Energy and Sustainable Development
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West Africa
Mali

The region of West Africa is comprised of 17[*] countries, with a total population of 354 million people, and is approximately 80% as large as the contiguous United States. It is one of the most impoverished regions in the world, with an average Multidimensional Poverty Index (MPI) of 0.361, and approximately 47% of the total population living on less than $1.90USD a day. The region has an average Human Development Index (HDI) of 0.42 for female inhabitants, 0.51 for males, and an average Gini coefficient of 39.1.[1]

Mali is a large, landlocked, and sparsely populated country in West Africa. The country ranks 2nd in terms of total land size for the region, but sixth in terms of total population, giving it the second lowest population density in the region of just 14.2 (inh./km^2). Mali has the 4th highest MPI rating for the region at 0.456, but approximately 78% of its population live in multidimensional poverty, and more than 55% are in a state of severe multidimensional poverty. In regards to HDI, Mali ranks fourth-to-last in the region, with a rating of 0.385 for females, and 0.491 for males. One highlight of Mali is its relatively low Gini coefficient; with a rating of 33 it's the second lowest in West Africa, and is only slightly higher than Mauritania (32.4).[1]

The region of West Africa has some of the lowest electrification rates in the world. National electrification rates in the region vary from as low as 10% in Liberia to as high as 96% in Cape Verde, but only 4 countries have electrification rates higher than 60%, which only accounts for 65.7 million people, or approximately 18.6% of the regional population. To further highlight the severity of this problem, only two countries, Cape Verde and Ghana, have rural electrification rates above 50%, yet close to 55% of the regional population lives in rural settings.[2] In many areas of West Africa the average electricity consumption per capita is not enough to power a single 50-watt light bulb continuously.[3][4]

In Mali, the problem is worse, with 60% of the population living in a rural setting, yet only 12% of rural inhabitants able to access electricity.[5] Major urban areas, the largest being the country's capital, Bamako, have significantly higher electrification rates (53%), giving the country an overall National electrification rate of 26%.[2] In 2008, electricity accounted for only 3 percent of the national energy balance.[20] To frame the issue another way, as reported by one researcher, average energy use in Mali amounts to about 57 kWh per year, compared to the West African average of 88 kWh per year, a world average of 2373 kWh per year, and an OECD average of 8000 kWh per year.[15]

Due to the general lack of access to traditional fossil fuels for baseload generation, and therefore the insufficient grid infrastructure, renewables make up a large, and growing, portion of the total electricity output. In 2014, renewable electricity accounted for more than 42% of total electricity output and more than 83% of total final energy consumption (TFEC) came from renewable sources.[5] Distributed energy resources play a big role in the county's current & long-term development plans and as the African Development Bank Group stated in their 2015 Mali Country Profile Report, "a parallel on-grid and off-grid energy access expansion approach is preferred, allowing both local private energy service companies and the national utility to sell electricity to customers in their respective concession areas."[6]

Traditional biomass is the primary fuel source in Mali, and represents the bulk of final energy consumption, with approximately 98% of the total population relying on it as a primary energy source for cooking.[2][7] The high usage of biomass aggravates environmental deterioration such as deforestation and land degradation, and is the main source of emissions, accounting for approximately 81% of all GHG emissions.(6) To alleviate these unsustainable levels, Mali's Nationally Determined Contribution (NDC) is primarily centered around lessening the high dependency on traditional biomass as a primary fuel source for cooking. This new proposal is a great attempt to slow the rate of deforestation and promote healthier cooking alternatives, both of which are vitally important to creating sustainable and meaningful change in the living standards of the Malian people.

