Mechanisms for Increasing Electricity Access for Entrepreneurs on Rural Islands of Indonesia

by

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ABSTRACT

The importance of developing alternative livelihoods in Indonesia is reaching a critical level. Over 60% of the population is reliant upon the ocean for employment and destructive fishing practices have destroyed over half of the marine habitat[1]. As a result, family incomes have suffered and fishers have been forced to travel farther from home, often leaving their families for a month at a time. In response, development efforts have begun to focus their attention on small entrepreneurial businesses that offer an increase in the average wage earned by rural fisherman while also reducing the pressure on wild fish stocks. The business model under analysis employs a franchise system of business development whereby fishermen buy kits to build backyard mariculture tanks capable of raising marine species for export and also for local consumption. While developers have observed success with local adoption and with species rearing, one major challenge remains. The mariculture systems require a constant energy supply to run the pumps but 47% of the country does not have access to electricity. This hurdle poses a significant challenge for the success of the mariculture program but also for other economic development initiatives that often rely on electricity access.

The purpose of this Masters Project was to investigate energy alternatives for rural regions of Indonesia, calculate the costs and feasibility of energy development and evaluate the efficacy of the mariculture business model after inclusion of full energy costs. This was accomplished over a five month period through extensive data collection in the field. NGOs, private firms and government agencies were interviewed and documents were obtained. Results of the data collection were analyzed using the Homer Energy Modeling System and other Excel based tools. The results of this study indicate that the costs of energy development in Indonesia are prohibitive for mariculture entrepreneurs. A series of hurdles including geographic isolation, government mandated price ceilings for rate payers and limited wind resource availability pose significant barriers. The results suggest that alternative economic development on island regions of Indonesia should focus on industries that do not require a constant and steady energy supply. Businesses that can take advantage of a short duration of electricity supply or one that is unpredictable will be more cost effective and appropriate to local income levels.

[1] *Briggs, Mathew. "Destructive Fishing Practices". Improving Coastal Livelihoods through Sustainable Aquaculture Practices. 2003.*

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INTRODUCTION

Energy has increasingly become the focus of International Development Agendas. According to the World Bank, inadequate energy resources have stunted the growth and development of rural economies around the globe and thus have suppressed much of the population living below the poverty line[2]. The economies in these remote regions are further at risk because they are often reliant upon degraded ecosystems that are incapable of meeting the needs of a growing population. If left unaddressed or unregulated, these environments threaten damage beyond repair which could leave communities in even lower levels of poverty with inadequate access to basic nutritional requirements. Development of alternative livelihoods is essential for addressing both poverty and environmental degradation in developing countries and energy is often targeted as the biggest hurdle.

The importance of developing alternative livelihoods is reaching a critical level in Indonesia. Destructive fishing practices have destroyed 60% of the marine habitat of Indonesia and as a result there has been a serious decline in fish populations worldwide.[3] Fishermen in Indonesia have been forced to travel long distances in search of marine resources often spending months at a time away from home. Other fishers have been lured into Australian waters where conservation laws and strict policing has resulted in abundant marine resources and potentially lucrative harvests. This is a risky endeavor; Indonesian boats caught pilfering marine resources in Australia are confiscated or burned on site and fisherman are deported home without the tools to generate income.

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[2] World Bank "Energy Access, Security, Key to Reducing Poverty". May 2006. <http://go.worldbank.org/HT2WKGTT20 >

[3] *Briggs, Mathew. "Destructive Fishing Practices". Improving Coastal Livelihoods through Sustainable Aquaculture Practices. 2003*.

The Indonesians and foreign developers alike are well aware of these issues and programs have been developed to address these challenges. The Indonesian government boasts a strong marine patrol charged with the task of enforcing better fishing practices. However, with 17,000 islands and only four patrol boats in the country the effect of the patrol boats is disputable[4]. Multi-lateral funding agencies such as the World Bank have sponsored education programs that promote responsible fishing through the deployment of local volunteer groups and educational lessons. While these initiatives do well to inform fisherman, literature suggests that the impact is minimal because fisherman often have few alternatives to make a reasonable income[5]. Other interested parties in Indonesia believe that environmental degradation and poverty alleviation can be reduced through the development of alternative livelihoods. The theory suggests that if a fisherman can make a better living at home there would be less dynamite fishing on reefs, a reduced pressure on wild fish stocks and fishermen will be able to patrol their local reefs against destructive fishing practices. Most of the development dollars are focused on this targeted outcome, the development of alternative livelihoods.

In Indonesia there has been a strong focus on proposing alternative job creation models for fisherman because much of the population is reliant upon an ocean declining in productivity. Historically, these efforts have focused on large pond fish farms and brackish shrimp farms as they demonstrate modest returns. However, these business models are often relegated to entrepreneurs who have access to a lot of property and direct access to the ocean. Small islands have fewer options because of the limited space and varying environmental conditions that make many marine-based businesses inappropriate. More recently, one type of marine-based business

[4] *Briggs, Mathew. "Destructive Fishing Practices". Improving Coastal Livelihoods through Sustainable Aquaculture Practices. 2003*.
[5] Liganga, Lucas. "Dynamite fishing destroys marine life and coastal livelihoods in Tanzania". Western Indian Ocean Marine Science Association. March 2009.
<http://www.wiomsablog.org/?p=70>

model has been proposed that may be adaptable to small island regions. The concept consists of a small-scale backyard mariculture tank capable of rearing various species. These tanks can fit alongside houses where they have the potential to raise various species in controlled environments. At present, there are numerous species being tested for this application. Revenue for these models will obviously vary depending upon the species, the yield and of course the market value but early data suggests that revenues could range from $4,000$ to $10,000 per year[6]. While this appears promising for many of the fisherman in Indonesia, only 53% of the people in Indonesia have access to electricity and mariculture businesses require constant and consistent electricity[7]. Therefore, in order to determine the validity and profitability of mariculture businesses in Indonesia, an in-depth examination of potential energy systems that could meet the demand is essential.

STATEMENT OF OBJECTIVES

The purpose of this Masters Project is to determine if there are cost effective methods of delivering reliable and consistent electricity to mariculture entrepreneurs on small rural islands in Indonesia. By examining both a single household and a community-scale approach to energy development, this project analyzed energy demands, energy infrastructure, energy resource availability, economic costs of technology, policy bottlenecks, and human capacity requirements involved in delivering electricity to rural entrepreneurs. The small island of Pulau Badi was chosen as an ideal case study for this subject, as the island has been the focus of recent development efforts and it currently hosts a prototype of a mariculture business that requires but does not have a reliable electricity system. The energy limitations that plague Pulau Badi are

[6] Indonesian Developer : Prefers to remain anonymous
[7] "Policy DB Details: Indonesia". Renewable Energy and Energy Efficiency Partnership (REEP). <www.reep.org/index.php?id=9353&text=policy-db&special=viewitem&cid=32>

indicative of issues found on islands all over Indonesia and in several other emerging economies around the globe. Therefore, if an economic solution can be identified to increase electricity availability to mariculture entrepreneurs on Pulau Badi, it could have wide ranging applications to the rest of Indonesia and the greater global South.

METHODS

A series of different methodologies were employed to obtain the data and information required for a thorough analysis of energy availability and the development of potential energy solutions for mariculture entrepreneurs on Pulau Badi.

Investigative Research

An extensive literature search was conducted to gain an understanding of the key players operating in this field, what has been done to date and what challenges are currently being encountered. The scope of this research included best practices and lessons learned from energy development projects, entities working in the region, projects that were under construction, microfinance institutions in Indonesia, and climate data. Solar data was obtained from Nasa's online resource and wind data was collected from a website called 3Tier First Look which is described below.

