FEASIBILITY OF REMOTE OFF-GRID PROCESSING FACILITIES IN THE PHILIPPINES

by
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Abstract

The investigation evaluates the feasibility of moving Improv'eat operations off the grid in terms of energy and water use. Discounted cash flow and risk analyses are used to consider the practicality of incorporating renewable energy technologies (hydropower, solar photovoltaic, solar tube, biomass and combined heat and power) to meet two energy demand scenarios (21kW and 12kW). The viability of rainwater harvesting and its cost savings are analyzed to meet current water demand of 150 gallons/day. Our energy results suggest hydropower offers the highest return and least risk, while solar PV offers the lowest positive returns under all scenarios when including feed-in-tariffs. In terms of water investigation, a rainwater storage unit ~50,000 litter capacity is recommended to meet monthly water demand and provide annual cost savings of USD$103 to USD$109.

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ii. Abbreviations & Acronyms

AC	Alternating Current
AGTs	Above-Ground Tanks
BGTs	Below-Ground Tanks
BOD	Biochemical Oxygen Demand
BWSA	Barangay Water and Sanitation Association
CHP	Combined Heat and Power
CBO	Community Based Organization
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CPV	Concentrating Photovoltaic
DC	Direct Current
DCF	Discounted Cash Flow
DENR	Department of Environment and National Resources (The Philippines)
DO	Dissolved Oxygen
DOE	Department of Energy (The Philippines)
EIA	Energy Information Administration (USA)
EMB	Environmental Management Bureau
EPIRA	Electric Power Industry Reform Act
ERC	Energy Regulator Commission (The Philippines)
FiT	Feed-in-Tariff
GMO	Genetically Modified Organism
GOCC	Government Owned and Controlled Cooperation
IRR	Internal Rate of Return
JMP	Joint Monitoring Program

LHV	Lower Heating Value
LGU	Local Government Unit
LWUA	Local Water Utilities Administration (The Philippines)
MDG	Millennium Developmental Goal
MTOE	Million Tons of Oil Equivalent
NIA	National Irrigation Administration (The Philippines)
NPC	National Power Corporation (The Philippines)
NPV	Net Present Value
NREB	National Renewable Energy Board (The Philippines)
NSCB	National Statistical Coordination Board
NSO	National Statistics Office (The Philippines)
NWRB	National Water Regulatory Board (The Philippines)
ORC	Organic Rankine Cycle
PEP	The Philippines Energy Plan
PHP	Philippine Peso
PPWS	Potential for Potable Water Savings
PV	Photovoltaic
PWD	Potable Water Demand
RWH	Rainwater Harvesting
RWSA	Rural Waterworks Sanitation Association
WESM	Wholesale Electricity Spot Market
WD	Water District
WRR	Water Resource Region

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Introduction

Improv'eat is seeking Nicholas School of the Environment analytical consulting to make its manufacturing more sustainable by evaluating the feasibility of moving its production off-grid, in regards to its energy and water use for its current and future operations.

Client Description

Since 2007, Improv'eat is a start-up company committed to supplying its consumers with convenient, tasteful, sustainable, and trustworthy food. Its key product, Coconut Wraps, is a tortilla substitute that is gluten-free and non-GMO certified. Its product is sold to US, Canada, Europe and Australia. Improv'eat operations are located at the source of wild coconuts in the Duero municipality of the province of Bohol, Central Visayas Region. This is the 10th largest island in the Philippines archipelago (*Figure 1*). Due to its sustainable mission, Improv'eat relies on the Nicholas School team to assess the feasibility of making the Coconut Wraps production off-grid for electricity generation, in current and future operations, while also taking into consideration other impacts related to efficient water use and financial capabilities (www.improveat.com).

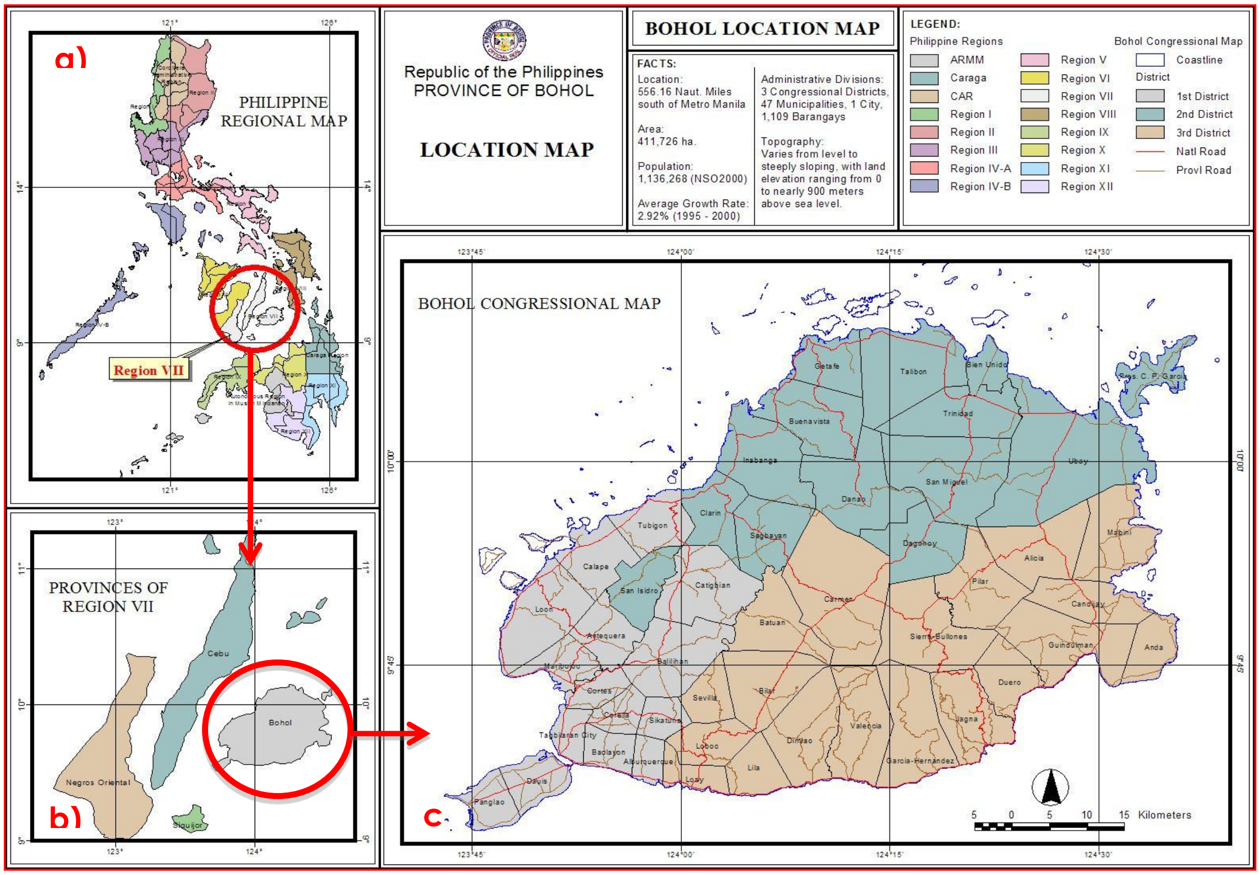

Figure 1. Study site location map. a) Philippine archipelago b) region VII Central Visayas c) Bohol Province

Note: Client operations located in Duero municipality.

Source: Woodfields Consultants Inc 2010

Improv'eat Operations in the Philippines

The estimate of total water use by the facility is of 150 gallons a day and total energy requirement for current operation is 21 kW (T. Fitts, pers. comm., Nov. 2013). The breakdown by individual electrical unit is shown on *Table 1*. It can be seen that the use of blenders and dehydrators dominate the electricity requirements for current operations at 5.4 kW and 9.6 kW. The client is currently working on renewable heating equipment to replace the dehydrators, and is hoping to reduce the total demand to 12 kW.

Table 1. Estimated Electricity Demand for Current Improv'eat Operations

Device	Power (kW)	Duration/day (hours)	Time of day
Blendtec Blenders *	5.4	20	4 to 24

Excalibur Dehydrators	9.6	24	all day
Lights - Day	1.12	12	6 to 18
Lights - Night	1.68	12	0 to 6, 18 to 24
2hp Window AC	1.8	12	4 to 24
Heat sealer *for packaging	0.5	2	18
Heat stamper	0.15	1	18
Wall fans	0.4	16	6 to 22
Refrigerators	1.07	22	2 to 24
Total power	21.7		
Total power without dryers	12.1		

Source: T. Fitts, personal communication, November 2013

Based on this electrical usage, the facility's demand load is shown in *Figure 2*. The facility is currently relying on grid electricity and utility water for operation; however since October 2013 production has been interrupted due to brownouts[1] and natural disaster events (i.e. Typhoon Haiyan). These disruptions in operations epitomize the potential business value provided by off-grid operations that meet the facility's energy and water demand.

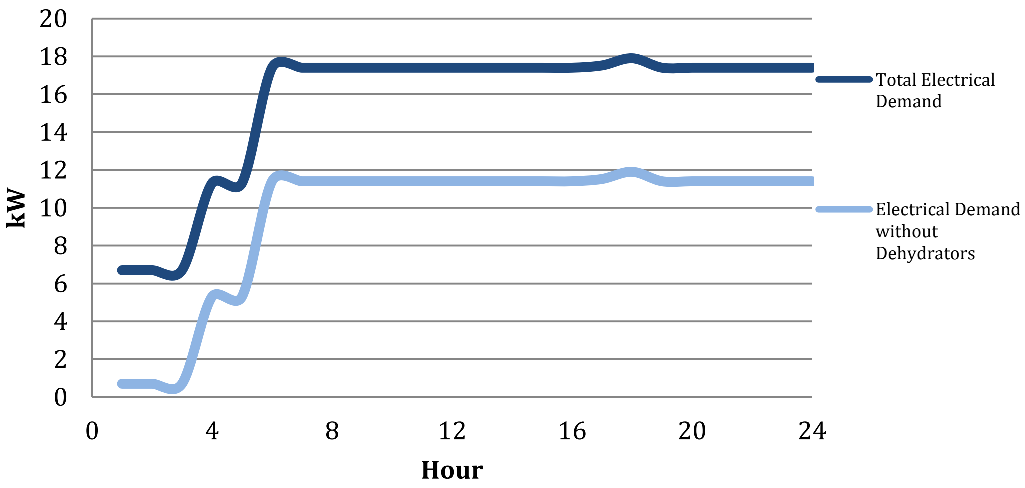

Figure 2. Improv'eat daily load demand curve for current electricity consumption.
Note: Two scenarios are investigated, with the current dehydrators and without.
Source: T. Fitts, personal communication, November 2013

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[1] A **brownout** is an intentional or unintentional drop in voltage in an electrical power supply system.

Improv'eat's unique manufacturing process begins with de-husking and washing of the coconuts, which are subsequently cracked, scraped and prepared into the proprietary mix. After undergoing filtration the coconut batter is spread on trays that are placed into the dehydrator to form the individual wraps. Each item is then inspected and packaged to be kept at room temperature or as low as 4°C prior to shipping. The current floor plan of the operations is shown on *Figure 3*. The floor plan was shared to give a better understanding of our client's facility and the area constraints faced by the physical operation when considering the technological and logistical implementations discussed in the investigation. We will refer back to the floor plan in our investigation.

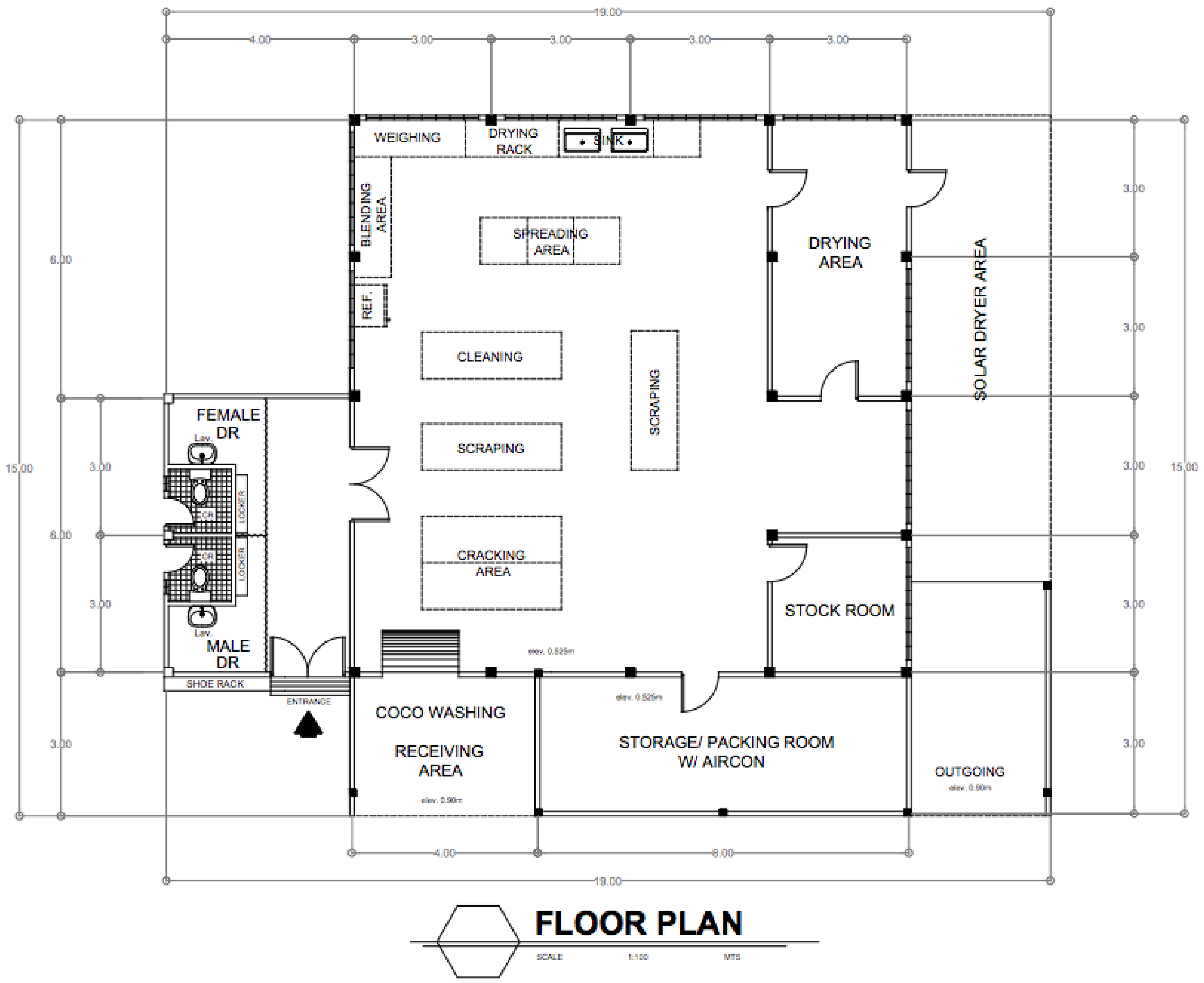

Figure 3. Current floor plan of Improv'eat operations in Duero municipality.
Source: T. Fitts, personal communication, November 2013

Project Outline

This investigation evaluates the feasibility of incorporating five renewable energy technologies and rainwater harvesting to meet our client's current and future energy and water demands. The report is divided into three parts – (1) an overview of the energy and water landscape in the Philippines; (2) the energy analysis; and (3) the water analysis. The objective is to provide our client with the current overview of Philippine energy and water utility sectors and investigate the practicality of moving current operations off the grid. The analysis includes potential risks and opportunities within each technological innovation explored. Analysis of various scenarios will be used to assess which off-grid technologies best meet our client's goals of obtaining cheap, reliable, and clean energy and water. Ultimately, implementation of one or more of these technologies should provide Improv'eat with means to improve its energy and water footprint in its onsite production of Coconut Wraps.

Part I: Energy and Water Outlook

This part provides an overview of the energy and water landscape and each sector's performance in the Philippines. It is meant as an introductory rationale for the benefit of off-grid production. Section I focuses on the Philippines current energy capacity and power sector efficacy, Section II gives an overview of the available water resources in the Philippines, the current water utility performance, and challenges to water management in the country. Such background provides our client with rationale to switch to more efficient, reliable, sustainable and autonomous operations. When possible we address data related to the Duero municipality and overall Bohol province, which is of interest to our client.

I. The Philippines Energy Outlook

The Philippines are a high-growth economy in Southeast Asia, whose power sector will be challenged in the near future given forecasts of projected demand exceeding the committed capacity (KPMG 2013). In 2012 electricity coverage reached 78.75% of households and almost 100% at *barangay* level[2]. Nevertheless, the government has committed to the target of 90% household electrification by 2017 (The Philippines DOE 2012a.).

The country's primary energy supply increased 7.7% from 2011 to 2012, reaching 42.9 MTOE (APEC 2013). The Philippine energy market distinguishes itself through its reliance on imports, mostly oil and coal, to meet the increasing domestic demand that leads to national self-sufficiency of only 60% in 2011 (See *Appendix 1* for energy production and net import historical values and projections from 1990-2035). The country's self-sufficiency may become a problem in future projections if more energy generation systems are not

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[2] A **barangay** is the smallest administrative division in The Philippines.

installed to match the estimated increase in demand from population growth, economic expansion, and urbanization trends (The Philippines DOE 2012a.).

Installed Capacity

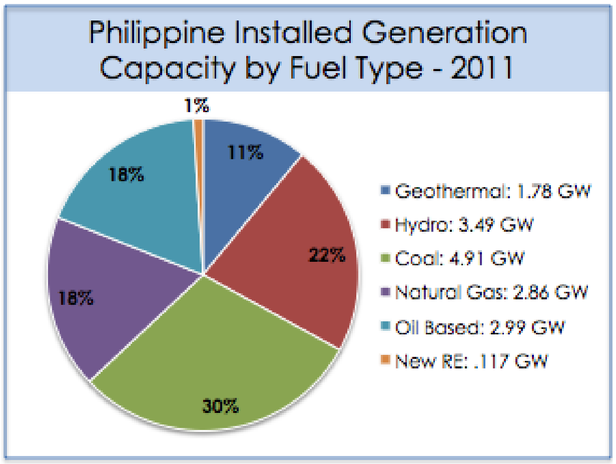
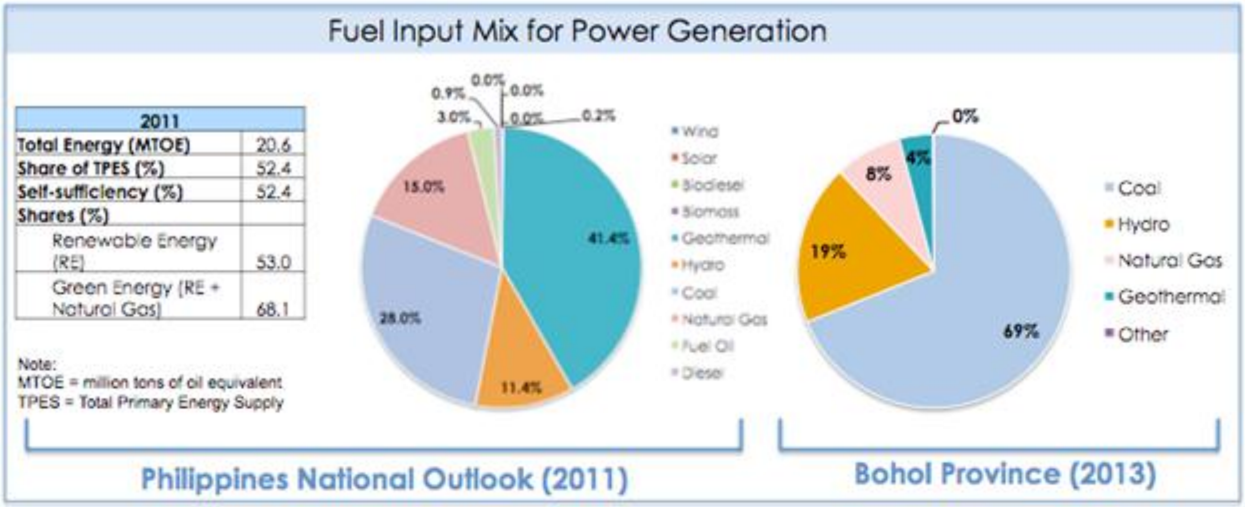


Figure 4. The Philippines Installed Generation Capacity by Fuel Type (2011).
Source: KPMG 2013

In 2012, installed capacity increased 6% at 17.04 GW (The Philippines DOE 2012a.) from 16.16GW in 2011 (KPMG 2013). *Figure 4* shows individual fuel type contribution to installed capacity in 2011. Fossil fuels dominate the mix, primarily due to their contribution to the transportation sector. The installed electricity generating capacity is expected to increase over 58GW by 2035 (APEC 2013). For the Visayas region, where our client operations are located, generation capacity increased 2.3% in 2012 from the previous year totaling 2,393 MW, mostly attributed to the region's vast potential for geothermal sources (The Philippines DOE 2012a; APEC 2013).

The Philippines have great prospects for renewable energy development with significant hydroelectric and geothermal operations already in place. In fact, estimates suggest, that with significant investment, the untapped renewable resource potential may contribute more than 50% of the country's energy by 2020 (Greenpeace 2013). Of the renewable energy sources, geothermal energy is expected to provide the largest contribution since The Philippines are already the second largest producer of geothermal in the world (Greenpeace 2013). Other renewable energy sources include biomass, wind, and solar energy application's feasibility are under investigation by the Philippine Government.

In terms of power generation by fuel type, the contribution of oil products is decreased (3.9%) while geothermal (41.4%) and coal (28%) shares are increased (*Figure 5*). The particular energy generation mix in Bohol, where the current facility is located, is 69% coal (Bohol I Electric Cooperative, Inc. 2014). By comparison, the US uses about 39% coal (EPA 2014). Not only is most of the electricity dirty, but also it is expensive, as will be discussed later. To improve reliability, lower costs, and increase sustainability, Improv'eat is exploring several off-grid technologies that the team will analyze.



2011	
Total Energy (MTOE)	20.6
Share of TPES (%)	52.4
Self-sufficiency (%)	52.4
Shares (%)	
Renewable Energy (RE)	53.0
Green Energy (RE + Natural Gas)	68.1

Note:
MTOE = million tons of oil equivalent
TPES = Total Primary Energy Supply

Figure 5. Fuel input mix for power generation in the PHL (2011) and Bohol province (2013).
Source: The Philippines DOE 2012b & Bohol I Electric Cooperative, Inc. 2014

Philippine Energy Policy

Historically the Government of the Philippines' ineffective management of the energy sector led to the 1990's power crisis. The National Power Corporation (NPC) was unable to operate and maintain plants or ensure cost recovery of its projects. Ultimately, this led to significant national debt, discouragement of private investment and widespread power shortage. The Government's response was the Electric Power Industry Reform Act (EPIRA) of 2001. Its objective was to motivate privatization efforts, particularly in the assets of the National Power Corporation (NPC), and create the Wholesale Electricity Spot Market (WESM) that was incorporated to the Visayas in early 2011 (KPMG 2013). Presently, the Philippine Department of Energy has created the Philippine Energy Plan (PEP) 2012-2030 to ensure the delivery of energy that is both dependable and sufficient to meet the projected population and economic growth rates (APEC 2013).

Regarding renewable energy policy, the Renewable Energy Act of 2008 was passed to incentivize the development and utilization of renewable energy particularly in the commercial sector (APEC 2013). The Act was motivated by the forecasted increase in dependency of the Philippines in energy imports. Furthermore in 2013, the Renewable Energy Board (NREB), the Philippines' Energy Regulatory Commission (ERC) and the Philippines Department of Energy (DOE), adopted a Feed-in Tariff (FiT) (The Philippines DOE, 2013). Originating in Europe, FiT has proven to be a great policy instrument to encourage renewable generation through renewable energy payments. Extra energy generated onsite through renewable resources can be sold back to the utility companies for a fixed period of time. Such FiT policy is relevant to our client because it might provide leverage and incentives for Improv'eat's off grid production. However, the effective implementation of FiT is debatable given the power sectors ineffective management previously discussed.

