

MASTER

Biomass gasifier applications in rural India past experiences and future plans reviewed

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Biomass gasifier applications in rural India

Past experiences and future plans reviewed

F.G.M. Ermers



Energy: Building blocks for development

F.G.M. Ermers
March 2008

Biomass gasifier applications in rural India
Past experiences and future plans reviewed



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Preface and acknowledgements

This Master Thesis is the result of a preparation period of 6 months in the Netherlands, a visit from February 2007 till August 2007 to South-India followed by a period of thesis writing in the Netherlands. It is the final project conducted for my M.Sc. education: Technology Policy, at the Technology Management faculty of the University of Technology Eindhoven, the Netherlands.

This project gave me the opportunity to test my academic skills by conducting independent research in a different culture. The 6 months period proved to be a very valuable and enriching experience, both on the academic as well as the personal level.

Although the un-avoidable cultural differences and hick-ups were encountered, my research in India went very smoothly. This I owe to the kind and helpful nature of the many Indians who assisted me with my research and non-research activities. I would like to thank VITU for the accommodation and prof. Natarajan, Mr. Karthikeyan and Mr. Tamil Maran for the useful contacts and support with visits during my research. I would also like to thank all the people who offered their time to me for interviews and who showed me in the right directions. I thank my tutors of the University of Technology Eindhoven for their advice and guidance during my stay in India and thesis writing in the Netherlands.

Ik wil ook graag mijn vriendin Monique en mijn ouders bedanken voor de steun en hun bezoek aan India.

Summary

The Indian context

India has been characterized by a high economic growth during the last decade. Despite this, a large portion of the population does not have a reasonable income, both in the rural as well as the urban areas. Supply of a reliable form of electricity can have a large positive influence on the development in the rural areas. In the current electricity situation in India, a large part of the population does not have access to reliable electricity due to the high demand. Especially the rural areas often lack a reliable source of electricity. Electricity can be used for lighting, radios, TV sets, drinking water pumpsets and flour mills. To supply reliable electricity, several biomass gasifiers have been placed in the Indian rural areas. These gasifiers gasify biomass (i.e. wood) into a combustible gas by combustion with a shortage of oxygen. The combustible gas can be used in gas engines to generate electricity. The placement of these gasifiers is supported by the Indian central and state governments.

The framework

This research has assessed the gasifiers already placed and the new plans to do so. An analytical framework has been constructed using a combination of different literature sources about the success factors in rural development projects and programs. It consists of 3 elements.

1) Ultimate goals of development as defined by Uphoff et. al. (1988), this consists of increase in production, well being and empowerment, 2) Application success, this consists of technological and financial success of the application and 3) Institutional success, this is the success of the initiating institute (i.e. a government or NGO) The fieldwork research has been conducted by field visits, interviews with actors and by a literature study.

Fieldwork research

In 1988, the IISc (a university in Bangalore) placed a biomass gasifier in the un-electrified village Hosahalli. This was later on replicated in the nearby village of Hanumanthanagara. Applications like drinking water pumps, a flour mill, public and domestic lighting were installed throughout the years. The goal was to test the technical and development related application of biomass gasifiers in the rural setting. A lot of experience was gained in several fields. The experiment was terminated in 2004 in both villages. During the research in India, I discovered that a large number of biomass gasifiers had been placed in already grid-electrified villages to reduce the state electricity board bill. These gasifiers were placed with a government subsidy. After the field visits, I however discovered that most of these gasifiers were no longer in operation and most of them had halted operation shortly after installation. This was mostly due to factors like bad planning concerning the availability of biomass, the technical support, finance and the applications that are to use the electricity. The central government continues to support these gasifiers and too little is learned about the failures.

There are also new plans for biomass gasifier applications in the rural setting. Three of these were visited during the fieldwork research. BERI is an Indian initiative of several (international) governments and NGOs to supply a region in Karnataka state with reliable

bio-power, among others by means of gasifiers. After several changes of the plans, BERI has constructed a cluster of 500 kW gasifiers and operation was only weeks away during the visit. BERI has plans for rapid expansion of the program. The electricity produced is sold to the grid, and surrounding villages are guaranteed of electricity. This is a new innovation in India. The program also comprises biogas installations and agricultural and bio-energy awareness education for the rural population.

The second new initiative is from the Periyar college. The Periyar college has plans to place one gasifier in a related village. The college is involved in a national development program (PURA), in which both developmental as well as technical support is provided to several villages. The biomass gasifier that is to be placed is to supply electricity to a (already electrified) village. The main goal is to create employment in the village and to create awareness through agricultural and environmental education. The third program visited was DESI. DESI is a development organization with the goal of promoting entrepreneurship in the rural setting. Plans are developed to place 100 biomass gasifiers in 100 villages in the north of India, to supply villages with electricity. The combination of education of DESI and the reliable power should encourage the villagers to start small businesses and thus generate extra income.

Conclusions

All applications and plans can be divided into three groups:

- 1) The developmental goal group, this group consists of the DESI and BERI plans. Although no actual plant was visited, the plans and previous experiences indicate a close fit to the ultimate goals as defined by Uphoff et. al., good preparations in the field of application success and a reasonable institutional experience in the field of rural development.
- 2) The educational and R&D group, this group consists of the IISc applications and the Periyar college plans, these are characterized by the combination of technological and developmental goals. Dependency between the college and the village remains. Ultimate goals are less compared to group 1, but still high for IISc, but application success is / will be high and institutional success is reasonable.
- 3) Cost saving group, this group consists of the gasifier applications in the villages, placed to save electricity bill costs. Most of these applications are unsuccessful due to too little support of the related government agency, both in technical as well as financial terms. The application success is low, and institutional learning is does not fit the rural requirements. Some developmental side-effects were observed, the ultimate goals, application success and institutional success are however low.

Recommendations

To improve the situation of the biomass gasifiers in the Indian rural setting, I made a number of recommendations. The formation of a biomass working group was one of these. In this working group all involved actors should share their experiences. Another recommendation is to demand a preliminary study before placement of biomass gasifiers, in which items like finance, technical support and the supply of biomass are investigated.

Samenvatting

De Indische situatie

India wordt gekenmerkt door een grote economische groei tijdens het laatste decennium. Tegelijkertijd is het een land met een grote groep mensen die verstoken zijn van een redelijk inkomen, zowel in de steden als op het platteland. De voorziening van een betrouwbare vorm van (duurzame) elektriciteit kan een positieve invloed hebben op de ontwikkeling van plattelands bevolking, o.a. door de voorziening van stroom voor verlichting, medische apparatuur en drinkwater pompen en informatievoorzieningen als TV, internet en radio. Op dit moment is een groot deel van de bevolking op het platteland verstoken van betrouwbare elektriciteit. In India zijn op verschillende plaatsen op het platteland biomassa vergassers geplaatst om te hierin te voorzien, en de Indische overheid biedt subsidies voor de plaatsing van deze biomassa vergassers. Een biomassa vergasser, vergast biomassa (als bijv. hout) door een verbranding met een tekort aan zuurstof. Hierbij ontstaat een brandbaar gas dat, na schoongemaakt te zijn, gebruikt kan worden voor elektriciteit opwekking in een gasmotor.

Het raamwerk

Voor dit onderzoek is gekeken naar de in het verleden geplaatste vergassers, en naar de nieuwe plannen die in ontwikkeling zijn. Een analytisch raamwerk is ontwikkeld, gebruik makend van verschillende literatuurbronnen over de succes factoren van projecten en programma's voor platteland ontwikkeling in ontwikkelingslanden.

Het raamwerk voor het onderzoek is als volgt opgebouwd: 1) Ultieme doelen van ontwikkeling, zoals beschreven door Uphoff et. al., deze bestaan uit een toename van productie, welzijn en zeggenschap, 2) Applicatie succes, dit is onderverdeeld in technisch en financieel en 3) Institutioneel succes, dit is het succes van het instituut of de overheid die het project uitvoert. Het onderzoek is uitgevoerd door middel van bezoeken, interviews met betrokkenen en een literatuurstudie.

Het veldwerk

In de staat Karnataka in Zuid-India is in 1988 door het IISc, een technische universiteit uit Bangalore, een biomassa vergasser geplaatst in het dorp Hosahalli, dat op dat moment nog geen elektriciteitsvoorziening had, en later ook in het dorp Hanumanthanagara. Hierbij zijn in de loop der jaren applicaties als drinkwater pompen, verlichting en een graanmolen geplaatst. Doel was om ontwikkeling te bieden aan het dorp, maar vooral ook om de technische haalbaarheid en factoren te testen van een biomassa vergasser die dagelijks benut wordt in een platteland situatie. Er werd veel technische en ontwikkeling-gerelateerde ervaring opgedaan. Het experiment is continu begeleid door IISc en werd uiteindelijk in 2004 in beide dorpen beëindigd.

Tijdens het onderzoek in India bleek dat veel dorpen een biomassa vergasser aangeschaft hebben voor de voorziening van elektriciteit, zodat de rekening van het elektriciteitsbedrijf omlaag kon. Deze vergassers werden geplaatst met een subsidie van de Indische overheid. Na bezoeken aan deze vergassers bleek dat het grootste deel niet meer gebruikt wordt. Dit is te wijten aan een aantal factoren zoals slechte planning van de voorziening van de biomassa, het onderhoud, de financiën en de koppeling van

verschillende applicaties aan de vergasser. De staatsoverheid promoot de plaatsing van deze vergassers maar trekt onvoldoende lessen uit de slechte operationele staat. Het leerproces binnen deze overheid is laag.

Tijdens het onderzoek in India bleken er een aantal nieuwe plannen te zijn voor biomassa vergassers toepassing op het platteland, waarvan er drie bezocht zijn. BERI is een Indisch initiatief van verschillende (internationale) overheden en NGOs om een regio in Karnataka staat te voorzien van verschillende bio-energie systemen, waaronder vergassers. Na verschillende wijzigingen van plannen heeft BERI nu een cluster van biomassa vergassers gebouwd met een gezamenlijke productie capaciteit van 500 kW. Er zijn plannen voor snelle uitbreiding. De stroom wordt verkocht aan het elektriciteitsnet waarbij de omliggende dorpen gegarandeerd zijn van stroom. Dit is een nieuw en innovatief initiatief in India. Het BERI programma omvat ook training en gewaarwording van de platteland bevolking en de plaatsing van biogas installaties. Het Periyar College heeft ook plannen om een biomassa vergasser te plaatsen in een dorp. Het college heeft een ontwikkelingsprogramma waarbij technische en educationele steun gegeven wordt aan verschillende dorpen. De biomassa vergasser die geplaatst zal worden voorziet een (al van elektriciteit voorzien) dorp van stroom. Het doel is vooral om werkgelegenheid te creëren voor mensen die de vergasser bedienen en voorzien van biomassa en om het bewustzijn t.o.v. educatie te verhogen. DESI is de laatste die onderzocht is. DESI is een ontwikkelingsorganisatie met als doel de creatie van kleine bedrijven binnen de dorpsstructuur te bevorderen. Men heeft plannen ontwikkeld om 100 biomassa vergassers te plaatsen in 100 dorpen in het noorden van India, om de dorpen van stroom te voorzien. Educatie van DESI en de stroomvoorziening moet de dorpelingen aansporen kleine bedrijven op te zetten om extra inkomen te genereren.

Conclusies

We kunnen alle hiervoor beschreven applicaties en plannen onderverdelen:

- 1) De ontwikkelingsgroep, dit zijn DESI en BERI. Het doel van beide is het bieden van ontwikkeling, door middel van toepassing van technologie. Beide beiden naast de technologie ook een groot programma van educatie aan de bevolking. De plannen zijn goed ontwikkeld voor de ultieme doelen van ontwikkeling van Uphoff et. al.. De voorbereidingen wijzen op hoog applicatie succes en het institutionele succes is redelijk.
- 2) De onderwijsgroep, dit zijn de applicaties van IISc en de plannen van Periyar college, het succes in plattelands ontwikkeling is groot door de ervaring hierin en de technische kennis en steun. Er blijft wel een technische afhankelijkheid tussen de dorpen en het technische instituut. De ultieme doelen voor het Periyar College zijn bescheiden, voor IISc zijn deze beter. Het applicatie succes is redelijk hoog en het institutionele succes is redelijk.
- 3) De kosten besparing groep, dit zijn de applicaties in de dorpen om te bezuinigen op de elektriciteit rekening. Deze applicaties zijn veelal onsuccesvol omdat de begeleiding van de staatsoverheid te wensen overlaat in de vorm van technische en financiële steun. Er zijn alleen enkele ontwikkeling voordelen, het applicatie succes is laag en het institutionele succes is tevens laag.

Aanbevelingen

Om de situatie van de biomassa vergassers toepassing op het Indische platteland te verbeteren zijn een aantal aanbevelingen gedaan. De formatie van een werkgroep biomassa vergassers, waarin de ervaringen van de verschillende betrokkenen gedeeld wordt. Ook zou het nuttig zijn als er voor plaatsing een vooronderzoek gedaan wordt waarin zaken als financiën, technische ondersteuning en de beschikbaarheid van biomassa onderzocht worden.

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1 Introduction

This chapter will discuss the goals of the research as conducted and the justification of the subject of biomass gasifier applications in rural India. During the fieldwork research in India, a number of differences between initial theoretical assumptions and the practical observations were encountered. This caused me to incorporate a number of new biomass gasifier projects in the research, some of which were not envisaged in the original research plan. The reasons for doing so are described in section 1.3.

This chapter also provides a report outline in section 1.4.

1.1 Justification

As part of my curriculum, with specializations in 1) Development studies and 2) Sustainable energy, I choose India as an interesting country to visit for the graduation project. India is a rapidly developing country with an economic growth of around 9% and a rapid growth in energy demand.

The government of India has a special focus on rural development and on the implication of sustainable energy; both are of interest to me. It is well known that rural electrification can be a difficult issue, because environmental, developmental, social, financial and technical issues are involved.

I have had 2 courses related to biomass usage for the production of energy during my M.Sc. program at the TU/e; looking at the application of biomass induced energy production for the graduation project was therefore a logical choice. During the preparations in the Netherlands I discovered that especially the Indian Institute of Science (IISc) Hosahalli biomass gasifier project was well documented in international papers. Other projects however were not. Little or no data was available concerning the combined technical, social and financial aspects of rural biomass gasifier projects from the past.

In short, before leaving to India, a framework was ready, but most of the other items were still unknown. I had very little information concerning other (Non-IISc) biomass gasifiers in the rural setting. Luck combined with a lot of effort and assistance of Indians resulted in a number of case studies and an overview of both past as well as future biomass gasifier projects in India.

1.2 The goal

As described above, little or no data was available about the technical, social and financial success of biomass gasifiers placed in the rural setting in the past, with the exception of the IISc projects. The main goals therefore became to assess the extent to which the rural biomass gasifiers have been successful and to investigate the factors leading to the success of failure. This was done by the use of a multi-level framework incorporating the scientific work of Korten, Uphoff et. al. and others about the

functioning of development projects and programs. Uphoff et. al. (1998) has researched the reasons for success of development projects in Asia and identified a number of factors leading to success of rural projects. Korten (1980) has identified three levels of learning by institutions for development projects and programs. This framework is the tool in achieving the goals. The research as conducted and described in this report has been conducted from Feb. 2007 up to Aug. 2007 in South-India.

1.3 Differentiations in the theoretical assumptions and practical observations

This section describes the differences encountered between the theoretical assumptions, as derived in the preparation process in the Netherlands and the practical observations in India during the research. It can serve as a guide for future graduation students and provides a theoretical basis for the research.

1.3.1 Theoretical assumptions

In the theoretical preparation leading to the research framework, the main basis, with reference to the Indian biomass gasifier situation, was formed by scientific papers, Indian government papers, internet data and the correspondence with prof. Natarajan of the Vellore Institute of Technology University (VITU). During review of the scientific papers, only two clearly described biomass gasifier applications in the rural settings were found: The IISc applications in Hosahalli and Hanumanthanagara villages. The oldest of these, Hosahalli village, had the following characteristics with reference to the biomass gasifier:

- The village was unelectrified before placement of the gasifier
- The village was dominated by poor living conditions and small-scale farming
- No plans existed for fast grid electrification before installation of the biomass gasifier
- Installation and operation of the biomass gasifier had a large developmental impact on the village

In correspondence with prof. Natarajan, an interview with prof. Paul of IISc visiting the TU/e and by internet data, it was clear that more villages had biomass gasifiers installed. Detailed data concerning the situation of these villages was however unavailable and could only be found in India. It was however assumed that more of these villages had similar characteristics as Hosahalli village (i.e. an unelectrified village with large developmental impacts due to the biomass gasifier).

In view of this, with the data available of the IISc experiments the analytical framework for this study was designed including methods to determine the developmental impact such as the well being, productivity increase and empowerment using the theories described by Uphoff et. al..

When the research was started in India, the practical situation of the biomass gasifier applications in the rural setting proved to be partly different.

1.3.2 Practical observations

The first visits for the research in India were held at the IISc and ASTRA/CST, followed by the visits to Hosahalli and Hanumanthanagara villages. The framework as designed proved well applicable for the fieldwork. These visits were followed by visits to a number of firms, institutes, colleges and universities, involved in biomass gasifier research and installation. When visiting and interviewing various actors involved, the following was discovered:

1. There are new and interesting plans for biomass gasifier applications, differing from the already installed gasifiers in terms of planning, goals and impact.
2. The installed biomass gasifiers were installed in villages already electrified by the electricity grid. Most of these gasifiers were however not operating anymore within a few months to a few years.

1)

The new plans encountered during the research are 3 (future) projects, with a substantial difference in planning and/or technical setup. These include the first application of grid-connected biomass gasifiers in the rural setting, a college guided village biomass gasifier application in the PURA program and a large scale plan for the electrification of 100 villages using biomass gasification. The framework will be used to determine the anticipated developmental impact as described by the related institute / NGO and with relation to past experiences of this institute / NGO. These applications are described and analyzed in chapter 6.

2)

The application of already installed biomass gasifiers in Tamil Nadu in the rural setting mostly proved to be initiated by the local panchayat authorities in order to create employment and cut down on the electricity grid charges. These applications are used for the street lighting and drinking water treatment plants and pumping. When operating well, costs per unit can be lower compared to the grid charges according to the involved persons. The gasifiers were placed, not for developmental reasons but mainly for economic cost-saving reasons, although some developmental impact was caused due to the gasifier installation. The panchayats wanted to save on the grid fees and therefore purchased the biomass gasifiers. Most of these applications, mostly a few years old or less, are not in operation anymore due to a number of reasons. These gasifier applications will be reviewed looking at the application success and institutional success as defined in the framework. These applications are described and analyzed in section 5.3.

The framework proved to be well applicable for the IISc experiments, and partly applicable for the other applications. More will be described in the respective chapters.

1.4 Report outline

The research framework, used as the guideline for the scientific research as conducted is described in chapter 2. It contains the theories, present knowledge and research questions. The framework forms the basis of the research and is used throughout the report as a guideline. To place the research in the correct Indian electricity context, chapter 3 will describe the current Indian (rural) electricity situation. The electricity production, power subsidies, corruption and the MNRE schedule for biomass gasifiers is described in the chapter. The biomass gasifier technology is explained in chapter 4. This chapter contains a short explanation of the history, chemical processes and the various components in the biomass gasifier. The first analyse of the biomass gasifiers visited during the fieldwork research is described in chapter 5. The biomass gasifiers visited are the IISc. gasifiers placed in Hosahalli and Hanumanthanagara villages and 7 other small-scale gasifiers placed throughout Tamil Nadu state. During the fieldwork research, 3 new innovative plans for biomass gasifier projects / programs were encountered. These are described and analyzed in chapter 6. These are: 1) The BERI program, 2) The DESI program and 3) The Periyar College. These new initiatives are characterized by a closer fit between the technology and developmental goals and especially BERI and DESI have new innovations incorporated such as grid connection and CDM finance. The conclusions are described in chapter 7. This chapter divides all projects and programs in groups and the characteristics of these groups are analyzed using the framework as described in chapter 2. The recommendations, drawn from the conclusions are provided in chapter 8. The latter part of the report contains the bibliography, abbreviations and the appendices. I have tried to make the report as accessible as possible, in order to provide the information to a large population of (non-)scientists. I wish the reader a pleasant time, reading this report.

2 Research framework

This chapter will describe the framework designed for the research as conducted.

2.1 An overview of existing literature into rural biomass gasification in India

Research into the application of biomass gasifiers in rural India has been performed by several authors (Visser 2007, Coninck, et. al. 2005, Ghosh, et. al., 2004, Somashekar, et. al. 2000, Dasappa, et. al. 2004).

Somashekar (2000) and his colleagues of the Indian Institute of Science (IISc), located in Bangalore, have published papers about the experiments in Hosahalli and Hanumanthanagara villages during the 1980s up to 2004 as described in chapter 5. A biomass gasifier was placed in the village of Hosahalli as part of a field experiment. The research resulted in learning and publications were made in the field of operationality, technical problems and to a lesser extent the social aspects related to biomass gasifiers in the field. The experience has helped future projects such as in the BERI projects. These projects were however not scientifically analyzed.

Other scientists such as Ghosh et. al. (2004) describe an analysis of biomass gasifiers in a broad field of applications. The rural applications are only a part of their analysis. The paper does offer insight into the methods of applications for rural biomass gasifiers. These include policy, technology, finance and experiments. The developmental impact and the difficulties related to the rural development are however referred to in a lesser extent and are simply related to the local NGO responsibilities.

Coninck et. al. (2005) of the Netherlands ECN and the Indian TERI have made an analysis of the rural electricity situation in India, and how rural electrification can help in development. A number of villages were selected and case studies were performed to assess the community and commercial, industrial and agricultural energy demands. Calculations were made to assess the costs and financial viability of sustainable energy methods in these villages; these include solar PV systems and biomass gasifiers. The document also discusses the use of CDM as a means of finance and assesses the sustainability of the MNRE electrification plans by interviews with stakeholders. The paper offers a broad look into the opportunities and constraints of sustainable energy methods in India. The paper concludes that the Indian government implementation model of electrifying remote villages is largely inappropriate.

Dasappa et. al. (2004) are working at the IISc and discuss a distributed power generation system as designed by IISc in the paper. Technicalities such as, biomass moisture content, emissions, tar formation and the use of producer gas engines are discussed. The

technical research as conducted at IISc is also described. The technical issues related to the field experience in the villages of Hosahalli and Hanumanthanagara are described.

Visser (2007) has described her fieldwork research in India with the objective to “*improve the understanding of good practice in design and implementation of rural energy systems, which respect local circumstances and needs*”. The framework used was based upon the importance of continuous learning in development projects and contains theories of Korten, Douthwaite and Uphoff et. al.. During the fieldwork research, four rural energy system projects were evaluated. One of these was a biomass gasifier project, the Hosahalli project of IISc. Problems related to the termination were in the field of commencement and start-up, lack of funds, management problems and the competition of government subsidies schemes. Factors to prevent or solve the problems are economic sustainability of the utility, consistent political planning, careful choice of the environment in which the utility is operated and participation of the local population during all phases of the planning and implementation trajectory.

Above papers are beneficial for the understanding of the rural biomass gasifiers setting. These papers do not provide an overview of the success of a number of the biomass gasifiers installed in the past. Neither do most of the reports offer a combination of the development goals, the success of the application itself and the success of the related institute.

This report differs in 2 aspects from most of the above described reports:

1. It provides a review of a large number of biomass gasifiers, as applied for different purposes and by different institutes and governments throughout South-India.
2. It intends to provides a completer approach, previous report has mostly analyzed either one project or program or looked at only one level of analysis, this report combines:
 - a. Ultimate goals of development (production, well being and empowerment)
 - b. Application success of the biomass gasifier (technical and financial)
 - c. Institutional success

The framework has been developed upon information gathered by international papers, interviews with Dutch and Indian scientists, and by e-mail contact with prof. Natarajan of Vellore Institute of Technology University (VITU).

2.2 Uphoff: Ultimate goals of development

Uphoff et. al. in “*Reasons for success: learning from instructive experiences in rural development*”, published in 1998, analyses the reasons for success and failure of development efforts in the rural setting performed in Asia. Uphoff et. al. describes lessons to be learned from rural development projects in the past, and they offer a number of successful projects and programs in particular, and hopes for successful rural

development in general. They describe a number of factors involved in successful rural development. Uphoff et. al. emphasise the importance of continuous learning in rural development projects, both for long and short term goals. Rigidity of ideas and programs (this is the un-ability to change ideas and programs when required for the benefit of the project / program) restricts rural development and thus flexibility (the ability to change ideas and programs when required for the project / program) and openness to information, ideas and instructions are vital. These factors make that rural development is often a difficult and unpredictable process; factors contributing to success can however be identified.

When researching rural projects, we can identify different levels of success and failure, as described by Uphoff et. al. (1998), all rural development should at least achieve all of the following:

- (Increase in) productivity
- (Increase in) well-being
- Empowerment

2.2.1 Productivity

Productivity means: *“that rural people are able to utilize those factors of production under their control and other to which they have access to produce combinations of goods and services that are demanded and reasonably remunerated by others through market transactions”* (Uphoff et. al. 1988, pg. 197).

In the practical sense, productivity increase in the rural setting will mostly be an increase of the crop yield per acre (or a decrease of input costs with equal yields) and/or an increase of income for the farmers (possibly by extra income due to non-farming activities), and an increase of production of the small-scale industries when present. With productivity increase, the farmers and their families gain more independence and purchasing power, thus reducing dependence on charity, government aid and relatives. With higher purchasing power, families have a better chance in breaking the vicious circle of poverty.

2.2.2 Well being

Well being constitutes a wide range of items and differs per situation.

Uphoff et. al. (1988, pg. 197) describes it as:

“Well being consists of a wide range of attributes, (...), good health and the vitality that comes from good nutrition and freedom of diseases are part of this. The knowledge of opportunities, of culture, of religious and other concepts that comes from literacy, (...), amenities such as water, electricity and clothing”

To indicate the connection between access to reliable energy and well being, the 7 items of the Millennium Development Goals (MDG) are described here. Every item is also

related to the access to reliable power. The MDG goals are not used throughout the report and function as an illustration of the positive benefits reliable energy can provide to a population. In 2000 United Nations members decided to adopt the millennium declaration, followed by the Millennium Development Goals (MDG), containing time-bound goals to reduce poverty and increase well being of poor people globally (International Bank for Reconstruction and Development 2005). A close link between energy access and poverty reduction is identified (IBRD 2005, pg. 8), making safe and reliable energy access one of the ways to achieve the MDG set goals.

The main well being items identified for this research are education and healthcare, both attribute to well being. When related to the energy availability the following can be identified as having links with the solutions (renewable) energy can offer (Worldwatch Institute 2005):

MDG 1: Cutting extreme poverty and hunger

- Enabling irrigation to increase and secure crop yields
- Improving the preservation of food by cooling
- Generating light for production beyond day light
- Providing power for food preparation

MDG 2: Universal primary education

- Providing light for reading beyond day light
- Reduction of child labour due to increased income as a result of electrification
- Providing electricity in schools for educational purposes (internet access, light, etc.)

MDG 3: Gender equality and women empowerment

- Providing power for flour mills and drinking water pumps, thus reducing food collection and preparation times.
- Street lighting to increase women's safety
- Lighting for home study and women self-help groups

MDG 4-6: Health

- Safer drinking water by water pumps
- Access to health information (i.e. radio)
- Better medical care through refrigeration of medicines
- Lighting for healthcare beyond day light
- Better food preparation

MDG 7: Environmental sustainability

- Reducing deforestation by plantation of forests
- Reducing greenhouse emissions

The well being can be improved if reliable energy such as electricity is available. This means electricity at 24 hours a day or at set times, with sufficient capacity and voltage.

2.2.3 Empowerment

The third element identified by Uphoff et. al. is empowerment. This is a difficult item to determine properly. Determining whether people feel or are more empowered depends upon their attitude and perception. Increased production as described by Uphoff et. al. also contributes to empowerment. Empowerment is also related to well being, since well being will increase when production increases. When poor people are empowered, power shifts and inequality between the poor and powerless and the rich and powerful decreases.

Uphoff et. al. (1998) describes empowerment as following.

Empowerment is: *“a degree of control over the circumstances and destiny of individuals, their families, and their communities. (...) Empowerment includes the ability to resist encroachment on the economic or cultural interests that are valued by the individual and the community and to promote those interests by means that others are willing to respect.”*

All items identified by Uphoff et. al. are interrelated and are identified as the minimal requirements rural development projects and initiatives should achieve.

For the programs to achieve the ultimate goals as defined above Uphoff et. al. defined the following criteria:

- Resource mobilization
- Scaling up and expansion
- Diversification
- Continued innovation

Uphoff's theory can only be a part of the analysis of the biomass gasifier programs run in India. The theory is applicable for programs run in the past as well as programs still running. More theories have to be applied however to make a complete analysis. The application success of the program cannot be measured by the theory of Uphoff et. al.. The rate of application success partially determines the achievements of the goals set by Uphoff et. al., and should therefore also be evaluated.

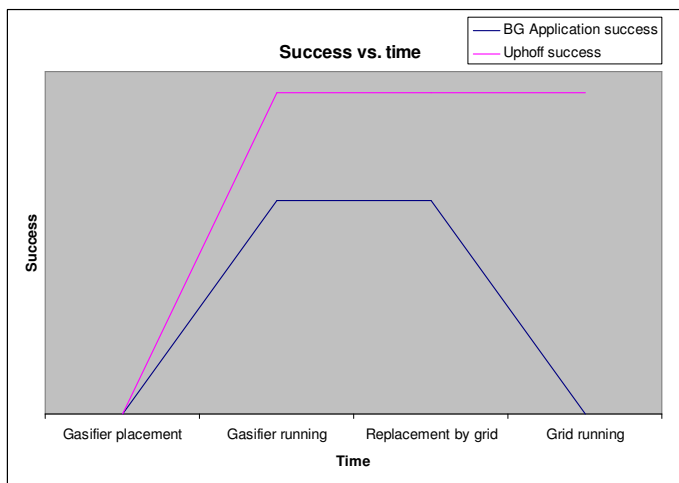
2.3 Application success

When evaluating the application success of a technical application two factors can be identified as relevant:

- Technical success
- Financial success

This application success is required to achieve Uphoff's goals. This does however not necessarily go vice-versa. After termination of the application, former success might have given rise to achievement of the Uphoff et. al. goals and the positive benefits might still stay present.

An example: A biomass gasifier electrifying a village for the first time gives new benefits and achieves Uphoff's goals such as street lighting for safety and lighting in house for reading and schooling. Other benefits such as empowerment and higher agricultural production may also be achieved. If the biomass gasifier is running successfully (technically, financially and socially), both Uphoff's developmental impact and the application success are high. If the biomass gasifier electricity is (in a later stage) replaced by grid electricity, the positive externalities caused by the gasifier might still be in place (street lighting, higher agricultural productivity), although the application success is no longer there (the biomass gasifier operation has been terminated). Although the biomass gasifier is no longer running the positive externalities caused in the past are still present. It is therefore relevant to determine both levels of success separately in order to perform a proper analysis. This is shown in graph 2.1.



Graph 2.1: A hypothesized theoretical success relationship between Uphoff's Ultimate goals of development and the application success

2.3.1 Technical success

The technical success concerns the technical aspects of the gasifier; these include the daily operation of the gasifier and all other technicalities concerned. The daily operation requires a skilled operator able to operate the biomass gasifier and perform small technical repairs and maintenance such as engine oil replacement, and cleaning of the components. Other technical issues, mostly required to be performed by others include larger engine maintenance and larger repairs. Learning of the people involved is also important, this includes technical learning for the operator, learning to grow biomass

crops for the local farmers and learning how to cope with electricity and the new applications that come with it, by the local population.

2.3.2 Financial success

The financial success of the application concerns the costs for daily operation, such as feedstock, operator salary and all maintenance costs. The financial success also concerns the collection of the fees for operation and the costs associated with the scheduled and un-scheduled maintenance requirements and initial purchase costs.

When expenses (for biomass and diesel fuel, maintenance, salaries, purchase costs, etc.) outweigh the income (by subsidies, fee collection, etc.), the application cannot be regarded financially sustainable. Learning is also involved, this includes fee collection, book keeping, costs of operation, maintenance and fuel costs, etc.

2.4 Institutional success

The institutional success involves the success and capabilities of the NGOs, institutes, companies and governments involved in placement and guidance of the biomass gasifiers. The highest level is the central government through the 5-years planning and the Ministry of New and Renewable Energy Sources (MNRE). On state level MNRE nodal agencies such as for example for Tamil Nadu, the Tamil Nadu Energy Development Agency (TEDA) represents the MNRE policy and are state-wide responsible for implementation and subsidy granting of renewable energy technologies and projects.

The institutional success is the success and experience of the institute / government instigating and running the projects and programs. The hypothesis behind this is that institutes / governments with a lot of experience and good learning processes have been able to run better projects and are likely to do so in the future.

Institutes should be able to increase their institutional capacity building (Korten 1980, pg. 484)

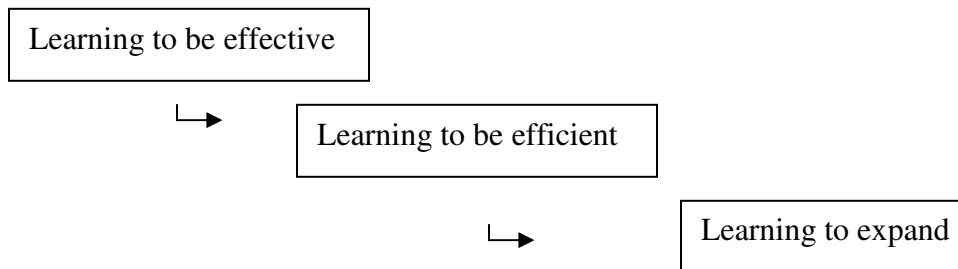
Korten has written about the institutional success, one of the main items is the flexibility to learn from errors in the past, and be able to adjust the program when necessary.

Various programs were evaluated by Korten, he wrote (Korten 1980, pg. 496): *“Each project was successful because it had worked out a program model responsive to the beneficiary needs at a particular time and place and each had built a strong organization capable of making the program work (...) they had achieved a high degree of fit between program design, beneficiary needs and the capacities of the assisting organization.”*

Korten’s view on the flexibility of programs corresponds with Uphoff; Uphoff et. al actually recognize Korten’s influence in the learning process (Uphoff et. al.1998, pg. 21).

In his research Korten has evaluated Asian rural development programs running for an extended period of time and described these. By analyzing the reasons for success and failure, 3 phases were defined which (non) governmental organizations and institutes involved in rural development programs should go through as they grow and gain experience. These 3 phases are well defined by Korten and can serve as a manual to evaluate the organizations, institutes and governmental organizations involved in the biomass gasifier programs as evaluated in this report.

Korten (1980, pg. 499) has defined the 3 phases in the evolution of development organizations as follows:



Phase 1: Learning to be effective

As stated by Korten (1980 pg. 499-500):

“...the major concern is with developing a working program model in the setting of a village level learning laboratory that has a high degree of fit with beneficiary needs.”.

This first phase requires sufficient freedom and time and is clearly characterized by a learning process between requirements and the appropriate fit. It requires learning about the community dynamics, but it also involves learning how to learn (Korten 1980, pg. 500). Error rates can be high and efficiencies low.

According to Korten (1980, pg. 500) the program starts to make the transition to phase 2 when: *“it is found to be effective in responding to an identified need and it achieves an acceptable level of fit between beneficiaries, the working program model, and the capabilities of the action research team”.*

Phase 2: Learning to be efficient

In phase 2, the main items are to reduce the input requirements per unit of output (Korten, 1980 pg. 500). It is the phase of normalization of the project in which the benefits have been shown in phase 1, and efficiency should be increased. It is possible that some effectiveness will be lost at the cost of efficiency. And (Korten 1980, pg. 500): *“...there should also be serious attention paid to the problem of achieving fit between program requirements and realistically attainable organizational capacities...”*

The amount of skilled staff should increase in phase 2, this is the phase in which to train new staff in gaining experience through the lessons learned and successes and failures within the program.