3TIER Wind Assessment Tool

3TIER is a "global leader in weather-driven renewable energy assessment and forecasting for wind, solar and hydro power projects of all sizes" (http://www.3tier.com/). It is an analysis tool that enables a user to take a "first look" at renewable energy potential in a specific geographic region. The tool was developed using localized data collection points overlaid with computer derived climate modeling. The model claims significant accuracy and is trusted by developers around the world, however it is important to note that it is a model and therefore it may not always account for microclimates or localized conditions. Energy developers who use this tool rely on it as an initial investigation to determine whether it is worthwhile to invest in localized testing devices such as wind anemometers.

Fieldwork

Field work on Pulau Badi was conducted over a 12 week period from June 1st – July 30th in 2008 and also from July 1st to August 1st of 2009. This time also included some trips to Jakarta for meetings.

Mariculture Information

During this 12 week period, several interviews were held on Pulau Badi. The first series of interviews were held with project developers (who prefer to remain anonymous) to determine the water pumping requirements and subsequent energy needs for the mariculture tank systems. Another set of interviews were conducted with local entrepreneurs to discuss business initiatives and energy implications that they encountered. The ministry of education also provided information regarding the average education level, content of material delivered at that average grade and subsequent skill levels.

Energy Production & Consumption Data

Several meetings were held with the energy utility on the island to obtain technical documents including energy production data, maintenance records, fuel costs, and payments received. Detailed data records obtained included the month of April 2007, May 2007, September 2007, April 2009, May 2009, and June 2009. Documents outside of the months listed above were not available for detailed analysis. However, an entire year of monthly records was available for a brief review at the PLN office to ensure that consumptive patterns had no seasonal variability. To verify reports and obtain additional information, measurements were taken from the diesel generator using a loop ammeter. Data was provided in rough form and all unit calculations such as $/kwh and maintenance costs per hour of operation were calculated.

Jakarta Meetings

Meetings were held with the Vice President of the energy utility, Ario Senojai in Jakarta to verify policy findings and discuss future direction of the energy utility. Meetings were also held with numerous energy developers in Jakarta to verify policies from the developer's perspectives, examine additional hurdles for energy development, obtain local pricing information on renewable energy systems, discuss energy financing options in Indonesia and verify assumptions on wind and solar data.

Survey of Local Companies in Makassar, Sulawesi

Makassar is the largest city on the island of Sulawesi and it is also the major source of parts and supplies for residents of Pulau Badi. A survey of Makassar was conducted to determine what energy companies were operating in Makassar and the surrounding regions. Names, addresses, capacity, services, and pricing data were recorded.

Data Collection from Local Ministries

Without wind companies or major wind energy investors in South Sulawesi, accurate hourly wind data was not available. However, climate groups and airports record some basic data about wind speeds and the climate group was willing to share data for a small fee. The closest region that could provide data was from an organization called *Badan Meteorologi Dan Geofisika (BMG)* which is located in Maros, a coastal village approximately 15 miles north of Makassar and about 15 miles directly east of Pulau Badi. A map of this region and a detailed report of wind data from 2006, 2007, and 2008 are included in the appendix. Data was taken every hour and then a daily average was recorded. Hourly data was not available from Maros.

Discussions with US-Based Engineers and Technology Manufacturers

Discussions were held with pump and aeration manufacturers to verify assumptions obtained in Indonesia regarding appropriate sizing and costs of technology. Investigations into up and coming technology was investigated to determine if there were evolving solutions that could be introduced to Indonesia.

Analytical Tools

There are two sizes of energy systems considered in the economic analysis section of this paper; those at the community scale and those at the individual scale. For the smaller individualized systems, excel based tools were used for the analysis. For the larger community-sized energy systems, the economic analysis and system sizing was performed using the HOMER Micro Power Systems Model.

HOMER Micro Power Systems Model

The HOMER model was designed by Dr. Peter Lilianthal and is proprietary information of Lilianthal's company Green Island Power. The HOMER model is a very comprehensive energy system design tool that is used by some the leading energy developers in the world. It requires the user to research and input various parameters including the types of energy hardware to consider (eg. diesel generator, solar panels, wind turbine etc). Additional inputs include measurements such as localized solar radiation, wind speeds, diesel prices, infrastructure costs and efficiency measures. "The model works by performing an hourly time series simulation of its operation over one year. HOMER steps though the year one hour at a time, calculating the available renewable power, comparing it to the electric load, and deciding what to do with the surplus in times of excess"[8]. After the model has been run, HOMER reveals the most reliable and cost effective system design for the specific load and environmental conditions entered. Project costs are calculated and the price per kwh is also generated. To ensure accurate analysis, HOMER has the capacity to provide a sensitivity analysis to consider varying inputs such as the fluctuating prices of diesel fuel. The author of the model, Dr. Peter Lilienthal provided continual advice and checks on each of the HOMER models that were designed for this project.

[8] Lilienthal, Peter. "Micropower Systems Modeling with Homer". Chapter 15. National Renewable Energy Lab. <www.NREL.gov>

RESULTS

The results in this section include several important sub components. The first section outlines the energy demands of a mariculture business model that is currently in operation on Pulau Badi. The second results section investigated the current energy availability on Pulau Badi to determine what deficits exist. The third section explores various energy resources including wind and solar to determine if there were opportunities for renewable energy development. The fourth section in the results takes into consideration the data from earlier sections and evaluates the cost of building and operating two different energy systems that work on a community scale. Although community systems are typically more economical because of scale, there are often challenged by numerous outside factors and therefore it was imperative to also review small-scale individual energy systems that could be purchased directly by entrepreneurs. The fifth section examines the cost of implementing energy systems at the individual business owner level. In designing these systems both at the community scale and at the individual scale, it was imperative to consider the local capacity. Without energy providers or a supply chain of materials the systems could be implemented in isolation but would not be replicable. Therefore, the sixth section reviewed the local capacity. The seventh section reviews Indonesian energy policies and their effect upon energy expansion in these rural areas to ensure project longevity. And finally, the last section takes all of the previous information about energy availability and assimilates it into a cost model for the mariculture business to determine the financial feasibility of this particular entrepreneurial design.

Energy Demand: Mariculture Business

This section identified the energy demanded by the mariculture business prototype located on Pulau Badi.

System Design

The mariculture businesses prototype on Pulau Badi consisted of two rectangular concrete tanks equal in measurement. The tanks were designed to sit side by side with one tank

built into the ground and the other tank built above ground. A pump drew water from the ocean to flush the upper tank and excess water accumulating in the upper tank was sent by gravity feed into the lower tank to flush that system. Water from the bottom of the lower tank was pumped up to ground level where it was purged from the system into a small gravity fed channel that would return it to the ocean.

Pump and Aeration Sizing

The backyard mariculture system requires three different energy draws for 24 hours a day. Based on the volume calculations a project engineer working with developers determined that a 43 W pump was necessary for pumping the water from the lower tank back up to ground level where it could exit the system. A larger 80 w pump was necessary to pull water from the ocean across 60 feet of sandy beach and to an elevation of 1.5 meters above sea level. A 60 W aerator was also deemed necessary. Excluding efficiencies, the system requires a total of 183 watts and operations were required consistently over 24 hours. Based on surge for priming pumps and pump/aerator operating efficiencies, the system sized was increased to a total of 300 watts.

Current Energy Availability on Pulau Badi: Regulations & Constraints

The Indonesia government has a mandate stating that all residents of Indonesia will have access to electricity. While this is the law, over 550 communities in South Sulawesi alone still do not have access to electricity because of their remote location and also because Indonesia has only one energy utility that is struggling to serve the entire country[9]. PLN is the government owned utility of Indonesia that is responsible for providing service to the nation. Several additional communities experience intermittent access sometimes receiving only six hours of electricity per day.

