journal of Agricultural Engineering and Technology,* (30), 55-65.

Alam, M.N. (2012). A socio-economic study of informal sector workers of Dhaka City. *Bangladesh e-Journal of Sociology, 9*(3), 101-108.

Ali, M. (1999). The informal sector: What is it worth?. *Waterlines, 17*(3), 10-12.

Aparcana, S. & Salhofer, S. (2013). Application of a methodology for the social life cycle assessment of recycling systems in low income countries: three Peruvian case studies. *Int J Life Cycle Assess*. Doi 10.1007/s11367-013-0559-3.

Baconguis, S.R. (2007). *Abandoned biomass resource statistics in the Philippines.* Paper presented during the 10th National Convention of Statistics. Manila, Philippines. October 1-2, 2007. 12pp.

Balat, M. (2009). Global status of biomass energy use. *Energy Sources Part A,* (31), 1160-1173.

Belonio, A.T. (2000). *Design and evaluation of a rice hull carbonizer and briquette molder for biocoal fuel production and agricultural use.* Unpublished research report, University Research and Outreach Center. Central Philippine University. Iloilo City, Philippines.

Bernstein, J. (2004). Social Assessment and public participation in Municipal Solid Waste Management. Environmentally and Socially Sustainable Development (ECSSD). The World Bank.

Bhattacharya, S.C., Leon, M.A., & Rahman, M.M. (2002): A study on improved biomass briquetting. *Energy for Sustainable Development*, *6*(2). 107-110.

Bhattacharya, S.C., Sett, S., & Shrestha, R.M. (1990). Two approaches for producing briquetted charcoal from wastes and their comparison. *Energy, 15*(6). 499.

Briquetting: *An Answer to Desertification, Health Problems, Unemployment and Reforestation in Developing Communities.* A Pre-Conference Workshop during the Sustainable Resources Conference. 2003. Colorado, USA. September 29 – October 1, 2003.

Chin, C.O. & Siddiqui, K.M. (2000). Characteristics of some biomass briquettes prepared under modest die pressures. *Biomass and Bioenergy, 18*(2000), 223-228.

Curran, S. & Perecman, E. (2006). *A handbook for social science field research: Essays and bibliographic sources on research design and methods.* Sage Publications.

David, F.P. (2005). *Understanding and doing research: A handbook for beginners.* Iloilo City, Philippines: Panorama Printing, Inc. 198pp.

Demirbas, A. & Sahin, A. (1998). Briquetting waste paper and wheat straw mixtures. *Fuel Processing Technology, 55*(2), 175-183.

Foroughbakhch, R., Hernández-Piñero, J.L., & Carillo-Parra. (2014). Adaptability, growth and firewood volume yield of multipurpose tree species in semiarid regions of Northeastern Mexico. *International Journal of Agricultural Policy and Research, 12*(2), 444-453.

Furedy, C. (1993). Garbage: Exploring non-conventional options in Asian cities. *Ekistics,* (60), 358-359; ProQuest Research Library p. 93.

Grigorion, A.H. (2003). Waste paper-wood composites bonded with isocyanate. *Wood Science Technology, 37*(1), 79-89.

Grover, P.D., Mishra, S.K., & Clancy, J.S. (1994). Development of an appropriate biomass briquetting technology suitable for production and use in developing countries. *Energy for Sustainable Development. 1*(1), 45-48.

Gunsilius, E. & Garcia Cortes, S. (2010). *Waste and livelihoods: Support of the informal recycling sector in Iloilo, the Philippines.* Report for the Sector Project "Recycling Partnerships". Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Eschborn, Germany.

Gunsilius, E., Spies, S., Garcia-Cortes, S., Medina, M., Dias, S., Scheinberg, A., Sabry, W., Abdel-Hady, N., dos Santos, A.F., & Ruiz, S. (2011). *Recovering resources, creating opportunities: Integrating the informal sector into solid waste management.* Report for the Sector Project "Recycling Partnerships". Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Eschborn, Germany.

Hood, A.H. (2010). *Biomass briquetting in Sudan: A feasibility study.* United States Agency for International Development. Women's Refugee Commission. 95pp.

Huang, C., Han, L., Yang, Z., & Liu, X. (2009). Ultimate analysis and heating value prediction of straw by near infrared spectroscopy. *Waste Management, 29*(6), 1793-1797.

Immergut, E.H. (1975). *The chemistry of wood.* New York: Robert E. Krieger Publishing Company.

