A Design-Space and Business-Strategy Exploration Tool for Infrastructure-based Ventures in Developing Communities

Chanakya Mehta

Electrical Engineering Department
The Pennsylvania State University
crm585@gmail.com

Khanjan Mehta

Humanitarian Engineering and Social Entrepreneurship
The Pennsylvania State University

Abstract – There are a growing number of curricular and extra-curricular programs that focus on developing appropriate technologies to address the needs of marginalized communities at the Base of the Pyramid (BOP). Technology ventures in developing communities often fail because of disconnects between the designer, the implementer, and the end-user. Finding an optimal distribution of time, money, and sweat across the stakeholders is pivotal to achieving sustainable impact for the communities. The design-space and business-strategy exploration tool described in this paper, the E-Spot canvas, identifies a technology venture's stakeholders, defines their individual roles, and suggests the forms of equity they might offer to meet the venture's overarching objectives while fulfilling their own needs. The E-Spot canvas facilitates consensus-building among stakeholders on how to match project requirements with time, money, sweat, and other equities to sustain their project socially, economically, and environmentally. Several case studies that apply the canvas to real-world ventures are discussed.

Index Terms – Design space, business strategy, E-Spot canvas, technology-based social entrepreneurship

INTRODUCTION

A growing number of educational opportunities offered at universities engage students in the development and implementation of appropriate technology-based ventures. The aim is generally two-fold: to provide students with valuable educational experiences and to address the needs of marginalized communities at the so-called base of the pyramid (BOP). These endeavors are usually well meaning, creatively designed, and enthusiastically deployed; however, for many of them, the sustainable impact does not match the vision set forth at the outset. This is due, in part, to an imbalanced valuation of immediate educational experiences for students over the long-term sustainable impact for marginalized communities.¹ This paper presents a design-space and business-strategy exploration tool, the E-Spot canvas, which has been crafted to address issues of project sustainability while providing a richer learning experience to students. The paper is organized into four sections, which cover challenges of project sustainability from practical, macro, and academic perspectives; a typology of technology ventures; the E-Spot canvas for developing implementation strategies for infrastructure-based projects; and case studies applying the canvas's methodology to real-world ventures.

From a macro perspective, evaluations of development efforts to assist communities in a sustainable fashion have revealed unsatisfactory results or failure. For example, in 2004, the African Development Bank judged that 78% of the funds it disbursed were for projects that were ultimately unsustainable.² Similarly, the Independent Evaluation Group (IEG), the World Bank's private sector arm, examined the performance of 627 projects which were implemented between 1996 and 2006. Its findings reveal that over 40% of all projects were unsuccessful at generating positive development results, and that in Africa specifically, more than half of the investments had low development ratings.³ Furthermore, when assessment of such projects is broadened to encompass a time frame beyond the immediate completion of the projects, the number of favorable assessments falls considerably.

Against this backdrop of highly mixed results from the efforts of professionals, we place the growing number of academic programs and extra-curricular clubs that engage students in developing appropriate technology-based solutions for developing communities around the world.⁴ Anecdotal stories and summaries of technology-based social ventures mirror the literature of more formal development assistance programs. Through these stories, we hear of foreigners going into communities and installing infrastructure projects, e.g., solar panels, biodiesel systems, and water treatment facilities. From our evaluation, it appears that the following questions are often not asked: Does this project result in sustainable value for partnering communities? Is the project's sustainable value measured? Does the project lead to *self-determined* development for the community? What are the results of the project in the long term? Thus, questions arise not only with respect to the engineering aspect of such projects, but also the context of globalization, social justice, professional ethics, and cultural balances.¹ A dismal track record of development efforts brings into question the ethics and sustainability of interventions by external agents.⁵

Beyond the participation of universities and village communities, there are a number of stakeholders who play crucial roles in project sustainability. These include non-governmental organizations (NGOs), community-based organizations (CBOs), religious groups, international aid agencies, foundations, and government-sponsored development groups. These groups serve to facilitate technology transfer and provide structure and support to interventions by university groups through their experience, personal relationships, and access to information. Many NGOs which have been operating for long durations have attained the trust and confidence of community members and leaders, providing an invaluable asset. Like all who endeavor in the development field, these entities are not without shortcomings. For example, they may have unsubstantiated wariness of university participation for various reasons, including a lack of understanding of the context and scope of projects, lack of formal relationship between themselves and university groups, fear of competition, and fear of the unknown.^{6, 7}

Our understanding of how to counter the failings of past development efforts has developed through our experience with the Humanitarian Engineering and Social Entrepreneurship (HESE) Program in the College of Engineering at Penn State. In this program, we define successful, sustainable projects as those largely determined by local people, with outsiders playing only a limited role.⁸ This is because external actors, while well-intentioned, may fail to understand the community dynamics and identify the most significant barriers to realizing the ventures. To mitigate this problem, HESE's students begin by identifying the *sticky information* that relates to the societal context of the problem in collaboration with appropriate partners to overcome impediments in a systematic fashion.^{9,10} For infrastructure-based projects in developing

communities, in particular, we have found that the implementation process is just as important as the product. As such, we focus on finding an optimal distribution of time, money, and sweat to be shared by the communities and partnering universities and organizations and have discovered it to be critical to achieving project sustainability.^{6,9} Sustainability, as we have come to understand it, refers to the notion that a project should be technologically appropriate, environmentally benign, socially acceptable, and economically sustainable. The quest for equilibrium among these factors necessitates a participatory approach that applies the tenets of systems thinking to the development of holistic solutions.^{11, 12}

Over the past ten years, HESE has led several infrastructure-based social ventures in Kenya, Jamaica, El Salvador, and other countries.⁸ The primary challenges of these projects were not on the technical engineering side, but rather with respect to the cultural, social, ethical, and business planning aspects, mostly during project implementation.^{6,9} The key challenges, from most to least important, have been designing and assessing appropriate systems; ensuring equity between the stakeholders; identifying marginalized stakeholders and engaging them in the project; understanding and managing power dynamics and privilege systems within communities; identifying and incentivizing champions; public relations; and business planning with non-cash equity.⁹

To touch on some of these projects, in Jamaica the most significant challenge for an anaerobic digester project was the development of trust between the partnering universities, identifying specific roles and duties, and following through with full participation by each. While building a bridge in El Salvador, disputes within the community as to where the bridge would be constructed and who would benefit were critical during construction. An understanding between all the stakeholders about their precise roles, duties, and benefits would have facilitated a smoother implementation of the project. For a windmill power system in Kenya, ensuring equitable contributions from the various stakeholders was the major challenge.⁶

These examples illustrate the need for a systematic process of implementing a solution in a collaborative and harmonious manner. This process encompasses several delicate activities including community identification and partnering, building trust, establishing communication protocols, relationship building, and making decisions by consensus. The community is the core entity that must not only claim ownership of the project, but also contribute to its genesis, organization, goals, funding allocations, and business plan. People in the community must have a voice and authority on all aspects of the project. These are not merely concerns which need to be intellectually acknowledged; rather, they demand systematic, concrete steps. Preparing students to engage in such projects enriches their educational experience while simultaneously serving as the first step towards increasing the probability of success of such ventures. There is a need for a structured methodology, along with practical tools, to ensure equity among various stakeholders. The E-Spot canvas presented in this paper brings together distinct stakeholders and engages them in a structured process to determine how they can create sustainable value for the communities while meeting their own objectives.