Apart from the recent NDC, and in recognition that the low electrification rate and high usage of biomass have serious implications for poverty alleviation and sustainable development in Mali, and the region more broadly, the Malian Government and various international organizations have launched a number of programs in an attempt to alleviate the country's many development issues. The most notable program to date is the UNDP's Multifunctional Platform (MFP) program, which began in 1996.(8)

The idea behind the MFP is quite simple and it has achieved relatively high levels of success in Mali, and other countries.(9) Recognizing that poverty is multidimensional, and that "limited access to modern energy carriers and the services they provide has a disproportionate effect on poor women in rural areas", the UNDP devised a program that can address multiple needs and power multiple devices. The program brings an energy source to the village, in the form of a one-cylinder 8 to 12HP diesel motor (approximately 7 kW) mounted on a chassis, to which various components can be attached, such as: grinding mills, huskers, straw shredders, battery chargers, vegetable or nut oil presses, welding machines, and carpentry tools. The engine can also generate electricity through mini-grids for lighting, refrigerators, and electric pumps for water distribution and irrigation. A key characteristic of the MFP is that it is owned and operated by a community-led group of women. Through the coordination of women groups who own and operate the MFP's, women have "experienced a significant reduction in the burden associated with typical household tasks as well as savings in the time devoted to these activities, which have allowed them to engage in income-generating opportunities and improve their overall socio-economic position."(10)

The benefits of well functioning MFP's can not be overstated. As the UNDP's 2004 assessment calculated, women who utilize the platform earn on average $44 per year in additional income, as well as two to six extra hours of time per day.(11) A follow-up assessment calculated $68 in additional revenue per year per family, which constitutes an astonishing increase in income given that the implied per-capita income in rural Mali is roughly $120 USD.(12) As concluded by yet another study, "the creation of a decentralized energy enterprise owned and managed by women can generate strong dynamics for structural transformation in a setting where land and agricultural based assets are primarily owned by men and tasks are performed by women as unpaid obligations to men." (13)

The development and installation of an MFP generally occurs through an eight-step process, as can be seen in Figure 1. The timeline of events varies considerably and many MFP's are monitored for many years after development. The ultimate effectiveness of the MFP's also varies considerably, with some being used as intended and for many different use cases, and some villages resorting to only one or two use cases.(9)

In fact, the "simultaneous multifunctionality" (the use of the platform for more than one or two tasks) is just one of many challenges faced by the MFP. When functioning well, villages equipped with MFP's accrue great benefits from the platform, but in a number of cases, the platforms fall into a state of complete non-functionality after some time. The various reasons for this state of decay are far-reaching, but as the NL Agency succinctly reported upon completion of their own assessment in 2010, "60% of the non-functioning units were due to socio-organisational problems (internal conflicts in the management committee, rivalry between the women's groups and other village structures etc.); 26% of the problems were due to technical problems; and 14% due to economic problems."[(14)] In the next section I will briefly describe these problems, and in a later section I will introduce plans to alleviate all three problems.

The entire extend of the social problems is beyond the scope of this report, yet most can be attributed to Mali's long-standing patriarchal society. As stated in one report, "Mali is an extremely patriarchal society where women are not allowed to drive a motor bike nor are they allowed to have a car, it's nonsensical to think that men will suddenly let them manage and operate complex electrical equipment."[(15)] To combat this strong social norm, it is vital that MFP's continue to be owned and operated by women-based groups, and that capacity building be a continuous and evolving effort.

Second to social problems, operation and maintenance problems are the most detrimental. As also stated in the report previously mentioned, "very few villages practice preventative maintenance. Parts are often replaced only after they break, and in some cases, repair costs of poorly managed systems can offset gains in income."[(15)] As a corollary to the social problems, a recurring O&M challenge that often makes matters worse is the fact that many villages have experienced high turnover in village leadership, which often leaves those with no formal training in charge of the platform.

