

Backcasting for sustainable dissemination of a Gasifier – SOFC – Microturbine System with cooking gas for Rural Areas

Ritah Mubbala

Postgraduate Program Renewable Energy
Institute of Physics, University of Oldenburg
Oldenburg, Germany
rmubbala@gmail.com

PV Aravind

Energy Technology Section, Faculty 3ME
Delft University of Technology
Delft, Netherlands
P.V.Aravind@tudelft.nl

Abstract—The need for Energy, both electrical & thermal is faced the world over, even in the rural areas of developing countries. Using gasifier – Solid Oxide Fuel Cell (SOFC) – Micro-turbine systems, the same amount of firewood used in traditional biomass technologies can be used to meet both cooking and electrical energy needs for villages in rural areas. This paper explores by way of a back-casting study, the activities that should take place in order for this technology to reach the peak of its technology adoption curve in 20 years. The strategic system location is in Uganda. Stakeholders such as the government, financing institutions, the private sector and the village folk, and their specific roles in achieving the future vision are identified. Higher order learning is agreed to result into stakeholder implementation of steps leading to sustainable technology dissemination in 20 years.

Keywords - Higher order learning; backcasting; Gasifier – SOFC-Microturbine system

I. INTRODUCTION

In the year 2001, Aravind et. al in [1] designed a gasifier – (SOFC) – Micro turbine (MT) system as a one stop energy supply for a rural village in typical developing country settings. Producer gas from firewood gasification is used as a fuel for an SOFC whose exhaust is used to run a micro turbine. One third of the producer gas is to be supplied to the village for direct utilisation in cooking while the other two thirds are for electricity generation. The same amount of wood used in traditional biomass can be used for the per capita cooking and electrical energy needs in a rural village, at a possible levelised cost in India of US\$0.0775 / kWh. The system advantages include; solving energy self sufficiency, avoidance of the negative health impact of in air pollution in kitchens, employment provision, creation of ground for improved / increased economic activities, introduction of an approximately CO₂ neutral technology and reduction of a country's energy import need .

In most developing countries, solid biomass makes the largest contribution to the total primary energy consumption, with up to 80% contribution in several Sub-Saharan countries in Africa. In [9], Uganda's biomass contribution to the energy mix is 93%, 79% of which is household energy for cooking and heating. Powered by Hydro electricity Uganda can barely meet the power demand which at nominal capacity serves only 5% of the households. This means that the other 95% are left without electricity [5]. There is need

therefore to sustainably introduce the gasifier-SOFC-MT system in the rural areas of these countries. This paper explores by way of back-casting experiments, the steps to be taken to sustainably introduce this technology in rural areas of developing countries.

II. METHODOLOGY

A back-casting experiment is a study initiated to explore, discuss, and elaborate possible and desirable future solutions for a persistent, complex and ambiguous (sustainability) problem. Such a study brings about societal learning, even higher order learning, which like in [2] is necessary to foster technological systems transitions. Back-casting experiments can thus be applied to ensure that a technology reaches a desired point in the technology lifecycle in spite of the barriers.

The main aspects about a back-casting study are [2,5,6]:

- It involves looking back from the future – the opposite of forecasting
- It is participatory – it involves active participation of stakeholders
- It is applied in solving persistent complex and / or ambiguous problems such as sustainability issues
- It is used to bring about higher order learning among stakeholders; it is an increase in knowledge that results in new decisions and taking action accordingly.

The back-casting methods that were applied include: strategic problem orientation where a suitable physical location is identified, envisioning where a normative future vision is developed, and back-casting analysis where, viewing from the envisioned future, the steps to be taken to arrive at this desired future are identified [2,5]. A Bounded Social Technical Experiment, BSTE, was designed for the next step in the back-casting experiments.