Key Challenges

Grid connectivity and strengthening. The Philippines suffer a geographical constraint of being an island nation, which leads to a complex energy system consisting of three major power grids: Luzon, Visayas (location of Improv'eat facility) and Mindanao. Interconnectedness of these grids would help energy supply dependability (KPMG 2013; APEC 2013). *Appendix 2* shows the installed power system of the Bohol Province.

Ensure energy security and expand energy access. Given the projected growth in demand, all three major regions in the Philippines (Luzon, Visayas and Mindanao) require substantial and continued capacity addition. Inability to do so may jeopardize electrification coverage at household level and commercial viability of business operations (KPMG 2013). This additional capacity, such as upgrade and expansion of transmission lines and development of the potential in renewable technology, will come with its own expense, substantial investment in infrastructure and development of the energy sector coverage and quality (The Philippines DOE 2012b).

High electricity rates. As an island nation, the Philippines also experiences high electricity rates. The average retail rate of electricity in the Philippines in 2011 was 18.1 US cents per kWh (Belena 2011). *Figure 6* expresses the results of a 2012 comparative study on weighted average of retail electricity tariffs, which ranks the Philippines as the 9th highest of the 44 markets investigated, and 24% above the average (See *Appendix 3* for average retail electricity tariffs of the 44 markets surveyed).

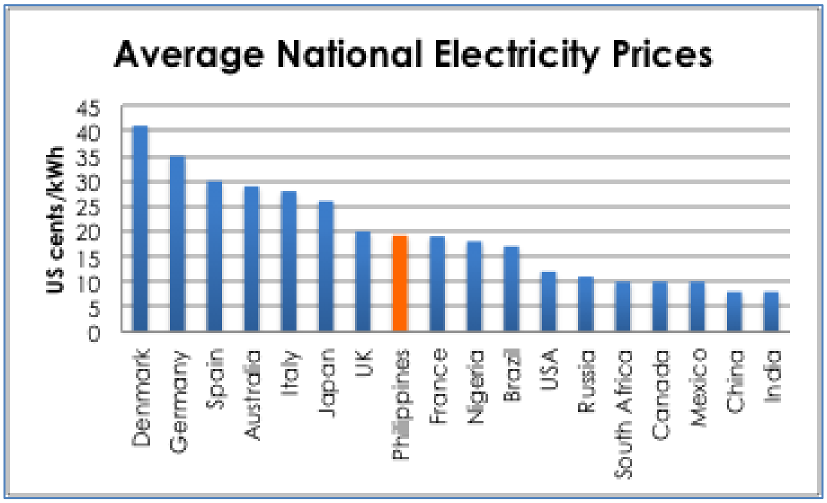


Figure 6. Average national electricity prices for various countries compared to the PHL.
Source: IEC 2012

The main contributors to these high rates are: (i) higher financing costs due to debt, (ii) geographical challenges of being an island nation that raise transmission costs, (iii) smaller grid size compared to regional counterparts, (iv) dependency on oil and coal imports priced at international market rates and (v) use of cross-subsidy in transmission rates (APEC 2005; IEC 2012). These rates will be further exacerbated by the global future trends of increasing electricity demand, need for CO2 emissions reduction, constraints on existing networks due to natural disasters and population growth, insufficient technological availability and inefficient government regulations.

Need for climate proof energy sector. Also important to note is the energy sector's vulnerability to extreme weather patterns, which in the past have led to widespread brownouts and interruption of production for the industrial and commercial sectors, and specifically, our client's operations. Only in 2013 our client suffered from both Typhoon Haiyan and small earthquakes in the Bohol island (T. Fitts, pers. comm., Dec 2013). Such climate risk requires mitigation by industry sector-specific climate change adaptation strategy to address the impacts of these potential future storms in the energy systems and infrastructure in place (The Philippines DOE 2012a).

II. The Philippines Water Outlook

Freshwater Resources

Table 2 outlines the water supply and use in the Philippines from multiple sources. In 2013, the Philippines had a total of 479 billion m^3/yr of renewable water resources, including surface water and groundwater. Surface water pertaining to rivers and lakes; encompass the majority of the water resource potential, with a total dependable surface water supply of 206.23 billion m^3/yr (*Table 2*). These waters are also used for transportation and fishing (WEPA 2012).

Table 2. Water sources and use in the Philippines.

Renewable Freshwater Resources		
Long-term average precipitation	2,380 mm/yr (1990-2009) (4)	
A renewable water resources (long-term average)	479 billion m^3/yr (2)	
Total Dependable Surface Water Supply	206.23 billion m^3/yr (2013) (5)	
Total Available Groundwater Supply	20.2 billion m^3/yr (2013) (5)	
Actual Annual Renewable Water Resources Per Capita	4,965 m^3/inhabitant (2012) (2)	
Water Withdrawal		
Total Water Withdrawal	81.55 billion m^3/yr (2009) (3)	
	Agriculture	83-85% (2013) (5)
	Industry	10% (2009) (1)
	Municipal (including domestic)	7.6% (2009) (1)
Total Water Withdrawal per Capita	889 m^3/yr (2009) (3)	
% of total actual renewable freshwater resources withdrawn	17% (2009) (2)	
Groundwater withdrawal as % of total freshwater withdrawal	4% (2009) (2)	
Access to Drinking Water		
Access to Improved Drinking Water Sources	Total Population	91% (2008) (3)
	Urban Population	93% (2008) (3)
	Rural Population	87% (2008) (3)

Source: (1) WEPA 2012; (2) UN Water 2013; (3) FAO - Aquastat 2011; (4) World Bank 2014, (5) ADB 2013

The country's groundwater supply consists of a reservoir with aggregate area of 50,000 km², and a total dependable amount of 20,200 million m³/yr. This reservoir serves as a source of water for drinking and domestic purposes (*Table 2*) (ADB 2013). In fact, 80% of piped water supply systems and 50% of drinking water sources tap groundwater as their main supply (WEPA 2012). However, groundwater monitoring of coliform concentrations by the Environmental Management Bureau (EMB), suggests that the majority of sites do not meet international groundwater quality standards (WEPA 2012).

Furthermore, the freshwater supply in the Philippines is not equally distributed amongst the country's territories (ADB 2013). *Table 3* shows surface and groundwater potential by Water Resource Region (WRR) (See *Appendix 4* for a map delineating each region). Improv'eat operations in Bohol are located in Water Resource Region VII (highlighted in red below).

Table 3. Water Resource Potential, by Region.

Water Resource Region (WRR)	Surface Water Potential (MCM)	Groundwater Potential (MCM)	Total
I	3,250	1,248	4,490
II	8,510	2,825	11,335
III	7,890	1,721	9,611
IV	6,370	1,410	7,780
V	3,060	1,085	4,145
VI	14,200	1,144	15,344
VII	**2,060**	**879**	**2,939**
VIII	9,350	2,557	11,907
IX	12,100	1,082	13,182
X	29,000	2,116	31,116
XI	11,300	2,375	13,675
XII	18,700	1,758	20,458
Total	125,790	20,200	145,99
% Share	86.16	13.84	100

Note: Region VII (highlighted in red) represents the Central Visayas Region where our client's current operations are located.
Source: World Bank 2003

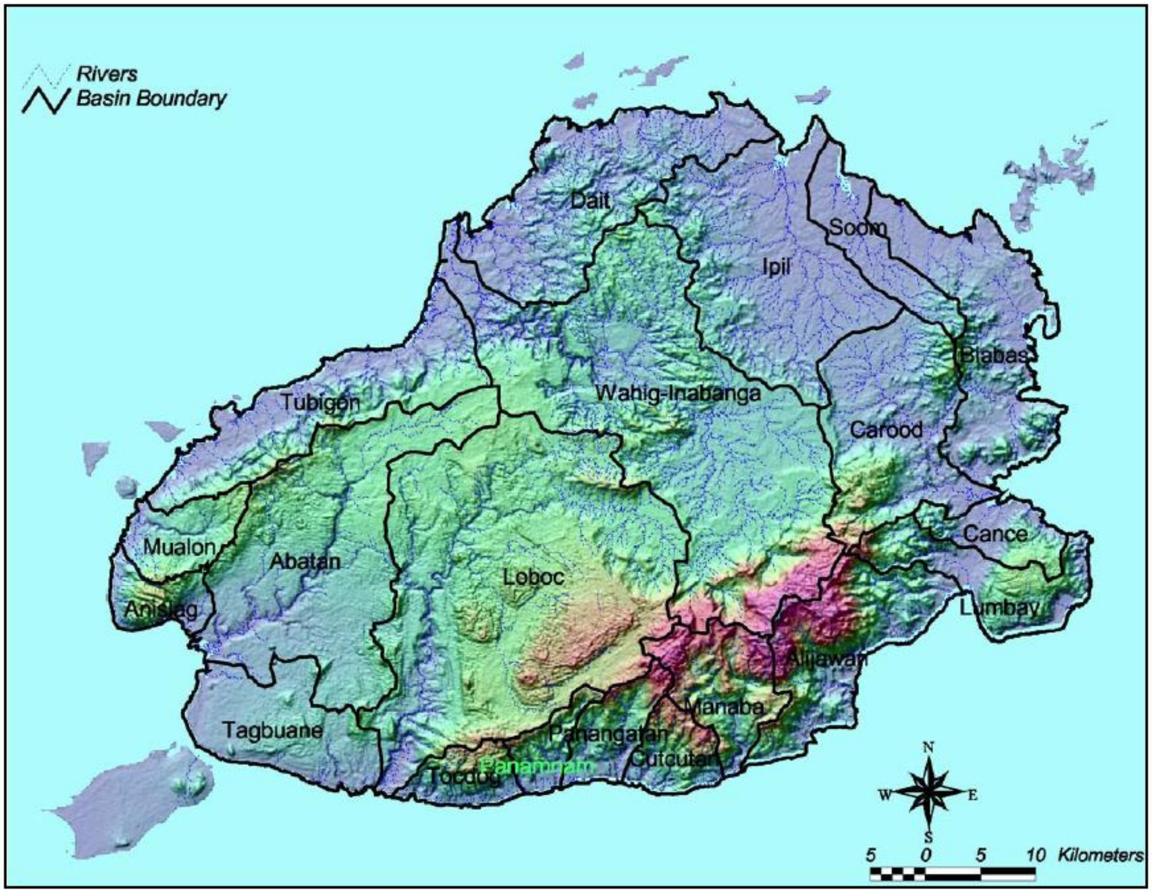


Figure 7. River Basins in the Bohol Province.
Source: Woodfields Consultants Inc 2010

The province of Bohol has 81 river basins (*Figure 7* above). However, even though there is ample water availability, the current water supply of 40,408 m^3/day and the current infrastructure of the water systems in place will not be able to sustain future increased water demand of the region (See *Table 4* for consistently increasing trend in water demand by sector). In fact, some water systems already in place do not meet local demand (Woodfields Consultants Inc. 2010).

Table 4. Summary of Projected Demand per User Category.

Demand Category	Demand (m3/d)					
	2010	2015	2020	2025	2030	2035
Domestic	59,985	94,769	112,526	131,073	143,411	152,195
Commercial/Industrial	4,007	5,000	13,155	15,480	16,543	17,273
Institutional	2,996	3,272	3,965	5,490	5,790	6,024
Tourism	1,954	3,387	3,675	5,249	5,249	5,249
Industrial Estate	-	11,985	21,420	21,420	21,420	21,420
Total	68,942	119,433	154,744	178,712	192,413	203,011
Non-Revenue Water*	37,122	29,858	38,685	44,678	48,103	50,753
Average Daily Demand (Total Water Demand)	106,064	149,291	193,430	223,390	240,516	253,764
Maximum Day Demand	134,499	188,924	244,840	281,637	303,223	319,906
Yearly Average Day Demand (mcm/yr)	38.71	54.49	70.60	81.54	87.79	92.62

Note: Non-revenue water accounts for real losses (leaks) and apparent losses (metering inaccuracies) in the system.
Source: Woodfields Consultants Inc 2010

Threats to the Philippines Water Resources

Rapid population growth. For the last four decades, the Philippines and Malaysia, have the largest annual population growth rate in Southeast Asia at 3.7%. This the population increased from 40.9 million inhabitants in 1975 to 87.8 million in 2010 (WEPA 2012). Such rapid population growth will significantly increase water consumption, as well as demand for food production and energy. This will lead to increased withdrawal for irrigation and energy cooling.

Increased urbanization. In 1975, 36% of the population lived in urban areas, while in 2010 49% of the population consists of urban dwellers (WEPA 2012). The migration from rural areas to cities continues to increase while water utility service coverage and infrastructure remains the same. This conglomeration leads to inadequate supply and/or quality of water, especially to lower classes (ADB 2013). Insufficient storage, distribution and access to clean water become even more apparent issues during the dry seasons and drought incidents (Naz, 2012/2013; WEPA 2012).

Increased run-off from agricultural lands. Amongst non-point sources, agricultural run-off is the major culprit in water quality deterioration to local Philippine rivers (Naz, 2012/2013). Runoff contains fertilizers and organic material that stimulate algal production and microbial decomposition, and may reduce oxygen concentration. This is known as biochemical oxygen demand (BOD). When more oxygen is consumed than produced by photosynthesis or replenished by mixing, the oxygen concentration in the water, also referred to dissolved oxygen (DO), becomes depleted. Larger concentrations of organic materials in the water can foster algal growth, which will further deplete the watershed. A comparative river water quality study suggests that between 2003 and 2010, the majority of in-situ rivers experienced increased BOD concentration and did not meet Department of Environment and Natural Resources minimum criterion of DO (WEPA 2012).

Wasteful and inefficient use. This is usually attributed to leaks originating from unmanaged infrastructure or open defecation. These factors negatively contribute to water quality and aggravate the reports of water-borne disease (WEPA 2012; NEDA 2010).

High deforestation rates. Forest cover is at risk to increased economic expansion, agriculture and urbanization (APEC 2013). Due to exploitation for sources of timber and biofuel in the Bohol region, only 25.44% of the land area is still forested (DILG 2003). Watersheds are particularly at risk because they are less adaptable and more sensitive to sedimentation of waterways and runoff (ADB 2013). Given that watersheds also provide the ecosystem service of water purification, the overall impact to water resources is exacerbated. Critical watersheds in the Bohol region include Alejawan (or Duero), Loboc and Wahig-Inabanga Watershed Forest Reserve. The conservation of existing watersheds and rehabilitation of critical watersheds will help regulate water flow, control soil erosion and minimize water pollution (DILG 2003).

Excessive groundwater withdrawal leading to saltwater intrusion. Saltwater intrusion occurs when communities exploit the groundwater through well development.

This is a major issue in metropolitan areas such as Cebu, Davao City and Metro Manila and coastal regions (ADB 2013; Naz, 2012/2013).

Climate Change. Climate change likely will have two specific impacts from extreme events. First, potential changes in mean and extreme precipitation patterns will increase the severity of droughts and/or floods. In fact, future modeling in high CO2 emission scenarios suggests that between July and August rainfall will likely increase, while December through February rainfall will decrease under high CO_2 emission scenario (ADB 2013). Second, the Philippines will experience a possible increase in severity and frequency of natural disasters, such as typhoons and earthquakes that can damage existing infrastructure and lead to increased flood risk (ADB 2013; Naz 2012/2013; World Bank 2005). The Philippines are prone to experience torrential storms that in the past have proven costly and damaging to existing infrastructure (APEC 2013).

Logistical Challenges to Water Availability within the Philippines Water Sector

The Philippines fortunately met the Millennium Developmental Goal (MDG) of 90% national coverage of water supply to its population by 2010 (Government of the Philippines, 2007). However, the National Statistics Office (NSO) does not agree with this value suggesting a national coverage of 85% (Government of the Philippines 2012). Either way, the prevalent inequality is apparent in the available infrastructure, especially when comparing rural to urban areas. *Figure 8* shows the existing private piped water systems in place in Bohol province.

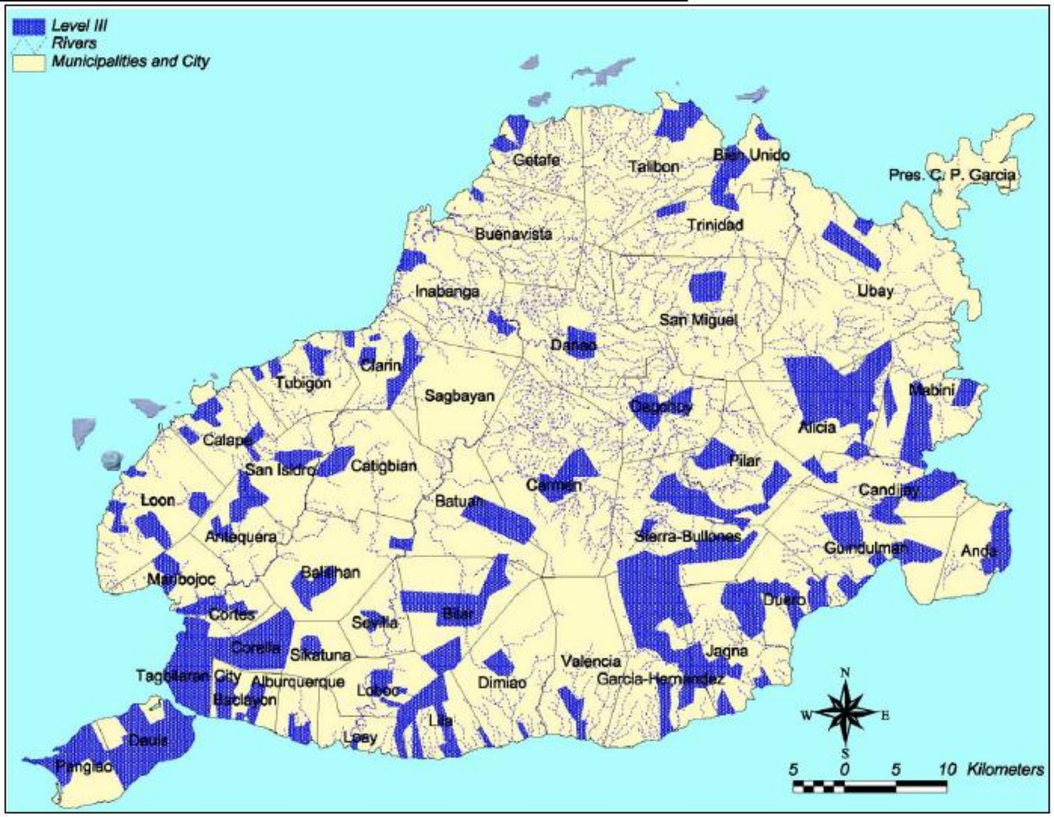


Figure 8. Existing Water Supply in Bohol Province.
Note: Level III Systems are private piped water systems or household service systems
Source: Woodfields Consultants Inc. 2010

Institutional Fragmentation. The Philippines water sector is highly decentralized, consisting of an assortment of over 5,000 water service providers ranging from Water Districts (WDs), systems managed directly by Local Government Units (LGUs), Community Based Operations (CBOs), Rural Waterworks Sanitation Associations (RWSAs), Barangay Water and Sanitation Associations (BWSAs), cooperatives, and private developers (World Bank 2005). This complicates the harmonization of enforcement strategies and policy reform implementation. Also, this decentralized organization leads to some water service providers being too small in scale, lacking autonomy to work efficiently (ADB 2013).

Additionally, over 30 agencies have some role in water resource management. The lack of a recognized sector leader results in entities with overlapping responsibilities, lack of coordination and inefficient communication, that hinders governmental capacity of the water sector (See *Appendix 5* for the key agencies involved in water management in the Philippines and their relevant roles). Thus overlapping and conflicting policies are enacted with little or inadequate enforcement (ADB 2013; Naz 2012/2013). In the Bohol Province, the National Irrigation Administration (NIA) is the agency responsible for accepting, investigating and processing water permit applications of the National Water Resources Board (NWRB) (Woodfields Consultants Inc 2010).

Inadequate data monitoring and gathering. There are no harmonized and comprehensive national database or information systems in place to track water supply coverage and performance. This lack of data is partially due to lack of resources by governmental agencies (Naz 2012/2013). Such deficiency inhibits appropriate planning and development of built infrastructure and governmental policy (ADB 2013).

Poor performance of many water utilities. Poor performance is correlated with ineffective allocation of water resources and regulation (ADB 2013). Since there is a lack of information systems in place, monitoring of water utilities performance is complicated, as discussed above. This lack of data also results in high levels of non-revenue water[3], that furthers inefficiency in the system. Studies also suggest that water utilities are not meeting performance standards for water service in terms of freshwater access, hours of service provided, compliance to drinking water standards and effective cost recovery strategies, particularly in the case of utilities run by LGUs (World Bank 2009). The same study suggests that WDs perform better than other WSPs (World Bank 2009).

*Limited access to financing for service expansion, climate change adaptation and natural resource management programs***.** Aside from the two concessionaires in Metro Manila there is very low private investment in the water sector and minimal public sector

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[3] Non-revenue Water (NRW) is water that is lost before reaching the end consumer. Loss is attributed to physical losses, such as leaks, or apparent losses such as metering inaccuracies.

financing through governmental funds. Many water utilities face financial difficulties for charging low tariffs that do not satisfy cost recovery (Naz 2012/2013; ADB 2013).

Inadequate support for poor urban communities and rural water utilities. Limited funds are available for grants and most is spent in urban areas, especially Metro Manila (ADB 2013). Furthermore, water distribution to isolated areas would require substantial investment in infrastructure where costs may not be easily recovered.

Part 2: Energy Analysis

Our energy analysis is divided into eight sections. First, we describe the methodology used to compare the energy technology investigated. The next five sections elaborate on natural lighting technology, solar photovoltaic, hydropower, biomass and combined heat and power. These sections investigate the feasibility of each technology to meet Improv'eat demand. Wind technology was not explored given that it is not viable for current operations. Finally, sections VII and VIII provide recommendations and conclusion statements.


Source: Tusk Energy Solutions 2012


Source: Dev-Dhan Enterprise 2010


Source: Inhabitat 2014

I. Methodology

Here we review the two analytic approaches used to compare the energy technologies investigated: solar tubes, solar photovoltaic, hydropower biomass and combined heat and power (CHP). First, the Discounted Cash Flow (DCF) analysis helps to formulate the business case for these technologies. Second, the benefit and risk discussion helps to elaborate on the current situation in the Philippines and potential future development.

Discounted Cash Flow Analysis

Discounted Cash Flow analysis is used in the financial viability evaluation of all five renewable energy projects considered in this report. Discounted Cash Flow is a common approach to estimate the performance of an investment opportunity spread over time. It adjusts the time value of money and helps decision makers compare certain investment opportunities with alternative investments (Damodaran 2013).

For each year during the project life, benefits and costs are evaluated. The sum of discounted net of each year forms the net present value (NPV), as well as the internal rate of return (IRR) is obtained from the undiscounted cash flow. Payback is calculated as the time it takes for the project to pay back the capital investment that is the project cost divided by the annual benefits without discounting.

The net present value (NPV) can be calculated by the following:

(Eq. 1)
$$\boldsymbol{NPV} = \frac{\mathrm{PV}_1}{(1+\mathrm{r})^1} + \frac{\mathrm{PV}_2}{(1+\mathrm{r})^2} + \cdots + \frac{\mathrm{PV}_\mathrm{n}}{(1+\mathrm{r})^\mathrm{n}}$$

Where PV is the cash flow for each year and r is the discount rate, or WACC, weighted average cost of capital.

Forecasting Benefits

We consider the benefits of the renewable energy projects to be two-fold. First, there is the avoided cost of buying electricity from local utility companies. In our forecasting analysis, an escalation is applied to the rate. This escalation is based on past electricity price history and price forecasting information provided by relevant government agencies.

Second, there is a Feed-in-Tariff (FiT). Recall that the Philippines adopted a FiT system targeting different technologies since 2013 (The Philippines DOE, 2013).

Risk Analysis – Scenario Forecasting

We consider a set of variables that might affect the viability of the renewable projects and demonstrate the business risk resulting from capital cost level and discount rate, as well as project sizing. We consider three discount rate scenarios - 9%, 15% and 20% based on our client's need. These rates were suggested by our client who wants to incorporate a large range of rates into the model to account for uncertainties, particularly those due to natural disasters and climate risk.