A transition to phase 3 would be achieved (Korten 1980, pg. 500): “*Once acceptance levels of effectiveness and efficiency have been obtained, the program model reasonably stabilized, and expanded cadre trained, and basic management systems requirements worked out...*”

Phase 3: Learning to expand

In this phase the emphasis will be on expanding the program. As described by Korten (1980, pg. 500): “*...expansion of organizational capacity, though continuous refinements may also be required in the program to respond to the demands of larger scale operation.*”. The expansion of the program will involve some loss of effectiveness and efficiency due to the increasing size of the program. The rate of growth is determined by the organizational capacities. According to Korten, the program leader can only start with new solutions to problems when phase 3 is successfully achieved and matured. Please see table 2.2.

Table 2.2: The three phases of Korten

	Certainty	Effectiveness	Efficiency	Required flexibility	Staff #	Program size
Phase 1	Low	To achieve	Low	High	Low	Equal
Phase 2	Medium	Equal / lower	To increase	Low	Expanding	Equal
Phase 3	High	Slightly lower	Slightly lower	Low	Equal	Expanding

For the research as described in this report, Korten’s definitions are used to determine the success of the institute, company or government involved as initiator or promoter of the biomass gasifier programs and projects.

This report contains an assessment of both past as well as future programs.

2.5 Indian rural electricity setting

The Indian rural electricity setting is the setting in which the technology is placed. It largely determines the success and failure of the biomass gasifier. The Indian rural electricity setting involves subsidies for the biomass gasifier, subsidies for the grid power, the government schedules for rural development and other items. It largely determines the boundaries of the biomass gasifier applications. More is explained in chapter 3.

2.6 The framework model

The framework items are also (partly) described as the main factors by Agarwall (1983) in the successful diffusion of woodstoves in various places around the world. The paper describes a number of aspects related to the diffusion of technology in the rural setting in developing countries. She identified the following aspects (see table 2.3):

Table 2.3: The Agarwal vs. Ermers aspects of rural diffusion of technologies

Agarwal	Ermers
Technical aspects	Analyzed in “application success: Technology”
Economic aspects	Analyzed in “application success: Finance”
Infrastructural aspects (credit, extension, etc.)	Analyzed in “Institutional success” and in “Energy in India”
Cultural aspects	Not analyzed, please see section 2.9
Social structure	Not analyzed, please see section 2.9

Although the Agarwal (1983) report was about a different technology (woodstoves vs. biomass gasifiers), the aspects identified by her can be seen as a particular approach into the diffusion of rural innovations. Agarwal does not describe the actual development impact within these aspects. In this report the development impact is analyzed using the “Ultimate goals of development” as defined by Uphoff et. al. (1988).

The framework as designed for the research is not a linear model. In the linear model innovation of a technology (in this case the placement and socio-technical innovations of biomass gasifiers in the rural setting) is depicted as a logical stepwise system from research to development to production to marketing (Kline and Rosenberg 1986). The linear model has no feedback paths. These are however required: “...redesigns are essential to ultimate success” (Kline and Rosenberg 1986, pg. 286). In the context of the framework, this means that the items are interrelated and feedback paths between i.e. the initiating institute and the success of the ultimate goals are required. The initiating institute, installing biomass gasifiers should adapt continues learning from experiences by the feedback paths. This is described by Kline and Rosenberg (1986) as the chain-linked model.

When we combine the above described, we can draw the following picture 2.4.

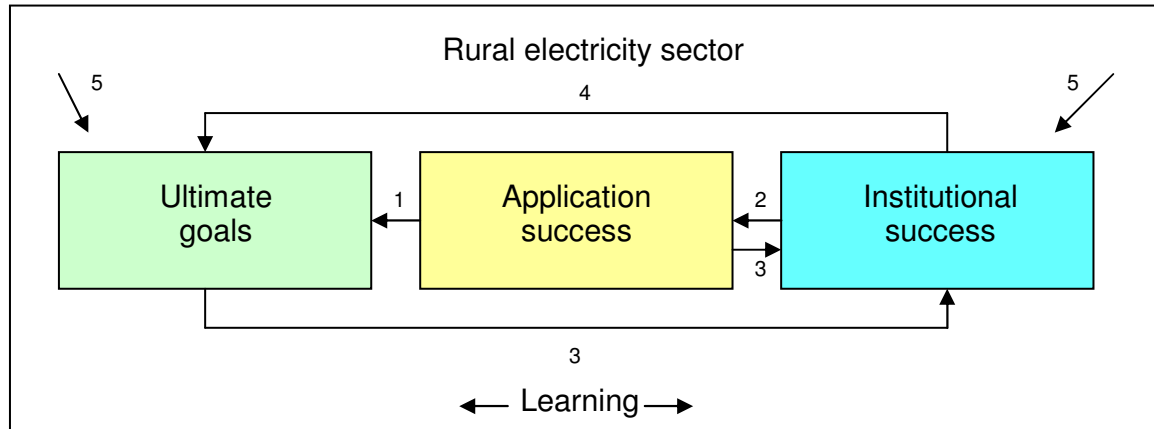


Fig. 2.4: The framework graphically represented with feedback paths

The three items of the framework are all set in, and influenced by, the rural electricity sector (lines 5 in fig. 2.4). This sector determines the boundaries of the biomass gasifier technology, in the form of regulation, subsidy schedules and the demands for energy.

Achievement of the ultimate goals is only possible when the application was / is also successful (line 1 in fig. 2.4). The ultimate goals and the application success largely determine the institutional success: when effectiveness has been reached (as in achieving the ultimate goals and application success), the institutional success can shift from phase 1 to phase 2 (lines 3 in fig. 2.4).

The application success is largely determined by the experience of the initiating institute / government (line 2 in fig. 2.4). These have to create a close fit between the technology and the requirements of the rural population. The institutional success also largely determines achievement of the ultimate goals (line 4 in fig. 2.4), because of the congruence between institutional experience and the fit between the program / project and the local requirements.

Learning is taking place on all levels, for all actors and throughout the time of the project / program. Learning is described in the sections in chapter 5 and chapter 6.

2.7 Techniques of research

The theoretical framework as described above is operationalised using interviews, observations and existing literature. In total, 18 people were interviewed, some of which several times, and more people were asked for their opinion in less official methods (discussions, village visits, etc.). A total of 12 (former) projects / programs were visited and described in this report.

The research is qualitative, and involves cross-checking by interviews with the involved actors and literature study. Possible disparities are described, and the opinion of the

author of this report is added, based upon the observations. Qualitative research was chosen over quantitative research because the statistical data required for quantitative research is difficult to acquire in developing countries, and data provided by the government is often less reliable. The information about the number of biomass gasifiers in India for instance is misleading, since power installed of all gasifiers is added up, but the actual number of gasifiers still in operation is unknown. Qualitative research provides for extended descriptions and is therefore better applicable in this research. The interview questions have been made in cooperation with Mr. Tamil Maran, a social scientist of Vellore Institute of Technology University (VITU). Different questions have been constructed for 1) Villagers and local politicians, 2) Involved institutes and governments, 3) Producers and 4) Involved NGOs. These questions are shown in appendix A. In total, 18 interviews were held, the most important of which are shown in appendix B. The technical success will be determined by the amount of operation, discussions with operators, village population and officials and by a literature study. The interviews combined with the observations made during the fieldwork research are combined into evaluations per project / program and by dividing these into groups of applications. By doing so, conclusions can be drawn into the reasons of success and failure of different projects and programs, run by different institutes and governments.

2.8 Research questions

For the research the following research questions were developed.

Questions with relation to the impact indicators:

- What is the extent of the success when looking at the ultimate goals of development (well being, productivity and empowerment)?

With relation to the application success:

- What is the extent of success when looking at the application (technological, social and financial)?

In relation to explaining the success:

- To what extent were the projects institutionally successful and to what extent did their institutional performance contribute to reaching the ultimate goals of development and the application successes?

In relation to the rural electricity context in India:

- What rural electricity system changes can be made to increase success of rural biomass gasifiers in India?

2.9 Limitations of the research

The goals of the research as conducted proved ambitious, and this has resulted in limitations of the research. The goals were to:

1. provide a broad overview of the current status of the biomass gasifiers in rural India.
2. Provide the reasons for failure and success of these gasifiers, based upon the 3 level framework (ultimate goals, application success and institutional success).

The main problem faced was the combination of both goals. Goal 1 is to be reached by visiting many rural biomass gasifier sites, talking to many people, without an in-depth analysis. The second goal is best achieved when these sites are analyzed in-depth, including all levels of people, organizations, (local, state and national) governments, etc. involved. This requires an extended period of time per site. With the limited time of 6 months available for the fieldwork research in India, this proved difficult. The village level dynamics have therefore been underexposed for analysis. The village level includes (among others):

- Power structures in the village
- Political affiliations in the village
- Landownership
- Equality division among the villagers
- Gender issues
- Personal agendas

During the fieldwork visits above factors proved difficult to determine, and beyond the possibilities of a researcher with limited time. Difficulties include the lack of knowledge of the local languages and the lack of knowledge of the local culture.

The dynamics in villages are very difficult to comprehend when looking from the outside; these also differ per village and require extensive research and observation per village. These structures do however play a role in the success or failure of the rural biomass gasifier applications. Agarwal (1983, pg. 372) about succesful diffusion: “...*to suit specific users’ needs, is a crucial factor in adoption, requiring a close interaction of the designer with the local people and the users*” and it “...*is seen to depend crucially on the structure of economic and social relationships characterizing the area*”. It would be interesting for another research to analyze the village dynamics involved with rural biomass gasifier applications. It is best to do this, in a few villages to be able to have sufficient time to perform the research.

The fieldwork research as described in this research has therefore been mainly based upon the discussion and interviews held with the villagers, with educational institutes, NGOs and governments and by an extensive literature study.

The research did achieve the following:

1. It is the first research analyzing the current state of a larger number of rural biomass gasifiers (and future plans) in India.
2. Conclusions and a set of recommendations were formed for changes in the current rural biomass gasifier applications and future plans. These are based upon the interviews, discussions and literature study performed during the fieldwork research.

3 Energy in India

3.1 Introduction

This chapter will describe the electricity situation in India, the relevance of electricity availability for rural development and the initiatives of the Government of India (GOI) for the promotion of rural electrification.

Some figures about India (see table 3.1):

Table 3.1: Indicative figures about India (Ref: CIA 2008)

Population	> 1,1 billion people
Age (total ¹)	Median of 24,7 years
Life expectancy at birth (total)	68 years
Infant mortality rate (total)	34,61 / 1000 births
Literacy (total)	61%
Labour force occupation	60% Agricultural, 12% Industry, 28% Services
Gini index	0,368
GDP per capita @ PPP	3800 USD
GDP real growth rate	9,4%
Inflation (consumer prices)	6,2%
Administrative division	28 states and 7 union territories

3.2 Energy in India

With an economic growth of around 9% in India, electricity demand is high and expected to increase in the next years (UNDP ???). Overall production of electricity has more than doubled from 264 billion units (1 unit means 1 kWh) in 1990-91 to 587 billion units in 2004-05 (Ministry of Power 2006). During the period of 1981-2000 average domestic production increased by 5.4% annually (Grover 2006) (see table 3.2). Despite the significant growth of power produced, shortages are very common (Bhattacharyya 2006). Peak shortages were up to 11.7% in 2004-05. The government of India has planned to increase production capacities by installing nuclear, hydro and thermal power plants. Although the largest portion of the planned capacity will be built within the designated time, the goals will not be achieved completely (Ministry of power 2006).

¹ Total means the average of male and female

Table 3.2: The installed electricity capacity in India (Source: Sharma 2007)

Power source	Installed capacity (MW)	Share (%)
Thermal (coal, gas, oil)	81.859	66,3
Nuclear	3.310	2,7
Renewable (wind, solar biomass, small hydro)	6158	5
Rest (i.e. large hydro)	32.135	26
Total	123.462	100

Those mostly affected by the power shortages and erratic power behaviour are the rural population, comprising over 70% of the Indian population. Specifically the problems of rural electricity are:

- Unreliable, the times of power availability are unknown and people cannot plan their activities accordingly.
- Unavailability of grid power. Although most of the Indian villages are grid connected, thousands of villages are not. Most of these villages are located in remote areas and providing grid power is too costly.
- Too low voltage, due to long power lines to the villages, the voltage is often too low for application of certain apparatus (light emitted is too little, TVs do not operate, irrigation pumps might not run).
- Connection costs, even if villages are grid connected, it is too expensive for most households to connect a line from their house to the village power line.
- Theft of power, a large amount of electricity is stolen, both by households and firms / (small scale) farms. The amount of legally available electricity is therefore less.
- Transmission and distribution losses, due to the large distances covered. This is as high as 40% (Sharma 2007).

Most of the production and distribution of the electricity is in the hands of the State Electricity Boards (SEBs) (World Bank 2006). Many problems exist in the electricity sector; these are mostly on state level. The sector is politically captured and suffers from huge deficits, unsustainable subsidies and large-scale theft. It is estimated that the current electricity situation causes a loss of 1,5% of GDP growth annually (World Bank 2006).

3.3 Rural development and electricity

Providing reliable power to the rural population can have a large positive impact; energy is truly essential for development throughout the world (Zomers 2001, Kishore 2004, Sharma 2007). Causal relationships have been observed between the availability of power and economic growth (Zomers 2001, Kanagawa 2007). Others argue that there is flexibility between the energy consumption and income relationship. Especially demand management policies are equally important (Pachauri 1982). Rural electrification in India has grown from a number of 1500 electrified villages in 1947 to the many hundred of thousand of villages currently electrified (Ministry of Power 2006).

The definition of an electrified village is: “A village will be deemed to be electrified if electricity is used in the inhabited locality within the revenue boundary of the village for any purpose whatsoever” and if: (Ministry of Power 2006, Sharma 2007)

- Basic infrastructure such as distribution transformer and distribution lines are provided in the inhabited locality as well as the hamlet where it exists
- Electricity is provided to public places like schools, health centres, etc
- The number of households electrified is at least 10%

Various programs have been initiated by the Government of India to provide electricity to the rural population. These have been launched throughout the 80s, 90s and in the beginning of the 21st century. These mostly comprised a capital subsidy for rural electrification projects, ranging from 40% to 90%. Subsidies are provided for creation of (Ministry of Power 2005):

- rural electricity distribution backbones, with one 11/33 kV substation where not already available
- Creation of village electrification infrastructure, for electrification of the un-electrified villages
- Decentralized distribution generation, for villages where grid power is not economically feasible

At the moment 43.5% of all households in the rural sector are electrified (Srivastava 2006). This largely differs per state, in Bihar, one of the least developed states of India the percentage of un-electrified (rural and urban) households is 94,9% (out of a total of approx 12.000.000 households). In Tamil Nadu this number is 28,8% (out of a total of approx 8.200.000 households) (Ministry of Power). The current goal of the Government of India is to have all households electrified in the year 2012 (Sharma 2007).

3.4 Power subsidies, theft and corruption

Rural power is highly subsidized by the state governments. Both kerosene and electricity are either free or highly subsidized. In 1999-2000 both subsidies amounted to a total of 5.5 billion US Dollars (Srivastava 2006, Sharma 2007).

The official argument for free electricity is the development and support to agriculture. Research by the World Bank however showed that those benefiting most are the rich farmers. Only the rich farmers can afford electrically operated water pumps for irrigation. In Tamil Nadu, only 20% of the farmers depend on power for irrigation of their crops (World Bank, 2006). It is estimated that only 10-12% of the subsidies rewarded is recovered by increased crop yields (Srivastava 2006). The reason to the existence of the current subsidy regime is indicated in the World Bank report and is due to the political power of the big and rich farmers. They mostly form the heads of their clans or communities. The political power of the small farmers is scattered and small.

The development of these subsidies took place in the 70s and 80s and still remains a large burden upon the state government budgets. This coincided with the increasing use of

High Yielding Variety (HYV) crops developed in the Green Revolution (Srivastava 2006) requiring more water. The HYV developments continued however and resulted in crops which are currently in use requiring less water.

Politicians discovered the ease of gaining votes accordingly and the State Electricity Boards (SEBs) could hide their transmission and distribution losses by claiming free electricity delivery. Providing free power also diverts attention away from sustainable (environmental friendly) solutions. Subsidies for kerosene reduces the need for the local and central governments to provide better solutions such as reliable (sustainable) electricity for lighting or natural gas lines for cooking.

Individually people indicate a willingness to pay for power, if the supply is reliable and continuous (World Bank 2006, Srivastava 2006). The withdrawal of subsidies is however difficult because those profiting actively oppose this and feel their position is threatened. The chicken and egg problem does occur however; if power supply is erratic and unreliable, people prove unwilling to pay; in turn the SEBs are unwilling and unable to supply enough reliable power when people are unwilling to pay.

The extensive subsidy program eventually resulted in the SEBs being unable to finance and maintain reliable electricity supply. The poor still lack access to electricity and do mostly not benefit by the subsidy regime (World Bank 2006, Srivastava 2006).

Corruption and theft are also large problems in the electricity production and finance system (World Bank 2006, ECN 2005, pg. 52, Ministry of Power 2005). There are several types of corruption ranging from government officials accepting bribes to villagers illegally connecting their house to the power lines (theft). Due to the lack of accountability officials get opportunities to enrich themselves and the power sector is ranked third in the list of most corrupt in the public perception, preceded by police and healthcare (World Bank 2006, pg. 12). As described by the World Bank (2006, pg. 11), an assistant engineer can increase his normal income of USD 450 to USD 4500 per month through corrupt means (i.e. by installing illegal connections). Villagers often self-connect their houses to the power lines in order to get power without paying for the fees and connection costs. This is often occurring as observed during the research. It is estimated that annually a total of 4 billion USD worth of electricity is stolen (World Bank 2006, pg. 11). An increasing transparency and accountability on all levels can decrease corruption. It will however be a long way, since corruption is present and wide-spread in all levels of society and government.

3.5 Clean energy developments in India

India is probably the only country in the world to have a Ministry of New and Renewable Energy Sources (MNRE). This ministry provides funds, subsidies, R&D support, attractive loans and advice for the implementation of renewable and sustainable energy methods in rural, urban and industrial settings. In 1992 the Ministry of Non-Conventional Energy Sources (MNES) came into being, in 2007 the name changed to MNRE. In 1992, it was already clear that sustainable energy methods were not financially viable and that the existing electricity subsidies formed a block against implementation. The sustainable energy methods did not get fully integrated in the overall energy planning process (Sharma 2007). Before 1992 subsidy funds were spent on the promotion of solar, wind and biomass in the rural areas. Much of these efforts remained at the demonstration level however. Solar systems in the rural setting soon became dysfunctional because of the low maintenance support. Biogas plants, installed in their thousands, mostly failed because of the lack of institutional support and the lack of ownership by people and communities. With the formation of MNES, the sustainable energy methods improved. The subsidy driven system was abandoned and a separate financial agency, the Indian Renewable Energy Development Agency (IREDA) started the finance of commercial wind power and other projects (Sharma 2007). Although a lot of inefficiencies still exist, as will be shown in this report, the situation improved, eventually resulting in a share of 5-10% of sustainable electricity production.

The potential for renewable sources of energy is high in India as shown in table 3.3.

Table 3.3: Renewable energy in India for march 2003 (ref.UNDP ????, table 1)

Source	Potential (MW)	Achieved (MW)	Share (%)
Wind power	45000	1870	4,2
Small hydro power	15000	1509	10,1
Biomass / bagasse cogeneration	19500	537	2,8
Waste to energy	1700	12	0,7
Total	81200	3928	4,8

At the moment approx. 5-10%² of the total electricity produced in India, is produced using sustainable energy methods; half of this by wind power, 30% by bio power and 20% by small hydro power (Sharma 2007, MNRE website). The energy sector is faced with increasing costs of the conventional electricity production inputs as oil, coals and natural gas. All of them are not expected to decrease in a short period of time.

Items related to policy, regulation, finance and institutional matters are still hindrances to an increase of sustainable energy systems. As Sharma (2007) wrote: *“The country needs a dedicated policy on decentralized power. (...) This needs to be followed up with a set of detailed guidelines, based on the experiences so far and written with involvement of all stakeholders concerned. (...) At the same time, results of all technology demonstration and pilot projects should be pooled, evaluated to derive a set of conclusions.”* This also

² Sharma indicates a share of 5% (Sharma 2007) for renewable energy, The Ministry of New and Renewable Energy Sources claims a share of 10% for renewable energy (MNRE website)

underscores the usefulness of this report as assistance towards the goal of having sufficient evaluating information for policy plans.

3.6 Critiques on the clean energy initiatives

The Government of India has received critical remarks about the clean energy programs in rural India, in international scientific papers and in the national newspapers. The lack of a clear policy framework is one of the main critiques (Srivastava 2006, UNDP 2004). Because of the limited purchasing power and energy demands of the rural population focus there is a bias away from a focus on rural solutions in the planning process. Another problem related to the clean energy in India is the division of energy related issues over a large number of ministries and agencies including the Ministry of Power, Ministry of New and Renewable Energy Sources, Department of Atomic energy and other agencies. When many parties are involved, responsibilities become unclear. The implementation of plans is done by different ministries (Srivastava 2006), thus increasing uncertainty of the programs.

The lack of access to clean technologies and fuels is another problem described by Srivastava (2006). The penetration rate of LPG for instance is very low in the rural areas; people are therefore forced to cook using environmentally unfriendly kerosene. Many people also do not have access to electricity; they are forced to use diesel-generator sets for electricity production when required.

The grid importance has been overemphasized, rural electrification is mostly considered equal to the provision of grid lines in the village. Whether people are able to actually pay for the power and especially for the power connection to their house is an under-appreciated problem (Ref: interviews during fieldwork). The reliability of the grid power is very low, power shortages and low voltages often occur in the rural areas and less often in the urban areas.

3.7 The biomass gasifier program of MNRE

The Ministry of New and Renewable Energy (MNRE) has a program to promote the application of biomass gasifiers in the rural setting. It is part of a larger program to promote sustainable energy methods throughout India; these also include wind power, solar power, biogas installations and small water dams.

With regard to the biomass gasifiers the following objectives are indicated by MNRE (Website MNRE):

- To deploy biomass gasifier systems for meeting unmet demand of electricity in villages
- To take up demonstration projects for 100% producer gas engines, coupled with gasifier for off grid and grid power operation
- To support and enlarge activities, through awareness creation, publicity measures, seminars / workshops / business meets / training programme etc

The MNRE has designated state nodal agencies (SNAs) as representatives. For Tamil Nadu, this is the Tamil Nadu Energy Development Agency (TEDA). It is the task of TEDA to promote the application of sustainable energy methods. TEDA has employees working on this promotion. A special truck equipped with sustainable energy examples is used to inform the urban and rural population (fig. 3.4).

As indicated by MNRE, so far (in 2005) a total of 1900 biomass gasifiers have been supplied with subsidies (MNRE 2005). This (probably) includes a large number of small scale 2-5 kW gasifiers placed in the 80s; none of which are running anymore.



Fig. 3.4: The TEDA truck used for promotion purposes

The MNRE subsidy schedule is as following (MNRE 2005, Website MNRE):

Table 3.5: The subsidy schedule of MNRE for rural biomass gasifier projects

Type of application	Capital subsidy (2005-2008)
Thermal, including cooking (up to 3 MWth)	Rs.125.000 / 300 kWth
Electrical, including pumping and captive power, with provision for surplus power to grid (Dual fuel system)	Rs. 150.000 / 100 kWe
Electrical with 100% Producer gas engines	Rs. 1.500.000 / 100 kWe or Rs. 1.000.000 / 100 kW for engines alone

Costs for biomass gasifier-based electricity generation systems range from Rs. 40.000.000 to Rs. 45.000.000 / MWe according to MNRE (2005). It practically means that around 1/3 of the required costs is provided by the MNRE subsidy. Besides the above schedule, MNRE also provides extra subsidy for special category states and islands (20% more) and for the organisation of seminars business meetings, workshops etc. In interviews people also indicated that approx 50% of the purchase costs were paid by MNRE subsidies.

The MNRE subsidy funds are provided via this schedule (MNRE website):

- 1st instalment of 20% along with the sanction letter
- 2nd instalment of 50% on supply of the equipment at the site
- 3rd instalment of the remaining 30% on erection and commissioning and after 3 months / 1000 hours of trouble free operation of the whole system and submission of audited statement of expenditure and utilization certificate

Applying for these subsidies can be taken up by any village level organization, panchayat, institution, private entrepreneur, industry, etc. in rural areas other than the industries and commercial establishments covered under urban, industrial and

commercial application programmes (Website MNRE). Proposals are to be submitted in a pre-described format to the concerned SNA (i.e. TEDA for Tamil Nadu), who will forward this to the MNRE.

For the financial year of 2007-08 a total of Rs. 10.000.000 is available for the North East states and a total of Rs. 22.500.000 of subsidies is available for the other states. The physical target of MNRE is to have 3 MW equivalent biomass gasifier systems for electrical applications installed in 2007-08 (Website MNRE).

4 Gasification technology

4.1 Introduction

This chapter will describe the gasification technology and gasifier components. Biomass gasifiers come in a range from 2 kW to 100+ MW and can therefore contain varying components. The main components and characteristics will be described. This will be done in a limited matter, since this is not the main focus of this report.

4.2 History

Biomass gasification to produce a combustible gas is a well known technology, first used in the 20s of the 20th century. In Sweden, biomass gasification for the propulsion of vehicles was promoted by the government due to the lack of petroleum resources and the abundance of wood. The technology was further researched and applied during the Second World War (as shown in fig. 4.1), when petroleum was limited throughout Europe. Extensive research was performed and over hundreds of thousands of vehicles were built equipped with a biomass gasifier (McKendry 2002). Equipping existing cars with biomass gasifiers was also common.



Fig 4.1: A mass production line of biomass gasifier cars in Germany in 1943 (Source: Biomass Energy Foundation)

4.3 Preparing the biomass

The biomass needs to be prepared before it can be gasified (as shown in fig. 4.2). The first process is to cut the biomass in smaller sizes, of approx. 10 cm. length. The biomass is then dried, either by use of the exhaust heat of the internal combustion engine, or by the ambient temperature and the sun. Moisture content must be below 15%. This is mostly estimated by the operator but can be determined by weighing the biomass before and after drying.



Fig 4.2: A biomass cutter

4.4 Gasification

When gasifying biomass, the biomass is converted to a gaseous fuel by heat. In the process, partial oxidation occurs and the intrinsic energy of the carbon in the biomass is converted into a combustible gas. The gasification process includes both bio-chemical as well as thermo-chemical processes, although the thermo-chemical are the main processes within the gasification process (McKendry 2002).

Biomass is a Hydro-carbon product with an average composition of $\text{CH}_{1.4}\text{O}_{0.7}$ for dry wood and a lower caloric value of 18,3 MJ/kg (Burgi 2003, pg. 27).

The basic reactions that are taking place in gasification are as following (fig. 4.3):

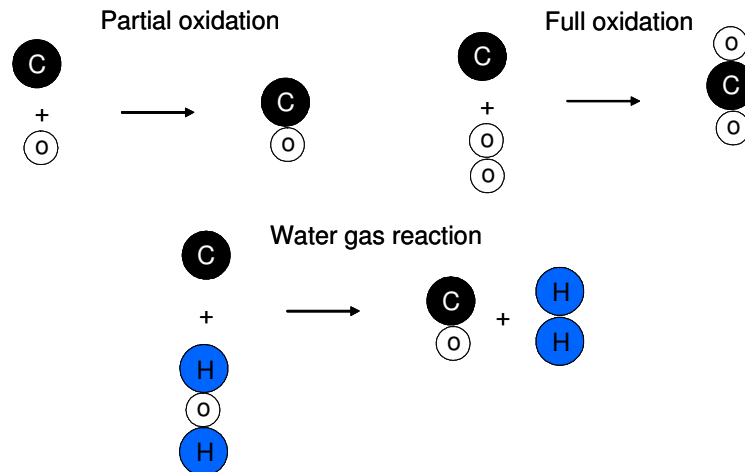


Fig 4.3: The basic reactions in a gasifier (based on McKendry 2002 And Burgi 2003)

The biomass gasifiers described in this report are downdraft gasifiers. The biomass is gasified to form producer gas (more specifically named wood gas). This gas has a heating value of approx. 5,7 MJ/kg and consist of the following components and (approx.) volume percentages (although the chemical composition may vary by biomass fuel and by method of gasification):

- Nitrogen N_2 , 50,9%
- Carbon Monoxide CO , 27,0%
- Hydrogen H_2 , 14,0%
- Carbon Dioxide CO_2 , 4,5%
- Methane CH_4 , 3,0%
- Oxygen O_2 , 0,6%

The schematics of a downdraft gasifier (fig. 4.4):

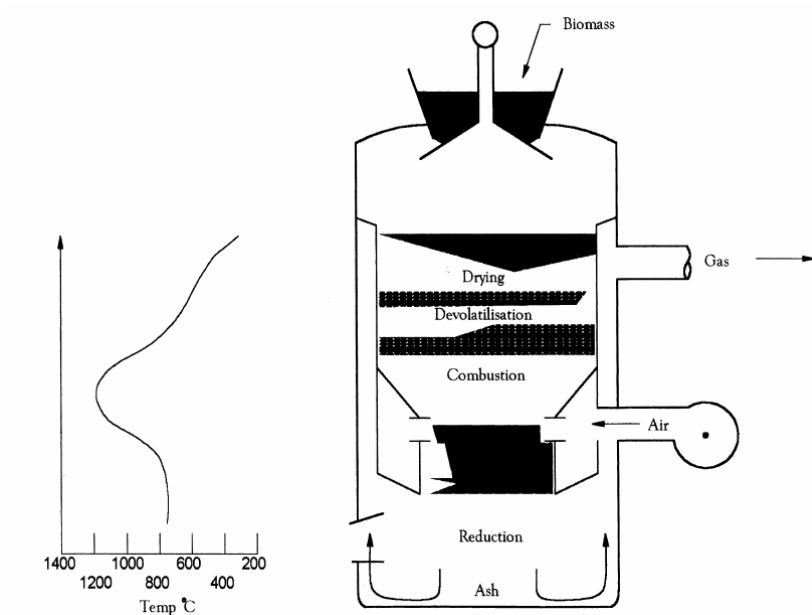


Fig 4.4: The schematic of a downdraft gasifier (Source: McKendry 2002)

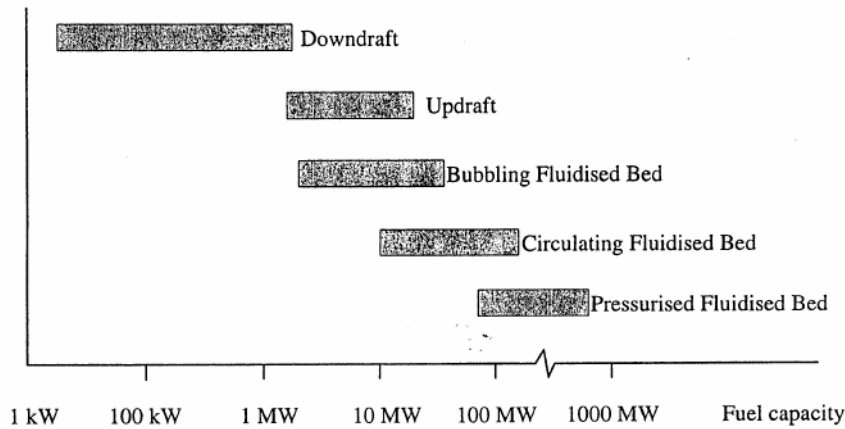


Fig 4.5: The best application of gasifier design depending on the required power (Source: Larson 1998)

Downdraft gasifiers are used in the range of 1 kW to 1 MW as shown in fig. 4.5. For larger applications, other types of gasifier are better suitable. In the downdraft biomass gasifier, the biomass is first dried by combustion heat in the top of the reactor. The air is moving in the same direction as the biomass (downwards). Combustion heat is around 1200 °C, and the gases leave the reactor at a temperature of around 900 °C, giving low energy efficiencies to this type of gasifier. The benefit of the downdraft type is the low tar formation in the gas (Larson 1998, McKendry 2002). These biomass gasifiers require a feedstock with a density of $\rho_{\text{biomass}} \geq 250 \text{ kg/m}^3$, a moisture content of $\leq 15\%$, and an ash content of $\leq 3\%$ (Burgi 2003). These requirements correspond with dry wood-like biomass.

4.5 The biomass gasifier system

A typical biomass gasifier system to produce electricity consists of four basic elements:

1. The gasifier
2. The gas cleaning and cooling system
3. Filters
4. The engine and alternator

The water needed for the cleaning and cooling is treated in a:

5. Water treatment unit

The gasifier

The open-top downdraft biomass gasifiers' main component is the reactor (as shown in fig. 4.6), in which the biomass is transformed from a solid state to a combustible gas. The biomass is inserted from the top and dried by the combustion heat, followed by the de-volatilization (pyrolysis) and thus produces a mixture of gases, vapour and tar. The volatile matters undergo oxidation with a lack of oxygen (sub-stoichiometric). The air required is drawn in partly from the top and partly from the air nozzles. After this, the gas flows through a hot charcoal bed, burning a large proportion of the tar in the gas. The raw producer gas undergoes reactions leading to the formation of by products as water-vapour (H_2O) and Carbon-dioxide (CO_2). The producer gas leaves the reactor at the bottom. The thermal energy in the gas can be used to pre-heat the new biomass on the top of the reactor. Whether this is done or not depends upon the producer and model of biomass gasifier (Burgi 2003). A small portion of charcoal (2-3%) remains in the reactor and is not gasified. This is removed using a screw conveyer during operation, or is removed manually after operation for smaller biomass gasifiers.



Fig 4.6: The reactor at RV Engineering college, India

The gas cleaning and cooling system

When the gas leave the reactor it is not ready to be used in an internal combustion (IC) engine. The gas has a high temperature and contains dust and tar particles that can damage the IC engine. The gas needs to be cleaned and cooled.

The first component to remove the particles is a cyclone. In the cyclone, the gas is subjected to a centrifugal force, due to which dust particles are expelled outward and drop in water at the bottom of the

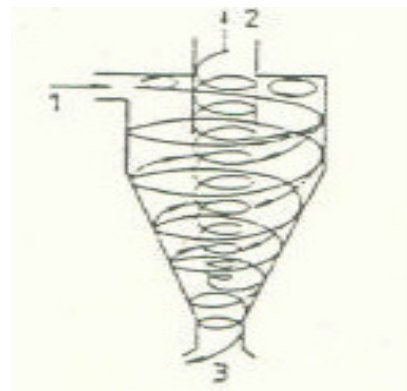


Fig. 4.7: A cyclone to remove particles (Source: Burgi 2003)

cyclone. The principles are depicted in fig 4.7: The gas enters at 1, dust particles are separated and go to 3. The gas leaves the cyclone at 2. The gas travels from the cyclone to the cooler and scrubber.

Cooler and scrubber

The goal of these components (as shown in fig. 4.8) is to lower the gas temperature and remove the tar. In the first stage, the gas is submitted to spray water, for cooling and washing purposes. Due to the drop in temperature to ambient temperatures, the tars in the gas will condensate and are absorbed by the water sprays. In the second stage, the gas is cooled to chilled temperatures ($\pm 5\text{ }^{\circ}\text{C}$), by chilled water to remove the remaining tar particles. The tar is collected in a water-sealed chamber.

Due to the cooling of the gas, the water vapour in the gas is condensed and absorbed by the spray water (Burgi 2003).