A. Strategic System Location

Uganda was fore - chosen as a case study country and the choice of the specific technology location for the back-casting study was chosen basing on the following factors:

- Accessibility
- Availability of wood (primary energy source)
- No / difficult grid connection
- Evidence of economic activity in the area

B. Envisioning and Backcasting

The relevant stakeholder groups for the back-casting study in Uganda were identified as:

1. Government
2. Beneficiaries (Village folk)
3. Private sector
4. Financing Institutions
5. Education, Research & Development – R&D
6. Community workers (NGOs, C.B.O s, local leaders etc)
7. Development partners
8. Politicians
9. Civil society
10. Media & Press

Specific key persons were identified from the groups; they were visited individually for the interactive information gathering process. They were given a brief introduction to the technology and its economic aspects with relevance to Uganda as reflected in tables I & II. More details on the system design can be found in the full thesis report. This information was presented together with guiding questions for the discussions on envisioning and back casting of the technology. The key questions for the discussions were;

- What does the technology’s ideal market situation look like in a future, about twenty years from its introduction?
- By looking back from this future, what are the steps taken along the way by all stakeholders to ensure we get there from the present?

TABLE I. SYSTEM SIZING FOR BUJIMBA VILLAGE

System sizing			
Component	Production	size	Units
Fuel cell	77.64	100	kW
Micro turbine	31.51	35	kW
Gasifier	79	80	Kg/hr
System efficiency	51.91		%

TABLE II. ECONOMIC CONSIDERATIONS FOR BUJIMBA VILLAGE

Economic considerations	
Costs	US \$
Total Installation Costs	252,560
Total running costs / year	30,479.9
Total income / year	297,949.1
Net Present Value	8,199,280.0
Levelised cost per kg (gas)	0.0710
Levelised cost per kWh (power)	0.0994

III. STRATEGIC SYSTEM LOCATION

The identified suitable system location in Uganda is in the outskirts of Kalangala town in Bujimba village, Bugala Island - Lake Victoria. It lies between Longitudes: 32° 0' and 32° 30' east of the Greenwich and Latitudes 0° 13' and 0° 32' south of the equator in South east Uganda. For accessibility to the mainland, the Island is visited by a ferry and ship 4 times a day. The largest land cover is forest; it was 60% in 2002. The population density is 84.9 people per square kilometre. The economic activities on this island are tourism, fishing, lumbering, commercial plantations and on a smaller scale, growing of sugar cane and pineapples.

The energy situation is such that each family uses 9.5 - 10kg of wood each day, which is 1.9 – 2 kg per capita per day [3]. The source of power for the Island is a 240KVA diesel generator which runs for 3 hours and is limited to the town [4]. The government’s energy policy is to support community schemes that use biomass technologies such as gasification [9]. The government is to provide subsidies and incentives for Renewable Energy – RE technologies; however this is yet to be clarified and enforced.

IV. ENVISIONING

In figure 1, the results of the participatory discussions with various stakeholders on the future vision are shown. Only the top 9 mentions appear in the chart.

A. The developed future Vision

In the year 2029 the gasifier - SOFC - MT technology has reached the peak of its adoption curve. There exists a network of stakeholders from all people groups coordinated by the government. Their major role is to keep monitoring the technology and to keep looking out for, as well as performing their roles in fostering the continued adoption of this technology.

All learning channels in the entire nation have been made open, available, and affordable. Several information dissemination pathways including trainings, seminars, workshops, interviews, word of mouth, are often used to pass on the relevant information to the targeted people groups. As a result, there is wide spread and sufficient knowledge on the system among all people groups.

The financial institutions have over the years since 2009 developed user friendly and profitable financing mechanisms. These have been made widely available in the country such that they are within easy reach by the people that need them. As a result the customers especially from the private sector have increased their use of the various credit packages from these institutions. As a contribution to sustainable energy & environmental protection, these institutions have set up special terms for such Renewable Energy projects making the access to finances much easier than with other projects. These projects are handled by the private sector under government support through the Public Private Partnership. The government’s RE policy has been activated along the years since 2009 and is now fully operational allowing for benefits for such RE projects.