TYPOLOGY OF PROJECTS

We use three broad product categories to distinguish technology projects:

1. Infrastructure: shared physical structures like renewable energy systems, wastewater management systems, and community water filtration plants.

2. Durable/Long-term Usage Products: expensive, shared items that are used repeatedly over time by a group of people or community, including large greenhouses, solar dryers, sisal decorticators, and computers.
3. Fast-Moving Consumer Goods (FMCGs): consumables that are individually purchased and used up quickly, including shampoo, chocolates, cooking oil, and cell-phone credit.

The E-Spot canvas is concerned with infrastructure-based and durable/long term usage products that are shared by a number of stakeholders. For such products, as shown in Figure 1, a business plan is necessary for two entities:

First, an entity that manufactures the system and sells it to the groups or communities. This business plan responds to the following questions:

- a. Who will make the system? Who will sell it?
- b. Where will they make the system?
- c. What are their incentives? What is their revenue stream?
- d. How will they provide after-sales support and maintenance for the system?

Second, an entity that will purchase the system and use it collectively in the community. This business plan focuses on the community or entrepreneur planning to bring the system to the community and responds to the following questions:

- a. What is the value created for the community?
- b. How will they pay the installation expenses for the system?
- c. How will they sustain the system and ideally scale it up as the community grows?

FIGURE 1
TWO-LEVEL BUSINESS PLAN

Consider an engineering firm that designs and builds small-scale, environmentally friendly wastewater treatment systems for use by communities that lack access to governmental wastewater processing plants. The firm needs to ascertain two things: first, whether they will have a customer base, and second, whether their customers will be able to afford, install, and sustain the systems. The engineering firm will need a business plan to define how the manufacturing and sale of the wastewater treatment systems will function. This business plan would look and function similar to a conventional business plan for a technology company; we term this a Level 1 business plan. Since the product will be a shared resource among the group or community, the engineering firm will also need to develop scenarios of how the end-users will purchase and maintain it.

For example, if a community of 15 households buys this system, how will they pay for it? Will every household pay an equal share? What should be done if a certain household doesn't have the required financial contribution? Through what means would such households contribute? How will the system be maintained and who will pay for that? How many families can the system service? What happens if some families leave the place or if more families move in? Are there any non-profits or faith-based organizations (like the local church) willing to contribute a certain amount? Will the contribution be on the capital expenses or will they help maintain it? Will the new system help the local government, and in-turn the community to save on property taxes? What are the duties and expectations of all the involved stakeholders?

We refer to a business plan which addresses these community/user concerns a Level 2 business plan. A fundamental hypothesis for this model is the criticality of balanced equity from all stakeholders, which brings with it pride and ownership in the system. The equity and ownership could also reduce social challenges or personal vendettas which hinder optimal utilization of the product, and hence further sustainability of the project. Without a realistic Level 2 business plan, the engineering firm cannot accomplish their sales goals, which in-turn imperils their Level 1 business plan.

VISUAL APPROACH TO BUSINESS PLANNING

Business planning can be a difficult task for entrepreneurs, especially those working on social ventures in chaotic international settings. Osterwalder and Pigneur have developed a highly efficient and easy-to-understand business model conceptualization tool.¹³ The E-Spot canvas is inspired by the Business Model Canvas and provides a structured mechanism for integrated design space, business strategy and implementation strategy exploration. Osterwalder's canvas helps develop Level 1 business plans whereas the E-Spot canvas can be used to develop strategies for Level 2 business plans. The stakeholders for the Level 2 business plan may include, but are not limited to, community members, local business people, US and foreign universities, US-based and local funding organizations, microfinance institutions, etc. Stakeholder equities will be combinations of money, time, sweat and other contributions. Ensuring equity can be thought of as finding the sweet spot between money equity, time equity and sweat equity 'arrangements' for all the stakeholders with appropriate returns. From an academic perspective, finding innovative methods to ensure equity requires students to have a thorough understanding of the social, economic, technological and logistical issues related to the project, and can lead to deeper learning.

FIGURE 2
 E-SPOT CANVAS

As shown in Figure 2, there are nine blocks in the E-Spot canvas – Design, End-of-Life Analysis, Bill of Materials, Failure Analysis, Stakeholder Analysis, Socio-Cultural Analysis, Economic Analysis, Leverage Points and E-Spot Determination Algorithm. Each of these blocks is explained in details in this section. The pre-requisite for the canvas is the validated, beta-tested design and necessary community and stakeholder information. This canvas focuses on the collaborative development of the Level 2 business model only. For brevity in the sections below, the term “system” is used for an infrastructure project or a durable/long term usage product.

Design: The design of the system assumes consideration of locally-available materials, and the skills, expertise and training capabilities within the community. A series of design iterations to adapt the system to local materials, as well as end-of-life considerations should be conducted in an iterative manner between the design, failure analysis and end-of-life analysis blocks. The goal is to repeat this cycle until an optimal localized design has been obtained, and continued maintenance as well as unexpected failures have been considered and analyzed. The localization might be done for a particular community, or more likely for a region with similar resources and characteristics.

Bill of Materials (BOM): The objective is to calculate the time, money, sweat and other equities required for the installation of the system described in the design block. The various equities can be defined as:

- Money (M): Money or other material support
- Time (T): Time + non-labor intensive work
- Sweat (S): Time + labor-intensive work
- Other (O): Knowledge, credibility, social capital, trust, permissions, etc.

The Bill of Materials block on the canvas should have a table with the MTSO needs for the installation of the system. Necessary tools, as well as supplies must also be identified in this table. Resources can be grouped together as appropriate. The final outcome of this block will be a table of the form shown in figure 3.