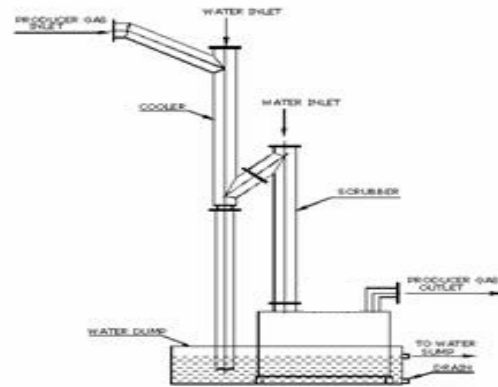


Fig. 4.8: A cooler and scrubber system from Netpro (Source: Burgi 2003)

Filters

Filters are used to remove the last small particles from the gas. Sand bed filters are easy to use and maintain and have been applied most in the past. Fabric filters are also used, these have a higher efficiency. Sand bed filters can have particles sizes of 200 to 600 μm (Burgi 2003). The quality of the gas can be determined by the operator before the gas enters the IC engine, by burning the gas in a gas flare device. A qualified operator can tell the gas quality by the flame colour and behaviour. A blower is used to increase the gas suction, lost in all the previous processes.

The IC engine and alternator

There are two different main engines used in combination with a biomass gasifier. These are the 1) Dual-fuel engines and the 2) 100% Producer gas engines (as shown in fig. 4.9).

The dual-fuel engines are started using 100% diesel fuel; this is then gradually replaced by the producer gas. A certain amount of diesel is required however during operation; diesel replacement is typically around 80% when the

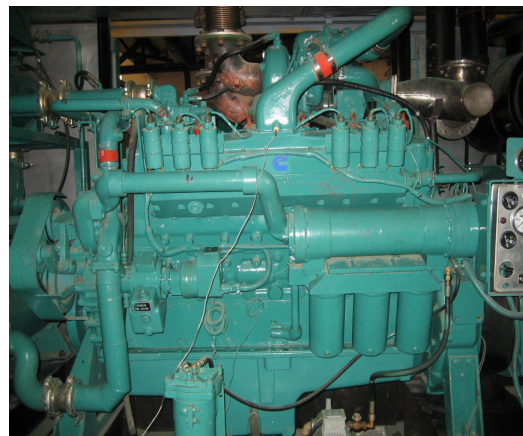


Fig 4.9: One of the IC engines of the BERI project

biomass gasifier operates well. Operation costs are high due to the diesel prices. The 100% producer gas (100% PG) engines are modified diesel engines and can be started and run with 100% producer gas. This requires a cleaner gas compared to the dual-fuel engines. In the last decade, research has been conducted into the 100% producer gas engines and new biomass gasifiers, both small and large-scale are always equipped with these engines due to the lower operation costs (no diesel is required). When electricity is required, an alternator is connected to the engine by a shaft, to produce electricity. In the past some of the biomass gasifier engines were directly connected to a pump set, without generating electricity. This is however not done anymore.

Water treatment unit

The water needed for the treatment of the gas for cooling and cleaning purposes is pumped into a sump. The particles removed from the gas can be removed and the water can cool down, to be reused in the gasifier system. The water treatment unit consists of a number of tanks, in which the water flows from one tank to another. The particles sink and remain at the bottom of the tanks. These are periodically removed manually. The water is reused.

4.6 Mass and energy balance

Burgi (2003) has made a mass balance for a Netpro 40 kWe dual-fuel down-draft biomass gasifier. It is given in table 4.10.

Table 4.10: The mass balance for a Netpro 40 kWe biomass gasifier (Source: Burgi 2003)

	Temp ¹⁸	Mass flow
Reactor Inlet		
Biomass mass flow	30°C ¹⁹	44.50 kg/hr
Air mass flow into reactor	30°C ¹⁹	80.21 kg/hr
Specific biomass consumption ²⁰		1.11 kg/kWh
air to biomass ratio		1.80 kg _{air} /kg _{biomass}
Reactor Outlet		
Producer gas mass flow (moisture content: 14.66weight%)	250°C ²¹	118.84 kg/hr
Charcoal mass flow		5.34 kg/hr
Ash mass flow (collected in cyclone and water seal, excluding ash contained in charcoal)		0.53 kg/hr
Specific charcoal production		0.13 kg/kWh
Gas Cleaning and Cooling System – Inlet		
Producer gas mass flow (moisture content: 14.66weight%)	250°C ²¹	118.84 kg/hr
Gas Cleaning and Cooling System – Outlet²²		
Producer gas mass flow (moisture content: 1.23weight%)	30°C ²³	107.65 kg/hr
Water removed from producer gas		11.19 kg/hr
Producer gas to biomass ratio		2.42 kg _{PG} /kg _{biomass}
Engine Inlet		
Producer gas mass flow (moisture content: 1.23weight%)	30°C	107.65 kg/hr
Diesel mass flow	30°C	2.81 kg/hr (3.40 ltr/hr)
Air mass flow	30°C	193.41 kg/hr
Specific diesel demand per kWh produced in dual-fuel mode ¹⁷		0.09 ltr/kWh
Engine Outlet		
Exhaust gas mass flow	500°C	303.86 kg/hr

The energy balance for the same gasifier is given in table 4.11.

Table 4.11: The energy balance of a Netpro 40 kW biomass gasifier (Source: Burgi 2003)

	Symbol used	Energy flow	% of total losses
Reactor Inlet			
Chemical energy flow – wet biomass	$\dot{E}_{Ch \text{ biomass}}$	196.77 kW	
Reactor Outlet			
Chemical energy flow – producer gas	$\dot{E}_{Ch \text{ PG}_1}$	137.09 kW	
Thermal energy flow stored in producer gas (at 250°C)	$\dot{Q}_{th \text{ PG}}$	9.60 kW	
Chemical energy flow – charcoal	$\dot{E}_{Ch \text{ charcoal}}$	37.08 kW	19.4%
Energy losses (heat losses through reactor walls, heat stored in charcoal and ash)	$\dot{Q}_{loss \text{ reactor}}$	13.01 kW	6.8%
Gas Cleaning and Cooling System – Inlet			
Chemical energy flow – producer gas	$\dot{E}_{Ch \text{ PG}_1}$	137.09 kW	
Thermal energy flow stored in producer gas (at 250°C)	$\dot{Q}_{th \text{ PG}}$	9.60 kW	
Gas Cleaning and Cooling System – Outlet			
Chemical energy flow – producer gas	$\dot{E}_{Ch \text{ PG}_2}$	137.09 kW	
Energy loss (loss of thermal energy due to gas cooling)	$\dot{Q}_{th \text{ PG}}$	9.60 kW	5.0%
Engine Inlet			
Chemical energy flow – producer gas	$\dot{E}_{Ch \text{ PG}_2}$	137.09 kW	
Chemical energy flow – diesel	$\dot{E}_{Ch \text{ diesel}}$	34.28 kW	
Engine Outlet			
Mechanical energy delivered to alternator	$\dot{W}_{mech \text{ engine}}$	45.45 kW	
Thermal energy flow stored in exhaust gas (at 500°C)	$\dot{Q}_{th \text{ eg}}$	44.66 kW	23.4%
Energy losses engine (heat losses, friction, chemical entropy)	$\dot{Q}_{loss \text{ engine}}$	81.31 kW	42.6%
Alternator Input			
Mechanical energy	$\dot{W}_{mech \text{ engine}}$	45.45 kW	
Alternator Output			
Gross electricity output	$\dot{W}_{el \text{ gross}}$	40 kW _e	
Energy losses alternator	$\dot{Q}_{loss \text{ alternator}}$	5.45 kW	2.8%
Internal electricity use	$\dot{W}_{el \text{ int}}$	1.4 kW _e	
Net electricity output	$\dot{W}_{el \text{ net}}$	38.6 kW_e	

As shown in table 4.11, the overall energy efficiency is around 17% for the dual-fuel system. This is a normal value for a biomass gasifier installation. Similar efficiencies are reached with the 100% producer gas systems. For some of the biomass gasifiers, the waste heat of the IC engine is used for the drying of wet biomass.

4.7 The small scale biomass gasifiers

In this report, a number of small-scale gasifiers, mostly built by Ankur will be described in section 5.3. These are slightly different (they are closed top downdraft biomass gasifiers) from the above described gasifier systems and are described in this section.

Most of the 9 kW biomass gasifiers as applied in the Coimbatore region are built by the Ankur company. The system consists of:

- Closed-top downdraft reactor (see fig. 4.12)
- Filter using rice husk or wood powder
- Fabric filter
- 100% Producer gas engine (Dipco or Field-Marshall)
- Water cooler
- Testing flare
- Generator
- Battery
- Vibrator
- Air pump
- Operating panel



Fig. 4.12: A 9 kW Ankur gasifier reactor

The biomass is burned inside the closed-top downdraft reactor. Producer gas leaves the reactor towards the filters. The rice husk or wood powder filter and the fabric filter are used to subtract particles from the producer gas. The water cooler removes sufficient tar from the gas.

The biomass used can differ; teak wood, eucalyptus and Juliflora are used. The biomass is required to be dry (moisture content < 15%) and cut in sufficiently small size (2-5 cm.).

The reactor is filled with biomass and closed. Once in operation the reactor-top will stay closed, until all biomass is burned or the system is shut down. Before starting the gas engine, the operator must ensure that the producer gas has a sufficient quality for the gas engine. The testing flare is used for this purpose. The operator fires the producer gas in a flare and visually inspects the quality of the gas. This rough method is not supported by all operators. If the gas quality is approved, the gas engine is started using the battery, followed by the producer gas.

The fabric filters are cleaned regularly in water. The rice husk or wood powder filters are cleaned by replacing either the rice husk or the wood powder. This maintenance is not costly and performed by the operator. The engine is maintained once a month (cleaning and oil change). Due to the limited running hours per day, the small maintenance is not necessarily affecting operation.

5 Past experiences

5.1 Introduction

This chapter will describe the existing and (formerly) running biomass gasifier projects visited throughout South-India. All applications visited will be described and the chapter will be finalized with conclusions. Appendix B offers interviews conducted for this research. The first part of this chapter will discuss two (oldest) biomass gasifier applications of IISc. The latter part of this chapter describes a number of (recent) small-scale biomass gasifier applications in villages in Tamil Nadu state.

The first form of small scale rural biomass gasification are the small scale dual-fuel biomass gasifiers with a maximum capacity of 2-5 kW used by farmers to run their irrigation pump sets. These biomass gasifiers have been built and sold in large numbers (1700+) throughout the 80s and 90s and are no longer running anymore (interview prof. Paul, IISc., appendix B and Dasappa 2008). Since these are no longer running and most likely no longer present anywhere, these were not visited for the research.

A second form of biomass gasifier applications is the placement of (100% producer gas and dual-fuel) biomass gasifiers in rural (un-)electrified villages. The biomass gasifier is the first electricity source for the village (except for expensive-to-run diesel generator sets). The framework for the research conducted has been designed for these situations. The placement of a biomass gasifier as a prime source of electricity is likely to have a significant influence in the village: It is the first reliable source of electricity, and provides opportunities for various (entrepreneurial) initiatives, such as drinking water pumping, flour milling, lighting for reading and safety etc. When preparing the framework I was aware of these applications. The framework has been largely designed for this type of biomass gasifier application. It however proved that another form of biomass gasifier application is applied to a larger extent in South-India.

The third form of rural biomass gasifier applications are the gasifiers placed and operated by the panchayats. The panchayat is the local assembly headed by the elected panchayat president, whose role is best compared to the mayor of a village. The biomass gasifiers' electricity is either used for drinking water pumping and/or for street lighting purposes. Both drinking water provision and street lighting are the responsibility of the panchayat government. In most panchayats the electricity required for this is purchased from the State Electricity Board (SEB), and thus provided by the grid. Panchayats have chosen to place biomass gasifiers for electricity production to reduce or eliminate the SEB bill. The villages are however connected to the electricity grid, which is reasonable reliable. The framework developed for the research does not completely harmonize with these applications. When looking at the framework, determining the Uphoff's goals of 1) productivity increase, 2) well being improvement and 3) empowerment is of lesser importance, since grid electricity was present before the biomass gasifier application and because the biomass gasifier electricity is only used by the panchayat. Positive

development effects were observed however and will be described in this report. The application success composed of 1) Technical success and 2) Financial success can however be determined in the same way as in all other cases. The institutional success of the related government body (TEDA / MNRE), is also determined in order to evaluate the application. The institutional success of the related panchayats has not been analyzed because of the lack of time for research.

The framework has not been changed, because it is still applicable to a large extent. Section 1.3 is dedicated to the lessons learned in the differences between the framework design and hypothesis in the Netherlands and the observations in India.

All biomass gasifier applications as described in this chapter are set in the rural electricity regime of India. This regime (as described in chapter 3) is characterized by power shortages and grid electricity subsidies, of up to 100%, differing per state, income level and panchayat. This poses the biomass gasifier with false competition, since operation costs are likely to be higher than the grid electricity charges. The biomass gasifier can increase the reliability of electricity availability compared to the grid electricity. Biomass gasifier purchase costs are subsidized, operation is not subsidized.

5.2 Hosahalli and Hanumanthanagara villages

The two villages described in this part are located in Tumkur district in Karnataka state in the south of India. Both villages have had biomass gasifier applications; these are no longer running. Hosahalli village was initially electrified using the biomass gasifier and Hanumanthanagara village was already connected to the grid when a gasifier was installed. Both villages are currently connected to the electricity grid.

The Indian Institute of Science (IISc), located in Bangalore, Karnataka state, has designed and placed both gasifiers in the villages as part of an experiment. Both villages are unique in the sense that the biomass gasifier performance has been extensively described throughout the years in scientific papers by the IISc scientists. These gasifiers can be regarded as the only biomass gasifier applications that are well scientifically documented and assessed after placement in India.

5.2.1 Actors involved

Indian Institute of Science and ASTRA / CST

The Indian Institute of Science (IISc) started research into the field of biomass gasifiers in 1982. At that time the only available gasifier model was the closed top downdraft gasifier. Two to three years later the IISc came across the first open-top downdraft gasifiers. When the first open top models were designed, built and tested it was decided that the benefits of the open-top downdraft outweighed those of the closed top downdraft gasifier and further research would be conducted into the field of the open top downdraft

gasifier. One of the benefits is the possibility of continuous operation of the gasifier; the biomass fuel can be added during operation. The closed-top downdraft gasifier had an erratic behaviour performance.

In 1987-1988 the first gasifier was placed in the field. This was a 3,7 kW (engine rating) gasifier directly connected to a water pump by means of a dual-fuel engine. Main benefits proved the abolition of diesel engines for pump sets. The 2nd oil crisis of the late 70s contributed to the development efforts and governmental subsidies. Around 1987-1988 there was a large-scale dissemination program resulting in around 300 gasifiers being placed in the rural field connected to pump sets all over India. Of these 300 gasifiers none are however running anymore. Experience was mixed; some of the systems ran efficiently, others did not. The high subsidies made it very attractive to purchase these biomass gasifiers, and literature indicates that one of the main reasons for farmers to purchase the system was because of the low-cost (dual-fuel) diesel engine included with the biomass gasifier (Shukla 2007, pg. 7). When the diesel fuel prices dropped again, usage of the dual-fuel biomass gasifier systems stopped.

The IISc has also placed a biomass gasifier to provide electricity power at the Andaman Islands by request of the Indian government. This required a scale-up to 80 kW systems and the incorporation of auxiliary equipment to produce electricity. This gasifier has not been very successful; the problems encountered did however contribute to the incorporation of ceramic materials in future gasifiers, to decrease corrosion inside the gasifier. The current trend into the R&D of biomass gasifiers is a further scale-up of the power produced, from 3,7 kW to 1,5 MW. Problems encountered here are mainly in the field of longer operation hours and the cleaning of gases. Research into the field of truly small-scale (rural) applications is not a focus of IISc anymore.

IISc was one of the first in India to be involved in biomass gasifier research and is recognized as one of the main knowledge centres. The IISc design is licensed to a number of companies. These producers provide IISc with field experiences and IISc helps them with R&D upon request (interview prof. Paul, IISc).

IISc has a large experience into the research and development of technical issues involved with the biomass gasifier. The social-economic involvement is less and mostly runs through the Centre for Sustainable Technology (CST) / Application of Science and Technology for Rural Areas (ASTRA).

Initially CST, formerly known as ASTRA started as an institute program of IISc in 1974 (Visser 2007). An extension unit was established in 1976 in Ungra, Karnataka. The objective was to test several different technologies (wind energy, medicinal plants, solar systems) and learn to interact with the rural population. Employees of IISc wanted to use their knowledge and skills to promote sustainable technologies for the poorer people. Focus would be on the practical applications of sustainable technologies in the rural setting. Main areas include energy, drinking water and agriculture. CST opposes to the idea of being a commercially paid consultant. This would compromise the objectivity. Finance for CST is provided by donors and by IISc (Visser 2007).

Hosahalli and Hanumanthanagara villages

Both villages are located in Tumkur district, Karnataka, South-India. The region is a semi-arid region with an annual rainfall of around 700 mm (Somashekar, 2000). Table 5.1 provides data about the villages.

Table 5.1: (taken from Somashekar 2000 and Ravindranath 1990, Situation before installation of the biomass gasifiers)

Particular	Hosahalli	Hanumanthanagara
Households	35 (in 43 houses)	58
Population	218	319
Number of houses with grid power	Unelectrified (in 2004 electrified)	25
Number of irrigation pumps	0	5
Number of farmers	35	58
Irrigated land (ha. for the year 2000)	13	17
Other land (ha. for the year 2000)	35	21

Both villages are a few kilometres apart but difficult to reach by road. The only access roads are dirt roads, located many kilometres from paved roads. When the experiment commenced in 1988, Hosahalli village was one of the few villages still unelectrified in Karnataka state. The experiment was extended to Hanumanthanagara village in 1995, this village was grid connected, although less than 50% of the houses were receiving grid electricity. Hosahalli received a grid connection in 2004. Most of the houses are however not (legally) connected to the electricity grid due to the high installation costs of the wire from the grid to the house.

Arrangements between the actors

The following arrangements were made between the actors.

The village was responsible for:

- Village committee (please see section 5.2.2 for more):
 - Biomass fuel forest protection
 - Assistance for collection of charges and maintenance of accounts
 - Supervision of operation and operators
 - Mediation in conflicts (in cooperation with IISc)
- Operation by a local operator, trained by IISc
- Collection of the biomass by local people

IISc was responsible for:

- Gathering of the required project funds
- Installation of the biomass gasifier
- Installation of the various additional items such as drinking water pumps, electricity lines to every house and lighting
- Technical support to the operator when required
- Financial support for operation and maintenance

5.2.2 History of the project

The project started at the IISc and ASTRA in Bangalore. Having gained experience in the field of biomass gasifiers, IISc was eager to field-test a biomass gasifier in a village. This experiment would provide IISc with prolonged operational data and with on-the-job experiences from the operators and those involved.

The first gasifier was placed in Hosahalli village in 1988. At the time, the village was un-electrified and determined suitable for the practical experiment. Finance was provided by the Council for Advancement of People's Action and Rural Technology (CAPART), which was in a later stage transferred to the Karnataka State Council for Science and Technology (KSCST) (Visser 2007). Group meetings were held with the village community and the project proposal was agreed upon. A new village committee consisting of four members was formed, with the following goals: 1) Protection of the biomass forest, 2) Supervision of operation and operators and 3) Assistance for collection of charges and maintenance of accounts (Ravindranath et. al. 1990). Land for installation of the gasifier as well as for plantation of the biomass forest was allocated. With the project funds, a forest was raised, all houses were wired, a generator room was built and two village youth were trained to operate the system.

The first gasifier system placed was a dual-fuel system designed and built by IISc with a capacity of 3,7 kWe. In cooperation with the village community, two lighting points were installed in every house (costs Rs. 5 per bulb-point per month), in addition to 8 street lights. The load would be 43 houses x (1 x 40W fluorescent tube + 1 x 15W bulb) + 8 x 40W streetlights = 2,685 kW. The biomass gasifier would provide the load for 4 to 5 hours a day, dependent upon the villagers requirements (Ravindranath 1990). The plantation area of 2-2,5 ha. consisted of several types of trees including Acacia and Eucalyptus, with a total of approx. 6600 trees per ha. (Ravindranath 1990). The annual requirements were around 5,1 tons. With the load at the time, 1 ha. was sufficient to provide the required biomass in a sustainable manner.

The operators were 2 youth trained at IISc and at the site in Hosahalli village. The cutting of the larger biomass wood into small particles would take place during gasifier operation to power the cutter. Although costs were low at the time, and funds were available, the system at the time was not financially independent. Enough funds were collected from the villagers for normal operation, funds for repair and replacement were however not included. Using an economic analysis, the IISc calculated that the more hours the system was run, the less unit costs would be (Ravindranath 1990). Diesel replacement of around 70-80% was achieved. People in the village were not keen on accepting responsibilities (i.e. ownership), when only lighting was offered. This changed when the first drinking water pumps were placed. This especially helped women; they ensured men participation in the project (Dasappa 2008). In a neighbouring village a biogas project was installed and powered drinking water pumps. The villagers of Hosahalli village requested provision of drinking water pumps to IISc. IISc installed a 3-phase 5 kWe gasifier that would be used for drinking water (costs Rs. 10 per house-hold per month) and home and street lighting purposes in 1990. Water was pumped up and stored in central tanks, providing the villagers with drinking water. Beforehand, mainly women used to walk for kilometres for the collection of water.

To increase the financial viability of the system, it was decided that commercial activities were needed. In 1994 the gasifier was replaced by a 20 kWe gasifier to continue the provision of the power for drinking water pumps and lighting and additionally the provision of power for a flour mill and irrigation pumps for farmers. Beforehand villagers had to walk 2-3 kilometres to another village to have the grain milled. Funds were provided from within the experiment of IISc. Around 1995 Hanumanthanagara was also provided with a biomass gasifier. The provision of irrigation water increased the income of the farmers and they were able to pay for the service (Dasappa 2008).

Although operational use was high throughout the years, the system was never financially independent. Approx. 40% of the operation costs were collected by fees during operation of the 20 kWe system. The IISc financed the additional operation costs for most of the years as part of the experiment. The rationale was to charge economic rates, once the incomes of the households increased. Payments of the households were good and over 80% of the households paid on time or promised to do so in better times. Confidence of the community in the technology increased during the experiment.

The experiment however halted in 2004, because the experiment was regarded as finished and sufficient scientific and practical experience had been gained. Shortly after, the gasifier in Hosahalli village was terminated and transferred to IISc in Bangalore for inspection. In both Hosahalli and Hanumanthanagara villages, the gasifiers are no longer running.

In 2004, Hosahalli village was connected to the electricity grid, by political motivation of an individual of the village. (ref. Interview Somashekar, interview Paul, Visser 2007 and Dasappa 2008). Experience was gained in the day-to-day operation of a rural biomass gasifier, technical problems that were encountered and the preparation of the biomass fuel. Institutional lessons learned were the involvement of the rural population and the impact a biomass gasifier can have on an unelectrified village.

5.2.3 System layout and operation

In the experiment of IISc in Hosahalli village the first biomass gasifier installed was a 3,7 kWe dual-fuel gasifier produced and designed by IISc in 1988 (first phase of the experiment). Tests with biomass gasifiers in local conditions using local operators were required to test the capabilities and reliability.

Hosahalli, being close to other villages already helped by ASTRA, and being unelectrified was chosen. Before placement, people were informed and plantation of biomass crops was started on barren land (2,5 ha.) by the local population. The initial system provided power for street and home lighting purposes. Funds for the installation of the street lights as well as the wiring to the homes were provided as part of the experiment. The local population was involved by the formation of a village committee. Throughout the years, equipment has been installed, to be powered by the biomass gasifier, these include: A drinking water pump, a flour mill, irrigation water pumps and home and street lighting.

Operational data had been recorded since 1998 in Hosahalli and Hanumanthanagara villages. The reliability of the systems was high, around 95% and 88% respectively (Somashekar 2000).

5.2.4 The fieldwork research

Before visiting both villages, interviews were conducted at the IISc with the following persons: Prof. Paul, chief executive of Advanced Bio-Energy Technologies Society (ABETS), Dr. Sridhar, fellow of ABETS, Mr. Somashekar, M.Sc. of ASTRA (please see appendix B) and also with the former operator of the Hosahalli biomass gasifier, currently working for IISc. Both villages were visited on the same day, with the former Hosahalli biomass gasifier operator and a translator present. The fieldwork research was conducted by interviews with the former gasifier operators, villagers and group discussions in Hosahalli and Hanumanthanagara village. The individual interviews were successful and provided a large amount of additional information (besides the interviews held at IISc and the scientific papers published concerning both villages). The group discussion in Hosahalli village was successful and both men and women actively participated. The group discussion in Hanumanthanagara village was less successful; the discussion led to loud (male) discussions between groups within the village and the group discussion was prematurely ended. The conflict was about IISc. Some of the male and female villagers felt abandoned by IISc when the experiment was terminated and biomass gasifier operation was terminated. Others did not agree with this opinion. In the individual interviews in both villages women were interviewed. The former operators of both villages are men.

A list of the interview questions can be found in appendix A.

5.2.5 Ultimate goals of development

Productivity increase

One of the three goals described by Uphoff et. al. (1988) as required for successful rural development is productivity. In both villages, the main source of income is agriculture. An increase of agricultural productivity should therefore be a result of successful application. An increase of agricultural production is however difficult to determine by a researcher. Local farmers do not keep track of exact production throughout the years and determination of productivity increase is therefore done based upon the scientific papers published about these gasifier applications and by the interviews conducted during the village visits. Before installation of the irrigation equipment of IISc, farmers relied on rain fed agriculture, subjected to the monsoon and occasionally hired diesel engines to pump water for irrigation (Dasappa 2008).

The farmers did indicate a crop yield productivity increase of around 20% after installation of the irrigation systems which were powered by the biomass gasifier. The exact ownership of these systems is however unknown.

Local employment was also created; people were hired for the operation of the biomass gasifier, preparation of the biomass prior to usage and for maintenance of the biomass fuel forest. The biomass gasifiers created income for over 10 people from the village.

Increase of well being

An increase of well being can be determined using different qualitative and quantitative data and methods. During discussions in the villages, both with men and women, the main items determined as important for well being were access to drinking water and access to lighting. Especially women pointed out the following well being issues. The availability of electricity for the villagers also increased their awareness and learning of the positive effects of this power. The learning included the availability of local drinking water, a flour mill and public and domestic lighting.

Drinking water

Before the experiment, women had to collect water from a polluted open water tank, nearly 1 km away (Dasappa 2008). As part of the IISc biomass gasifier experiment, drinking water pumps and storage tanks (as shown in fig. 5.2) were placed in the villages and these were powered by the biomass gasifier. All houses were freely connected to the tanks. During operation of the biomass gasifier, the storage tanks were filled with drinking water and sufficient capacity was available for 24 hours of drinking water. People were charged approx Rs. 10 (€ 0,17) per month for the drinking water connection. After shut down of the biomass gasifier in 2004, the drinking water pumps were not powered anymore and people are currently required to use either their own bore well (very expensive to install) or to collect the drinking water elsewhere. The installation of the biomass gasifier and additional applications for drinking water provision have contributed to the well being after installation, this level of well being was however not maintained after the biomass gasifier was shut down. The drinking water situation got worse.



Fig. 5.2: The drinking water tanks of Hanumanthanagara village, these are no longer in use.

Lighting

With the installation of the biomass gasifier, all houses were provided with an electricity line leading to the gasifier. For a charge of approx Rs. 5 (€ 0,08) per month per light bulb, people had access to lighting for the first time (other than by diesel generator or batteries). Lighting proved helpful for the children (as indicated during the interviews) for their studying. At the time of operation of the biomass gasifier all 35 houses in Hosahalli village were electrified. In cooperation with the operator villagers could determine the hours of operation.



Fig. 5.3: Illegal connections to the grid power

In 2004 the biomass gasifier operation halted and grid power became available. This however decreased the pre-described well being. Although grid power is (almost) free of charge, connection costs from the grid line to each house are around Rs. 2000 (€ 33,-) and unaffordable for most households. Illegal connections are common (as shown in fig. 5.3), and only 10 of the 35 houses are (officially) connected to the grid power. The school is not connected (which was the case during the biomass gasifier operation). Another downside of the grid electricity is the unreliable availability of electricity as described in chapter 3.

Food preparation

Flour is used in many Indian dishes and the flour mill in the village was placed as a part of the auxiliaries of the biomass gasifier. The flour mill provided income for the mill operator and additional income for operation costs of the biomass gasifier. After the gasifier was shut down, the flour mill has no longer been used due to inefficient power. Villagers have to go to other villages again to have the grains milled.

Conflicts

During the 1998-2003 period, 28 social problems occurred, including committee disagreements and political rivalry (Ravindranath 2004, Interviews in villages, interview with the former operator of the Hosahalli gasifier). One example: When the irrigation pumps were placed (paid for by IISc), agreements were made with the farmers owning the land with the pumps to be installed on. In a later stage one farmer did no longer agree to share the water from his (new) bore well with the other farmers. In cooperation with the village gasifier committee, this problem was solved by discussions with the farmer and irrigation water was again available (ref: interview Somashekar, CST/ASTRA).

After termination of the gasifiers, with the villagers disagreeing, many started to dislike IISc. They blame IISc for shutting-down and removing the gasifiers, and thus worsening the situation in the villages. It has caused a division within the villages; this became especially apparent during the group discussion held in Hanumanthanagara village³. Determining the exact interests and social structure lines of this division proved however to difficult to determine, because of the complex power structures in Indian villages; the research time was too limited to do so.

Despite the large social differences in (rural) Indian communities, such as castes, political affiliations, economical situations and land ownership, the social problems in both villages arising due to the gasifier proved reasonably small and solved in a short period of time by IISc and the village committee as indicated by Somashekar in the interview.

³ Ref: group discussion in Hanumanthanagara village, interviews in villages

5.2.6 Empowerment

Empowerment is about the say people have over their own lives. The biomass gasifier increased the empowerment of the villagers, although it remained unclear whether this was the case for all villagers. The time of research in the village was too limited and the social structure is too complex to determine this, please see section 2.9 for more information. Women however proved enthusiastic about the biomass gasifier project as observed during the fieldwork interviews and discussions in the villages. Due to the local electricity production, villagers could, in cooperation with the operator, decide the timing of electricity production themselves. Whenever electricity was needed, for example at religious festivities, electricity could be generated outside the regular hours. The elected village committee of 4 members was responsible for the daily decision making concerning the biomass gasifier (the exact composition and interests of this committee was however not part of the research). Conflicts were solved by IISc in cooperation with this committee. The committee increased the empowerment of the villagers. When the biomass gasifier was shut down, these benefits disappeared, and the people are currently dependent upon the unreliable electricity grid.

5.2.7 Application success

The application success is about the performance of the installation itself, on the following levels:

- Technical
- Financial

Technical application success

The biomass installations, especially in Hosahalli village changed during the lifespan of the IISc experiment. Starting with a small scale system of 3,7 kWe, the gasifier was upgraded to a 20 kWe system in the experiment lifespan of 16 years.

The installed end-use capacity of the appliances connected was around 30 and 37 kW (Ravindranath 2004), but the distribution was divided in irrigation load (with not all pumps operating at the same moment) for day hours and the other loads for evening hours.

The technical application success in both villages is relatively high, with guidance of IISc. The system in Hosahalli operated for 16 years and the system in Hanumanthanagara operated for 8 years. The planning leading to the placement was well set up.

Scientists of IISc have described the application in several papers and provide a good insight into the application success of the biomass gasifier. This is shown in tables 5.4 and 5.5.

Table 5.4: Statistical data for Hosahalli village (from Ravindranath 2004)

Operation and services provided	2003	2002	2001	2000	1999	1998
Days of operation	355	358	347	298	343	349
Days on dual mode	287	272	250	162	257	269
Days on diesel mode	68	86	97	136	86	80
Days of lighting provided	455	349	347	287	310	300
Days of drinking water provided	353	344	339	293	338	295
Days of flour mill provided	162	97	155	92	180	125
Days of irrigation water provided	79	88	39	-	-	-

Table 5.5: Data for Hosahalli village (from Ravindranath 2004)

Description	2003	2002	2001	2000	1999	1998
Electricity generated kWh/yr in dual fuel mode	18651	17185	12775	7238	9617	9300
Electricity generated kWh/yr in diesel fuel mode	3326	3992	3476	5251	3267	2723
Total generated kWh/yr	21977	21557	16251	12489	12884	12023
Average wood consumption in kg/kWh in dual fuel mode	1,8	1,64	2,07	1,28	1,27	1,32
Diesel substitution in % in dual fuel mode	85,55	87,02	80,69	80,67	54,35	58,33

Both tables 5.4 and 5.5 show the data for the Hosahalli village biomass gasifier. It shows that the diesel substitution increased during the last years, indicating an increasing experience with and reliability of the gasifier system. The data also indicate the high reliability a biomass gasifier system can offer. Of the 365 days a year, when well maintained, a biomass gasifier can be run for approx 350 days. Dual fuel mode was achieved in approx 80% of the days. When not possible, this might be due to insufficient or wet biomass, or due to required maintenance of the gasifier, thus only running the diesel engine.

Problems encountered include 152 days of gasifier-related problems in the period of 1998-2003 (7% of the total time), including the failure of material in the top shell, filter replacements and grate repairs. In the 1998-2003 period, gasifier maintenance problems occurred 98 times, such as usage of moist or wrong fuel. Engine related problems occurred 33 times and electrical problems occurred twice (Ravindranath 2004).

Due to the good and close guidance of the IISc and ASTRA employees and the proper training of the operators, technical problems were quickly solved. It is however safe to state that less close contact between IISc and the biomass operators would have caused an increase of non-operationality.

Acceptance of the local villagers for the technology is required for pro-longed operation. Before placement of the gasifier in both villages, discussion meetings were held and gasifier committees were formed. This was done to prepare and involve the villagers. The first operator of the biomass gasifier in Hosahalli village was from outside the village because the villagers could not decide upon the operator from within the village. In a later stage, this conflict was solved and an operator from Hosahalli village was trained.

Learning occurred both in the villages as well as with IISc on the technical level. Biomass gasifier operators were trained, and other people were trained to maintain the biomass woods. Learning within the village was however not a focus of this research.

For IISc the experiment proved very beneficial, learning and experience was gained in the field of setup, operation and maintenance of biomass gasifiers in the rural setting. Technical problems observed during the operation were solved in new designs. There was a close cooperation between the (technical) IISc staff and the operators. One of the former operators is currently employed by IISc to share his knowledge and skills.

The experiment of IISc proved that a biomass gasifier is technically applicable in villages, when well planned, closely guided and operated by skilled operators.

Financial application success

Financial success of biomass gasifier applications is highly related to load factors and when the load is low, unit costs rise sharply. This is widely recognized as one of the determining factors during the interviews conducted in India. Loads in both villages differed per day and time of day due to the loads for the flour mill (2-3 days a week at 5,6 kW), and the irrigation pumps. The total load ranges from 6 kW during 4 days a week and 12 kW during 3 days a week excluding the irrigation pumps. Total costs per unit include:

- Diesel costs
- Biomass costs (forest maintenance, transport, labour)
- Maintenance (engine and gasifier)
- Labour (operator)

The total costs per unit were 5,85 Rs./kWh at a load of 6 kW and went down to 3,34 Rs./kWh at a load of 20 kW (prices for 2003 from Ravindranath 2004). Increasing the load from 6 to 20 kW would decrease costs by approx 40%.

A fixed rate was set for households to pay for the usage of the biomass gasifier power. The fee was Rs. 5 for a bulb per month/household, Rs. 10 for drinking water per month/household and the operator of the flour mill paid Rs. 150 per month, irrigation costs were Rs. 40 per hour (interview former operator Hosahalli village). The set rates are well affordable by the villagers and farmers, and cheaper compared to grid prices. Financial sustainability was however never achieved. Write off of the installed applications was not incorporated and IISc experiment funds were needed to keep the project running. When the funds were stopped in 2004, the biomass gasifiers stopped running in both villages, with the gasifier in Hanumanthanagara currently partly remaining in the village and the gasifier of Hosahalli being removed and relocated to the IISc for research purposes.

With the highly subsidized (though unreliable) grid power charges as they are, costs to commercially operate the biomass gasifier cannot compete with grid charges.