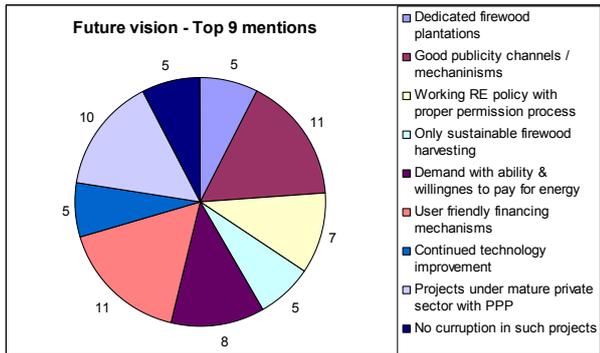


Figure 1: Aspects describing the future vision.

One such incentive is the tax on the equipment being levied in a way that allows for profitability. The permission process for RE projects has been made clear and simple along the years.

In all villages where these systems have been installed as well as those identified as potential beneficiaries, the energy demand is from all consumer sectors; domestic, industrial as well as service. The ability & willingness to pay has been addressed along the years through enhancement of the economic activities in these villages such that the beneficiaries now earn enough to be able to pay for these energy services. The village industries have been equipped with improved technology and their products and services are well marketed ensuring improved productivity and market availability.

There is sustainable well planned Firewood harvesting for energy from the available resources. Especially for such systems, dedicated plantations have been set up such that in no way will they have a negative environmental impact.

Due to ongoing Research and Development on the system and on the individual components both locally and internationally, the system has improved immensely in terms of cost, robustness, ease of operation and handling. Research and academia especially on the local scene is now relevant to the needs of the market and industry. As a result, the relationship between these bodies has improved as they are working on several projects together and are benefiting each other. This has also resulted in a big pool of trained technicians to run these projects thus availing the necessary manpower.

The politicians are well informed about this technology and its benefits and they support it through relevant lobbying in parliament. It's mainly supported due to its positive impact on the environment which the politicians have learnt to look out for over the years.

Government support for such technology is still strong especially in terms of continued trainings and good publicity. Government still carries out monitoring and whenever there is need for intervention, they come in to help. The village houses are well planned and as such gas distribution is through a well laid out gas piping system. Uganda has already established itself in the carbon credits trade and all such RE projects are benefiting from CDM trade.

V. BACKCASTING

In order to reach the envisioned future, the stakeholders came up with roles that would have to be played by each stakeholder group; one such result is shown in table III, the roles of the private sector. In the last column is the number of stakeholders that mentioned the role.

A. Back-casting

In order to reach the future vision, several stakeholders will have to play different roles with the government taking on the most important role. The government first undergoes higher order learning from the R&D group and then together they introduce the technology to the other stakeholders with demonstrations by way of pilots. The government will take a lead role in initiating and coordinating the stakeholders in the earlier years, but will not interfere in the roles of the other stakeholders especially those of the private sector. The private sector with both governments as well as R &Ds support takes on the business, with a strong and well established business enterprise being the fore runner.

The forerunner then subcontracts other private businesses as he spreads out into different parts of the country, while some of them join in the business of running these energy plants on their own accord. Government support of the private sector is to be in the form of subsidies and incentives, as well as putting in place favorable and operational policies.

TABLE III. THE ROLES TO BE PLAYED BY THE PRIVATE SECTOR AS RAISED BY THE STAKEHOLDERS.

No.	Roles	No.s
1	Learn from R&D and Government about the technology	7
2	Funding advertising / awareness campaigns, R&D on feasibility & economic viability	5
3	Running the utility	8
4	Create and keep networking with relevant stakeholders for profitability	3
5	Work with the government through the Public private partnership	17
6	Create / have a good working relationship with the beneficiaries	9
7	Work out a pre- paid mechanism for the services	5
8	Work out post paid mechanism for these services	2
9	Create a feedback mechanism from and to the beneficiaries, operate with transparency	2
10	Should devise ways of operating in case of no government contribution	1
11	Ensure good management of the Utility / have the capacity for it (O&M too)	4
12	Draw an MOU with government with clear role demarcations	2
13	Establish a good source of spare parts	2
14	Bridge the gap between academia & the private sector	4

The financing sector is to undergo higher order learning on financing such RE projects with results such as new and suitable financing mechanisms, with the governments support.

