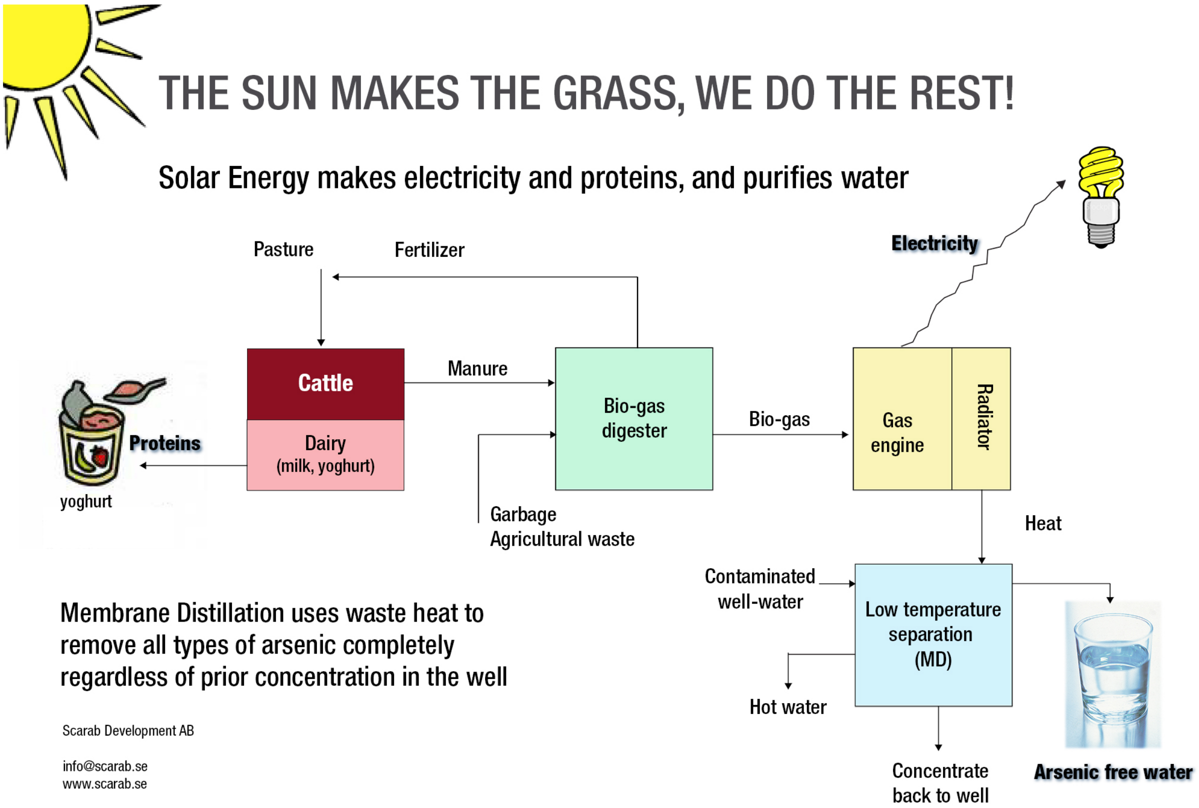
DEMONSTRATION PHASE OF BIOGAS BASED POLYGENERATION FOR RURAL DEVELOPMENT IN BANGLADESH



October 2015

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EXECUTIVE SUMMARY

Bangladesh is one of the world's most densely populated countries, with its people crammed into a delta of rivers that empties into the Bay of Bengal. Three major problems confronting the 25 million people who live in rural areas are:

- Only 42% of the rural population has electricity;
- 77 million people are exposed to high levels of arsenic contamination in their well water; and
- Biomass for cooking is depleting scarce resources.

There are known technical solutions to the three problems. Many are however not economically viable given low spending power of rural communities. Through Polygeneration they can be made viable. 'Co-generation' describes generation of electricity that utilises heat released in the process, 'Polygeneration' maximises the use of fuel by creating additional products and revenue flows.

There are two aspects to the problems. The first is to find a technical solution. The second is developing a Business Model to implement the technical solution. Finance and profitability are both vital drivers of the latter.

Sida has been helping tackle the problem of arsenic contamination in well waters. In one intervention, the Royal Institute of Technology, Scarab Development AB, HVR Water Purification AB (HVR), all of Stockholm and Grameen Shakti, Dhaka, undertook a three year feasibility project financed by Sida to marry biogas with electricity, arsenic free water, cooking gas and fertilizer. Based on meeting needs of 50 households at one location the project proved it possible to have a profitable Polygeneration solution. The feasibility report was given in 2015.

The Sida research program confirmed that while using biogas to cook with is a viable proposition, using some of the biogas for generating electricity strengthens profitability and using some of the heat generated by the latter for water purification adds to profitability still further. That is the conclusion from the research project. By using some of the residual heat from the system for crop drying, the system becomes an even more attractive investment as well as helping raise farmer incomes.