Ikuse, M., Yokoo, H.F., Romallosa, A.R.D., & Horita, M. (2014). How to promote a job change of dumpsite waste pickers? Evidence from a field experiment in the Philippines. Fifth World Congress of Environmental and Resource Economists. June 2014. Istanbul, Turkey. 59pp.

Kajornboon, A.B. (2005). Using interviews as research instruments. *E-Journal for Research Teachers, 2*(1).

Laryea-Goldsmith, R., Oakey, J., & Simms, N.J. (2011). Gaseous emissions during concurrent combustion of biomass and non-recyclable municipal solid waste. *Chemistry Central Journal,* (2011), 5:4.

Lee, C.C. (2007). *Handbook in environmental engineering calculations.* USA: McGraw-Hill, Inc.

Medina, M. (2000). Scavenger cooperatives in Asia and Latin America. *Resources, Conservation and Recycling, 31*(1), 51-69.

Njenga, M., Karanja, N., Prain, G., Malii, J., Munyao, P., Gathuru, K., & Mwasi, B. (2009). *Community-based energy briquette production from urban organic waste at Kahawa Soweto informal settlement, Nairobi.* Urban Harvest Working Paper Series, No. 5. International Potato Center, Lima, Peru.

NSWMC. (2009). *National framework plan for the informal waste sector in solid waste management.* National Solid Waste Management Commission of the Philippines. Quezon City, Philippines. 55pp.

Olorunnisola, A.O. (1998). The performance of sawdust briquettes combusted in a conventional coal stove. *Nigerian Journal Forestry, 28*(1), 15-18.

Olorunnisola, A.O. (2007). *Production of fuel briquettes from waste paper and coconut husk admixtures.* Agricultural Engineering International: the CIGR Ejournal. Manuscript EE 06 006. Vol. IX.

Omer, A.M. (2012). Biomass energy resources utilization and waste management. *Agricultural Sciences, 3*(1), 124-145.

Onuegbu, T.U., Ekpunobi, U.E., Ogbu, I.M., Ekeoma, M.O., & Obumselu, F.O. (2011). Comparative studies of ignition time and water boiling test of coal and biomass briquettes blend. *IJRRAS, 7*(2), 153-159.

Paclibar, N.B. (2002). *Design, construction and performance testing of a rice hull briquette molder.* Unpublished bachelor's thesis. College of Agriculture. Central Philippine University. Iloilo City, Philippines.

Paul, J.G., Jaque, D., Kintanar, R., Sapilan, J., & Gallo, R. (2007). *"End-of-the pipe" material recovery to reduce waste disposal and to motivate the informal sector to participate in site improvements at the Calahunan Dumpsite in Iloilo City, Panay, Philippines.* International Conference Sardinia 2007, Eleventh International Waste Management and Landfill Symposium, Italy, 16pp.

Paul, J.G., Lange, S., Ravena, N., & Paredes, E. (2009a). *Technical and socio-economic aspects of a 100-day material recovery test for the production of alternative fuels and raw materials (AFR) in Iloilo City, Philippines.* In: Proceedings International Conference Sardinia 2007. Eleventh International Waste Management and Landfill Symposium, Italy. 12pp.

Paul, J.G., Lange, S., & Romallosa, A.D. (2009b). *Results of a value adding test to produce alternative fuels and raw materials (AFR) for industrial purposes and for household energy supply with appropriate technologies.* In: Proceedings International Conference Sardinia 2007. Eleventh International Waste Management and Landfill Symposium, Italy. 12pp.

Paul, J.G., Arce-Jaque, J., Ravena, N., & Villamor, S.P. (2012). Integration of the informal sector into municipal solid waste management in the Philippines – What does it need?. *Waste Management, 32*(11), 2018-28.

Psomopoulos, C.S., Bourka, A., & Themelis, N.J. (2009). Waste-to-energy: A review of the status and benefits in USA. *Waste Management, 29*(2009), 1718-1724.

Quiroga, M.A., Hamhaber, J., Nehren, U. & Paul, J.G. (2011). *Assessment of a solid waste management system: social impacts on former waste pickers. Case study: San Carlos City, Philippines.* In: Proceedings of the International SWM Conference – Moving Towards Sustainable Resource Management in Hong Kong, 2-6 May 2011. 4pp.