Materials	Time	Sweat	Other

FIGURE 3
MTSO BLOCK FOR INSTALLATION BOM

End-Of-Life Analysis: This block will depict the plan of how every item used in the system will be recycled after its life term. These might be items that are discarded after a regular maintenance cycle, or when the entire system is decommissioned. The overarching goal is to have a cradle-to-cradle design. Items that cannot be recycled should be identified as such, with specific instructions on how they can be discarded safely. The outcome of this block will be a table (Figure 4) that identifies the life expectancy of every item on the bill of materials and provides detailed guidelines and MTSO resources necessary to recycle or discard the items.

Item on BOM + Lifespan	M	T	S	O
Item 1 @ 3years				
Item 2 @ 20 years				
...				

FIGURE 4
MTSO BLOCK FOR END-OF-LIFE ANALYSIS

Failure Analysis: This block identifies the failure modes of the system as well as regular maintenance requirements. Time, money, sweat and other resources necessary to conduct preventive maintenance as well as fix common failures are identified in this block. The failure analysis will inform the localization process as well as clarify the resources necessary for sustaining the project. The output of this block will be two tables (Figure 5) for routine maintenance and common failures with frequency specified for both of them.

Routine Maintenance (RM) Common Failures (CF)	M	T	S	O
RM 1 @ 3months				
...				
CF 1 @ 2 years				
...				

FIGURE 5
MTSO BLOCK FOR FAILURE ANALYSIS

Stakeholder Analysis: The E-Spot methodology assumes that a community assessment to understand the community's needs, resources and concerns was conducted, and formed the basis for the design. Community assessment will help identify the primary, secondary, tertiary and marginalized stakeholders. Primary stakeholders are those that are directly affected by the venture. Secondary stakeholders include 'intermediaries' that are indirectly affected by the project. Tertiary stakeholders are entities like funding agencies, governmental and UN agencies that have an interest in the project. Marginalized stakeholders are stakeholders that have traditionally not been involved in the domain of the project, generally due to various social and economic reasons. Key stakeholders (amongst all categories) might have significant influence (positive or negative) on the operation of the venture and need to be identified. It is essential to identify and engage marginalized stakeholders that have not been traditionally involved in the domain of the project, generally due to various social and economic reasons. The goal is to understand who the stakeholders are and what their capabilities and limitations are. It is

important to list the kinds of equities they can invest in the venture, and what their expectations are in return of their investment. For every stakeholder, summarize:

1. Who they are and what they do?
2. What are their problems and needs and how does it related to the venture?
3. What are their expectations from the venture?
4. What equities can they offer/bring to the table?
5. What are their limitations?

Socio-Cultural Analysis: The people in the community are the major stakeholders on infrastructure-based projects and a sense of ownership and pride in the project is pivotal to its adoption and sustainability. Community assessment from a social and economic perspective is essential to understand the community's needs, resources and potential challenges. The assessment can highlight collaborators, on-the-ground champions, and also those who can create problems. Several methods exist for community assessment and analysis: focus groups and interviews, community-wide forums, asset mapping, etc.

The objective in this E-Spot canvas block is to analyze the community's make-up from a social/cultural perspective - their lifestyles, occupations, historical and religious background, etc. There should be a specific emphasis on relations between the community and the other stakeholders, and the socio-cultural status quo. Key issues include how the people living and working day-to-day before arrival of the new system and what are their current community mores and ways of thinking. This block's outcomes are responses to questions like:

1. What social or cultural factors need to be considered for the project's implementation? Will the project disrupt the way things work right now and how can they be avoided or minimized? (E.g. potential issue for a biogas digester project could be that people are not willing to use human waste, or women will be required to feed the anaerobic digester, thus further increasing their workload)
2. Why are the marginalized stakeholders being marginalized (in that situation)? How can the project create a win-win situation for them, too?
3. How will the community's needs evolve over time? How does that time duration work with (or against) the life of the project?
4. In the longer term, will the community formalize ownership of the project (e.g. cooperative)? What socio-cultural issues need to be considered for this to happen?

The outputs of this block will be specific factors that the stakeholders think will impact the project. These factors will help identify what equities can be shared by the community members for installation or maintenance, and what socio-cultural factors need to be considered while negotiating these equities. Explicitly identifying these factors will help the stakeholders understand each other's inherent capabilities and limitations and build trust in the longer-term.

Economic Analysis: The analyses of the local markets and trends both regionally and in the country are essential for the Level 1 Business Plans. The focus of this block are the economics of sustaining the shared resource in the community. The community is the major stakeholder. The assumption is that there will be a (possibly non-cash) revenue stream from the system that will

be used by the community to maintain the system and use for other valid community issues. The most important questions are:

1. What is the cost of the competing value proposition with an emphasis on the status quo - How are people addressing the problem right now? What are its implications?
2. How much are community members willing to pay and why? A detailed community and customer profile in terms of occupations, income levels, disposable income (or other equity), economic choices, and spending habits related to the product needs to be determined.

Other relevant economic factors include: average family income, savings ability, affordability of capital costs, ability to provide/seek informal loans, additional spending and business growth opportunities. The outputs of this block will help identify what equities can be shared by the community members for installation or maintenance, how the supply chain and distribution channels might work, and how the community might own the project in its entirety over time and have an formal business structure (like a cooperative) to make it sustainable.

Leverage points: The objective of this block is to delve deeper into social dynamics to identify specific 'power' relationships. The leverage points for the project can be identified through social deconstruction. Deconstruction, in this sense, refers to the idea that there are multiple ways to analyze social situations, and an understanding of this multiplicity can help expose the workings of various power relations in communities. Understanding the power dynamics can help us develop equity schemes that create value for everyone and not reinforce traditional 'winners' and 'losers' or destabilize the power structure just to create new 'winners' and 'losers'. This analysis could be related to the distribution of power, money, gender roles, opinion leaders, tribal leaders, governmental authority figures, popular naysayers, religious leaders, etc. The leverage points will lead us to marginalized stakeholders and resources not considered earlier. It will help identify key stakeholders within the community that need to be strengthened or weakened - individuals and issues that need to be engaged in the process. The output of this block will be specific power relationships that affect the equity model.

E-Spot Determination: The E-Spot determination block includes algorithms to find the sweet spot between time, money, sweat and other equities from various stakeholders in the backdrop of the economic and social context. The outcome of this final block will be two separate tables (Figure 6; for installation and sustainability) that shows each stakeholder group in the left-most column and what resources will they be responsible for.

Stakeholder	Installation / Sustainability			
	M	T	S	O
Community				
Local Univ				
....				
X Funder				

FIGURE 6

FINAL EQUITY MATCH TABLE

Developing these tables is a collaborative process that the stakeholders engage in to negotiate how their equity contributions meet the resource needs of the venture for installation and

sustainability. Stakeholders start by studying the MTSO tables in the “Bill of Materials” and “Failure Analysis” blocks. These tables provide details for the resources necessary for the project’s installation and sustainability. Stakeholders identify what resources they will provide their equities towards, depending on their capabilities, limitations and expectations. This process happens with the previously identified social and economic context in mind to ensure that the equity matches are realistic.