In 1982, PLN installed electrical capacity on Pulau Badi. The utility provided a diesel generator and enough fuel to provide electricity on the island for 6 hours per day between the hours of 6 pm and midnight. However, during the month of September (month of weddings and celebrations) the duration of consumptive hours increases by 10-20%. Since the island is less than 1 km squared and hosts 400 households, a 100 kw diesel generator has been more than adequate in providing basic electricity services to residents who commonly use it to power lights, fans, televisions, radios and occasionally refrigerators. Refueling, maintenance, grid installations, and bill collection is performed exclusively by PLN.

The electricity prices charged by the utility are regulated by the Indonesian government. All residents in Indonesia are placed in various “R” categories (R1, R2 etc.) depending upon their consumption level. Pricing in each R level is consistent and legally mandated throughout the country despite the varying cost of electricity production. The residents on Pulau Badi are in

[9] Meeting with Ministry of Energy. Anonymous. Makassar, Indonesia. July 15, 2009.

the lowest consumptive tier and are considered R1 residents which enables them to access a maximum of 900 kwh/month. For the first 20 kwh that households consume the cost is $0.02/kwh. The next 20 kwh costs $0.04/kwh and any usage above 40 kwh costs residents $0.05/kwh. Additional fees include a monthly service charge of $1.30 plus a 5% tax. In 2008 and early 2009, the total population of Pulau Badi paid approximately $575.31/month using an average of 7484 kwh. For each of these kwh produced, it costs PLN a price range of $0.25-$0.49/kwh due to fluctuating fuel prices. After accounting for all revenues from Pulau Badi and all costs including maintenance, hardware, labor, fuel transportation, oil and diesel fuel PLN looses between $1,711 and $3,749 per month on Pulau Badi. *See Appendix 1 for details.*

The VP of Renewable Energy at PLN, Mr Ario Senoaji was asked if there was an intention or a mandate to increase the duration of electricity access in rural communities. He stated that they "would be interested in increasing service if no additional costs were incurred"[10]. The results show that PLN will not be increasing electricity access with current energy costs in place.

Alternative Energy Sources

As discussed above, mariculture entrepreneurs on Pulau Badi require 24 hour access to electricity in order to meet the needs of their businesses. At present, the service provided by the energy utility is inadequate and questions regarding the feasibility of using renewable energy to meet business demands have been raised. The rest of this section examines the availability of natural resources including solar and wind to determine if there is energy generation potential. Biomass was not included in this study, as it is more expensive than diesel fuel in Makassar and it cannot be produced locally. Local biomass is limited on the island by small acreage, housing

[10] Meeting withVP of Renewable Energy PLN Indonesia. Ario Senoaji. Jakarta, Indonesia. July 29, 2009.

density and sandy infertile soils. Wave data was considered initially but a small wave generator was recently installed to test local wave resources and data was not available. Data will be available after one year and further analysis could be examined at that point in time.

Solar Resources

According to Nasa, the average solar insolation in South Sulawesi is 5.88 kWh/m^2/day[11]. Data collected over a twenty year period from NASA reveals average monthly values ranging from 4.75 kWh/m^2/day in the rainy season to 7.22 kWh/m^2/day in the middle of summer, which is on par with two major solar development regions; Australia and Arizona. Most developers view an annual average of 5 kWh/m^2/day as an exceptional region for solar development and Indonesia exceeds that value. *Monthly averages are reflected in the Appendix 2.*

Wind

Most wind developers view an average wind speed of 8 m/s as an opportunity for investment in wind energy systems. However, additional considerations include variations in wind intensity, duration, seasonal patterns and speeds at different heights above land. Models can offer some insight on wind speed but hourly data from site specific locations is essential for making an investment decision. Localized hourly data was not available for Pulau Badi so several resources were sought to gain an informed estimation.

[11] National Aeronautics and Space Administration. Modeling and Similation. March 2010. <http://disc.sci.gsfc.nasa.gov/mdisc>

Wind - Literature

Several sources of literature reviewing alternative energy projects in Indonesia suggest that wind resources are minimal. According to a published document from Winrock International "wind energy in Indonesia is the odd one out with an estimated installed capacity of less than 0.1 MW. Whereas in many countries including in developing countries like India and Brazil, wind energy has been the Renewable Energy success story, such has not been the case in Indonesia. One straight forward reason for this is that the wind regime in many areas in Indonesia is sub-optimal with average wind speeds of only 2 to 4 m/s"[12].

Wind - Anecdotal Evidence

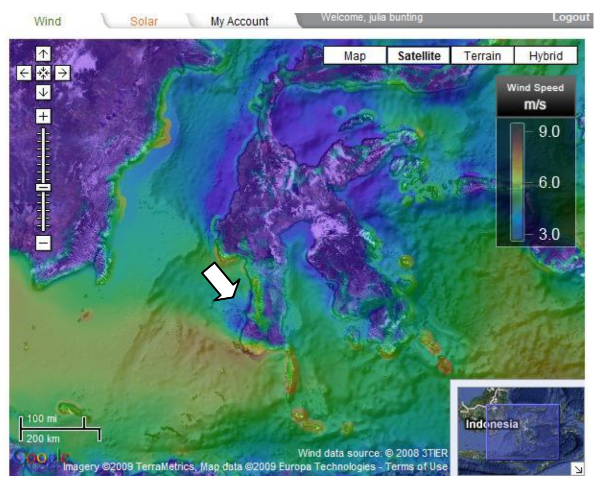
On July 29th, an interviewed was conducted with a wind developer in Indonesia. He has been working for a prominent energy development company in the United States and also for Winrock International to develop various wind projects around Asia. While there have historically been limited wind developments in Indonesia, he is currently monitoring a site in South Sulawesi on a ridge of a mountain range. With significant elevation and open exposure to wind, average wind speeds are reaching 8-9 m/s. However, according to the developer, it is extremely unlikely that there would be sufficient wind resources in Spermonde (Pulau Badi Region) to develop even small scale wind turbines at an economical advantage.

Wind - 3Tier First Look

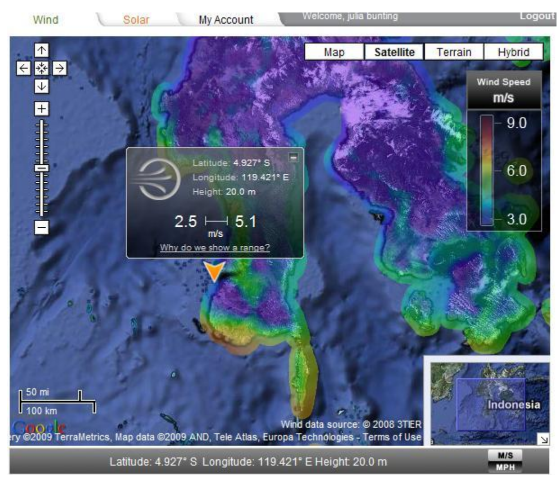
"First Look"online investigations into the wind speeds around South Sulawesi reveal some regions with wind speeds reaching up to 8 or 9 m/s (red/orange). However, it is evident

[12] *Active Frameworks Pte. Ltd. "Opportunities for Wind Powered Productive Use Projects in NTT". Produced for Winrock International. Singapore. June 2004.*

that these speeds are only achieved in off-shore locations or at high altitudes. On the left hand map below, the region of Spermonde (Pulau Badi) is highlighted in blue indicating wind speeds of approximately 3-4 m/s. The outer region surrounding Spermonde shows wind speeds of 4-6 m/s. The map on the right hand side demonstrates a more pinpoint view of the region surrounding Pulau Badi indicating wind speeds of 2.5 m/s to 5.1 m/s. It is important to note that this data pinpoints a region approximately 10 miles from P. Badi. Information was unattainable for the specific longitude and latitude of Pulau Badi due to inadequate data inputs at this time.