Republic of the Philippines. (2001). *Republic Act 9003 – The Ecological Solid Waste Management Act of the Philippines.* Congress of the Philippines 2000. In: Eleventh Congress of the Philippines, Third Regular Session, Released on January 26, 2001. Quezon City, Philippines. 43pp.

Romallosa, A.R.D. & Hornada, K.J.C. (2014). *Briquetting of biomass and urban wastes using a household briquette molder.* Patubas – Multidisciplinary Research Journal. Central Philippine University, Jaro, Iloilo City, Philippines. June 2014. ISSN 1908-515X. Vol. 7(1). pp. 1-22.

Romallosa, A.R.D., Hornada, K.J.C., & Paul, J.G. (2011a). *Production of briquettes from biomass and urban wastes using a household briquette molder.* In: M. Alamgir, Q.H. Bari, I.M. Rafizul, S.M.T. Islam, G. Sarkar, & M.K. Howlander (eds) Proceedings of Executive Summary of the 2nd International Conference on Solid Waste Management in the Developing Countries. Feb. 13 – 15, 2011. Khulna, Bangladesh. 249-250.

Romallosa, A.R.D., Hornada, K.J.C., Ravena, N., & Paul, J.G. (2011b). *Testing of briquette production for household use by informal waste workers at the Calajunan dumpsite in Iloilo City, Philippines.* International Conference on Solid Waste 2011 Moving Towards Sustainable Resource Management. May 2-6, 2011, Hong Kong.

Samson, R., Stohl, D., Elepano, A., & De Maio, A. (2001). *Enhancing household biomass energy use in the Philippines.* National Research Laboratories Subcontract Number AXE-0-30001-01.

Sanada, A. & Yoshida, M. (2011). *Internalization of informal sector into formal urban waste management in low-income countries.* ISWA 2011 World Congress. October 19, 2011. Daegu, South Korea. 11pp.

Schutt, R.K. (1999). *Investigating the social world: The process and practice of research.* Second edition. California: Pine Forge Press.

Singh, A. & Singh, Y. (1982). Briquetting of paddy straw. *Agricultural Mechanization in Asia and Africa and Latin America,* 42-44.

Sivakumar, K. & Mohan, N.K. (2010). Performance analysis of downdraft gasifier for agriwate biomass materials. *Indian Journal of Science and Technology, 3*(1), 58-60.

Speight, J.G. (2008). *Synthetic fuels handbook: Properties, process and performance.* USA: McGraw-Hill Companies, Inc. 421pp.

Stanley, R. (2003). *Briquetting: An answer to desertification, health problems, unemployment and reforestation in developing communities.* A Pre-Conference Workshop during the Sustainable Resources Conference. September 29 – October 1, 2003. Colorado, USA.

Steele, S. & Taylor-Powell, E. (1996). *Collecting evaluation data: Direct observation. Program Development and Evaluation.* University of Wisconsin.

Stolarski, M.J., Szczukowski, S., Tworkowski, J., Krzyzaniak, M., Gulczynski, P., & Mleczek, M. (2013). Comparison of quality and production cost of briquettes made from agricultural and forest origin biomass. *Renewable Energy, 57*(2013), 20-26.

Tamura, K. *Waste pickers' performance and their social networks in the recyclable materials market: The case of Calajunan disposal site at Iloilo City, Philippines.* (2015). Master's thesis. The University of Tokyo. Japan. February 2015. 123pp.

The World Bank Group. (2009). Country Assistance Strategy for the Philippines 2010-2012.

Tirado-Soto, M.M. & Zamberlan, F.L. (2013). Networks of recyclable material waste-picker's cooperatives: An alternative for the solid waste management in the city of Rio de Janeiro. *Waste Management, 33*(2013), 1004-1012.

Uzun, B.B. & Kanmaz, G. (2013). Effect of operating parameters on bio-fuel production from waste furniture sawdust. *Waste Management & Research, 31*(4), 361-367.

Vassilev, S.V., Baxter, D., Anderson, L.K., & Vassileva, C.G. (2010). An overview of the chemical composition of biomass. *Fuel, 89*(2010), 913-933.

Voicea, I., Danciu, A., Matache, M., Voicu, G., & Vladut, V. (2013). Biomass and the thermo-physical-chemical properties of this related to the compaction process. *Annals of Faculty Engineering Hunedoara – International Journal of Engineering, 11*(1), 59-64.

Wallace, B.J. (2006). *The changing village environment in Southeast Asia: Applied anthropology and environmental reclamation in the northern Philippines.* USA: Routledge. 144pp.

