Friday, 1st March 2013 // Block III // 9:00 am - 11:00 am // Room H2037, TU Berlin

Microperspective on microgasifiers for researchers and practitioners – Demand for networking

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In this session everything was about a special type of cooking stoves: the so-called "micro-gasifier". These stoves convert dry biomass to wood gas and charcoal before the gas is burned. This gasification process needs heat and the absence of oxygen. The flame which offers sufficient heat for cooking is fed by the ascending wood gas and oxygen. This simple principle is used in a variety of contexts with different aims which mostly reflect local conditions. The aim was to discuss the impact of changes in the stove-design on the performance of the stove with special focus on type of substrate in use, efficiency, emissions, handling and other unexpectable side effects. The presentation included different models of microgasifiers and substrates which were presented by the participants in the room.

Participants introduced themselves: names, background and their interests in micro-gasifiers and expectations to this session. We started with two introductive talkes that are short inputs about history, processes and low-tech aspects of micro-gasifiers to get an overview and the relevance of this topic for everybody in the room**.**

1) Joachim Betzl*: *What are micro-gasifiers? // Short story about the history of micro-gasification*

As **descendants of the steam-engines**, microgasifiers went through different stages with changing names, models and usage. Gasifiers of smaller size and weight conquered individuals lives trough **mobility, cooking and agriculture**. Woodgas drove millions of vehicles equipped with Imbert-generators during the 1930s and 40s in Europe. After propagation trough international cooperation since the 80s many households in Africa nowadays use microgasifiers as efficient cooking-stoves. Charcoal is a product of pyrolysis and stabilizes a highly fertile soil called Terra preta – an anthropogenic product rediscovered and reconstructed in recent years. Terra preta combines by-products of micro-gasifiers with recycling processes which form the basis of an ecological and social sustainable economy.

* KompostKreis (Link: http://www.kompostkreis.blogspot.de)

2) Ariane Krause: *What is micro-gasification? // About the process and products*

The **challenge**:

- Elimination of unacceptable emissions of CO and particles and pre-dominant use of firewood;
- Realize low-cost and user-friendly cookstoves to provide household-energy;
- Use wood and other dry biomass materials efficiently: with micro-gasifiers biomass is used with little emissions only to produce heat but at the same time also some charcoal is produced in little amounts.

Technical and **chemical processes**:

- Differences of *woodgas* as a product of a heat-related process and the use of dry biomass and *biogas* as a product from biochemical digestion of wet biomass.
- *“Gasifiers” are devices in which the dry biomass is transformed into combustible gases on processes distinctly and controllably separate in time and location from the eventual combustion of the gases.*

- Comparison of the processes: they happen one after the other or simultaneously when biomass is burnt directly or gasified first.
- Explanation of the stove's design in relation with the processes; what is happening in which part of the oven according to the design of Paal Wendelbo and Paul Anderson called TLUD standing for “Top-Lit UpDraft”
- There are two zones: (1) gasification of fire wood where pyrolysis happens (*Pyrolysis is a thermo-chemical decomposition of organic material at elevated temperatures without the participation of oxygen)* and (2) combustion of woodgas; there are primary and secondary airflow respectively. As for the gasificiation a little amount of oxygen is needed and for the combustion sufficient oxygen needs to be on spot, the secondary airflow is bigger than the primary airflow.

Characteristics of the products:

- Emissions of Carbon Monoxide (CO) and Particulate Matter (PM) from micro-gasifiers are comparatively low to other cookingstoves
- With micro-gasification also a valuable by-product is produced: approx. 10% of the carbon that was contained in the biomass will be thermally stabilized and bounded in little amounts of charcoal that remain in the stove. There are stove-designs that also use the charcoal produced for thermal purposes and thus burn it. Another approach would be to use the charcoal as so-called “biochar” which means to add the charcoal to compost pits or directly to the soil to improve soil quality after the principles of “Terra Preta”

This presentation included slides of Christa Roth (FOODandFUEL consultant) and Paul S. Anderson (Ph.D. Biomass Energy Consultant) with their agreement from different sources (see literature list and downloads)* * in cooperation with GIZ-HERA, Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Programme for Poverty oriented basic energy services

Follow-up discussion:

1, How large can you build the model with that simple structure?