The objective of the E-Spot Determination block is to iterate the equity allocations until all aspects of the MTSO equity match, stakeholder analysis, social and economic assessment have been accounted for and all the stakeholders are satisfied by the equity match. The outcome of this step will be clearly defined roles, responsibilities and potential benefits for all the stakeholders. The equity match must also be in harmony with the leverage points identified earlier. The leverage points will inform the equity match-ups and help identify additional tasks to be conducted during the implementation phase of the project to ensure project success.

The methodology employed to actually match-up the stakeholders’ equities with the resource needs will vary from culture to culture and will need a facilitator who truly understands the project’s needs as well as the needs and expectations of all the stakeholders. The canvas can be printed out on a large sheet of paper and then post-it notes can be used to place factors/issues/block outcomes on the canvas. The post-it notes can be moved around the canvas, combined with others, or eliminated when that particular issue has been addressed. In some ventures, there might be a need to trade the MTSO equities amongst the stakeholders. For example, a funding agency might refuse to pay for community member’s wages (so that they are not seen as employers) but be willing to subsidize another object (e.g. batteries, LED lamps) which the community members would have to pay for otherwise. In this case money is being traded for sweat and the object. This equity trade, when done collaboratively, would meet the needs and expectations of the stakeholders while maintaining equity between their contributions (equities).

It is important to update the final E-Spot matrix as the equity match changes and evolves during the implementation phase. Project evaluation instruments and methodologies will ultimately be a part of the software tools and will help track the project from conceptualization to eventual decommissioning. Tracking the lifecycle of the product will help design better technologies, business strategies and effective scale-up strategies. The next section presents several case studies on the application of the E-Spot canvas to real ventures.

CASE STUDIES

Case Study 1: Bio Gas Digester

The first case study describes the E-Spot match-up for a biogas digester. Substantial research was conducted on this project between January and May of 2010, followed by the construction of the digester in Kenya during the Summer of 2010. Several assumptions were made based on contextual data available from previous trips. These assumptions were validated or modified during fieldwork in Kenya. Biogas refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. It is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and energy crops. Burning methane produced from biogas has been proven to reduce greenhouse gas emissions by over 13%. The many benefits that anaerobic biogas generation offers to the environment and public health coupled with the wide

availability of the resources needed for its production make it an appropriate technology for implementation in developing countries. Widespread adoption of biogas generation in sub-Saharan countries like Kenya could potentially offset the use of charcoal and serve to combat deforestation and poor indoor air quality. Some of the organizations/groups involved in this case are:

- CYEC: Children and Youth Empowerment Center is a public-private organization that provides basic needs and vocational training to former street-dwelling children in Kenya.
- PSU: The Pennsylvania State University is a large public university in eastern USA.
- JKUAT: Jomo Kenyatta University of Agriculture and Technology offers accessible quality training, research, and innovation in order to produce leaders in the fields of Agriculture, Engineering, Technology, Enterprise Development, Built Environment, Health and other Applied Sciences to suit the needs of a dynamic world.
- UNIDO: United Nations Industrial Development Office aspires to reduce poverty through sustainable industrial development.

FIGURE 7
FIELD TESTING OF A BIOGAS DIGESTER IN KENYA

Design

The design for the biogas digester was developed based on various successful models in the market. These designs were modified based on locally available materials, the biogas

requirements of the target market, and the quantity of feed for the digester. Another important consideration was the environmental and geographic factors influencing the durability and sustained operation of the system.

Bill Of Materials

TABLE 1
BILL OF MATERIALS FOR CONSTRUCTION OF A BIOGAS DIGESTER

Money	Time [Time + non-labor intensive work]	Sweat [Time + labor intensive work]	Other
Poly Tanks	Design digester and the entire system	2-3 days to dig	Transportation
PVC pipe	Survey land	Cut entry holes	PVC Maintenance
Couplers	Match w/ pipe	Saw pipes	Wood Protecting Oil
Elbows	Match w/ hose	Prep for sealant	
Gas valves	Calculate feed amount	Attach to gas tank	
Sealant		Apply to connectors	
Wood		Support structure	
Hose		Structures to valves	
G.I. Pipe		Thread pipe	
T connector		Attach to hose	

End of Life Analysis

End of life analysis is not covered in this case study since the market survey and project design had been conducted before the E-Spot canvas was applied. In this capacity, the E-Spot canvas was applied for developing a stakeholder-to-equity matching simulation.

Failure Analysis

The failure analysis is conducted in two phases. In phase 1, the routine maintenance for the items listed is completed, along with detailed timelines. In the second phase, any errors or failure modes brought on due to wear and tear or other natural reasons are anticipated, with approximate timelines. Table 2 outlines the failure analysis for the Bio Gas Digester.

TABLE 2
BILL OF MATERIALS FOR ROUTINE MAINTENANCE AND SPECIFIC FAILURES OF A BIOGAS DIGESTER

Routine Maintenance	Money	Time	Sweat
@3 Mo		Check Sealant	
		Check Gas Valves	
@1 Yr		Check Tank	
@3 Yr	Wood Coating material		Wood Coat
@10 Yr	PVC		Change PVC

Failure Modes	Money	Time	Sweat
Blockage			Empty + Clean
Gas Leak	Tubing + Valves		Install new tubing, valves
Tank Leak	Sealant / New Tanks	Assess quality	Dig entire system

After obtaining the above matrices for all of the required forms of equity; installation, routine maintenance and failure modes, the next step is to analyze the stakeholders of the project/venture.

Stakeholder Analysis

The goal of the Stakeholder Analysis (Table 3) is to assess the community and classify all involved parties into three categories: Primary, Secondary and Tertiary stakeholders. Amongst these stakeholders, identifying the marginalized stakeholders is very important.

TABLE 3
LIST OF STAKEHOLDERS CLASSIFIED AS PRIMARY, SECONDARY OR TERTIARY

Primary	Secondary	Tertiary
Sustenance Farmers (M)	Large Farm Owners	PSU / JKUAT
Villagers (M)*	Labor Workers (M)*	CYEC (M)*
CYEC Youth (M)	CBO / NGO	UNIDO
Community members	Manufacturer/ Suppliers	Community Heads

*Stakeholders marked by (M) are marginalized stakeholders.