This Polygeneration solution now needs to be demonstrated in field conditions and it is proposed that four demo systems are financed over a two year period to do so. KTH will provide technical lead, HVR commercialisation, and Shakti field operation for the demonstrations.

If all arsenic contaminated wells in Bangladesh were to be tackled with conventional technology on a grant basis, billions of Euros would be required and the result would require continuing funding.

The scale of the total potential cost has discouraged donors from becoming involved. The Polygeneration solution does not depend on grant funding and is economically sustainable. It does not or should not depend on subsidies.

After a successful demonstration, finance is required in the form of soft credit lines of the sort often used by the World Bank Group in Bangladesh. The World Bank, in fact, has a new credit line of $600 million for rural electrification.

1 INTRODUCTION

Bangladesh is an intensely populated country with very high levels of poverty. Amongst the challenges faced by the country, three are addressed in this proposal:

Shortage of electricity

The country faces extreme shortages of electricity and is forced to buy it from neighbouring India. Large tracts of rural Bangladesh have no electricity at all. The sector has been highly regulated with maximum tariffs that were often below cost of production. The Government has limited resources and diverse needs while the private sector finds it uneconomic to provide electricity at regulated tariff rates. In order to tackle the problem a huge amount of cash is required as well as an ability to absorb it.

Widespread contamination of water by arsenic

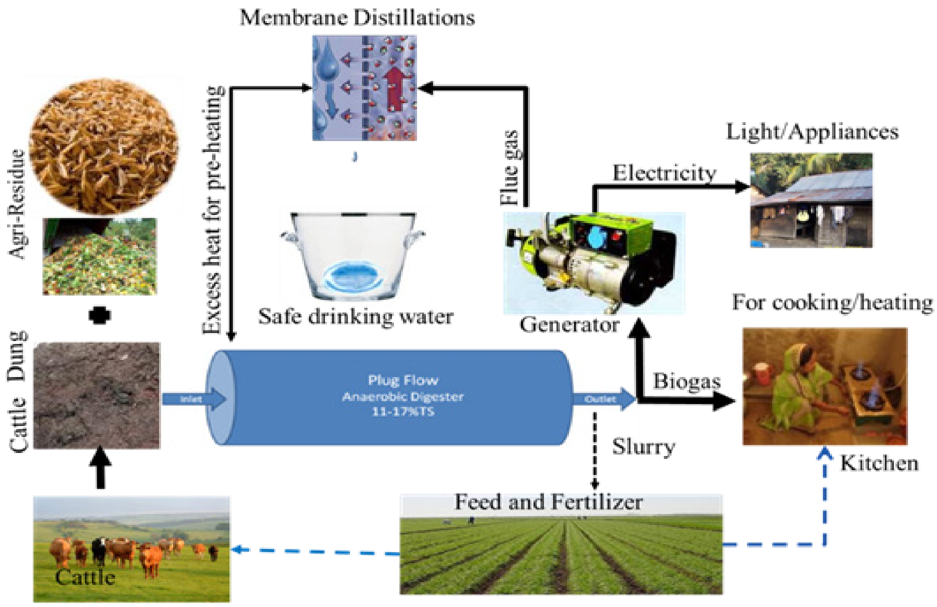
Groundwater in Bangladesh is contaminated by arsenic to the point where millions of people have become ill and thousands die every year. The Arsenic is a natural component of the soil. It is accepted to be one of the worst environmental disasters in the world. The problem has been tackled through greater understanding, identification of contaminated regions and wells and drilling some new deeper wells which have not yet become contaminated. These measures ameliorate but do not remedy the problem. Moreover, arsenic contamination is now being found in produce such as rice where it is already above maximum safety levels permitted for imports in the EU.

Demand for fuel for cooking

Most rural households cook with bio-mass. Because of the increasing scale of twigs and woods required collection of bio-mass is becoming an increasing problem. Biogas technology uses available agricultural waste and is much safer to use. Biogas has been introduced for cooking purposes but production of gas solely for cooking purposes is only marginally commercially viable.

2 SYNERGY IN TACKLING THE RURAL PROBLEMS

Biogas for cooking or for generating electricity has long drawn attention, mainly because a hamlet based system can easily avail cow dung being produced within that hamlet as well as a perceived need for cooking gas in preference to biomass. There is a value judgement implied as villagers are more willing to pay for electricity than cooking gas. However, neither of the two uses has proved economically attractive enough by themselves to attract widespread application. That is why the Sida program was launched. Biogas as a renewable fuel for electricity generation is more profitable than merely producing cooking gas but can be improved further by Polygeneration.



3 KTH, GRAMEEN SHAKTI, SCARAB AND HVR WATER PURIFICATION COLLABORATE

The Royal Institute of Technology (KTH), HVR Water Purification AB (HVR) developer of Membrane Distillation (MD) and Grameen Shakti (Shakti) a leading NGO established in 1996 active in sustainable energy rural projects in Bangladesh have collaborated in the Sida financed research project at KTH to integrate production of biogas, electricity and water purification.