Capital costs are more variable for some of the renewable energy projects that have not yet been widely commercialized. This includes the biomass and the combined heat and power technology. Due to the vastly different cost information obtained (i.e. biomass $2000 to $10000), we consider scenarios of high cost and low cost conditions for these technologies with wide variation.

Lastly, due to the uncertainty in the facilities source of heat for the drying process during production (i.e. dehydrators), we consider energy projects with two nameplate capacities. The first is a 21 kW system, assuming that the facility continues to use mechanical dryers to dry their product. The second scenario is a 12 kW system, assuming a source of heat other than the current dryers that use significantly less amounts of electricity. This scenario drops the on-site generation to meet a lower load demand. Due to economies of scale, the cost varies across the two conditions (i.e. 12 kW and 21 kW).

II. Natural Lighting – Solar Tube Technology

Solar tubes are gradually becoming great substitutes for light bulbs. These tubes can take advantages of the daylight and help save electricity from compact florescent lamps (CFL) or incandescent lighting. A single tube can be installed on the roof and usually looks like a 10- or 14-inch-diameter metal tube with polished interiors. Solar tubes are now commercially available from the retailers such as Lowe's Home Improvement and are reported to have effective cost savings (Skylight Solutions 2013).

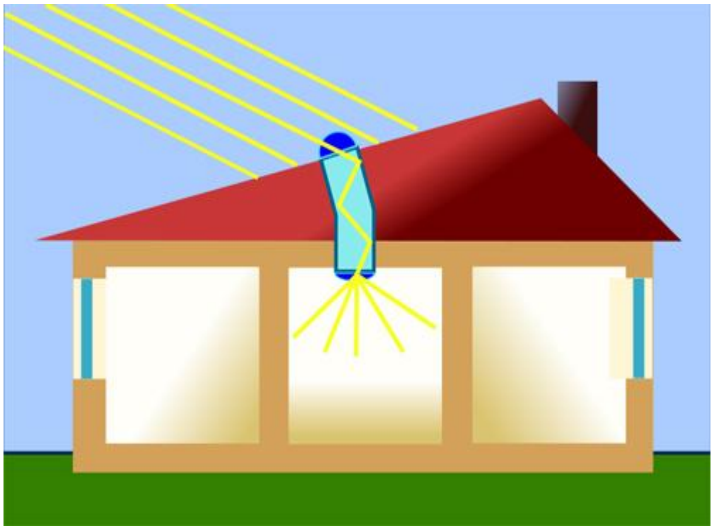

Figure 9. Diagram of solar tube.
Source: Solar Contact 2014

Solar tubes direct solar radiation into the room. The polished interior of the tubes act like mirrors, capturing the sunlight incident on the roof and directing light along its length to the inside of the room (Skylight Solutions 2013) (*Figure 9*). Like PV, solar tubes require sunlight and therefore their efficiency depends on cloud cover, rainfall patterns and hours of daylight. Solar tubes applications are widespread in Brazil and in the Philippines partly due to their low cost and abundant sunlight in these equatorial locations. In the Philippines, people even use plastic bottles to direct light into their houses (Mercola 2012).

Methodology

For installation, Improv'eat has enough roof space to fit a solar tube system. The facility has a lighting need of 2.8 kW that can easily be sustained by a solar tube system. The facility is located in a region where sunlight is abundant for at least half the year with long daylight lengths. Such solar input can contribute to a high capacity factor for a solar tube system. However, the humidity level is also high, thus the tube system will need wraps for protection against high humidity (Mercola 2012). Note that solar tube technology investigated here is used solely to displace the facility's lighting requirements.

Description of the Model:

The assumptions made for the conditions in the Philippines and relevant inputs are described in *Table 5*. Local solar radiation can be reliable and relevant cost information is obtained by summarizing the local price reported by the merchandisers (Skylight Solutions 2013). Electricity price escalation is taken from US Energy Information Administration (EIA) forecasts from 2013 at a level of 1.52% (EIA 2014).

Table 5. Program Information Input for Solar Tube Models

Program Information Input	
Capital Cost per Watt	$0.53
Maintenance Costs (Annual per kW)	
Labor cost (per W)	$0.3
Inefficiency Rate (years 1-10)	1.00%
Inefficiency Rate (years 10-25)	0.80%
Intermediate Production Results	
Annual Production per Installed Watt - (kWH/year)	4.38
PV System Nameplate Rating (Watts)	2800
Capital Investment	$1484
Financial Assumption input	
Discount rate	9%, 15% and 20%
Value of Electricity - (Avoided Cost)/kWH	$0.15
Feed-in Tariff (FiT)	$0.22
Escalation Rate Avoided	1.52%

Current solar tube systems have a warranty of 20 years and the financial performance of the first 10 years is summarized in the *Appendix 6*. According to current lighting devices, the lighting demand is 2.8 kW and solar tubes are only applicable when sunlight is available.

Results

Expected Electrical Output:

The whole system has an annual output of 4.38 kWh per installed Watt. This output varies throughout the day and during the year according to the weather conditions. The system can potentially be regulated by smart operation, where the owner can run facility operations more during sunny days to make better use of the available sunlight.

Sensitivity Analysis:

For a 2.8 kW system, the net present value of the solar tube system reaches $15,541 with an internal rate of return (IRR) at 388%, paying itself back in less than 1 year (*Table 6*). Additionally, 2.63 tons of carbon emission can be avoided annually. Different discount rates also make a difference on the NPV of the solar project. A lower discount rate gives a better project financial performance. With discount rates ranging from 9% to 20%, the net present value of the system can range from $15,541 to $7354.

Table 6. Decision results for 2.8 solar tube system.

	2.8 Solar Tube System		
Discount rate	**9%**	**15%**	**20%**
NPV	$15,541	$9,990	$7,355
IRR	387.99%	-	-
Payback	0.81	-	-

III. Solar Photovoltaic

Solar photovoltaic (PV) generates electrical current by absorbing solar radiation and can provide electricity to households and commercial buildings with zero emission of carbon dioxide or any other greenhouse gases. Solar PV systems can now easily connect to the grid and have become one of the most popular renewable energy sources in the world. Different countries have proposed incentive programs to encourage solar PV installation. Incentive programs include the feed-in tariff policy in the European Union or the renewable energy portfolio in the United States. PV has become a viable option for corporations, especially the large store retailers like Wal-Mart and IKEA who have invested in this technology (Solar Energy Industries Association 2012).

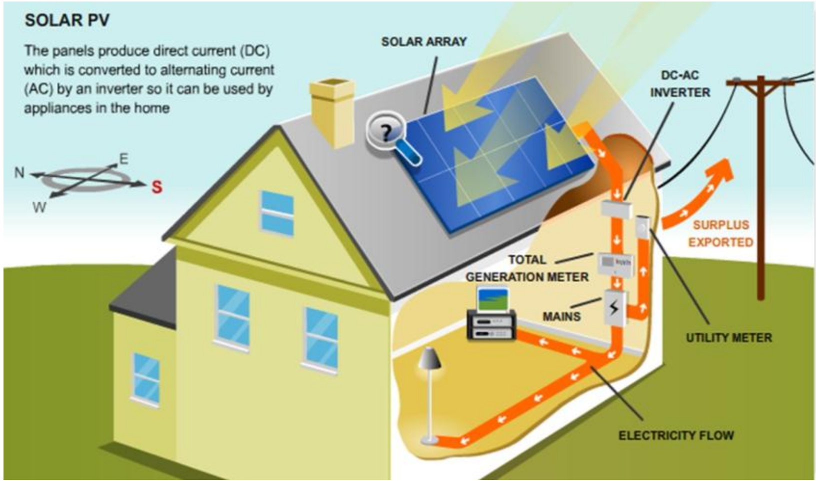

Figure 10. Rooftop solar PV system.
Source: Phoenix Home Energy Audits Blog 2013

PV panels turn solar radiation into electricity using semiconductors in the panels that stimulate the photovoltaic effect. A PV system is comprised of several PV cells aligned together, which forms a module, with auxiliary equipment including an inverter, and controls. The photons hit the panel and stimulate electrons that form the direct current. The direct current (DC) is converted to alternative current (AC) by the inverter and the electricity can be used directly or fed back into the distribution lines (Power One 2013). Solar photovoltaic systems range from small-scale to large-scale systems. They can be mounted on the ground or on rooftops (*Figure 10*).

Three types of PV cell arrangements are recognized. This kind of classification is based on the main material used in the cell and their level of commercial maturity:

- **First generation**: wafer-based crystalline silicon (c-Si) technology, either single crystalline (sc-Si) or multi-crystalline (mc-Si).
- **Second generation**: thin-film PV technologies, including amorphous (a-Si) and micromorph silicon (μc-Si).
- **Third generation:** concentrating PV (CPV) and organic PV cells.

Figure 11. MATEC Grid-tied PV residential rooftop installation design.
Source: MATEC 2013

There are several commercially available systems implemented in the Philippines. The Maschiene & Technik, Inc. launched its first grid-tied photovoltaic residential rooftop installation in Manila. They used mutli-crystalline modules and Sunny inverters with aluminum mounting frames (*Figure 11*). The system's capacity is 12.74 kW and started operation in August 2012. It produced 18,320 kWh of electricity for the first year (MATEC 2013).

Figure 12. Solar Frontier PV design.
Source: Solar Frontier 2013

Solar Frontier launched the first Philippine solar car park in Canlubang City in 2011. This 176 kW system takes the advantage of the 1985 kWh m^{-2} annual irradiance at the location and the 2129 mm precipitation (*Figure 12*). It used 75 W CIS thin-film solar module (SC75-a) and Solar Frontier 140 W (SF140-l) modules, and SMA (manufacturer) inverters. The system produces 296,700 kWh of electricity per year and reduces annual carbon emissions of 156 tons (Solar Frontier 2012).

Methodology

The site requirement for installation at the Improv'eat facility follows. For mounting the solar panels, Improv'eat has a roof space and/or a surrounding ground area that can fit the solar PV system. For natural solar irradiance conditions, the facility's equatorial latitude provides constant and abundant sunlight year-round. During the wet season, however, the amount of sunlight is hindered by cloud cover and rainfall patterns. Overall these considerations can contribute to a high capacity factor for a solar PV system. As for local policies, we incorporate feed-in tariff rate for solar installations to be 9.68 PHP (US$0.22) per kWh, with nothing to do with the size of the system or technology used.

Description of Model:

Local solar radiation and PV monthly output information is taken from a case study in the Philippines (MATEC 2013). PV cost information is obtained by summarizing the local price reported by the merchants (TradePostManila 2013). Annual electricity price escalation is taken from EIA's forecast from 2013 at a level of 1.52% (EIA 2014).

Model Assumptions:

PV systems usually last 25 years and the financial performance of the first 10 years are summarized in *Appendix 7* and *8*. The assumptions made for the conditions in the Philippines and relevant inputs are described in *Table 7*. A 12 kW system would have a capital cost of USD$2.3 per watt from local vendors and we assume the same installed cost for a system of 12 kW or 21 kW. We also assume that 292W Solar panel, Model P292W, Mono crystalline cells are used. Lastly, the carbon emission factor for the Philippines' grid is assumed to be 0.6 tons/MWh (Philippines DOE 2012a).

Table 7. Program Information Input for Solar PV Models

Program Information Input	
Capital Cost per Watt	$2.290
Maintenance Costs (Annual per kW)	$14.00
Utility Service Charges (Annual per meter)	$300
Inefficiency Rate (years 1-10)	1.00%
Inefficiency Rate (years 10-25)	0.80%
Intermediate Production Results	
Annual Production per Installed Watt - (kWH/year)	1.438
PV System Nameplate Rating (Watts)	12,740
Capital Investment	$29,175
Financial assumption input	
Discount Rates	9%, 15% and 20%
Value of Electricity - (Avoided Cost)/kWH	$0.1400
FIT	$0.2100
Escalation Rate Avoided	1.52%

Results

Expected Electrical Output:

The whole system has an annual output of 1.4 kWh per watt installed. This amount of electricity generated from a 12 kW system will be enough to fulfill the demand of the facility at the peak load without using the dehydrators. Electricity generated from a 21 kW system will be enough to meet the peak load of the facility with all equipment turned on. This output varies across the day and also during the year according to the weather conditions and potentially can be adapted by smart operation (i.e. to work more when the sunlight is more abundant).

Sensitivity Analysis:

Table 8 summarizes the results of each scenario investigated for a 12 kW and 21 kW system.

- For a 12 kW system, NPV reaches $21,532 with an IRR at 22.3%. The simple payback is around 4.6 years and 10.8 tons of carbon emission can be avoided.

- For a 21 kW system, the NPV of the system reaches $37,403 with an IRR at 23.0%. The simple payback is around 4.6 years and 18.9 tons of carbon emission can be avoided.
- Without the FiT incentive, neither of the two systems will be worthwhile given negative NPV results using all discount rates.
- Note that the NPV calculations are a function of discount rates used. A lower discount rate gives a better project financial performance. With different discount rates (9%, 15%, 20%), the net present value of the 12 kW system ranges from $1,921 to $21,532, while the NPV of the 21 kW system ranges from $4,128 to $37,403. The client therefore should make the decision depending on the availability of alternative uses of his capital.

Table 8. Decision results for solar PV.

12 kW

	Discount rate	9%	15%	20%
FiT	NPV	$21,532	$7,947	$1,921
	IRR	22.3%	-	-
	Payback	4.55	-	-
No FiT	NPV	($4,754)	($11,104)	($13,492)
	IRR	7%	-	-
	Payback	11.37	-	-

21 kW

	Discount rate	9%	15%	20%
FiT	NPV	$37,403	$14,356	$4,138
	IRR	23.03%	-	-
	Payback	4.55	-	-
No FiT	NPV	($5,925)	($17,047)	($21,278)
	IRR	7.17%	-	-
	Payback	11.37	-	-

IV. Hydropower

Hydropower is one of the oldest renewable energy technologies, and thus has become one of the most widely used systems for generating electricity. In the Philippines, hydropower comprises 22% of total installed generation capacity, while new sites have been identified that could potentially generate almost six times as much power, an additional 43,427 GWh (Hayes 2002; KPMG 2013). While the bulk of utility hydropower in the Philippines and worldwide is associated with traditional, large-scale hydropower systems, run-of-the-river hydro systems, pertinent to our client's demand, are emerging as a more environmentally friendly and cheaper alternative for smaller projects.

Traditional hydropower systems require building a reservoir to store water and provide a consistent water flow at all times. Therefore in this system electricity is constantly generation. Run-of-the-river systems do not store water. As such its electrical generation is subject to the river's current flow rate. The advantages of run-of-the-river systems are avoidance of flooding a plain and distorting river dynamics to accommodate a reservoir, as wells as lower installation costs. We will be investigating run-of-the-river operations in this investigation.

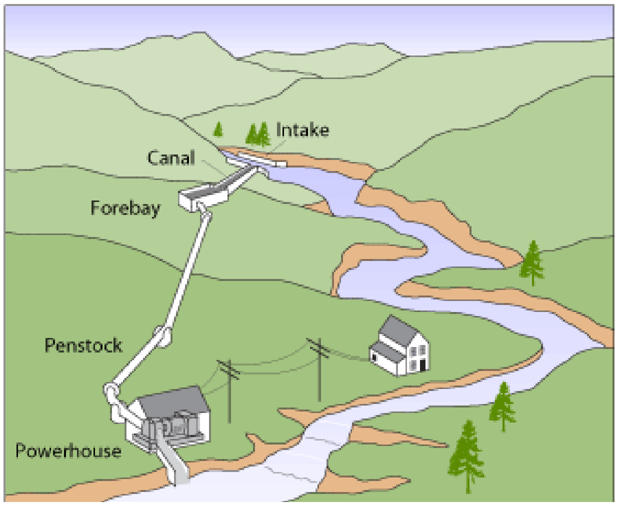

Figure 13. Run-of-the-river system.
Source: Synergy Holdings N/A

Many people picture run-of-the-river systems as little turbines placed directly into a river whose flow causes the turbines to spin, but this is not the case. First, an intake location is identified upstream where a canal is built to divert a portion of the water away from the river and towards the hydro system (see *Figure 13*). Then, depending on the system, water is channeled through a high-pressure penstock to raise the force of water flowing to the turbine and increase efficiency. The channels of water and penstock are typically built underground and lead to the powerhouse site, that hosts the turbine. The collected water flows through the turbine to generate electricity, and is then returned to the river.

It is also important to note the difference between small hydro and micro hydro. Often times, the term, small hydropower, is thrown around to mean small, micro, and mini hydropower generation. However, in the literature, small hydropower refers specifically to hydro systems between 1 and 10 MW, mini hydro refers to 100 kW to 1 MW, micro hydro refers to 5 to 100 kW, and pico hydro refers to 0 to 5 kW (Renewables First 2014).

Technology Overview

Within the run-of-the-river hydropower systems, five main types of technologies exist. These include (1) Archimedes screws, (2) Pelton turbines, (3) Turbo turbines, (4) Kaplan turbines, and (5) Crossflow turbines. Whichever technology is used depends on the site characteristics, as well as, the electrical demand. *Table 9* describes the conditions under which each technology is best deployed (Renewables First 2014).

Table 9. Optimal head and flow values for different hydropower turbines

		Head (meters)					
		1 to 2	2 to 5	5 to 8	8 to 20	20 to 40	40 +
Flow (m^3/ second)	0.0005 to 0.04					Pelton/ Turgo	Pelton/ Turgo
	0.04 to 0.1		Crossflow	Crossflow	Crossflow	Crossflow	
	0.1 to 0.3		Archimedes/ Crossflow	Archimedes/ Crossflow	Crossflow	Crossflow	
	0.3 to 1.5	Waterwheel	Archimedes/ Crossflow/ Waterwheel	Archimedes/ Crossflow	Crossflow	Crossflow	
	1.5 to 3.0		Archimedes	Archimedes			
	3.0 to 5.0		Archimedes/ Kaplan	Archimedes/ Kaplan	Kaplan		
	5.0 to 20.0		Archimedes/ Kaplan	Archimedes/ Kaplan	Kaplan		
	20.0 to 30.0		Archimedes/ Kaplan	Archimedes/ Kaplan	Kaplan		

Source: Renewables First 2014 & National Resources Canada 2004

Although both the flow rates and the head[4] determine the best hydro sites; the most cost-effective systems are usually those with higher heads. This is because the high-head and low-flow systems, like Pelton and Turgo turbines, are much smaller so require less space and cost less to install. Due to energy physics, this makes sense because high-head turbines only have to turn over about 5% of the water that low head turbines use (Renewables First 2014). Their efficiencies are also typically greater than systems best suited for low-flow sites and can reach up to 90% for micro systems[5] (Renewables First 2014). The disadvantage to Pelton and Turgo turbines is that they typically require a pressurized penstock to reach these high efficiency levels, which end up more expensive than the turbine itself (Renewables First 2014). Environmentally however, these systems may affect local fish populations that get caught into the conveyance system.

Crossflow systems can also work in high head environments, but have the added ability to work with lower flow rates. They were once hailed as the most environmentally friendly turbine because the nature of the turbine whips out debris and fish in a non-harmful way. This process also cuts down on maintenance costs because the system self-cleans. However, with the use of fish screens that also capture debris, this advantage is now slightly downplayed. Crossflow turbines are more costly since they are bigger systems and can reach efficiencies of 82% (Renewables First 2014).

Kaplan turbines can work at any site, but because they are the most expensive, they are typically used in rivers with low head and high flow rates, e.g. in lowland rivers. Archimedes screws are also used in low head, high flow rate sites, but are found to be more cost-effective than Kaplan turbines when placed in rivers with lower flow. These

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[4] **Flow rate** refers to how much water comes down the conveyance while **head** refers to the vertical difference between your intake location and the turbine.

[5] Note that these efficiency values are for the turbine only and do not include efficiency losses associated with the gearbox, generator, and inverter losses (approximately 15% in total) (Renewables First 2014).

micro systems can reach efficiencies up to 85%, and decrease dramatically as flow rate decreases (Renewables First 2014). In addition, to accommodate low flow rates, Archimedes screws are advantageous because the system tolerates debris and large fish, so maintenance costs are low and environmental effects are mitigated (Renewables First 2014). Finally, in extremely low head rivers, a water wheel, the oldest form of hydropower, can be used.

Hidden Costs

Unlike many other renewable energy technologies, hydropower technologies generally include several hidden costs and obstacles. The drawback is the energy system must typically be installed off-site and is subject to outside regulations. First, before installation of the hydropower system, a water permit must be obtained from the Philippines National Water Resource Board (NWRB)[6]. Costs for the water permit range greatly from site to site and depend largely on the environmental condition, characteristics of the river, size and type of the turbine, and generation capability (NWRB N/A). A range of cost estimates were difficult to find; thus, we recommend contacting the NWRB directly to obtain accurate cost information when our client chooses a facility site in the future.

Second, an environmental impact clearance must be obtained from the Philippines Department of Environment and National Resources (DENR) (Hayes 2002). The cost of this clearance was also unclear at the time of the study and is likely to vary depending on the site selection. However, although hydropower has raised concerns in the past over potentially damaging effects on fish populations, recent innovations like fish-friendly screens installed with the intake channel have classified hydropower as a low environmental risk (Renewables First 2014).

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[6] The water permit application can be found here: http://www.nwrb.gov.ph/index.php?option=com_content&view=article&id=610&Itemid=94

Methodology

Figure 14. Sierra Bullones limestone formation map in relation to Improv'eat operations.
Source: Gonzales 2005

Bohol Topography:

Improv'eat's current facility is located in an area that is not suitable for hydropower given very low flow rates of nearby rivers. However, the client has indicated that the next facility could target good hydropower locations if cost-effective. The Philippines' island of Bohol, where the client is currently located, is a fairly mountainous region with several rivers that could serve as good sources for micro hydropower. The island is home to the Sierra Bullones limestone formation that boasts 5-50 meter drops (DILG 2003). *Figure 14* shows the location of these formations relative to our client's current operations (marked by the blue star). Proximity of a future Improv'eat site relative to the Sierra Bullones might allow for appropriate hydro development. In between the Sierra Bullones and Duero is Mt. Mayana – the highest peak in Bohol – at 827 meters (DILG 2003). The topography of the surrounding area of the current Improv'eat facility suggests that there exists a potential for low cost, high head hydro sites.

Flow Duration Curves:

There are four main rivers in the southeast region of Bohol where the current facility resides – Manaba, Bilar, Loboc, and Alejewan. Although the Alejewan River is closest to Duero, there was no information regarding its flow, Thus, no calculations could be made regarding the hydro potential of the Alejewan River. Each of these rivers is located in mountainous region, suggesting potential to access higher drops of falling water (see *Figure 15*). For example, the Manaba River flows through high elevations of 700 meters down to lower elevations of 200 meters (DILG 2003).