A third problem that limits the overall effectiveness of MFP's are the financial challenges faced by villagers. The financial model of the MFP is based on cost-sharing, with grants being provided for the initial platform costs, and women's groups being responsible for financing a significant portion of additional equipment costs for platforms, as well as the associated depreciation, maintenance, wages, and operational costs. The affordability of the platform has proved difficult for some villages, even if they could benefit from one. As stated by a UNDP researcher, "the MFP has targeted villages with the capacity to request an MFP, raise money for it, and band together to operate it- but in Mali, these types of villages are the exception, rather than the norm. In away, it has therefore benefited the wealthier and more capable villages but excluded the poorest and most in need."[(15)]

In recognition that tackling the lingering ailments demands endless effort by all direct stakeholders, I propose a multifaceted approach of creating more sustainable MFP Enterprises by introducing a 3 tier scale-up strategy that builds off previous endeavors to improve MFP's, as well as equipping each platform with a remote monitoring system to alleviate ongoing O&M challenges. A crucial aspect of my proposal is that each tier is intended to be iterative in nature, meaning each step in the process should persist in a repetitive fashion, continuously building upon itself. Figure 2 presents an illustration of my proposal.

For Tier 1, I propose a Continuous Capacity Building and Educational Program. This program closely resembles the existing capacity building, but additional criteria have been added in an attempt to equip all stakeholders with the knowledgebase needed to ensure the longevity of MFP functionality. For many metrics I've added minimum amounts of personnel needed per step. By introducing minimum headcount thresholds for various steps, I'm proposing built-in redundancies to diversify operational know-how and limit the risk associated with the departure of any one individual. Additionally, the structure of the educational program is such that, after initial set-up, any members of the women's group can become involved with the platform by starting with base-level engagement, and then working their way up through the program. This succession of roles ensures that platform beneficiaries with more oversight and responsibility understand all dependent tasks and requirements. A breakdown of Tier 1 can be seen in Figure 3.

For Tier 2, I propose more a more robust E-C Framework and platform Utility Inspection, that both rely on semi-annual formal assessments to ensure that current platform abilities and services provided meet the needs of various internal and external stakeholders. By introducing these semi-annual formal assessments, I'm proposing a 'stock-taking' of system components to ensure that platform capabilities meet the evolving demands of the community. In addition to ensuring current platform capabilities meet community demands, these semi-annual formal assessments will provide valuable insights into future needs, such as additional module installations, or increased replacement parts & capacity. Figures 4 & 5 provide breakdowns of the E-C Framework & Utility Inspection frameworks.

The Improved Capital Structure I propose for Tier 3 is largely based on prior research conducted in Senegal by Professor Ellen Morris and Professor Phil LaRocco.(16) I have adopted their Sustainable Scale-Up Strategy Decision Tool, added a one-time platform cost for the Remote Sensor, and assessed top and bottom performing MFP-enabled villages in Mali under different platform enhancement scenarios. The village size, usage, and annual turnover metrics are substantially different in Mali as compared the work Professor Morris & LaRocco conducted in Senegal, namely due to the larger village sizes. Please note that the scenarios provided below are hypothetical and some assumptions have been made on village size, usage patterns, and estimates of additional income per respective investment addition.

The set of top performing villages had an average village size of 1,537 individuals with an average of 3 modules installed per village. These top performing villages had an average of 236 annual useage days, and an average annual turnover of over 58,000 kg. The set of under performing villages had an average village size of 1,412 individuals with an average of 3 modules installed per village. These villages only had an average of 121 annual usage days, and an average annual turnover of just over 21,000 kg.

To assess the financial implications of various platform enhancements, I used the Decision tool and plugged in different platform modules for three different scenarios, the Base Case, Scenario 1, and Scenario 2. The Capital Expenditure of a platform with no modules is estimated to be $4,650 USD, and the Soft Costs are estimated to be $900 USD. For the Base Case Scenario, three modules are installed, a Grinder, De-husker, and Battery Charger, bringing the Total CapEx of the Base Case platform to $6,400 USD. The investment in these three enhancements is expected to result in $362 USD of net income from operations and results in a subsidized simple payback period of 9.0 years, and an unsubsidized simple payback period of 17.7 years for the Base Case Scenario. Assuming a discount rate of 5% and a useful lifetime of assets of 10 years for the MFP and its functions, the net present value (NPV) of the Base Case Scenario is $2,796 USD.