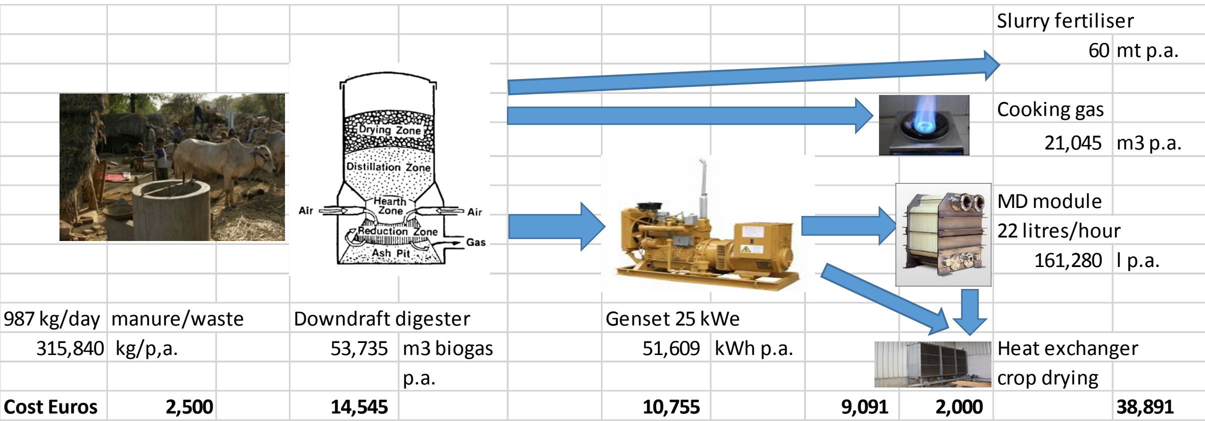
The three year program validated integration of digesters, internal combustion engines, generators and membrane distillation. Focus was on researching rural needs and then configuring integration of systems to meet those needs. The two models developed are designed for a 30 and a 50 household rural community but can be upscaled for larger numbers. The main sensitivities encountered were access to feed stock and efficiency ratios.

The consortium has completed its program and the report is finalised. The concept has been translated into a system. Workshops have been held in Dhaka for stakeholder participatory analysis. Shakti, for one, has the field experience in sub optimal rural areas, but not the finance to implement the system in rural areas.

Groundwater in Bangladesh is contaminated by arsenic to the point where millions have become ill and thousands die every year. Arsenic is a natural component of the soil in these tracts. It is accepted to be one of the worst environmental disasters in the world. The problem has been tackled through greater understanding, identification of contaminated wells and drilling some new deeper wells which have not yet become contaminated. These measures ameliorate but do not remedy the problem.

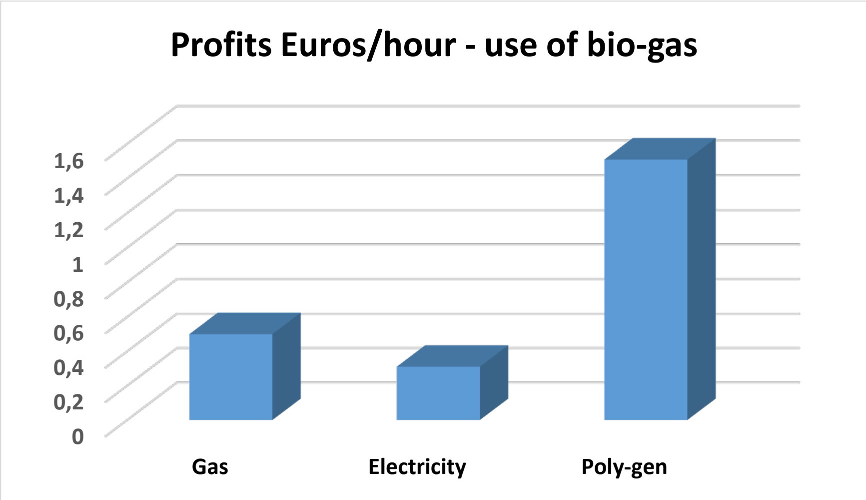
What is now required is to demonstrate the Polygeneration system tested by KTH in the field and to refine the possible configurations in design and in practice. The matrix of revenues from cooking gas, electricity, purified water and other uses for waste heat such as crop drying has to be adjusted according to financial and social criteria.

The system developed is given below:



Access to feedstock is a function of prices paid to mobilise the resource. Small villages do not have enough cows to provide enough dung but it is common practice to mix dung with rice husks and other agri-waste.

Village communities need cooking gas to cook with in order to substitute more expensive bio-mass but at current market prices cooking gas would probably be the lowest profit contributor even if it has a high use value.