Based on our initial assumptions, we identified and validated the above stakeholders. However, we were able to classify them as primary, secondary or tertiary stakeholders only after learning more about their needs, expectations, capabilities and limitations during fieldwork in Kenya. Furthermore, it was crucial to identify the marginalized stakeholders, the ones previously ignored by conventional systems, the economy and society in general. Based on various analyses and social studies, we identified the marginalized stakeholders, who are marked with (M) in the table presented above.

Socio-Cultural Analysis

Community assessment from a social and economic perspective is essential to understand the community's needs, resources and potential challenges. The objective of this analysis was to identify and highlight collaborators, on-the-ground champions, and potential troublemakers. After a thorough analysis of the community, we identified the following socio-cultural issues:

- **Food scraps fed to dogs:** In the current system, the residual food scraps are fed to the local dogs. If, now, the food is processed as feed into the digester, that takes away from the street dogs!

- **Human waste as a feed to system:** Can human waste be used as feed for the digester? It has been proven through studies that human waste is an excellent feed for a biogas digester but do the community members feel comfortable using such fuel for cooking meals and other everyday purposes? This is a highly culture-dependent question, as is evident from the widespread use of human waste as digester feed in China.
- **Environmental safety vs. putting food on the table:** A major economic factor to consider in the cost of using fuel from a biogas digester versus using natural fuel such as wood from a nearby tree, which is free. While one is the more environmentally fair choice, it is also the more expensive one. The decision to use either option is a very important socio-economic factor.
- **Equity in feeding reactor and sharing the biogas:** In situations where a digester may be shared by more than one household, a second level of equity distribution comes into play. Which household shall be responsible for feeding the digester on what days? How much feed do they provide? How much of the gas produced do they consume? Unless there are sophisticated quantifiable methods of tracking this activity, it is difficult to ensure equal distribution.
- **Bio Gas use:** How will the biogas be used for the community and by the people? For example, is the plan to use the bio gas as a cooking stove fuel? Is this desired by the people? Will they have the money to buy the new stoves?
- **Cleaning “bio-digested” waste – Whose job is it anyway?:** How will the community share responsibility for routine cleaning of the digester?

Economic Analysis

Based on the list of stakeholders, we then analyzed the economic conditions of the stakeholders in the specific geographical area with the goal of building an economic model of the target market. Some of the factors analyzed, along with the (approximate) financial amounts, were:

- Average Family income: KSh 170/day (\$2.1/day)
- Cost of (purchased) coal: KSh 35/kg (\$0.45/kg) [Note: 1 kg. of coal lasts 3-4 days on average for a typical family]
- Cost of wood (lost wages): Mostly KSh 0 (Wood collection is done by women or children, who do not earn incomes directly)
- Cost of gathering digester feed – should someone be hired?: If not hired, KSh 0 (done by women and children of the house. If someone hired, average daily salary for such jobs at KSh 100/day (\$1.25/day)

Leverage Points

After studying various power relationships off the community and analyzing the social dynamics, we identified the following potential leverage points:

- **CYEC youth as champions – higher employment:** CYEC youth stand to benefit the most from the various projects and ventures, as they can pursue them in an entrepreneurial manner.
- **CYEC leaders as disseminators of information:** For the marketing efforts to be successful, gaining the trust of the local people is essential. CYEC is respected by the community and hence the management can effectively promote the biogas digester as a healthier option to charcoal.

- **CYEC as a demonstration site – Increased publicity:** If the project is successful, the CYEC can get publicity and social capital within the local economy, and amongst the several non-profit groups visiting the center. This would help get CYEC get access to more resources and further accelerate the dissemination of this technology.
- **Feeding digester in place of collecting firewood, coal:** A major issue is deciding whether to collect conventional fuels or digester feed – and how that might affect the women's lives.
- **Permission from Town Clerk:** Permission from the town clerk is essential for the project to go forward.

E-Spot Determination

Based on the results of all the individual blocks on the canvas, we developed the following E-Spot matrix (Table 4) for installation of the system:

TABLE 4
E-SPOT DETERMINATION MATRIX FOR INSTALLATION OF A BIOGAS DIGESTER

Stakeholders	Installation		
	Money	Time	Sweat
Primary Users (Community)	Supplies		
PSU Students		Tech Design Bus. Planning	
CYEC Youth (as field experts)		Ensuring safety Community organization Access to digester feed Education	Digging, Construction of the biogas digester
Community Chiefs		Promotion of system within community	

The biogas digester venture had several inadequacies that needed to be corrected in unique and innovative ways. One major requirement was the need for physical labor at a low cost; while there was also a need for trainees who could start this as a venture. While mapping the E-Spot matrix, we realized that the older youth at the CYEC were the ideal candidates for pursuing the biogas digesters as a business endeavor. With that as the motivation, selected youth were engaged for the physical work and trained in the installation process. Similarly, another requirement was finding adequate feed for community-level digesters. It was difficult to develop a metering system whereby every member's individual usage could be monitored and billed. At the same time, a significant portion of the population could not afford such a large scale system. While developing the E-Spot matrix, the solution of smaller local digesters setup as a shared resource between 3-4 houses emerged. The idea was that individual houses would be responsible for providing the feed and monitoring their own usage. These unique solutions

emerged due the equity mapping carried out through the E-Spot Canvas. The biogas digester was successfully deployed in Kenya in June 2010.

Case Study 2: Kochia Windmill Project

The Kochia windmill project was based in Homa Bay, Kenya in 2007-2008 and is currently functional as a successful enterprise for the last 4 years⁶. Over these 4 years, more than 90% of the principal invested by the foreign sponsors has been recovered. The overall goal of the Kochia Windmill project was to set up an alternate electrical power system in a rural community called Kochia near Homa Bay. This village had never experienced an electrical system of its own but people were used to the concept of using car batteries for their small-scale power needs. Battery owners often had to walk for over 6 hours each way to the nearest charging station to get their batteries charged. It is important to note that this venture had been placed on the ground much before the conceptualization of the E-Spot canvas. The below analysis is a post-implementation analysis and hence not as detailed.

FIGURE 8
WINDMILL SETUP AT HOMA BAY, KENYA

FIGURE 9
COMMUNITY MEMBERS LEARNING ABOUT WINDMILL MAINTENANCE

Design:

The design of the Kochia Windmill in Kenya was in response to a lack of electricity in the local community. The exorbitant cost of electricity, paired with political and administrative issues, left a huge need for affordable and accessible electricity. The current solution to the problem was car batteries. For charging a car battery, a person needed to spend about 6 hours and KSh 100 (~\$1.17 USD). For an average resident in rural Kenya earning less than USD \$2/day, this was worth more than half a day's salary. A weather station installed for a year revealed that the large open fields in the surrounding area were ideal windmill locations. Energy generated from the windmill would be used to charge more batteries that would operate lights and accommodate more evening and late-night activities. Increased working hours would boost productivity, generate more customer sales, earn higher profits and even increase employment. A closer examination with the E-Spot Canvas explains the success of the system.

