Biomass gasification for village electrification

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1. Introduction

Biomass gasification is a thermo-chemical process in which solid biomass is converted into a combustible gas. This gas can be used in a generator set for the production of electricity. Gasification is one of the renewable energy technologies suitable for rural electrification, as it can be applied on a small scale (from several kWe upwards), with a reasonable efficiency (typically more than 15%). On the other hand, gasifiers are sensitive to fuel quality fluctuations, and operating a gasifier requires more skills than operating a diesel engine set.

Although biomass gasification is not a new process – during the Second World War, millions of cars were fueled with wood gas – it has so far not been commercialized on a large scale. Particularly small scale gasification for electricity production has suffered from persistent technical problems related to fuel and gas quality, and very few systems have proven themselves reliable enough to be supplied under commercial conditions.

However, the Indian supplier of biomass gasification systems Ankur Scientific seems to be very successful with their downdraft fixed bed gasifier. This system, which comes in different variations for biomass like wood, rice husk or corn cobs, produces a clean gas that can be used in a diesel or gas engine. The systems are offered in a range of 5 to 850 kWe, at modest investment costs (some 1500-2000 US$/kWe in the smaller scale range). In recent years hundreds of units have been installed in South and Southeast Asia.

Figure 1: A 22 kW gasifier used for village electrification in Cambodia

This case study on gasification for rural electrification is based on information gathered during a fact-finding mission in Cambodia, November 2009. During this mission, a number of Ankur gasification systems have been visited by FACT and SME Renewable Energy Ltd., the local supplier of the units.

2. Technical description

The basis of this case study is a biomass gasification system that supplies electricity to a small isolated grid in a rural area. The selected system capacity is 50 kWe, which should be sufficient to serve several hundreds of households[1]. It operates for 12 hours per day, 350 days per year, so 4200 hours per year. The average loading rate is 25%, so the (gross) electricity production is 52,500 kWh/a. Technical losses and own consumption account for 20%, so 42,000 kWh is eventually supplied to the consumers.

The gasification system consists of several parts. First of all there is the gasifier itself (see figure 1), which is a fixed-bed downdraft system that is fueled with wood or corn cobs. The biomass and air are introduced into a hopper on top of the reactor. The biomass chunks are up to several cm in size and

[1] The maximum number of connections depends on a number of factors, such as the maximum load per household and the presence of productive (generally larger) loads. In Cambodia for example, average per-household loads in small villages are around 100 W, so that a 50 kWe system could in principle serve 500 households (not accounting for distribution losses and the power plant's own consumption).

have a maximum moisture content of 20%. They are converted to gas in the reactor, and the remaining char and ash are removed from the bottom of the gasifier and carried away with a water system.

Figure 2: Gas cleaning system

Figure 3: 30 kVA generator set (gas)

The gas that exits the gasifier needs to be cooled down and cleaned before it can be used in the gas engine. The first step is a water scrubber, which cools the gas and removes part of the tars and ash. After that, the gas is led through a number of filters that are packed with a biological filter material (e.g. sawdust or rice husk), and finally a bag filter to remove any remaining particles. The clean gas is then used in a gas engine which drives an alternator, producing electricity for the mini grid.

The biomass consumption of the system depends on the type of fuel and its characteristics. For wood and corn cobs, with a moisture content of 20%, fuel consumption is about 1.5 kg per kWh of electricity, provided that the gas is used in a gas engine. When the gasifier is running at a low load, this will be somewhat higher. Annual biomass consumption is thus nearly 80 tonnes. Wood can be collected or grown in the vicinity of the gasifier plant, as long as it is cut down to the right size and dried down to the required moisture content before use. Corn cobs can be collected from villages in the area.

Figure 4: Fuel wood chunk

Figure 5: Corn cobs

In Anlung Tamey village in Cambodia, farmers have planted some 10 hectares of Leucaena, a fast-growing species that can be cut several times per year. The wood is harvested when the stems are about 3-5 cm in diameter, and is sold to the community energy cooperative. Leuceana is an attractive crop for farmers: the tree improves soil fertility by nitrogen fixation, and apart from the additional income from the wood, the leaves can be used as animal fodder.

Figure 6: Leucaena tree

Figure 7: Cows feasting on Leucaena leaves

Operation and maintenance of the gasifier plant does require continuous attention and some technical skills. It is very important that the fuel is supplied to the gasifier regularly, and at the right specifications. The gas filter systems need to be checked regularly for saturation, and the filter bed material needs to be replaced when necessary. Char and ash need to be removed from the water system, and scrubber water needs to be refreshed every 3-4 weeks. The gas engine requires regular maintenance; the gasifier needs to be overhauled by the supplier once every few years.

Personnel requirements depend on the extent to which different activities are executed by a single person, or by different persons working part time. Presumably, the plant can be run by two full time staff, but in practice, several people may be involved part time (e.g. a technician, a plant operator, a fuel operator, and some people in the organization and administration of a cooperative).

3. Financial assessment

When assessing electricity production costs, one can broadly distinguish operational costs (fuel, personnel, and maintenance) and capital costs (depreciation and financial costs). In the table below, the results of a first-order assessment of the different cost items are listed.