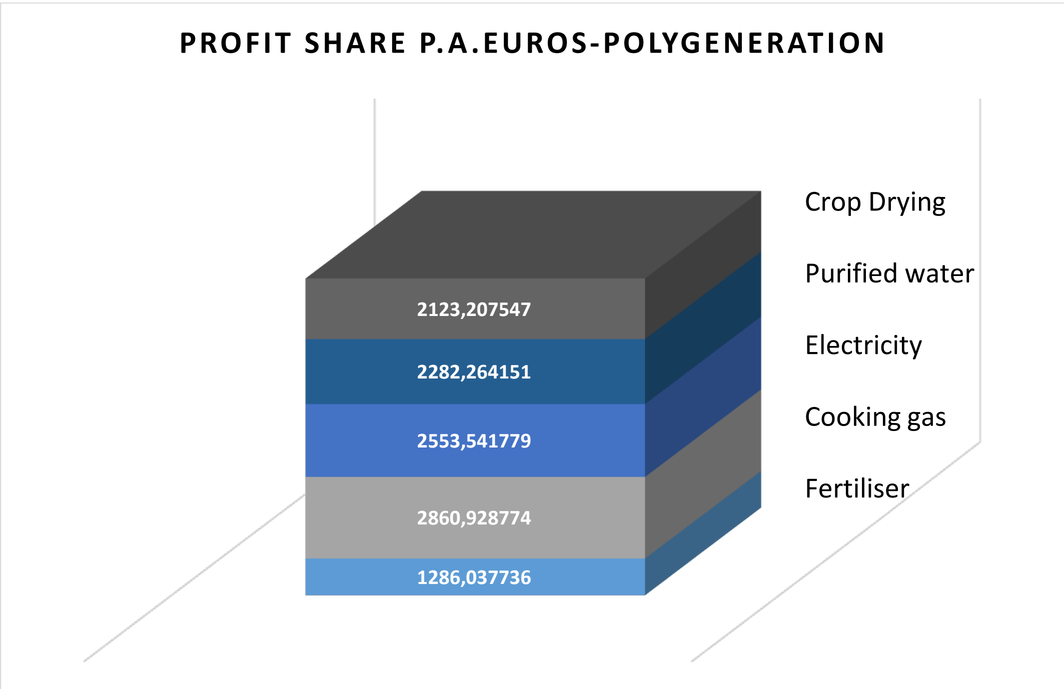


Biogas can break even when exclusively used for cooking but when combined with electricity profits are likely to be 60% higher and with Polygeneration twice the level of co-generation. Bio-gas for cooking in Bangladesh has often been funded by donors but a large proportion of sys-tems fell into disuse due to problems which proved too big for the narrow margins to absorb. Profits from use for generation of electricity have been limited by regulatory factors such as a maximum 6 US cents per kWh that utilities may charge and the regulation has contributed to a dire national energy shortage.

A majority of energy used in power generation takes the form of heat and is seldom harvested for commercial purposes. Introduction of MD within the system allows some of the now wasted heat to be used to purify water. Any sort of water can be purified, be it arsenic contaminated, surface or sea water. The result is a drinking water that could be promoted as being totally arsenic free and sold at a premium in urban areas but is also a profitable activity in its own right. In the Bangladesh context, MD offers the possibility of using contaminated wells.

Water purification and crop drying add value through commercial use of the wasted heat from the engine. Heat energy is released through the flue and by use of cooling water in the generator. Rice and jute are the most common crops that could use the waste heat but there are many others. The four leading financial returns are from water, electricity and cooking gas for cooking and crop drying, followed by a by-product used as fertilizer.

The relative contribution of the five revenue flows in Euros is given below:



The conclusion flowing from the research is that there are at least five significant revenue streams – Cooking gas, crop drying, water, electricity and fertiliser.

4 DEMONSTRATION PROGRAM PROPOSED

All the technologies involved are well established and verified independently. What the Sida financed program achieved is to identify and marry five different revenue streams from one feedstock, namely low value agri-waste.

By combining them, the synergy is a game changer. This needs to be demonstrated in the field so that all those interested in the 5 applications can see the impact. The use value is obvious but commercial value needs demonstrating. It is a new concept and has to be seen to be applied.

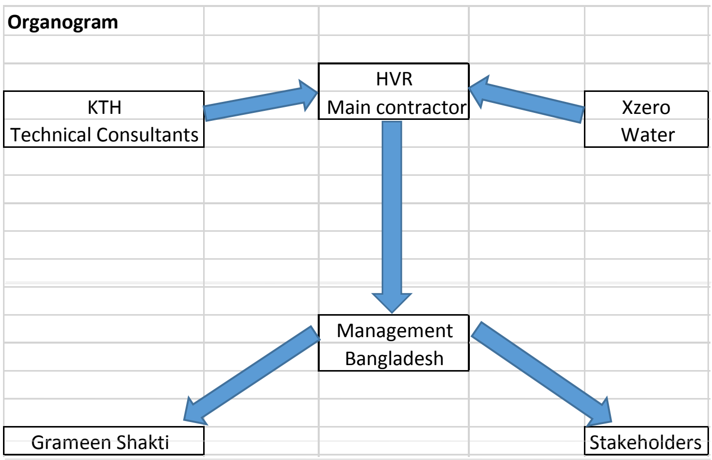
A two year program is proposed where four units of the general scale would be built. The sites are communities where water is contaminated by arsenic and there is no electrical grid coverage.