Although the learning of the financial success for the villages has not been determined, learning for IISc was observed. IISc learned from the costs of operation for a biomass gasifier, and the requirements for a high plant load factor (PLF). With the applications IISc found out that a high PLF was required, something incorporated in the project in a later stage, with the installation of a (commercial) flour mill, increasing the PLF during

daytime operation, and increasing the level of income needed for operation. Learning in the form of fee collection, running policies and pricing policies also occurred during the years of operation.

5.2.8 Institutional success of the IISc and ASTRA/CST

The initiating institutes involved in the biomass gasifier projects in Hosahalli and Hanumanthanagara villages are IISc and ASTRA/CST. The institutional success of the panchayats has not been analyzed because of the limited time available for the research in the villages. This is a limitation of the research.

When analyzing the ASTRA/CST institutional success, Korten's definitions are used, consisting of the 3 phases defined as: 1) Learning to be effective, 2) Learning to be efficient and 3) Learning to expand.

ASTRA was established in 1974, consisting of IISc staff. The need for energy in rural areas was identified as one of the most important items required for development (ref: Interview Somashekar, ASTRA). Sustainable energy methods such as biomass gasifiers and biogas systems were placed in villages to provide reliable electricity to the villagers and learn from the experiences gained. The biomass gasifier in Hosahalli was the first ASTRA biomass gasifier project.

Regarding the biomass gasifier projects, ASTRA started in phase 1 as defined by Korten: Learning to be effective. This phase is characterized by a high required flexibility of the project employees and low efficiencies. The initial planning leading to the installation of the biomass gasifier was good. Discussions were held and a village committee was formed. Houses were freely connected and villagers' trust increased. A forest was designated as the biomass fuel source. During discussions with the villagers the need for expansion of the provided services was identified, these include the provision of drinking water, and a flour mill. There was a reasonable fit between the identified needs and the provided services.

When experience increased and sufficient funds proved available for a number of years, the project uncertainty decreased and the ASTRA program entered phase 2: Learning to be efficient. Technical efficiency of the gasifier program increased in the form of diesel replacement of the dual-fuel system, eventually achieving approx 85%. The project expanded to Hanumanthanagara village, because of the success and experience gained in Hosahalli village.

Phase 3: Learning to expand; was partly achieved by the ASTRA program. There was no further expansion into the application of biomass gasifiers in the rural setting beyond these villages when the experiment funds were ended. IISc did however assist in other projects / programs to promote the application of biomass gasifiers in the rural setting, i.e. in the BERI case as described in chapter 6. Fuel efficiency was increased, but financial independency was not achieved.

IISc functions as the main hub in the biomass gasifier knowledge. They have licensed a number of gasifier producers like Netpro, Energreen and others to build the IISc biomass gasifier designs. Other producers such as Ankur are building gasifiers of their own design.

The scientists involved in the program, such as Somashekar, Dasappa, Paul, and others have published several papers throughout the years of the program in international papers, and thus shared the knowledge and experience gained. This is unique in the Indian situation: No other applications of biomass gasifiers in India are as well described in public literature. The potential of this information is however not put into use well enough by others, such as NGOs, governments and producers. During the research scientists of other institutes and universities involved in rural biomass gasifiers proved unaware of the field experience of IISc and ASTRA/CST. A closer fit between available knowledge in (South) India would be very useful. This includes more frequent open discussions and openly sharing experiences of rural energy projects.

5.2.9 Conclusion about the Hosahalli and Hanumanthanagara projects

The impact caused by the installation of the biomass gasifier in both villages was large, especially in Hosahalli village, unelectrified at the time of installation. The installation of the biomass gasifier proved to be beneficial for agricultural production, for the wellbeing by installation of drinking water pumps and public and domestic lighting and for the empowerment; people were involved in the decision making process through the village committee. Several technical problems were encountered throughout the years; these were however solved in cooperation with IISc. The number of social problems decreased throughout the years and tensions due to the biomass gasifier stayed relatively low.

IISc and ASTRA/CST have learned and gained valuable information through the experiments and these have certainly contributed to the further development of biomass gasifiers in IISc and the application of (industrial) biomass gasifiers. IISc supported the experiment financially during the operation of the biomass gasifier. When grid electricity was installed, it was however clear that the biomass gasifier could not financially compete with the (cheap but unreliable) grid electricity, without further support of IISc. The Indian grid electricity regime has proved to be false competition to the biomass gasifier. This is based on the grid vs. biomass gasifier unit costs.

Summary:

Achievements

- For the villagers:
 - An increase of well being by lighting, water and the flour mill
 - An increase of agricultural production due to irrigation services
 - An increase of empowerment by involvement in the decision taking process
 - Learning about the benefits of electricity

- For IISc and ASTRA/CST
 - Valuable scientific and practical experience was gained
 - The biomass gasifier proved applicable in a village setting
 - Villagers were helped for a period of years
 - Learning about the operational costs and requirements for a high PLF

Downsides

- The experiment was never financially independent
- Communication of the results was insufficiently shared with others
- Technical guidance was required throughout the entire experiment period
- Developmental success deteriorated after termination of the experiment (see fig. 5.6)

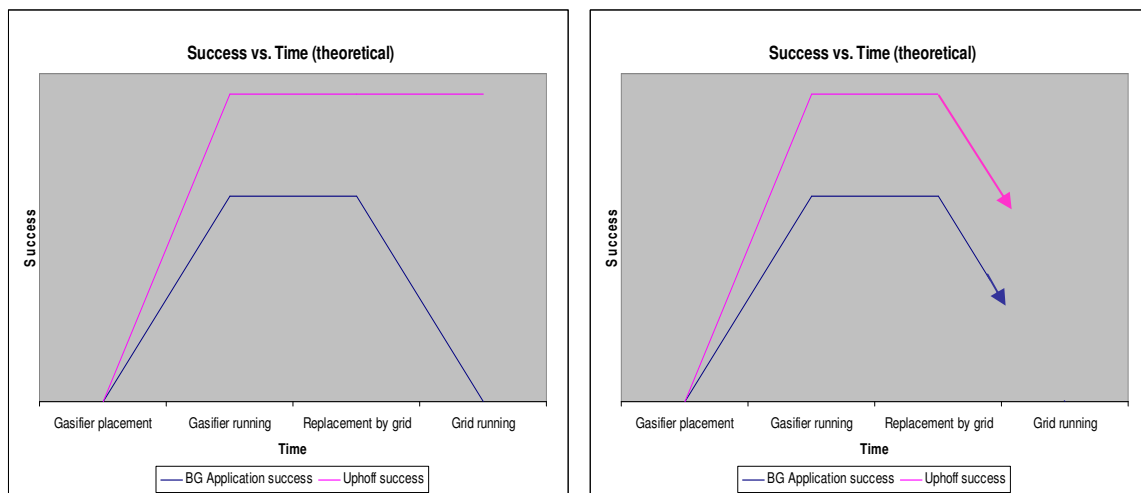


Fig. 5.6: The difference between the theoretical and observed Ultimate goals and Application success

5.3 The small scale biomass gasifiers in rural Tamil Nadu

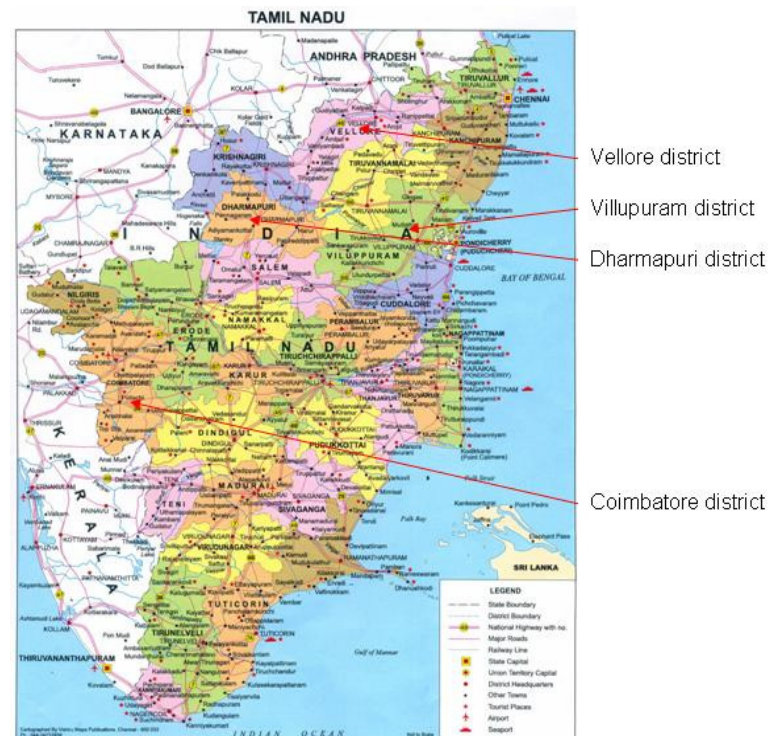
5.3.1 Introduction

To promote rural electrification the Ministry for New and Renewable Energy Sources (MNRE formerly known as MNES) promotes the installation of biomass gasifiers throughout India. In Tamil Nadu, MNRE has sanctioned an amount of 135 of 9 kW rural biomass gasifiers, 60 have so far been placed (TNEB 2006, pg. 12). These gasifiers are mostly purchased by Panchayats for power production used for drinking water cleaning and storage. Through special subsidies schemes, a portion will be paid by MNRE according to a schedule, please see section 3.7 for more information. The biomass gasifiers as described in this report are mostly the 9 kW biomass gasifiers built by the Ankur company from Gujarat, India. This company has made its own biomass gasifier design which is not licensed by IISc (ref: e-mail contact with Ankur 2007), please see section 4.7 for more information. Like the IISc biomass gasifiers, The Ankur biomass gasifiers are also placed in the rural Indian setting. Promotion of the 9 kW gasifiers in Tamil Nadu is done by TEDA. This government agency informs and trains District Rural Development Agency (DRDA) project officers (TNEB 2006, pp. 12-14).

The biomass gasifiers are influenced by the Indian rural electricity regime. This regime offers cheap and in Tamil Nadu reasonable reliable grid electricity. As also described in section 5.2, it is difficult for the biomass gasifier technology to compete financially with the (subsidized) grid electricity. Please see chapter 3 for more information.

In Tamil Nadu state, a total of 7 small scale biomass gasifiers were visited for analysis, all applications were placed by local panchayats for water provision and/or public lighting. In Coimbatore region, a total of 28 gasifiers have been commissioned and partly placed, of which 4 were visited; the 3 other gasifiers were placed and visited in the North-Eastern regions of Tamil Nadu state. Of all gasifiers visited, 2 were AEW 10 kW and 12 kW gasifiers and the others were Ankur 9 kW gasifiers. The gasifiers visited were placed in:

- Coimbatore district:
 - Odanthurai panchayat
 - Nellithurai panchayat
 - Chikarampalayam panchayat
 - Kunnathur panchayat



- Villupuram district
 - Valudavur panchayat
- Vellore district
 - Pachal panchayat
- Dharmapuri district
 - Periapatti panchayat

5.3.2 Actors involved

Biomass gasifier producers

Most of the biomass gasifiers as described in this report are built by the Ankur company. This company has produced a large number of 9 kW biomass gasifiers for the rural setting. In e-mail contact, Ankur indicated that over 800 projects have been executed in the past, with a success rate of about 70%. The applications as described in this report are however less successful. Ankur has indicated that they have not been paid a large portion for the projects by the panchayats as described in this chapter. They are responsible for technical support (typically for one year) but have halted this because payments were not met. As a result, most gasifiers are no longer in operation. Another producer is Aruna Electrical Works (AEW). This company also produces small-scale biomass gasifiers for the rural setting. AEW is located in Valudavur district in Tamil Nadu. Conflicts have also risen between the panchayats and AEW. These also concern technical support.

The biomass gasifier producer Ankur has indicated to be responsible for:

- Technical training of the operator
- Installation of the biomass gasifier system
- Technical support for at least one year as indicated by Ankur (not performed due to lack of payments by the panchayats)

The panchayats

In Tamil Nadu, the local panchayat authorities are responsible for the provision of drinking water and street lighting to the villagers. Villagers are charged an amount of money for this. In the state, nearly all of the villages are connected to the central electricity grid. This grid is reasonably reliable in the state of Tamil Nadu, and available most of the 24 hrs. per day, also in the rural areas. The electricity required for the provision of the drinking water (by pumps) and lighting is mostly purchased from the SEB electricity grid. To save on the grid electricity charges, some were motivated by TEDA to place biomass gasifiers. Several panchayat presidents agreed and purchased a (100% producer gas) biomass gasifier for the production of electricity. Costs were shared between the panchayat and the MNRE subsidy for biomass gasifiers. Please see section 3.7 for more information.

The panchayats are responsible for:

- The purchase of the biomass fuel
- The financial issues involved (salaries, biomass purchase costs, etc.)

- Daily operation by the operator
- Part of the purchase costs (the rest is paid for by MNRE / TEDA subsidies)

MNRE and TEDA

The government ministry MNRE and the nodal agency for Tamil Nadu TEDA are also actors. TEDA is responsible for the creation of awareness in the rural areas about renewable energy methods. TEDA is also the nodal agency for the MNRE and any renewable energy method subsidy requests in Tamil Nadu state are to be posted to TEDA, who forwards these to MNRE. TEDA does not (seem to) require preliminary (independent) research before biomass gasifier subsidy requests are forwarded.

MNRE is responsible for:

- The provision of subsidies
- The promotion of renewable energy methods in India

TEDA is responsible for:

- The promotion of renewable energy methods in Tamil Nadu
- Approval and forwarding of the requests for (among others) biomass gasifier subsidies in Tamil Nadu state.

5.3.3 Planning process and applications

All applications as described in section 5.3 have been placed by request of the local panchayat authorities. TEDA has promoted these placements.

Around 2003, a large scale plan was set up to install 28 gasifiers in Coimbatore region. These gasifiers were to be placed with subsidies provided by MNRE, through TEDA, by additional TEDA funds, and with the funds of the involved panchayats. The gasifiers would be applied in the provision of drinking water and/or public lighting. The involved panchayats agreed with the placement, and plans were made. The Ankur company was chosen (because of financial aspects) to provide 9 kW biomass gasifiers.

Besides the large scale planning of the 28 gasifiers in one region, other regions have had individual installations of biomass gasifiers in the last years. These were also jointly financed by MNRE through TEDA and by the local panchayat authorities. All villages visited were already connected and supplied with grid power before installation of the biomass gasifiers, the gasifiers in most cases replaced parts of the grid power in order to reduce the panchayat grid electricity costs. When the biomass gasifier does not operate, power for the applications is supplied by the electricity grid. The biomass gasifiers have been purchased to supply the required power primarily.

It is indicated by TEDA that before installation, a feasibility report has to be made, these reports have however never been shown for this research and MNRE does not have any indication for this requirement on their website or included in the official subsidy request forms. TEDA admits that most gasifiers (especially those in Coimbatore region) are not running properly and indicates the lack of raw material as the main reason for failure (ref:

Interview, Mr. Selvaraj, TEDA Coimbatore, Appendix B). Once the gasifiers are placed, operation and costs are to be handled by the local panchayat. Panchayats can choose the type and producer of the biomass gasifier themselves, TEDA will provide subsidies as the nodal agency of MNRE. Training of the operator is done by the gasifier producer.

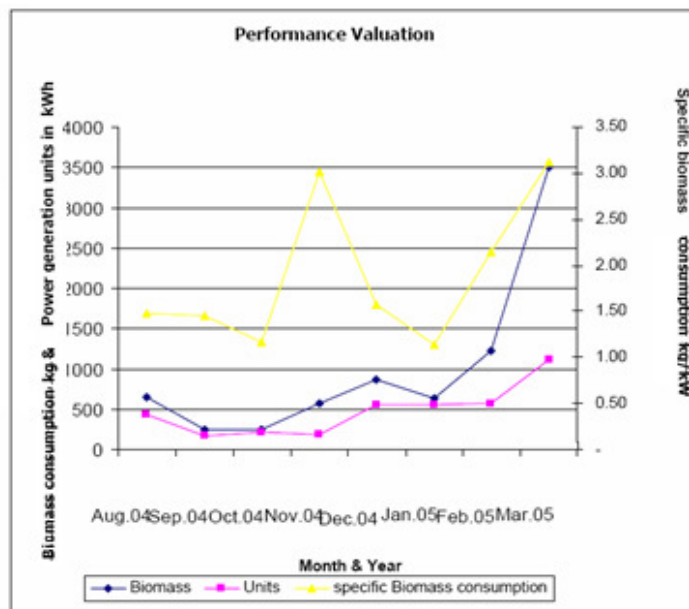
The biomass gasifier application in Odanthurai village in Coimbatore district functions as an example of a good application for others. Panchayat presidents have visited the village, and were informed about the daily operation of the system. During panchayat president meetings, the Odanthurai president informed his colleagues about the application and motivated them (ref: discussion in Pachal village).

5.3.4 The biomass gasifiers case studies

This section will discuss the applications of the biomass gasifiers in the villages. Information was provided by TEDA Coimbatore, interviews conducted with Panchayat presidents, biomass gasifier producers and operators and by observations. As this research is the first analysis of the installed gasifiers in South India, little literature is available concerning these applications. For the research an attempt has been made to provide a good view into the application of the biomass gasifiers. The lack of literature and previous research is however a constraint. This is solved as much as possible by conducting interviews with more than one person at the site and by checking claimed data, i.e. by looking at the actual production of kWh, displayed on meters in the biomass gasifier building.

Nellithurai panchayat

Nellithurai panchayat is located in Coimbatore district, Tamil Nadu state. The village population is around 900 and the village is equipped with a biomass gasifier since May 2004 which is still operating. The village and most houses are connected to the electricity grid. The gasifier is operated during the night and powers 90 street lights and a river water pump and attached filters. The 3 water tanks, with a combined capacity of 100.000 litres are filled during the night. A total of 60 kg of biomass can be gasified at one time in the closed top gasifier. One operator trained by the producer Ankur runs the gasifier.



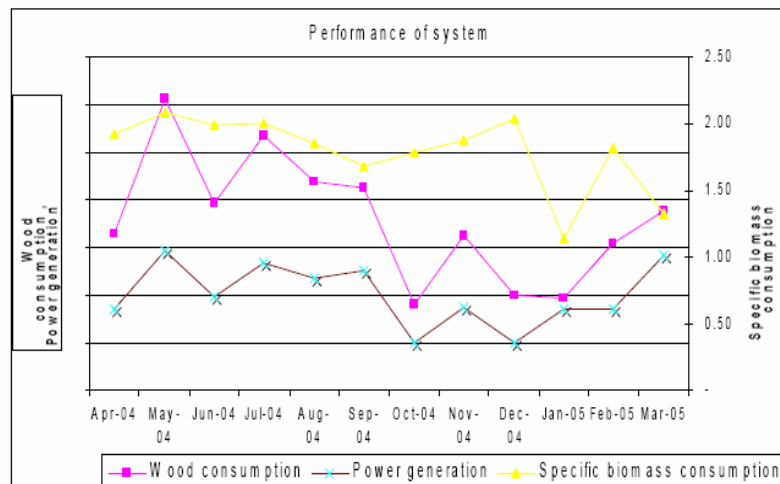
Graph 5.7: The performance of the Nellithurai biomass gasifier (Source: ITCOT 2006)

Recently the (former) operator died, resulting in an extended period of time of no operation. A new operator has been trained and is operating the gasifier again. Each household contributes 30 Rs./month for the drinking water provision to the panchayat. The EB bill savings were 50% at 10,000 Rs. and biomass costs are around 700 Rs./ton as indicated by the panchayat president. Waste wood from the teak processing industry is used for this purpose. Of the initial investment costs of 341,000 Rs., approx. 50% was paid for by MNRE subsidies and the other 50% was paid for by the panchayat. From Aug. 2004 to Mar. 2005, 3827 kWh was generated using the biomass gasifier; this is an average of 480 kWh per month. Please see graph 5.7. A total of 7965 kg of biomass was used in the same period (ITCOT 2006). This indicates that although running at the time of visit, (non-)regular stops did occur in the past. When operating at full capacity for 10 hours per night, a 9 kW gasifier can generate 2000+ kWh per month. Stops occur when waiting for maintenance and parts. As is also the case in the other villages, the population is not too concerned with the biomass gasifier, and do not have a clear opinion regarding. The people view the gasifier as a panchayat government item.

Odanthurai panchayat

Odanthurai is a village in Coimbatore district, Tamil Nadu state. All houses in the village of 3000 families are connected to the electricity grid, and grid power is available most of the time. The required biomass is provided as waste wood from a nearby saw mill. The biomass gasifier is operated during the day for 10 hours and provides power for drinking water pumping. The operator is trained by the producer Ankur. The panchayat president was responsible for the installation of the biomass gasifier. Sufficient biomass is available for this purpose. As in Nellithurai village, each household contributes 30 Rs./month for the provision of drinking water. A total of 45 kg of biomass can be gasified at one time in the closed top gasifier. The cutting of the wood in small sizes is done by a women self help group, and paid for by the panchayat. Biomass costs in Odanthurai are around 1000 Rs./ton.

From October 2003 till May 2007, a total of 18719 kWh was produced using the biomass gasifier. This is an average of 435 kWh per month. Please see graph 5.8. The Odanthurai application is described in international papers as a successful biomass gasifier project such as in ITCOT (2006).



Graph 5.8: The performance of the Odanthurai biomass gasifier (Source: ITCOT 2006)

Chikarampalayam panchayat

This village is located in Coimbatore district, Tamil Nadu state and has a biomass gasifier installed since April 2004. The biomass gasifier has not been running for at least one year due to generator problems. According to the panchayat, Ankur is to be held responsible for the problems and requires Ankur to perform the repairs. There is a general dissatisfaction with the support offered by the producer. The application was used for pumping of drinking water; these installations are currently powered using grid electricity. TEDA is unwilling to repair the generator as well; they feel responsibility is with Ankur. According to the biogas technician of TEDA, the DIPCO engine and generator sets have caused problems in 10 of the total 28 cases they were installed. Ankur replaced 2 of them for better Field-Marshall engines and generators (Nellithurai and Odanthurai villages), but did not improve the remaining 8 installations. As for all of the Coimbatore district applications, no feasibility reports were made prior to commissioning and installation. A total of 960 kWh was produced using the biomass gasifier in the past. The operator, not present at the time of visit has been trained by Ankur.

Kunnathur panchayat

Kunnathur panchayat is located in Coimbatore district, Tamil Nadu state and has a biomass gasifier installed since July 2006. The village consists of 400 houses. The biomass gasifier was installed to provide power for street lights and drinking water pumping. Immediately after installation, wood proved unavailable in the village and direct surroundings. Biomass would have to be provided from further thus increasing costs to 2000-3000 Rs./ton. No saw mill or other wood industry is available in the neighbourhood.

The MNRE subsidy has not been provided completely, because of the lack of operation hours. At the moment grid electricity proves cheaper for the application of drinking water pumping and street lighting. There is no longer an operator present and operation in the nearby future is not to be expected. The biomass gasifier has produced a total of 8,3 kWh, the equivalence of 1 hour of operation.

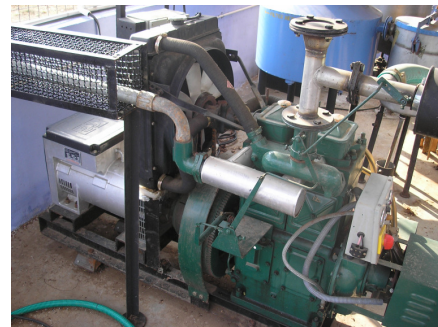


Fig. 5.9: The idle biomass gasifier in Kunnathur panchayat

Valudavur panchayat

This village is located in Villupuram district, Tamil Nadu state and has a biomass gasifier installed since 2006. The gasifier is a 12 kW gasifier built by AEW. The costs of the installation were Rs. 450,000. The gasifier is currently not running, the exact reasons stay unclear but technical issues are the most probable reason as indicated by the operator. AEW is, according to the villagers, unwilling to perform the required repairs. Operation and preparation of the biomass is done by 2 people. Daily operation is supposed to be done for 4-5 hours. Grid power is available for approx 6 hours per day, according to the

villagers. The gasifier has run for a total of 2 months and produced approx 280 kWh. Biomass costs are around 700-800 Rs./ton and sufficient biomass is available.

Pachal panchayat

This village is close to Thirupathur, in Vellore district, Tamil Nadu state. The gasifier installed is a 9 kW closed-top downdraft Ankur model, same as the gasifiers installed in Coimbatore district. The gasifier was installed to provide street lighting during the night for 5-6 hours. In the beginning the biomass was available at no cost, and the installation was run by a women self help group. The president of that time was motivated by the positive stories and visits to Periyar College for women and Odanthurai panchayat. The available amount of biomass was assessed and it was determined to install a gasifier. In addition a project report was written by Dr. A.J. Christopher of the Sacred Heart College in Thirupathur, Vellore district, titled: “*Project report for electric power savings using biomass gasifier at Pachal panchayat*”. This small report analyses costs excluding the biomass purchase costs, the biomass gasifier proves profitable in this case (3,60 Rs./kWh). The operator of the gasifier was trained by the operator in Odanthurai village. After a while, market purchase costs had to be spent on purchasing the biomass. The responsibility for the biomass gasifier shifted to the panchayat and the biomass gasifier no longer proved profitable.

Problems encountered during operation were voltage fluctuations and the results from wet biomass causing problems in the gasifier. The project was stopped a year ago when a new president was elected. The current president is not enthusiastic about the biomass gasifier and abandoned the project. Instead he had a biogas installation built next to the biomass gasifier. The former president has plans to commercially produce electricity using the biomass gasifier. He plans to sell the electricity to local applications. Whether financial sustainability is reachable is unclear at the moment.

Periampatti panchayat

This panchayat has a 10 kWe AEW closed-top downdraft gasifier (purchase costs: Rs. 480,000) (as shown in fig. 5.10) similar to the gasifier in Valudavur panchayat. The gasifier was placed in 2005, and was used for drinking water pumping for 8 hours per day. It is currently no longer running for the last 2 months (in August 2007), according to the panchayat president. There are engine problems and they are waiting for mechanics for AEW to repair the engine. One of the problems indicated by the director of AEW (ref: Interview with S. Adhavan, director of AEW) is the support of maintenance. Maintenance contracts are available but too expensive for most panchayats. Once problems arise, repairs may take long to be performed.

Biomass costs are around 750-1000 Rs./ton. The panchayat president claims that operation costs are



Fig.5.10: The biomass gasifier in Periampatti panchayat

around 1,5 Rs./kWh with the biomass gasifier, this is probably too low. Although the biomass gasifier was not in operation at the moment of visit, plans exist to extend usage to street lighting and night operation. A total of 2 to 3 people operate the gasifier and have been trained by Aruna staff. Technical problems encountered include voltage fluctuations, problems arising due to wet biomass and a long start-up time. Although out of service for 2 months, the president indicates to be reasonably satisfied with the biomass gasifier because of the alleged economic benefits. The drinking water installation is currently powered using grid electricity, which is sufficiently available.

5.3.5 Application success

When looking at the application success, we differentiate between the following as described in the framework:

- Technical success
- Financial success

Technical success

In all of the visited biomass gasifiers, the applied biomass gasifier electricity was used for drinking water pumping. This involved the pumping of ground water into the local water tanks, or the pumping of river water, followed by a cleaning system, followed by pumping into the local water tanks. A few of the gasifiers are also used to provide street lighting during the night. The options are depicted in fig. 5.11.



Fig. 5.11: The applications of the biomass gasifiers

Especially the applications in the Coimbatore region are interesting to analyse: A number of 28 gasifiers have been commissioned in the years 2003-2005, of which only 7 are

functioning. Out of the 28 gasifiers in this region, 4 have been visited for analysis: 2 were in operation and 2 were not. A table was presented by TEDA Coimbatore with all the gasifiers and their respective operational status. Please see table 5.12.

Table 5.12: The 28 biomass gasifiers as commissioned by TEDA Coimbatore

#	Panchayat name	Date of purchase order	Date of supply	Date of erection	Date of completion	Date of trial run	Remarks
1	Odanthurai	22-8-03	10-10-03	15-10-03	18-10-03	21-10-03	Running (visited)
2	Semmipalayam	14-4-04	13-5-04	18-5-04	22-5-04	22-5-04	Running
3	Nellithurai	11/2003	03/2004	5-4-04	5-5-04	20-6-04	Running (visited)
4	Chikarampalayam	31-4-04	20-4-04	30-4-04	30-4-04	30-4-04	Engine problems (visited)
5	Malumichampatti	22-6-04	10/2004	01/2005	01/2005	25-1-05	Running
6	Kalangal	22-8-03	10/2004	04/2004	04/2004	1-2-04	Engine problems
7	Devarayapuram	22-6-04	10/2004	04/2005	04/2005	12-4-05	Engine problems
8	Karaipudur	22-6-04	10/2004	01/2005	01/2005	9-6-05	Engine problems
9	Arumuthampalayam	22-6-04	10/2004	01/2005	01/2005	31-3-05	Engine problems
10	Poomalur	22-6-04	10/2004	01/2005	01/2005	21-7-05	Engine problems
11	Cheyur	22-6-04	10/2004	01/2005	01/2005	7-5-05	Load problems
12	Periakottai	22-6-04	10/2004	01/2005	01/2005	18-4-05	Running
13	Vavipalayam	22-6-04	10/2004	-	-	31-5-05	Running
14	Arasur	22-6-04	10/2004	02-09-05	-	-	Load not connected
15	Chinniyampalayam	22-6-04	10/2004	-	-	20-5-05	Load problems
16	Kadathur	22-6-04	10/2004	-	-	22-7-05	Wood deficiency
17	Kannakkampalayam	22-6-04	10/2004	-	-	-	Trial run to be given
18	Theethipalayam	22-6-04	07/2004	-	-	-	Trial run to be given
19	Zamin Kottampatti	02/2005	-	-	-	-	Trial run to be given
20	Chikkarayapuram	02/2005	04/2005	-	-	-	Trial run to be given
21	Singanallur	02/2005	04/2005	-	-	-	Trial run to be given
22	Kovilpalayam	02/2005	04/2005	-	-	-	Running
23	Kattur	22-6-04	10/2004	-	-	-	Trial run to be given
24	Pungamuthur	22-6-04	11/2004	-	-	-	Trial run to be given
25	Kunnathur	22-6-04	04/2005	-	-	-	Wood deficiency (visited)
26	Kattampatti	22-6-04	04/2005	-	-	-	Wood deficiency
27	Veelapandi	02/2005	-	-	-	-	Not erected
28	Nellithurai II	02/2005	04/2005	-	-	-	Not erected

The technical problems observed during the visits in the 7 respective villages are:

Engine problems

The first 10 gasifiers in Coimbatore region were equipped with Dipco produced gas engines and generator sets. These proved to be unreliable (ref. interview Mr. Raja and Mr. Selvaraj). The gasifier producer Ankur was willing to replace 2 of the engines. Most of the gasifiers equipped with Dipco engines are not running. From gasifier number 11 to 28, other engines and generators were used (Field-Marshall), causing no such operational engine problems.

Load problems

The gasifiers are used to provide electricity for water treatment plants. The water treatment plants existed before the biomass gasifier, and were originally powered by grid electricity. For some of the installations the electrical motor, to pump clean drinking water into the water tower, is a 10 hp electrical motor. The 9 kW gasifier is capable of providing only 7.5 hp effectively. The 10 hp motor subsequently receives too little power from the gasifier to successfully pump water to the required level. The biomass gasifier can not be used for the required application and grid electricity is used as was the case before. These problems have not been solved, and gasifier operation has been halted after a short period.

Wood deficiency

In some areas, wood for the biomass gasifier is not sufficiently available. Wood cannot be harvested from the forests by law but must be collected (i.e. from barren land or private land) or purchased from a wood related industry (i.e. saw mills). Purchasing wood outside the direct region results in high transport costs, making the application economically infeasible. Although wood prices are normally around 1000 Rs./ton, at some sites these are around 2000-3000 Rs./ton, making operation unfeasible (ref: Interview Kunnathur village). The gasifier visited in Kunnathur village has only been running for a few hours totally and has not operated for the last year.

Maintenance

Small maintenance is performed by the operators, trained for this. These include filter cleanings, oil changes and other small maintenance. One of the problems encountered however was related to the larger regular and non-regular maintenance. Skilled labour is required and not available in the related villages. Support is not sufficiently performed by the producers. Local (car) mechanics have not been employed to do repair works as far as is known. Producers such as AEW do offer maintenance contracts; these are contracts in which guaranteed maintenance support is provided; no panchayats have however chosen for these contracts due to the involved costs. The physical distance between the manufacturer and the gasifiers is large. Ankur has indicated to be responsible for technical support to the involved panchayats. They were however not paid the full

purchase costs and refuse to support the operation and technical issues concerning the biomass gasifiers. Ankur is not positive about the future of these gasifiers and Ankur no longer cooperates with TEDA.

Wet biomass

Wet biomass was used on several occasions and causes problems related to the formation of tar and voltage fluctuations. When tar formation increases, extra engine cleaning is needed. Wet biomass might be used because it is fairly difficult to determine whether biomass is dry enough, especially in rainy seasons. In the rainy seasons, drying the biomass can be difficult, a dry storage place is required, but might not be available.

Learning

Technical learning has occurred by identifying above described problems. The problems are not solved however. The producer Ankur indicates to be unsatisfied with the results of the biomass gasifiers performance, and indicates a lack of payment for the installations. Ankur is unwilling to support the applications. TEDA is aware of the problems, but unable to solve these, as indicated by the staff. Clear responsibility regarding these technical problems is lacking.

Within the villages, people were not involved in awareness of the biomass gasifiers and most of the people did not care too much about it. Without sufficient support of the involved biomass gasifier producer and government, it proved to be almost impossible to keep the gasifier running successfully. Involved people, with a willingness to learn are required. In the applications that are running, these people were present. This was mostly in the form of an enthusiastic panchayat president and one or more operators. They learned from the mistakes made in the past in running the application; this includes maintenance, biomass availability, etc.

Conclusion

Most of the technical problems are related to a poor planning and implementation process. Technical issues such as wood deficiency, lack of maintenance skills, producer support and the described load problems could be assessed beforehand and has not been done sufficiently.

Support of the producers is low, this is however predictable when producers are located far away and panchayats sometimes difficult to reach by public transport. Although TEDA shares the concerns of the low operational performance of the biomass gasifiers, they do not see technical support in the form of maintenance, replacement and/or support as their role.

A lot of the problems might have been avoided if a proper independent preliminary investigation would have been conducted. If this would have been done, subsidies could be related to the outcome of this investigation. A too strict government goal to install gasifiers in the rural setting is causing a waste of public money; after all especially the lack of biomass and the load problems are very easy to determine beforehand.

Financial success

A problem arising with low running hours is the subsidy schedule of MNRE, subsidies are rewarded according to a running schedule, please see section 3.7 for more information. So far only 5 of the 28 commissioned biomass gasifiers in Coimbatore region have received the full MNRE subsidy of approx. 50% of the purchase costs (ref: Interview TEDA Coimbatore).

Operation costs are highly dependent upon the biomass prices; these can differ from 800 to 3000 Rs./ton, depending upon availability and season. Another factor is the plant load factor, when the PLF is low, expenses per kWh will rise.