- No scientific answer is known to the speakers, but the largest personally observed one is in operation at ATB, *Leibniz Institute of Agricultural Engineering in Potsdam-Barnim* and has the size of an oil barrel. The model works well. The advantage of micro-gasifiers is that they are easy to build only with resources that are available on spot to be used for constructing. So the size may depend on the available materials also.

- There is also thermo-chemical process named “gasification” which is realized mostly in swirling beds and ment for larger scale implementations. Experiments at TU Berlin are done e.g. at the chair for *Energy Process Engineering and Conversion Technologies for Renewable Energies* (FG EVUR). But here we focus on decentralized and small-scale realization of gasificiation in micro-gasifiers.

- There is also a minimum size as well so that the volume of substrate should be at least 300 ml. Otherwise heat losses at the stove's surface are too big compared to the produced heat inside and the stove will not run properly.

2, What are health implications?

- There are certain improvements in the new design: the CO level falls extremely, also for the PM (clean emissions, few smoke)

3, How can we prevent the users from inhaling carbon monoxide?

- Design: Make sure to have sufficient secondary air

4, Have you compared the effectiveness and efficiency of biogas, wood gas and LPG?
- We personally not yet. But there is research done to compare the efficiency of biogas, wood gas and maybe also LPG. For example the *Centre for Research in Energy and Energy Conservation* (CREEC) at the College of Engineering, Design, Art and Technology (CEDAT) at Makerere University, Kampala, is working on that. It is also our plan to set up a closer cooperation between TU Berlin (esp. Postgraduate program "Microenergy Systems") in CREEC to continue to work on this in the future.
- We started with water boiling tests to compare the demand of resource needed with a particular cooking method to boil a certain amount of water (and thus offer a specific amount of thermal energy to use) to see how much wood we would have used with open fire in comparison with the improved cooking method. We also want to compare this to "rocket stoves" which uses charcoal. But then we also have to account the process of making charcoal from wood first. There will be a more information about this in another presentation later.

5, How old is the TLUD system?
- It was first invented in the 1980s, but the first commercial use started in 2000 (so it is a quite new technology)

6, Could the design be improved by using a fan?
- There are two designs possible concerning the air flow: a forced air flow using fans or natural air flow only using the differences in temperature and thus in density of the air. Today we only show self-made lowtech designs with natural air flow. We decided for this because we wanted to be independent from electricity. You could easily use nearly empty batteries to operate a fan to have an improved forced airflow, but the problems come when the batteries are empty and there is no place to dispose or recycle them safely. We also plan to work on the design of lowtech bellows to make the natural draft micro-gasifier more convenient in use, esp. at the starting time.

We continued with three presentation of practical examples and gained interesting insights inro practitioners' perspectives on micro-gasifiers as well as in the work of students at TU Berlin.

1) Adelard Ndibalema and Andrea Berten*: Low tech-micro-gasifiers as a solution for deforestation and health problems caused by indoor air pollution (Practitioner)*

Tanzania faces a series of serious problems related to the heavy usage of fuel woods and charcoal in cooking, such as deforestation (especially in rural areas like Karagwe), health issues caused by indoor air pollution and great time consumption for its collection. "Micro-gasifiers" use organic wastes as fuel and have the potential to decrease the usage of fuel woods as well as the emissions, thus representing a possible solution for all these problems. This presentation described the development of a new type of micro-gasifier, a combination of TLUD and sawdust stove using sawdust (or in future coffee shells) and the testing methods which are being applied to prove the efficiency and the health improvements. This project is a cooperation project of Engineers Without Borders Germany/Berlin and CHEMA, an organization in Tanzania/Karagwe.