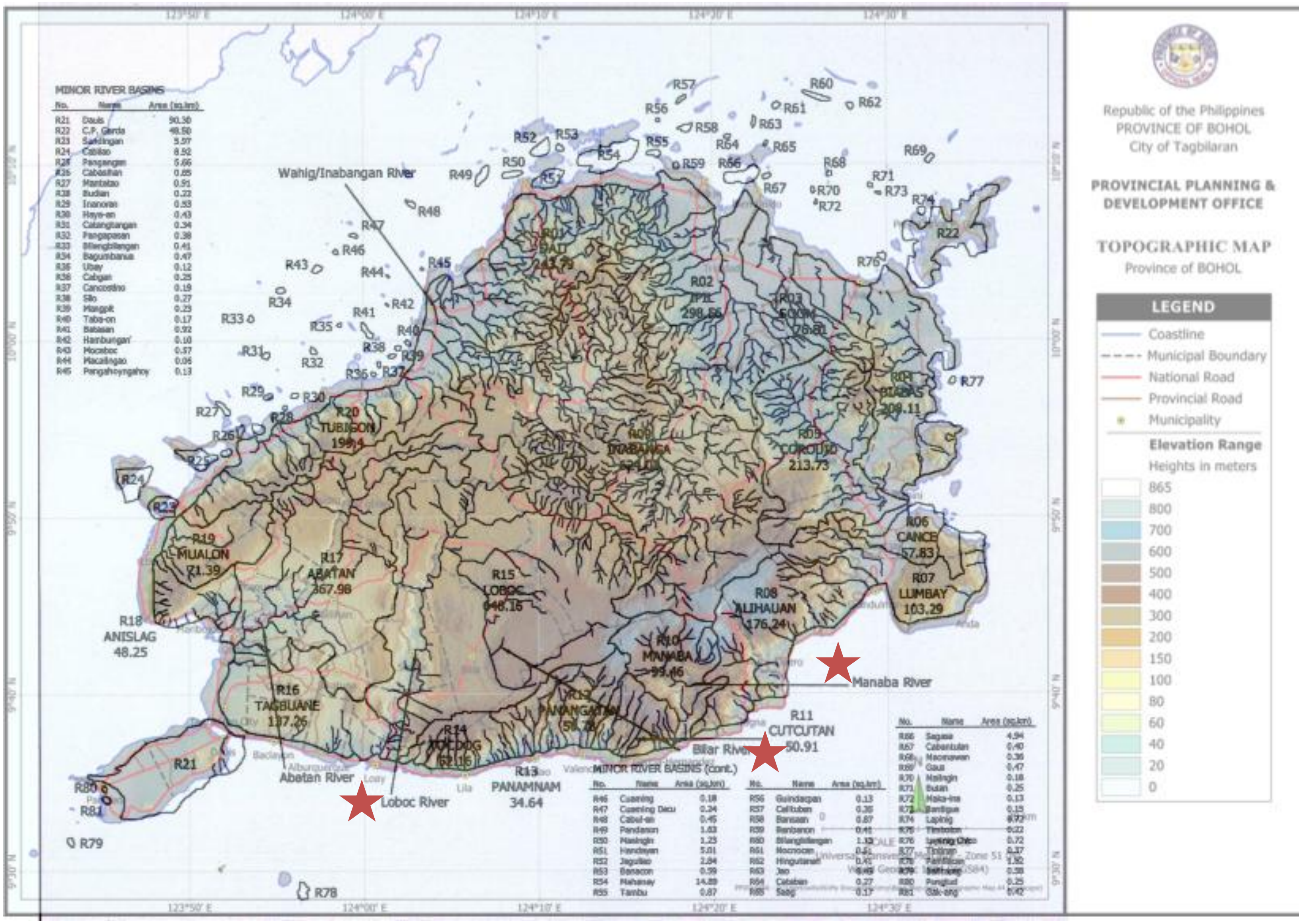

Figure 15. Overlaid river and elevation map for Bohol province, PHL.

Note: The stars indicate the rivers used in the analysis.

Source: PPDO 2014 and DILG 2003

Table 10. Maximum and minimum flow rates for rivers in Bohol Province.

	Flow Rate (m3/s)	
River	Min	Max
Manaba	0.10	233.35
Bilar	0.01	72.02
Loboc	3.90	441.8

Source: DILG 2003

Maximum and minimum flow rates for the other three rivers are presented in *Table 10*. The actual flow duration curves were extrapolated using the flow duration curves of four other major rivers (Payo River, Tenane River, Panay River and Daquitan River) within the Visayas Islands in the Philippines where Bohol resides (Philippine NSCB 2003). These calculations can be found in the *Appendix 9-11*. The estimated flow duration curve results are presented in *Figure 16*.

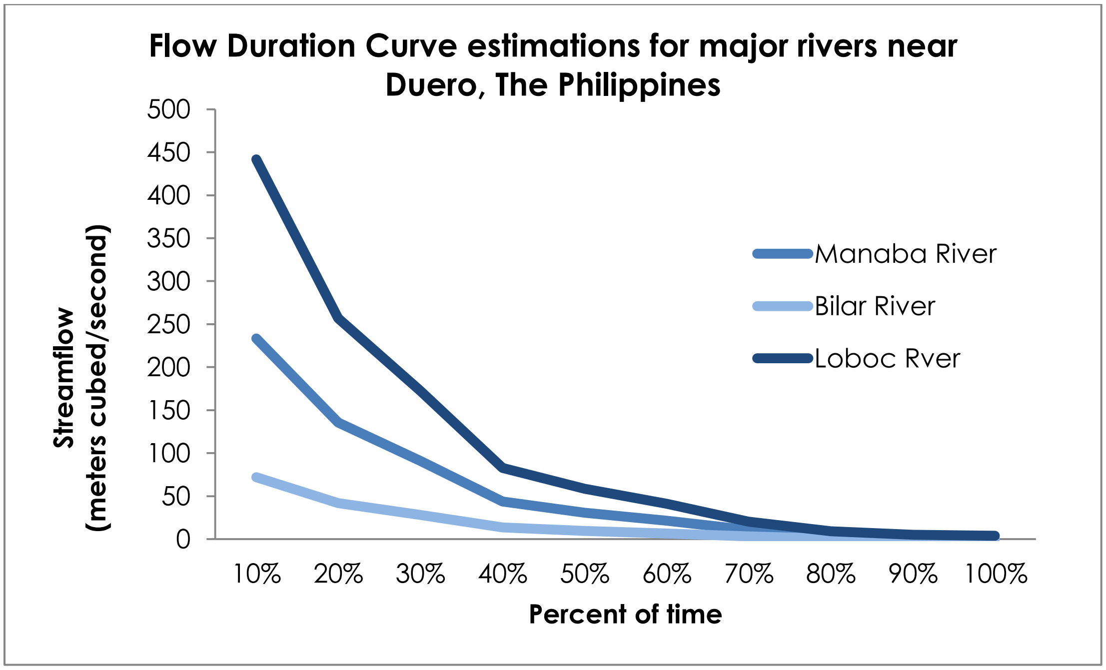

Figure 16. Flow Duration Curve estimations for major rivers near Duero, the Philippines.
Source: Philippine NSCB 2003 and DILG 2003

Most of the literature recommends using the lowest flow rate for hydro calculations to ensure that electricity is generated year-round (National Resources Canada 2004). Given that the Bilar River has no year-round water flow requiring the use of complementary renewable technologies, it was eliminated from the analysis. Because the exact location of the potential hydro site is unknown, the minimum flow rates for the Manaba and Loboc rivers at 0.1 and 3.9 m^3/s, respectively, were used as different scenario conditions to perform the NPV calculations. Note that the actual flow rate of the particular hydro site will depend on the point location on the river. For example, flow rates of the same river will be lower near the source and higher as the river picks up more water volume from incoming sources. However, low flow rates near the source are typically located in mountainous region with higher potential head, thus balancing both input factors.

Costs:

Although the exact cost of a micro hydro system will vary slightly with the type of technology chosen, we used an average range of capital costs for micro hydropower systems to determine profitability. Capital costs for micro hydro systems range from $2,590/kW to $12,349/kW (Philippine NSCB 2003). The wide range is understandable considering that 75% of hydro capital costs are site-dependent (IRENA 2012b). Without knowledge of the actual site, calculations were performed for both low and high capital costs.

A major advantage of hydropower is very low typical operating and maintenance costs. For an average micro hydro system, the yearly operating and maintenance costs are estimated around 6% of the total capital costs (IRENA 2012b). Of course, both of these costs vary depending on the specific technology chosen.

Power Output:

The total amount of output that can be expected from a hydropower plant is calculated with the following equation:

(Eq. 2)
$$\boldsymbol{Power\ output\ (kW)} = Flow\ (m^3/sec) * Head\ (m) * Gravity\ (9.8\ m^2/second) * Efficiency\ (\%)$$

The range of minimum flow rates used were described above while the average efficiency was about 53% in the literature (although this may be as high as 70% for larger micro hydro systems located in high head sites) (Philippine NSCB 2003). Because the head depends heavily on the site selected for the hydro project, the optimal head was calculated based on the minimum flow rates of the rivers in the surrounding area. This method sets the power outputs equal to the electrical demand of the facility so that Improv'eat can select a hydro site that meets its minimum demand.

Discounted cash flows were used for this estimate using the optimal head and power output to maximize NPV under the sensitivity of different flow rates for each electrical demand scenario. The Feed-In Tariff rate for run-of-the-river hydro in the Philippines is $0.12/kWh with a 5% digression rate after the first two years (Philippines DOE, 2013). The revenue from the feed-in tariff was calculated in one scenario and left out of another scenario, reflecting the uncertainty of feed-in tariff implementation.

Results

Based on the assumption that Improv'eat will use one of the rivers located within the current facility region, a 12 kW demand will require a hydro turbine with a nameplate capacity of 22.6 kW, while a 21 kW demand will warrant a hydro turbine with a nameplate capacity of 39.6 kW. For the Manaba River with a low minimum flow rate of 0.1 m^3/sec, the amount of head required to meet the demand for a 12 kW and 21 kW system, respectively, are 23 meters and 40 meters (*Table 11*). If a hydro site were located along the Loboc River with a higher minimum flow rate of 3.9 m^3/sec, the amount of head for each site is 0.59 and 1.04 meters, respectively for a 12 kW and 21 kW micro hydro systems (*Table 11*).

Table 11. Minimum head for given flow rates to meet demand.

	Head (meters)	
Flow (m^3/second)	**12 kW**	**21 kW**
0.1	23.1	40.4
3.9	0.59	1.04

Given these potential optimal flow and head characteristics, the best technology for the Manaba River is the Pelton or Turgo turbines, while the Archimedes screw or Kaplan turbine are best used for the Loboc River. Pelton and Turgo turbines are generally more cost-effective and efficient, but the terrains suitable for these turbines may be more difficult to access than other technologies. Therefore, it is difficult to determine which site and technology would be best without knowing the exact conditions of a proposed site.

Table 12. Program information inputs and assumptions used for micro-hydro systems.

Hydro Model Inputs and Outputs

	12 kW	**21 kW**
Head (meters)	0.59	1.04
Flow (meters cubed/second)	3.9	3.9
Turbine Characteristics		
Nameplate capacity (kW)	22.6	39.6
Efficiency	53%	53%
Power output (kWh)	12	21
Lifetime (years)	50	50
Costs		
Capital cost ($/kW)	2,590	2,590
Capital cost ($)	58,642	102,623
O&M costs (% of installed cost/year)	6%	6%
O&M costs ($/year)	3,518	6,157
Annualized system cost ($)	3,589	6,282
Levelized Cost of electricity ($/kWh)	0.03	0.03

Table 12 shows the inputs and outputs used in our models and *Appendices 12* and *13* show the financial models created for the 12kW and 20kW micro hydro systems respectively. Due to low operation and maintenance costs and the high degree of historically commercialized micro hydro turbines, a micro hydropower system along the Manaba and Loboc Rivers that can be situated at the previously specified amounts of head can meet the demand for Improv'eat for each demand scenario and generate enough extra electricity to sell back on the grid to earn a positive return on their investment (see *Table 13*).

Table 13. Decision results for micro hydropower

12 kW

	Discount rate	**9%**	**15%**	**20%**
FiT	NPV	$58,368	$24,984	$9,790
	IRR	25%	-	-

	Payback	5	-	-
No FiT	NPV	$38,593	$10,549	($1,887)
	IRR	19%	-	-
	Payback	5	-	-

21 kW

	Discount rate	9%	15%	20%
FiT	NPV	$123,532	$56,972	$26,728
	IRR	28%	-	-
	Payback	7	-	-
No FiT	NPV	$107,320	$45,138	$17,155
	IRR	25%	-	-
	Payback	6	-	-

Any proposed project would return a positive NPV under every calculated discount rate, except for the 12 kW system, with no FiT, and a 20% discount rate. Because the model was performed to meet the facility's maximum demand, little extra power is available to feed back to the grid. This may explain why Improv'eat could incur a positive net present value whether or not the FiT is applied.

The highest hypothetical positive return expected is $107,320 for a 21 kW system at a 9% discount rate, while the lowest is $9,790 for a 12 kW system at a 20% discount rate. Since the bulk costs of hydropower lie in the upfront costs, the 21 kW system will generally be more profitable than the 12 kW system. Finally, the levelized cost of electricity for a micro hydropower system of either size is $0.3/kWh, which is much higher than the current the Philippines utility cost of electricity of $0.19/kWh as stated by our client.

The results from this study are promising because the amount of head required to make a profitable project that meets the facility's demand is relatively low for the Loboc River. Even the higher amount of head required on the Manaba River may be found easily as high differentials in elevations exist in both these areas.

Note, however, that several pieces of information would greatly improve the results of this model. Although it is known that both a water permit and environmental clearance are required before beginning a hydro project, the exact costs in the Philippines was not found. Incorporating these costs may or may not substantially affect the return on a hydro project.

V. Biomass

Energy that is stored in organic matter is referred to as biomass. The photosynthetic process converts sunlight into useful energy. Plants serve as solar collectors, similar to PV cells, by transforming energy from captured photons into chemical energy and by absorbing CO_2 molecules into organic compounds to produce biomass. The solar potential energy stored in organic matter, mainly carbohydrates, can be released by burning the biomass. However, when biomass is burned, stored CO_2 is released generating a short-term cycle with a zero net addition of carbon dioxide to the atmosphere. Biomass fuels can vary from any short-term organic matter like wood, manure, and agricultural by-products (Union of Concerned Scientists 2010).

The type of technology used to convert the biomass material into electricity varies depending on the electrical needs of the end user. The most common type of biomass technology is the organic rankine cycle (ORC) used to directly combust biomass materials in a boiler; that creates steam to spin a turbine (Lane & Beale 1997). However, the average sized biomass power plant using an ORC system is 200 kW. From *Table 14*, comparing alternative biomass systems, the Stirling engine technology is the more relevant to Improv'eat operational needs. Stirling engines differ from ORC systems since they use a furnace to heat the biomass material that lies outside of the piston engine system. Stirling engines are generally more costly than ORC systems because they are used on a smaller scale. However, Stirling engines have fewer moving parts than ORC systems, thus operating at lower costs for maintenance (Lane & Beale 1997).

Table 14. Biomass electrical and CHP system.

	Electric Power (kw)	Thermal Output (kW)	Electrical Efficiency	CHP Overall Efficiency	Power: Heat Ratio	Cost Estimate ($/kWh)
Direct combustion, ORC	200	980	14%	85%	0.20	8152
Direct combustion, IFGT	100	200	20%	80%	0.50	8560
Downdraft gasifier, ICE	250	500	23%	70%	0.50	7336
Direct combustion, Stirling Engine *	35	215	12%	86%	0.16	9782
Updraft gasifier, Stirling Engine *	35	145	18%	90%	0.24	9782
Modified ICE	400	630	33%	85%	0.63	3056

Note: ORC = Organic Rankine Cycle; IDFG = Indirectly Fired Gas Turbine; ICE = Internal Combustion Engine; * = micro biomass systems relevant to Improv'eat
Source: Wood & Rowley 2010

Although most commercially available micro biomass systems are design to be fueled exclusively by wood or charcoal pellets, new designs that incorporate the direct feed of agricultural by-products into a Stirling engine are emerging. In many rural parts of the world, agricultural by-products are plentiful and nearly free since most of these potential biomass materials would ordinarily be discarded as waste. At the same time, rural electrification remains a problem in developing countries, specifically the Philippines. Micro biomass offers a potential solution to this problem by providing rural, agricultural communities with electrical power.

In South Africa, for example, Scandinavian biomass companies have designed a business model to bring Stirling engine biomass systems to rural communities where unprocessed or little processed agricultural products can be fed directly into the system (Lane & Beale 1997). Applications of small-scale biomass systems have also been found to be technically and economically feasible in rural Kenya, subject to the degree of government control of agricultural lands (Senelwa & Sims 1999). However, costs of these systems vary greatly since technology on this scale is not very commercialized. Suppliers of micro-scale biomass systems can provide more accurate information regarding costs and efficiencies for a fee[7].

Methodology

Given that Improv'eat operations uses coconuts for their main product, the facility generates a large quantity of waste in the form of young coconut shells and husks. Improv'eat has the opportunity to reuse the biomass waste, turning it into fuel to generate electricity for the facility. The potential for electric generation from coconut shells and husks is high due to their low inherent moisture (15%) and ash content[8] (0.6%) (Sundaram & Natarjan 2009). These percentages determine the overall estimated heating value for coconut shells at 23.2 MJ/kg (Sundaram & Natarjan 2009).

The lower heating value (LHV) of coconut shells is used in our model because most current biomass systems are not designed to use released water vapor as energy. To put this into perspective, heating values for different fuels are listed in the *Table 15*, including coconut husks and rice husks. This is of interest as Improv'eat plans to expand its operations and rice husks are readily available in rural the Philippines where the facility is currently located and can be a new source of biomass fuel. In addition, only de-husked coconuts are received by the facility, but reclaiming the husks would provide additional sources for electricity.

Table 15. Heating values and characteristics for several types of fuels.

	Heating Value (MJ/kg)	Moisture Content	Ash Content
Coconut shells	23.2	15%	0.6%
Coconut husks	16.7	5-10%	6%
Rice husks	13.4	15%	15-20%
Coffee husks	16.7	13%	8-9%

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[7] Additional resources: Cleanenergy (Sweden): http://www.cleanergy.com/technology/technical-concept/; Sunpower (Ohio): http://www.sunpowerinc.com/library/pdf/productlit/Engine%20Brochure.pdf; Stirling DK (Denmark): http://www.stirling-energie.de/en/company

[8] The **moisture content** of a biofuel indicates what percentage of the fuel is comprised of water, which reduces the amount of heat and energy that can be released while burning the fuel. **The ash content** refers to the residue remaining after a fuel has been burned, which has not contributed to the heat and energy released.

Wood	13.8	30%	4%

Source: FAO 2000, Banzon 1980, Sundaram & Natarian 2009

To determine how much biomass energy becomes available each day, the number of coconuts used in production was multiplied by the average weight of the coconut shell, which was measured by the client. The mass of the coconut shells was multiplied by the empirical LHV to obtain a measure of energy potential. Given the daily quantity of available coconut shells, the largest possible biomass plant was found by using the calculated energy potential and the heat rate of a typical micro-scale biomass plant of 14,840 BTU/kWh (EPA 2007). Efficiencies for micro and small-scale biomass systems ranged widely from 15% for ORC systems to an expected average of 22% for Stirling engines (Lane & Beale 1997). Efficiencies increased to over 80% when combined with heat, and will be discussed in the next section (Lane & Beale 1997). The efficiency rate of 22% was used in this study because the Stirling engine was determined to be the best option for Improv'eat's electrical demand.

Although the specific costs for a micro biomass system were difficult to find as they are not widely commercialized, cost estimates from the literature average $6000/kW, while within one standard deviation the range starts at $10,000 for smaller systems and goes down to $2,000 for large-scale biomass systems (NREL 2013). Variable costs are low because the fuel source is free, as a by-product, and requires only operation and maintenance costs at about $0.001/kWh (EPA 2007). The operation and maintenance cost are particularly low for a biomass system using coconut shells since the ash content is very low. Typically, biofuels with higher ash contents can require more frequent routine maintenance in a Stirling system (IRENA 2012a).

Results

The expected nameplate capacity of a micro biomass generator using only the coconut shells discarded throughout Improv'eat production process is 123 kW (see *Appendix 14-17*) This translates to a yearly electrical output of 864 MWh, which is higher than the electrical demand from the facility in both the 12 kW and 21 kW scenarios. This allows flexibility to our client to sell energy back onto the grid at the FiT rate of $0.13/kWh, digressing at a rate of 5% after the first two years.

The levelized cost of electricity for biomass ranges from $0.01/kWh to $0.02/kWh, depending on upfront capital costs. Compared to the average the Philippines electricity price of $0.19/kWh, micro biomass systems are estimated to be cheaper by energy usage. Even though the capital costs for micro biomass systems are very high, the results show that biomass can be profitable for systems with an average lower bound capital cost of $6000/kW (*Table 16*). At a 9% discount rate, both a 12 kW and 21 kW demand scenario prove to be profitable for Improv'eat with the Feed-In Tariff, at $181 million and $250 million, respectively. The 21 kW demand scenario also reveals a positive NPV at the 15% discount rate of $19 million with the inclusion of the FiT. However, none of the scenarios reveal a positive NPV without revenue from the FiT.

Table 16. Decision results for the micro-biomass

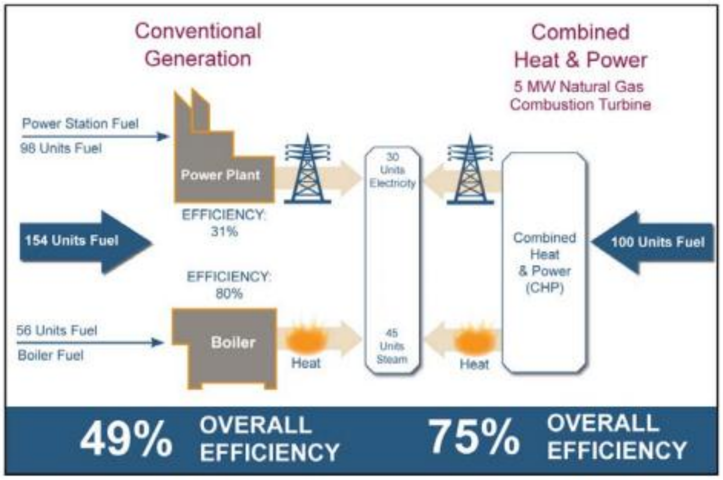
12 kW Demand					
		Discount rate	**9%**	**15%**	**20%**
FiT	Average Cost	NPV	$180,941	($22,813)	($117,909)
		IRR	14%	-	-
		Payback	7	-	-
	High Cost	NPV	($271,689)	($451,827)	($529,048)
		IRR	4%	-	-
		Payback	13	-	-
No FiT	Average Cost	NPV	($562,323)	($565,366)	($556,802)
		IRR	-9%	-	-
		Payback	n/a	-	-
	High Cost	NPV	($1,014,953)	($994,380)	($967,940)
		IRR	-12%	-	-
		Payback	n/a	-	-
21 kW Demand					
FiT	Average Cost	NPV	$250,045	$19,775	($87,194)
		IRR	16%	-	-
		Payback	7	-	-
	High Cost	NPV	($202,584)	($409,239)	($498,333)
		IRR	6%	-	-
		Payback	12	-	-

No FiT	Average Cost	NPV	($644,805)	($610,020)	($584,297)
		IRR	n/a	-	-
		Payback	n/a	-	-
	High Cost	NPV	($881,787)	($905,029)	($899,397)
		IRR	-7%	-	-
		Payback	n/a	-	-

Improv’eat has access to a large quantity of biomass energy resources that allows for a larger micro biomass system than their current needs. Thus, Improv’eat has extra capacity to share with the grid and to receive revenue from the FiT that is large enough to make the system profitable despite high upfront costs. Putting renewable energy onto the grid using resources that would have been wasted provides Improv’eat with a great opportunity to decrease not only their own carbon emissions, but also those of the community.

VI. Combined Heat and Power

Combined Heat and Power (CHP) is the generation of several forms of useful energy (usually mechanical and thermal) at the same time or in sequence in an integrated system. It enhances the distributed generation (DG) and the overall fuel efficiency by simultaneously producing thermal and power output for commercial or residential use. It can be located at the point of energy use or within some distance. In the former case, one can effectively avoid transmission and distribution losses of electricity purchase from the central grid. Moreover, CHP systems can be integrated with some other existing and planned technologies for several. *Figure 17* shows a cartoon comparison of a CHP system to a conventional power plant (EPA 2013a).



Note: Assumes national averages for grid electricity and incorporates electricity transmission losses.