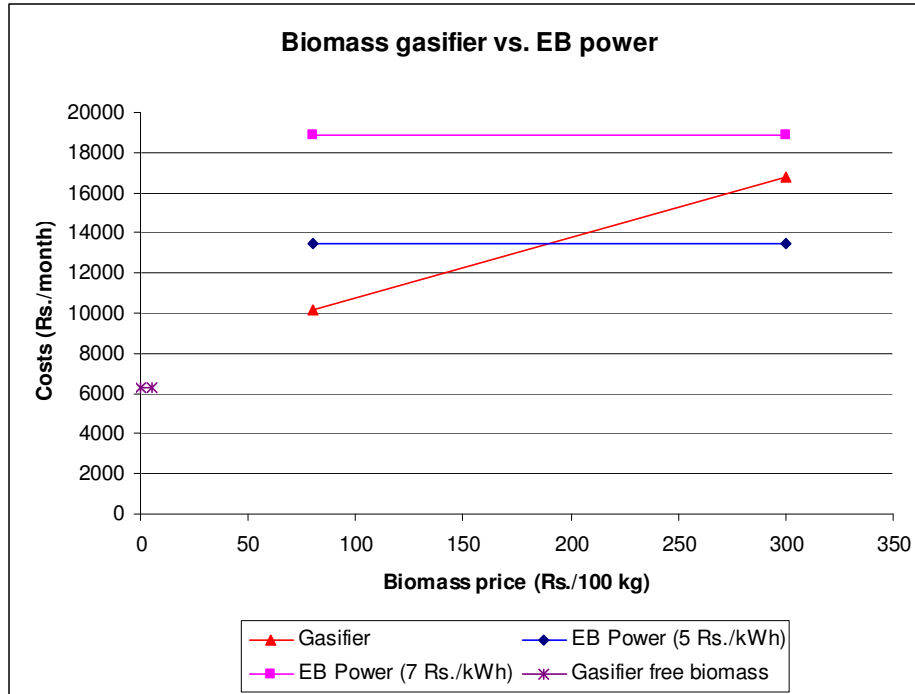
A typical (simplified) cost calculation of the installation and operation costs of a 9 kW gasifier for the purpose of water pumping and street lighting is shown in table 5.13. The 9 kW gasifier requires 10 kg of biomass for the production of 9 kWh.

Table 5.13: A typical cost calculation (Ref: Cristopher (????), Interview TEDA, interviews in villages)

Item	Costs	Unit
Installation costs		
Biomass gasifier (9 kW)	360.000	Rs.
Building (approx. costs)	180.000	Rs.
Total	540.000	Rs.
Operation costs		
100 kg biomass	80-300	Rs./day
Night labour 2x (running)	150	Rs./day
Day labour 2x (cutting of biomass)	60	Rs./day
Total (@ 30 days/month)	8700-15300	Rs./month
Production by gasifier		
Electricity generated	90	kWh/day
Total (approx)	2700	kWh/month
Grid electricity		
Grid electricity costs (approx)	5-7	Rs./kWh
Total (@ 90 kWh per day)	13500-18900	Rs./month

If we use the depreciation of the installed biomass gasifier (360.000 Rs. of which approx. 50% are MNRE subsidies), for the panchayat in a period of 10 years or 120 months:

$$\frac{180.000}{120} = 1500 \text{ Rs./month, we can draw graph 5.14.}$$



Graph 5.14: Costs per month for a 9 kW gasifier (at full load) vs. State Electricity Board power (the “gasifier free biomass” are the fixed costs excluding the biomass purchase costs, this is Rs. 6300 / month).

These costs are excluding unforeseen costs and excluding maintenance and material costs. The previous (simplified) calculations show that financial sustainability of the biomass gasifier is difficult to achieve when the biomass has to be purchased for market prices. The panchayat users in the villages did indicate that their costs for the EB bill did decrease by as much as 50%, the costs for the biomass gasifier were however less clear. Applications such as in Hosahalli and Hanumanthanagara villages where “free” biomass (from allocated land) was available are more likely to achieve financial sustainability.

Learning in the field of finance of TEDA and the panchayats was low, above calculations show that it is very difficult to achieve financial sustainability with a biomass gasifier. TEDA remains positive about the financial viability of the biomass gasifiers but was unable to produce a costs calculation for analysis.

The benefits of the gasifier are in other fields, such as the introduction of labour and the availability of power whenever requested compared to the less-reliable grid electricity.

In summary:

- Biomass gasifier costs per month can be comparable to grid power costs depending on biomass purchase costs
- This is excluding unforeseen and maintenance/parts costs
- It does create employment
- Village has their own responsibility and availability over electricity

5.3.6 Institutional successes

The institutional success of the TEDA has been determined; the institutional success on village level has not been determined due to limitations of the research. Please see section 2.9 for more information.

The institutional successes of the involved projects are low. The involved institute is the government, in the form of TEDA. Little to no lesson seems to have been drawn concerning the failed biomass gasifier applications in the panchayats. When performing the interviews, some of the higher staff of TEDA indicated that the biomass gasifiers were a success, lower staff disagreed however. When looking at the steps of institutional learning as described by Korten, TEDA has expanded the program without “learning to be effective”. This has resulted in a largely failed program. Because of the lack of transparency within the government bodies and because of the lack of previous evaluations of these projects, TEDA is not sufficiently willing to learn from the mistakes made. The program is still expanding and unlikely to be successful in new applications.

5.3.7 Incidental developmental impact

The goal of all panchayats in this section was to save on the SEB costs and the installation of the biomass gasifiers had no developmental goal. Some (incidental) developmental impacts did occur however.

Developmental impacts did occur in the field of women’s employment. Women’s self help groups were asked to either operate the biomass gasifier or provide labour for the preparation of the biomass (i.e. cutting, and drying) in most of the villages. Employment for women increases their independence and mostly benefits their entire family. Where women self help groups were asked to run and / or assist in the biomass gasifier, income was created for 1 to 3 women.

Grid power availability differs per village, although reasonably reliable in Tamil Nadu state. A biomass gasifier can prove beneficial, also when financial sustainability is not achieved. Where drinking water pumping is powered by the biomass gasifier, the panchayat can decide (if the biomass gasifier is operational) when to fill the water tanks, independent of grid power availability, thus continually provide the households with drinking water and when available street lighting.

5.3.8 Conclusions

The applications in the rural panchayat setting as described in this report are mostly unsuccessful. They fail due to a number of reasons, mostly related to poor planning and implementation. This leads to biomass gasifiers being placed in villages without biomass available, loads that cannot be connected to the biomass gasifiers, no or unreliable maintenance arrangements and no clear structure of finance. The poor learning leads to problems being replicated in new applications. In general, it is very difficult to

successfully operate the biomass gasifiers in the villages. This is due to the following reasons: 1) The biomass gasifier applications only offer an (assumed) financial benefit, and are not very beneficial in reaching developmental goals, 2) With this in mind and with the availability of (reasonably reliable) grid electricity, it is tempting for the panchayats to use the grid electricity if it proves to be difficult to operate the gasifiers in terms of maintenance and 3) Support of the involved government and producers is lacking, this involves support for maintenance and the requirements before installation. 4) Local support is low. When local support in the village is better, success of the application is likely to be higher. In the villages with successful applications, local people were present (i.e. the panchayat president), with enthusiastic views towards the biomass gasifier and a motivation to spend time and energy into support and operation. The influence of these opinion leaders on the success of the biomass gasifiers is interesting to be investigated for future research.

6 The new biomass gasifier initiatives for rural India

6.1 Introduction

In this chapter all the new biomass gasifier initiatives visited during the fieldwork research will be described. The three described projects differ from the (mainly failing) projects from the past as described elsewhere in this report.

The three projects are:

- BERI 500 kW biomass gasifiers connected to grid power: This is a project within the larger BERI initiative. The BERI program focuses on rural development by providing bio-power in the rural setting. It has clear developmental and environmental goals.
- Periyar Maniammai College for Women biomass gasifier for one village: This is a plan to provide a village with a biomass gasifier to create employment as part of a national program. The village is already electrified and the developmental goals of this plan are less clear.
- 100 villages electrification of DESI power: This is a program to electrify 100 villages in the North of India. The program has clear developmental goals, especially in the field of promoting entrepreneurship for the rural people.

Representatives of these projects and the BERI biomass gasifier site were visited.

The projects within this report have a focus on reaching developmental goals, such as the promotion of entrepreneurship activities in the villages and the provision of reliable electricity to the rural population. Every project will be described using the framework:

- Ultimate goals of development
- Application success
- Institutional experience

Besides the framework, lessons concerning the reasons of failure of the previously described projects and programs of chapter 5 are used in this analysis.

Focus regarding the reasons of failure from chapter 5 will be on:

- Technical operational plans and support
- Availability of biomass
- Financial sustainability
- Local support

All analysis in chapter 6 is based upon experience of the related NGO / government / educational institute and upon plans. The plans as described in this chapter were not operational at the time of fieldwork research.

6.2 Biomass Energy for Rural India

6.2.1 Introduction

BERI stands for Biomass Energy for Rural India and was originally developed by ASTRA, currently known as CST (Jayakumar 2005) of the IISc. It is currently not related to ASTRA / CST anymore. BERI is a large scale project and has been started as an intervention in the area of climate change, by making a replicable model project for the reduction of greenhouse gas (GHG) emissions (Swaminath 2006, UNDP / GEF 2007), please see text 6.2. BERI was, at the time of fieldwork research almost finished building the first site with clustered biomass gasifiers.

For the research as described in this report, the BERI biomass gasifier site in Koratgere taluk was visited and an interview was held with a local NGO officer, Mr. Dyasa and with the BERI director Mr. Swaminath in April 2007.

6.2.2 The BERI Program

The first signatures for the BERI program were signed in May 2001 (ref: Website BERI). Financial support for the BERI projects is provided by the Global Environment Facility (GEF), through the United Nations Development Program (UNDP) with co-financing from the India Canada Environment Facility (ICEF). Both MNES and the Government of Karnataka (GOK) provide financial support (Swaminath 2006). UNDP co-finances BERI as part of millennium development goal 7: Ensure Environment Sustainability (UNDP 2007). Table 6.1 provides the finance of the related agencies.

Table 6.1: Subsidy contribution (from: Website BERI)

Agency	Budget (Million USD)	Budget (millions Rs.)	% Share
UNDP/GEF	4,02	188,1	46.6
ICEF	2,49	114,19	28.9
Gov. of Karnataka	1,48	68,4	17.2
Gov. of India	0,39	18,1	4.5
Others	0,24	11,1	2.8
Total	8,62	400,6	100

The BERI project will be implemented in 28 villages (though this number differs slightly in the literature) in 5 different talukas in Tumkur district, Karnataka state. Please see box 6.2. The main goal is to demonstrate the feasibility of using renewable energy options to reduce carbon emissions. This is done by plantation of carbon consuming biomass (a green belt ref: Swaminath 2006) on farmers and government land (as shown in fig. 6.3) and by the reduction of emissions by the use of this biomass for the production of power. The project will enable the provision of good quality services for lighting, drinking water supply, cooking gas and irrigation (UNDP / GEF 2007). A total of 2980 hectares of plantation has been established to serve as the source for the biomass energy production (UNDP / GEF 2007).

Our mission is to develop, promote and implement through participatory approaches, a decentralized, cost effective, renewable and sustainable bio-energy technology package;
- to meet rural energy needs,
- to enhance income opportunities for the poor,
- to reduce green house gas emissions to the atmosphere

Box 6.2: The mission statement of BERI (BERI 2004)

As to date (March 2007) a total of 5 10 kW gasifier systems have been installed in four districts. On one site, the electricity produced is used for irrigation for the forest department. 51 community biogas plants, operating on dung, each serving around 3-4 households, have been constructed. Plans are to install 100 individual and 100 community biogas plants (BERI 2007). Vermi-compost units were built for the farmers in the region. NGOs have undertaken capacity building activities, comprising of 51 biomass user groups and self help groups (SHG) for men and women (BERI 2007). Training was provided to over 10.000 people, comprising of 58% women. Training was given in the field of technology, management, exposure trips, promotion, irrigation, income generation, bee-keeping, etc. The complete BERI program is a large multi-million dollar program sponsored by several governments and organizations. It has an exposure to a large number of people. The biomass gasifier projects are a part of the larger BERI initiative.

6.2.3 The biomass gasifier plans

History

Expectations were to run the biomass gasifier project from 2001 to December 2007. This goal will not be achieved. In the beginning of the project experiences were low. As indicated by Jayakumar (2005) several barriers exist towards successful implementation of bio-energy systems such as:

- Technical barriers, There is a limited track record of the gasifier technology and a lack of experience on large scale rural biomass gasifier applications
- Institutional barriers, there is a low capacity of the village level institutions for implementation of the bio-energy systems
- Information barriers, there is a principal lack of awareness of visible technological configurations and a low level of access to information in the rural areas
- Financial barriers, this is due to the high technical and institutional risks
- Market barriers, caused by the subsidized electricity and fossil fuels and the freely available fuel woods and biomass residues

Plans for the biomass gasifier have changed drastically throughout the years. When the program was started in 2002, the idea was to install 40 kW gasifiers with a total capacity of 1200 kW (so a total of 30 gasifiers) in island mode (this is independent and not

connected to the central electricity grid). These were to be placed in 28 villages that were already connected to the (unreliable) electricity grid. At the time, no gas engines with a 40 kW capacity were readily available and a survey showed that 40 kW would not meet the village requirements. At least 100 kWe is required per village to provide electricity for lighting, irrigation, small industries and households. The plans were changed to place a total of 28 100 kWe gasifiers in the 28 designated villages. To increase efficiency, the plans were then again changed to go for a cluster-mode. This means that gasifiers would be clustered to produce 500 kWe and be connected to 5 villages. The site at Koratgere taluk is the first of these. Special electricity lines were installed to the villages. The problem still remaining would be the load variation throughout time. The peak load demands would exceed the gasifier capacity while the minimum loads would be much lower than the gasifier capacity. The idea was to install 4 gasifiers (instead of 1 x 500 kW) which could be switched on and off according to the required loads. The peak load problems would however not be solved with this solution, so it was eventually decided to grid-connect the clustered biomass gasifiers. Excess power would be sold to the grid for a fixed price and power shortages can be solved through provision by the grid. The grid power connection lines have been improved in the area to make this possible. Now more grid power is available due to the improved lines (Interview with M.H. Swaminath, appendix B).

Delays occurred during the project. In 2005, it was expected that 12 biomass gasifiers would be installed by March 2007 (Jayakumar 2005), this has not been achieved; a total number of 4 biomass gasifiers at the same site was installed by March 2007.

As indicated by the current director, Mr. Swaminath, the major problems related to the biomass gasifier are in the field of biomass availability and financial problems. Currently, the biomass gasifiers do not generate money, but forest committees have been working on growing and maintaining the biomass forests during the past years. Local people are being paid to do so. The biomass gasifier costs are according to Mr. Swaminath around 65.000 Rs. / kW capacity (approx € 500.000 for 500 kW). The installed gasifiers at the site (3 x 100 kW and 1 x 200 kW) are built by Netpro and Energreen from Bangalore. These companies were selected after a public tender.



Fig. 6.3: A biomass fuel plantation close to the BERI biomass gasifier site

The director of BERI indicates that the cooperation with the biomass gasifier producers is bad; there are various delays and a lack of capacity and knowledge within those companies. They do not have enough finance to invest and improve the technology according to the BERI director. The fact that problems exist is confirmed by the director of Energreen, he however blames BERI for the delays, claiming managerial and financial

problems as the main reasons (ref: Interview M.H. Swaminath, Appendix B, interview Krishnaswamy 2007).

Technical problems with the biomass gasifier have also occurred; synchronizing the biomass gasifier with the electricity grid is a difficult technical issue and dependent upon cooperation of the state electricity utility.

A benefit as indicated by the BERI director is the fees collection. In the grid connected mode, the state electricity utility is responsible for collection of the electricity fees, which can be difficult in the rural areas due to the unwillingness of people to pay for the electricity. A fixed price of 2,80 Rs. per unit produced by the biomass gasifiers is paid by the utility to BERI, although difficulty in doing so is indicated by A. Sarkar⁴ in discussions. Plans are to operate the biomass gasifiers for 24 hrs. a day, they will provide 3 phase power.

In 2002, it was expected that a biomass gasifier would be operational within 6 months, it took 5 years due to the technical problems encountered and due to the changes as described (Ref: Interview Swaminath). Looking back at the decisions taken, it would have been better to buy 1 x 500 kWe biomass gasifier per cluster. For the next cluster, 2 x 250 kWe gasifiers will be used and for those after that, 1 x 500 kW gasifier will be applied. Throughout the years, BERI has seen several directors come and go. Out of the total BERI budget of Rs. 400.000.000, Rs. 145.000.000 has been spent so far.

The current plans

The BERI program is unique in the field of rural biomass gasifiers because it is the first program in which rural biomass gasifiers are grid connected. So far all biomass gasifiers in the rural setting were installed on island mode. This means that the biomass gasifier powers a number of appliances without any connection to any other power system (i.e. the central grid). One of the problems with biomass gasifiers and the financial sustainability is the varying plant load factor (PLF) throughout time. When loads are below optimum, costs rise and financial sustainability will be unachievable. When surplus or shortages occur, these can be sold or purchased to and from the grid in order to let the biomass gasifiers run on optimum performance.

One of the planned sites has 4 gasifiers installed (3 x 100 kW and 1 x 200 kW) with a combined



Fig. 6.4: The 200 kWe BERI biomass gasifier, built by Netpro

⁴ Student of the University of Technology Eindhoven, The Netherlands, she visited the BERI project in Jul-Aug. 2007. Her report is expected mid-way 2008.

capacity of 500 kW in Koratgere taluk (as shown in fig. 6.4). At the time of fieldwork visit the installation was only weeks from operation. The planned production is 2,5-.3 million kWh per year of which 0,7 million kWh will be used for the village and surrounding villages. The remaining will be sold to the state electricity board (SEB). When fully implemented a total of 1200 tons of CO₂ emissions is expected to be avoided annually. The biomass plantations will sequester 5000 tons of CO₂ annually (UNDP / GEF Website October 2007).

The local assembly has signed a power purchase agreement (PPA) with the state utility BESCOM, to supply electricity generated by the 4 gasifiers already installed in Koratgere taluk.

6.2.4 Ultimate goals of development

The ultimate goals of development for rural applications as described by Uphoff are the following:

1. Increase of production
2. Increase of well being
3. Empowerment

These goals will be assessed in terms of the BERI plans. An assessment is made to look whether the goals as defined by Uphoff are also present in the plans of BERI.

The BERI plans are large plans and the project is divided into several sections, including biomass gasifiers, biogas installations, training of local villagers, etc.

An increase of well being is an important goal within the BERI program. This increase includes the provision of locally produced electricity and gas for cooking, by the installation of biogas installations, and the provision of drinking water in the villages. Training has already been given to a large number of people in the field of agriculture, management and technology. This training can provide an increase of well being (health education), production (new techniques) and empowerment (increased awareness and assertiveness). In the mission statement it is stated that providing bio-energy technology packages to meet the rural needs, combined with an increase of income for the rural population are part of the main goals of the BERI projects. A local NGO officer confirmed these goals and stated that many results have been achieved already in the field of (agricultural) education, and an increase of awareness. Local people are hired to work in the biomass fuel forests and women self help groups are formed and employed to start (among others) new biomass forests plantations.

With a successful biomass gasifier running, electricity availability is assured in the rural area, this will increase the reliability for the farmers to use irrigation, thus increasing yield production. The plantation and maintenance of the biomass, which has been in process for the last years also contributes to the income of local people.

The plantation of the biomass crops also increase the amount of oxygen production in the area and likely to increase air quality thus supporting well being.

Although the results of the complete BERI program are not yet known, BERI has a focus on the goals as defined by Uphoff. The projects have been planned over the years and results have already been obtained, such as large scale education for villagers.

6.2.5 Application success

The application success is divided in:

- Technical success
- Financial success

When analyzing the applications as described throughout chapter 5, the following items proved the most important reasons for failure of the biomass gasifiers:

- Technical operational plans and support
- Availability of biomass
- Financial sustainability
- Local support
- Learning process

Above items are analyzed using the application success from the framework with respect to the BERI program. This is based upon planning of BERI, and not on actual experience because at the moment of fieldwork research, the gasifiers were not in operation.

Technical success

As described, technical plans for the biomass gasifiers have changed drastically from 2002 to 2007. This has resulted in a less-than-optimal configuration for the first cluster in the Koratgere taluk of 3 x 100 kW and 1 x 200 kW 100% producer gas biomass gasifiers. Problems exist with the biomass gasifier producers. In general we can state that the technical planning process has been poor, with the many changes and unanticipated problems encountered.

Much effort has been put in ensuring biomass feedstock availability, and no problems are expected in this field. This is very different from the small-scale biomass gasifiers as in the Coimbatore region described in chapter 5.

With the current cluster mode and grid connection of the biomass gasifiers BERI has chosen a new approach in India with an uncertainty. In theory, the benefits are clear, grid connecting biomass gasifiers has however only been done before in industrial applications and production and not in the rural setting. The BERI plans are to rapidly build the 4 remaining biomass gasifier sites with the grid connection to catch up lost time. Long-term experiences in operating the first cluster can not be incorporated in the new to-build biomass gasifier clusters and (technical) mistakes related to day-to-day operation are likely to be replicated. The clustering of the biomass gasifiers does drastically simplify maintenance. Mechanics are not required to travel to all separate gasifiers but can perform maintenance at a central location.

Financial success

For the moment and in the coming years financial sustainability is ensured because of the remaining funds as provided by UNDP, ICEF, Government of Karnataka and Government of India. Although CDM funds are not yet incorporated, these can play a role in the future for new projects. The financial sustainability increases when all the power produced by the biomass gasifier is sold at a fixed price to the state electricity utility. This reduces costs for fee collection and ensures efficiency of the plant load factor. In theory, financial success is guaranteed.

6.2.6 Institutional success

Institutional success is analyzed looking at the experience of BERI into the rural development in the past and looking at the current developments of the biomass gasifier clustering by BERI. The institutional success of the panchayats and rural organizations has not been determined due to limitations of the research, this is described in section 2.9.

BERI has been founded in 2001 with the goal of developing and implementing a decentralized (cost effective) bio-energy package to meet the rural needs, enhance rural income and to reduce green house gas emissions. When looking at the steps as defined by Korten we can determine institutional success of BERI:

1. Learning to be effective
2. Learning to be efficient
3. Learning to expand

The BERI program is large, it comprises (agricultural, biomass plantation and awareness) education to a large number of people and it involves the installation of various bio-energy systems such as biomass gasifiers (small scale and 100+ kW scale) and biogas installations. Determining the institutional success of the entire program is difficult and beyond the scope of the research. The program has not been analyzed completely because of the large amount of various projects. The institutional success of BERI may differ per project. Education has been provided during the last years to a large number of rural people. The biomass gasifiers were however not in operation at the time of fieldwork research. The institutional success of the biomass gasifier projects will therefore be determined in this section.

Especially the planning and implementation process of the biomass gasifiers has seen a number of changes throughout the last years. Plans have been changed from island-mode of 40 kW gasifiers to clustering of 500 kW gasifier(s). Experience gained in the past by IISc has been used in this project. The BERI program originated from IISc. Technical knowledge is currently supplied by the companies Ankur and Energreen, although cooperation has been difficult at times. The biomass gasifier grid-connection clustering project is in the phase of “learning to be effective”. Although experience has been gained with rural biomass gasification, the innovation of clustering of biomass gasifier and the connection to the grid electricity has not been applied before. Much is unknown at the moment, this includes whether the SEB can afford paying for the electricity produced by the biomass gasifier, the assurance of electricity for the rural people when demand is

higher than production, the success for maintenance of the clustering of the gasifiers, the alleged financial benefits of clustering and grid connection.

In theory the benefits (of grid connection and clustering) are clear, practical experience has not been gained however.

Learning has occurred during the planning and implementation process. The many changes of plans for the biomass gasifiers do indicate this learning process. Experience of IISc has been utilized for the project. Technical learning was also observed for the producers Ankur and Energreen in the connection of the biomass gasifiers to the electricity grid. This includes a correct alignment between the grid electricity frequency and the biomass gasifier electricity production and a correct connection of the biomass gasifiers' produced electricity.

Learning within the panchayats and the rural population has not been analyzed, please refer to section 2.9 for more information.

6.2.7 Conclusion

The BERI program has a focus on improving the rural lives of the people in Tumkur district. Although exact results are unknown, a local NGO officer confirmed that results have been achieved. The BERI initiative is a large scale initiative, incorporating several projects, with a focus on rural development. It integrates social and developmental goals, such as education, with the provision of new technologies. The integrated approach differs from the small-scale applications in Tamil Nadu as described in chapter 5.4. This approach is similar to the lessons described by Uphoff, for good rural development, this is: the integration of all aspects related to the development, including social as well as technical aspects.

Regarding the biomass gasifiers, we can conclude that grid-connecting the biomass gasifier looks very promising, but experience in doing so is very limited. The project has had a lot of delays throughout the years, resulting in a catch-up at the moment. This catch-up incorporates the risk that mistakes are replicated because operational experience is not there when the new clusters will be built in the nearby future. The entire BERI program is however promising with an impact on a large number of rural people, although not completely analyzed for this report. It includes training and an increase of well being and awareness of the rural population, combined with a decrease of greenhouse gas emissions. Large international organizations such as ICEF and UNDP have invested in the project, increasing trustworthiness and accountability of the project. Learning has been observed in the changes in the biomass gasifier plans. The plans changed from island mode to clustering with grid connection. This learning process will increase financial sustainability. Learning also occurred in the preparations made, this includes training to the population and the plantation of biomass fuel.

6.3 Periyar Maniammai College of Engineering for women

6.3.1 Introduction

This college located in Vallam, Tamil Nadu is a training institute for (mainly) women in the field of engineering studies. The college has 4 biomass gasifiers operating at the campus. The college has plans to install a biomass gasifier in a village to provide electricity under the national PURA program.

6.3.2 The Periyar / PURA program

Actors involved

National PURA program

PURA stands for Providing Urban Amenities in Rural Areas. The program was founded in 2003 by the former president of India, dr. A.P.J. Abdul Kalam. The program aims at providing amenities to the rural population (ref: Agrawal 2004). In the plans, institutes including educational ones receive a role in the development of rural areas. As Abdul Kalam stated: *“The PURA enterprises can undertake management of schools, healthcare units, vocational training centres... building a market, local industrial and ICT parks, tourism services, banking system and the regional business or industrial units”* (The Hindu, 28 Feb. 2004). The PURA plans are to be implemented in over 4000 rural clusters in the period of 2004/5 – 2009/10.

The program is run by the Ministry of Rural Development and *“aims at meeting the gap in social and physical infrastructure in the identified rural clusters consisting of 10-15 villages within a radius of 4 to 5 kilometres around selected towns to enhance their growth potential”* (ref. Panchayat Raj Department 2004).

The main goal is to increase empowerment of the rural people, by increasing the connectivity, these consist of four components (ref: Prayatna 2003 and Panchayat Raj Department 2004):

1. Physical connectivity, by providing roads
2. Electronic connectivity, by providing reliable communication
3. Knowledge connectivity, by providing better and higher education, primary health centres and employment opportunities
4. Economic connectivity, by providing economic incentives and the promotion of businesses such as agricultural products

These goals are depicted graphically in fig. 6.5.

Colleges, entrepreneurs and local people around India have implemented the PURA program and operate this according to the four components as described.

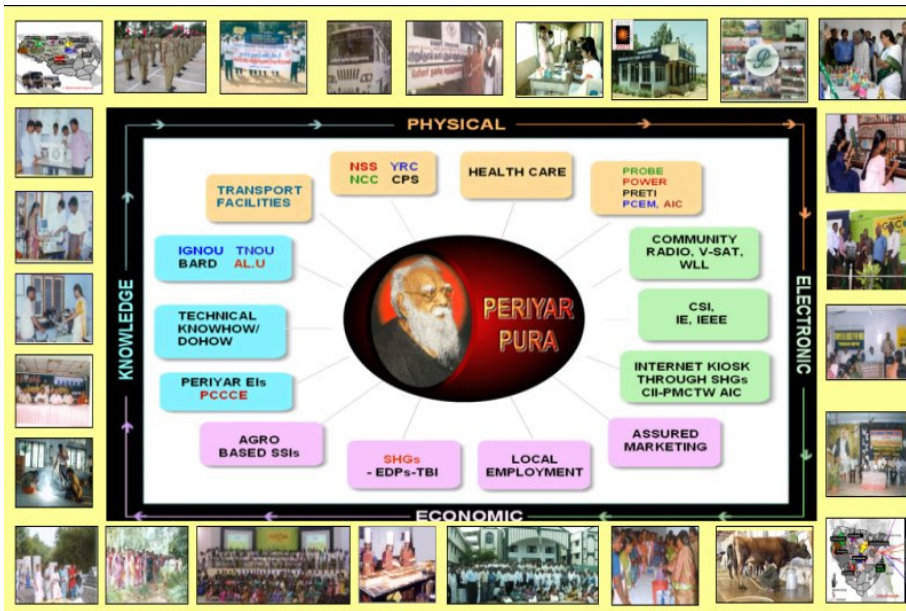


Fig. 6.5: The PURA program (ref: Website of Periyar Maniammai college)

Periyar Maniammai College of Engineering for Women

The college trains (mainly) female students in the field of various engineering studies, including computer, electrical engineering and civil engineering. Several renewable energy technologies are installed at the campus of the college, such as PV panels, a bio-fuel plantation and four biomass gasifiers. The producer gas from the biomass gasifiers is used for cooking purposes for the staff and students and for the production of electricity.

Prof. Nalini, Dean and head of planning and development of the college is responsible for planning of the installed biomass gasifiers. A female scientist/operator is in charge of the daily operation and maintenance.

The college is involved in the national PURA program and supports a number of villages (as shown in fig. 6.6) close to the college by technical support. Students are required to do community work in the villages such as education and training. The college has programs for rural development within the PURA

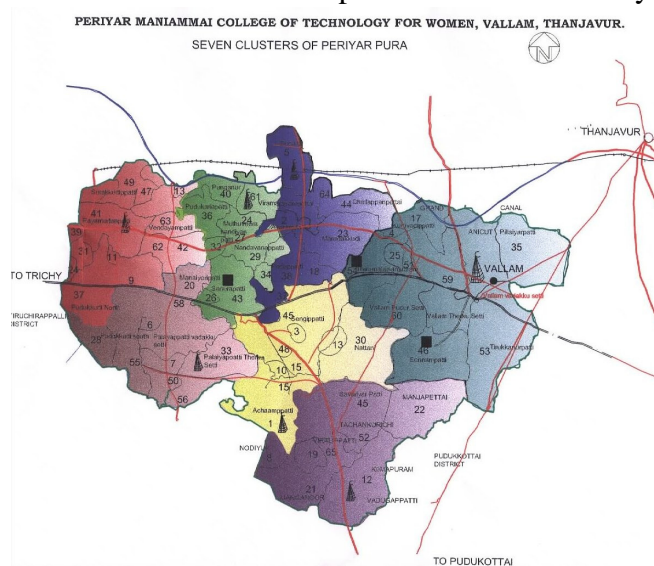


Fig 6.6: The PURA villages of the college (ref: Website Periyar Maniammai college)

program. A total of 65 villages have been identified, of which 5 nodal villages were chosen. In these 5 nodal villages, people are trained, who will train the people in the 60 other villages. Students of the college go to the villages to perform the training through the National Service Scheme (NSS). Funds have been requested from the National Government but have not been awarded so far. Students are made aware of the poor rural life, since most students come from the better-off families. The college regards this service as a duty every engineer should do to the community and it is an obligatory part of the curriculum (ref: Interview with prof. Nalini, appendix B). The college has not placed a biomass gasifier in a rural setting before.

Technical and operational experiences

Of the 4 biomass gasifiers installed at the college campus, 2 are daily used for cooking purposes and 2 are used for electricity production. A 100 kWe biomass gasifier for the production of electricity has been installed in 2001, and a 200 kWe gasifier has been installed in 2004.

The first gasifier is a dual-fuel engine downdraft engine, built and installed by Associated Engineering Works (AEW), costing 3,500,000 Rs. The 200 kWe Ankur downdraft biomass gasifier is installed with a 100% producer gas engine, and is operated daily. The 100 kWe dual-fuel system only operates when the 200 kWe system is out-of-order. This is due to the high costs for the diesel fuel. The biomass gasifier provides power to the campus for a maximum of 14 hours a day, during the day for the colleges and in the evening for the dorms. Initially the 100 kWe biomass gasifier was installed for R&D purposes. Research has been done on the biomass feedstock, pellet size, gas flow and quality. In the Vallam region, grid shortages are common in the summer period. Learning about operation of the biomass gasifiers happened through trial and error. Experience was gained into the sufficient drying of the biomass in the rainy season to prevent engine problems. A drying facility using the waste heat of the gasifier was built.

Most problems were solved within the college, for larger problems the producer was contacted however.

Research was done within the college without any cooperation with other institutes and/or firms. Others have however visited the biomass gasifiers at the college. These include the panchayat representatives of Odanthurai village, as described elsewhere in this report.

With the 100% producer gas 200 kWe biomass gasifier, the operator claims to be financially sustainable. Grid charges for educational institutes are 4.80 Rs./kWh; the 200 kWe system can produce electricity for 3.25 Rs./kWh (ref: Interview with Srividhya and Nalini, Appendix B).

The technical and operational knowledge within the institute is high. The institute has proven to be able to successfully operate biomass gasifiers for the last 6 years, and innovate by installing the 200 kWe biomass gasifier in 2004. The operator (Mrs. Srividhya and involved professor (Prof. Nalini) have published scientific papers about operation of the biomass gasifier.

6.3.3 The biomass gasifier plans

The plan from the college is to place one 100 kWe biomass gasifier in a related PURA nodal village, located close to the college by the end of 2007. The village has around 800-1000 houses, and is already connected to the (unreliable) electricity grid. The main reason for placement of the biomass gasifier is the availability of sufficient biomass in the surrounding area and the creation of employment (15-20 people for cutting, transport and operation). Placement will take place within the PURA program in the field of the creation of economic connectivity. Both Ankur and AEW were contacted to build the biomass gasifier. Eventually Bharat Heavy Electricals was chosen to build the gasifier, an initiative to do so was taken by them and they are positive towards cooperation with the college. Training of the operators will take place within the college. With the 100 kWe produced, only 400-500 houses can be connected to and provided with the power, for lighting and a fan. If successful, the program will be extended to the remaining households. The costs of 3.000.000 Rs. will be paid for 50% by the MNRE through a subsidy, the remaining funds have not been found so far. The plan is to let the people pay for the received power to create revenue within the village. The grid electricity provided is only for free for agricultural purposes, households using grid electricity will be charged according to prof. Nalini.

According to prof. Nalini, the villagers will gain an increase of knowledge with regard to technology and technological education.

Different analyses were made into the operational hours, such as from 6 pm to 6 am or 24 hours during cultivation periods. In the surveys conducted before, the number and type of technical appliances used in the households were determined. The biomass gasifier will provide power for the minimum requirements such as lighting and a fan.

Technical and maintenance support will be provided by the college, daily operation responsibilities are with the village administrative offices. Load management is done by segregating the houses into groups. When the load is varying, groups of houses can be connected or disconnected manually.

Financial sustainability is possible according to prof. Nalini, calculations were not shown however. When successful, plans exist for the placement of biomass gasifiers in the other 4 nodal villages (ref: Interview with prof. Nalini, appendix B).

When these plans were set up, the IISc was visited to take a look at the biomass gasifiers. Villages already equipped with a biomass gasifier (i.e. in Coimbatore region) were not visited. The idea as described above has been developed within the college.

6.3.4 Ultimate goals of development

The ultimate goals of development for rural applications as described by Uphoff , namely the 1) Increase of production, 2) Increase of well being and 3) Empowerment, will be assessed in terms of the Periyar Maniammai college plans.

The college has experience in the field of rural development through the PURA program. The program has 4 components, with the goal of increasing the empowerment of the people, one of the goals defined by Uphoff. With the plans for the biomass gasifier as defined by the college, production and well being will most likely not increase to a large extent. The village is already grid connected and has a level of well being, including street lighting, domestic lighting and drinking water. The placement of a biomass gasifier will create employment for an operator and for people collecting and preparing the biomass. It is the goal of the PURA program to increase empowerment, it is however doubtful if empowerment will increase in the related (grid-electrified) village with placement of a biomass gasifier. The biomass gasifier will be supported by the college for a pro-longed period. The biomass gasifier cannot provide power for the complete village, deciding who does and who does not receive the biomass gasifier power seems difficult. Benefits do exist for the college; the students are placed in the village and are exposed to the rural life. Employment is created and the college increases its experience of rural work.