Wehenpohl, G. & Kolb, M. (2007). The economical impact of the informal sector in solid waste management in developing countries. International Conference Sardinia 2007, Eleventh International Waste Management and Landfill Symposium, Italy, 9pp.

Wilson, D.C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. *Habitat International, 30*(2006), 797-808.

Yaman, S., Sahan, M., Haykiri-acma, H., Sesen, K., & Kucukbayrak, S. (2000). Production of fuel briquettes from olive refuse and paper mill waste. *Fuel Processing Technology,* (68), 23-31.

Yaws, C.L. (1999). *Chemical properties handbook.* USA: McGraw-Hill Companies, Inc. 779pp.

Internet References:

[1] Annan calls for greater efforts to ensure access by poor to renewable energy. http://www.un.org/apps/news/story.asp?NewsID=15483&Cr=development&Cr 1. (Accessed September 9, 2013).

[2] Ahmad Fuad, M.Y., Ismail, Z., Mohd Ishak, Z.A., & Mohd Omar, A.K. Rice husk ash. (1998). http://link.springer.com/chapter/10.1007%2F978-94-011-5862-6_62. (Accessed February 15, 2017).

[3] Biomass Conversion: Emerging Technologies, Feedstocks, and Products. http://www.epa.gov/sustainability/pdfs/Biomass%20Conversion.pdf. (Accessed September 9, 2013).

[4] Briquettor Boosts Income of Coconut Farmers. (2013). http://www.pcaarrd.dost.gov.ph/home/joomla/index2.php?option=com_ content&task=view&id=1423&pop=1&page=0&Itemid=748. (Accessed June 5, 2013).

[5] C.A. No. 158, Iloilo City Charter. http://philippinelaw.info/statutes/ca158-iloilo-city-charter.html. (Accessed October 22, 2013).

[6] Calorific Value of Waste. http://www.igniss.pl/en/calorific_value_of_waste.php. (Accessed February 5, 2015).

[7] Chaney, J.O., Clifford, M.J., & Wilson, R. (2008). An experimental study of the combustion characteristics of low-density biomass briquettes. http://www.ewb-uk.org/system/files/Joel+Chaney+report.pdf. (Accessed June 5, 2013).

[8] DIN 19747:2009-07 Investigation of solids – Pretreatment of samples, preparation and processing of samples for chemical, biological and physical tests. (2009). http://www.beuth.de/de/norm/din-19747/118510306. (Accessed May 22, 2014).

[9] DIN 51731:1996-10 Testing of solid fuels – natural wood briquettes – requirements and testing. (1996). http://www.beuth.de/de/norm/din-51731/2842397. (Accessed July 17, 2014).

[10] DIN 51732:2007-08 Testing of solid fuels – Determination of total content of carbon, hydrogen and nitrogen – Instrumental methods. (2008). http://www.beuth.de/de/norm/din-51732/98893967. (Accessed May 22, 2014).

[11] DIN 51900-2 Determining the gross calorific value of solid and liquid fuels using the isoperibol or static-jacket calorimeter, and calculation of net calorific value. (2013). http://www.cal2k.com/index.php/international-standards-din-51900-2. (Accessed May 22, 2014).

[12] DIN EN ISO 11885:2009-09 Water surface – Determination of selected elements by inductively coupled plasma atomic emission spectrometry (ICP-OES). (2009). https://www.beuth.de/de/norm/din-en-iso-11885/118931490. (Accessed May 22, 2014.

[13] Elauria, J.C. Policy and actual situation on biomass utilization in the Philippines. http://www.jie.or.jp/pdf/19[1].Prof.Elauria.pdf. (Accessed October 17, 2013).

[14] ERDB (Ecosystems Research and Development Bureau). Production of DENR Charcoal Briquettes from Forest Wastes. Philippines: Department of Environment and Natural Resources. http://erdb.denr.gov.ph/publications/denr/denr_v10.pdf. (Accessed May 29, 2013).

[15] FAO (Food and Agriculture Office) Statistics. 2000. http://apps.fao.org. (Accessed December 4, 2006).

[16] Feasibility and Impact Assessment of a Proposed Project to Briquette Municipal Solid Waste for Use as a Cooking Fuel in Rwanda. http://www.cleancookstoves.org/resources_files/feasibillity-and-impact.pdf. (Accessed September 10, 2013).