Average wind speeds in South Sulawesi
Blue indicates 3-4 m/s, Green indicates 4 -5 m/s



Wind Speeds in Spermonde (10 miles from P. Badi)
Wind speeds around Pulau Badi are 2.5 – 5.1 m/s

Wind - Badan Meteorologi Dan Geofisika (BMG)

BMG does meteorological testing of wind and solar data in various regions of Sulawesi. According to the report obtained from BMG, the average daily wind speeds varied between 0 m/s and 6.64 m/s and the average annual wind speed was 1.5 m/s.

While there was little evidence of sufficient wind to support an investment in a wind anemometer, it is the only accurate measure of the location specific wind resource availability.

Design of Community-Sized Energy Systems

The design of a community-sized energy system was analyzed first to determine if there were opportunities to increase electricity availability to all island residents and take advantage of scale. Scale can be an important factor in assessing energy affordability and thus it is imperative to evaluate the costs of increasing the electricity supply to the entire community by utilizing and building upon current infrastructure.

The energy utility operating on Pulau Badi (PLN) was contacted in July of 2009 to discuss their interest in increasing electricity supply on the island. PLN stated that they would consider increasing electricity service if there were no additional annual losses incurred. In 2008 and half of 2009 the costs for electricity production averaged $3305/month. The residents on Pulau Badi paid an average of $575/month leaving PLN recording an average net loss of $2,730/month. In order for PLN to support increased electricity development efforts the losses experienced by PLN would have to be equal to or less than $2,730/month or $32,770/year.

In order to evaluate the costs of increasing electricity service at the community level, two systems were compared. The first was an expansion of the current diesel generator system and the second was the installation of a solar-diesel hybrid system. Due to the unavailability of wind resources, it was not considered viable.

Expansion of Diesel Generator Operational Hours

To install and operate a diesel system capable of operating for 24 hrs/day the cost of electricity production would be $0.35/kwh – $0.75/kwh. The range in price is due to the price volatility of fossil fuels. If operating with this type of system for 24 hrs, PLN would encounter a range of losses from $5,297/month to $12,711/month. This calculation includes a projected increase in revenue generated from residents. See appendix for calculations and assumptions.

Hybrid System: Diesel Generator & Solar PV Combined

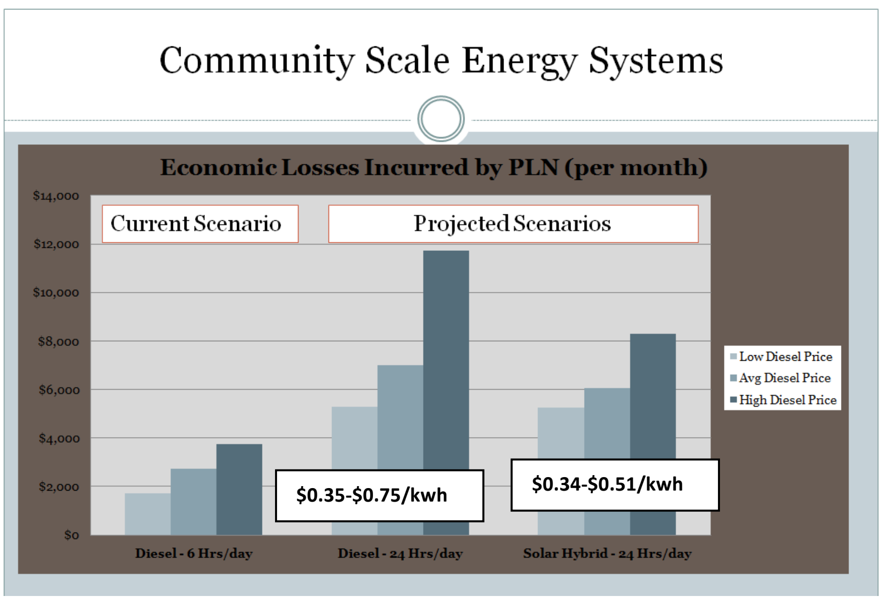
It is apparent that island nations experience increased costs of electricity production due to their remote location and subsequent high cost of fossil fuel deliveries. Due to these costs, renewable energy strategies can actually be more price competitive if the climatic conditions are supportive. Several islands around the world have benefited from stand alone renewable energy systems but more often than not the systems are designed to act as a hybrid system relying on solar or wind resources when they are abundant and utilizing a diesel generator for backup power during times of darkness or insignificant wind. As discovered in earlier research results, Pulau Badi appears to have inadequate wind resources for project development but solar resources appear to be abundant. Therefore, in this scenario a hybrid system consisting of solar pv panels combined with a diesel generator was evaluated to determine the economic feasibility. The HOMER Energy model was used for this analysis.

If electricity capacity was increased to 24 hours/day by installing a solar-hybrid system the cost of production would range from $0.35/kwh – $0.51/kwh.

Comparison of Two Community-Scale Systems

If considering 24 hrs of electricity provided by a centralized community scale system, the solar hybrid system would be more cost effective, especially in a scenario with high fuel prices. If PLN or a private entity installed a hybrid system, the monthly losses would range from $5,261 to $8,303. If a diesel generator system were used to provide the same 24 hr service, the monthly losses would range from range from $5,297/month to $12,711/month. The calculation accounts for all potential revenues and reflects the losses incurred by the energy provider.

The graph below demonstrates the economic loss in each of the three scenarios. The first set of bar graphs on the right is business as usual (operating a diesel generator for 6 hours). The second set reflects the use of a diesel generator to supply power for a 24 hour period and the third demonstrates the solar-diesel hybrid system.



PLN stated they would not increase their cost of production and therefore, the community electricity supply will remain at 6 hrs/day. In addition, there is no incentive for outside players to enter the market because rate payers are capped at $0.05/kwh and the cost of generation is significantly higher as seen above. However, if the government ever mandates 24 hours of service to all residents, a solar-diesel hybrid system would be more economical than a straight diesel system on Pulau Badi. These calculations include all upfront and operational costs.

Please see appendix 3 for assumptions used in the models for community scale systems.

Design of Individual-Sized Energy Systems

Individualized energy systems can benefit users by reducing transmission losses and also by eliminating the need to overcome challenging hurdles for developing energy at the community level. After examining natural resource availability, two different scenarios were chosen and were examined below. The first system examined the use of small sized diesel generators for 18 hours combined with electricity from PLN for 6 hours/day. The second scenario examined the costs of utilizing a solar pv pumping system with a battery back-up.

In both of these scenarios, the energy load considered was for backyard mariculture tanks. As described in earlier sections, the load was calculated to be 300W.

Small Generators & Electric Utility (PLN)

In this scenario, two 35 kw generators were required to supply enough power consistently to pump water for 18 hours/day. The remaining 6 hrs of electricity required came from PLN's current electricity service from 6 pm to 12 pm. Two generators were required in this scenario because they could not operate for more than 6 consecutive hours.

In order to obtain 18hrs of electricity with a generator and 6 hrs of service from PLN, the upfront energy costs required to purchase the appropriate infrastructure totaled $3134. In addition to upfront costs, the system required an average annual cost of $1984 to cover fuel, maintenance costs and service from PLN. The generators have an average lifetime of 10 years and therefore at the end of 10 years replacement costs would have to be considered. The cost of generation calculated from this model ranged from $0.58/kwh to $1.24/kwh depending upon the price of fuel. To see more details please see Appendix 4. For a review of assumptions please see Appendix 5.