Figure 17. CHP v. Separate Heat and Power (SHP) Production
Source: EPA 2013a

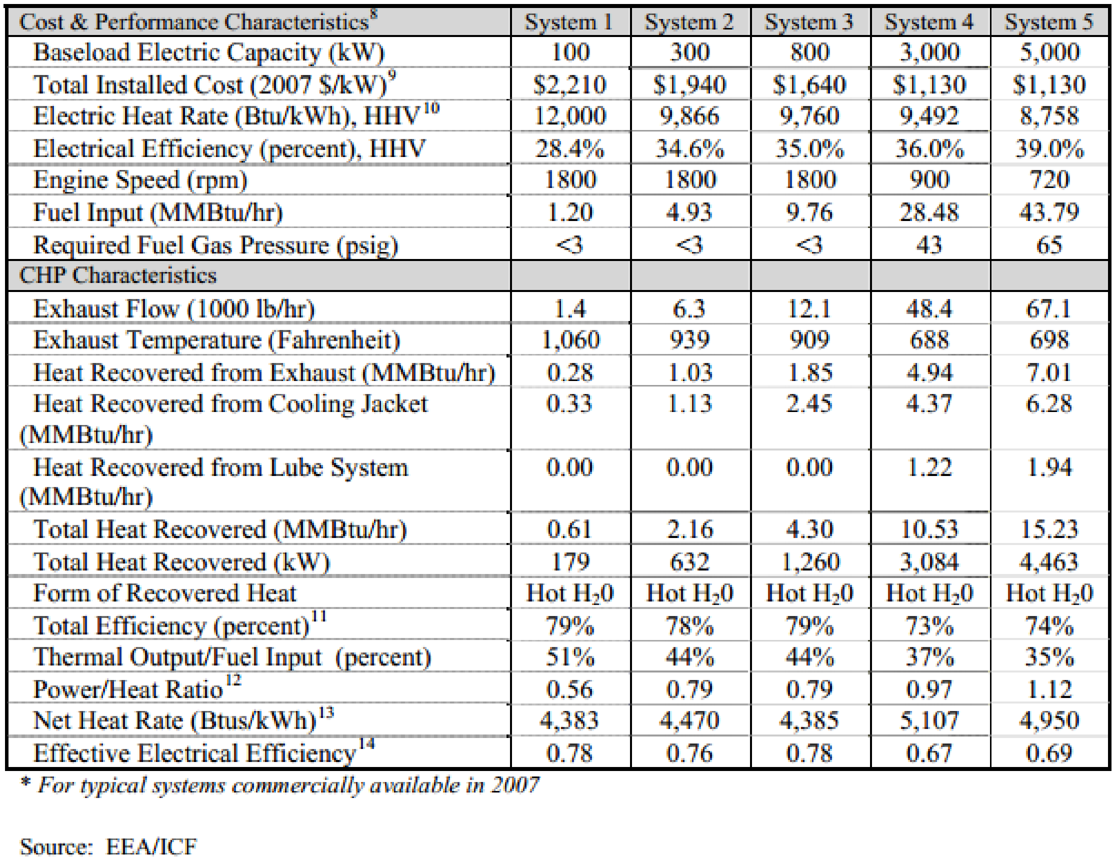
How CHP Works

Components include the prime mover (heat engine), heat recovery, generator and electrical interconnection. The system produces thermal energy, which can be used in direct process applications or indirectly "to produce steam, hot water, hot air for drying, or chilled water for process cooling" (EPA 2013a). The prime mover typically identifies the CHP system, and includes "reciprocating engines, combustion or gas turbines, steam turbines, micro-turbines, and fuel cells" (EPA 2013a).

Methodology

Given the capacity need of Improv'eat and the installation cost, reciprocating engines are the best choice. They can be customized for a 12 kW system, or 21 kW, which usually is the minimum amount of CHP system capacity (EPA 2013b). Detailed cost information is taken from the CHP project development handbook from EPA and Technology characterization: Reciprocating Engines *(Table 17)*. CHP systems usually last for 20 years and the financial performance of the first 10 years are summarized in the *Appendix 18-21*. The fuel cost information and the necessary capital cost is based on the biomass plant financial analysis in the biomass section above.

Table 17. Gas Engine CHP - Typical Performance Parameters



Cost & Performance Characteristics[8]	System 1	System 2	System 3	System 4	System 5
Baseload Electric Capacity (kW)	100	300	800	3,000	5,000
Total Installed Cost (2007 $/kW)[9]	$2,210	$1,940	$1,640	$1,130	$1,130
Electric Heat Rate (Btu/kWh), HHV[10]	12,000	9,866	9,760	9,492	8,758
Electrical Efficiency (percent), HHV	28.4%	34.6%	35.0%	36.0%	39.0%
Engine Speed (rpm)	1800	1800	1800	900	720
Fuel Input (MMBtu/hr)	1.20	4.93	9.76	28.48	43.79
Required Fuel Gas Pressure (psig)	<3	<3	<3	43	65
CHP Characteristics					
Exhaust Flow (1000 lb/hr)	1.4	6.3	12.1	48.4	67.1
Exhaust Temperature (Fahrenheit)	1,060	939	909	688	698
Heat Recovered from Exhaust (MMBtu/hr)	0.28	1.03	1.85	4.94	7.01
Heat Recovered from Cooling Jacket (MMBtu/hr)	0.33	1.13	2.45	4.37	6.28
Heat Recovered from Lube System (MMBtu/hr)	0.00	0.00	0.00	1.22	1.94
Total Heat Recovered (MMBtu/hr)	0.61	2.16	4.30	10.53	15.23
Total Heat Recovered (kW)	179	632	1,260	3,084	4,463
Form of Recovered Heat	Hot H_20	Hot H_20	Hot H_20	Hot H_20	Hot H_20
Total Efficiency (percent)[11]	79%	78%	79%	73%	74%
Thermal Output/Fuel Input (percent)	51%	44%	44%	37%	35%
Power/Heat Ratio[12]	0.56	0.79	0.79	0.97	1.12
Net Heat Rate (Btus/kWh)[13]	4,383	4,470	4,385	5,107	4,950
Effective Electrical Efficiency[14]	0.78	0.76	0.78	0.67	0.69

** For typical systems commercially available in 2007*

Source: EEA/ICF

Results

Expected Electrical Output:

The whole system has an annual output of 19,008 kWh installed. This amount of electricity generated from a 12 kW system will be enough to fulfill the demand of the facility at the peak load without using the dehydrators. Electricity generated from a 21 kW system will also be enough to fulfill the demand of the facility with all equipment at peak load. This output does not vary across the day and during the year and potentially can be adapted by smart operation where the facility runs more when inputs are sufficient. Nevertheless maintenance can be a concern for the client, as well as, the availability of the fuel source that is now assumed to be the coconut husk as described in the biomass section.

Sensitivity Analysis:

Table 18 summarizes the results of each scenario investigated for a 12 kW and 21 kW system under average and high costs. Under average costs, a 12 kW system can generate 19,822.6 kWh of electricity and an equivalent of 39,645.3 kWh of heat. The NPV of the system reaches $53,980 dollars with an IRR of return at 27.1%. The simple payback is around 4.6 years. For a 21 kW system, the system can generate 19,008 kWh of electricity and an equivalent of 38,016 kWh of heat. The NPV of the system reaches $94,465 dollars with an internal rate of return at 27.1%. The simple payback is around 4.6 years (See *Table 18*). Considering that the electricity generation portfolio in the Philippines relies mainly on coal, Improv'eat could reduce its carbon emissions by adopting the CHP system.

Table 18. Decision results for CHP system.

		Discount rate	9%	15%	20%
12 kW Demand					
FiT	Average Cost	NPV	$53,980	$24,459	$10,923
		IRR	27.07%	-	-
		Payback	4.6	-	-
	High Cost	NPV	$5,718	($20,159)	($31,309)
		IRR	9.99%	-	-
		Payback	n/a	-	-
No FiT	Average Cost	NPV	$35,608	$11,048	$74.04
		IRR	20%	-	-
		Payback	n/a	-	-
	High Cost	NPV	($11,899)	($33,019)	($41,712)
		IRR	7%	-	-
		Payback	n/a	-	-
21 kW Demand					

FiT	Average Cost	NPV	$94,465	$42,803	$19,114
		IRR	27.07%	-	-
		Payback	4.6	-	-
	High Cost	NPV	$10,006	($35,279)	($54,791)
		IRR	6%	-	-
		Payback	12	-	-
No FiT	Average Cost	NPV	$62,314	$19,335	$129.58
		IRR	20%	-	-
		Payback	n/a	-	-
	High Cost	NPV	($20,823)	($57,783)	($72,996)
		IRR	7%	-	-
		Payback	n/a	-	-

VII. Recommendations

12 kW

Our results are summarized on *Table 19.* Based on the calculations for solar PV, hydro, biomass, and CHP, the best technology adoption for Improv'eat depends on the client's risk preference. The highest net present value on a renewable generation technology is $181,000 for a biomass plant under a 9% discount rate, average capital cost, including FiT. However, the return drops dramatically for any other scenario, resulting in negative NPVs. If Improv'eat invested in a biomass technology, they run the risk of achieving the lowest NPV of -$1,105,000 for a high capital cost and zero FiT revenue. Nevertheless, chances of a positive NPV are enhanced if biomass is used for CHP. In this case, Improv'eat could see a high return of $54,000, while only risking a negative return in high capital cost scenarios when the discount rate is greater than 9%.

The renewable technology with least risk and offering the highest returns is hydropower. Although not deployable at the current site, if the optimal location is identified, then hydro would be the best option for the new facility. A high positive return of $58,000 is possible under the best proposed scenario, while the client only risks a negative return (-$2,000) without a FiT at a high discount rate of 20%.

The lowest returns are found for solar PV, where the highest NPV is $22,000. Despite a relatively low NPV, the client could expect a positive return under any scenario that includes a FiT. Therefore, given that the current site cannot deploy hydro and there exists a high uncertainty regarding the capital costs for biomass and CHP, the client may choose to invest in solar PV, with FiT, to ensure a positive net present value. If a feed-in tariff is unlikely, then the client may choose to deploy CHP that will incur a positive return without the feed-in tariff, provided the capital costs stay in the lower range.

Table 19. Summary results for 12 kW system.

12 kW				
Technology	**Scenario**	**NPV (thousands)**	**IRR**	**Payback**
Solar PV	FiT, 9%	$22	22%	5
	FiT, 15%	$8	-	-
	FiT, 20%	$2	-	-
	No FiT, 9%	($5)	7%	11
	No FiT, 15%	($11)	-	-
	No FiT, 20%	($13)	-	-
Hydro	FiT, 9%	$58	25%	5
	FiT, 15%	$25	-	-
	FiT, 20%	$10	-	-
	No FiT, 9%	$39	19%	5
	No FiT, 15%	$11	-	-
	No FiT, 20%	($2)	-	-
Biomass	Fit, Avg Cost, 9%	$181	14%	7
	Fit, Avg Cost, 15%	($23)	-	-
	Fit, Avg Cost, 20%	($118)	-	-
	Fit, High Cost, 9%	($272)	4%	13
	Fit, High Cost, 15%	($452)	-	-
	Fit, High Cost, 20%	($529)	-	-
	No Fit, Avg Cost, 9%	($562)	-9%	n/a
	No Fit, Avg Cost, 15%	($565)	-	-
	No Fit, Avg Cost, 20%	($557)	-	-
	No Fit, High Cost, 9%	($1,015)	-12%	n/a
	No Fit, High Cost, 15%	($994)	-	-
	No Fit, High Cost, 20%	($968)	-	-
CHP	Fit, Avg Cost, 9%	$54	27%	4.6
	Fit, Avg Cost, 15%	$24	-	-
	Fit, Avg Cost, 20%	$11	-	-
	Fit, High Cost, 9%	$6	10%	n/a
	Fit, High Cost, 15%	($20)	-	-
	Fit, High Cost, 20%	($31)	-	-
	No Fit, Avg Cost, 9%	$36	20%	n/a
	No Fit, Avg Cost, 15%	$11	-	-
	No Fit, Avg Cost, 20%	$74	-	-
	No Fit, High Cost, 9%	($12)	7%	n/a
	No Fit, High Cost, 15%	($33)	-	-
	No Fit, High Cost, 20%	($42)	-	-

21 kW

The results for the 21 kW demand scenario are similar to those for the 12 kW demand scenario except for a greater magnitude of returns (*Table 20*). The highest return the client may see is for biomass with a FiT, average capital costs, and 9% discount rate at $250,000. Although slightly less risky than for the 12 kW system because the same scenario has a positive return with a 15% discount rate, the risk is still high for all of the other scenarios which result in negative returns. The lowest possible NPV is higher than the 12 kW system at -$882,000. If the biomass is combined with CHP, the client will see either higher positive or lower negative returns than those for 12 kW system.

Hydropower is also the best technology when combining high net present value and low risk. The hypothetical site would return a positive NPV for every scenario, while also increasing the return from the 12 kW system to an upper bound of $124,000. The lowest expected return for hydro is $17,000.

The estimates for solar PV are generally much larger than those for the 12 kW system, except when there is no FiT. Under this scenario, the negative returns are fairly similar, indicating that there are higher returns expected for a larger system, but similar negative returns expected for either size, which would favor installing a 21 kW system.

Table 20. Summary results for 21 kW demand system

21 kW				
Technology	**Scenario**	**NPV (thousand)**	**IRR**	**Payback**
Solar PV	FiT, 9%	$37	23%	5
	FiT, 15%	$14	-	-
	FiT, 20%	$4	-	-
	No FiT, 9%	($6)	7%	11
	No FiT, 15%	($17)	-	-
	No FiT, 20%	($21)	-	-
Hydro	FiT, 9%	$124	28%	7
	FiT, 15%	$57	-	-
	FiT, 20%	$27	-	-
	No FiT, 9%	$107	25%	6

	No FiT, 15%	$45	-	-
	No FiT, 20%	$17	-	-
Biomass	Fit, Avg Cost, 9%	$250	16%	7
	Fit, Avg Cost, 15%	$20	-	-
	Fit, Avg Cost, 20%	($87)	-	-
	Fit, High Cost, 9%	($203)	6%	12
	Fit, High Cost, 15%	($409)	-	-
	Fit, High Cost, 20%	($498)	-	-
	No Fit, Avg Cost, 9%	($645)	n/a	n/a
	No Fit, Avg Cost, 15%	($610)	-	-
	No Fit, Avg Cost, 20%	($584)	-	-
	No Fit, High Cost, 9%	($882)	-7%	n/a
	No Fit, High Cost, 15%	($905)	-	-
	No Fit, High Cost, 20%	($899)	-	-
CHP	Fit, Avg Cost, 9%	$94	27%	-
	Fit, Avg Cost, 15%	$43	-	-
	Fit, Avg Cost, 20%	$19	-	-
	Fit, High Cost, 9%	$10	10%	-
	Fit, High Cost, 15%	($35)	-	-
	Fit, High Cost, 20%	($35)	-	-
	No Fit, Avg Cost, 9%	$62	20%	-
	No Fit, Avg Cost, 15%	$19	-	-
	No Fit, Avg Cost, 20%	$130	-	-
	No Fit, High Cost, 9%	($21)	7%	-
	No Fit, High Cost, 15%	($21)	-	-
	No Fit, High Cost, 20%	($21)	-	-

Part 3: Water Analysis

The water analysis section deals with satisfying our client's water budget of 150 gallons per day through the implementation of a rainwater harvesting system.

Section I reviews rainwater-harvesting system, how it works in practice, major opportunities and threats of such technology, as well as general cost considerations. Section II describes the methodology and calculations used to estimate (1) the potential water harvested on-site given the roof constraints, (2) optimal sizing of storage tank and (3) potential cost savings of implementing a RWH system. Section III applies these calculations to data relevant to Improv'eat current operations. Section IV summarizes our recommendations.


Source: Buildipedia 2012

Source: Wimberly Wind & Solar

I. Rainwater Harvesting System (RWH)

The objective of this section is to provide an overview of small-scale commercial rainwater harvesting system design. It is intended as an introduction to rainwater harvesting, its advantages and constraints, given our client's demand (TWDB 2005). Rainwater Harvesting (RWH) entails the capture, diversion, storage and use of surface runoff during rain periods for productive purposes. Harvested rainwater has a variety of end uses including but not limited to agricultural irrigation, drinking and domestic use and storm water abatement (TWDB 2005, Kahinda et al 2007).

RWH is a particularly relevant application given increases in water scarcity and rampant impoverished water quality in the Philippines due to escalating global water demand instigated by incessant population growth, urbanization, industrialization and variable weather patterns (TWDB 2005; Worm & Hattum 2006). As discussed earlier, water usage is increasing in the Bohol region with demand potentially exceeding water table's natural capacity to replenish, resulting in limited water resources in the future. In regards to our particular client, he has already experienced brownouts and lack of water availability due to natural disaster risk. In the past, Improv'eat has trucked water at an additional cost to meet their needs (T. Fitts, pers. comm., Nov 2013). Water shortage threatens business continuity and may impede Improv'eat's operations, jeopardizing their production's timeline.

Therefore the effective management of in-situ water resources and water supply is necessary to address our client's water security or the "accessibility, reliability and timely availability of adequate safe water" to satisfy his small-scale water budget (Areerachakul 2013; Abdulla & Al-Shareef 2009). As such, rainwater harvesting is an ideal component of water management strategy for Improv'eat commercial applications.

How RWH Works

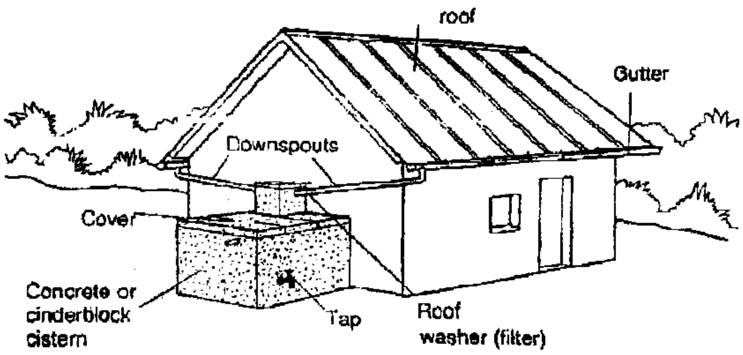


Figure 18. Rainwater harvesting system diagram with roof catchment.
Source: UNEP-IETC, 1998

Figure 18 is a diagram of a roof catchment RWH system. Rainwater flows from catchment area (i.e. roof) and is captured by guttering system that transports collected water to a storage tank. Most guttering systems are equipped with screens to filter debris from the system and first-flush diverters to ensure better water quality. From the storage tank water is then gravity-fed or pumped to the point of use. (Fulton et. al 2012). *Table 21* outlines key advantages and disadvantages of installing a RWH system.

Table 21. Advantages and disadvantages of incorporating RWH system.

Advantages	Disadvantages
• **Alternative resource for supplying freshwater.** Displaces the demand for municipal water supply (1); provides a water source when groundwater is unacceptable/unavailable (2) and increases assurance of water supply (3). • **Increases access to water during dry season or droughts.** Storage may serve as essential reserve during natural disasters (4). • **Generates potential cost savings (5).** Simple to install and operate, leading to negligible running costs, particularly cost-competitive in locations where rates are high (5). This may result in an overall reduction in the utility bill (4, 6) • **Flexible and adaptable technology.** System can be built to meet the	• **Uncertainty of rainfall.** System effectiveness limited by rainfall frequency and volume.(7,8) • **High capital costs**. In areas where water rates are low, the high capital costs of the system make the system cost prohibitive (5, 9). • **Human health risks related to inadequate water quality provided by system**. If proper measures are not taken, the RWH system can result in mosquito breeding ground, fecal contamination and ultimately instigate the spread of water-borne disease (10). Measures can be taken to reduce the chance of human health risks particularly in terms of overall maintenance of the storage unit and treatment of the water before its use.

capacity needs that are location specific. There are also a wide array of materials and types of systems to install (4, 5, 7). - **Reduce storm runoff.**	

Source: (1) CA Evans 2006 (2) TWDB 2005 (3) Kahinda et. al 2007 (4) Worm & Hattum 2006, (5) Abdulla & Al-Shareef 2009 (6) Areerachakul 2013 (7) Zhu et al 2004 (8) Dasch 2003 (9) Helmreich & Horn 2009, (10) Kahinda 2007

All rainwater harvesting systems consist of three principal components: (1) catchment area, (2) conveyance system and (3) storage tank.

(1) The *catchment area* is the actual surface where the rainwater is collected. This may be a rooftop catchment or land surface catchment. The effective roof area and roofing materials directly influence efficiency of collection and water quality. It is important to note that roofing materials may be a source of nonpoint water pollution (Chang 2004). For potable water use, ideal surfaces are clean, impervious, free from overhanging trees, and made of chemically inert materials (Abdulla & Al-Shareef 2009; Areerachakul 2013). Zinc and copper roofs are not ideal for potable water use because they may result in high heavy metal concentrations (Helmreich & Horn 2009). Galvalume however, is 55% Aluminium/45% Zinc alloy-coated sheet of steel that is commercially available and has proven not to impact water quality (TWDB 2005). Tiled roofs sheeted with corrugated mild steel are another alternative that has in practice resulted in clean water (Abdulla & Al-Shareef 2009).

(2) The *conveyance system* includes all gutters, downspouts and pipes integrated for the purpose of transporting rainwater from catchment area to storage unit. Overflow designs should be installed to eject water from the system in case of heavy rainfall events (TWDB 2005). Given that the Improv'eat manufacturing site is in a rainfall-prone area, special attention must be given to the strategic installation of gutters to avoid rainwater loss. The most common materials to

use for all elements of the conveyance system are "half-round PVC, vinyl and galvanized steel" (Abdulla & Al-Shareef 2009; TWDB 2005).

(3) The *storage tank* collects and stores harvested rainfall in above-ground (AGTs) or below-ground tanks (BGTs). *Table 22* provides a comparison between each operation. For potable clean water supply, tanks should be covered with draw-off pipes at least 100mm above tank floor to avoid sludge in water supply (Ogale 2011; Helmreich & Horn 2009). The tank should be regularly cleaned and a manhole should be constructed to facilitate inspection and access (Ogale 2011). Common materials used for storage tanks include brick wood, stonework, and reinforced cement concrete (Abdulla & Al-Shareef 2009). Plastic tanks are to be avoided for AGTs since their transparent nature can lead to algal blooms (Helmreich & Horn 2009).

Table 22. Comparison between above-ground and below-ground storage units.

Above-Ground Tanks (AGTs)	Under-ground Tanks (UGTs)
Pros	
• Easy to inspect and/or detect cracks & leaks. (4) • Water extraction can make use of gravity (3). • Can be raised off ground to increase water pressure (4) • Easy to drain for cleaning (4) • Arguably less costly than BGTs (1, 4). • Many designs to choose from with wide variety of materials (3)	• Good at preventing algal growth (light cannot penetrate) and keep water cool (4) • Surrounding ground gives support allowing lower wall thickness (3) • Not as noticeable and does not take up space (3, 4).
Cons	

• Requires space (3, 4) • Subject to weather conditions, sunlight and prone to erosion (3, 4) • Require anchoring to the ground when tank has less water (4) • Prone to mosquito breeding if proper netting measures not employed. (2) • Higher risk of contamination by humans or animals (2)	• More difficult to extract water from, often need a pump.(3, 4) • Hard to detect leaks or problems. • Structure can be damaged by tree roots, heavy vehicles driving near the cistern, or pressure by soil (3,4) • Drowning risk to children if left uncovered (3, 4). • Risk of contamination from groundwater or flood-waters (4). • Difficult to drain for cleaning. (4) • Larger excavation costs and cost of more heavily reinforced tank to resist soil pressure. (4)

Source: (1) TWDB 2005 (2) Arerrachakul 2013 (3) Worm & Hattum 2006 (4) Abdulla & Al-Shareef 2009

Rainwater Quality and Treatment

Before storage, rainwater is "free" from physical and chemical contaminants including pesticides, lead, and suspended materials. It is usually acidic in nature and low in sodium (Abdulla & Al-Shareef 2009; Sazakli et al 2007). However, the water quality is also dependent on particulate matter and gasses in atmospheric air (i.e. SOx, NOx, etc.), having higher concentrations of these contaminants when close to the source (i.e. industrial locations). In terms of stored rainfall, there is a lack of consensus in available literature regarding its quality due to limited understanding and conflicting reports. Some studies suggest acceptable quality for domestic use, that satisfy limits imposed by international organizations, (Areerachakul 2013; Helmreich & Horn 2009; Sazakli et al, 2007; Kahinda et al 2007; Zhu et al 2004). Other studies suggest presence of microbial pathogens and chemical contaminants that would render water quality unacceptable (Abbott et al 2006; Evans et al 2006).