[17] Fuel Briquettes from Waste Materials: An Alternative Fuel for Cooking. Enviro-Coal and Beaverton Rotary Foundation. http://www.clubrunner.ca/Data/5100/2431/HTML/88563//How%20to%20Make%20Fuel%20Briquettes%20-%20web.pdf. (Accessed June 5, 2013).

[18] Haan, H.C., Coad, A., & Lardinois, I. (1998). Municipal waste management: Involving micro-and-small enterprises. Guidelines for municipal managers. Turin, Italy: International Training Centre of the ILO, SKAT, WASTE. http://www.skat-foundation.org/publications/waste.htm. (Accessed June 5, 2013).

[19] Heating Value. http://www.engineeringtoolbox.com/gross-net-heating-value-d_824.html. (Accessed May 23, 2014).

[20] IPCC (Intergovernmental Panel on Climate Change) Guidelines. (2006). IPCC guidelines for national greenhouse gas inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland. http://www.ipcc_nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/v2_1_ch1_Introduction.pdf. (Accessed February 2, 2016).

[21] Kuti, O.A. & Adegoke, C.O. (2008). Comparative performance of composite sawdust briquette with kerosene fuel under domestic cooking conditions. http://www.journal.au.edu/au_techno/2009/apr09/journal124_article08.pdf. (Accessed May 29, 2013).

[22] Making Fuel Briquettes from Everyday Waste. http://www.paceproject.net/UserFiles/File/Urban%20Living/make%20briquettes.pdf. (Accessed May 24, 2013).

[23] Millennium Development Goals. http://www.un.org/millenniumgoals/reports.shtml. (Accessed March 27, 2015).

[24] Mabona, M. (2013). Ndirande Nkhuni Biomass Briquette Program in Malawi. http://stoves.bioenergylists.org/ndirandebriquette. (Accessed May 25, 2013).

[25] Paul, J.G., Arce-Jaque, J., Ravena, N., & Villamor, S.P. (2012). Integration of the informal sector into municipal solid waste management in the Philippines – What does it need?. *Waste Management, 32*(11), 2012-2028. http://dx.doi.org/10.1016/j.wasman.2012.05.026. (Accessed May 24, 2013).

[26] Regions of the Philippines. http://nap.psa.gov.ph/activestats/psgc/SUMWEBPROV-SEPT2016-CODED-HUC-FINAL.pdf. (Accessed May 17, 2017).

[27] Saceda, J.F., de Leon, R.L., Rintramee, K., Prayoonpokarach, S., & Wittayakun, J. (2011). Properties of silica from rice husk and rice husk ash and their utilization for zeolite y synthesis. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-40422011000800018&lng=en&nrm=iso&tlng=en. (Accessed on February 15, 2017).

[28] Sample Size Calculator. http://www.raosoft.com/samplesize.html. (Accessed June 6, 2014).

[29] Shakya, G.R., Shakya, I. & Leon, M.A. (2014). Biomass briquetting of agricultural and forest residues and herb wastes in Nepal. http://www.researchgate.net/publication/242389350_BIOMASS_BRIQUETTING_OF_AGRICULTURAL_AND_FOREST_RESIDUES_AND_HERB_WASTES_IN_NEPAL. (Accessed October 3, 2014).

[30] The 2010 Philippine Census of Population and Housing. http://www.census.gov.ph/content/2010-census-population-and-housing-reveals-philippine-population-9234-million. (Accessed June 17, 2013).

[31] The United Nations. Sustainable Development Goals. 17 Goals to Transform Our World. http://www.un.org/sustainabledevelopment/sustainable-development-goals. (Accessed November 8, 2016).

[32] Toan, P.K., Cuong, N.D., Quy, N.T., & Sinh, P.K. (1998). Application of briquetting technology to produce briquettes from agricultural residues and by-products. http://www.faculty.ait.asia/kumar/rets/Publications/WREC%202000-IE.pdf. (Accessed October 21, 2013).

[33] Understanding Briquetting. http://www.cd3wd.com/cd3wd_40/vita/briquette/en/briquette.htm. (Accessed May 24, 2013).

[34] http://learningstore.uwex.edu/assets/pdfs/G3658-5.PDF. (Accessed October 12, 2013).

[35] http://siteresources.worldbank.org/INTUSWM/Resources/463617-1202332338898/socialassesstoolkit.pdf. (Accessed June 18, 2013).