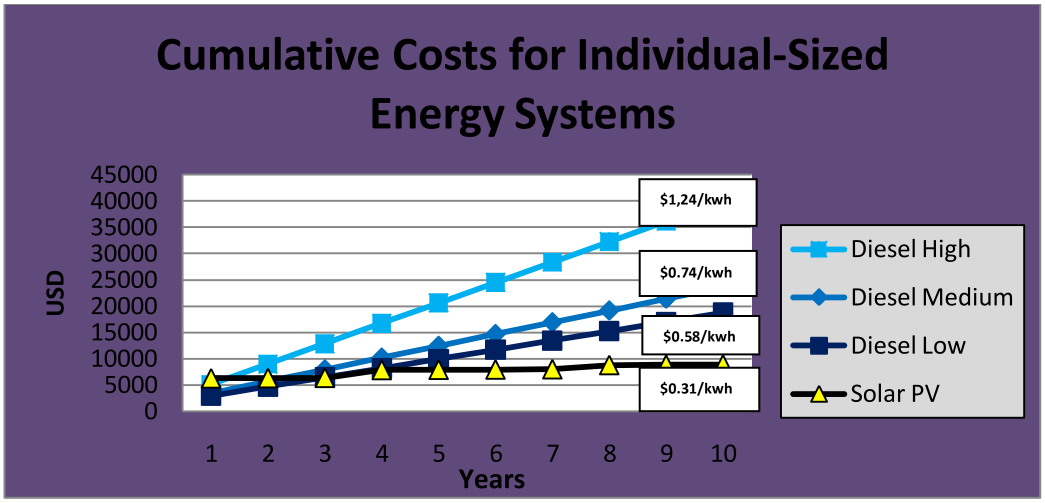
Solar PV for Pumping Water

Due to the high average solar insolation, a standalone solar PV system was evaluated for cost. The system contained one specialized submersible DC pump, an aerator with storage system, solar panels equaling 625 w and 3 12v 100 AH batteries. The HOMER model was not used for analysis due to the small size of system and complicated pump surge demands. In order to obtain accurate local pricing, a leading energy development company on Java was contacted to determine competitive pricing in Indonesia. The company was called Contained Energy. A description of the components for this individual sized system is included in appendix 6.

Upfront costs for installing a solar pv system capable of meeting the energy needs of a mariculture tank start at $6246. Annual costs would include minimal charges for maintenance. However, every three years an investment of $1430 would be required to replace the batteries that are predicted to deteriorate quickly due to the harsh heat and salt exposure. Generation costs totaled $0.31/kwh when using a solar pumping system as described above. For a list of assumptions, please see Appendix 7.

Comparison of Two Individualized Energy Systems

The following graph compares the two different individualized energy systems described above. The blue lines represent the diesel generator scenario with varying diesel prices. Upfront costs are low but annual costs are high. The yellow line demonstrates the high upfront costs of solar pv systems but also reflects the low annual costs.



Upon examination of both community scale and individual scale systems, it is evident the the most cost effective solution is the installation of an individual sized solar pumping system. As seen above, the cost for that system would be approximately $0.31/kwh and there would be no risk associated with price volatility as we see with systems relying on fossil fuels.

Local Capacity: Support of Energy Development

Local capacity is an essential consideration for energy system development. If there is limited local capacity, significant financial and time commitments will be required otherwise energy solutions will not be transferrable and replicable to other entrepreneurs on other islands. According to the director of Winrock Indonesia, "95% of all renewable energy projects fail because of the absence of supporting infrastructure"[13].

For this research analysis, local capacity included an examination of Makassar Energy Companies, Access to Capital and Local Behavior.

[13] Meeting with Director of Winrock Indonesia. Bernard Casterman's. Jakarta Indonesia. July 28th, 2009.

Makassar Energy Companies

A survey of renewable energy businesses was completed in Makassar to identify and examine local energy development capacity. It was imperative to determine who was operating in the space and what additional capacity would be required to develop a maintenance or distribution mechanism for the marketing, installation, maintenance and deployment of energy systems. Prices discovered in Makassar were also compared to those in Java where manufacturing occurs.

A month of investigation of renewable energy companies revealed a total of one wind shop and four solar sales offices. Two of the solar shops were open infrequently and unpredictably so data was not able to be obtained. A third solar shop was unwilling to provide information about products unless a deposit was paid. Of the two companies available for investigation (one solar and one wind) neither of the shops were actively involved in any type of maintenance service. Their focus was exclusively on point of sale. Surya Puzulindo (wind) and Total Parabola (solar PV) were asked how they marketed their products, as the World Bank states that this is a critical factor for “self-replication”. The wind company advertises in the yellow pages and the solar company advertises by word of mouth. Neither company had any developments in the island regions around Makassar including Pulau Badi.

Price comparisons between Java and Makassar revealed significant price differences. A 50 watt panel sold in Java can be purchased for an average of 250$ while the same panel in Makassar costs on average 350$. Parts for solar panels and for solar components were on average 40% higher in Makassar than in Java.

Access to Capital

The second analysis completed was an evaluation of access to financing. The average wage on rural fishing islands is approximately 40 USD/month and therefore financing would be required for accessing energy systems.

With energy projects and parts ranging from 350$ for a 50 watt panel to 400,000$ for community scale systems, financing systems becomes increasingly important. None of the energy companies interviewed in Makassar offered financing. Several banks in Makassar did claim to offer micro-financing and they were called BRI lending institutions. However, banks or micro-lending institutions in Makassar and in the rest of Indonesia are unwilling to finance energy projects because they are unable to assess risk[14]. In the past the World Bank and the IFC have backed large scale renewable energy projects with large sums of money placed in trust in the Indonesian Banks[15]. Despite this historical support, it is unlikely to work for small scale entrepreneurs seeking financing.

Another option for accessing capital in the form of micro-financing comes from global non-profit organizations or specialized banking institutions. These organizations are often equipped to deal with small scale revenue generating projects. Micro-finance organizations require a strong pre-existing business model to prove validity, charge 30-40% interest rates due to high management costs and require regular monthly payments. There are no microfinance agencies currently operating in Indonesia that provide lending for energy projects. Therefore, significant infrastructure development would be required.

[14] Meeting with Director of Winrock Indonesia. Bernard Casterman's. Jakarta Indonesia. July 28th, 2009

[15] Meeting with International Finance Commission. Anonymous. July 13, 2009. Makassar Indonesia.

Local Behavior/Appropriateness

The third analysis was an investigation into local behavior. Projects that require minimal behavior change are often met with success while projects requiring different skill sets or different ways of operating are often extremely challenging to achieve[16]. In order to examine this complex arena, literature and observation was the key methodology. The first paragraph describes an observed behavior labeled the "Lego Effect" and the second paragraph describes its applicability to the energy sector.

According to the founder of International Development Enterprises and author Paul Pollock, people living below the poverty line in developing countries adhere to the metaphor of building with one brick at a time. When they earn a little money, they buy a few bricks and build a room. When a little more money is earned, another room is built. Although it is not the most efficient and cost effective method of building a house, it is the only possible method when you don't have access to capital and all you have is the money in your pocket. It is a behavior that has been studied by development experts around the world and it has been coined the LEGO effect by Pollock. There is evidence of this behavior throughout South Sulawesi including the way people buy things like housing materials and everyday purchases such as single cigarettes or shampoo packages.

One private company in India call Distributed World Power (DWP) models the LEGO concept well and the major learning's are transferrable to Sulawesi. DWP has started a manufacturing facility in India to produce very low quality, low rated and cheap solar panels.