Bill of Materials

TABLE 5
BILL OF MATERIALS FOR CONSTRUCTION OF A WINDMILL

Materials	Time	Sweat	Other
Concrete, steel	Design research	Digging, steel painting, transportation of materials to site	Permissions from relevant authorities
Wind turbine, blades	Construction	Clearing ground	Land
Lights	Market analysis	Building structure	Long term support
Battery bank, individual batteries	Seeking permissions		Security

End of Life Analysis

End of life analysis is not covered in this case study since the market survey and project design had been conducted before the E-Spot canvas was applied. In this capacity, the E-Spot canvas was applied for developing a stakeholder-to-equity matching simulation.

Failure Analysis

TABLE 6
BILL OF MATERIALS FOR ROUTINE MAINTENANCE AND SPECIFIC FAILURES OF A WINDMILL

Routine Maintenance	Money	Time	Sweat	Other
3 months	Greasing	Marketing	Cleaning	Bookkeeping
1 year	Repainting	Analyze tech, business model, structural analysis		Reinvesting, strategizing
5 years	Change metal structure		Rebuilding structure	
Common Failures	Money	Time	Sweat	Other
Turbine gets stuck	Greasing		Cleaning	
Batteries not charging	Charge controller	Check electrical system	Check all connections	
No profit	Marketing	New markets		

Stakeholder Analysis

The primary and marginalized stakeholders in this case study are the community members – subsistence farmers, local business owners, families and the Kochia Design Group (KDG). These community members usually work 12 to 14 hours per day, and earn the equivalent of \$10 USD per month. Electricity is mainly used for basic needs such as lighting and business-related use. For the successful implementation of this pilot venture, neither the community nor the KDG could raise the complete funds. Community members primarily provide sweat equity for the windmill, while KDG provided the land. The secondary stakeholders in this situation included the University of Nairobi, Pennsylvania State University and National Collegiate Inventors and Innovators Alliance (NCIIA). The University of Nairobi and Pennsylvania State University both provided student and faculty with technical and business knowledge, as well as their university resources, brand recognition and trust to the project. NCIIA was the primary funding agency. Because of the closed setting of this venture, none of the stakeholders were remote enough to be classified as tertiary stakeholders.

Socio-Cultural Analysis

The main socio-cultural factors related to the windmill project were issues with the neighboring communities, political entities and popularity of special functions. Visiting “mzungus”, (white people), from the outside community are a strong influence on the traditional culture of the community. These visits breed jealousy among community members and lead to false perceptions of certain individuals getting more wealth. Political powers within the community are the village chief of Kochia, four pastors, three local chiefs, two district officers and a district commissioner. The approval of these leaders is crucial to the success of such a large project. Also, the popularity of special functions such as weddings, funerals and religious festivals was identified as a very important part of the culture and lifestyle of the people of Homa Bay.

Economic Analysis

The most important customer segment for the Kochia Windmill was the business group in the community. The average salary of community members is \$10 USD per month, with a monthly savings of about 10-15%. Small business owners such as telephone operators and entertainment center owners earn Ksh 150 per month. The local bicycle repair shop earns Ksh 450 per month while the local library earns Ksh 1200 per month. Prospective entrepreneurs within the community work in areas such as sisal decortication, handyman services and cell-phone charging and repair. This range of income can be considered quite stable, and similar needs exist for the majority of working community members. During the course of our analysis we also learned that a brand new battery on average cost about \$40, while the community members on average could provide \$30 toward a new battery.

Leverage points

Important leverage points were determined with the power players of the community in mind:

- The Kochia Development Group
- A well-respected NGO in Homa Bay
- An established professor and well trusted member of the local community
- Local pastor
- Local village & tribal chief.

The assistance and support of these power holders was leveraged at several instances. In one instance, the team was traveling to a neighboring village to get certain supplies, however the road was found to be blocked by large stones and broken tree branches. Upon investigation, it was found that the road was blocked by the youth of the neighboring village, as they also wanted to work with the “white people”. A simple meeting with the village chief and an explanation of the project and future goals enlisted their full support and the roads were cleared immediately.

E-Spot Determination

TABLE 7
E-SPOT DETERMINATION MATRIX FOR INSTALLATION OF A WINDMILL

Stakeholder	Installation			
	Money	Time	Sweat	Other
Community			Majority of construction	Land for construction
University of Nairobi		Collaborative system design	Construction	Transportation
PSU	Funds for daily meals	System design, project management	Construction	Knowledge
NCIIA	Materials and supplies			Start-up knowledge, social capital

TABLE 8
E-SPOT DETERMINATION MATRIX FOR SUSTAINABILITY OF A WINDMILL

Stakeholder	Sustainability			
	Money	Time	Sweat	Other
Community	Maintenance, Breakdown repairs from income	Local project management, Marketing	Maintenance, KDG routine operation	Knowledge
University of Nairobi			Breakdown repairs	Knowledge (Repairs)
PSU		Expertise for complex tech. problems		
NCIIA				

Significant equity disparity existed between the people in Homa Bay, Kenya. While the need for electrical power was evident and extremely crucial to its development, the village lacked economic resources. It was essential to ensure that the electricity generated through the windmill was made available to the people through non-monetary forms of payment. There should be some level of ownership from the villagers to ensure a sustained market for the power.

Meanwhile, the windmill governing body needs a revenue source for maintenance and repairs during breakdowns. Based on the stakeholder and economic analyses, the design team found that batteries were the only feasible solution for distributing the power generated by the windmill. The initial plan was for the KDG to buy several batteries to be loaned out for a fee. However, the community analysis made it evident that such a system could be compromised by using nails to extend the battery's operation. This is a standard method for extending the charge in a battery at the cost of drastically reducing battery life. It was clear that every user should own their battery personally.

Based on market surveys, the team found the cost of a brand new battery to be \$40. However, information in the community analysis revealed that almost all users could spend \$30 on average for a battery. On the other side of the canvas, there was a need for physical laborers who could help with the construction of the windmill and other odd jobs. Through equity matching in the canvas, the team developed a very innovative solution. All those wanting to buy batteries were invited to help with the construction of the windmill in various forms; none were hired for monetary compensation. Those who participated were given \$2 coupons that could be reimbursed towards the purchase of a battery from the team. Several men and women participated in this scheme. Women incapable of physical labor participated in other forms such as cooking for everyone, taking care of kids while their mothers worked, etc. Construction of the windmill was finished in 5 days, at the end of which, the \$40 batteries were sold to the community members at \$30 in cash, and \$10 worth of coupons. The coupons could not be reimbursed in any other way. A win-win situation was created for all. This approach for providing batteries was developed and used to address the equity matching principle of the E-Spot canvas.