6.3.5 Application success

The application success is divided in:

- Technical success
- Financial success

When analyzing the applications as described throughout chapter 5, the following items proved the most important reasons for failure of the biomass gasifiers:

- Technical operational plans and support
- Availability of biomass
- Financial sustainability
- Local support
- Learning process

Above items are analyzed using the application success from the framework with respect to the plans of Periyar college.

Technical success

The college plans, indicate a close technical support for the biomass gasifier as planned in the nodal village. Daily operation will be done by trained villagers, larger maintenance and technical support however will be provided by the college. When sustainable, this eliminates one of the main problems as observed in the small-scale biomass gasifiers in the panchayats as described elsewhere in this report, namely: Who is responsible for the technical maintenance and support? The college is well capable to perform most required maintenance, thanks to their experiences gained in the past with the biomass gasifiers installed at the campus. The independence of the project does decrease, when dependency upon the college increases. The college is however bound to the village through the PURA program, and has been so for the last years. People are already aware of the College efforts and good intentions, thanks to the years of work and presence in the related villages.

The availability of biomass is sufficient at the moment as indicated by prof. Nalini. Variations per season do occur however. The drying of the biomass in the wet season may become a problem, and requires a long period of time. Availability may be low at those moments.

Financial success

Financial success is not the main factor within the project. Installation costs will not be earned back within a period of time, and the social benefits as indicated by prof. Nalini outweigh financial success. Whether costs will be met can only be shown when operating for a period of time. Support can be offered by the College when required. Funds have not yet been found for purchase of the biomass gasifier. The college is not capable of affording these, was indicated.

The College has experience in supporting and operating within the villages' structure, thanks to the PURA projects. This close contact enlarges village requirement fit and villagers' cooperation for the biomass gasifier project. The present knowledge and the study performed beforehand increase the success predictions compared to the already existing biomass gasifiers as described in chapter 5.

6.3.6 Institutional success

The institutional success as defined by Korten, is analyzed, using the Periyar PURA program and the college biomass gasifier experience. The college has adopted 65 villages as part of the National PURA program. Experience has been gained throughout the last years, with the program, in the field of creation of (technical) awareness to the villagers and technical assistance offered by the college students. The achievements of the entire program were however not analyzed, these were not part of the scope of the research. The institutional experience in the field of biomass gasification is however good. Experience in the field of biomass gasification, both technical as well as financial, was gained with the biomass gasifiers used on the campus during several years.

The village level has not been analyzed, this is a limitation of the research and more is described in section 2.9.

In the PURA program and with the biomass gasifiers on campus, the college gained valuable experience, that was part of a learning process. This includes learning about:

- Rural life and requirements, as part of the PURA program
- Technical operation of biomass gasifiers, by operation on campus
- Financial operation of biomass gasifiers, by operation on campus

The future experiences of the college can help other (educational) institutes to implement biomass gasification in the rural setting.

6.3.7 Conclusion

The project setup as designed by the college has a close fit between the college and the village biomass gasifier operation for technical and possible financial support. Ambitions are not too high and the project will only be extended when success is proven in the first nodal village. The goals to be reached do not fit to the Uphoff goals, employment will be created in the form of an operator and people collecting the biomass but the gasifier will most likely not increase production, empowerment and well being to a large extent.

Due to the experience gained with biomass gasifiers, the large experience with the PURA villages and the ambition level the project is likely to become reasonably successful in the field of operation and technology. The same goes for the social success, due to the close contacts between the village inhabitants and the college staff. The village is already electrified. The division of those who will and those who will not receive the biomass gasifier power might cause some social issues. This can threaten the social support base of the college in the village.

Experience with rural biomass gasifiers is however low within the college and villages were not visited to learn from the experiences. Start-up problems can thus be encountered, including technical and financial, but the support of the college will most likely continue in this crucial phase. This is different from the mostly unsuccessful biomass gasifiers placed in the past, some of the local people involved (operators, panchayat presidents) were left alone to solve problems in the start-up phase, leading to shutdown of the biomass gasifiers. When in operation, a large dependency between the operators and the college will remain; the college will be responsible for support of the maintenance and operation. This is not likely to change within a short period of time. The success of the biomass gasifier might decrease if this support would be decreased. Looking at the plans for the biomass gasifier to be placed in the rural setting by the Periyar Maniammai College of Engineering for Women, these are well prepared. The college has learned about the biomass gasification technology, by operation of the successful on-campus biomass gasifiers, and learned about the rural life and requirements by the PURA program as implemented by the college.

6.4 The DESI power 100 villages electrification project

6.4.1 Introduction

DESI stands for Decentralized Energy Systems India, and the headquarters is located in Bangalore, South India. Various authors have published about the DESI projects and future plans. These include Swiss students analyzing specific DESI projects. An interview was held with the DESI Development Manager Abhishek Sharan in the DESI office in Bangalore.

6.4.2 The DESI program

DESI

DESI is a not-for-profit organization, setup by DASAG⁵ India and Technology and Action for Rural Advancement⁶ (TARA) and runs a program on the installation of Independent Rural Power Producers (IRPPs). It seeks to implement renewable energy projects in India under the Employment & Power partnership program (EmPP), with the aim to reduce emissions and to support local development and entrepreneurial activities (Gantenbein 2005).

The DESI goal is to break the vicious circle:

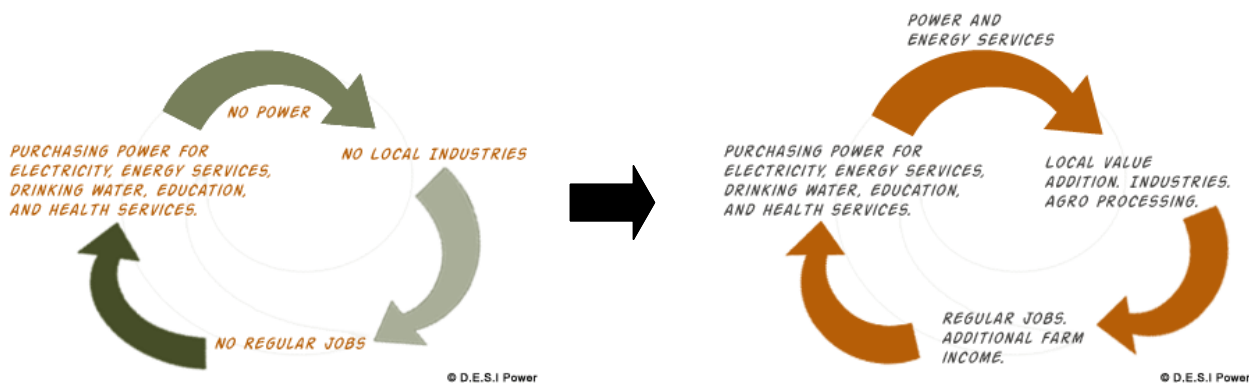


Fig. 6.7: The vicious circle of rural poverty as defined by DESI (Source: DESI website)

In this EmPP local partners are involved in providing funds and biomass, and the IRPP provides power and funds for the biomass costs (see fig. 6.7). This approach resulted in support of different governments and institutes, such as the UN, Government of the Netherlands and the World Bank (SEI 1999, Zomers 2001).

⁵ This is part of the Swiss DASAG Energy Engineering Ltd. Switzerland

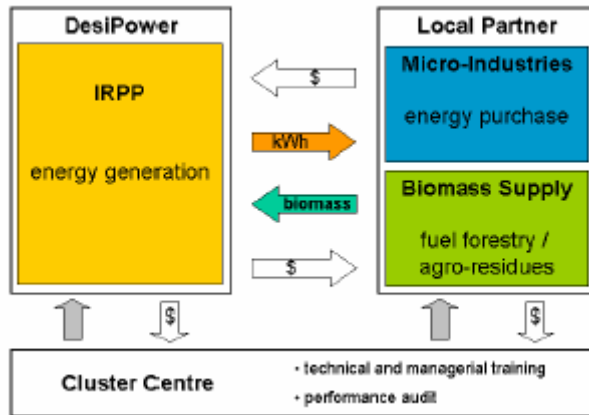
⁶ This is a social enterprise based in India with the objective of improving well being of people and their communities

DESI promotes the formation of small scale enterprises in the villages, thus offering a complete approach of development.

Finance for new projects is as following (SEI 1999):

- 25% by the partner
- 25% by equity of DESI
- 50% raised by the market (commercially, green initiatives or CDM)

Through this construction, DESI seeks to find social investments for a public-private partnership (website DESI power) (fig. 6.8).



The biomass gasifiers placed by DESI are built by Netpro, a Bangalore based biomass gasifier producer with experience in the field of rural and industrial biomass gasifier applications.

So far (2003), DESI and/or Netpro has installed the following biomass gasifier plants as indicated in table 6.9.

Fig 6.8: The DESI Power practical village setup (Source Burgi 2003)

Table 6.9: The plants built by DESI/Netpro (Ref: ESMAP 2003)

Project	Location	Commissioning year	Rating kWe
DESI power Orcha	Orcha, Madhya Pradesh	1996	2 x 50 DF
Badadhara	Badadhara, Orissa	2000	1 x 36 DF
BOVS	Baharbari, Bihar	2001	1 x 24, 1 x 50 DF
MVIT Phase 1	Yelahanka, Bangalore	2002	2 x 50 DF
MVIT Phase 2	Yelahanka, Bangalore	2002	1 x 120 DF
GB Engineering	Trichy, Tamil Nadu	2002	1 x 120 DF
WSD Varlakonda	Kolar, Karnataka	2002	1 x 50 DF
GB Food Oils	Trichy, Tamil Nadu	2002	1 x 120 DF
Vellore Institute of Technology	Vellore Tamil Nadu	2002	1 x 100 DF
WERE/UNDP/GEF	Assembo Bay, Kenya	Dispatched 2002	1 x 50 DF

DESI MANTRA

With the experience gained by DESI in daily operation of a biomass gasifier placed in 2002 in the state of Bihar, a training program was established named DESI MANTRA (DESI Management Training Centre for Rural Women) (ref: Interview Sharan, appendix B). DESI encountered the fact that trained (male) biomass gasifier operators would move to the city away from the village because of their technical training and potential in the cities of India. DESI decided to start training women in the field of operation and especially management, since women are more accurate and less likely to leave the village according to Sharan. The first batch of 10 female and 5 male students has been trained already and more people will be trained for the 100 villages electrification plans (ref: Interview Sharan, appendix B). Specifically training is provided in the field of (DESI 2006b, pg. 4):

- Biomass gasification, biogas, power management
- Rural energy services
- Rural enterprises
- Basics of office administration
- Basics of project management and monitoring
- Basics of financial management
- Basics of micro-finance
- Fuel and agro forestry
- Vermiculture, organic farming and biogas

The training to the rural women is both in the field of operation and management of the biomass gasifier as well as in the field of management and the promotion of rural entrepreneurship. This is the distinctive aspect of the DESI initiative, the promotion of entrepreneurial activities in combination with the supply of sustainable energy.

Operational experience

DESI has built biomass gasifiers in three locations in the past: Orchha in the state of M.P., Baharbari in the state of Bihar and Varlakonda (as shown in fig. 6.10) in the state of Karnataka (DESI 2006b). The plant in Bihar started operation in 2002, plans to do so started in 1999 with a village survey by a local organization, looking at the demographic structure in the village, the energy needs and the biomass and fuel situation. The power produced at the time consisted of expensive diesel generators. Local entrepreneurship was low according to Sharan (ref: Interview Sharan, appendix B). Local entrepreneurship was promoted and power produced by the biomass gasifier was offered to new enterprises. According to Sharan, this eventually led to the start-up of new micro-enterprises such as a rice mill, a wheat grinder, and a battery charging station. Local management is done by a committee consisting of village members, operation is done by local operators trained at the IISc. in Bangalore. Once new micro-enterprises were started, others started to see the benefits and also started small businesses such as a cloth shop and a tailor shop. A market place was built and most of the money spent in the village, stays in the village with people from surrounding villages attending the market. The biomass fuel is purchased for a fixed price from the farmers. According to Sharan

(interview, appendix B), the biomass gasifier is still operating successfully daily, although the site has not been visited due to the remote location, and no independent evaluations were found concerning the Bihar biomass gasifier.

Three main factors, as also indicated in this report and by DESI, are imperative for financial sustainability, these are: The costs of the capital, the load factor and the costs of the biomass fuel. A biomass gasifier was installed at Orchha in Madhya Pradesh to gain experience in this field. The information in this report concerning this aspect comes from the interview with the DESI representative and a literature study, the site itself was not visited. In 1996 the 80 kWe dual-fuel biomass gasifier was placed to provide power to a TARA research campus. Purchase costs were around USD 53,700 (Shrestha 2005). In the feasibility report leading towards installation, items such as electricity requirements, biomass availability and interested partners. A weed growing rapidly in the surroundings was chosen as appropriate fuel, it is not used for cooking, and not eaten by animals (SEI 1999). Different methods of procuring the biomass were used and experimented with, such as internal management and a market approach. The latter proved better. In 1999 problems with the long-term availability were observed, more acres needed to be harvested to provide sufficient dried biomass. Operation of the plant is done by 3 people (one operator and 2 assistants) per shift. The plant is normally operated on 2 shifts per day. Over 10 families provide the biomass at market prices to the plant. In 1999, the plant had operated for over 5000 hours, running approx 10-12 hours a day. Diesel replacement was around 75% on average (SEI 1999). With the achieved plant load factor, costs per unit were comparable to grid prices. Experience was gained about the identification of the most important factors for financial sustainability and about the use of innovations such as the application of the exhaust heat for other purposes. Modifications were made to make the technology more robust. In 1999 an agreement was signed with the Netherlands Ministry of Development Cooperation providing capital in the form of a grant to set up 6 100 kW IRPPs, to demonstrate commercial viability under the UN Climate Change Convention (UNCCC) (SEI 1999, Zomers 2001, Srestha 2005, Dankers 2007, Interview with A. Sharan 2007).

In 2003 a Swiss student (Burgi) made a sustainability assessment of one of the DESI projects. DESI installed a 40 kWe dual-fuel open-top downdraft biomass gasifier close to Varlakonda, in the state of Karnataka, about 80 km north of Bangalore in April 2002. The plans were for DESI to run the gasifier for a period until local knowledge was sufficient for responsibilities to be transferred to the local organization. The achieved emission reductions are sold in the form of Verified Emission Reductions (VER) to the Netherlands Government (Burgi 2003, pg. 13). At the time of publication of the Burgi paper, not all possible micro enterprises were connected to the gasifier installation. A

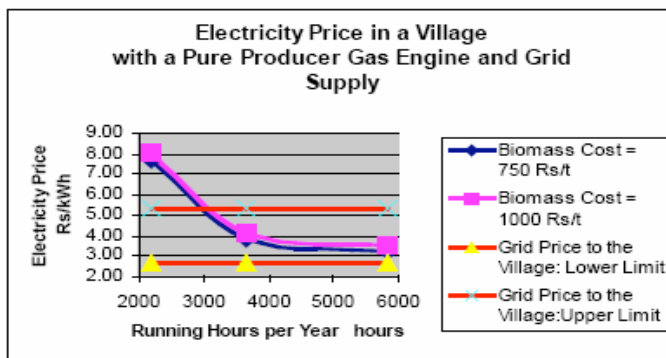


Fig 6.10: The biomass gasifier in Varlakonda (source: Burgi 2003)

total of 63 kW peak load could be connected; these comprise a rice mill, irrigation pumps, a flour mill, a computer centre, etc. Biomass prices have been fixed for a number of years at 1200 Rs./ton in cooperation with a trust for women. At the time of publication of the Burgi paper, the biomass gasifier power plant had produced 866 kWh in 14 months, corresponding to a plant load factor of approximately 0,2% (Burgi 2003, pg. 17). The indicated reason of the low plant load factor is the rice mill (the only connected micro enterprise at that time) that was not operating regularly due to technical and managerial problems. The situation with the SEB in Karnataka is similar to other states; there is a constant power deficit due to low energy tariffs, high subsidies and high losses of power produced. Power availability in the rural areas is around 3-4 hours per day. With the increasing experience plans existed to install 2 100% producer gas biomass gasifiers in Gaiyari using rice husk briquettes, as described by Gantenbein (2005).

6.4.3 The 100 villages biomass gasifier plans

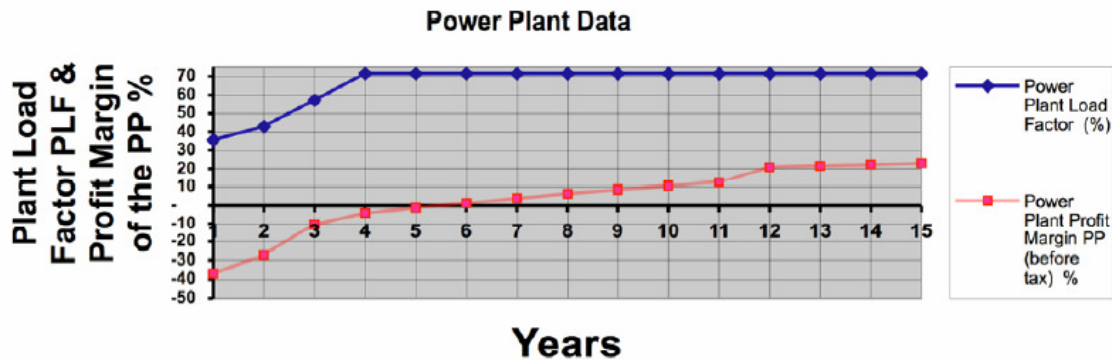
DESI Power has plans to electrify 100 villages in the state of Bihar using biomass gasifiers. The state of Bihar is the least developed state within India, and has a low electrification rate. Most of the villages have not been electrified. Plans are to set up 10 clusters, each consisting of 10 villages. Each village will be provided with a (island-mode) biomass gasifier with a 50 kW capacity. The energy services and setup of new micro-enterprises will be promoted simultaneously. As indicated on the website and indicated in the interview, the setup of successful new programs for decentralized power production is difficult. The local villagers, local organizations and entrepreneurs, NGOs, plant promoters, suppliers and builders, financiers and corporations are involved (ref: Website DESI). For daily operation, management and entrepreneurship local people will be trained by DESI MANTRA. DESI will especially focus on training women for all levels (DESI 2006). The 100 (unelectrified) villages have been designated and the villagers have been informed about the plans. DESI indicates that the villagers recognize the benefits and are prepared to put effort in financing, building and managing the project. DESI has calculated that a total of Rs. 740.000 (+/- €12550) is needed per village



Graph 6.11: Unit costs for different electricity production methods (Source: DESI 2006)

for the local infrastructure, capacity building, training and running costs of support services for 3 years (DESI 2006). Investment is sought by local equity from the village, the government subsidy, external equity, carbon certificate sales, commercial bank loans and grants. MNES has been designated by the GOI to electrify 18000 unelectrified villages by renewable energy. According to DESI the

biomass gasifier can be profitable as indicated in graph 6.11. The goal is to have a large-scale reproduction of the public-private experience of DESI. The 100 villages are to be electrified using the biomass gasifiers within 4 years. DESI has the ambitious goal to use the experience gained for these 100 villages and once proven, reproduce the program in 10 different locations, leading to 1000 villages per year, within the EmPP setup.



Graph 6.12: the profitability of the biomass gasifier power plant according to DESI (Source: DESI 2006)

Graph 6.12 shows the profitability of the biomass gasifier according to DESI. The graphs 6.11 and 6.12 show that especially the plant load factor and the operating hours are determining factors in achieving financial sustainability. DESI does acknowledge that rate of returns for private investment is lower compared to commercial initiatives. Investors are requested however to consider social and ecological benefits.

In February 2007, construction of the 5 first biomass gasifier plants as part of the 100 villages EmPP started in the Gaiyari area. These have been financed with 1) local equity from DESI and a local co-operative, 2) the World Bank DM2006 grant, 3) Certified Emission Reductions (CERs) from a Swiss organization, 4) the MNES subsidy for biomass gasifiers and 5) a bank loan from the ICICI Bank (DESI 2007). Local staff has been trained by DESI MANTRA.

In February 2007, 10 more villages were identified for implementation as the new batch of the EmPP. Negotiations for finance were held with an Indian Trust and a Netherlands fund for equity participation (DESI 2007).

In May 2006 the 100 village electrification project received the global competition Development Marketplace held by the World Bank and cosponsored by the GEF (ISA 2007), a price of USD 200.000 was awarded.

6.4.4 Ultimate goals of development

The ultimate goals of development for rural applications as described by Uphoff, namely 1) Increase of production, 2) Increase of well being and 3) will be assessed in terms of the DESI 100 villages electrification plans.

DESI has gained experience in the field of rural development throughout the years with various (biomass gasifier) projects in different places in India.

The increase of rural production as defined by Uphoff is one of the main goals for DESI. The DESI formula focuses on the promotion of rural entrepreneurship. The supply of reliable electricity will enable the rural population with the possibility to increase production and diversify into new fields. The electricity supply does not function as the goal, but as means to a higher goal, namely stimulation of the local economic activities through entrepreneurship. New money is generated and stays within the village structure. When people are trained and have a better income, well being can increase. DESI MANTRA does not offer training directly focussed upon the increase of well being (i.e. health training), but generally a better trained (female) population will prove beneficial for everybody. With the increase of entrepreneurship the empowerment is likely to increase. People are made aware of their capabilities in the field of micro-enterprises and are less likely to suffer from power structures. The diversification of income generation (through the start of a micro-enterprise) will ensure a better income which is less dependent on external factors such as climate, etc. In general, the DESI plans have a focus on a high developmental impact within the village. This is performed using a comprehensive approach incorporating the provision of reliable electricity combined with training to promote and increase the independence of the rural population in the remote and least developed areas in the state of Bihar.

6.4.5 Application success

The application success is divided in:

- Technical success
- Financial success

When analyzing the applications as described throughout chapter 5, the following items proved the most important reasons for failure of the biomass gasifiers:

- Technical operational plans and support
- Availability of biomass
- Financial sustainability
- Local support
- Learning process

Above items are analyzed using the application success from the framework with respect to the DESI program. This is based upon planning of DESI, and experience from the past.

Technological success

Experience in the field of technology for DESI is reasonable. Although no DESI project was visited during the research for this report, a literature study and the interview conducted with A Sharan, shows that the experience of DESI in the field of technical operation is reasonable. One plant as indicated in the interview with A Sharan is operated successfully since 2002 in Bihar, providing electricity for irrigation purposes and micro enterprises. The Burgi paper shows a low plant load factor for the plant in Varlakonda, at the time of publication. Mr. Sharan indicated in the interview that all maintenance is done by the local operators in the Bihar case, this is however unlikely to be completely correct, in other cases throughout (South) India larger maintenance had to be performed by outside mechanics, mostly from the producer or IISc. With the clustering of the villages for the 100 villages electrification plans, permanently placing mechanics for larger maintenance close to the village locations is beneficial due to the large number of gasifiers in the area. Little information is available about the current status of maintenance operation.

Preparations leading to installation, including the village surveys and discussions with the villagers and cooperation with local organizations are better compared to the government motivated biomass gasifier placements as in the Coimbatore region. The DESI people are aware of the constraints of rural development and of the villagers' attitude towards outside help. Time is required to change people's attitudes and create awareness. With the promotion of biomass plantations (ref: interview Sharan), biomass availability is promoted. Tests have been conducted by the IISc for DESI into the use of various locally available biomass types to ensure sufficient availability throughout the seasons (ref: interview Sharan).

Financial success

Financial sustainability has not been reached in the Varlakonda case as described in the Burgi paper, the same goes for the biomass gasifier in Bihar state, as indicated by Sharan (2007), no profit was made; according to him because of the diesel required for the dual-fuel system. DESI claims that financial sustainability is achievable in the 100 villages electrification case. This is however difficult. DESI indicated (see graph 6.11 and 6.12) that the biomass gasifier costs are lower compared to the grid power and profit can be achieved when operation hours are over 3000 per year and with a plant load factor of at least 70%. Both figures are however difficult to achieve and are an optimistic assumption based on previous biomass gasifier experiences throughout rural (South) India. When running 6 days a week, 3000 hours would mean operation of approx 10 hours a day excluding maintenance requirements.

The inclusion of the bank loans and the CDM credits is a new development and ensures extra funds for the projects. The Netherlands Government and the World Bank have supported this project financially. DESI can sell the CDM credits to developed countries to compensate for the emissions as part of the Kyoto protocol. DESI has planned to use

the CDM funds for the 100 villages plans, and is to the knowledge of the author, one of the first to do so in India in the field of rural biomass gasification. With this development both India as well as the developed countries benefit.

6.4.6 Institutional success

Institutional success is analyzed looking at the experience of DESI into rural development in the past, and looking at the current 100 villages' biomass gasifier electrification plans.

With the present knowledge and experience, as proven in the Bihar state, effectiveness was achieved with local entrepreneurship expanding, thanks to the DESI and local organizations efforts. DESI is currently trying to achieve higher efficiencies with the plans to change the biomass gasifier installation in the Bihar state with a 100% producer gas system, and with the new availability of funds such as the CDM funds and the commercial bank loans. DESI is working on expansion with the 100 villages electrification plans, finance and construction of the first 5 installations has been started. Because the villages are yet un-electrified, providing reliable electricity is likely to have a large positive impact on the village, as observed in the Hosahalli case. In general we can state that DESI has expanded the programs according to the steps as defined by Korten:

1. Learning to be effective
2. Learning to be efficient
3. Learning to expand

The program as planned and described in this section is however a large program, comprising of 100 (remote) villages, which will cause specific unanticipated problems, as also happened in projects / programs from other NGOs / institutes / governments. The configuration of island mode biomass gasifiers can cause problems related to maintenance and operation. Clustering could be beneficial. The village sites have however not been visited due to the remote location in Northern India and it is impossible to state conclusions related to the feasibility of clustering.

DESI has learned from programs and projects from the past, and adopted a learning-based approach. This proved to be a correct approach. One of the main items learned is the integration of the requirements on village level and the technology that fits best. DESI does not just offer a technology; the goal is instead to improve village conditions by the promotion of entrepreneurship. This is achieved by combining the right technology (in this case a biomass gasifier) with education and a pro-longed period of presence and guidance in the related villages. Local support is sought by discussions, meetings to inform the villagers and the use of opinion leaders. DESI also learned to train especially women in the field of technology, management and entrepreneurial skills because women are more reliable to remain in the village, once trained and are more reliable to perform the work in general.

6.4.7 Conclusions

In general we can conclude that the DESI plans with the combination of supporting entrepreneurship and the provision of sustainable electricity is an approach that is beneficial to the villagers. New money is generated within the village and less money will leave the village for other villages. The approach is an integrated one, comprising of all aspects related to rural development, including awareness, education, sufficient time and the (appropriate) technology. The integrated approach has similarities to the BERI initiative and is the most successful method of rural development of all projects and initiatives as described in this report. More will be explained in chapter 7.

Experience had been gained with the concept and this has been recognized internationally by the Netherlands Government and the World Bank. Although little information is available about the current status of the already placed biomass gasifiers in the past, the planning process and the scale of the program are promising. DESI has seen a learning process in which experience was used to benefit future projects and programs.

7 Discussion and conclusions

This chapter will describe the conclusions, based upon the framework and the research questions.

We can divide all projects as described in this report in 3 main groups:

1. The developmental goals driven group. This group consists of:
 - a. The BERI program
 - b. The DESI program

Both of the programs have a clear goal towards rural development. They are financed by Indian governments, private finance, foreign governments, NGOs and the UN. The main goal is to provide rural development (using among others biomass gasifiers), rather than technical learning. The involved organizations are large and the programs are extensive. The BERI program is run in Tumkur district and has the developmental goal of rural development by the provision of bio-energy for the rural population in the form of education, biogas and biomass gasifiers. DESI has the goal of development for the rural population by providing electricity and education in order to increase rural entrepreneurship in the related villages in the state of Bihar.

2. The educational research institute group. This group consists of:
 - a. The IISc. projects in Hosahalli and Hanumanthanagara villages
 - b. The Periyar College plan to provide a biomass gasifier to a related village

The characteristic of this group is that it is initiated by an educational research institute and that it incorporates both a combination of (technical) learning for the institute and a developmental goal for the village. The IISc started the experiment to learn about day-to-day use of a biomass gasifier in a (un-electrified) village. It was especially interested in the technical aspects related to this use. From the beginning onward, it was clear that the project would be run for a period of time. At the same time, IISc provided funds for extra applications that were connected to the biomass gasifier, such as drinking water pumps. The Periyar College plan is to provide an electrified village with a biomass gasifier. The goal is to increase employment. The college will learn from the experience, they have no experience yet in rural application of biomass gasifiers.

3. The cost saving projects. This group consist of:
 - a. All TEDA promoted small scale biomass gasifiers in rural Tamil Nadu Panchayats (Nellithurai, Odanthurai, Chikarampalayam, Kunnathur, Valudavur, Pachal and Periampatti panchayats)

All of these projects are small scale biomass gasifier applications run by the panchayats. The biomass gasifiers have been subsidized by MNRE and are applied by the panchayat to save on the grid charges fees. Most of these applications are no longer in operation.

There are large differences in the success of these three groups.

7.1 Group 1: The developmental goals driven group

This group consists of the DESI and BERI program, both are running, but the biomass gasifier plans were not yet initiated during the research for this document. For this reason the information below is based upon the plans of both programs and upon the results in other projects within the DESI and BERI program.

Ultimate goals of development

Both BERI and DESI have developmental goals stated as the main goals. For BERI this is to provide the rural population with reliable bio-power. This is done by large-scale education and by the installation of a large number of biogas installations and by the installation of biomass gasifier clusters. The goal is to meet the rural needs and to increase the level of income for the rural population. The goal of DESI is to break the vicious circle of poverty by the promotion of rural entrepreneurship. This is achieved by providing biomass gasifiers in small unelectrified villages in the state of Bihar. With the power available and with training of the rural population, small businesses can be setup. DESI has already gained experience in this field by former programs. A large part of both programs consists of education to the rural population. This includes education related to the biomass gasifier (operation etc.) and related to other items such as entrepreneurship, women empowerment, agricultural processes, etc. With both programs combined, 10.000+ people were already trained.

Application success

The application success is based upon the applications run in the past by the programs and based upon the plans for the biomass gasifiers.

Both programs have innovations, to improve the application success. For BERI, this is the grid-connection and clustering of the biomass gasifiers. This simplifies the technical support by technicians, and assures the income of the SEB. This has however not been applied before and experience is low. For DESI the innovation is the application of CDM credits. CDM credits have large potential benefits, because both developed countries as well as developing countries can benefit from this development. The island mode of the biomass gasifiers for all 100 villages does require a lot of traveling time for maintenance personnel and increases costs. Both BERI and DESI have been able to attract foreign (NGO) money to assure financial sustainability for the coming years. Especially BERI has put a lot of effort in awareness training and planning into the biomass forests. This ensures the availability of supply of biomass fuel.

Institutional success

BERI is financed by several organizations including the Government of India, and the United Nations Development Program. The program has been running since 2001 and experience has been gained since. The various elements in the program are varying in success. The plans for the biomass gasifiers have changed drastically throughout the years. Conflicts with the biomass gasifier producers also occurred. DESI has experience in the field of biomass gasifiers through former projects. They have been awarded a World Bank price for their current 100 villages electrification plans. Both programs went through a changes in strategy, this is institutional learning.

Conclusion

Success anticipation of these programs is high because of the complete structure offered. These include the provision of the hardware (the bio-energy equipment), combined with the software in the form of training. The range of both programs is large; thousands of people are influenced, by the training. Both programs have indicated that independence of the involved rural population is the eventual goal. This means that the programs will provide support and training for a period of time. The programs contain the reaching of goals that increase independence of the rural population in combination with an increase of development. The provision of electricity is a means to a higher goal, namely rural development.

7.2 Group 2: The educational research institutes group

For Periyar College, the application success is determined with reference to the biomass gasifiers on the campus of the College.

Ultimate goals of development

Both educational institutes from this group have combined a developmental goal with a technological goal; this is especially the case for the IISc applications. IISc has proven that it is possible to create a positive impact in the village by conducting the experiments of the biomass gasifier placement in the villages.

The developmental impact that will be caused by the Periyar college application is likely to be less than the IISc impact. Production and employment may increase however because of the required biomass. The developmental impact of the entire PURA program run by the college is good however.

Learning by all actors involved in the projects was good. IISc has made a positive impact on the learning process in the village. The villagers of Hosahalli were faced with the benefits of (reliable) electricity for the first time, and gained experience in the use of the drinking water pumps, irrigation, public and domestic lighting.

Application success

Since both colleges have experience in the field of biomass gasifiers, both IISc and Periyar College are regarded successful in the field of technical success. IISc has proven to be able to maintain the biomass gasifiers in both villages for a prolonged period.

Periyar College has experience with biomass gasifiers on campus and is willing to support the biomass gasifier in the village for a period of years. Financial sustainability was not achieved by IISc and is not the goal of Periyar College.

The experience gained by IISc proved beneficial for the development of the technical and social issues related to the biomass gasifier. Several papers have been published about the technical and social issues concerning this experiment.

Institutional success

Both colleges have experience in the field of rural development, and have grown throughout the years. For IISc, this was done by CST and by the extension of the biomass gasifier applications in the villages. Experience was gained throughout the years. For Periyar College this is done through the PURA program run during the last years, experience was gained, and the program was extended accordingly. IISc did lack the experience and skills of NGOs (i.e. DESI) concerning the motivation and awareness raising of the villagers. Experience was gained though, throughout the years.

The IISc and CST staff learned from the experience and used the information for new projects and for extension of the program in Hanumanthanagara village.

The students of Periyar College are trained in rural life, problems and solutions by the projects in the related PURA villages; this benefits both the awareness of the students as well as the development of the villagers.

Conclusion

This group is relatively successful because of the focus on both technological as well as developmental solutions. The people of the educational institutes feel a need to support the rural population and have the required technological level to do so. Reaching financial sustainability was not a requirement set by the institutes. Because of the open scientific attitude in the educational institutes, experience was shared in the form of scientific papers. Dependence between the villages and the educational research institute, in the form of technical support and social support base, remained however.

7.3 Group 3: The cost saving projects group

The ultimate goals will not be described because this group consists of applications that were placed by Panchayats in order to decrease the costs of the SEB bill. The placements had no developmental goals, although some (incidental) developmental impact occurred.

Application success

Almost all applications visited were not running anymore. This mostly occurred within a few months after installation. The problems were related to the lack of biomass, the lack of skilled maintenance personnel and materials and to the poor planning process. Disputes between the producers and the users have resulted in a lack of the technical support by the biomass gasifier producers. Little requirements of the governmental related agency resulted in a lack of planning, leading to a mismatch between biomass gasifier capabilities and demands. Reaching financial sustainability proved difficult, although some indicated to be financially sustainable. This can only be reached when the plant load factors are high and the biomass purchase costs low. Calculations showed that the unit costs for the grid power are comparable to the unit costs of the electricity produced by the biomass gasifier. No panchayat has their own biomass plantation, which might reduce costs. In the panchayats, most of the people did not show much interest in the biomass gasifier. It was observed that in the few successful applications, the panchayat presidents were very motivated to keep the biomass gasifier in operation. The lack of broader social support ensures the likelihood of failure of these types of projects.

People in the villages were insufficiently trained to properly maintain the biomass gasifier installations, and panchayats had difficulty with day-to-day operation. The producers of the biomass gasifiers have neither learned a lot from the failed applications. They continue to deliver the biomass gasifiers as done in the past and at the same time feel frustrated because of the financial difficulties involved.

Institutional success

The institute involved in these placements in TEDA. This is the nodal agency of MNRE, and has the role of promotion of sustainable energy sources in the state of Tamil Nadu. There are no demands for a feasibility study before instalment of the biomass gasifier. This has resulted in placements in the wrong places and mismatches as described above. Although the TEDA staff is aware of the problem, no changes seem to be made. The program has extended, in the form of new installations of biomass gasifiers, without proper learning.