For Scenario 1, I added the Remote Sensor as a ‘module’, which is estimated to have a cost of $500 USD and is estimated to generate $300 USD per year, namely due to increased efficiency and decreased maintenance costs. This brings CapEx to a total of $6,900 USD and increases net income to $438 USD, which results in a slightly higher subsidized simple payback period of 10.0 years, and an unsubsidized simple payback period of 15.8 years. Assuming a discount rate of 5% and a useful lifetime of assets of 10 years for the MFP and its functions, the net present value (NPV) of $3,381 USD for Scenario 1.

For Scenario 2, I added 2 additional modules, a Peanut Press and a Welding Set, meaning the platform is fitted with 5 modules, and a Remote Sensor. These additions bring CapEx up to $8,480 USD, which result in $924 USD in net income from operations, and a subsidized simple payback period of 5.8 years, and an unsubsidized simple payback period of 9.2 years. Once again, assuming a discount rate of 5% and a useful lifetime of assets of 10 years for the MFP and its functions, the net present value (NPV) of $7,134 USD.

When assessing the new NPV's, post-investments, we see substantial subsidy savings for Scenario 1 and Scenario 2, as opposed to the Base Case, of 61% and 23% respectively. Appendix A provides a full breakdown of the Financial Projections and Village Assumptions.

The final component of my proposal that I have not discussed in detail yet is the Remote Sensor. As previously stated, the necessity of this device comes from the recognition that operational & maintenance challenges are some of the most detrimental problems faced by the Multifunctional Platform. The device I propose is a simple, low-cost hardware component with basic monitoring capabilities to record usage patterns, anticipate problems, and communicate with local technicians. The device design and capabilities are based on a similar remote sensor utilized by New Sun Road for their microgrid configurations.[(17)] The addition of this component will ensure that respective stakeholders are aware of platform usage patterns and malfunctions in an attempt to optimize preventative maintenance and limit platform downtime. As discussed in the financial section, the estimated cost of one remote sensor, is $500 USD, and it has an estimated lifetime of 10yrs. All software updates will be performed automatically, and the sensors run off batteries, or can be charged like a phone. Through the use of predictive analytics to optimize preventative maintenance and limit platform downtime, the sensor is estimated to save an MFP approximately $300 USD per year.

Even with the the additional framework proposed above, it should be noted that the introduction of a small diesel engine in rural villages should be seen only as an "intermediate step, between the more elementary level of having only human and animal energy sources, and the more advanced level of having rural electrification", and that much more work needs to be done to ensure that these early efforts to allow Malians to escape the energy-poverty trap have not been thwarted.[18][19] To ensure the ongoing advancement of enterprise-grade MFP's, future research should focus on plant-based biofuels, solar-and-wind-powered MFP enhancements, larger microgrid configurations, and access to microcredit platforms. These four areas of research pose significant challenges such as low yields for plant-based fuels, intermittency of renewable generation, and legacy financial services, but once achieved, these steps will allow MFP's to break their tie with conventional fossil fuels, and transition to a truly sustainable source of energy. Although my proposed strategy may not be foolproof, it equips all parties involved with significantly higher surety that any one MFP is not only the first rung, but also a springboard for creating sustainable and meaningful change in the living standards of the Malian people, and for all inhabitants of West Africa.

Notes:

(*) 16 countries excluding the United Kingdom overseas territory of Saint Helena, Ascension and Tristan da Cunha.