[36] http://chooseweb.s3.amazonaws.com/ckeditor/maybepiccio/2015/03/06/iloilo-locator-3.jpg (Accessed March 4, 2017).

[37] http://www.lehrafuel.com/briquettes-manufacturing-process.html. (Accessed March 30, 2010).

[38] http://www.aseanenergy.org/download/eaef/105-2004ProjectSummaryfor web.pdf. (Accessed August 3, 2009).

[39] http://www.iloilo.gov.ph/tourism/wp-content/uploads/map3-815x1024.png (Accessed October 19, 2013).

[40] http://media.photobucket.com/user/rjb0x3s/media/panay-map.gif.html?filters[term]=panay%20map&filters[primary]=images&filters[secondary]=videos&sort=1&o=0. (Accessed October 19, 2013).

[41] http://www.census.gov.ph. (Accessed October 19, 2013).

[42] http://nro6.neda.gov.ph/?s=western+visayas+region. (Accessed March 21, 2017).

[43] http://www.swm4lgus.net. (Accessed October 22, 2013).

[44] http://www.ket.org/Trips/Coal/AGSMM/agsmmtypes.html. (Accessed March 23, 2015).

APPENDIX

Appendix A. Production rate in pcs/hr and its analysis of variance

Type of Machine	I	II	III	Mean
		Paper		
Hand-Press, new	148	149	152	150
Jack-Driven, 4x4, old	170	164	183	172
Jack-Driven, 4x4, final	206	248	212	222
		Paper + Sawdust		
Hand-Press, new	171	206	179	185
Jack-Driven, 4x4, old	230	202	187	206
Jack-Driven, 4x4, final	212	207	201	207
		Paper + Sawdust + CRH		
Hand-Press, new	126	158	158	147
Jack-Driven, 4x4, old	167	174	189	177
Jack-Driven, 4x4, final	236	249	211	232

Source of Variation	Deg of Freedom	Sum of Squares	Mean Square	Comp F	Tab F	
					0.05	0.01
Treatment	8	21,828.97	2,728.62	10.69**	2.51	3.71
Type of Machine (A)	2	16,075.63	8,037.81	31.48**	3.55	6.01
Type of Briq (B)	2	1,629.41	814.70	3.19^{ns}	3.55	6.01
A x B	4	4,123.93	1,030.98	4.04*	2.93	4.58
Error	18	4,596.67	255.37			
Total	26	26,425.63				

c.v = 8.47%

Appendix B. Production rate in kg/hr and its analysis of variance

Type of Machine	I	II	III	Mean
		Paper		
Hand-Press, new	2.10	1.82	1.85	1.92
Jack-Driven, 4x4, old	4.50	4.10	4.28	4.29
Jack-Driven, 4x4, final	3.40	3.16	3.49	3.35
		Paper + Sawdust		
Hand-Press, new	2.04	2.55	2.26	2.28
Jack-Driven, 4x4, old	5.64	4.47	4.58	4.90
Jack-Driven, 4x4, final	4.36	4.13	3.85	4.11
		Paper + Sawdust + CRH		
Hand-Press, new	2.11	2.35	2.48	2.31
Jack-Driven, 4x4, old	4.85	4.39	4.50	4.58
Jack-Driven, 4x4, final	4.40	4.69	4.55	4.55

Source of Variation	Deg of Freedom	Sum of Squares	Mean Square	Comp F	Tab F 0.05	Tab F 0.01
Treatment	8	31.63	3.95	49.38**	2.51	3.71
Type of Machine (A)	2	28.60	14.30	178.75**	3.55	6.01
Type of Briq (B)	2	2.17	1.09	13.63**	3.55	6.01
A x B	4	0.86	0.22	2.75^{ns}	2.93	4.58
Error	18	1.51	0.08			
Total	26	33.14				

c.v. = 8.07%

Appendix C. Boiling time and its analysis of variance

Type of Machine	I	II	III	Mean
		Paper		
Hand-Press, new	14.38	12.50	13.16	13.35
Jack-Driven, 4x4, old	12.00	11.83	12.00	11.94
Jack-Driven, 4x4, final	12.20	12.68	12.53	12.47
		Paper + Sawdust		
Hand-Press, new	12.80	13.40	11.58	12.59
Jack-Driven, 4x4, old	13.30	12.00	13.72	13.01
Jack-Driven, 4x4, final	12.50	12.28	12.82	12.53
		Paper + Sawdust + CRH		
Hand-Press, new	17.80	13.80	15.22	15.61
Jack-Driven, 4x4, old	19.07	19.23	19.88	19.39
Jack-Driven, 4x4, final	16.45	17.38	15.82	16.55