TEDA does not seem to have learned from the failed biomass gasifiers. The failure of these biomass gasifiers is not described elsewhere, and this report is the first publicly available report doing so. The information does not seem to be shared among the panchayats. In public promotion by the Government, only the successful applications were named (Odanthurai and Nellithurai panchayats). Learning by the producers was also low; Ankur is no longer involved in the installations and is not motivated to become involved anymore in the future.

Conclusion

This group has the lowest success rate of the three groups. This is most likely due to the focus on providing the technology, without proper training, embedding in the rural setting

and the creation of social support in the villages. The poor planning process also contributes to the failure of most of these applications. Learning by the related agency is low, plans were not changed when failure occurred and most of the biomass gasifiers remained idle, once stopped. No one knows who is responsible for a revitalization of the idle biomass gasifiers and they are likely to remain idle in the next years. The experiences were not shared publicly.

7.4 Success per group compared

Table 7.1 provides a summary of the success of the three groups with reference to the framework. The scaling is based on a 5 level (Likert) scale. It is intended to indicate the differences between the groups as described in sections 7.1-7.3.

- ++ Very high success / Very good learning
- + High success / Good learning
- +/- Mediocre success / Mediocre learning
- Little success / Little learning
- No success / No learning
- N.A. Not applicable

Table 7.1: The success matrix of the three groups

Success	1) Educational research institutes	2) Developmental goals driven ⁷	3) Cost savings projects
Ultimate goals of development			
Well being	+	++	N.A.
Production	+	+	N.A.
Empowerment	+	++	N.A.
Application success			
Technical	++	+/-	-
Financial	--	+/-	-
Institutional success	+ / ++	+	--
Learning	+	++	--

⁷ The data of group 2 is based on expectations and past experiences

7.5 Requirements for success of biomass gasifiers in rural setting

When analyzing all data as described in this report, a number of requirements can be stated, that are likely to increase the success rate of biomass gasifier projects.

Experience

Experience, both in the technological field as well as in the rural development field prove vital. Technological knowledge is required because it is shown that during day-to-day operation of biomass gasifiers, regular problems do occur. Although the technology is old, it is a difficult technology, requiring sufficient maintenance and knowledge. Personnel need to be trained accordingly and skilled mechanics need to be available within a reasonable period of time to perform larger maintenance. Educational institutes and the biomass gasifier producers can provide and share this knowledge.

Rural development is a difficult subject, because of the cultural, social and institutional issues in a village. In India, the caste system still has a large influence and the power structures in villages are often complex. Rural population is often sceptical about outside help. Experience of the initiating NGO/institute is therefore crucial. This also involves a period of time in which the villagers are informed and made aware of the technical and social impact of the biomass gasifier and their own responsibilities in the project. Only an integrated approach as shown in the BERI and DESI cases can provide the required benefits. For future projects run by the government (as in the Coimbatore cases), it would be wise to inform the villagers about the benefits and responsibilities concerned with the biomass gasifier applications. Ownership is by the panchayat, this is however financed by the population.

Finance

Reaching financial sustainability with the biomass gasifier is highly dependent on the plant load factor and the biomass purchase costs. Achieving a high plant load factor in the rural applications is difficult, especially when multiple applications are to be connected to the biomass gasifier electricity production. Coordination between the applications is required. With commercial biomass costs, reaching financial sustainability, compared to the grid electricity charges is difficult. A plantation run by the villagers is less expensive. This was/is performed in the IISc and BERI programs. CDM finance is applied for the first time by DESI and looks promising as an extra source of income for new projects. The plans of BERI to commercially earn money with the biomass gasifiers selling power to the electricity grid, combined with the efforts into rural development are interesting and are likely to be replicated in the future.

Planning process

Before installation of biomass gasifiers, a feasibility study should be required. Many problems could have been prevented if a feasibility study was made before installations,

i.e. the Coimbatore region biomass gasifiers. The availability of sufficient affordable biomass, technical knowledge and support, finance, electricity demand and local support should be sufficiently investigated.

Please see chapter 8 for the recommendations concerning this subject.

Learning

All involved in the installation of rural biomass gasifiers (including users, village committees, panchayats, producers, sponsors, governments, scientists), should learn from failures and success of themselves and others. These include the users, involved institutes, governments and the biomass gasifier producers. An increase of transparency will benefit new projects. Please see chapter 8 for the recommendations concerning this subject.

7.6 Conclusion

Biomass gasifiers can have a large positive impact on the lives of rural population. Providing reliable electricity can help in promoting lighting, drinking water, irrigation and new entrepreneurship. It is however not easy; successful applications required a lot of efforts in the field of technology and rural guidance. Problems in the failed applications include a lack of planning, maintenance, biomass and knowledge. When the installation of a biomass gasifier is part of a larger initiative to improve the lives of the rural population, the application is likely to be most successful. Local villagers become motivated about the biomass gasifier and experience the benefits. Experience has been gained throughout South-India during the last decades of rural biomass gasifier applications. The experience was partly communicated publicly, but remained unpublic too much. Especially educational institutes and organizations with the goal of combining the technology with rural development proved to be capable of reaching success in the field of rural biomass gasifier applications. The government programs proved less capable of doing so. The MNRE subsidies have been used throughout South-India for small-scale biomass gasifiers; these applications mostly failed shortly after installation.

It is interesting to note that although the grid electricity regime rules for all actors involved are equal (i.e. biomass gasifier subsidies), some projects / programs are much more successful than others. This is thanks to the involved institute / NGO / government. The internal project / program factors, such as planning, design and implementation largely determine the success or failure of the related project / program. Reaching a fit between the installation of the technology and reaching development goals (i.e. water pumps, entrepreneurship, increase of well being) in the rural setting proved to be vital for success of the biomass gasifiers in the rural setting. This is done by creating a social support base and by using the biomass gasifier as a means of reaching a higher goal: Rural development. This does however require an extended period of time. The difference of success between the various applications also indicates the importance of this research. The internal dynamics of the involved institutes has not been analyzed in depth in this report because it is beyond the scope. Research in the future is however

interesting to analyze institutional factors such as: consultation with villagers, error embracing and staff responsibilities.

One of the most important lessons is that application and experience information should be shared more freely between the actors and that sufficient time is needed to gain experience into the field of rural development. Simply placing a biomass gasifier, without sufficient support will mostly fail. The integrated approach, in which rural development, by i.e. education is combined with the installation of the technology is likely to succeed.

7.7 The conclusions with reference to existing literature

This section will describe some existing literature and compare the conclusions in the literature with the conclusions in this report.

The goals of rural development as defined by Uphoff et. al. (1988) proved to be largely applied (although in various forms) by Group 1 (section 7.1): BERI and DESI. Both have developmental goals as the main items on their agenda. Both BERI and DESI are working on the increase of income for the rural population; this can be defined as (increase of) productivity. The education in combination with the technology offered is intended to increase well being (i.e. sufficient electricity) and empowerment (i.e. entrepreneurship). It is interesting to notice that these (BERI and DESI) projects as described in this report largely confirm to the goals described by Uphoff et. al.

A fit between the village requirements and the appropriate technology is crucial for successful development. This means that providing a technology unaided will not benefit the villagers. For rural development efforts are needed by a related NGO / government, mostly for an extended period of time. Although the (biomass gasifier) technology is known for the last 80 years, the technology cannot simply be installed in the rural setting without soft skills (awareness training, social support, etc.). This is confirmed by Uphoff et. al. (1988, pg. 116): *“Even projects focused on technological change need to proceed slowly, not just to prove lab-tested technology under field conditions but also to build up essential organizational scaffolding and institutional incentives.”* And Mog⁸ (2004, pg. 2140) stated the following: *“While immediately influencing, educating, and empowering people is an important goal for a development program, the long-term perspective of sustainability demands that this process continue indefinitely, long after the program has ended. To achieve this, programs need to engage in community organizing to help build locally-controlled institutions which can eventually take over the roles of the program, and to create a sense of local investment in, control over and ownership of the development process to ensure that it is sustained.”*

Especially DESI is involved in this by the creation of entrepreneurship in the village structure.

⁸ Mog (2004) wrote about the evaluation of sustainable development programs. He offers a new framework in the paper.

Regarding the financial sustainability, Nouni et. al. (2006) performed a research in which the costs per kWh were calculated for decentralized dual-fuel biomass gasifiers and for decentralized 100% producer gas biomass gasifiers. He used the capital costs, the capacity utilization, the specific fuel consumption (at full and at partial loads), the useful life of the gasifier, the useful life of the (modified) diesel engine, the price of biomass feedstock, the price of diesel (in the dual-fuel mode) and miscellaneous input parameters (as transmission and distribution losses and the local network) in his calculations.

Depending on the PLF, costs for a 5 kW dual-fuel system were ranging from 24,99 Rs./kWh (@ 100% PLF) to 43,23 Rs./kWh (@ 50% PLF). Costs for a 40 kW dual-fuel system were ranging from 13,14 Rs./kWh (@ 100% PLF) to 20,51 Rs./kWh (@ 50% PLF). For a 9 kW 100% Producer Gas system (as the 9 kW Ankur systems analyzed in chapter 5), costs were ranging from 18,53 Rs./kWh (@ 100% PLF) to 33,68 Rs./kWh (@ 50% PLF). In all calculations, the biomass price was considered to be 1,50 Rs./kg. The calculations show, as was also done in this report (in section 5.3.5), that it is very difficult to compete financially with grid charges. Grid costs per kWh are lower.

This study has contributed to the existing literature when compared with the existing literature described in section 2.1. The main contribution of this report is the amount of rural biomass gasifiers and the diversity of reasons of installation (i.e. development, entrepreneurship, saving on grid charges) compared and analyzed using the same method, namely the framework. This report is the first report to offer an indication of success of a larger number of rural biomass gasifiers in India. It also offers an analysis of the reasons of success or failure, when looking at the reasons of installation of the biomass gasifiers.

8 Recommendations

8.1 Introduction

This chapter will describe the recommendations to the actors involved in the rural biomass gasifier applications. These actors involved include:

- Colleges, such as IISc, Periyar college, VITU and others
- Governments and governmental organizations, such as the MNRE, TEDA, GOK, DRDA and local panchayats
- NGOs and government programs such as DESI, BERI and the MNRE programs
- Producers, such as Netpro, Energreen, IISc, AEW and Ankur

The recommendations will be described based upon the conclusions described elsewhere in this report.

8.2 Formation of a biomass working group

Throughout the years, experience has been gained on the level of both scientific research as well as application in the field of rural biomass gasifiers by several actors. Colleges, NGOs, governmental organizations, international organizations, producers, operators and users contain experiences, these are however insufficiently shared. Limited public and open information concerning the practical experience in the field of day-to-day operation is available. This report can be regarded as the first broad operational field evaluation of the rural biomass gasifier applications, including government, educational institutes and NGOs.

It would be beneficial for the involved actors to share experiences openly more often.

With a technology like the biomass gasifier applied in the rural setting, a lot of uncertainty is still present; these include local acceptance, initial finance and finance for operation, the appropriate technology and maintenance. Sharing the information among the actors will encourage evolution of the technology and improve likelihood of replication. This is beneficial for all actors involved.

In the interviews conducted it was indicated that many actors are related to the IISc, but few actors are related among each other. Another observation was the fact that experiences in the villages were not known and/or used by actors involved in the rural biomass gasification projects. This has resulted in placement of biomass gasifiers in inappropriate places, because of the lack of biomass, or maintenance possibilities.

It is recommended that a biomass gasifier work group is formed, possibly by the IISc, with the goal of integrating and sharing all information related to biomass gasification in the rural setting and sharing this information openly. This can be done by information on

a website, or via a magazine. It is crucial that all those involved can share the information, these include the scientists, NGO officers, politicians (National, State, Panchayat), but also the mechanics, the biomass gasifier operators and users. Finance for the biomass work group can be provided by the MNRE biomass gasifier funds for workshops etc. as indicated in chapter 3.7.

8.3 Grid connection of larger scale applications

BERI has been the first to apply grid connection the rural biomass gasifiers in India. The motivations to do so are financial, when the local rural applications do not require the electricity produced by the biomass gasifiers, the electricity is sold to the state utility for electricity for a fixed price. BERI is not concerned with the fee collection. This saves costs. Although delays for BERI were common and experience in the field of grid connected biomass gasifiers is still limited, the configuration seems promising. It is interesting to keep a close look at BERI and regularly evaluate the findings of the grid connected biomass gasifiers. When running properly and if the state power utility pays according to the agreed price, the problem of a low plant load factor is history. The plant can always run optimally, and sell excess power to the state electricity utility. Shortages of power in the villages can be purchased from the grid for market prices.

The configuration seems promising, but experience is still limited at the moment.

8.4 Requirements for appropriate feasibility study

As described in this report, biomass gasifiers have been placed in several places throughout rural (South) India without sufficient initial planning. These include application in Coimbatore and Dharmapuri districts. In the plans of MNRE a number of gasifiers to place in the next years is set. Success of these and prior placed gasifiers is not determined however. The Indian government and MNRE have a top-down structure in which the rate of success of the applications installed in the past does not reach the decision makers in Delhi. This is a common problem for government ministries around the world. It would therefore be better for MNRE or the state utilities like TEDA to design and execute an appropriate feasibility study before awarding any subsidies. The main items should include:

- Financial analysis. These would include an analysis of the costs, and means of finance, for the initial purchase and for the day-to-day operation. A cost benefit analysis is useful.
- Technical analysis. Is the desired technology appropriate for the rural setting? Who will maintain the installed biomass gasifier, and how is the support of the producer arranged? How will training of the operators be done and by whom? Is it possible to connect the existing infrastructure to the new biomass gasifier installations?
- Presence of institutions that can achieve social involvement and support. In the villages, most of the people do not care about the biomass gasifier, unless they

feel that they benefit. Means of informing the people and creating awareness as well as enthusiasm is beneficial for the success of the biomass gasifier.

In general we can state that the (educational) institutes and NGOs as described in this report, performed much better on the field of planning and feasibility studies than the state utilities did. Governments can learn from these institutes and NGOs. Close involvement as shown in the IISc (Hosahalli and Hanumanthanagara villages) case can result in successful application for a prolonged period. The involvement of DESI with the villagers, by promoting entrepreneurship, seems beneficial for the success of the rural biomass gasifier applications. A prolonged period of time is required in which a number of routines is required, including awareness training, social support structures, requirements by the villagers and all technical and financial items, such as the availability of sufficient biomass, technical support, income, etc.

8.5 Adaptation of CDM finance

The Kyoto protocol has created the possibility for developing countries to earn money by preventing the emission of greenhouse gases (CO²). Carbon credits can be sold to the developed countries that are emitting a large amount of CO². DESI has proven that it is possible to earn surplus money with biomass gasifier projects. The government of the Netherlands has made financial contributions to DESI through the Clean Development Mechanism. Future projects can benefit and gain financial sustainability using the CDM credits. Although not completely analyzed in this report, it is clear that the CDM credits can prove beneficial for future projects of biomass gasifiers.

8.6 Review of subsidy schedule

At the moment, large amounts of grid electricity are available for free for farmers. As a result, the SEBs have too little income and cannot provide reliable electricity. More can be read in chapter 3. Even in the cities, blackouts are common. When the subsidies for the grid power and fuels would decrease, money to provide reliable power would be available. People have indicated a willingness to pay less for reliable power. This argument is also published by others, but unlikely to change rapidly, because of the political influence in the SEBs. With the current situation of highly subsidized (but in most States unreliable) rural electricity, the biomass gasifiers are faced with false competition. This makes it very difficult to operate them successfully. The biomass gasifiers can be used in niches, such as in the DESI case in unelectrified villages and in the BERI and DESI case as part of a larger program to promote rural development.

8.7 Closer fit between the beneficiaries and the technology

A close fit is required between the beneficiaries in the villages and the technology offered (i.e. a biomass gasifier) for rural development. This is achieved by involvement of the rural population in all processes. To ensure sustainable “Ultimate Goals” to be achieved, an appropriate technology can serve as a means to reach these goals. This requires organizations that guide the rural development, with the eventual goal of transferring this to the local community. This is best done by NGOs due to the close fit between them and the village population for other projects. The democracy within Indian villages can also prove beneficial if committees are elected and required to substantiate promises.

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List of abbreviations

ABETS	Advanced Bio-Energy Technologies Society
AEW	Aruna Electrical Works
ASTRA	Application of Science and Technology for Rural Areas (currently CST)
BERI	Biomass Energy for Rural India
CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CST	Centre for Sustainable Technology (Part of IISc)
CO ²	Carbon-dioxide
DESI	Decentralized Energy Systems India
DRDA	District Rural Development Agency
EmPP	Employment & Power Partnership Program
ESMAP	Energy Sector Management Assistance Programme
Fig	Figure
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GOI	Government Of India
GOK	Government Of Karnataka
IBRD	International Bank for Reconstruction and Development
IC	Internal Combustion
ICEF	India Canada Environment Facility
IISc	Indian Institute of Science (located in Bangalore, Karnataka state)
IREDA	Indian Renewable Energy Development Agency
kW	Kilo Watt
kWe	Kilo Watt Electricity
kWh	Kilo Watt Hour (or one unit)
kWth	Kilo Watt Thermal
MANTRA	Management Training Centre for rural women
MDG	Millennium Development Goals
MNRE	Ministry of New and Renewable Energy
MW	Mega Watt
MWe	Mega Watt Electrical
MWth	Mega Watt Thermal
NGO	Non Governmental Organization
PG	Producer Gas
PLF	Plant Load Factor
PPA	Power Purchase Agreement
PPP	Purchase Power Parity
PV	Photo Voltaic
Rs.	Indian Rupees
SEB	State Electricity Board

SHG	Self Help Group
SNA	State Nodal Agency
TARA	Technology and Action for Rural Advancement
TEDA	Tamilnadu Electricity Development Agency
TNEB	Tamilnadu Electricity Board
TU/e	University of Technology Eindhoven, The Netherlands
UN	United Nations
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States of America Dollar
VER	Verified Emission Reductions
VITU	Vellore Institute of Technology University

Conversion factors

1 Horsepower = 0,756 kW

1 Unit = 1 kWh

1 Euro = 60 Rs. (approx exchange rate)

Appendices

Appendix A: Questionnaires

Appendix B: Interviews

Appendix A: Questionnaires

To determine the success and failure of the bio mass gasifiers in Tamil Nadu

Objective:

- To collect information on the various biomass gasifiers in Tamil Nadu
- To find out how effectively the biomass gasifiers are functioning
- To find out the failures of the biomass gasifiers
- To find out the people's participation in biomass gasifiers
- To find out the socio-economic issues related to biomass gasifiers

Questionnaire for the villages

Grid power:

1. Is grid power present?
2. Is the supply of grid power for free / what are the costs?
3. Is the supply of grid power 24 hours / how many shortages are there (approx.)?
4. How is the power shortage during summer?
5. How many days a time they cut power?
6. What are timings they give full supply for irrigation purposes?

Electrification in the village:

7. How many of the houses are electrified?
8. How many SME (small scale industries) what are the industries (increase after gasifier)?
9. How is electricity applied?
10. What other public services are present in the village (water, etc.)?

The village:

11. What is the population?
12. What is the population division (age, occupation, wealth)?

Biomass production:

13. How is the biomass produced / acquired?
14. What is the usage of biomass per day / week / month?
15. Are special forests designated for biomass production / forest size?
16. Are fertilizers applied?

Power generation (ask to operators / biomass gasifier producers):

17. What are the gasifier components?
18. What are the applications of the energy (lightning, irrigation, etc.)?
19. What is the production of electricity per day?
20. How many days per month is power generated?
21. What happened on the days, no power was generated?

Performance (ask to operators / biomass gasifier producers):

22. How much diesel fuel was required / month?
23. How many times is maintenance required, how many days does it take (approx.)?
24. Who does maintenance / is there enough support / what is the support?
25. Are there regular check-ups?
26. Who does the repairing and services?
27. Do you have trained personnel or you hire from outside?

Financial:

28. Are there subsidies (if so, how much and by who)?
29. Do the villagers contribute in the costs?
30. How much are the costs for connection to the gasifier?
31. Are all costs covered?
32. How could the financial situation be improved (subsidies, more contribution by the villagers, etc.)?

Management / operation:

33. What is the management structure of the gasifier in the village?
34. Do the villagers have a saying in the management (village assembly)?
35. How many meetings are there by the management?
36. What problems arose within the management?
37. Are NGOs involved (if so which and what is their role)?
38. How many operators are there / how are they trained?

Social issues:

39. Talk about possible social tensions arising due to the gasifier use.
40. Do all people feel equally benefiting from the gasifier (and if not why)?
41. What are the benefits the gasifier brought?
42. Do people have a feeling of increasing saying into their lives (more political involvement / having ones own electricity production)?
43. Do you think the standard of living of the people has improved after the biomass power production? (Increase in agriculture, industries etc.)

Open discussion themes for focus group discussion (beneficiaries):

1. What are the benefits, the biomass gasifier brought for the people in the village?
2. What changes occurred due to the biomass gasifier?
3. What do you think can be done to improve the gasifier (technical, social, financial)?
4. Do you face any problem because of the biomass gasifier (probe questions in terms of Pollution, environment, deforestation, increase in the price of the firewood, what about the conflict for land for food crops / biomass wood etc?)

Open discussion themes for focus group discussion (plant operators):

1. In your opinion, what can be improved on the gasifier?
2. What changes have you seen, after placement of the gasifier?
3. How do people react to the gasifier?
4. Talk about the support, the institutes give to your operation.

Questionnaire for the institutes

General:

1. How is your institute involved in rural development?
2. How is this done by your institute?
3. How is contact with the rural population maintained?
4. Are (biomass gasifier) projects regularly evaluated (please have)?
5. What (biomass gasifier) projects have you done in the past?
6. Do you have a list of these?
7. Which gasifier producers do you cooperate with?
8. How is this cooperation (good, bad?)?
9. How can gasifier application be improved (social, technical, financial)?
10. How successful do you consider your institute in the rural development?
11. Substantiate this.

Subsidies:

12. Who subsidizes these projects?
13. Do villagers contribute themselves?
14. Is there also commercial or private financing?
15. Are you satisfied with the governmental subsidies?

Initiating:

16. Who takes the initiative to place gasifiers?
17. How are the villagers involved in the start-up phase?
18. Talk about the study done before placing the gasifier (availability biomass, enough social support, prices)

Social support:

19. How do you involve the rural society in the placements?
20. Can you show a field study paper?
21. How are the people convinced?

Education:

22. How are the operators trained?
23. How is maintenance arranged?
24. How is the technical support arranged?

Open discussion themes for group discussion (institute officials / rural development workers).

1. How can the success of biomass gasifiers in the rural application be improved?
2. How can the government support the success?
3. What can the villagers themselves do to improve success?
4. Looking back at the projects from the past, what would you have done different?

Questionnaires for the biomass gasifier producers

Product:

1. Talk about the technical characteristics of the (rural) biomass gasifiers (power, biomass usage, etc.)
2. Are there special changes made for rural application (easier control, etc)?
3. Does your company focus on rural applications or more on industrial applications?
4. Do you find your gasifier to be good applicable by the rural population?
5. If it is rural applications, how is this done (surveys, talks with villagers, focus group)?
6. Are rural operators trained / instructed?
7. How is this done?
8. What (technical) support do you offer to the rural operators and villages?
9. Are there maintenance contracts with villages?
10. Are you cooperating with other gasifier producers?
11. Are you cooperating with (rural focused) institutes?
12. Are you cooperating with the government in rural development?

Opinion:

13. What do you think of the rural application of biomass gasifiers?
14. Are they successful in your opinion?
15. How would success be improved?
16. What can the government do to improve success of the biomass gasifiers?
17. Are villagers in your opinion capable of running a gasifier for a prolonged period?
18. If not, what should be done?

Questionnaires for the government

General:

25. How is your government involved in rural development?
26. How is this done by your government?
27. How is contact with the rural population maintained?
28. Are (biomass gasifier) projects regularly evaluated (please have)?
29. What (biomass gasifier) projects have you done in the past?
30. Do you have a list of these?
31. Which gasifier producers do you cooperate with?
32. How is this cooperation (good, bad?)?
33. How can gasifier application be improved (social, technical, financial)?
34. How successful do you consider your government in the rural development?
35. Substantiate this.
36. How is the rural area electrified?
37. What do farmers/villagers have to pay? Rate? Connection costs?
38. How much time is electricity present? 3 phase?

Subsidies:

39. Who subsidizes these projects?
40. Do villagers contribute themselves?
41. Is there also commercial or private financing?
42. Are you satisfied with the national subsidies?
43. Who pays for the electrification?
44. How much is distributed per year? To rural gasifiers?
45. Do villagers pay for their electricity?
46. How are people / NGOs / companies motivated to place biomass gasifiers?
47. Talk about the small scale 5 kW biomass gasifier pump sets, are they successful?

Initiating:

48. Who takes the initiative to place gasifiers / electrify?
49. How are the villagers involved in the start-up phase?
50. Talk about the study done before placing the gasifier (availability biomass, enough social support, prices)

Social support:

51. How do you involve the rural society in the placements?
52. Can you show a field study paper?

Appendix B: Interviews

- Interview with prof. Paul and Mr. Sridhar at IISc, Bangalore.
- Interview with mr. H.I. Somashekar, M.Sc. (agro), technical officer.
- Interview with M.H. Swaminath, Biomass Energy for Rural India (BERI), project coordinator
- Interview with Mr. Selvaraj, M.I.E., Deputy General Manager, Tamilnadu Energy Development Agency (TEDA) Coimbatore
- Interview with prof. Nalini of Periyar Maniammai College of Engineering for women, Vallam.
- Interview with Mrs. Srividhya, operator of the biomass gasifiers at Periyar College, Vallam.
- Interview with Abhisek Sharan, Development Manager, DESI Power, Bangalore

Interview with prof. Paul and Mr. Sridhar at IISc, Bangalore

Date: April 2007

Research into the biomass gasifiers at IISc started in 1982. In 1982, IISc started with small scale gasifiers research, at that time the available gasifier was a closed top gasifier. This research went on for 2-3 years. In that period IISc came across experiments conducted with open top gasifiers. In 1986 a model was developed quite similar to the current model. Only open-top models were placed for experiments in the field. Closed top performance proved erratic, open top proved significant improvements. The performance is not erratic.

In 1987-1988 the first gasifier was placed in the field for experimenting, funded by a government program. This was a gasifier (engine rating 3.7 kW) directly connected to a water pump (directly connected to dual-fuel engine). This can replace the diesel pump sets used for irrigation pumping. The 2nd oil crisis in the late 70s contributed to the research. The same diesel engines as used before were used. The goal was to replace the diesel fuel. Around 80% diesel replacement was achieved. After this, electricity generation became a subject of research.

Around 87-88 there was a large-scale dissemination program resulting in around 300 gasifiers put in the field connected to pump sets all over India. None are still running. Experience was mixed, some ran it sufficiently, and others did not. This is one of the problems of giving it for free. They accept it, whether they intend to use it or not. The diesel was no longer expensive, so the usage stopped. This was the first experience in the field. Before this, there was only lab experience.

After this, there was a project of the Indian government to provide power to the Andaman Islands, and this required a scale-up from the 3.7 kW to 80 kW, and going from direct water pumping to electricity production. Ceramic parts were not yet used.

Gas cleaning system went through a lot of modifications (1989-1990), such as the replacement of sand filters. This was a requirement of the MNES (for the Andaman Islands). It was erected there with the consideration for special development for backward areas. This was the first field experience (dual-fuel engine) for electricity production. The idea was that the saw mill (wood processing industry) could be electrified partly by the biomass gasifier. The fuel was provided by the waste of the saw mill. It was a metal reactor, thus it has a limited lifetime, it failed after 1000-1100 hours, and repairs were costly, this was done a few times. Ceramic tiles were developed later on (1992-1993) to solve the limited lifetime. A gasifier was exported to Switzerland in 1995. A second one was placed in Oorcha, India. In 1988 the Hosahalli gasifier was placed, originally for water pumping, after this, the villagers required more power / services and the power output was increased. From 2000 onwards, the main subjects of research were gas cleaning and 100 producer gas engine applications. Because of the rising oil prices, the dual-fuel applications were getting to costly, and 100% producer gas engines became economically attractive. The focus of IISc has shifted to industrial applications. Right now around 60 gasifiers from 10 kWe to 1.5 MWe have been placed. There is a trend of up-scaling the power produced by BGs. Problems encountered with up-scaling are mainly in the field of longer periods of operation and the cleaning of the gasifier.

No other parties were involved in the developing of the technologies. Companies are now licensed to produce gasifiers using the IISc technologies and design.

Now help is used from these manufacturers, because they are aware of the field problems. In the beginning, there were no partners. For later experiments, there was cooperation with a Swiss company (near Geneva). NGOs were mostly users. Names not known anymore. An example is the Tumkur district project funded by UNDP / GEF.

A paper has been published about the rural application of IISc. about the rural industry. In the industry the gasifiers are used for thermal heat applications, such as heat treatment for castings. Applications for electricity production also exist. Mainly large scale in the industry. In Andra Pradesh 10 kW applications are there

Performance of the gasifier so far in India is mixed; it can do better but as for all new technologies, trial and error make for the technology to improve.

The technology has potential for the future, especially with the oil prices increasing. Biomass prices will also increase if usage increases. Niche markets for the gasifier are possible. Electricity costs in India are high, even compared to Europe (5 Rs. / unit). The reliance of electricity in India is also low, power cuts are frequent and in rural areas costs can be 10 Rs. / unit. There is a scope for applications for companies using gasifiers to provide reliable electricity.

IISc has been looking at the social aspects involved in rural biomass gasification, but for the IISc the main focus is to find solutions for technical (rural) problems. Especially the Centre for Sustainable Technologies (CST) is involved in the rural development. The management department is also involved.

Contact with the rural population is mainly maintained through the CST.

The gasifiers produced are made by the licensees such as Netpro, Energreen and others. Subsidies for rural electrification are mostly given by MNRE. In Tamil Nadu a special program exists for rural electrification, supported by the Asian bank for development and monitored by DRDA. There are no commercial or private financing of the rural electrification. DESI is now involved in a program (sponsored by World Bank) into electrifying 100 villages. One of the problems for rural electrification, the return of investment is negative, the load is too low, and operation hours also (5 to 6 hours /day). Collecting tariffs is also difficult, most people are unwilling to pay. Electricity boards do not shut off villages when tariffs are not paid because all EBs are government owned. Government subsidizes or for political reasons power is not shut off.

Villagers will say that if you provide reliable power, they are willing to pay, if it is not there, why should we pay?

Government is not able to give more energy, so it is only supplied for short periods.

More facilities should be provided by the government such as promoting private initiatives. A good example is what BERI is currently doing. So increase private initiatives and entrepreneurship. Initiative for placement of rural gasifiers, is mostly taken by governments (both local, state and central), money comes from the central government through MNRE. Surveys conducted before placement differ per application, if it is for

drinking water pumping, knowing the number of households is sufficient. Surveys are conducted by independent organization.

Operators of the gasifiers are trained by the manufacturers. Technical support is also given by the manufacturers. The long term goals for IISc for rural development are limited, they have not much influence because it depends on the manufacturers. Most of the information comes from the manufacturers. IISc usually gets second-hand information. Direct visits do not occur very often.

END

Interview with mr. H.I. Somashekar, M.Sc. (agro), technical officer.

Date: April 2007

Centre for sustainable technologies (CST)

Indian Institute of Science (IISc.), Bangalore, South-India

The CST was formerly known as ASTRA (Application of Science and Technology for Rural Areas). It is an integrated department with IISc in which people from various faculties work together in finding solutions through science and technology for day-to-day problems for rural India. He identifies fuel for various applications as one of the main problems for rural India; applications can be cooking, electricity etc.

In the supply of electricity, the rural areas are ignored; the large majority of the power is given to the urban and industrial sector. The rural power is therefore too little and very unreliable, not even enough for lighting and drinking water (pump) purposes.

ASTRA studied and identified a number of things that can improve the well being of the rural population; among these is the improvement of biomass availability required for cooking etc. This should be done by using the local resources. By improving the local resources the quality of life is to be improved. That was the object.

ASTRA starting working (among others) into the fields of biogas, biomass gasifiers, cooking stoves and energy plantations. ASTRA also looked into the use of wind and solar power.

Biogas plants have been applied on community level, cow dung is used for electricity production through methane production, usable for industrial and rural applications. Through decentralized small-scale production, dependence on government and state electricity boards is reduced.

With this in mind, the experiment in Hosahalli was taken up, the system is very simple. The village has 50 to 60 families and was an un-electrified village. The experiment was conducted because in the 80s the knowledge to produce electricity in a sustainable way through biomass gasification was known, by using the wood from the wasteland. This could be done by using gasifiers thus meeting the requirements.

ASTRA wanted to test this technology under local conditions with participation of the local people, in that time the gasifier had just evolved within IISc (with the own design). The application in Hosahalli village was setup as an experiment.

There was some barren land available and the government was asked to permit plantation on this land. People participated in planting and maintaining this plantation for usage in the gasifier.

The initial first phase of the experiment was the application of a 3,5 kWe gasifier system. This system was used to provide street and home lighting on fixed hours every day. People were impressed and started realizing the value of maintaining the forest.

A biogas experiment project was conducted in a neighbouring village using cow dung to produce electricity. Lighting and drinking water were supplied through this system.

The people in Hosahalli saw this, and also asked for drinking water. In the second phase of the project the power production was upgraded to 5 kWe and drinking water was also supplied. A clean drinking water bore well and tank were installed and houses were connected to this tank with one tap per house.

In the third phase of the experiment the system was upgraded to 20 kWe and a flour mill was installed in the village to mill the grains. Otherwise the people have to walk 2 to 3 kilometres to a different village.

Irrigation to some farmers was also started, 3 to 4 bore wells were constructed, which were used for irrigation purposes. All the energy for these activities comes from the energy forest with a size of approx. 4 ha. This plantation has a mixed vegetation, with Eucalyptus and other woods.

Technically the system performed very well, with diesel replacement around 85%. The supply of biomass of the plantation was sustainable. Local people were trained to operate and maintain the system.

In terms of the expenditure, ASTRA could not make it self-sustainable, because of the low plant load factor and the small size of the village. The project was run on project-mode which meant for 3 to 5 years, just to experiment. So after the completion of the experiment, there were no more funds to continue operation. People did contribute, but not enough to cover costs. Operation eventually ended in 2004.

The project is regarded successful because it ran during the experiment phase and it proved that it is possible to run a gasifier by local population for a prolonged period. People are however unable to pay complete operation and maintenance costs, if no subsidy is involved. Competition with grid electricity is unfair because grid charges are zero. Pumpsets are free and lighting is very cheap (10 to 30 Rs. / 3 months). For drinking water also, people are not charged. So because of this with the biomass gasifier in operation, people only paid for irrigation water, the 100% charges needed to run the system. For drinking water and lighting, they paid, but this did not meet the total expenditure of the running and maintenance costs of the system.

Monthly expenditure in the third phase was around 10.000 to 12.000 Rs., while income by charges was only around 40%. During the project period, IISc supplied the shortage because project money was available. Till 2004, project money was available.

Around 2004 Hosahalli village was connected to the grid.

Well being improved by the application of lighting (reading), safer drinking water, irrigation and the flour mill. Land was used more efficient due to improved irrigation, and crop yields did increase. The employment also increased because people were paid to maintain and cut the forest. There were no small scale industries evolving, the population lives by agriculture. Systems close to urban centres can cause small scale industries to start.

Empowerment was increased by the application of irrigation bore wells. If you want to increase yields, irrigation is required. To make a bore well, approx. 100,000 Rs. are required. The 3 bore wells drilled by IISc in Hosahalli and everybody was given irrigation water for ½ acre land regardless the amount of land people have. For people with little land and little money, irrigation of their land will increase their income, even after paying the biomass gasifier charges. Up to approx. 80% of the money earned was profit, the rest was paid for the biomass gasifier water charges.