The reviewed literature does agree that quality and composition of stored rainwater is highly dependent on characteristics of the individual study site. These characteristics include local topography, weather patterns and seasonality, atmospheric characteristics, proximity to industrial emission sources, type of catchment area, type of water tank and overall water management (Sazakli et al 2007; Helmreich & Horn 2009; Evans et al 2006; Kahinda et al. 2007; Abdulla & Al-Shareef 2009). Due to the various sources of contamination, the chemical quality of the water should be tested before defining its intended end use. A first step for Improv'eat would be to collect precipitation samples for quality analysis in current and future facility locations.

Harvested water should undergo further treatment if it is to be used for drinking purposes. Given that our client will most likely use this water to wash the coconuts, potable water quality is a must (Helmreich & Horn 2009). In order to do so many treatment mechanisms can be incorporated, the most common methods are described below.

- *First Flush Diverters.* Debris tend to accumulate naturally on rooftops; therefore, removal of the first flow of rainwater improves overall quality of stored supply by ensuring that rainwater only enters the storage tank after the catchment area has been washed off (TWDB 2005, Ogale 2011, Zhu et al 2004, Sazakli et al 2007; Abdulla & Al-Shareef 2009). In fact, studies show that water quality of RWH systems with first flush diverters in place has significantly lower concentration of contaminants than those systems without this treatment technique (Areerachakul 2013; Abdulla & Al-Shareef 2009). A rule of thumb is to divert 10 gallons for every 1,000 sq. ft. of catchment area (TWDB 2005).
- *Chlorination.* The addition of chlorine as a disinfectant, preferably after water is retrieved from the storage tank, is a common and applicable treatment practice to ensure potability of harvested rainwater (Helmreich & Horn 2009; Sazakli et al 2007; Kahinda et al 2007). Chlorine additions can take the form of a gas, hypochlorite tablets and/or sodium hypochlorite solution (Ogale 2011).

- *Pasteurization by Solar Technology.* Photo-oxidation using UV light removes both coliform and streptococci by placing transparent bottles of water in direct strong sunlight for up to 5 hours (Areerachakul 2013; Helmreich & Horn 2009). There are also available technologies such as the SODIS reactor that allows for pasteurization as a continuous flow system, and produces 1000L of disinfected water per square meter of solar collector and day (Helmreich & Horn 2009).
- *Slow Sand Filtration.* This technique uses a biofilm to improve bacteriological quality of water, which lasts a few weeks and produces low nutrient level water. This process solely reduces microorganisms and requires constant flow of water (Helmreich & Horn 2009).
- *Rapid Sand Filtration.* Water is physically filtrated as it moves vertically down sand covered by activated carbon or anthracite coal. This method removes suspended solids and organic compounds and improves with depth of filter (Helmriech & Horn 2009).

Costs

The capital costs are significantly higher than O&M costs and highly dependent on the harvesting system's type of catchment, conveyance system, and storage tank size and materials used. However, the storage tank in itself is the most costly individual unit. A rule of thumb for a traditional system is that "a 2,500-5,000 gallon system costs $1.75 to $2.25 per gallon stored. Systems larger than 10,000 gallons cost between $1.00 and $1.75 per gallon" (Abdulla & Al-Shareef 2009). *Table 23* summarizes upfront cost estimations for RWH systems.

Table 23. Upfront Cost Estimations for Rainwater Capture System.

	Cost	Size	Maintenance	Additional Information
Storage Tank Cost Estimates				
Fiber Glass	$0.50-2.00/gallon	500-20,000 gallons	-	Can last for decades without deterioration; easily repaired; can be painted
Concrete	$0.30-1.25/gallon	≥ 10,000 gallons	-	Risks of cracks and leaks, but these are easily repaired; immobile; smell and taste of water sometimes affected but the tank can be retrofitted with a plastic liner
Metal	$0.50-1.50/gallon	150-2,500 gallons	-	Lightweight and easily transported; rusting and leaching of zinc can pose a problem but this can be mitigated with a potable-approved liner
Polypropylene	$0.35-1.00/gallon	300-10,000 gallons	-	Durable and lightweight; black tanks result in warmer water if tank is exposed to sunlight; clear/translucent tanks foster algae growth
Wood	$2.00/gallon	700-50,000 gallons	-	Aesthetically pleasing, sometimes preferable in public areas and residential neighborhoods
Polyethylene	$0.74-1.67/gallon	300-5,000 gallons	-	-
Welded Steel	$0.80-4.00/gallon	30,000-1 million gallons	-	-
Rain Barrel	$100	55-100 gallons	-	Avoids barrels that contain toxic metals; add screens for mosquitoes.
Gutter Cost Estimates				
Vinyl	$.30/foot	-		Easy to install and attach PVC tank lines
Plastic	$.30/foot	-		Leaking, warping, and breaking are common problems.
Aluminum	$3.50-6.25/foot	-		Must be professionally installed.
Galvalume	$9-12/foot	-		Mixture of Aluminum and galvanized steel; must be professionally installed.
Roof Washer Cost Estimates				
Box Washer	$400-800	-	Clean filter after every substantial rain.	Neglecting to clean the filter will result in restricted/blocked water flow and may become a source of contamination.
Post Filtering with Sand Filter	$150-500	-	Occasionally backwash with filter.	Susceptible to freezing; a larger filter is best
Smart-Valve Rainwater Diverter Kit	$50 for the kit	-	Occasional cleaning.	Device installed in a diversion pipe to make it self-flushing and prevent debris contamination; resets automatically

Pumps and Pressure Tanks				
Grundfos MQ Water Supply System	$385-600	-	-	Does not require a separate pressure tank
Shallow Well Jet Pump or Multi-Stage Centrifugal Pump	$300-600	-	-	Requires a separate pressure tank.
Pressure Tank	$200-500	-	-	Galvanized tanks are cheaper than bladder tanks, but often become waterlogged, and this will wear out the pump more rapidly.
Filtering/Disinfection				
Cartridge Filter	$20-60	-	Filter must be changed regularly	A disinfection treatment is also recommended. **Effectiveness:** Removes particles >3 microns.
Reverse Osmosis Filter	$400-1500	-	Change filter when clogged (depends on the turbidity)	A disinfection treatment is also recommended. **Effectiveness**: Removes particles >0.001 microns.
UV Light Disinfection	$350-1000; $80 to replace UV bulb	-	Change UV bulb every 10,000 hrs. or 14 mo.; the protective cover must be cleaned regularly	Water must be filtered prior to exposure for maximum effectiveness. **Effectiveness:** Disinfects filtered water provided there are <1,000 coliforms per 100 mL
Ozone Disinfection	$700-2600	-	Effectiveness must be monitored with frequent testing or an in-line monitor ($1,200 or more)	Requires a pump to circulate ozone molecules. **Effectiveness:** Less effective in high turbidity, can be improved with pre-filtering
Chlorine Disinfection	$1/month manual dose or $600-3000 automatic self-dosing system	-	Monthly dose applied manually.	Excessive chlorination may be linked to negative health impacts. **Effectiveness**: High turbidity requires a higher concentration or prolonged exposure but this can be mitigated by pre-filtering.

Source: TWDB 2005

II. Methodology

Rainwater Harvesting Potential (VR)

"Rainwater harvesting is only practical when the volume and frequency of the rainfall and size of catchment surface can generate sufficient water for the operation's intended purpose" (TWDB 2005). In our investigation we will apply commonly used rainwater harvesting potential equation shown below (Abdulla & Al-Shareef 2009).

(Eq. 3) $$VR = \left(R \times A \times \frac{C_r}{1000}\right)$$

- **VR** is the mean monthly volume of rainwater that could be harvested (m^3/mo.)
- **R** is the mean monthly rainfall (mm/mo.),
- **A** is the total roof area (m^2),
- **C_r** is the run-off coefficient (dimensionless), and
- **1000** is the conversion factor from mm to m.

The **average rainfall frequency** is first investigated on a monthly basis and plotted for both the Philippines and Duero region to evaluate geographical and spatial differences in rainwater harvesting potential. For the purposes of Improv'eat current operations, Duero data taken from NASA and World Bank datasets were used (POWER N/A; World Bank 2014).

Roof area dimensions (12m x 15m) provided by our client are used to estimate roof catchment area (*Figure 3*). It was assumed that the catchment area would not include solar drying area, outgoing station, entrance or restrooms, resulting in 180m^2 of available workspace for the installation of a catchment area.

The **run-off coefficient** is the "ratio of the volume of water that runs off a catchment surface to volume of rainfall that falls on the surface" (Abdulla & Al-Shareef 2009). Therefore, the higher the runoff coefficient, the more rainwater harvesting yields from the system. It takes into account the runoff loss from the collection system due to leakage, overflow of gutters, evaporation, roof cleaning, first flush diverters wind, minor infiltration into surface itself and/or roof composition (Lancaster 2013). *Table 24* identifies run-off coefficients for traditional roofing materials. For the purposes of this investigation, we used a conservative run-off coefficient of 0.8, which indicates a 20% loss of rainwater due to first flush diverters and evaporation (Abdulla &Al-Shareef 2009; Worm & Hattum 2006).

Table 24. Run-off Coefficients for Traditional Roofing Materials

Type	Run-off Coefficient
Galvanized Iron Sheets	> 0.9
Tiles (Glazed)	0.6 -0.9
Aluminum Sheets	0.8 - 0.9
Flat Cement Roof	0.6 - 0.7
Organic (i.e. thatched)	0.2

Source: Worm & Hattum 2006

Potential for Potable Water Savings (PPWS)

The monthly Potential for Potable Water Savings (PPWS) is then calculated to describe the relationship between potential volume of harvested rainwater (VR) and the potable water demand in the study site (PWD) using equation below (Abdulla & Al-Shareef 2009).

(Eq. 4) $$PPWS = 100 \times \frac{VR}{PWD}$$

- **PPWS** is the percent savings once harvested water is used to satisfy existing demand (%)
- **PWD** is potential water demand (m^3/mo.)
- **VR** is the potential harvested rainwater (m^3/mo.)

The **potential water demand** value of 150 gallons/day was obtained from our client as an estimate for Improv'eat daily water needs. The primary purpose of water is meant for washing coconut shells; however other end uses include its employment as gray water (i.e. servicing toilets, laundry facilities, lawn irrigation, etc.). Since our client's product is ultimately for human consumption and to ensure system simplicity, we assume that the entirety of his daily water consumption requires potable water quality.

Sizing the Storage Tank

The size of the storage reservoir is relevant to ensuring a reliable supply that meets water consumption rates during the dry season. In this investigation we will be using both a demand side and a supply side approach to evaluate sizing of the reservoir (Worm & Hattum 2006).

1. Demand Side Approach. This approach is used by professional installers to meet quarterly water user demands and generates a simplistic rough estimate of storage tank sizing (TWDB 2005). It should be used in locations with sufficient rainfall, adequate roof catchment area, and in areas with a distinct dry season (Worm & Hattum 2006). These are similar conditions to our client even though the distinct dry season is not as pronounced as other locations. Required storage capacity (S) is thus product of average monthly water demand (WD) and three, or the number of months in a quarter of a year (Worm & Hattum 2006).

$$\text{(Eq. 5)} \qquad \boldsymbol{Storage\ Capacity = Water\ Demand\ \left(\frac{m^3}{mo}\right) \times 3}$$

2. Supply Side Approach. This approach requires monthly rainfall data for the site under investigation and requires graphical analysis (Worm & Hattum 2006). It is meant to ensure that all rainwater in contact with the catchment area is harvested and should provide an upper bound for the potential harvesting for Improv'eat operations.

1. Potential monthly averaged harvested rainwater is compared to the potable water demand per month of the Improv'eat facility.
2. Cumulative monthly run-off is then graphed against the cumulative water demand for the Improv'eat facility. This will allow for the cumulative investigation of inflow and outflow from the tank. The capacity of the tank

should be calculated as the “greatest excess of water above the water demand (greatest difference between both gradients)” (Worm & Hattum 2006).

Cost Savings Evaluation

The potential monthly harvested water displaces Improv’eat’s need to use municipal water from the Philippine utility provider, which in the long-term generates cost savings to its operations. Average water tariff rates for 2013 (in PHL pesos), retrieved from the Philippines Local Water Utilities Administration for the province of Bohol and the country’s average, are used to create lower and upper bound cost savings (LWUA 2013). The rates were then converted to US dollars using the exchange rate of 1 USD = 45.0001 PHP, which was the same conversion, used in the Part I of this investigation (Exchange Rates UK 2014). Cost savings can then be investigated in regards to the potential volume of water that the rainwater harvesting system (RWH) in place is able to obtain compared to the tariff that would have been imposed on Improv’eat if no RWH system were installed.

III. Results RWH for Improv'eat Operations

Average Rainfall and Climate Overview

The Philippines experience a tropical maritime climate with uniform temperature pattern year round. For the purposes of this investigation we used data relevant to the following coordinates: 9.43 N, 124.24 E, which are for the Duero municipality in the Philippines. These were the closest coordinates we were able to find providing data that was in proximity to client's current operations. The average temperature for the Philippines is 25.5°C, with slightly higher average annual temperatures of 27.1°C, for our specific study site (World Bank 2014). The year round average temperature range is of 23-32°C (KPMG 2013). The national annual precipitation is of 2,380 mm/year (World Bank 2014) and slightly lower for our study site at 1,987 mm/year (POWER 2014).

It is important to note the considerable seasonal variations and variability of rainfall due to geographic location. Historically this value has a significant range from 1000 to 4000 mm/year, of which "1,000 to 2,000 mm/year are collected as runoff" (Greenpeace 2007). While the northwest experiences a distinct wet and dry season, the southeast region of the nation experiences rainfall year round. However, there is still monthly variability in precipitation patterns regardless of location. In fact, the months of November to April are considered the dry season while November to January characteristically experience peak precipitation due to the northeast monsoons (FAO - Aquastat 2011). *Figure 19* shows averaged monthly temperature and rainfall for the Philippines and our study site location for Duero in the Bohol province.

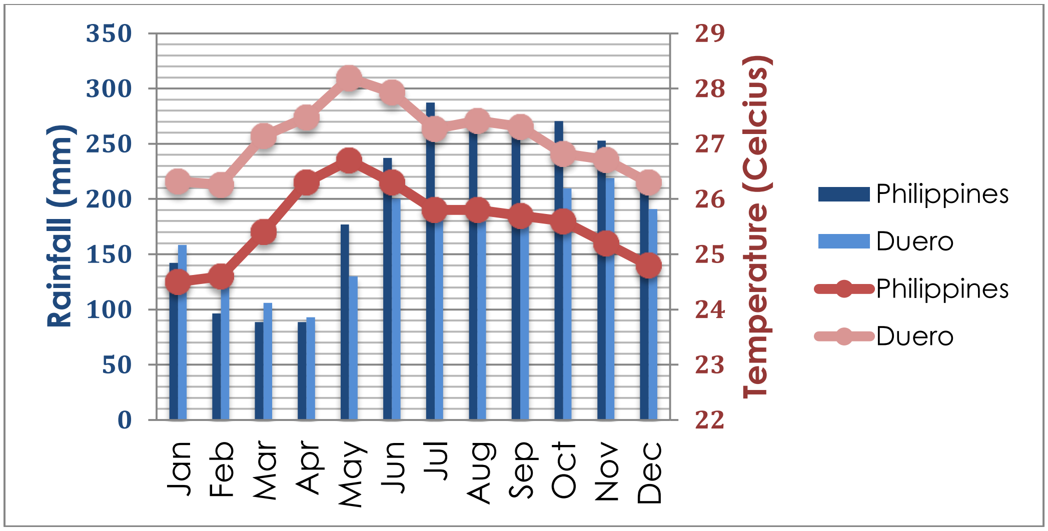


Figure 19. Averaged Monthly Temperature and Rainfall for The Philippines and Duero province from 1900-2009
Source: World Bank 2014 & POWER N/A

Aside from temporal variation, rainfall patterns also vary spatially. This causes a substantial range in annual rainfall ranging from General Santos City at a lower bound of 960 mm/year and Infanta in Central Luzon at an upper bound of 4,050 mm/year (FAO - Aquastat 2011). Most of this variation is due to the wind patterns and location relative to mountain ranges. Since, in general, the mountain ranges run north-south, during the northeast monsoon period (October to March) and southwest monsoon (May to October), there is increased precipitation in slope facing the wind and rain shadows on the opposing slope (FAO – Aquastat 2011). For the region of Bohol, a 30-year record from 1975-2005 suggests that the rainfall in basin can vary from 1,000 mm to 3,500 mm, however overall the distribution is even throughout the year (Woodfields Consultants Inc. 2010).

Results Rainwater Harvesting Potential

The results by monthly basis are summarized in *Table 25*, while *Table 26* expresses monthly averages and annual totals. The maximum of 286 m^3/year, equivalent to 75,587 gallons/year, can be collected from Improv'eat's current operations, provided that the 12 x 15 meter roof catchment surface is used and that all rainfall is collected. This exceeds the annual potable water demand of Improv'eat current operations of 207 m^3/yr. The potential for water harvesting is highly dependent on rainfall and varies on a monthly basis, ranging from a minimum of 13.39 m^3 in the month of April to a maximum 31.54 m^3 in November. Results suggest an average monthly potential water savings of 138%.

Table 25. Monthly potable water demand, mean precipitation, potential for harvested water and potential for potable water savings results for Improv'eat current operations.

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Potable Water Demand	m³/mo	17.60	15.90	17.60	17.03	17.60	17.03	17.60	17.60	17.03	17.60	17.03	17.60
Mean Monthly Precipitation (22 year Avg.)	mm/mo	158.41	121.52	106.02	93.00	129.89	200.40	199.95	179.80	178.50	209.56	219.00	190.96
Mean Monthly Harvested Water	m³/mo	22.81	17.50	15.27	13.39	18.70	28.86	28.78	25.89	25.70	30.18	31.54	27.50
Potential for Potable Water Savings	%	130	110	87	79	106	169	164	147	151	171	185	156

Table 26. Monthly averages and annual total for potable water demand, mean monthly precipitation and mean monthly harvested water.

	Monthly Average	Annual Total
Potable Water Demand	17.27 m³	207.25 m³
Mean Monthly Precipitation (22 year Avg.)	165.58 mm	1,987 mm
Mean Monthly Harvested Water	23.84 m³	286.13 m³
Potential for Potable Water Savings	138%	-

Cost Savings Calculation

LWUA water rates for 2013 were used to estimate the lower and upper bound of cost savings from harvesting the rainwater run-off from the catchment area (See *Appendix 22* for LWUA water rate data used in Philippine pesos and US dollars). We assumed that all harvested rainfall was collected and used these values to generate the cost savings. On average, a RWH system would result in an average monthly cost savings in current operation in the region of Bohol roughly between $18 and $20, and an annual cost savings between $103 and $109. *Appendix 23* expresses the extensive results.

Sizing Storage Tank

1. Demand Side Approach.

Figure 20 represents potential monthly average harvested rainwater potential compared to the monthly potable water demand of the Improv'eat facility. The graph shows that for current operations March and April are the only months where potential average harvested rainfall is below the facility's water budget. In fact, the deficit during those months is 6 m^3 (6000 liters or roughly 1585 gallons).

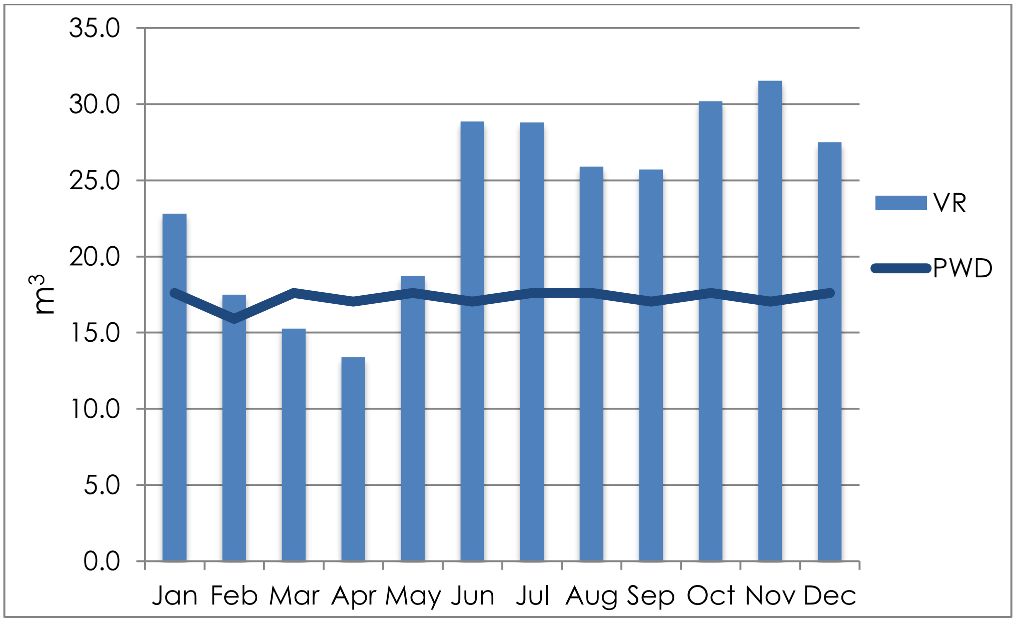


Figure 20. Monthly potential average water harvested and average potable water demand for Improv'eat operations in Duero municipality, Bohol province.

Note: VR = volume of rainwater that could be harvested; PWD = Improv'eat potential water demand

Required storage capacity (S) equals the product of average monthly water demand (WD) and the number of months in a quarter of a year (3). This results in a **required storage capacity of 51,813 L (13,688 gallons).**

As mentioned, this is a simplistic approach that gives a rough estimate. It also does not take into account inter-annual variation such as drought, typhoons and other significant events that are prone to the study site region and would have an effect on the RWH system's successful implementation (Worm & Hattum 2006). However, given the historical data obtained sizing a tank in such a manner should satisfy Improv'eat current water demand without making the operation cost-prohibitive.

2. Supply Side Approach.

This approach is commonly used in places where there is a distinct dry season with no rainfall. It is meant to optimize the RWH potential to store the absolute amount of rainfall runoff from catchment area. In this investigation the cumulative water demand and harvested rainwater are graphed.

Cumulative water demand is found by adding the monthly demand to that of all previous months. So for January it is simply 17.60m^3, while for February it is the sum of 17.6m^3 of January and the subsequent 15.90m^3 for February resulting in 33.9m^3. The same approach is used to calculate cumulative potential rainwater harvested values. The month with the largest difference between water demand and harvested rainwater represents the optimal sizing of the storage unit (*Figure 21* highlights December as the largest difference).

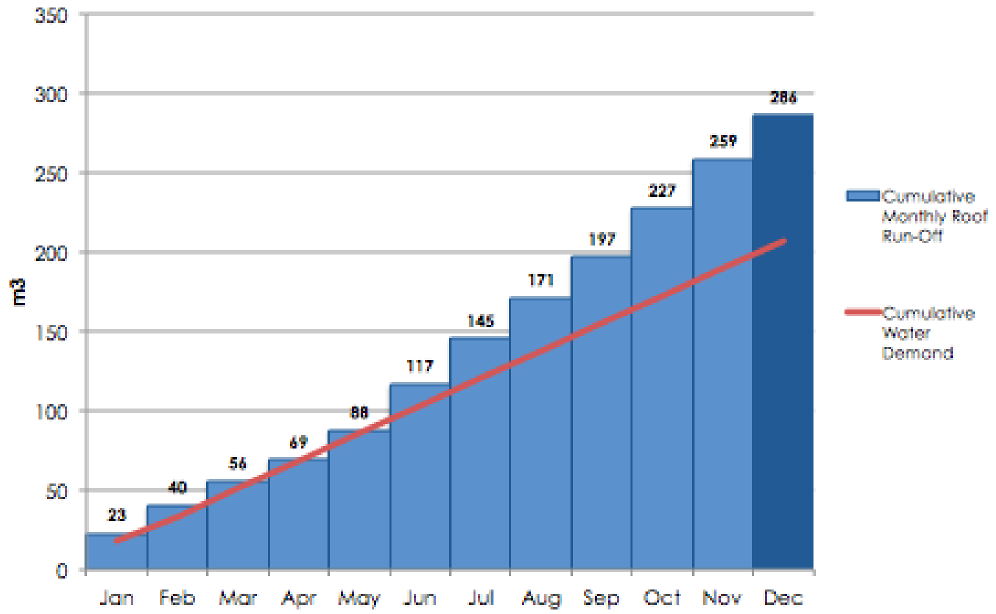


Figure 21. Cumulative monthly run-off vs. cumulative water demand for Improv'eat facility.