HVR will play the lead role for the project. Systems will be based on the KTH recently completed research project with the drinking water system and support provided by Xzero. KTH will select sites together with local partners in Bangladesh, monitor and help maintain systems, collect and collate data and disseminate project results. KTH can make use of former graduates who have returned to Bangladesh.

Xzero will supply water purification modules, HVR will take the lead in marketing, integrating and monitor the economics of the operation and take the lead role in securing credit lines for the systems.

In order to ensure access to sufficient feedstock, some of the proposed demonstration systems could be coordinated with the Associations for Poultry and for Dairy. This would have the added benefit of early exposure of the demonstrations to the industry

Grameen Shakti was a partner in the KTH study and has operations in regions and at sites that meet project conditions. They have worked at those sites with rural partners and consumers. Grameen can help implement and can arrange operation of the four units.



5 ACTIVITIES

KTH, HVR and Shakti will, in consultation with local industry and relevant public institutions, decide on the four sites to be selected, and also the scale and nature of system configuration at each site and specifications on scope of work. Shakti will manage construction and installation with guidance from HVR.

The systems will be fine-tuned to site specific requirements to ensure that there is access to sufficient feedstock and that products such as cooking gas, electricity and drinking water are made available in a convenient way. Cooking gas and electricity will have to be delivered to consumers in the form of piping and mini grids. Water can be dispersed to convenient points and could be delivered to doorstep by contracted parties.

There are a number of suitable local partners, which will be charged with management of activities in Bangladesh. As such, they will contract and employ all national entities required to establish, operate and maintain the demonstration units. The experience of NGOs such as Grameen Shakti, BRAC and CARE in working with rural populations is valuable and will be used in the demonstration. Shakti have already supplied solar systems as well as digesters to small communities living in areas of poor infrastructure and has worked with KTH during the entire Sida program.

HVR will manage and coordinate the project as such and will channel technical assistance provided from outside Bangladesh. Any replacements, repairs and engineering required by the four units under guarantees given by suppliers. Some of the equipment will be imported and co-ordination will be required with foreign suppliers. Many systems financed through development funds fall into disuse when problems are encountered. Deep knowledge of the technologies and their integration is required and, in this case, available.

Every six months there will be a workshop to discuss operations, results and implications and will be attended by the local management, KTH, Scarab, HVR, Shakti, community representatives, the local Sida desk officer, industry partners and relevant public officials. There will be a report following each workshop. On completion, there will be an independent evaluation.

In order for results to be sustainable, HVR has experience in collecting, analysing and then presenting data to those who can apply it in a business like fashion.

The project proponents have each excellent networks in Bangladesh which will help implement and ensure continuity. KTH has most recently been working with Shakti and HVR on the Sida financed co-generation project and has for a long time had post-graduate researchers from Bangladesh. Some have returned to the country and are familiar with the project components. Also, Grameen is a household name in the country with a unique network of contacts.

6 BUDGET

HVR will receive and manage funds with a local Bangladeshi management company, KTH, Xzero and other equipment and service providers acting as sub-contractors.

Euros					
		year one	year two		Total
Mobilisation		150,000	-	-	150,000
Action Fiche		150,000	-	-	150,000
Capital Cost		600,000	-	-	600,000
Operational		200,000	200,000	-	400,000
KTH Technical		400,000	400,000	-	800,000
Field costs		100,000	100,000	-	200,000
Management,marketing		400,000	400,000	-	800,000
Follow up		-	-	400,000	400,000
Total		**2,000,000**	**1,100,000**	**400,000**	**3,500,000**

Expenditure is likely to be distributed evenly between Sweden and Bangladesh:

Euros		of which		
		Sweden	**Bangladesh**	
Mobilisation		100,000	50,000	
Action Fiche		120,000	30,000	
Capital Cost		150,000	450,000	
Operational		-	400,000	
KTH Technical		600,000	200,000	
Field costs		-	200,000	
Management,marketing		600,000	200,000	
Follow up		200,000	200,000	
Total		**1,770,000**	**1,730,000**	**3,500,000**

7 DELIVERABLES

The project will deliver four operational Polygeneration systems, and will install, run, maintain and monitor them for two years. The four will include variations in capacity and configuration.

Results will be shared with potential users as well as presented and marketed to them. Interested stakeholders will continuously be informed in preparation for future finance, management, technology development and marketing.