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Supporting Documents:

1. "Energy & Sustainable Development: West Africa || Data Collected by Marc Johnson"
https://docs.google.com/spreadsheets/u/2/d/e/2PACX-1vQHH6SuLNcAhvg3w1oUKQAFxNFVUxRes1PcL21bJ9vIXdnP5CDvKh0e-eMhQ5CnDCkzNvuT5JINfnFb/pubhtml
2. "MFP Financial Projections || MJ"
https://docs.google.com/a/columbia.edu/spreadsheets/d/1iQQ_POAvVeUWA5ywbrewiXzyi4O6rY5Om8YySh1W5kE/edit?usp=sharing
3. "MFP 2.0 Figures || MJ"
https://docs.google.com/a/columbia.edu/spreadsheets/d/1jC-Mv3UMYPilkwUdyVdjCcszK6G5J7k9YrdyRNN0P_Q/edit?usp=sharing

Figure 1: Existing MFP Framework

Existing Framework		
	Step	**Description**
1	Assessing demand and selecting a women's group	Assesses demand for an MFP by receiving requests from registered entities such as village women's associations and groups
2	Conducting participatory pre-feasibility and feasibility assessments	Conducts participatory social, economic, and technical feasibility studies to ensure the basic conditions for MFP performance are present
3	Configuring the multifunctional platform to fit the community's needs	Configures the platform to specific village needs, including the positioning of end-use equipment and the level of energy services villages are able and willing to pay for
5	Building women's capacity to operate the multifunctional platform	Trains the members of women's associations in managerial skills to ensure the technical viability of the platform
6	Implementing a business approach	Trains the members of the women's associations in market-based business approaches and strategies to maximize cash flows from the platform
7	Building the capacity of local artisans	Builds the capacity of local machinists and artisans to purchase, install, repair, and maintain platforms
8	Monitoring and evaluation	Monitors technical and economic performance and provides advice to overcome difficulties

Figure 2: Proposed Scale-Up Framework

Existing Framework			Additional Framework		
	Step	**Description**	**Tier 1**	**Tier 3**	**Tier 2**
1	Assessing demand and selecting a women's group	Assesses demand for an MFP by receiving requests from registered entities such as village women's associations and groups	Continuous Capacity Building and Education Program	Iterative Utility Inspection	Improve Capital Structure
2	Conducting participatory pre-feasibility and feasibility assessments	Conducts participatory social, economic, and technical feasibility studies to ensure the basic conditions for MFP performance are present			
3	Configuring the multifunctional platform to fit the community's needs	Configures the platform to specific village needs, including the positioning of end-use equipment and the level of energy services villages are able and willing to pay for			
5	Building women's capacity to operate the multifunctional platform	Trains the members of women's associations in managerial skills to ensure the technical viability of the platform		Iterative E-C Framework	
6	Implementing a business approach	Trains the members of the women's associations in market-based business approaches and strategies to maximize cash flows from the platform			
7	Building the capacity of local artisans	Builds the capacity of local machinists and artisans to purchase, install, repair, and maintain platforms			
8	Monitoring and evaluation	Monitors technical and economic performance and provides advice to overcome difficulties			

Figure 3: Continuous Capacity Building and Education Program

Tier 1	Type of capacity building	Beneficiary	Results
Continuous Capacity Building and Education Program	Oversight and Enhanced Feasibility Study	Buyers and managers of platforms	Ability to make decisions on the acquisition of a platform and assess utility of system components
	Operation and Management of the platform	Womens management committees (a minimum of 3 committee members per 100 platform users)	Ability to manage and operate platforms and present results to the Womens Association on a quarterly basis
	Literacy, numeracy, & financial management	Womens management committees and operatives (a minimum of 10 per installed module)	Effective use of record keeping, bookkeeping, and forecasting as well as increased ability to manage and operate platforms
	Entrepreneurial activites	Womens management committees (a minimum of 5 per installed module)	By consulting with othe business owners in surrounding areas, such as markets and other villages, this results in diversification of employement, increases in community income, and increased time saved by clients
	Manufacturing	Fabrication artisans (a minimum of 2 per every MFP enabled village)	People able to produce batches of platform replacement parts, components, and enhancements
	Maintenance	Maintenance artisans (a minimum of 2 per 1 installed module)	Ability to operate remote monitor and perform general module maintenance reduces the chance of downtime and increases effective preventative servicing
	Awareness raising	Gov officials and community members	Knowledge about how each MFP is benefiting its village which leads to better understanding and awareness of harmonization with national poverty objectives