Follow-up discussion:
1, In Tanzania, people living in urban areas prefer to use firewood, but people living in rural areas prefer to use charcoal. What are the differences between these two materials?

- Firewood and charcoal: they are different. Usually it is more common that people in the rural areas use firewood while people in urban areas prefer charcoal because firewood is mostly not available in bigger amounts in the cities. Also people in rural areas prefer to use charcoal for cooking. But many people have to collect firewood instead of using charcoal because on the one hand charcoal is expensive (the price of charcoal is higher than fire wood) and on the other hand it is not available anymore (due to law it is now forbidden to make charcoal in Tanzania for environmental reasons). In rural areas people also use grasses to cook if there is no charcoal or firewood available. There is also a big fall in using fire wood when switching to biogas or using micro-gasifiers.

2, What are the best approaches to collect coffee husks?

- There are two coffee factories in Karagwe and behind the factory buildings themselves there are mountains of coffee husks. Usually farmers bring the coffee beans to the factory but don't take back the husks after drying process. We are currently working to find the ways to use coffee husks to apply in micro-gasifier technology to use them for cooking.
- The technology in using coffee husks for energetic purposes may also have the disadvantage to make people stay away from using them as materials in agricultural practices. Some people use the husks as a fertilizer or add them to the compost. So we have to be careful of creating (no) competition. It seems to be crucial anyway that the remaining charcoal and also the ashes will be removed to the soil and be used for fertilizing.
- Also the problem of transportation needs to be faced. So the potentials to use of coffee husks for cooking will depend on the distance of e.g. A village to the coffee factory to get the husks available at the houses.

3, Could you please compare different kinds of wood relating to their potential use with micro-gasification?

- We have not tried to compare different kinds of woods, but there are sources in literature which compare the efficiency of different kinds of wood. In Tanzania, it was not possible to compare different types of woods, but when we conduct more research in Berlin, we will be able to do this. However, literature also shows that different kind of wood does not affect strongly the result of the performance of the stove.

4, Does the amount of moisture influence the performance or the efficiency of the stove? Did you test it?

- Yes, the amount of moisture influences a lot the efficiency of the stove because more energy is needed to evaporate the water. It is considered in our calculations but we had difficulties to test the moisture content of the sawdust used in Tanzania (because of missing instruments and infrastructure) that is why we estimated it. We will run more scientific tests in Berlin considering the actual amount of moisture.

2) Fabian Schmid: Experimental Analysis of the thermo-chemical conversion processes of a modified sawdust-microgasifier stove (Bachelorthesis)

This work wants to increase the transparency of the thermo-chemical processes in a modified sawdust-microgasifier. The temperature distribution in the fixed bed and the gas composition of the combustion gas are measured and should illustrate more details about the different processes. Connected to this there can be a theoretical optimization of the stove design.

Defining the used biomass

- Sawdust out of beech, walnut and pine wood

- Sorting of the particle size – three different kind of particle size distribution shall demonstrate the influence of the particle size on the behaviour of the stove.

Temperature distribution

- The temperatures are measured with 8 thermocouples (typ K) at three different levels inside of the fixed bed. Hence the radial and axial distribution can be studied.
- The highest temperatures (~1000°C), which are attributed to exothermic combustion reactions, are measured at the bottom of the air column.
- These reactions provide the heat for endothermic gasification, pyrolysis and drying processes, which occur inside of the fixed bed.
- The "pyrolysis front" (300°C) reaches after 40min the middle and after 90min the edge of the fixed bed.
- There is a different heating-up rate of the fixed bed at the different levels, therefore the "pyrolysis front" has an axial and a radial progress.