[16] Pollack, Paul. "Out of Poverty-What Works When Traditional Approaches Fail". Berrett-Koehler Publishers Inc. 2000.

With the low cost of production, rural farmers are able to afford the initial price hurdle and can enter the market without financing. As they save money, they are able to build like a "Lego model" and add several additional panels to increase their volume of electricity. According to James Burgess, a founding member of DWP, it is enabling people to slowly build their capacity through their own means with very little risk. DWP is charging approximately half of the price of their competitors and they are providing an inclusive maintenance service to ensure project longevity. They claim that their model is more sustainable than the larger community-scale energy projects because they are more appropriate in scale and people can maintain direct ownership.

In Sulawesi, projects need to be designed to encourage local adoption through low price points, strong distribution networks and systems that energy systems that require simple maintenance. Hi-tech wind or wave technology may be too difficult to maintain with current capacity and infrastructure. Even for low end solar panels, skill development would be required in order to increase marketing, installation and maintenance capacity.

Indonesian Energy Policies

Energy policies can make or break energy development projects. On the promotional side, policies can offer financial incentives or price subsides that can enhance the economic or business case for developing renewable energy. On the other hand policies can also present hurdles for the distribution of energy systems by subsidizing fossil fuels or reducing capital markets by placing constraints on consumer pricing. Relevant Indonesian energy policies are discussed below.

Policies Regarding Private Energy Producers

Recent policies state that private energy producers can enter the electricity market. However, they must sell their electricity directly to PLN at a negotiated price. Last year the prices were set at 80% of the electricity cost[17]. However, recent policy changes has eliminated this pre-set price and each project has to negotiate purchase prices with PLN. Developers in Jakarta claim that prices can be negotiated between $0.05– $0.11/kwh, but they state that it is too low to cover the costs of most renewable energy projects[18].

To investigate this policy further, Ario Senoaji of PLN was asked if there was a possibility of negotiating private power producer agreements on Pulau Badi. He stated that PLN will not purchase renewable energy from regions that already have sufficient capacity and most rural islands are in that category. Pulau Badi has a 100 kW diesel generator and the community uses only 40 kw at peak resulting in a surplus of available capacity.

Policies Impacting the Development and Deployment of Individualized Energy Systems

In the analysis above, community systems were not feasible and upon examination of individualized energy systems solar pv proved to be the most economical. Thus, it was imperative to examine policies that would impact the development and deployment of solar pv systems around Makassar.

Additional Policies

The Ministry of Energy and Mining has recently been given authority to provide electricity infrastructure to remote rural villages that currently have no electricity supply from

[17] Meeting with VP of Renewable Energy. PLN Indonesia. Ario Senoaji.. Jakarta, Indonesia. July 29, 2009.
[18] Meeting with Director of Contained Energy. Peter DeVries. Jakarta Indonesia. July 28th, 2009.

PLN. Every year the Ministry that is responsible for South Sulawesi selects one village to receive an energy system. This year an island was chosen to receive a solar PV system costing $500,000 (US). The development community is concerned that these projects will not last because the Ministry required no up-front fees from the community, no payment plans were determined and no contracted maintenance service existed. Energy developers in Jakarta claimed that the policy was negatively affecting their business. They stated that "rural communities that were previously interested in small scale energy solutions were no longer interested in paying the higher fees because they believed energy was supposed to be free". This policy has directly impacted the development of energy businesses and will continue to distort the market development of alternatives.

In addition to large scale systems, the Ministry has given away 60-70,000 100w solar home systems for to rural villages in Indonesia[19]. According to the Founder and Director of Contained Energy Jakarta, Pieter DeVries, these solar house systems were installed without any consideration for maintenance. DeVries earned the contract for several of the installations and he donated his time to try and train local repair capacity. Despite these efforts, he claims that at least 85% of the systems failed during the 3 month to 1 year time period because of maintenance challenges and inaccessibility of parts. He also noted that no one was willing to purchase a new battery to repair their systems because they thought there were more arriving for free.

The implications of these policies were discussed in numerous meetings with energy developers in Jakarta and the statements were similar to those discussed above by Peter DeVries. The current director of Winrock Indonesia claimed that the free give-away policies resulted in the collapse of several renewable energy businesses. The organization that he had previously

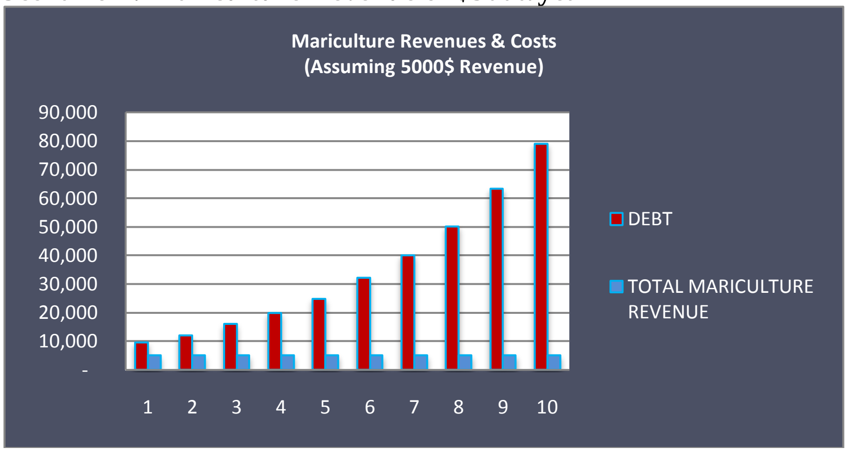
[19] Meeting with Director of Contained Energy. Peter DeVries. Jakarta Indonesia. July 28th, 2009.

worked for had manufactured and distributed small solar house systems. They developed a distribution system by partnering with local entrepreneurs and providing them with training to install and maintain energy systems. Initially they encountered a lot of success particularly with the engagement of local entrepreneurs and the development of a maintenance system. The capacity grew for five years until the Ministry entered their region and gave away some free solar home systems. Their entire business model disintegrated within 6 months because entrepreneurs started to eject themselves from the business claiming that no one wanted to buy their systems.

Feasibility of Mariculture Business Model

The high costs of obtaining a reliable and consistent electricity supply pose significant challenges for mariculture entrepreneurs. As discussed above, the most economically feasible energy option (individual solar pv units) will cost entrepreneurs over 6000$ to install and with an average annual income of $480 it is an extremely large investment. According to data collected from developers, mariculture entrepreneurs will have to spend additional capital to build the mariculture system which would result in a total upfront investment between $10,000 and $14,000. The fluctuation in price is due to a varying number of juveniles purchased (bibbet) and a corresponding fluctuation in food costs, as there are two scenarios investigated in this model for growing species. The first scenario is based on annual harvest and resulting revenue of $5000. The second scenario doubles the harvest resulting in annual revenues of $10,000. In these scenario's the annual costs range from $3100 to $7460, although these are highly speculative at this time.