Case Study 3: Husk Power Systems

Design

Husk Power Systems (HPS) is a company based in Bihar, India that uses rice husks to generate power through gasification. Several rice millers in the state of Bihar were using the decades old technology of biomass gasification to power their mills using rice husk – largely a useless by-product of their operations with rice farming. Rice husks, which was the only large-scale bio-waste available to most rural people, was just the perfect source to implement rural electrification in this region. However, one the biggest issues with this concept was that the prevalent rice-husk based gasifier systems ran in the 'dual-fuel' mode of operation where the gas produced by the gasifiers was used in conjunction with 35-50% diesel to power the turbines. Hence the husk powered gasification system suited rice millers just fine by saving them 50-60% of diesel but wasn't good enough to fit the economic model of rural electrification. A documented major issue was that rice husk biomass gasification causes significant tar generation, which leads to engine clog-ups. This issue needed to be addressed in some manner of equity distribution. As to the system specifications, the boiler and steam generation system allowed 30,000 kg/hr of 42 kg-cm steam pressure to evaporate, with a boiler efficiency of 83%. The steam turbine used as the generator had an output of 5,000 kW @ 8,000 RPM.

It is important to note that Husk Power Systems is not affiliated with the HESE program. However, we have conducted the E-Spot analysis for HPS because it is a well-known and rapidly growing social enterprise in India. Their approach to rural electrification is the subject of several

case studies. Their business model and implementation strategy works with rice farmers as both, clients as well as customers. They purchase husks from farmers, which makes them providers, and after converting the husks into electricity, it is sold back to them for farm operations and lighting, which makes them customers. This approach brings up several unique features related to stakeholder identification and equity allocation.

FIGURE 10

HUSK-BASED POWER GENERATION SYSTEM

Image courtesy of 'New Ventures' (<http://www.new-ventures.org/files/nv/HuskPower.jpg>)

Bill of Materials

TABLE 10
BILL OF MATERIALS FOR CONSTRUCTION OF A HPS

Materials	Time	Sweat	Other
Husk burning furnace	Assessment on availability of husk	Metal work	Billing systems
Generator, turbine, meters	System development based on local resource availability	Gathering husk from farmers, cleaning	
Metal for support structure	Market/customer research	Painting of all metallic parts	
Feed system for husks	Develop strategy for 'char' recycling		

End of Life Analysis

End of life analysis is not covered in this case study since the market survey and project design had been conducted before the E-Spot canvas was applied. In this capacity, the E-Spot canvas was applied for developing a stakeholder-to-equity matching simulation.

Failure Analysis

TABLE 11
BILL OF MATERIALS FOR ROUTINE MAINTENANCE AND SPECIFIC FAILURES OF A HPS

Routine Maintenance	M	T	S	O
15 days			Clean furnace	
1 month	Greasing of generator	Tar disposal	Tar removal	
1 year	Paint metal structure		Rebuilding structure	
Common Failures	M	T	S	O
Turbine gets stuck	Greasing		Cleaning	Manage tar
Reduced stesam	Charge controller	Furnace choke-up	Clean furnace	
No profit	Marketing	New markets		

Stakeholder Analysis

An interesting facet of this system is that the primary, secondary as well as the marginalized stakeholders are all part of the community. In this study, the customer base is 100% marginalized. Prepaid group billing is used as a way to mitigate risk associated with late or skipped payments. The Husk Power Systems (HPS) University is also a major stakeholder because it is also a customer of HPS. Husk Power Systems is a unique example because the community is not only the user, but the supplier as well. Rice farmers own largest stake in the

plant by providing husks, and they become integral customers of the HPS University system. The Ministry of New & Renewable Energy subsidizes resources in order to accelerate HPS reach, and the Acumen fund also provides support for the venture. These are both considered secondary stakeholders. Tertiary stakeholders include any other smaller, external funding sources.

Socio-Cultural Analysis

One important aspect to consider in the implementation of an electricity generating system is the use of the resource. How will the community use the electricity, and how can productive use be fostered? There is no scientifically perfect source of energy – one that is 100% efficient or clean. The tradeoff between various energy sources must be considered in order to determine which of the options is the most efficient choice. Before HPS, over 42,000 liters (11,111 gallons) of kerosene and 18,000 liters (4,762 gallons) of diesel were used by the community on average. After implementing technology from Husk Power Systems, the monthly emission of CO₂ was reduced by 50,000 tons. This is equivalent to the CO₂ emission from over 5,000 homes over an entire year based on EPA averages.

Economic Analysis

Main customer segments within the community are community members and small business owners. Community members make an average income of \$30 per month and save about 10% of it every year. Small business owners work mostly within the wood and metal repair industry or within the service provision industry. Husk Power Systems charges Rs 50 (~\$1 USD) per month for enough electricity to light 1 bulb. This amounts to \$900-\$1,000 USD per kW in capital costs. The same amount of energy produced by coal costs twice as much, wind and hydraulic energy costs 7 times as much, and solar energy costs 10 times as much. Therefore, rice husks provide an alternative energy source that saves consumers half of their initial expenses. However, the calculation is not limited to savings from the cost of electricity. With the added convenience of a reliable light source, business owners are now able to work longer hours and children are able to study more conveniently. This has indirectly amounted to a much higher standard of living for several families.

Leverage points

The three main power players in this example are the US-educated students, the village panch (local governing body) and Mr. S.K. Singh, a scientist at MNRE. Students educated in the United States are vulnerable to systems of privilege, where they can be put on a pedestal even without superior technical or social skills. The village panch has a very strong political influence on the decisions made by the village. Mr. Singh is a well-respected scientist who commands respect within the community. As such, his involvement with the design of the system adds credibility to the venture. The local school headmaster who was instrumental to community involvement expressed his emotions as “after sixty independent years, [the community has] found freedom from darkness.” The Samta Samidhi Foundation, which was the original name of the organization that developed the first husk power system, received twice their original investment as ROI. After demonstrating the success from the first gasifier, the foundation built HPS and transformed its role into that of a community-based social organization. The profit made from first gasifier, as well as a part of HPS’s annual profit are used to provide free tuition for over 250 children.