Gas composition

- Each run, three gas samples at different levels with specific temperatures are recorded from inside of the fixed bed. The temperatures are in a range of 200-600°C.
- The average combustible gas composition consists of 55-60% carbon dioxide, 20-25% carbon monoxide, 7-10% hydrogen, 6-9% methane.
- Gas samples near the riser at the top of the stove point out a low content of carbon monoxide.

First conclusions

- Not every particle size is usable.
- The big particle size distribution (>3,5mm) isn't suitable for this stove design, because the fixed bed collapses after 20-30min. Due to the low density and big hollows inside the bed, it needs to be stabilize with a kind of grate for usage in this stove design.
- There is a different temperature distribution between the small particle size (<3,5mm) and the mix particle size distribution as a mixture of both sizes.
- Furthermore the heating-up rate differs with different particle sizes.
- Different thermo-chemical conversion phases take place in the sawdust stove:
  Drying – Pyrolysis – Gasification – Combustion.
- There is sufficient heat for char gasification, but nevertheless a bit of char always remains as leftover.
- A low content of carbon monoxide in the exhaust gas can be expect out of gas samples, but has to be proved during a continuous measuring during a complete stove run.

Follow-up discussion:

1, Stove system - how to control the sawdust stove?

- Basically a stove can be controlled e.g. by adjusting the airflow. There is no possibility to adjust this at the sawdust at the moment; but you can close the surface and all holes to stop oxygen (primary and secondary airflow) getting inside and thus to stop the process running.

2, Have you tried using fans?

- No, because we want to be independent from electricity and the question of recycling of batteries.
- Maybe it does make sense to test the difference in efficiency by using a mechanical fan.

3, With this design, do you have problem with possible burns to people surrounding: the temperature is really hot outside the stove, do people get hurt?

- Due to the design with two layers, the outer part always remains much cooler then inside and remains handable.

4, What are the implication for Tanzania?
- Open a workshop so that more people will have knowledge and experience to build and use the stoves. The dimension, design and other information will be published (as creative commons) so that people are informed. Also we want to be part of a development&production network for micro-gasifiers. Also Paul Anderson shared all the information about his stoves, e.g. Mwoto stove, to spread the idea of micro-gasifiers.
The technology of micro-gasifiers is quite new. A lot of the knowledge sharing is based on creative commons and thus community-based. Commercialization only started recently within the last 10 or 15 years.

3) Malte Dik: *The concept of "Swirl Flow"(Student and lowtech-engineer)*

The creation of rotational flow is a common technique in combustion engineering to enhance the mixing of fuel and air and stabilize the flame. Micro-Gasifiers utilizing this technique are equally easy to build and possibly offer a more stable flame under a wider range of conditions. This talk explained the physics of fluid dynamics and how the design of the stoves affects the air flow, mixing and stability of the flame.

Follow-up discussion:
1, What are possible other side-effects?
- The rotational air flow of the secondary air cools the outer tin, so it is even safer to handle than in other stove designs.

2, How much research has been done on this topic?
- Until now, only a few proof of concept stoves have been built, but they look promising and further research is due.

Site-event
hosted by Joachim Betzl, Malte Dik, Ariane Krause

During lunch break we also invited to a little siteevent. We operated different types of micro-gasifiers such as different stoves in different sizes following the "Top-Lit Up-Draft"-Design (TLUD) built out of old cans and a modified sawdust stove built in Tanzania. Many interested people came to join our demonstration and the discussions were ongoing for more than 2 hours.

Unfortunately other people whose papers had been accepted could not come to the conference to present their results personally. Nevertheless we also want to give a short insight into their work by adding their papers to this session's summary.

1) Rajnish Jain and Adhiraji Vable: *Village-Level Pine Needle Gasification to Meet Rural Electrical and Cooking Energy Needs in the Indian Central Himalayas*

2) Raphael Iddphonce, John P. John, Masoud Kamoleka: *The Effect of Using Biomass Gasification as Source of Energy to Small Scale Bio-Ethanol Production*