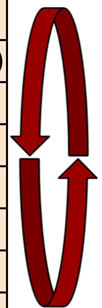
Level of Involvement

Figure 4: Iterative E-C Framework

	Tier 2		
	Iterative E-C Framework		
Entreprenuer: Womans Management Comittees Operate the Multifunctional Platforms (WMC)	Enterprise	Customer	**Demand:** Installation of a platform is demand-driven. A duly registered women's association must request it, with the active support of the village community. Demand for additional functions, including electricity generation, has remained high, and no change is expected for the forseeable future. The ongoing assessment of optimal village module count should be assessed by semi-annual utility inspections.
Technology: The platform consists of a small 8-12 horsepower diesel engine (approximately 7 kW) mounted on a chassis, to which a variety of end use equipment can be attached The platform can also support a mini-grid for lighting (150-200 bulbs) and electric pumps for a small water distribution network or irrigation system. The configuration of equipment modules is flexible and can be adapted to the specific needs of each village, as assessed from semi-annual utility inspections. In addition to the platform and variable enhancements, a remote monitor will be added to record usage patterns, anticipate problems, and advise local technicians.			**Knowledge:** As decribed in Tier 1: Continuous Capacity Building and Education Program, women's committee members will receive educational courses about mechanical power, entrepreunural training, literarcy, numeracy, financial management, manufacturing, and others.
Service: As decribed in Tier 1: Continuous Capacity Building and Education Program, women's committee members will receive additional entrepreunural training and preventive maintenance training.			**Service:** By consulting with othe business owners in surrounding areas, such as markets and other villages, market access strategies should be established to increase customer services.
Finance: Up to 90% of Start-up costs are subsidized by UNDP. All operational costs are self-financed by WMC. Some WMC's also have access to microfinance options. As described in Tier 3: Improved Capital Structure, a stakeholders can benefit from a significant savings in capital outlay in the form of a subsidy by leveraging the alternative capital structure.			**Finance:** End-user finance options such as micro-saving-and-loaning mechanisms to be assessed upon completion of additional customer services.

Figure 5: Iterative Utility Inspection

Tier 2	Type of Service
Iterative Utility Inspection	*Grinder (cereal)*
	Grinder (nuts) (Broyeur)
	Carpentry
	Dehusker
	Battery charger
	Generator
	Welding set
	Other



Appendix A: Financial Projections and Village Assumptions

ASSUMPTIONS FOR MID-SIZED VILLAGE

Average village size	1,412	
Min. village size	963	
Max. village size	1,947	
Average annual MFP usage (days)	121	
Average annual turnover (kg)	21,043	
Average daily turnover (kg)	173	
Modules Installed (Grinder, Deshusker, Battery Charger)	3	
Capital Cost (3 modules)	5,500	*one-time costs*
Soft Cost	900	*one-time costs*
Total Cost	6,400	*one-time costs*
Average annual revenue	861	
Average annual total OPEX	499	
Average annual net income	365	
Average annual margin	42%	
OPEX/Revenue	58%	

OTHER ASSUMPTIONS

All prices are in USD

		Expected Annual Revenue
Peanut Press	630	315
Grinder	750	360
De-husker	700	360
Battery Charger	300	180
Welding Set	950	540
Remote Sensor	500	300
CAPEX MFP w/ No Functions	4,650	
OPEX/Revenue	58%	
Interest on Loan	3 or 4.5%	*based on affordability; monthly payment should not decrease monthly income from base case by more than 10%*
Payback Period	5	
Discount Rate	5%	
Total subsidy	90%	
Useful life of Asset	10	years

SUMMARY TABLE

indicates which of the functions installed are financed through investments and according interest expense