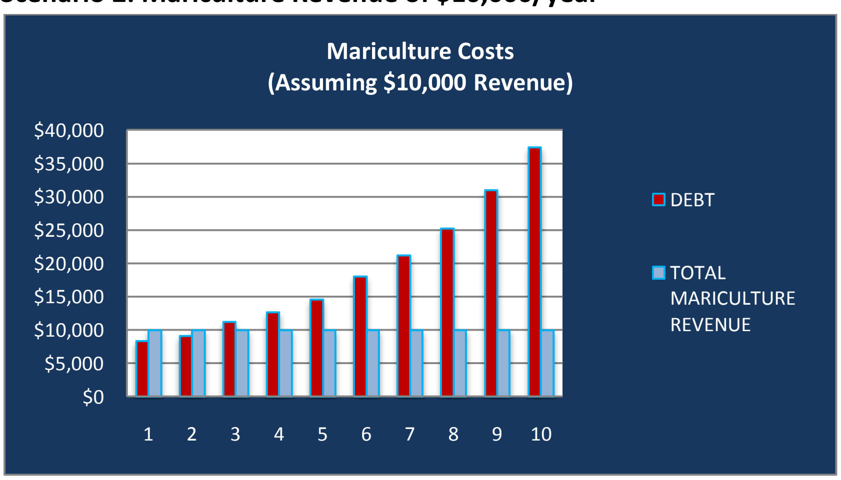
Scenario 1: Mariculture Revenue of $5000/year



In this scenario, the mariculture entrepreneur faces an increasing debt that he is unable to repay.

Other development models suggest that entrepreneurs maybe able to generate revenues of up to $10,000/year. In this scenario, all costs would remain the same except for bibbet costs and food costs which would double. With this scenario debt would continue to accumulate and the entrepreneur would be unable to pay off the loan.

Scenario 2: Mariculture Revenue of $10,000/year



Additional Hurdles

Due to the high upfront and annual costs, entrepreneurs who currently make $480/year would be required to obtain significant loans to cover the costs as shown above. However, at this time there are no financing institutions in Indonesia and it is unlikely that any financing institution would provide financing of this level of risk. Fishers do have land titles, collateral and their crops are inherently risky due to disease and other environmental conditions.

As mentioned above, there are numerous hurdles in addition to the financing challenge with developing a viable energy infrastructure capable of supplying energy systems to these rural entrepreneurs.

The assumptions used in the model were made in favor energy development and assumed success of mariculture entrepreneurs. For example, I assumed that we would be able to achieve an extremely low financing rate of 25%. I also assumed that all seed stock that was purchased survived until harvest. Even though a best case scenario was used, the mariculture business appeared to be prohibitively expensive and unprofitable.

To see a complete list of assumptions, please see Appendix 8.

DISCUSSION

Indonesia is an extremely complex environment for generating stable and consistent electricity. With 17,000 islands, traditional large scale energy systems and grid delivery is not a feasible solution for reaching most rural residents. Islands are left facing energy challenges themselves and as noted above the options are extremely limited. In order for energy access to reach the millions of Indonesians with limited or no energy access, several changes are required. These changes will require significant time and financial resources combined with significant policy changes at the government level.

Investments of Time and Capital

There are numerous hurdles that need to be overcome before mariculture entrepreneurs will be able to access the energy services and before developers see wide spread adoption. Technology prices must come down significantly, financing systems will have to be built, and local skill capacity will require a large infusion of time and capital to strengthen services. In addition, the 40% price premiums charged in Makassar will need to be eliminated while the efficiency and speed of part delivery will have to increase. These changes are not something that can be built in a short period of time.

Pricing Policies

The government mandates a price ceiling on the amount paid per kwh so residents of Pulau Badi pay between $0.02 and $0.05/kwh. This poses a significant hurdle for energy developers, as it is currently impossible to provide electricity for those rates on remote islands such as Pulau Badi. With this rate structure it is unlikely that energy access will increase on rural islands because there is no economic incentive for utilities to increase service. Discussions were held with the energy utility providers and with energy developers regarding this challenge and there seems to be limited solutions. Most people agree that residents cannot afford price increases. However, based on a survey of current pricing structures, there may be one opportunity to explore. Residents currently pay a very substantial electricity hookup fee to have their house connected to the grid (>$100). This fee has deterred residents from obtaining energy service directly from PLN and it is not uncommon to see houses running extension cords to their neighbor's house to avoid the high hookup costs. There is a need for a study to investigate the potential benefits of reducing the upfront price hurdle and raising prices per kwh to determine if these are more cost effective methods of delivering electricity.

Free System Give-Aways

As mentioned earlier, some companies have managed to achieve some success developing and deploying small solar home systems to regions without electricity access or to those regions that receive inadequate service. In some of these regions, people were willing to pay more than the government rate of $0.02- $0.05/kwh to have cell phone chargers or television for periods of the day. Several companies were finding success and delivering this model by designing strong marketing and maintenance programs around Indonesia. However, with the introduction of the government's free systems, residents began to see energy as something that should be free and provided by the government and these profit making companies dissolved. Unfortunately these projects have also had minimal success rates due to user misinformation and lack of maintenance programs resulting in poor public opinions about solar energy. This policy has created a gap in local capacity to market, install, and maintain energy systems and because sales have halted, technology costs will remain in low volumes with high prices. It seems that the "free energy systems" policy needs to stop to encourage market solutions and to encourage Indonesians residents to view energy as a service that will require maintenance and investment.

CONCLUSION

The challenges and resulting high costs associated with energy infrastructure development poses significant challenges for mariculture entrepreneurs today. From the analysis conducted throughout this paper, it is clear that the most economical energy system found was a small scale solar pv pumping system. If purchased in Jakarta, this system would costs more than $6000 to install which is more than twelve times the average annual wages. This poses a significant challenge to entrepreneurs as financing is currently unavailable. Even if it became available in the future, mariculture entrepreneurs would be unlikely candidates for financing as their project costs are extremely large, they have very high risks and most of the entrepreneurs do not have any collateral. The high costs of producing electricity on these remote islands provide a seemingly insurmountable hurdle for mariculture entrepreneurs.

If the hurdles associated with energy development could be overcome (access to capital, local skill development, cost reductions etc.) developers suspect that profits could still be generated with the mariculture business model. To test this hypothesis, several analyses were conducted to evaluate profitability. In the first scenario, the assumption was that mariculture entrepreneurs could afford all of the project upfront costs (>$14,000). If this were true, entrepreneurs would break even at year seven. However, as we have seen the average income on Pulau Badi is $480/year and therefore financing from the community or from an institution would be required. No matter where the money comes from there is opportunity costs and risks that need to be incorporated into rates. Micro-lenders typically offer rates between 25% and 40%, although community or family loans in Indonesia often have higher percentages. Using a low estimate of 25%, two scenarios were examined including revenues of $5000 and revenues of $10,000. Both of these scenarios result in a growing debt that mariculture entrepreneurs would be unable to pay back over time.

It is evident that there are numerous hurdles facing mariculture entrepreneurs at this point in time. While some of the hurdles could potentially be overcome with significant time and resources, the question emerges of whether there is a more effective and more appropriate location for the mariculture business model or whether there are alternative models that would be more reasonably suited to Pulau Badi. With regards to the first question of location, it may be possible to reduce energy costs by moving the mariculture model to other regions where electricity is cheap and reliable. For example, facilities could be located in regions where there is constant grid access or where micro-hydro power has proven viable. To address the second question of economic development on Pulau Badi, the solution may lie in the development of business alternatives that can take advantage of current electricity availability. Businesses that can capitalize on six hours of electricity offered on Pulau Badi would have cheap electricity to conduct various activities. Also, businesses that can take advantage of renewable energy solutions such as solar or wind and use electricity during times of production would avoid the high costs of energy storage.

As developers move forward and question business models, it is imperative that local behavior and local capacity remain a strong consideration. Residents earn $480/year and thus any financial outlay required should be incremental. Capacity development expectations should be reasonable and the time it will take to make changes should not be underestimated. PLN employees on Pulau Badi are no longer charged with maintenance responsibilities of the generator because of poor quality servicing. Policy changes should not be required unless developers are willing to lobby for changes or partner with those who will participate. On an optimistic note, there are several business opportunities that have been discovered in Indonesia that follow these guidelines and also require little or no electricity. These businesses include seaweed farms, spirulina growing operations and coral farming. A more thorough analysis of these business opportunities should be pursued to determine if they are profit generating and to determine if they are suitable for rural fisherman in Indonesia.