Source of Variation	Deg of Freedom	Sum of Squares	Mean Square	Comp F	Tab F 0.05	Tab F 0.01
Treatment	8	150.17	18.77	22.08**	2.51	3.71
Type of Machine (A)	2	5.20	2.60	3.07^{ns}	3.55	6.01
Type of Briq (B)	2	123.44	61.72	72.80**	3.55	6.01
A x B	4	21.53	5.38	6.35**	2.93	4.58
Error	18	15.26	0.85			
Total	26	165.42				

c.v. = 6.50%

Appendix D. Cooking time and its analysis of variance

Type of Machine	I	II	III	Mean
		Paper		
Hand-Press, new	17.00	19.00	16.00	17.33
Jack-Driven, 4x4, old	25.58	28.10	28.58	27.42
Jack-Driven, 4x4, final	19.80	19.45	20.35	19.87
		Paper + Sawdust		
Hand-Press, new	17.00	19.60	18.50	18.37
Jack-Driven, 4x4, old	25.25	24.02	25.10	24.79
Jack-Driven, 4x4, final	21.33	20.92	25.40	22.55
		Paper + Sawdust + CRH		
Hand-Press, new	22.00	24.00	22.00	22.67
Jack-Driven, 4x4, old	32.00	31.43	33.97	32.47
Jack-Driven, 4x4, final	21.07	23.90	22.45	22.47

Source of Variation	Deg of Freedom	Sum of Squares	Mean Square	Comp F	Tab F	
					0.05	0.01
Treatment	8	528.75	66.09	32.08**	2.51	3.71
Type of Machine (A)	2	375.43	187.71	91.14**	3.55	6.01
Type of Briq (B)	2	103.81	51.91	25.20**	3.55	6.01
A x B	4	49.51	12.38	6.01**	2.93	4.58
Error	18	37.07	2.06			
Total	26	565.82				

c.v. = 6.21%

Appendix E. Bulk density and its analysis of variance

Type of Machine	I	II	III	Mean
Paper				
Hand-Press, new	101.13	100.56	100.78	100.82
Jack-Driven, 4x4, old	689.69	688.59	691.44	689.91
Jack-Driven, 4x4, final	468.97	538.46	448.79	485.41
Paper + Sawdust				
Hand-Press, new	100.45	99.67	101.23	100.45
Jack-Driven, 4x4, old	542.28	546.91	530.59	539.93
Jack-Driven, 4x4, final	387.12	390.36	392.70	390.06
Paper + Sawdust + CRH				
Hand-Press, new	200.01	199.17	201.03	200.07
Jack-Driven, 4x4, old	563.44	567.39	579.17	570.00
Jack-Driven, 4x4, final	465.05	459.72	452.25	459.01

Source of Variation	Deg of Freedom	Sum of Squares	Mean Square	Comp F	Tab F 0.05	Tab F 0.01
Treatment	8	1,086,447.06	135,805.88	508.58**	2.51	3.71
Type of Machine (A)	2	1,014,355.27	507,177.63	1,899.29**	3.55	6.01
Type of Briq (B)	2	34,013.66	17,006.83	63.69**	3.55	6.01
A x B	4	38,078.13	9,519.53	35.65**	2.93	4.58
Error	18	4,806.65	267.04			
Total	26	1,091,253.71				

c.v. = 4.16%

Appendix F. Survey instrument used

SURVEY ON THE ACCEPTABILITY OF BRIQUETTES AS ALTERNATIVE SOURCE OF FUEL FOR COOKING
Conducted by Central Philippine University
Jaro, Iloilo City, Philippines

Dear Respondent:

Please fill-up the survey questionnaire. All your answers would be treated with utmost confidentiality. Thank you.