In the neighbouring village Hanumanthanagara the people observed the program of IISc and requested IISc for help. In this village domestic electrification was installed to use for lighting, flour mill and drinking water. It could not be extended to irrigation because of the lack of project money. This was around 2004.

The village is now also grid connected, they do not have to pay for the electricity charges, and if people have enough money they can pay for their own bore well to be installed. The objective was to provide lighting to all the houses, regardless rich or poor. This also goes for drinking water, it was provided to all the houses. Then all will pay for these services, this is the system that evolved.

But now, whoever has money, has access to these services. Even though the power is for free, installation of the wires from the houses to the grid connection has to be paid, and is unaffordable for most people. The installation of the wires from the biomass gasifier to all houses was paid for by IISc.

He regards the government policy of providing free electricity as a bad thing. The government only does this to gain popularity and votes. Most people are able to afford the electricity charges.

There were also some social problems with regard to the bore well, these were however sorted out by involvement of the local administration. One of the bore wells was drilled on a site of a farmer that first allowed the bore well but after construction refused sharing of the water. Wood was also stolen sometimes; this was mostly done by people of neighbouring villages.

Many operators were trained.

State government and national government subsidized the projects. The gasifiers are no longer in the 2 villages. They were returned to IISc, for further testing. It was interesting

to have a look at the state after the long running time. Minimum maintenance was conducted by the local people like for instance the changing of the sand filters or changing oil. Larger maintenance was done by IISc.

CST IN GENERAL

Initially CST/ASTRA was started as the own institute program. It was started out of own interest of the senior staff and director. To do something for the rural people, you cannot stay in your office. So an extension centre was placed in villages and conducted several survey studies, and found the exact problems. We identified energy as the main problem, both in villages as well as in urban areas.

When ASTRA was founded in 1977 this were the first steps taken.

Evaluation of the projects running is regularly conducted and the whole department is evaluated by using a SWOT (Strength, Weaknesses, Opportunities and Threats) analysis.

The main difficulties in rural development are the transfer of technologies to the field successfully. Under lab conditions, everything is under control. In the field, working with the people, many other factors play a role, like social and economic factors. Also local environment and climatic conditions. All these things beyond our control play a critical role.

Social factors can be political pressure, caste pressure and local dominance. Some may ask for favours. CST can overcome most of these things because IISc. is an educational institute. IISc cannot be pressurised politically, the mandate is clear and research funds are available. We do not associate with any group in the villages, with respect to political or caste. We performed independently. Prices of the electricity are decided in cooperation with the villagers, but are equal to everyone.

The gasifiers placed in the villages were built by IISc.

With regard to the future, mr. Somashekar believes that if a proper policy is in place, it is a technology to stay. This is the best technology that is environment sound and meets the requirements of the people. The government should have a biomass generation policy, biomass utilization policy and technology adaptation policy. For grid power, you have to depend on large high-tech capital investments, international support, etc. The biomass gasifiers have small capital investments and dependence on others is reduced.

In both the industrial and irrigation power service, there are still major power cuts. The industries have alternative power systems like diesel sets to coop with these power cuts. If you plan the availability of woody biomass, with the current technologies where 100% producer gas engines are available gasifiers can also coop with this problem. Decentralized systems are better.

The initiative for the villages was taken by ASTRA and supported by the government to test the experiment. Now based upon the gained knowledge the government of India, UNDP have started BERI. The technology is provided by IISc.

There is no resistance in the villages; the only thing is that you have to find a place for the plantation. You need the help of the people to grow and maintain this. The operators were trained by IISc.

According to mr. Somashekar, the future for rural biomass gasifiers is bright. The government of India is currently looking into it and is also using this concept of rural electrification using gasifiers. List of gasifiers is not available, CGPL can give these.

Currently biomass gasifiers do not have a fair change with the current free electricity available by the government.

There is no conflict between food and cash / biomass crops. This is because the biomass trees can grow on land, on which food crops cannot grow. The moisture and food for the crops are taken from different depths, so there is no conflict between these either.

Regarding deforestation, when sustained well, it can help against deforestation. Rules are however not always followed and forests are illegally felled. Agro residue can also be used for energy production such as rice husk and coconut shell.

END

Interview with M.H. Swaminath, Biomass Energy for Rural India (BERI), project coordinator

Date: 1-4-2007

Rural industries pay 3 times more for the power than the rural people do.

Rural people pay 1 Rs. for domestic lighting per unit. Farmers pay 0.40 Rs. per unit for irrigation, and industries in the rural setting pay 4 Rs. per unit. The average price is around 2 Rs. in rural India. Production costs are around 3 Rs. There is a loss of 1 Rs. per unit. The capital costs are not taken into account in this equation.

The BERI project is supported by UNDP and GEF (Global Environment Facility), this is about the reduction of greenhouse gases globally. Both support with the goal to replace conventional energy with sustainable energy. Sustainable agricultural and rural development is also one of the goals.

Problems for the project are mostly financial. Another problem is the availability of biomass, enough should be generated to meet the demand of the plant. The challenge is to make it economically viable, ecologically sustainable and environmentally feasible. Eventually by involving the rural population more money should be generated and lead to an increase of income for the villagers.

For instance: formerly irrigation was done by the use of irrigation directly on the land, now drip irrigation is used. Less water will evaporate. If less water is used, less power is required and the electricity bill is paid, because it is feasible to do so. If trees (Eucalyptus) are grown and harvested, after 4 years there will be a return. The amount of forest land will also increase. Forest committees take care of this; they are paid for work, maintenance and after harvesting.

Local members are working at the plant. Women grow seedlings and vermi-compost to sell it to the towns (zie folder). More cattle is also grown, resulting in more cow dung, used for cooking (biogas). There is a replacement of fossil fuels and wood fuel usage. CO₂ analysis have been made and CO₂ has been reduced and will so in the future due to the plantation of new trees and reduction of fossil fuels usage.

6 years ago, trees have already been planted for the biomass gasifier. 4000 hectares have been planted so far.

CDM funds are not available, GEF awards points for this, and this project will not receive CDM funds because there is no additionality. This means that you should start with a base-line in 2004/2005, and then provide additionality.

BERI is trying to develop 500 kW biomass gasifier systems.

The costs of the project are 65000 Rs. / kW (1200 USD / kW or €1100 / kW), this comes down to 500 * 65000 = xxx Rs. This money is paid to the producers Energreen and Netpro, the infrastructure of the plant and the various village committees (forest / biomass management / self-help groups). Women self-help groups have various programs such as road development, biomass management, seedlings production, tree plantation, management and cutting. In the district there are several various rural development programs such as plantations, agricultural development etc.

The BERI project started in 2002, this is the first plant for BERI and they do not have a lot of experience yet. It was funded by GEF and UNDP. The producers cooperated with are Netpro and Energreen. This was done by a public tender. Cooperation with the producers is regarded as very bad. There are a lot of delays and lack of capacity and knowledge of the companies. These companies are small contractors and they do not have enough finance to invest and produce and improve the technology. There have been technical problems with the fuel efficiency, equipment, ?????? is not available, servicing is not available.

The synchronization is also a problem. Much equipment of many producers (wood cutter, gas engines, biomass gasifiers, filters, connection to grid power) is placed and if one thing goes wrong or is delayed, the entire project is delayed. The Energreen plant has been placed for 2 years now, and now only it is finished (in the last 6 months). Energreen proved unwilling to supply service / finish the project. Money needed to be paid in advance to make them work. The gasifiers can operate now, this is no problem.

When the project was started in 2002, the idea was to have 40 kW gasifiers placed with a total capacity of 1200 kW (so 30 gasifiers). These were to be placed in 28 villages. This is island mode (every village has a separate connection to a gasifier, no connection to grid or other gasifiers). The problem encountered was that there were no producer gas engines for 40 kWe applications. The engine would have to be designed for these applications. A survey was conducted in the villages into the electricity demand. They found that the minimal load requirement per village is 100 kWe for lighting, irrigation, industries and households. 40 kWe applications proved inadequate. Then it was decided to place 28 x 100 kWe gasifiers in island-mode. Only after this it was decided to go for cluster-mode without grid connection. This means 5 villages are connected to one (500 kWe) gasifier. The Tumkur application is the first of this. Special electricity lines for this were installed. Grid power was already present in the villages (but unreliable).

Still the biggest problem was the load, for 5 villages between 10 am and 4 pm; the load is 60 amps because flour mills, irrigation pumps and industries require power. The 500 kWe applications can only provide 22 amps. If we would go for 60 amps, 3 MWe would be required. Investment costs would rise sharply.

After 4 pm, requirements reduce to 2 amps, because only domestic lighting is used, the capacity utilization would be 10%.

The idea then was to use 4 producer gas engines, which could be switched on and off, regarding the load requirements. This is also applied in the Tumkur application.

For start-up you need one engine in dual-fuel mode (using only diesel) providing power for the start-up. Still the load was a big problem (60 amps vs. 22 amps). It was then decided to grid connect the plant. The plant will be connected to the 11 kV grid. The power will be provided to the grid, with a guarantee to the villages that they will always be provided with power (24 hr.), the load management is no longer a problem, excess power will be provided to the grid and shortages will be provided by the grid. The synchronization with the grid is currently in progress. The Tumkur plant will produce 3.000.000 units per year; the villages only require 1.700.000 units per year. The excess 2.300.000 units can be sold. The gasifiers will be running 24 hr. per day to make it economically viable. The excess power is sold to the Electricity board for a guaranteed

price. Earlier in the island mode, they wanted the biomass management village committee to collect the electricity fees for the power produced. The costs of the committee proved to be higher however than the fees collected. This is also because approx. 20% of the clients would pay the electricity fees as proven in a survey. Especially farmers and households do not pay for the electricity fees. To collect the fees, 5 people would be required, salaries would have to be paid and still they would only collect 20% of the fees. Running the plant would prove impossible. Now PPAs (Power Purchase Agreements) are made.

With electricity producers deals were made, they will pay 2.80 Rs. per unit for every unit produced by the plant. So for 3.000.000 units approx. 9.000.000 Rs. Power is guaranteed to the 5 villages. This money is used for running the plant.

The villages will get the power supply from the grid. Whether they pay or not is not a concern of BERI but of the electricity company / board. The BERI plant will be guaranteed a fixed income per unit (2.80 Rs.). In 2002 the initial plans were to have the plant be managed, run and biomass collected and stored by the villagers. Mr. Swaminath does not think it is possible for the villagers to manage all this.

Deals are made with NETPRO to maintain the gasifiers (for 1.000.000 Rs. annual).

The biomass can be supplied by the villagers; they can cut it from barren land and thus collect extra income. The role of BERI in the future will be mainly advise.

Next week the second project will start (second cluster) in a village 4 km from this project. This first project has taken 6 years, and the goals are to have the other clusters finished in 6 months. This is not possible so it will take another 10 months.

Enough biomass is available. Entrepreneurs should be started to provide the biomass.

Biomass has been grown for the last 5 years (price 1000 Rs. / kg).

Charcoal as a residue can also be sold (price 60 Rs./kg). CDM can also provide extra money.

To grid connect takes over 2 months, due to the lack of knowledge to do so. On island-mode all can already run, but there will be no income.

In 2002, it was expected that within 6 months, power would be produced. It took longer also because the biomass was grown on special lands, this takes time, and due to the many changes of plans (island-mode, cluster-mode, grid connection).

So far 145.000.000 Rs. is spent for this project (biomass 45 M, land 40 M, people 20 M, for officers, salaries, meetings, workshops etc). Out of 400.000.000 Rs. grant from the UNDP/GEF totally for the project. So 30% of the money is already spent, and time spent is 110% so far.

For the biomass 4000 hectares have been planted, resulting in 40000 tons of biomass annually. This will save 40.000.000 Rs., but the costs spent are much higher already.

The project was written by IISc., and they wanted to start with small gasifiers (20 kW-100kW). The engine was the main problem in the beginning. Looking at it backward, the best application would be one 500 kW gasifier because it will be grid connected. So one engine is enough. For the next project, 2 x 250 kW engines will be used, for the following after this, only 1 x 500 kW will be applied.

In rural India, most people do not pay; they either do not pay, or do not have to pay. There is no disconnection or sanctions. The supply is mostly only 8 hours, 3 phase. The remaining 16 hrs. single phase is supplied. Irrigation is not possible, only lighting.

This plant can supply 24 hrs. 3 phase power. Rural management schemes are used for the first time in this project, to provide the same power scheme as above described. So only 3 phase power during the day. Irrigation cannot be done in the night because then farmers keep their pumps on 24 hrs, and then the costs will be high.

Problems are technology, peoples attitude, government policy.

The people in the city pay for the free electricity of the rural areas. 2/3 is used in the urban areas (Bangalore 5.000.000), remaining 45.000.000 people use the rest of the power. 80% of the total costs however are paid by the urban areas, and the rural areas pay the remaining 20%. That is also why the rural areas get unreliable power, they do not pay and so are the last ones to get power.

IISc. initiated the project. Especially for this project BERI was founded. IISc. is no longer involved.

Much experience has been gained in the last 5 years.

Next week the plant will be able to run, because at the moment the connection to the grid is being made.

It is expected to be possible to run the plant for 6000 hrs. per year producing 3.000.000 units.

END.

**Interview with Mr. Selvaraj, M.I.E.
Deputy General Manager
Tamilnadu Energy Development Agency (TEDA) Coimbatore**

Date: 30-4-2007

In Coimbatore district 28 numbers of 9 kWe gasifiers have been placed in the past years. One of the problems is that in some places the raw material is not available in the neighbourhood, the material has to travel for larger distances. The material costs will be too high to economically operate the gasifier. Another problem is the load. The 9 kWe gasifier can power a 7.5 hp motor. In some places 10 hp motors are connected to the gasifier, and the load requirements are thus too high. Water pumps of 10 hp connected to the 9 kWe gasifier can therefore not pump water over a required distance sufficiently. Without properly assessing the load, the gasifier cannot be used fully. The operator will be paid between 50-100 Rs. per day.

The gasifiers are used for drinking water pumping, and this is paid for by the government. Drinking water is free of cost. Providing water is the Panchayat's responsibility. The house tax paid by the villagers includes water charges.

The hours of running of the gasifier depends upon the water tank size and water requirements of the villages.

The panchayat is responsible for costs and running of the gasifier.

TEDA is providing subsidies from the central government (MNRE) and the panchayat also shares in the costs. A 9 kW gasifier costs approx. 315,000 Rs. Half of the costs are paid for by the MNRE subsidies.

In every district, there is a project officer of the District Rural Development Agency (DRDA). He will announce the government subsidies schemes to the panchayats. The panchayat officials can approach this person and he will order a feasibility report to be made. TEDA will provide the required subsidies. The rural population is not involved in the decision taking, the panchayat and DRDA/TEDA do this.

The operators of the gasifiers are trained by Ankur. One technician of the DRDA office is also available for questions of the operators. Ankur will solve problems if there are any major ones.

The gasifiers are over 2 years old. The biogas technician knows more about the problems. Each company is producing according to their own specifications; the MNRE has set guidelines for the biomass gasifier producers. TEDA is the promotional unit for renewable energy sources. MNRE is giving financial support to the promotional, research and new projects in the field of renewable / sustainable energy sources. Each state has a nodal agency to implement this in the state, for Tamilnadu this is TEDA. Implementing the schemes can only be done through these nodal agencies. The state government also supports in the form of the DRDA officer. So the MNRE pays for the gasifier and the DRDA / Panchayat pay the rest. For all the gasifiers the DRDA paid the balance costs.

Most of the gasifiers are not running (properly).

The situation can be improved by assessing how raw materials can be made available. Local people can do this. The interest of the public should be improved. Normal operation of the gasifier by local people is possible. When trained and guided properly.

The panchayats pay for the biomass and salaries of operators. Awareness will be improved by TEDA by seminars, lectures and visits to the villages. There are training programs. As TEDA we have to concentrate on the available sources for energy in the villages. This goes beyond the usage of biomass gasifiers. For example cow dung can be used to produce biogas and thus cooking and electricity. This is an integration of all renewable energy sources.

The availability of biomass for gasifiers is also a problem for other users such as PSG college. The people can grow the biomass in the villages but this is not done, people should get more interested and aware. There are plans to improve awareness by education. If sufficient biomass is grown nearby the gasifier the installation can run properly and economically.

Before placing the gasifiers, feasibility studies have been performed. This is the first time gasifiers have been placed and we have learned from the experience. Next time, things will be different. Evaluations are made but not available.

In the future more gasifiers can only be placed when the raw material is available. Mr. Selvaraj does not expect a bright future for the biomass gasifier use in the rural settings because of the many problems that have arisen in the Coimbatore experience (raw materials, load). Biomass gasifiers can however be useful especially in remote places without grid electricity. This can be in forest areas. There are plans to do this, through a “village energy security plan”, the forest project is in Hosur and one other district (village project).

END

Interview with prof. Nalini of Periyar Maniammai College of Engineering for women, Vallam.

Date: 26-04-2007

Periyar college has planned to place 1 gasifier in a village. The village has been identified and has around 800-1000 houses.

Initially the plans were to place a 100 kWe gasifier. All houses would be connected and have 3 lights, a fan and the operation of electrical appliances as grinder and mixer etc. To fulfil the primary requirements.

Drinking water pumping will not be connected to the gasifier. This will be done by hand water pumps and TNEB power. The village is already grid connected.

The reason to place the gasifier is the availability of biomass in the surrounding, thus creating employment for people felling the biomass trees and 4 to 5 people will be directly employed for operation of the gasifier.

The plans for the gasifier are made through PURA (Providing Urban amenities for Rural Areas). PURA is looking at electrical connectivity, knowledge connectivity and economic connectivity. Placing the gasifier would be in the field of economic connectivity. The plans are initiated by Periyar college. For PURA 65 villages were identified, of which 5 nodal villages were chosen. People in these nodal villages are trained and these will in turn train people in the remaining 60 villages.

The students of the college go to the villages to train people. This is done through the National Service Scheme (NSS).

The government of India has been requested for funds for the PURA plans of Periyar college. So far no funds have been received.

The contact with the rural population is good, students go to the villages and some students also come from the villages. They are aware of the needs of the rural population. The students of the cities are mostly not aware of the needs of the rural population. They mostly don't know the sufferings for the basic needs as water and food still present in the villages. The college believes every engineer should contribute to society and all students are therefore required to do rural development as part of the curriculum.

Regarding the gasifier Ankur and AEW (Associated Engineering Works) have been contacted for the future plans. With the own experience gained by the 4 gasifiers at the campus, Periyar is able to give training inside the campus to future operators.

The future gasifier will be build by Bharat Heavy Electrical, they took initiative and want to cooperate with the college. It is expected that the gasifier can run economically, people should feel the responsibility and inclination towards the promotion.

The requirement is minimal and the 100 kWe application is not going to electrify the total village, approxomality 400-500 houses will be provided with the power. If it will be successful, the program will be extended. One gasifier costs approximately 3.000.000 Rs. The government will provide 50% of the costs through subsidies and because it is a rural project, other funds might be available. This is however yet unknown.

Staff of Periyar college went to the IISc in Bangalore, and visited an industry using a biomass gasifier. Villages were not visited.

When the gasifier is placed, the villagers are to pay for the electricity. This will create revenue for their own village. Regarding the grid electricity, the government provides free electricity for agricultural purposes. For house electrification, villagers have to pay (+/- 75 Rs. per month per light). Grid electricity is not used during the day because people are working on the lands; only in the evening and electricity is required for light and fans. Availability is not a problem.

When the gasifier will be placed positive benefits will be an increase of knowledge in the villages with regard to the technology and the inclination towards technical education. Their own children will (due to this) be better educated. Another positive aspect is the fact that they provide their own village with electricity. Revenue and employment within the village will also be created due to the gasifier.

Well being will be improved by employability and inclination towards education.

The government should increase the subsidies for the rural biomass gasifiers. As an educational institution funds are limited for the placement of gasifiers.

In the future biomass availability will reduce because more biomass will be used for other purposes such as construction building. Biodiesel made from local crops in combination with a dual-fuel engine and biomass gasifier running on agricultural waste will solve this problem. The proposed project by Periyar however is for a 100% producer gas engine.

By the end of 2007, the gasifier will be placed, probably. Approxomality 15-.20 people will be trained for 2 to 3 months to operate the gasifier. Training will be done at the Periyar college gasifier. This will be done to insure the operation when people have other duties. A minimum of 5 people is required to operate the gasifier. In the initial stage, Periyar operators will assist the new operators in the villages.

For the operation times, different analysis were made, one is operation from 6 pm to 6 am only for housing uses. Another analysis looked at operation of 24 hours during cultivation periods (light and fan during night and water pumping during day).

The project will be financially feasible.

To create awareness in the past, Periyar college would go to the villages and explain the plans, now the level and awareness of the villagers has increased and they are approaching Periyar college with questions and plans. For the last 7 years Periyar is associated to the 5 nodal villages. Villages are motivated to compete with one another by appointing prizes for cleanest village and for best practices village. Throughout the years the villagers have started to realize that Periyar college was working for the villages and now the villagers come with their own plans for improvements. To create thrust takes time. This will take at least 1 to 2 years.

If this is not present, it will not work.

Village administrative offices will take responsibility for the gasifier. Technical and maintenance support will be given by Periyar college.

The reason of the low number of rural gasifiers are because of the industrialization, more and more barren land is used for industries. Another reason is that the remaining land is

cultivable land and these are used for food crops. Running the gasifier with powdery biomass such as grass, saw dust and rice husk is better. These biomasses are nowadays fired in open land causing pollution.

Other educational institutions have not placed gasifiers before because these mostly feel responsible for their students and not for rural development. Periyar college's founder motto was societal service. The gasifier concept within the PURA scheme is visited by people from whole of India.

If this first application is successful, more gasifiers will be placed within the villages by Periyar college. At least for the 4 remaining nodal villages.

Load management will be done by segregating into groups of houses. If the load will be too much, groups will be cut off, and will have to use the grid power. A similar is used inside the campus, blocks can be connected and disconnected to the biomass gasifier and grid power, this is determined by the load requirements.

In the villages a separate power line systems of the biomass gasifier needs to be installed; houses will be connected to both grid and biomass gasifier power.

In the survey conducted before, the number of members per house, number and sort of electrical appliances used (separated between major such as fridge and minor such as lights), minimum requirements of light, fan and grinder were investigated.

Prof. Nalini agrees that the contact between the colleges and companies in the field of rural biomass gasifiers is too little. Many have good ideas and research, but do not communicate this to others, own experiences are hidden. This is the practice in India. A network would be very useful.

Even when official requests were issued for scientific discussion with the staff of IISc, this was not allowed, they were not willing to discuss with prof. Nalini. In 2001 an international conference was conducted on energy and environment by Periyar college. Biomass gasification was one of the topics. People from IISc were also invited. Mukunda of IISc could not substantiate the questions of people from other universities.

It also proved that with the IISc gasifier costs per unit were higher than the grid unit costs. Initially Periyar College had plans to install an IISc gasifier, these plans were changed after the conference because it proved to be an unsuccessful gasifier according to prof. Nalini.

Indian politics are also involved, depending on the person in power, electricity schemes are changed, to gain votes free electricity is promised regularly.

END

Interview with Mrs. Srividhya, operator of the biomass gasifiers at Periyar College, Vallam.

Date: 26-4-2007

Periyar College has 2 downdraft open top gasifiers, one dual-fuel of 100 kWe, installed by Associated engineering works in 2001 costing 3.500.000 (paid by college) and one 200 kWe 100% producer gas engine installed by Ankur in 2004 costing 7.000.000 (50% by MNRE, 50% by college through a bank loan) using a converted Cummins engine.

The Dual-fuel engine is only used when the 200 kWe system is not used because of the diesel costs. For the 2 systems, 6 workers are hired. Work is done in 2 shifts.

Power is produced for maximum 14 hours per day at 6am to 2pm (shift 1) and 2pm to 10pm (shift 2) per day, this depends on the requirements of the campus, 10 hours is average running of the gasifier. Only during the peak hours, requirements are there for power. For the dual-fuel engine 25% diesel is required, there is 70-75% replacement. Usage is 125 kg biomass per hour. Biomass availability is difficult. During cultivation periods wood is scarcely available because the rural population do not have time to collect the biomass. In the summer, enough biomass is available (Juliflora, Eucalyptus occasionally, any solid wood can be used). The biomass is cut on site to 2-.3" size. Cutting is done on contract basis. Nearby PURA villages provide the biomass. Small-scale farmers collect it from their own barren land. During the summer and off-cultivation period this is done. The biomass will grow on it own. Eucalyptus is grown by the farmers. Juliflora grows by itself. The price differentiates between 850-.1350 Rs./ton depending on the season and availability. Juliflora is also used for furnaces and paper mills. There is competition for the biomass. The 100 kWe gasifier was placed for R&D purposes. Many criticized the purchase, from the forest size, for cutting the trees, and those who doubted whether it would be a successful project. Running for 24 hr. is possible. Less maintenance is required in that situation because the start-up and stopping of the system will cause faster blocking of the filters. R&D has been done into pellet size, type of biomass and gas flow and quality per biomass specie. Juliflora proved to be the best biomass to use, because the costs, availability and gas quality are good. If periodic maintenance is not performed reactor breakdowns will occur. Grid failures are frequent during summer periods, from march to august. 60% of the college electricity requirements are produced by renewable energy systems such as the biomass gasifiers, solar and PV systems and wind power systems. The biomass gasifiers prove to be economic, the costs of the diesel are currently high and therefore the 100 kWe system is currently not economic.

The learning process was by trial and error, experience. For major problems the suppliers are called.

Various industries have visited the gasifiers and learned from the experience. Later on industries placed gasifiers. Village panchayats also visited the college, such as Odanthurai. No subsidies were paid for the 100 kWe gasifier, the college management paid the complete installation because in 2002 subsidies were not yet there.

For the 200 kWe, 50% was paid by a MNRE subsidy. In both gasifiers, there was no cooperation with other colleges / companies (except for the gasifier producers).

For the 200 kWe system the number of breakdowns is higher compared to the 100 kWe system. The fabric and saw dust filters clog up more often. If the moisture content is too high, problems occur in the engine. This is mostly the case in the rain season because the drying of biomass is difficult. Storage of minimum 20-25 days is required. Problems were not expected, but with trial and error experience has been gained, especially in the field of filters and reactor maintenance. One time, people fainted due to carbon-monoxide formation.

With the 200 kWe system, there is an approximate 50% gain on electricity costs. Grid electricity for the colleges (special scheme for educational institutes) is 4.80 Rs. per kWh and with the 200 kWe system it is around 3.25 Rs. per kWh.

END

Interview with Abhisek Sharan, Development Manager, DESI (Decentralised Energy Systems India) power

Date: 27 March, 2007.

Location: Netpro/DESI office, Bangalore.

The DESI objective and goal is rural development through energy services, mainly through employment.

DESI made a program called employment and power partnership (in short empower partnership), and it is a program to generate employment by using energy and energy services by utilizing the local resources. Energy is the central part, of the development cycle. DESI believes that when power is there, through this power rural entrepreneurs and electricity users can benefit, and once they increase the profit, the local jobs and income level will increase. Then these can also purchase the electricity from the sector. So this is a circle: If power is there we have to create a demand for that, and that force is related to the requirement of the rural sector. The DESI program is not at all rural electrification basically, we focus more on the use of electricity for the employment and income generation of the rural population.

The DESI concept is that if villagers are there, first let's increase their salary, if their income is higher, they will be able to purchase the electricity. Then we do not need to subsidize the electricity. And let them run it. This is the concept around which DESI is working since the last 11 years. DESI are not subsidizing anything, the concept is completely different. It is running the program where a power plant is setup and load is created and this load is for the micro enterprises and energy services.

The program is bigger and not at all related to the village electrification directly. It is a complete employment creation program. One part of it is providing electricity to the villagers.

I'll give you an example, a case study which is running, so it is clear how we got this idea. We are not from the beginning stick on this idea, when we started the project 11 years back, this was not our plan. It changed and changed and now at this stage we have the kind of formula for our program, a strategy.

Our first start was in Andra Pradesh, Oocha in a village, there we setup our first plant, which is still running. First let me explain the technology used, there are a lot of rural energies available at this moment. We can talk about biogas, biomass, PV and wind. In rural setting we should talk about decentralized, because if you go for centralized, energy efficiency will go down.

So we focus on decentralized small power plants which will be efficient to cover the requirements of one village. Wind is not suitable because of the lack of wind at times; also our experience throughout the years is that one village requires at least 50 kWe capacity to sustain. Below that it will not sustain. Above that, power plant load factor will be less, because you don't have that much demand. So the DESI assessment is that you should go to nearby 50 kWe, in-between 50 to 75 kWe. That is enough to sustain and develop that village. The wind technology for these small capacities is not there. Biogas has been tried, but it didn't work, because the area where we are working is flood area, so it doesn't work that well and there is not much cattle. It differences a lot where you do

your project in India, some parts are very resourceful such as Bihar, others are not. Bihar is one of the underdeveloped states, and we are working in that. We assumed and determined that biomass is the most appropriate. If PV's come it is very costly. Biomass is the most appropriate technology for the rural areas, especially where we are working at. PV's and wind have not been tried due to the costs and low required capacity.

Biogas actually, with a technical team we investigated it at a biogas machinery producer, but they said: you need this amount of cattle, this much cow dung, so you need to develop to get the cows. So we looked at, what things are there, which technologies can you use to use the available things already there. So that is why biomass got in our mind, and at the time that we started, biomass energy was in the start-up phase. So we went to these biomass gasification plants, and we wanted to see if this technology would do well in the villages. How do you get that skilled person? How do you get the engineer? So it should be a technology which can be run by local persons, because our motto was employment. We can't take any person from Bangalore to run the plant. The whole objective would fail. We wanted a technology that is easy, reliant and can be run by the local persons. We would train them a few months, and they would be able to run. So I will explain one case study, in which a lot of questions you will have are explained.

In 1999 in Bihar we got a local partner in a village, it is a village cooperative, the village is called Beharbari (see website for more information).

DESI power is a company, we are not a NGOs or nothing like that and if we go in a village and tell them we want to setup a power plant to supply the electricity, no committee will commit, why? It is not an IT shop you are going to setup, this is the work in which the local community is involved, and without that it is not possible. Local communities have to be involved very positively. So in whole our program, the main concept is that DESI power identifies the local partners. And we work together with local partners, or any organisation which is working in the village. There are a lot of NGOs, partners can be anyone, it can be panchayat, it can be a NGO, it can be a company which is working in the village or it can be cooperatives. In Bihar we identified a village cooperative.

This cooperative was made especially for DESI power. It has 23 members, with a president, a CEO, a board of directors; all members are villagers (local farmers). They have meetings every week. They are doing excellent. The president is a retired school head master. Also small farmers without land are involved.

In rural sectors nothing is implemented for the last 60 years. There are no roads. It was very difficult to mobilize the local people due to the distrust. Local respectable people were asked to help and create trust. In 1999 the coop was made and a village survey was held, not by DESI. An influenced person was made (opinion leader) as the CEO of the coop. The survey was conducted by 3 guys from the village with house to house questions, relating to income, persons, fuel used, etc. Basic data collection. Shareholders with 10 Rs. shares were made. Villagers can buy the shares and get a saying in the coop related to the infrastructure. Just like in a company. The key persons informed the people. It is going good. The gasifier started operation in 2002. The micro-enterprises to setup were identified, energy services also in terms of the irrigation pumps. In Beharbari the

power plant is owned by DESI power, and the micro enterprises by the villagers. Operation is done by 2 young people from the village. Migration rates in Bihar are huge; no young men are in the villages. People move to the cities for work. In Bangalore 60% of the labourers are people from Bihar. The goal was to stop the migration (AIDS/social problems). Especially social issues are the goals of DESI. They received the training at IISc in Bangalore. They also helped building the gasifier so they know every aspect. The 2 trained also trained 2 more people in the village. All the technical problems can be solved by the operators. Monthly logsheets are sent to DESI about the power plant and the micro enterprises such as rice mill, wheat grinder, battery charging station, briquetting making business. Till now no households receive the BG power. Irrigation pumps power for 300 ha. of land, crop yields increased 20-25%. More sells by the farmers. Rice husk was designated as biomass fuel and a local weed (bushes). Jute is produced in Bihar and region, and the main cash crop. The biomass was asked to be produced by the locals, and a fixed price was guaranteed. The BG is fuelled for half by this fuel. Briquetting of the fuel is tested and evaluated in Bangalore. No problems were encountered. The fuel is also used in the households for cooking purposes. So prices rose due to the high demand of the biomass fuel. The farmers pay per hour for the irrigation, not for the power used, so they pay for the village.

Around 2/3 of the economics in the village stay in the village. Around 1/2 of the village irrigation water is powered by the BG (dual fuel), the rest with diesel generators. There are plans to modify the BG to a 100% producer gas system.

This is the first phase in Beharbari, a demand in the village was created. Now a market is created due to the BG. A market place is there now. A fish pond in the village is now used initiated by the coop in cooperation with DESI. A telephone line was also created, and also a fertilizer shop. After that a fellow opened a tea shop. Now 35 shops are there in the village. There is no public lighting, now there is a demand from the villagers for this, for the shops operating in the evening. Also there is a tailor / cloth shop. People saw the initiative from others, and they opened their own shop, a seed is needed for growth. An entrepreneurship bomb. Indirectly due to the DESI project tenths of people were employed in the shops etc.

Rural development takes a lot of time and commitment. A lot of ideas were received from the project. Now in the same district, 5 more projects are planned. And the 100 villages project in 4 years. If successful, this can be multiplied throughout India. Every village will get 1 gasifier. This is now done under the CDM. It is already validated by a consultant. Now in Beharbari more pumps will be installed, there is a demand for them. Also the up gradation to 100% PG. With a point of sell concept, we will give one wire to each cluster of houses, one person of this cluster will sell the electricity to the houses on point bases. DESI does not have to worry about the collection of the money. The BG is currently running without profit (no losses or profit). They are still dependent on the diesel, plant load factor is not up to the good level. A World Bank Development Market Place competition price was won out of 2500 competitors in 2006. Two million USD were received for 5 project villages. Total project costs are 7.500.000 Rs. per village. Micro enterprises and BG are paid with this by DESI. This is done by packaging through subsidies (7.500.000), and CO₂, (14% of costs) agreements have been signed and money

received (from Netherlands). Rest is equities and grants as from the World Bank. The rest will come from a commercial loan (11,2% interest rate) at ICICI bank. New funds are searched for. Currently running is Beharbari. With an AIG program from the Dutch gov. 7 projects are partly financed through the CDM program. The gasifiers are built by Netpro, but they are not fixed to the company. No technical changes are made for the rural applications.

Maintenance is done at the site by the operators. Each year the reactor etc. is cleaned by the worker, as defined by the Netpro manual. This requires a shut down of a few days.

DESI started a training centre, the problem was that trained people went away to the city, because they had knowledge. A management training centre for rural women was started (DESI_MANTRA). 10 rural women and 5 men were trained in the area of management, for the 5 villages. They are working in the office now. The training took 6 months. Training and management is the main issue. Not just place the gasifier and go away. A MOU is made with the village. Both technical and management training is provided. Management include budget, managing etc. things. The first objective is to provide skilled women power. Women are more reliable and accurate in terms of working. Men will leave for the towns.

For the BG reliability is important. The Beharbari plant is still running for the last 5 years. DESI works together with the CDM, World Bank, local partners and IISc. Projects are bundled. Benefits are not just economic but also socio-economic and environment. DESI arranges training, bank loans and the BG, but the village should run and earn the BG. Beharbari took a long time because implementing takes a long time. It was initiated by DESI power. The local coops are choosing the next villagers for the projects. DESI has not yet earned a profit. Not all benefit equally. There are no social conflicts in a large order. Contradictions etc. will always be there, once the mass is with you, problems will be solved. It is very difficult to do work in the villages. The villagers do not trust people from outside to much. Awareness takes a time and is a job.

END