Note: December is highlighted as month with largest difference between cumulative water demand and cumulative potential for harvested rainwater.

For Improv'eat, the largest difference, experienced in December, between cumulative water demand and cumulative potential for harvested rainwater, results in a **required storage capacity of 78.9 m^3 (78,900 liters or 20,843 gallons).** This value represents the storage size that would collect *all* of the run-off flowing from the catchment area. This large value is attributed high rainfall patterns in the region, as seen for harvesting potential exceeding water demand for all months except for March and April (*Figure 20*). This value is useful in understanding the upper bound potential RWH system in Improv'eat current operations. Nevertheless, it is ultimately not a viable option since the expense attribute to such a large storage tank size will make such an installation cost prohibitive.

IV. Recommendations

A rainwater harvesting system (RWH) would be a practical mechanism to incorporate into Improv'eat current operations. It would ultimately help our client's goal to become self-sufficient and sustainable in terms of facility's water use. According to our analysis, the current site has a high potential for roof rainwater harvesting, beyond Improv'eat water budget, due to suitable patterns of historical rain frequency.

As previously discussed, the quality and composition of stored rainwater is highly dependent on characteristics of the individual site (i.e. local topography, weather patterns, proximity to industrial emission sources, etc.). A logical first step for Improv'eat would be to collect precipitation samples for quality analysis, in current and/or future locations, to define the water's quality. Furthermore, since Improv'eat makes food products, harvested water may require further treatment in order to satisfy global standards drinking standards before its use in the operations (*See 'Rainwater Quality & Treatment'*).

Nevertheless, we suggest a storage unit of ~50,000L (~13,209 gallons). A cistern this big will provide roughly three-month water supply when full, and should meet our client's monthly water budget, even during dry season. Given Improv'eat's current operation size and water needs, we further suggest that a RWH system be installed as a supplementary water source, where the facility is still connected to the main centralized municipal water supply. Such a strategy will hedge for uncertainty of future rainfall patterns and drought incidents (Zhu et al 2004). Systems larger than 10,000 gallons cost between USD$1.00-$1.75 per gallon (Abdulla & Al-Shareef 2009), however given our calculations this exact same system should be full every month and will provide a monthly cost savings in the Bohol region of USD$8.60 to $9.11.

Conclusion

The purpose of this investigation was to assess the feasibility of moving Improv'eat Philippine production off-grid in terms of its energy and water requirements. The objective in doing so was to ensure that our client's operations become more reliable, self-sufficient and sustainable.

In terms of energy demand, solar tubes were investigated to displace the facility's lighting requirement, while solar PV, micro-hydro, biomass and CHP technologies were assessed to determine their feasibility to meet current facility electrical demand scenarios of 21 kW and 12 kW (without dehydrators). *Figure A* presents the results based on the calculations and scenarios analysis for solar photovoltaic, hydropower, biomass, and combined heat and power (CHP). Given our extrapolated results, we recommend the implementation of (1) solar tube technology – to displace lighting requirements – (2) solar PV, if the client can guarantee a FiT and is risk averse, or (3) combined heat and power, if the client is risk prone.

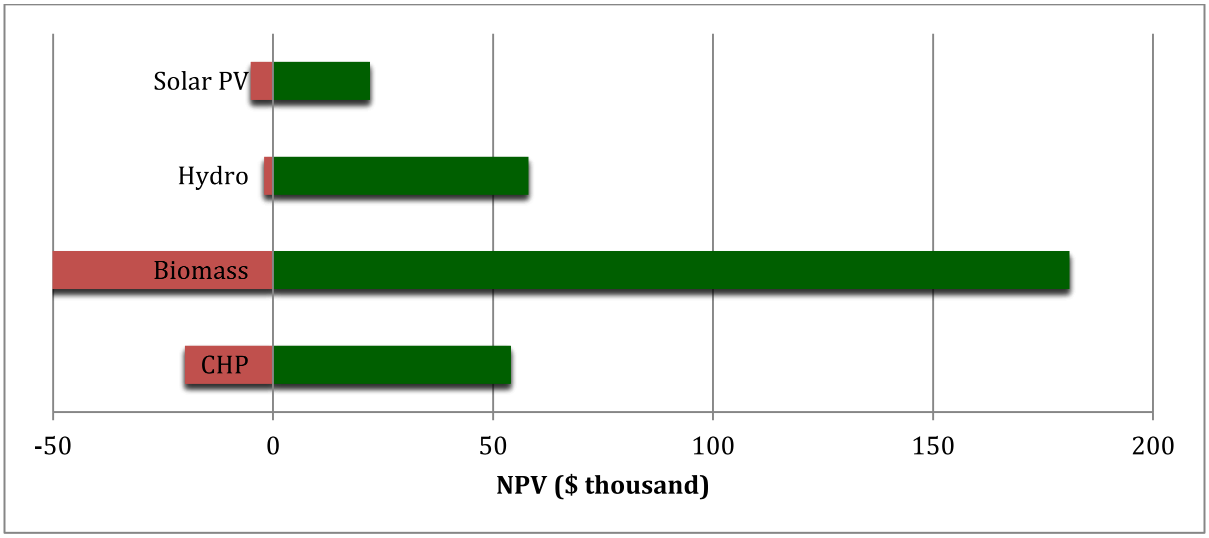


Figure 9. Comparative results across scenarios for 12kW four renewable energy technologies investigated.

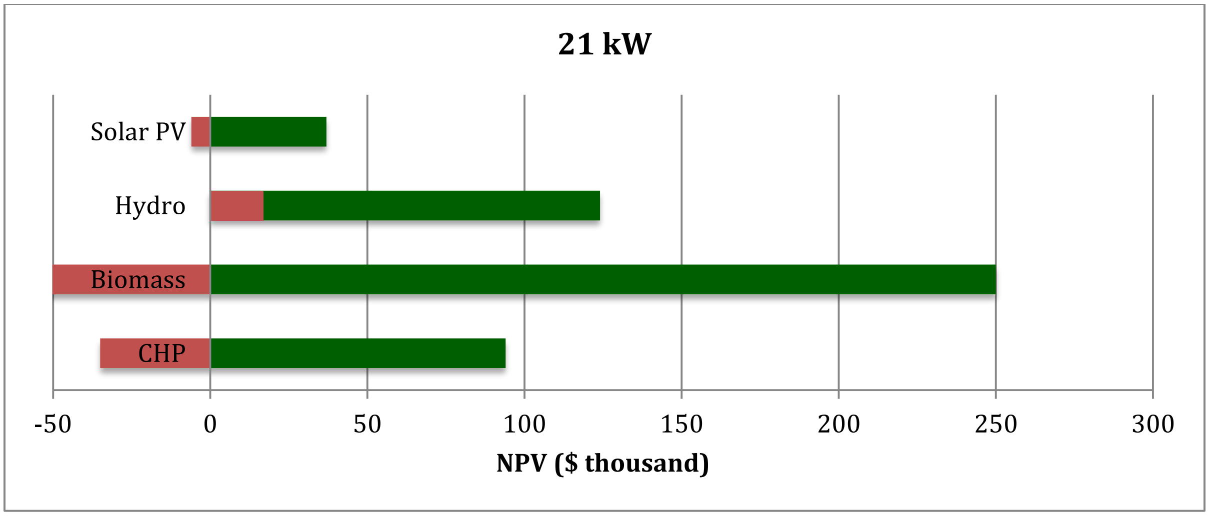


Figure 10. Comparative results across scenarios for 21kW four renewable energy technologies investigated.
Note: The worst-case results for biomass are cut off at -$50k to focus on differences between the other technologies.

For the next facility, we highly recommend choosing a strategic location so that micro-hydro can be incorporated. The optimistic results of high net present value and low risk for both a 12 kW and 21 kW systems are ideal for ensuring the objective of off-grid production, reliability, autonomy and clean production. However, more information on water permitting costs and environmental clearance should be incorporated to increase the accuracy legitimacy of the results. We also recommend solar tube technology to displace the facility's lighting requirements. Lastly, even though micro-hydro would satisfy our client's energy budget, given the high returns for CHP, future Improv'eat facilities should also consider the incorporation of this energy technology.

We further recommend that Improv'eat incorporate a rainwater harvesting system to take advantage of the location's year-round rainfall to meet the facility's water budget. Our models suggest that a ~50,000 liter storage unit would be ideal to guarantee a three-month supply when full. This should avoid events of discontinuation to Improv'eat operations due to water shortages, especially during drought incidents. It is important to note that implementing RWH in the roof, however, will limit the use of roof-installed solar PV and potentially hinder the incorporation of solar tubes. Our client should consider these tradeoffs when evaluating the best option for Improv'eat current and future operations.

Lastly, these models were based on several assumptions that may change as Improv'eat continues to grow and evolve. In addition, exact prices for costs of equipment, installations, and permits in the Philippines could greatly affect the estimates. These values were unknown at the time of the study; thus, the team has attached the spreadsheets used to create the models so that the client can manipulate these assumptions and prices to accurately reflect an estimated net present value for each of the technologies as more information becomes available.

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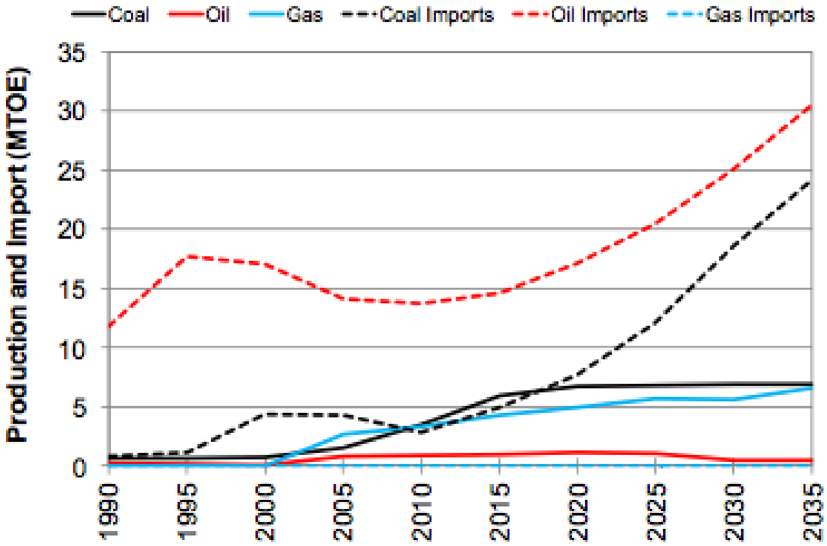
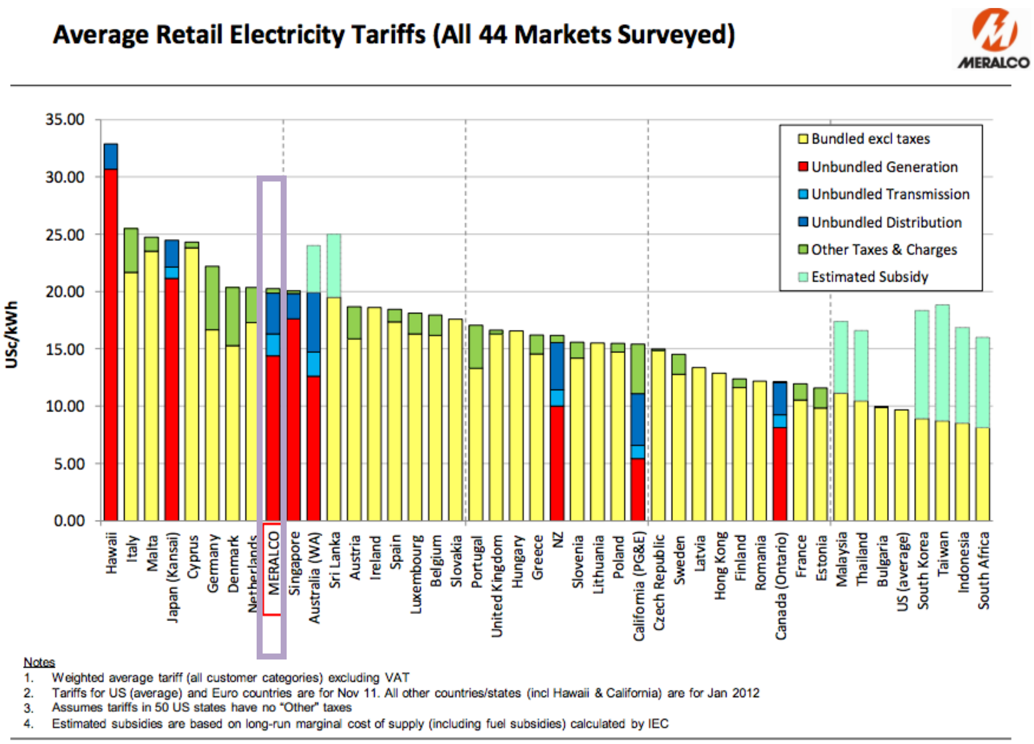
Appendix



Appendix 1. BAU Energy Production and Net Imports
Source: APEC 2013

Appendix 2. Bohol province power system.
Source: Woodfields Consultants 2010



Average Retail Electricity Tariffs (All 44 Markets Surveyed)

Notes
1. Weighted average tariff (all customer categories) excluding VAT
2. Tariffs for US (average) and Euro countries are for Nov 11. All other countries/states (incl Hawaii & California) are for Jan 2012
3. Assumes tariffs in 50 US states have no "Other" taxes
4. Estimated subsidies are based on long-run marginal cost of supply (including fuel subsidies) calculated by IEC

Appendix 3. Average Retail Electricity Tariffs 44 Markets Surveyed

Source: IEC 2012

Note: Purple box indicates rates for Meralco (Philippine enterprise)

Source: 1972 National Economic Atlas

Appendix 4. Water Resources Region* Map

*The Philippines were divided into 12 water resource regions (WRRs) based on hydrological characteristics for logistical and planning purposes.

Source: Philippine NSCB 2003

Appendix 5. Principle Entities Involved in Water Management in The Philippines.

Agency, Department or Governmental Entity	Function
Local Water Utilities Administration (LWUA)	GOCC with dual role of tariff regulator and institutional development advisor to WDs (1). Sets and enforces standards of service for water supply systems operated by local WDs, providers technical advisory services and financial assistance to local WDs, and regulates tariffs of WDs under LWUA jurisdiction. (2,4)
Metropolitan Waterworks and Sewerage System (MWSS)	GOCC responsible for the provision of water supply and sanitation services to the cities and municipalities of Metro Manila and maintains existing assets and infrastructure. The Regulatory Office, under MWSS, is entrusted with regulation of the two private concessionaries, Manila Water Company, Inc. (MWCI) and Maynilad Water Services, Inc. (MWSI). (2,4)
Department of Interior and Local Government (DILG)	Water Supply and Sanitation Project Management Office of the DILG defines and enforces quality and performance standards of service for LGU-managed systems. Also, assist service providers through capacity building and technical assistance. (2)
Department of Environment and National Resources (DENR)	DENR regulates effluent standards for wastewater quality and grants permits for effluent discharge (1,3)). Executive department responsible for national management of exploration, development, proper utilization and conservation of the country's national resources. The River Basin Control Office (RBCO), under DENR, acts as the implementing office for all plans or projects concerning country's river basins.
National Water Resources Board (NWRB)	Has legal mandate for overseeing Water Code and is lead coordinator for resource management projects(4). Yet, has structure and budget that are inadequate to allow proper exercise of this administrative function (1). NWRB is responsible for economic regulation of WDs (except those falling under MWSS or LWUA jurisdiction). Should act as an appeals body on tariff disputes arising between WDs and LWUA (2)
Forest Management Bureau (FMB)	Formulates policies and programs for protection, development and management of forests, lands and watersheds (4).
Environmental Management Bureau(EMB)	Classifies water bodies in The Philippines according to its beneficial use and water quality. Sets and enforces water quality and effluent standards, criteria and guidelines for all aspects of water quality management (3,4).
Department of Finance (DOF)	Sets and implements policies on the use of grants and guarantees from the national government and official development assistance (ODA). (2)
Department of Health (DOH)	Regulation of drinking water through the city and municipal health offices and municipal health offices of the LGUs (1) Responsible for water supply and sanitation programs and strategies to fight water-borne disease (4).
Department of Interior and Local Government (DILG)	Water Supply and Sanitation Project Management Office of the DILG defines and enforces quality and performance standards of service for LGU-managed systems. Also, assist service providers through capacity building and technical assistance.

Department of Public Works and Highways (DPWH)	Primary engineering and construction arm of the government, responsible for planning, design, construction and maintenance of infrastructure such as roads and bridges, flood control systems, water resource development projects and other public works in accordance with national objectives.
Government Financial Institutions (Developmental Bank of The Philippines & Land Bank of The Philippines)	Provides financing to water infrastructure projects (2)
Local Government Units (LGUs) - provincial, city and municipal levels	De facto responsibility for policy, planning and regulatory functions specific to their jurisdictions (i.e. Investigating financing and management options, deciding on tariffs, providing investment and funding support and setting performance standards).
National Economic and Development Authority (NEDA)	Key agency for policy formulation and planning in water supply sector, with regard to preparing national development plans and investment programs, formulating sector policies and strategies and monitoring implementation of these programs.(1,4) Defines institutional roles and responsibilities of sector agencies, sets broad coverage targets for country and defines broad policies, particularly regarding access of low-income groups to services, cost recovery to support sustainability, incentives to improve operational efficiency, and mechanisms for private sector involvement. (2)
National Statistics Office (NSO)	Provide statistics on coverage and data monitoring (2)

Source: (1) ADB 2013 (2) World Bank 2005 (3) WEPA 2012 (4) Senate Economic Planning Office 2011.

Appendix 6. Discounted Cash Flow - 2.8 kW solar tube system

Year	1	2	3	4	5	6	7	8	9	10
COST										
Project Cost	$1,484	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses	($840)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Utilty Service Charge	($840)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Annual Production(kwh)	**$12,264**	**$12,141**	**$12,020**	**$11,900**	**$11,781**	**$11,663**	**$11,546**	**$11,431**	**$11,317**	**$11,203**
Year's Production Revenue from Electricity	$1,840	$1,877	$1,886	$1,896	$1,906	$1,915	$1,925	$1,935	$1,944	$1,954
Year's Production Revenue from FiT	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Balance	($484)	$1,877	$1,886	$1,896	$1,906	$1,915	$1,925	$1,935	$1,944	$1,954
CASH FLOW										
Scenario 1 – (discount rate 9%)	($484)	$1,877	$1,886	$1,896	$1,906	$1,915	$1,925	$1,935	$1,944	$1,954
Scenario 2 – (discount rate 15%)	($484)	$1,877	$1,886	$1,896	$1,906	$1,915	$1,925	$1,935	$1,944	$1,954
Scenario 3 – (discount rate 20%)	($484)	$1,877	$1,886	$1,896	$1,906	$1,915	$1,925	$1,935	$1,944	$1,954

SUMMARY

Scenario	Internal Rate Of Return	Net present value	Simple payback
Scenario 1 – (discount rate 9%)	387.99%	$15,541.13	0.81
Scenario 2 – (discount rate 15%)	387.99%	$9,990.45	0.81
Scenario 3 – (discount rate 20%)	387.99%	$7,354.55	0.81

Appendix 7. Discounted Cash Flow - 12 kW Solar PV system

12 kW Solar PV System NPV Model

Year	1	2	3	4	5	6	7	8	9	10
COST										
Project Cost	$29,175	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses	($478)	($478)	($478)	($478)	($478)	($478)	($478)	($478)	($478)	($478)
Maintenance Costs	($178)	($178)	($178)	($178)	($178)	($178)	($178)	($178)	($178)	($178)
Utilty Service Charge	($300)	($300)	($300)	($300)	($300)	($300)	($300)	($300)	($300)	($300)
Total Annual Production(kwh)	**$18,320**	**$18,137**	**$17,956**	**$17,776**	**$17,598**	**$17,422**	**$17,248**	**$17,076**	**$16,905**	**$16,736**
Year's Production Revenue from Electricity	$2,565	$2,617	$2,630	$2,643	$2,657	$2,670	$2,684	$2,697	$2,711	$2,725
Year's Production Revenue from FiT	$3,847	$3,809	$3,582	$3,369	$3,169	$2,980	$2,803	$2,636	$2,479	$2,332
Balance	($23,241)	$5,947	$5,734	$5,534	$5,347	$5,172	$5,008	$4,855	$4,712	$4,578
CASH FLOW										
Scenario 1 – (discount rate 9%)	($23,241)	$5,947	$5,734	$5,534	$5,347	$5,172	$5,008	$4,855	$4,712	$4,578
Scenario 2 – (discount rate 15%)	($23,241)	$5,947	$5,734	$5,534	$5,347	$5,172	$5,008	$4,855	$4,712	$4,578
Scenario 3 – (discount rate 20%)	($23,241)	$5,947	$5,734	$5,534	$5,347	$5,172	$5,008	$4,855	$4,712	$4,578
Scenario 4 - no FiT discount rate 9%	($27,088)	$2,139	$2,152	$2,165	$2,178	$2,192	$2,205	$2,219	$2,232	$2,246

SUMMARY

Scenarios	Internal Rate Of Return	Net present value	Simple payback
Scenario 1 – (discount rate 9%)	22%	$21,532.14	4.55
Scenario 2 – (discount rate 15%)	22%	$7,946.72	4.55
Scenario 3 – (discount rate 20%)	22%	$1,920.72	4.55
Scenario 4 - no FiT discount rate 9%	7%	($4,753.86)	11.37

Appendix 8. Discounted Cash Flow - 21 kW Solar PV system

21 kW Solar PV System NPV Model

Year	1	2	3	4	5	6	7	8	9	10
COST										
Project Cost	$48,090	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses	($594)	($594)	($594)	($594)	($594)	($594)	($594)	($594)	($594)	($594)
Maintenance Costs	($294)	($294)	($294)	($294)	($294)	($294)	($294)	($294)	($294)	($294)
Utilty Service Charge	($300)	($300)	($300)	($300)	($300)	($300)	($300)	($300)	($300)	($300)
Total Annual Production(kwh)	**$30,198**	**$29,896**	**$29,597**	**$29,301**	**$29,008**	**$28,718**	**$28,431**	**$28,147**	**$27,865**	**$27,586**
Year's Production Revenue from Electricity	$4,228	$4,314	$4,335	$4,357	$4,379	$4,401	$4,424	$4,446	$4,468	$4,491
Year's Production Revenue from FiT	$6,342	$6,278	$5,905	$5,553	$5,223	$4,912	$4,620	$4,345	$4,086	$3,843
Balance	($38,115)	$9,998	$9,646	$9,317	$9,008	$8,720	$8,449	$8,197	$7,961	$7,740
CASH FLOW										
Scenario 1 – (discount rate 9%)	($38,115)	$9,998	$9,646	$9,317	$9,008	$8,720	$8,449	$8,197	$7,961	$7,740
Scenario 2 – (discount rate 15%)	($38,115)	$9,998	$9,646	$9,317	$9,008	$8,720	$8,449	$8,197	$7,961	$7,740
Scenario 3 – (discount rate 20%)	($38,115)	$9,998	$9,646	$9,317	$9,008	$8,720	$8,449	$8,197	$7,961	$7,740
Scenario 4 - no FiT discount rate 9%	($44,456)	$3,720	$3,741	$3,763	$3,785	$3,807	$3,830	$3,852	$3,874	$3,897

SUMMARY

Scenarios	Internal Rate Of Return	Net present value	simple payback
Scenario 1 – (discount rate 9%)	23.03%	$37,403.09	4.55
Scenario 2 – (discount rate 15%)	23.03%	$14,356.29	4.55
Scenario 3 – (discount rate 20%)	23.03%	$4,128.36	4.55
Scenario 4 - no FiT discount rate 9%	7.17%	($5,925.48)	11.37

Appendix 9. Flow Duration Curves for Visayas regional rivers.