The stakeholder network keeps taking part in the monitoring and follow-up of the technology along the way to the future vision.

The following aspects are to be taken into account in the strategy to be followed by the various stakeholders:

1. Ensuring and demonstrating that the technology works and is economically viable, mainly a role of R&D as well as government
2. Awareness creation through marketing and publicity, requires all stakeholders' participation
3. Building capacities is a role mainly of R&D, Government and development partners
4. To be addressed are regulation, permission procedures and financing, by the government, the private sector and the financial institutions
5. Dissemination of the technology should be first through a strong and well established pioneer from the private sector.
6. Ensure Monitoring from the start, a role of the government as well as Research and development

For the above strategy, the following is needed:

- Proponents - the strong network of highly involved stakeholders
- Demonstration – through piloting
- Good financing mechanisms
- Willingness of people to try it out
- Appropriate locations
- Addressed sustainable use of natural resources and gender mainstreaming

The key players in this strategy would be the government, R&D, the beneficiaries, the private sector and the Press & Media.

VI. BOUNDED SOCIAL TECHNICAL EXPERIMENT

The stakeholders pointed out that the system would need to be introduced by way of a pilot project. BSTEs under back-casting experiments are initiated as participatory pilot projects to bring about higher order learning among all stakeholders. This results in the introduction of a technology into the intended market, initiates societal acceptance and brings about market preparation for technology.

A BSTE as a pilot project was designed for this system. The details are available in the full thesis report which can be requested from the authors.

VII. CONCLUSION

For sustainable introduction of the gasifier – SOFC – Micro-turbine system in rural villages of developing countries, a desirable future vision was produced with the system reaching the peak of its adoption curve in 2029. The steps required to reach the vision were identified. After undergoing higher order learning, the various stakeholders would have to play their respective roles, to keep fostering the success of the technology. However, the technology would have to be introduced by way of a pilot project. Initiating a Bounded Social Technical Experiment (a project piloting study under back-casting) would be the next step in realizing the sustainable introduction of this technology in rural Uganda.

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REFERENCES

- [1] P. V. Aravind, J. Andreas, H. Splithoff, "Sustainable energy systems for tropical villages using a combination of gasifier, fuel cells, microturbines and cooking gas supply". Delft: Delft University of Technology, 2003.
- [2] J. P. Vergragt, S. H. Brown, "sustainable mobility: from technological innovation to societal learning". *Journal of Cleaner Production* 15 (2007) 1104e1115 Science Direct. Internet (2006): www.elsevier.com/locate/jclepro
- [3] B. Malinski, "Impact monitoring study on the Rocket Lorena stove dissemination in Bushenyi district – A study on behalf of the Ministry of Energy and Mineral Development under the GTZ / Energy Advisory Project". Kampala: GTZ – EAP, 2006.
- [4] W. Jagwe, "Kalangala Island energy solution possibilities". A GTZ – PREEEP – Rural Electrification Expert, formerly with NOPLAN. Personal communication 2008.
- [5] J. Quist, "Backcasting for a sustainable future, the impact after 10 years". Delft: Eburon Academic Publishers 2007.
- [6] R. Hoogma, R. Kemp, J. Schot, B. Truffer, "Experimenting for sustainable transport: the approach of strategic niche management". London UK: Spon Press 2002.
- [7] H. S. Brown, P. J. Vergragt, K. Green, L. Berchicci, "Learning for sustainability transition through bounded socio-technical experiments in personal mobility". *Technology Analysis and Strategic Management* 2003; 13(3):298e315.
- [8] H. S. Brown, P. J. Vergragt, K. Green, L. Berchicci, "Bounded socio-technical experiments (BSTEs): higher order learning for transitions towards sustainable mobility". In: Elzen B, Geels FW, Green K, editors. *System innovation and the transition to sustainability: theory, evidence and policy*. Cheltenham: Edward Elgar; 2004. p. 191e222.
- [9] MEMD - Ministry of Energy and Mineral Development, "Renewable Energy Policy for Uganda". Kampala: MEMD, 2007.