There will be six monthly reports and an independent evaluation on completion. Final results will be physical and thus open to being objectively verifiable.

8 BENEFICIARIES

The immediate beneficiaries of the project will be people living in areas with no electricity and arsenic contaminated wells.

By allowing use of community shallow wells again, the task for women and children to carry water can be greatly reduced. Having to access deep wells increases the arduous task that women have to perform.

For local communities who become investors as a cooperative or farmer association, Polygeneration offers a good investment opportunity of transforming agro-waste into saleable commodities.

There will also be a long term effect on the environment through reduction of carbon emissions.

9 COMMERCIALISATION

9.1 Finance

If all arsenic contaminated wells in Bangladesh were to be tackled with conventional technology on a grant basis, billions of Euros would be required and the result would require continuing funding.

The scale of the total potential cost has discouraged donors from becoming involved. The Polygeneration solution does not depend on grant funding and is economically sustainable.

Researchers have advocated use of subsidies to get the process underway. However, since Polygeneration is economically viable, it does not or should not depend on subsidies.

After a successful demonstration, finance is required in the form of soft credit lines of the sort often used by the World Bank Group in Bangladesh. The World Bank, in fact, has a new credit line of $600 million for rural electrification.

9.2 Economic Model

The model developed is suited for small communities. They are the ultimate consumers of any gas, electricity, water or heat produced. With roughly five revenue streams that can emanate from a single biogas Polygeneration system, pricing will depend on community priorities and preferences. A matrix of charges is possible. Water, electricity, cooking gas, fertiliser and crop drying are all positive revenue streams.

Ownership offers a number of possibilities. The best solution would be that the communities own the systems which are financed through loans and managed by an intermediary such as Shakti. The latter would require finance and it could be on soft terms via the World Bank Group or the Asian Development Bank or other international financial institution. Shakti and BRAC, among others, have served as preferred conduits for credit lines and have availed funding through credit lines for other similar community programs.

Following successful demonstration of the Polygeneration system, and starting during the process itself, HVR and Shakti, or equivalent, would enter into discussions with the World Bank Group or equivalents to arrange a credit line which would then finance organised rural community groups to commission Polygeneration units with a management contract which would manage the loan and repayments as well as the running of the units and their maintenance. Bangladesh is fortunate in having a number of suitable management companies and technical personnel, who could work with the equipment.

The systems would be integrated and sold by HVR. Components will be from a number of suppliers with most of the system supplied locally.

9.3 Financial Analysis

The Sida research program confirmed that while using biogas to cook with is a viable proposition, using some of the biogas for generating electricity strengthens profitability and by using some of the heat generated by the latter for water purification adds to profitability further and is very viable. That is the conclusion from the research project. Using some of the residual heat from the coolant of the MD system for crop drying, the system becomes an even more attractive investment as well as helping raise farmer incomes, as illustrated below.

Profit per system

	output per annum	Euro price	output revenue/ per annum p.a.		cost/ p.a.	profits p.a.
Fertiliser	60 mt	23.02	60	1,381	95	**1,286**
Producer Gas	21,045 m3	0.151	21,045	3,177	316	**2,861**
Electricity	51,609 KWh	0.057	51,609	2,921	368	**2,554**
Pure water	161,280 litres	0.028	161,280	4,565	2,282	**2,282**
Dry crops	90 mt	25	90	2,250	127	**2,123**
Totals				**14,292**	**3,188**	11,106

Euros	years									
Bangladesh	1	2	3	4	5	6	7	8	9	10
Baseline Case										
Revenues										
Fertiliser		1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381
Producer Gas		3,177	3,177	3,177	3,177	3,177	3,177	3,177	3,177	3,177
Electricity		2,921	2,921	2,921	2,921	2,921	2,921	2,921	2,921	2,921
Pure water		4,565	4,565	4,565	4,565	4,565	4,565	4,565	4,565	4,565
Dry crops		2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250
Revenues		**14,294**	**14,293**	**14,293**	**14,293**	**14,293**	**14,293**	**14,293**	**14,293**	**14,293**
Costs										
Fertiliser		95	95	95	95	95	95	95	95	95
Producer Gas		316	316	316	316	316	316	316	316	316
Electricity		368	368	368	368	368	368	368	368	368
Pure water		2,282	2,282	2,282	2,282	2,282	2,282	2,282	2,282	2,282
Dry crops		127	127	127	127	127	127	127	127	127
Costs		**3,188**	**3,188**	**3,188**	**3,188**	**3,188**	**3,188**	**3,188**	**3,188**	**3,188**
Profits										
Fertiliser		1,286	1,286	1,286	1,286	1,286	1,286	1,286	1,286	1,286
Producer Gas		2,861	2,861	2,861	2,861	2,861	2,861	2,861	2,861	2,861
Electricity		2,554	2,554	2,554	2,554	2,554	2,554	2,554	2,554	2,554
Pure water		2,282	2,282	2,282	2,282	2,282	2,282	2,282	2,282	2,282
Dry crops		2,123	2,123	2,123	2,123	2,123	2,123	2,123	2,123	2,123
Profits	**- 30,302**	**11,106**	**11,106**	**11,106**	**11,106**	**11,106**	**11,106**	**11,106**	**11,106**	**11,106**
IRR	**37%**									