Table 1: Electricity production costs using a 50 kW gasifier system

Item	Units	Unit cost (US$)	Costs (US$/a)	Costs (US$/kWh*)
Wood fuel (tonnes)	78.8	25	1,969	0.05
Personnel (fte)	2	1200	2,400	0.06
Maintenance			1,450	0.03
(% of investment cost)	2%			
Operational costs			***5,819***	***0.14***
Depreciation		72,500	7,250	0.17
(% of investment cost)	10%			
Financial costs			4,549	0.11
(interest over 10 year loan)	10%			
Capital costs			***11,799***	***0.28***
Total production costs			**17,618**	**0.42**

**per kWh sold*

Remarks:

- Wood fuel is purchased at a price of 25 US$/tonne (at 20% moisture). This price level is based on what is paid in Anlung Tamey village in Cambodia. If other biomass residues are available, such as corn cobs, the costs may be somewhat lower.

- In this analysis, personnel costs are based on two full time staff with a salary of 100 US$ per month. Although in reality more people can be employed, the monthly personnel costs correspond to those found in Cambodia.
- Average annual maintenance costs are estimated using a percentage of the investment costs.
- All hardware (gasifier and generator set) is depreciated over a period of 10 years.
- Financial costs concern interests paid over a 10 year loan covering all investment costs.
- Distribution costs have not been included in the calculations; these amount to 14 US¢/kWh (including maintenance, depreciation and financial costs).

The analysis shows production costs of about 42 US¢/kWh[2], of which two-thirds concerns capital costs (particularly depreciation). This means that production costs are most sensitive to variations in investment costs and interest rate (e.g. to scale increases and soft loans, investment support measures) and much less to operational cost items like fuel prices and personnel.

Moreover, a more extensive use of the system (higher loading rate or more operating hours) results in large cost reductions. For example, increasing the loading rate from 25% to 30% results in a cost decrease from 42 to 36 US¢/kWh. Higher loading rates can be achieved by adding (continuous) productive loads such as water pumps, cereal mills or battery chargers.

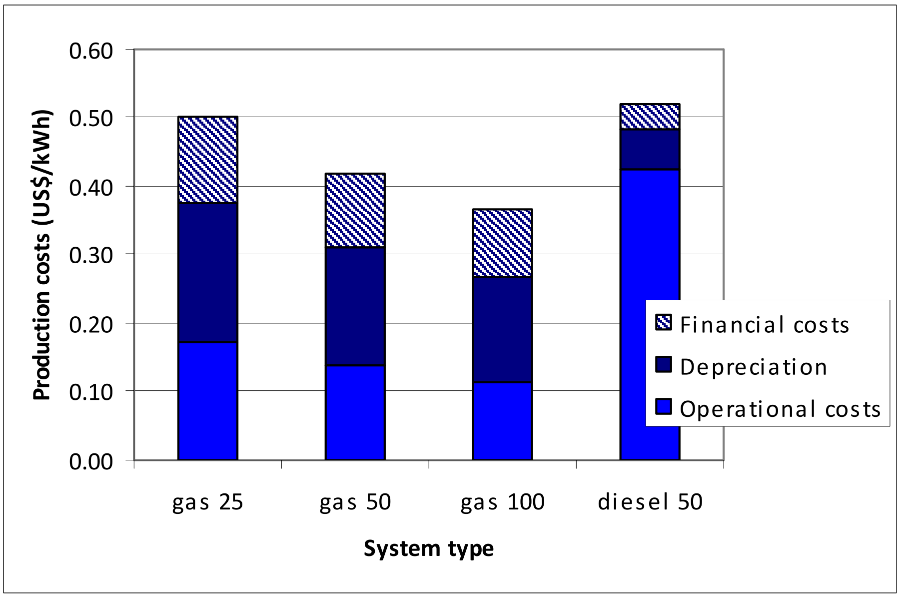

Figure 8: Electricity production costs for gasification on different scales (25, 50 and 100 kWe) and diesel (50 kWe).

Figure 8 shows a comparison of cost components of systems of different scales, and of a 50 kWe diesel powered electrification system. It shows that at the same scale, diesel generation appears substantially more expensive (52 US¢/kWh at a fuel price of 0.85 US$/l), but that in this case some 80% of the costs concerns operational costs (mainly fuel costs). Any diesel price changes will thus have a large effect on the production costs.

It also shows that production scale has a considerable effect on production costs. This is due to decreasing per-unit investment costs, and to some extent to decreasing operational costs (e.g. personnel).

[2] For comparison: the electricity tariff in Anlung Tamey village in Cambodia is about 58 US¢/kWh, at a production capacity of 35 kWe. The rate at Bat Doeng village, where a 200 kW gasifier is operated in combination with a diesel generator, is 54 US¢/kWh. These rates include distribution costs.

4. Conclusions

It can be concluded that gasification is a viable renewable energy technology that can be applied for rural electrification. Examples from Cambodia and elsewhere show that despite the organizational challenges, gasifier systems can indeed be operated in a rural village environment. In contrast to other biofuel production (e.g. certain oil crops), gasifier fuel production can offer real income opportunities for local farmers.

With respect to production costs, gasification can result in lower production costs in comparison to diesel generated electricity, and is less sensitive to variations in operational costs (e.g. fuel costs). Nevertheless, per-unit costs remain substantial so optimization is recommended, for example by:

- Looking for combinations with productive applications such as water pumping, milling, battery charging or other activities with a continuous load. This will result in better loading rates and allow production on a larger scale.
- Looking for possible investment cost reductions, for example by producing parts of the system locally.

In addition, possible benefits from the valorization of char residues should be assessed. So far, the options that are being considered are production of cooking fuel briquettes, or for agricultural soil improvement. Both require further investigation.

One important aspect that requires additional attention is that of the liquid effluents (i.e. spent scrubber water). The effects of disposing these effluents should be investigated; if needed, measures should be taken to avoid the release of any potentially harmful substances to the local environment.