APPENDICES

Appendix 1: Calculation of Production Costs (Per Month)

Production Costs (Per Month)

Production Data Report (Month Produced)	Diesel Fuel Cost (LOW)	Diesel Fuel Cost (HIGH)	Oil Lubricant Cost (IDR)	Transportation Cost (IDR)	Labor Cost (IDR)	Maintenance Costs (IDR)
Sep-07	17235000	42130000	1378605	2301000	2700000	2,027,797.22
Apr-09	13657500	33385000	698745	2301000	2700000	2,027,797.22
May-09	15120000	36960000	642090	2301000	2700000	2,027,797.22
Jun-09	14625000	35750000	226620	2301000	2700000	2,027,797.22

Monthly Portion of Generator Replacement Costs	Total Cost US$ (Low Diesel Price)	US$/Kwh (Low Diesel Price)	Total Cost (high diesel price)	US$/Kwh (High Diesel Price)	Average Cost
777302.7594	2549.17	0.25	4876.23	0.48	2475.22
777302.7594	2138.39	0.27	3966.85	0.49	2035.17
777302.7594	2274.04	0.26	4306.32	0.48	2193.54
777302.7594	2186.19	0.25	4149.49	0.48	2111.98
Average	**2286.95**		**4324.72**		**2203.97**

Appendix 2: Natural Resources Solar Insolation Data

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m^2/day)

Lat -5.14 Lon 119.43	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	4.57	4.84	5.75	5.91	5.97	5.67	5.95	6.70	7.22	7.05	6.09	4.75

http://eosweb.larc.nasa.gov/cgi

Appendix 3: Community Scale Energy Systems: Assumptions for Model

Electricity Consumption Data

Electricity consumption data collected from 2007 and 2009 revealed no significant annual growth in consumption patterns and no seasonal differences were noted. However, the month of September was 10-20% higher in consumption level due to festivals. Consumption patterns for six hours of generator production were averaged from four months of data in 2007 and 2009 providing an average of 33.64 kw each hour and a peak of 40 kw. To make projections about energy consumption beyond 6 hours of service additional calculations were necessary. The developers working on Badi had historical survey data reflecting consumers' willingness to pay for service and particularly what appliances they would use during different time periods. The results showed that from 1:30 am until 6:30 a.m (the end of morning prayer) consumption would most likely include lights, fans, and refrigerators and thus energy demand was estimated to total 50% of peak daily usage. From the hours of 7:30 a.m until 5:30 p.m consumption would most likely include fans, refrigerators, radios and televisions and energy demand was calculated at

60% of peak daily usage. Totaling all calculated data revealed an average island consumption of 614 kwh/day.

Technology Pricing
All prices for technology were obtained from manufacturers and distributors in Java. Where differences were found, lower prices were used.

- 100 w solar panel: $300
- Converter: $800/kw
- Trojan L16 Batteries: $200/battery
- Diesel generator: $25,000 price provided by Utility PLN
- Diesel fuel: Inputs for the model included three different prices to reflect fluctuation in fuel prices over a five year period. Prices were obtained from Pertamina and the costs of transportation to the island were added to produce the following totals;
  (Low = $0.51, Average = $0.66, High = $1.16)
- Maintenance costs for the generator were calculated based on historical maintenance records over five years and averaged over the lifetime of the generator. The maintenance price was $0.20/hour.

Additional Assumptions
Cost of capital: 10%
Solar radiation data: Obtained from Nasa
Maximum Annual Capacity Shortage: 10%

Appendix 4: Individual Sized Energy System: Generator and PLN
The following chart outlines the upfront costs to entrepreneurs and also monthly costs for generating electricity from generators combined with service from PLN.

Energy Price for Pumping Water (Diesel Generator & PLN Service)										
YEARS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fuel Prices	$1,902	$1,902	$1,902	$1,902	$1,902	$1,902	$1,902	$1,902	$1,902	$1,902
PLN electricity (6 hrs/dayx365 days)	$32	$32	$32	$32	$32	$32	$32	$32	$32	$32
Gen Set Prices	$1,000	$50	$50	$50	$50	$50	$50	$50	$50	$50
Pump/aerator prices	$200									
Total Cost for Pumping	**$3,134**	**$1,984**	**$1,984**	**$1,984**	**$1,984**	**$1,984**	**$1,984**	**$1,984**	**$1,984**	**$1,984**

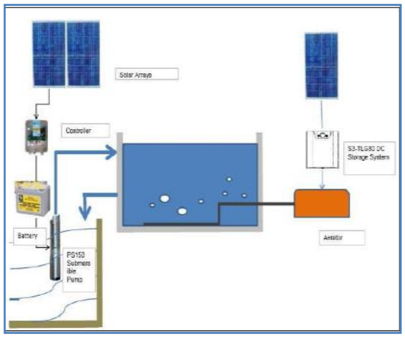
Appendix 5: Individual Sized Energy Systems: Assumptions for Model of Generator and PLN

Generator Cost & Lifetime
Costs and sizing was determined from dealers in Makassar, Indonesia. Dealers suggest that the life span of the generators is 10 years. While generators are typically used longer in developing countries, they are not operating efficiently and fuel expenses increase. Also, on an island salt in the air seriously degrades machinery. Therefore, 10 years was the assumed lifetime of the generators in this scenario.

Cost Assumptions
The following table outlines the cost assumptions. Maintenance costs for the small generators were not included due to inadequate data and assumptions that costs would be minimal if replacements occurred after 10 years.

Cost Assumptions	August 1 Price	Peak pricing
Utility Costs		
Utility Bill for 300 w pump/aerator (USD/month)	2.70	
Infrastructure Costs		
Cost of Pumps/Aerator	200$	
Cost of two generators (lifetime = 10yrs)	1000$	
Fuel Costs		
Fuel/year (IDR) (9 L/day x 365 days x6000IDR/L)	19710000	36135000
Fuel/year (USD)	1901.77	3486.58
USD per month	158.48	290.55

Appendix 6: Component Design and Pricing of Individualized System: Solar PV



Quote (2a) for Solar Submersible Pump

no	Item	Unit	Unit Price	Total Price
1	PS150 Centric Submersible pump	1	$ 1,635.00	$ 1,635.00
2	Solar Panels 125	4	$ 625.00	$ 2,500.00
3	Battery 12 v 100 AH	3	$ 310.00	$ 930.00
			subtotal	$ 5,065.00

Quote (2b) for Solar Aerator

no	Item	Unit	Unit Price	Total Price
1	17 W DC aerator 1500 L/H	1	$ 56.00	$ 56.00
2	Solar Panels 125	1	$ 625.00	$ 625.00
3	S3-TLG 80(Storage System)	1	$ 500.00	$ 500.00
			subtotal	$ 1,181.00

Appendix 7

The pricing model assumes that all internal pumping that currently requires a second pump could be replaced with design changes that take advantage of gravity feed. The additional costs required to modify designs were not added to this calculation.

Appendix 8

There are numerous assumptions made in this model which include;

- Financing will be available at some future date in Indonesia that will offer rates of 25%
- Institutions will offer financing to these entrepreneurs with no collateral
- Entrepreneurs earning $480/year qualify for a loan greater than $10,000
- All bibbet survive the year and reach market (no death rate)

- No additional costs required (no disease, no food spoilage, no equipment replacement etc.)
- Buyers continue to purchase species at quoted prices
- Only one person draws a salary of $480/year