The Internal rate of return (IRR) was estimated by the KTH Project with an investment of 30,302 Euros to be in the range of 13.8% to 31.6%, depending upon fertiliser sales. Feedstock price estimates and the period over which deprecation was calculated meant that the IRR was more likely to tend towards the lower quartile of the range of possibilities. The main constraint on scale was feedstock availability. The research phase explicitly favoured the potential supply in the immediate vicinity of the site.

The rate of return is higher, at over 37% if crop drying is included. It may be still higher at higher electricity charges. With a higher price for electricity at 8 US cents per kWh, 4 cents per litre for drinking water and a faster drying rate, the IRR could be 54%.

One of the central purposes of the demonstration phase is that it allows scale, efficiency, delivery, feedstock and pricing to be optimised.

Euros	years									
	1	2	3	4	5	6	7	8	9	10
Best case analysis using marginally higher prices for electricity, water and drying.										
Revenues										
Fertiliser		1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381
Producer Gas		3,177	3,177	3,177	3,177	3,177	3,177	3,177	3,177	3,177
Electricity		3,895	3,895	3,895	3,895	3,895	3,895	3,895	3,895	3,895
Pure water		6,086	6,086	6,086	6,086	6,086	6,086	6,086	6,086	6,086
Dry crops		4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Revenues		19,039	19,039	19,039	19,039	19,039	19,039	19,039	19,039	19,039
Costs										
Fertiliser		95	95	95	95	95	95	95	95	95
Producer Gas		316	316	316	316	316	316	316	316	316
Electricity		368	368	368	368	368	368	368	368	368
Pure water		2,282	2,282	2,282	2,282	2,282	2,282	2,282	2,282	2,282
Dry crops		127	127	127	127	127	127	127	127	127
Costs		3,188	3,188	3,188	3,188	3,188	3,188	3,188	3,188	3,188
Profits										
Fertiliser		1,286	1,286	1,286	1,286	1,286	1,286	1,286	1,286	1,286
Producer Gas		2,861	2,861	2,861	2,861	2,861	2,861	2,861	2,861	2,861
Electricity		3,527	3,527	3,527	3,527	3,527	3,527	3,527	3,527	3,527
Pure water		3,804	3,804	3,804	3,804	3,804	3,804	3,804	3,804	3,804
Dry crops		4,373	4,373	4,373	4,373	4,373	4,373	4,373	4,373	4,373
Profits	- 30,302	15,851	15,851	15,851	15,851	15,851	15,851	15,851	15,851	15,851
IRR	54%									

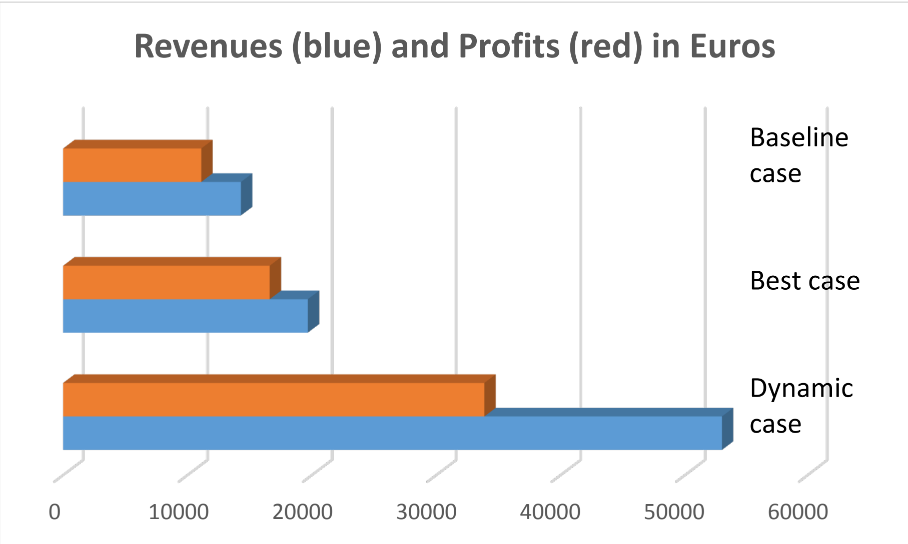
There is a radical improvement in profitability if electricity with the same investment of 30,302 Euros, is charged at 8 cents per kWh instead of the 6 cents assumed in the base case, 4 cents per litre for drinking water instead of 3 and a more realistic crop drying margin. The IRR rises to 54% instead of the 37% in the base case. The commodity price for electricity is nearer the 8 cents at present while the regulated price of 6 cents over recent years in Bangladesh may have discouraged investment in the sector according to the World Bank.