E-Spot Determination

TABLE 12
E-SPOT DETERMINATION MATRIX FOR INSTALLATION OF A HUSK BASED POWER SYSTEM

Stakeholder	Installation			
	Money	Time	Sweat	Other
Community (User)			Construction	
Community (Supplier)	Husk		Rice milling	Transportation
Ministry of New & Renewable Energy	Governmental subsidies			
Acumen Fund	Materials and supplies			Start-up knowledge, social capital

TABLE 13
E-SPOT DETERMINATION MATRIX FOR SUSTAINABILITY OF A HUSK BASED POWER SYSTEM

Stakeholder	Sustainability			
	Money	Time	Sweat	Other
Community (User)	Usage charges, increased usage through productive use	HPS University training	Breakdown repairs	Knowledge
Community (Supplier)	Continued supply of husks			HPS University
Ministry of New & Renewable Energy	Subsidies, land grants			
Acumen Fund				Topical help

The unique aspect for Husk Power systems is the dual responsibility and benefit from the community, both for the installation and sustainability of the system. As a general principle, HPS purchases discarded rice husks from farmers (community) at fixed prices. The farmers get money for something that used to rot by their farm and spread diseases. For HPS, these husks function as the fuel for their business. Power generated by these husks is then sold to the same and other farmers at modest rates. The company makes a decent profit, while the community (farmers) gets access to electricity several years sooner than any governmental initiative that may reach them.

During the installation phase, the community as the user provided sweat by helping with the physical construction of the system. At this time, the community as the supplier supplied sweat equity in the form of rice milling, provided transport of husks to the plant and in return obtained

direct monetary compensation. In this phase, the user's role was negligible. Suppliers had majority of the duties. In the sustainability phase, the suppliers' responsibilities thinned to continually providing husks and running the HPS University as a side venture. Power consumers paid usage charges and learned how to use power more efficiently at the HPS University. This educational component helped quadruple power sales. At the same time, they also invested time within the HPS University significantly increasing their knowledge base. Post training, the same users also undertook repairs during breakdowns and provided specialized knowledge.

CONCLUSION

The E-Spot canvas is a tool that enables students and practitioners to explore design space, business strategy and implementation strategy by bringing various stakeholders together to discuss exactly how a project will be designed, implemented, operated, and sustained. It seeks to match a project's needs with stakeholder's equities. In this paper, we have described the application of the E-Spot canvas to three distinct infrastructure projects. In each case, the E-Spot canvas provides a clear picture of the exact roles and responsibilities of all the involved parties, and can help develop the timeline for carrying out designated tasks. The students working on the ventures also benefit from the methodology, because it provides a comprehensive and structured approach in an environment fraught with uncertainty and chaos.

Development and validation of the E-Spot canvas and methodology is a work in progress. Approximately 90 students representing twenty student teams have use the canvas for their ventures over the last year and provided us valuable feedback. We encourage academic and non-profit partners to employ the E-Spot canvas in their own projects and help refine it while developing more case studies demonstrating its application. During the 2011-2012 academic year, our team is applying the E-Spot canvas to infrastructure projects in Kenya, Tanzania, Nicaragua, and India. Further, we are working to develop a computer-based modeling and simulation engine that will allow technology innovators and social entrepreneurs to apply the E-Spot canvas to their own projects, to identify an optimal distribution of equity among a venture's diverse stakeholders. To this end, we are studying existing design-space exploration tools and business-strategy simulation tools with the objective of adapting and integrating relevant tools for the engine. In parallel, we are researching techniques to aid the visualization of the design space and modeling process. The E-Spot canvas is based on the tenets of systems thinking and provides students an opportunity to practice it in a real-world context. We are working on another manuscript that delves into systems theory and argues that the E-Spot canvas fosters systems thinking amongst students to develop business strategies for social ventures. Ultimately, the aim of our efforts is to assist with the creation of resilient and sustainable technology ventures—that is, those that employ organic, participatory approaches for project conceptualization, development, implementation, and assessment—and to engage students in learning experiences that are comprehensive and rigorous.

ACKNOWLEDGMENT

We would like to thank Melanie Fedri (PhD candidate, Higher Education) and Shruthi Baskaran (Senior, Civil Engineering) for critiquing and editing this manuscript. Dr. Thomas Colledge helped develop the E-Spot model which forms the basis of the E-Spot canvas and we are grateful to him.

REFERENCES

- ¹ D. Nieusma, D. Riley, "Designs on Development: Engineering, Globalization and Social Justice," *Engineering Studies*, 29-59, 2010
- ² D. Poate, "Enhancing the Impact on Rural Poverty through Support to the World Bank's Portfolio," *Natural Resources Institute*, 2005
- ³ Independent Evaluation Group, "Independent Evaluation Finds over 40% of IFC Projects Fail to Deliver Development Results," *Bank Information Center*, 2007
- ⁴ B. Agle, R. Mitchell, D. Wood, "Toward a theory of Stakeholder Identification and Salience: Defining the principle of Who and What Really Counts," *Academy of Management Review*, 1997
- ⁵ D. Riley, "Resisting Neoliberalism in Global Development Engineering," *American Society for Engineering Education Annual Conference*, Honolulu, HI, 2007
- ⁶ K. Mehta, "Lessons from the Field: Setting up a Windmill Based Business in Rural Kenya," *NCHIA Annual Conference*, Dallas, TX, 2008
- ⁷ T. Bergdall, "Reflections on the Catalytic Role of an Outsider in Asset Based Community Development," *Community Wealth*, 2003
- ⁸ Humanitarian Engineering & Social Entrepreneurship Program, The Pennsylvania State University, <http://www.hese.psu.edu/>, 2011
- ⁹ C. Mehta, K. Mehta, T. Colledge, "The E-Spot Model for Designing Business Strategies for Technology-based Ventures in Developing Communities," *NCHIA Annual Conference*, Alexandria, VA, 2011
- ¹⁰ A. Fleishman, J. Wittig, J. Moreau, A. Baxter, J. Milnes, K. Mehta, "Validation Process for a Social Entrepreneurial Telemedicine Venture in East Africa: A Case Study." *International Journal for Service Learning in Engineering Humanitarian Engineering and Social Entrepreneurship*, Vol 5, No 1, 2010
- ¹¹ J. Austin, R. Gutierrez, E. Ogliastri, E. Reficco, "Capitalizing on Convergence," *Stanford Social Innovation Review*, 2007
- ¹² R. Stepler, S. Garguilo, K. Mehta, S. Bilen, "Applying Systems Thinking for Realizing the Mission of Technology-based Social Ventures in Africa", *Systems Engineering Division, ASEE Annual Conference*, Louisville, KY, 2010.
- ¹³ A. Osterwalder and Y. Pigneur, "Business Model Generation," *Flash Reproductions Ltd.*, 2010