Investment

Sustainable Scale-Up Strategy with Remote Sensor: Financial Projections	Base Case		Scenario 1		Scenario 2	
	Plug		Plug		Plug	
Basic Costs	1	4,650	1	4,650	1	4,650
Peanut Press		-		-	1	630
Grinder	1	750	1	750	1	750
De-husker	1	700	1	700	1	700
Battery Charger	1	300	1	300	1	300
Welding Set	-	-	-	-	1	950
Remote Sensor		-	1	500	1	500
CapEx		**6,400**		**6,900**		**8,480**
Base Case Rev		861		861		861
Additional Revenue*	-	-		180		1,335
Total Revenue		861		1,041		2,196
Opex		499	58%	603	58%	1,272
NI From Operations		**362**		**438**		**924**
Investment						
Peanut Press	-	-	1	630	-	-
Mill	-	-	-	-	-	-
De-husker	-	-	-	-	-	-
Battery Charger	-	-	-	-	1	300
Welding Set	-	-	-	-	1	950
Remote Sensor	-	-		-		-
Total Investment				**630**		**1,250**
Interest Expense*	-		3.5%	($140)	4%	($281)
Total Subsidy of Total CapEx	90%	5,760	91%	6,270	85%	7,230
Subsidized/Financed CapEx		640		630		1,250
Subsidized Simple Pay Back		9.0	years	**10.0**	years	**5.8**
Unsubsidized CapEx	0%	6,400		6,900		8,480
Unsubsidized Simple Payback		17.7	years	15.8	years	9.2
Net Revenue * Useful Life (10yrs)	0%	3,622		4,379		9,238
NPV	5%	2,796		3,381		7,134
New Subsidy	*same*	5,760		3,519		1,346
Subsidy Savings		-		2,241		4,414
Subsidy Savings in %		-		**39%**		**61%**
New Net Income (for first 5 years)		**362 [1]**		**298**		**643**
Village Portion	60%	217.29	60%	179	60%	386
Revolving Fund	40%	144.86	40%	119	40%	257
NI after Investment is paid off (year 6)		**362**		**438**		**924**
Interest income for UNDP or MFI				68		154
Portion of interest income for UNDP/MFI		NA	1.75%	34	1.75%	67
Portion of interest income for Womens Group for administration		NA	1.75%	34	2.25%	87

** see conjectures in assumptions table at top of spreadsheet*

SCENARIO 1

Cashflow projections		0	1	2	3	4	5	6	7	8	9	10
	IRR	(6,399)	362 [2]	362	362	362	362	362	362	362	362	362
Original Subsidy		5,760										
Subsidized CapEx	56%	(640)	362	362	362	362	362	362	362	362	362	362
630 OpEx-CapEx	2%	(630)	76 [3]	76	76	76	76	76	76	76	76	76
IRR	32%	(1,270)	438	438	438	438	438	438	438	438	438	438

NPV considering investment option	5%	3,381
New CAPEX		6,900
New Subsidy		3,519
Subsidy Savings		2,241
Subsidy Savings in %		**61%**

SCENARIO 2

Cashflow projections		0	1	2	3	4	5	6	7	8	9	10
	IRR	(6,399)	362	362	362	362	362	362	362	362	362	362
Original Subsidy		5,760										
Subsidized CapEx	56%	(640)	362	362	362	362	362	362	362	362	362	362
1,250 OpEx - CapEx	43%	(1,250)	562 [4]	562	562	562	562	562	562	562	562	562
IRR	47%	(1,890)	924	924	924	924	924	924	924	924	924	924

NPV considering investment option	5%	7,134
New CapEx		8,480
New Subsidy		1,346
Subsidy Savings		4,414
Subsidy Savings in %		**23%**