Commercial viability improves still further by increasing digester and system capacity by 30% with capital costs higher than in the base case. Feedstock being purchased from a region greater than that immediately being served by the system will result in higher yields of all products. Resulting economies of scale albeit with a larger catchment area improve profitability.

The dynamic case is what happens when the constraint of feedstock solely from the community is broadened as it would be in practical operation. With a higher investment, the IRR should be 59% and beyond. In this form the system becomes more an attractive profitable venture and a bit less of a community service development project. Clearly, a balance has to be struck.

Euros	**years**									
Bangladesh	1	2	3	4	5	6	7	8	9	10
Dynamic Case with higher investment cost										
Revenues										
Fertiliser		4,143	4,143	4,143	4,143	4,143	4,143	4,143	4,143	4,143
Cooking Gas		7,942	7,942	7,942	7,942	7,942	7,942	7,942	7,942	7,942
Electricity		13,633	13,633	13,633	13,633	13,633	13,633	13,633	13,633	13,633
Pure water		18,258	18,258	18,258	18,258	18,258	18,258	18,258	18,258	18,258
Dry crops		11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250
Revenues		55,225	55,225	55,225	55,225	55,225	55,225	55,225	55,225	55,225
Costs										
Depreciation		8,491	8,491	8,491	8,491	8,491	8,491	8,491	8,491	8,491
Feedstock		3,373	3,373	3,373	3,373	3,373	3,373	3,373	3,373	3,373
Labour		1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Maintenance		4,245	4,245	4,245	4,245	4,245	4,245	4,245	4,245	4,245
Management		1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Costs		**19,109**	**19,109**	**19,109**	**19,109**	**19,109**	**19,109**	**19,109**	**19,109**	**19,109**
Profits										
Profits	**- 39,393**	**36,116**	**36,116**	**36,116**	**36,116**	**36,116**	**36,116**	**36,116**	**36,116**	**36,116**
IRR	**91%**									

The demonstration phase is designed to allow practical permutations in scale, costs and prices to be tried out in field conditions to derive an optimal model.



9.4 Market scope

Bangladesh is reported to have more than 4 million shallow wells. The overall need for Polygeneration systems in Bangladesh easily exceeds one million contaminated well communities. In the short term, following successful demonstration, a target of a 1,000 units p.a. would be well below what is required but a good beginning. The target can be increased over the first three years. In the Medium Term, a larger credit line will be required for a target of tens of thousands units. In the long term, credit lines can be safely left to indigenous banks and no specific target needs to be set. An industry will have developed to progress the commercial implementation.

Interest in the systems proposed is likely to be strongest from those communities afflicted by arsenic contaminated wells.

However, also communities afflicted with salt water intrusion, which is very common in the coastal areas, or any other water problems, fluoride, bacteria and other, will benefit from the system.

Judging from present developments in more affluent areas in the world, high class drinking water may become a high priority also in Bangladesh in which case the Polygeneration business may increasingly interest the entire population of 140 million.

Cooperatives are organised to supply the two value chains. At the apex are large commercial enterprises which are supplied by the respective chains that link them to the small farmer cooperatives. Polygeneration offers incremental benefits to the farmer cooperatives. By investing in Polygeneration equipment the industries would benefit from a more robust economic situation.

The marketing of Polygeneration systems offers a good business opportunity. The Bangladesh market is sizeable due to particular problems but there are other markets of interest. Finalising a product in Bangladesh offers the possibility of offering off-the-shelf solutions.

In all probability, a Polygeneration company would provide a great impetus to the process. The latter will market systems, supervise implementation and maintenance. Industrial parties in the country could also be investors in such a company.

9.5 Global implications

There are three global implications for the systems developed, namely:

- Rural communities whose water is contaminated by arsenic, but also fluoride and iron, amongst others. India is the most obvious candidate amongst many others.

- Second is rural farming communities in general not necessarily suffering from exceptional contamination but requiring the five benefits identified: drinking water, energy, cooking gas, fertiliser and crop drying.

- Thirdly, there are small island communities. They have feedstocks such as coconut and cocoa shells and other agri-waste. They also need desalination, energy, cooking gas and crop drying and have a possible additional revenue by including charcoal or fertiliser manufacture in the Polygeneration loop.

Arsenic contamination is almost as widespread in west Bengal in India as it is in Bangladesh. In addition, there is widespread contamination from excessive natural fluoride in states such as Andhra Pradesh and Gujrat and excessive iron in wells in Assam. Polygeneration is of interest because the feedstocks are similar as are the output needs.

Electricity grids do not reach all rural communities, while bio-mass for cooking is under pressure as is supply of adequate drinking water and need for crop drying. A proven Polygeneration system would be an attractive prospect for many communities in developing countries and also many communities in developed countries.