A. Personal Background

1	Name:	
2	Age:	
3	Address:	
4	Gender: *1=Male 2=Female*	
5	Highest Educational Attainment: *1=Elementary undergraduate* *2=Elementary graduate* *3=High school undergraduate* *4=High school graduate* *5=College undergraduate* *6=College graduate*	
6	Civil Status: *1=Single* *2=Married* *3=Widow/Widower* *4=Separated* *5=Living together*	
7	No. of Children (if applicable):	
8	Household Size:	
9	Source/s of Income:	
10	Estimated Daily Income:	

B. Waste Management/Waste Picking Background

1	UCLA member *1=Yes 2=No*	
2	No. of Years with UCLA:	
3	Level of Involvement with UCLA: (Officer, organizer, active member, if others, please specify)	
4	Years of Wastepicking in Calajunan:	
5	Years of Wastepicking in other Places (if applicable)	
6	No. of household members working in Calajunan (if applicable)	

C. Housing Condition

1	Floor Area of your House (square meters):	
2	Ownership of the House: *1=Owned 2=Rented 3=Others, please specify*	
3	Housing Condition: *1=Reasonably built* *2=Dilapidated* *3=Others, please specify*	
4	Housing Description: *1=Concrete* *2=Concrete and wood* *3=Wood* *4=Bamboo* *5=Others, please specify*	
5	No. of Rooms: *1=1 room only 3=2 bedrooms* *2=1 bedroom 4=4 bedrooms*	
6	Do you have toilet facilities? *1=Yes 2=No*	
7	Is it inside the house? (If the answer is yes) *1=Yes 2=No*	
8	Do you have electricity? *1=Yes 2=No*	
9	Do you have water source? *1=Yes 2=No*	

10	Type of Water Source *1=Water District* *2=Water Pump* *3=Get it from the neighbor* *4=Others, please specify*	

D. Kitchen/Cooking Devices

1	Type of Cooking Device (Please indicate all) and No of Units: *1=LPG Stove* *2=Wood Stove* *3=Steel Bars* *4=Stone* *5=Charcoal Stove* *6=Rice Husk (Labhang) Stove* *7=Others, please specify*	
2	Type of Fuel Used (Please indicate all) *1=LPG* *2=Wood* *3=Charcoal* *4=Rice Husk (Labhang)* *5=Sawdust* *6=Briquettes* *7=Others, please specify*	
3	Source of Fuel: *1=Bought* *2=Dumpsite* *3=Nearby places* *4=Given* *5=Others, please specify*	
4	Estimated Daily Expenses Spent on Fuels Used	

E. Acceptability/Use of Briquettes

1	Are you familiar with briquettes as fuel for cooking? 1=Yes 2=No	
2	How did you learn about it? *1=UCLA* *2=Seminar* *3=From other people* *4=Newspaper* *5=Others, please specify*	

3	Prior to the briquettes provided, do you use this fuel already? *1=Yes 2=No*	
4	Do you produce your own briquettes? (If applicable) *1=Yes 2=No*	
5	Type of Briquettes Provided *1=Pure Paper* *2=Paper + Sawdust* *3=Paper + Sawdust + Carbonized Rice Husk (CRH)*	
6	Weight and Pieces of Briquettes Provided	
7	Ways of utilizing briquettes provided *1=For cooking rice* *2=For cooking food (sud-an)* *3=For boiling water* *4=For cooking food of animals (damog)* *5=Others, please specify*	
8	Estimated no. of pieces of briquettes utilized per cooking operation?	
9	How many cooking operations or days were you able to utilize the briquettes provided?	
10	Do you find the briquettes useful as a substitute/alternative fuel for others like LPG, wood, or charcoal? *1=Yes 2=No*	
11	Did you find any problems in using the briquettes? *1=Yes 2=No*	
12	What are the problems you encountered in using briquettes? Please write your answers.	
13	Are you willing to buy briquettes if sold in the market? *1=Yes 2=No 3=Not sure*	
14	What are your reasons for using/buying briquettes? Please write your answers.	

Thank you very much for participating in this survey.

Ehrenwörtliche Erklärung

Ich erkläre hiermit ehrenwörtlich, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Die aus anderen Quellen direkt oder indirekt übernommenen Daten und Konzepte sind unter Angabe der Quelle gekennzeichnet.

Es waren keine weiteren Personen an der inhaltlich-materiellen Erstellung der vorliegenden Arbeit beteiligt. Insbesondere habe ich hierfür nicht die entgeltliche Hilfe von Vermittlungs- bzw. Beratungsdiensten (Promotionsberater oder anderer Personen) in Anspruch genommen. Niemand hat von mir unmittelbar/mittelbar geldwerte Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

Die Arbeit wurde bisher weder im In- noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.

Ich versichere ehrenwörtlich, dass ich nach bestem Wissen die reine Wahrheit gesagt und nichts verschwiegen habe.

Weimar, 18 Mai 2017 ARIES RODA D. ROMALLOSA