Appendix A: Financial Projections and Village Assump

1 Background caculation for medium-sized village

	Name of Villages*	Population	No. of modules installed	Installation date	Number of Functioning Days	Annual turnover (kg)	Annual revenue (USD)	Annual expenditures (USD)	Annual Balance (USD)	grains/day	net margin	profit/kg
8	Village O	963	2	13/11/2002	118	16,822	826	510	316	142.56	38.26%	$0.05
9	Vilage P	997	2	22/02/2003	117	11,432	570	370	200	97.71	35.09%	$0.05
10	Village Q	1094	2	18/11/2001	110	15,640	773	466	307	142.18	39.72%	$0.05
11	Village R	1176	2	24/02/2007	101	21,181	817	440	377	209.71	46.14%	$0.04
12	Village S	1294	2	16/2/2004	125	23,734	932	540	392	189.87	42.06%	$0.04
13	Village T	1383	2	20/4/2006	119	17,899	842	490	352	150.41	41.81%	$0.05
14	Village U	1414	2	1/1/2010	132	25,649	954	500	454	194.31	47.59%	$0.04
15	Village V	1577	3	28/6/2001	165	30,145	1,003	600	403	182.70	40.18%	$0.03
16	Village W	1608	3	9/3/2004	108	17,389	847	480	367	161.01	43.33%	$0.05
17	Village X	1689	3	5/26/2005	137	26,392	972	520	452	192.64	46.50%	$0.04
18	Village Y	1803	3	9/2/2011	143	28,347	989	530	459	198.23	46.41%	$0.03
19	Village Z	1947	4	26/01/2010	82	17,887	804	500	304	218.13	37.81%	$0.04

** village data included here is modelled after a select group of 25 villages in Senegal on which basic data was avaialble*
The villages selected here form a group minimal the standard deviation in their characterics (e.g. size, turnover, profits)

Average village size	1,412	
Min. village size	963	
Max. village size	1,947	
Average Modules Installed	3	
Average annual MFP usage (days)	121	
Average annual turnover (kg)	21,043	
Average daily turnover (kg)	173	
	Annual	**Monthly**
Average annual revenue	861	71.7 XOF
Average annual total OPEX	499	41.5 XOF
Average annual margin	42%	
Average annual net income	365	30.4 XOF

2 Background caculation for top-performing, medium/large-sized village*

	Name of Villages	Population	No. of modules installed	Installation date	Number of Functioning Days	Annual turnover (kg)	Annual revenue (USD)	Annual expenditures (USD)	Annual Balance (USD)	grains/day	net margin	profit/kg
1	Balanfina	2003	4	5/11/1996	266	80,664	3,574	2,430	1,144	303.25	32%	0.04
2	N'Gorona	1957	4	30/12/2001	287	93,749	4,154	2,409	1,745	326.65	42%	0.04
3	Lobougoula	1901	4	1/1/2000	274	89,967	3,986	2,830	1,156	328.35	29%	0.04
4	Banzana	1798	4	28/5/2001	261	78,214	3,465	2,183	1,282	299.67	37%	0.04
5	Tendely	1707	3	6/9/2001	272	88,458	3,919	2,312	1,607	325.21	41%	0.04
6	M'Pegnesso	1611	3	17/7/2001	254	63,410	2,809	1,826	983	249.65	35%	0.04
7	Kolango	1482	3	9/9/2002	246	55,190	2,445	1,516	929	224.35	38%	0.04
8	Zoumana D	1396	3	11/11/2001	233	36,431	1,614	1,065	549	156.36	34%	0.04
9	Manaco	1302	2	1/3/2000	197	34,126	1,512	937	575	173.23	38%	0.04
10	Sabenebougou	1217	2	24/02/2002	197	29,230	1,295	907	389	148.38	30%	0.04
11	Kolayerebougo u	1089	2	6/2/2002	192	27,084	1,200	708	492	141.06	41%	0.04
12	Bogotiere	985	2	29/03/2002	152	23,770	1,053	769	284	156.38	27%	0.04

** not included in decision tool, but can applied to different village context*

Average village size	1537	
Min. village size	985	
Max. village size	2003	
Modules installed	3	
Average annual MFP usage (days)	235.9166667	
Average annual turnover (kg)	58,358	
Average daily turnover (kg)	236.04	
	Annual	**Monthly**
Average annual revenue	2,586	215
Average annual total OPEX	1,658	138.15
Average annual margin	35%	
Average annual net income	928	77