	Payo	Panay	Daguitan	Tenane
10%	104.5	20.4	12.12	13.37
20%	21.8	15.2	9.72	8.29
30%	9.5	13	7.42	5.85
40%	4.8	11.2	3.3	4.71
50%	2.7	10	2.23	3.98
60%	1.36	8.5	1.59	3.39
70%	0.06	7.5	0.87	3.04
80%	0.36	6.5	0.35	2.68
90%	0.21	4.9	0.25	2.22
100%	0.05	1.17	0	1.61
MIN	0.05	1.17	0	1.61
MAX	104.5	20.4	12.12	13.37
Average	22.315	39.59	9.885	18.538

Source: Philippine NSCB 2003

Appendix 10. Percent change in flow with percent in time.

	Payo	Tenane	Panay	Daguitan	Average
20%	-79%	-38%	-25%	-25%	-42%
30%	-56%	-29%	-14%	-31%	-33%
40%	-49%	-19%	-14%	-125%	-52%
50%	-44%	-15%	-11%	-48%	-29%
60%	-50%	-15%	-15%	-40%	-30%
70%	-96%	-10%	-12%	-83%	-50%
80%	500%	-12%	-13%	-149%	82%
90%	-42%	-17%	-25%	-40%	-31%
100%	-76%	-27%	-76%	0%	-60%

Source: Philippine NSCB 2003

Appendix 11. Percentages applied to minimum and maximum flow rates of the Bohol Rivers to estimate their flow duration curves.

	Manaba	Bilar	Loboc
10%	233.3	72.0	441.8
20%	135.7	41.9	257.0
30%	91.1	28.1	172.6
40%	43.8	13.5	83.0
50%	30.9	9.5	58.5
60%	21.7	6.7	41.0
70%	10.8	3.3	20.5
80%	2.0	0.6	9.3
90%	1.4	0.4	5.1
100%	0.1	0.0	3.9
MIN	0.1	0.01	3.9
MAX	233.25	72.02	441.8
Average	134.27	41.44	264.68

Source: Philippine NSCB 2003 and DILG 2003

Appendix 12. Discounted Cash Flow - 12kW Micro hydro System

12 kW Hydro NPV Model

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COSTS																				
Project Cost ($)	58,642	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M Annual Costs ($/year)	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518	3,518
Total Annual Production (kwh)	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400
FiT INCOME																				
Biomass FiT (PHP/kWh)	5.90	5.90	5.61	5.32	5.06	4.81	4.57	4.34	4.12	3.91	3.72	3.53	3.36	3.19	3.03	2.88	2.73	2.60	2.47	2.34
Biomass FiT ($/kWh)	0.12	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05
FiT Income ($/year)	2,829	2,829	2,688	2,553	2,426	2,304	2,189	2,080	1,976	1,877	1,783	1,694	1,609	1,529	1,452	1,380	1,311	1,245	1,183	1,124
Costs from Grid Use (BAU) ($)	12,295	12,479	12,665	12,855	13,048	13,243	13,441	13,643	13,847	14,054	14,265	14,479	14,695	14,916	15,139	15,366	15,596	15,830	16,067	16,308
Balance with FiT ($)	(47,036)	11,789	11,835	11,890	11,955	12,029	12,112	12,204	12,304	12,413	12,529	12,654	12,786	12,926	13,073	13,227	13,388	13,557	13,732	13,913
Cumulative Cash Flow ($)	(47,036)	(35,247)	(23,412)	(11,522)	433	12,461	24,573	36,777	49,082	61,494	74,024	86,678	99,464	112,390	125,463	138,690	152,079	165,635	179,367	193,280
Balance *without* FiT ($)	(49,865)	8,960	9,147	9,337	9,529	9,725	9,923	10,124	10,328	10,536	10,746	10,960	11,177	11,397	11,621	11,847	12,078	12,311	12,549	12,789
Cumulative Cash Flow ($)	(47,036)	(38,076)	(28,929)	(19,592)	(10,063)	(339)	9,584	19,708	30,037	40,573	51,319	62,279	73,456	84,853	96,474	108,321	120,399	132,711	145,259	158,049

Appendix 13. Discounted Cash Flow - 21 kW Micro hydro System

21 kW Hydro NPV Model

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COSTS																				
Project Cost ($)	102,623	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M Annual Costs ($/year)	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157
Total Annual Production(kwh)	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200	151,200
FiT INCOME																				
Biomass FiT (PHP/kWh)	5.90	5.90	5.61	5.32	5.06	4.81	4.57	4.34	4.12	3.91	3.72	3.53	3.36	3.19	3.03	2.88	2.73	2.60	2.47	2.34
Biomass FiT ($/kWh)	0.12	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05
FiT Income ($/year)	2,319	2,319	2,203	2,093	1,989	1,889	1,795	1,705	1,620	1,539	1,462	1,389	1,319	1,253	1,191	1,131	1,075	1,021	970	921
Costs from Grid Use (BAU) ($)	25,427	25,810	26,199	26,594	26,995	27,401	27,814	28,233	28,659	29,090	29,529	29,974	30,425	30,884	31,349	31,822	32,301	32,788	33,282	33,784
Balance ($)	(81,033)	21,972	22,245	22,530	22,826	23,133	23,452	23,781	24,121	24,472	24,833	25,205	25,587	25,980	26,383	26,796	27,219	27,652	28,095	28,548
Cumulative Cash Flow ($)	(81,033)	(59,061)	(36,815)	(14,285)	8,540	31,674	55,125	78,906	103,027	127,499	152,332	177,537	203,125	229,104	255,487	282,283	309,501	337,153	365,248	393,796
Balance *without* FiT ($)	(83,353)	19,653	20,042	20,437	20,837	21,244	21,657	22,076	22,501	22,933	23,371	23,816	24,268	24,727	25,192	25,664	26,144	26,631	27,125	27,627
Cumulative Cash Flow ($)	(81,033)	(61,380)	(41,338)	(20,902)	(64)	21,180	42,836	64,912	87,414	110,347	133,718	157,535	181,803	206,529	231,721	257,386	283,530	310,161	337,286	364,912

Appendix 14. Discounted Cash Flow - 12kW Biomass (Average Cost)

12 kW Biomass of Average Capital Cost Scenario																				
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COSTS																				
Project Cost ($)	740,049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M Annual Costs ($/year)	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864
Total Annual Production (kwh)	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377
FiT INCOME																				
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40	4.18	3.97	3.77	3.58	3.40	3.23	3.07	2.92	2.77	2.63
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.05
FiT Income ($/year)	106,339	106,339	101,022	95,971	91,172	86,614	82,283	78,169	74,260	70,547	67,020	63,669	60,486	57,461	54,588	51,859	49,266	46,803	44,462	42,239
Costs from Grid Use (BAU) ($)	12,295	12,479	12,665	12,855	13,048	13,243	13,441	13,643	13,847	14,054	14,265	14,479	14,695	14,916	15,139	15,366	15,596	15,830	16,067	16,308
Balance ($)	(622,280)	117,953	112,823	107,962	103,356	98,992	94,860	90,947	87,243	83,737	80,421	77,283	74,317	71,513	68,863	66,360	63,998	61,768	59,665	57,683
Cumulative Cash Flow ($)	(622,280)	(504,327)	(391,503)	(283,542)	(180,186)	(81,194)	13,666	104,614	191,857	275,594	356,015	433,298	507,615	579,128	647,991	714,351	778,349	840,117	899,782	957,465
Balance *without* FiT ($)	(728,619)	11,614	11,801	11,991	12,183	12,379	12,577	12,778	12,983	13,190	13,401	13,614	13,831	14,051	14,275	14,502	14,732	14,966	15,203	15,444
Cumulative Cash Flow ($)	(622,280)	(610,666)	(598,864)	(586,874)	(574,690)	(562,312)	(549,735)	(536,957)	(523,974)	(510,784)	(497,383)	(483,769)	(469,938)	(455,887)	(441,612)	(427,110	(412,379)	(397,41)	(382,210)	(366,767)

Appendix 15. Discounted Cash Flow - 21kW Biomass (Average Cost)

21 kW Biomass of Average Capital Cost Scenario

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COST																				
Project Cost ($)	740,049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M Annual Costs ($/year)	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864
Total Annual Production (kwh)	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377
INCOME																				
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40	4.18	3.97	3.77	3.58	3.40	3.23	3.07	2.92	2.77	2.63
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.05
FiT Income ($/year)	97,174	97,174	92,315	87,699	83,314	79,149	75,191	71,432	67,860	64,467	61,244	58,181	55,272	52,509	49,883	47,389	45,020	42,769	40,630	38,599
Costs from Grid Use (BAU) ($)	25,427	25,810	26,199	26,594	26,995	27,401	27,814	28,233	28,659	29,090	29,529	29,974	30,425	30,884	31,349	31,822	32,301	32,788	33,282	33,784
Balance ($)	(618,312)	122,120	117,650	113,429	109,445	105,686	102,141	98,800	95,654	92,693	89,908	87,291	84,833	82,528	80,368	78,347	76,457	74,693	73,048	71,518
Cumulative Cash Flow ($)	(618,312)	(496,193)	(378,543)	(265,114)	(155,669)	(49,984)	52,157	150,958	246,612	339,305	429,213	516,504	601,338	683,866	764,234	842,581	919,038	993,730	1,066,778	1,138,297
Balance *without* FiT ($)	(715,486)	21,355	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)	(864)
Cumulative Cash Flow ($)	(618,312)	(596,958)	(597,822)	(598,686)	(599,551)	(600,415)	(601,280)	(602,144)	(603,008)	(603,873)	(604,737)	(605,601)	(606,466)	(607,330)	(608,195)	(609,059)	(609,923)	(610,788)	(611,652)	(612,516)

Appendix 16. Discounted Cash Flow - 12kW Biomass (High Cost)

12 kW Biomass - High Cost Scenario

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COSTS																				
Project Cost ($)	1,233,415	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M Annual Costs ($/year)	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864
Total Annual Production(kwh)	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377
FiT INCOME																				
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40	4.18	3.97	3.77	3.58	3.40	3.23	3.07	2.92	2.77	2.63
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.05
FiT Income ($/year)	106,339	106,339	101,022	95,971	91,172	86,614	82,283	78,169	74,260	70,547	67,020	63,669	60,486	57,461	54,588	51,859	49,266	46,803	44,462	42,239
Costs from Grid Use (BAU) ($)	12,295	12,479	12,665	12,855	13,048	13,243	13,441	13,643	13,847	14,054	14,265	14,479	14,695	14,916	15,139	15,366	15,596	15,830	16,067	16,308
Balance with FiT	(1,115,646)	117,953	112,823	107,962	103,356	98,992	94,860	90,947	87,243	83,737	80,421	77,283	74,317	71,513	68,863	66,360	63,998	61,768	59,665	57,683
Cumulative Cash Flow	(1,115,646)	(997,693)	(884,869)	(776,908)	(673,552)	(574,560)	(479,700)	(388,752)	(301,509)	(217,772)	(137,351)	(60,068)	14,249	85,762	154,625	220,985	284,983	346,751	406,416	464,099
Balance *without* FiT	(1,221,985)	11,614	11,801	11,991	12,183	12,379	12,577	12,778	12,983	13,190	13,401	13,614	13,831	14,051	14,275	14,502	14,732	14,966	15,203	15,444
Cumulative Cash Flow	(1,115,646)	(1,104,032)	(1,092,230)	(1,080,240)	(1,068,056)	(1,055,678)	(1,043,101)	(1,030,323)	(1,017,340)	(1,004,150)	(990,749)	(977,135)	(963,304)	(949,253)	(934,978)	(920,476)	(905,745)	(890,779)	(875,576)	(860,133)

Appendix 17. Discounted Cash Flow - 21kW Biomass (High Cost)

21 kW Biomass - High Cost Scenario

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COST																				
Project Cost ($)	1,233,415	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M Annual Costs ($/year)	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864	864
Total Annual Production(kwh)	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377	864,377
FiT INCOME																				
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40	4.18	3.97	3.77	3.58	3.40	3.23	3.07	2.92	2.77	2.63
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.05
FiT Income ($/year)	97,174	97,174	92,315	87,699	83,314	79,149	75,191	71,432	67,860	64,467	61,244	58,181	55,272	52,509	49,883	47,389	45,020	42,769	40,630	38,599
Costs from Grid Use (BAU) ($)	25,427	25,810	26,199	26,594	26,995	27,401	27,814	28,233	28,659	29,090	29,529	29,974	30,425	30,884	31,349	31,822	32,301	32,788	33,282	33,784
Balance	(1,111,678)	122,120	117,650	113,429	109,445	105,686	102,141	98,800	95,654	92,693	89,908	87,291	84,833	82,528	80,368	78,347	76,457	74,693	73,048	71,518
Cumulative Cash Flow	(1,111,678)	(989,559)	(871,909)	(758,480)	(649,035)	(543,350)	(441,209)	(342,408)	(246,754)	(154,061)	(64,153)	23,138	107,972	190,500	270,868	349,215	425,672	500,364	573,412	644,931
Balance *without* FiT	(1,208,852)	24,946	25,335	25,730	26,130	26,537	26,950	27,369	27,794	28,226	28,664	29,109	29,561	30,020	30,485	30,957	31,437	31,924	32,418	32,920
Cumulative Cash Flow	(1,111,678)	(1,086,732)	(1,061,397)	(1,035,668)	(1,009,538)	(983,001)	(956,051)	(928,682)	(900,888)	(872,662)	(843,997)	(814,888)	(785,327)	(755,307)	(724,822)	(693,865)	(662,428)	(630,504)	(598,086)	(565,166)

Appendix 18. Discounted Cash Flow - 12kW CHP (Average Cost)

12 kW CHP – Average Cost Scenario

Year	1	2	3	4	5	6	7	8	9	10
COST										
Project Cost ($)	$50,400.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
O&M Annual Costs ($/year)	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12
Total Annual Electricity Production(kwh)	19822.63	19822.63	19822.63	19822.63	19822.63	19822.63	19822.63	19822.63	19822.63	19822.63
Total Annual Heat Production(kwh)	39645.26	39645.26	39645.26	39645.26	39645.26	39645.26	39645.26	39645.26	39645.26	39645.26
FiT INCOME										
FiT Degression Rate	0.05									
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09
FiT Income ($/year)	2628.48	2628.48	2497.06	2372.20	2253.59	2140.91	2033.87	1932.17	1835.57	1743.79
Costs from Grid Use (BAU) ($)	8325.50	8452.05	8580.52	8710.95	8843.35	8977.77	9114.23	9252.77	9393.41	9536.19
Balance with FiT	($39,731.14)	$10,795.41	$10,792.46	$10,798.03	$10,811.83	$10,833.57	$10,862.98	$10,899.83	$10,943.86	$10,994.86
Cumulative Cash Flow	($39,731.14)	($28,935.72)	($18,143.26)	($7,345.23)	$3,466.59	$14,300.16	$25,163.14	$36,062.97	$47,006.83	$58,001.69
Balance *without* FiT	($42,359.62)	$8,166.93	$8,295.40	$8,425.83	$8,558.23	$8,692.65	$8,829.11	$8,967.65	$9,108.29	$9,251.07
Cumulative Cash Flow	($39,731.14)	($31,564.20)	($23,268.80)	($14,842.97)	($6,284.74)	$2,407.91	$11,237.03	$20,204.68	$29,312.97	$38,564.04
RESULTS										
	with FiT			***without* FiT**						
Discount Rate	**9%**	**15%**	**20%**	**9%**	**15%**	**20%**				
Net Present Value	$53,980.08	*$24,459.29*	$10,922.56	$35,608.13	$11,048.50	$74.04				
Internal Rate Of Return	27.07%			20%						

Appendix 19. Discounted Cash Flow - 21 kW CHP (Average Cost)

21 kW CHP – Average Cost Scenario

Year	1	2	3	4	5	6	7	8	9	10
Costs from Biomass Generation										
Project Cost ($)	88,200	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
O&M Annual Costs ($/year)	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96
Total Annual Production(kwh)	34689.60	34689.60	34689.60	34689.60	34689.60	34689.60	34689.60	34689.60	34689.60	34689.60
Total Annual Heat Production(kwh)	69379.20	69379.20	69379.20	69379.20	69379.20	69379.20	69379.20	69379.20	69379.20	69379.20
Feed-In Tariff (FiT) Income										
FiT Degression Rate	0.05									
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09
FiT Income ($/year)	4599.84	4599.84	4369.85	4151.36	3943.79	3746.60	3559.27	3381.31	3212.24	3051.63
Costs from Grid Use (BAU) ($)	14569.63	14791.09	15015.91	15244.16	15475.87	15711.10	15949.91	16192.35	16438.47	16688.34
Balance	($69,529.49)	$18,891.97	$18,886.80	$18,896.55	$18,920.70	$18,958.74	$19,010.22	$19,074.69	$19,151.75	$19,241.01
Cumulative Cash Flow	($69,529.49)	($50,637.52)	($31,750.71)	($12,854.16)	$6,066.54	$25,025.28	$44,035.50	$63,110.19	$82,261.95	$101,502.95
Balance *without* FiT	(74,129)	14,292	14,517	14,745	14,977	15,212	15,451	15,693	15,940	16,189
Cumulative Cash Flow	($69,529.49)	($55,237.36)	($40,720.40)	($25,975.20)	($10,998.30)	$4,213.84	$19,664.79	$35,358.18	$51,297.70	$67,487.07
RESULTS										
	with FiT			***without* FiT**						
Discount Rate	**9%**	**15%**	**20%**	**9%**	**15%**	**20%**				
Net Present Value	$94,465.15	*$42,803.76*	$19,114.48	$62,314.23	$19,334.87	$129.58				
Internal Rate Of Return	27.07%			20%						

Appendix 20. Discounted Cash Flow - 12 kW CHP (High Cost)

12 kW CHP - High Cost Scenario

Year	1	2	3	4	5	6	7	8	9	10
COSTS										
Project Cost ($)	98,400	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
O&M Annual Costs ($/year)	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12	$285.12
Total Annual Production(kwh)	19008.00	19008.00	19008.00	19008.00	19008.00	19008.00	19008.00	19008.00	19008.00	19008.00
Total Annual Heat Production(kwh)	38016.00	38016.00	38016.00	38016.00	38016.00	38016.00	38016.00	38016.00	38016.00	38016.00
FiT INCOME										
FiT Degression Rate	0.05									
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09
FiT Income ($/year)	2520.46	2520.46	2394.44	2274.72	2160.98	2052.93	1950.28	1852.77	1760.13	1672.13
Costs from Grid Use (BAU) ($)	7983.36	8104.71	8227.90	8352.96	8479.93	8608.82	8739.68	8872.52	9007.38	9144.29
Balance with FiT	($88,181.30)	$10,340.05	$10,337.22	$10,342.56	$10,355.79	$10,376.63	$10,404.84	$10,440.17	$10,482.39	$10,531.30
Cumulative Cash Flow	($88,181.30)	($77,841.25)	($67,504.03)	($57,161.48)	($46,805.69)	($36,429.05)	($26,024.21)	($15,584.04)	($5,101.65)	$5,429.65
Balance *without* FiT	($90,701.76)	$7,819.59	$7,942.78	$8,067.84	$8,194.81	$8,323.70	$8,454.56	$8,587.40	$8,722.26	$8,859.17
Cumulative Cash Flow	($88,181.30)	($80,361.71)	($72,418.93)	($64,351.09)	($56,156.28)	($47,832.58)	($39,378.02)	($30,790.62)	($22,068.36)	($13,209.19)
RESULTS										
		with FiT			**without FiT**					
Discount Rate	**9%**	**15%**	**20%**	**9%**	**15%**	**20%**				
Net Present Value	$5,717.85	*($20,159.43)*	($31,309.40)	($11,899.09)	($33,019.09)	($41,712.08)				
Internal Rate Of Return	9.99%			7%						

Appendix 21. Discounted Cash Flow - 21 kW CHP (High Cost).

21 kW CHP – High Cost Scenario

Year	1	2	3	4	5	6	7	8	9	10
COSTS										
Project Cost ($)	172,200	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
O&M Annual Costs ($/year)	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96	$498.96
Total Annual Production(kwh)	33264.00	33264.00	33264.00	33264.00	33264.00	33264.00	33264.00	33264.00	33264.00	33264.00
Total Annual Heat Production(kwh)	66528.00	66528.00	66528.00	66528.00	66528.00	66528.00	66528.00	66528.00	66528.00	66528.00
FiT INCOME										
FiT Degression Rate	0.05									
Biomass FiT (PHP/kWh)	6.63	6.63	6.30	5.98	5.68	5.40	5.13	4.87	4.63	4.40
Biomass FiT ($/kWh)	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09
FiT Income ($/year)	4410.81	4410.81	4190.27	3980.75	3781.72	3592.63	3413.00	3242.35	3080.23	2926.22
Costs from Grid Use (BAU) ($)	13970.88	14183.24	14398.82	14617.68	14839.87	15065.44	15294.43	15526.91	15762.92	16002.52
Balance	($154,317.27)	$18,095.08	$18,090.13	$18,099.48	$18,122.63	$18,159.11	$18,208.47	$18,270.30	$18,344.19	$18,429.77
Cumulative Cash Flow	($154,317.27)	($136,222.19)	($118,132.06)	($100,032.58)	($81,909.96)	($63,750.85)	($45,542.37)	($27,272.08)	($8,927.89)	$9,501.89
Balance *without* FiT	($158,728.08)	$13,684.28	$13,899.86	$14,118.72	$14,340.91	$14,566.48	$14,795.47	$15,027.95	$15,263.96	$15,503.56
Cumulative Cash Flow	($154,317.27)	($140,633.00)	($126,733.13)	($112,614.41)	($98,273.50)	($83,707.02)	($68,911.54)	($53,883.59)	($38,619.63)	($23,116.08)
RESULTS										
	with FiT			***without* FiT**						
Discount Rate	**9%**	**15%**	**20%**	**9%**	**15%**	**20%**				
Net Present Value	$10,006.24	*($35,279.00)*	($54,791.45)	($20,823.40)	($57,783.41)	($72,996.15)				
Internal Rate Of Return	9.99%			7%						

Appendix 22. LWUA Water Rates for Bohol Province and Philippine Country Average (2013)

	Currency	Cost per 20 m³	Cost per 30 m³
Bohol Province	PHP	$324.5	$515.75
Country Average	PHP	$399.51	$631.78
Bohol Province	USD	$7.21	$11.46
Country Average	USD	$8.88	$14.04

Source: LWUA 2013a; LWUA 2013b & Exchange Rates UK 2014

Appendix 23. Cost savings calculations for lower and upper bound for Improv'eat operations if RWH system is installed (in PHP).

Cost Savings		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average (per month)	Annual Total (per year)
Bohol Regional Average (PHP)	**Upper**	$392.16	$300.83	$262.46	$230.23	$321.56	$496.11	$495.00	$445.11	$441.89	$518.79	$542.16	$472.74	$409.92	**$4,919.04**
	Lower	$370.11	$283.92	$247.71	$217.29	$303.47	$468.21	$467.16	$420.08	$417.05	$489.62	$511.67	$446.16	$386.87	**$4,642.45**
Country Average (PHP)	**Upper**	$480.39	$368.51	$321.51	$282.03	$393.90	$607.72	$606.36	$545.25	$541.31	$635.50	$664.13	$579.09	$502.14	**$6,025.70**
	Lower	$455.66	$349.55	$304.96	$267.51	$373.62	$576.44	$575.15	$517.19	$513.45	$602.79	$629.95	$549.29	$476.30	**$5,715.58**
Bohol Regional Average (USD)	**Upper**	$8.71	$6.69	$5.83	$5.12	$7.15	$11.02	$11.00	$9.89	$9.82	$11.53	$12.05	$10.51	$9.11	**$109.31**
	Lower	$8.22	$6.31	$5.50	$4.83	$6.74	$10.40	$10.38	$9.34	$9.27	$10.88	$11.37	$9.91	$8.60	**$103.17**
Country Average (USD)	**Upper**	$10.68	$8.19	$7.14	$6.27	$8.75	$13.50	$13.47	$12.12	$12.03	$14.12	$14.76	$12.87	$11.16	**$133.90**
	Lower	$10.13	$7.77	$6.78	$5.94	$8.30	$12.81	$12.78	$11.49	$11.41	$13.40	$14.00	$12.21	$10.58	**$127.01**

Source: LWUA 2013a; LWUA 2013b & Exchange Rates UK 2011