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Report on German Practice in Small and Medium-scale Thermochemical Gasification of Biomass for Combined Heat and Power regarding Health, Safety and Environment

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Executive Summary

The authors having briefed mainly developers, manufacturers and sellers of biomass gasification plants (BGPs) for combined heat and power generation (CHP) in Germany and other German speaking countries on the work done in the Gasification Guide (GG) during this project. They discussed the results with them, gathered their expertise, needs and know-how and transferred them continuously to the GG-Project team.

This report is a result of one GG workshop (29-01-2009, Stuttgart, during CEP Conference and Exhibition) as part of the subcontract, organized as international expert meeting targeted mainly to German speaking countries, of three brainstormings (since February 2008, one every six months, the last from 14 to 15 August 2009 in Berlin) dedicated to subjects of health, security and environment (HSE) issues with manufacturers and last, but not least, invited papers at the 2nd and 3rd International Conference on Biomass Gasification 2008 (Berlin) and 2009 (Stuttgart). Topics of GG have played a role at almost all 12 meetings of the national task group of FEE "Gasification of Biomass" since 2007.

Doing this, already rather realistic expertise could be involved into this report with regard to Germany, as far as plants with a overall thermal capacity of < 1 MW are concerned. The authors could rely on the know-how of more than 10 manufacturers, almost all of them having delivered more than one plant to their clients since 2004 (in total more than 75 plants) as well as more than 15 further operators of prototypes. Medium scaled BGPs with a capacity of > 1 MW are being built or engineered, only currently.

To summarize conclusively, expectations to a very first GG were already much more differentiated as originally expected. The guide is urgently needed, most of all for plants that do not fall under the regulations of the immission protection acts and ordinances. Any regulation in this capacity scale should be specified for manufacturers and the growing number of operators.

It is an important issue to define application of BGPs exacter to their physical-chemical fundamental properties in order to exclude in future the still usual practice to draw conclusions on HSE-issues solely by similarities to other technologies and plants.

To increase safety of BGPs, much more efforts should be made for augmenting understanding and domination of the reactions. Furthermore, components for improving safety should be developed, tailored to the special features of these plants. To protect health of developers, operators and neighbours as soon as possible solutions have to be found to fulfil emission limits for benzene, not only in the exhaust gases of the CHP-plants but also in the air of the workshops, and in the surroundings of working places.

To guarantee environment protection, as a principle, developers, manufacturers and sellers of plants < 1 MW energy equivalent in the gasification gas (that in Germany do not need a legal permit for operation), nevertheless, should orientate themselves to the Federal Emission Act and its ordinances.

The Gasification Guide is a start document on the way to more safe and environmentally approved BGPs. The technological diversity and the expertise gathered from numerous realised plants urge for continuation.

The authors express their gratitude and respect to the developers, manufacturers and operators that contributed with their knowledge in open discussions, to the participants of the task group “Gasification of Biomass”, namely Mr. Gerhard Schmoeckel of the Bavarian Environment Agency for his valuable help and the colleagues of the GG team for the confidence for subcontracting and steady exchange of points of view.

1 Role in the Gasification Guide-Project

Fördergesellschaft Erneuerbare Energien e.V. (FEE; Society for the Promotion of Renewable Energy) with its federal task group “Gasification of Biomass” has been subcontractor of the Technical University of Vienna in this project. Being a network of scientists, developers, manufacturers and sellers of biomass gasification plants (BGPs) its basic responsibility was to integrate German speaking professionals of practice. In close contacts to them it was expected to collect best practical experiences on solving problems in health, safety and environment (HSE).

Closely related with the renaissance of biomass gasification technology since 2004, FEE was engaged already to due consideration of aspects of HSE. The work on these partial subjects consisted mainly in

- hints to the specific challenges and pointing to chances to solve them
- elaborating step by step joint positions in clarifying modalities of permitting procedures and
- putting together researchers, engineering companies and authorities aiming at jointly advancing to solutions for HSE-issues.

FEE was able to build on the development of small and medium-sized gasification plants from the state-of-the-art of the beginning of the earlier nineties that have never come to a complete standstill since the beginning of the 90ties in Germany. FEE informed mainly German manufacturers on results of systematic Austrian efforts concerning fundamentals of HSE-issues in BGPs [4]. From the very moment of being integrated into the Project all activities of FEE with regard to HSE-issues were put into relation to Gasification Guide [2, 3], as

- a first basic workshop on fundamentals of HSE targeted to manufacturers and developers of BGP at Technical University Dresden in Pirna at February 15, 2008 [5]
- the immediate involvement of German speaking experts, mainly manufacturers himself, into the professional discussions on the drafts of the Gasification Guideline, as at 08 – 09 August 2008 with Stadtwerke Rosenheim [6]
- special activities to contribute to surmount basic challenges as limiting benzene emissions (see chapter 6), among them the 5th manufacturers’ meeting at 14 – 15 August 2009 in Berlin

To the last two workshops FEE invited also partners from the Gasification Guide project and experts from permitting authorities.

It would be a presumptuous exaggeration intending to present “German Best Practice” (as originally wanted in the draft of the Project). It simply does not yet exist. The process of its formation is still ongoing and is running rather contradictory. Even manufacturers who had contributed much more in Germany than their competitors in this field are not yet free of setbacks and continue their efforts to find solutions in HSE-related aspects, too.

Just this process of finding best suitable solutions is characterised by pros and cons. Hence this paper is mainly a summary of ideas, recommendations and proposals aimed at supporting the final version of the draft deliverable 10 Gasification Guide and should serve as an updated basis for continuing the discussion in Germany, hopefully in Europe also. This report is focused to HSE-issues regarded as being important in developing BGPs, realising projects and introducing plants into the market².

- 1 2004 were put into force the first amendment of the Act on Granting Priority to Renewable Energy sources with improved conditions for the use of biomass [1]
- 2 The discussions should lead among others to conclusions being directed mainly to manufacturers.

2 Development of biomass gasification plants in Germany

This chapter treats only the development of biomass gasification plants (BGPs) of < 5 MW_{th}, the applied thermal capacity dealt with in the Project Gasification Guide.

During Project time of Gasification Guide important progress in the development and in building of BGPs was made in Germany. As of January 2009, more than 75 plants were in operation with clients.

This development was caused almost completely by the special basic and additional remunerations paid for electricity generated from renewable energy sources (RES) according to the Act on Granting Priority to Renewable Energy Sources (in German: Gesetz für den Vorrang erneuerbarer Energien, short: Erneuerbare Energien Gesetz, officially abbreviated: EEG). A further impulse came from the efforts of owners of biomass to save expenditures for heating oil by utilising BGPs. It became gradually a yet weak trend to use such plants mainly for supplying heat and to generate electrical power only additionally.

In almost all cases, main initiators were always mini and small, in rare cases only medium enterprises.

Except a few plants duplicated at one site, almost all BGPs were put into operation for decentralized combined heat and power (CHP) of a capacity of ≤ 1 MW_{th}. Plants with a larger capacity are still in preparation¹.

These larger plants, also the biomass gasification combined cycle plant with 4.5 MW_{el} and 6.4 MW_{th} at Senden (Baden-Württemberg) or the prototype of the Blauer Turm® (Blue Tower) with 13 MW_{th} at Herten (North Rhine-Westphalia), will be outside the capacity limits of the Project.

At kick-off of the project the pioneers of renaissance of biomass gasification technology

were passing a difficult period. Some of them, being active at that time, had to withdraw themselves from the market or to change the enterprises. But the development never stopped as shown in figure 1.

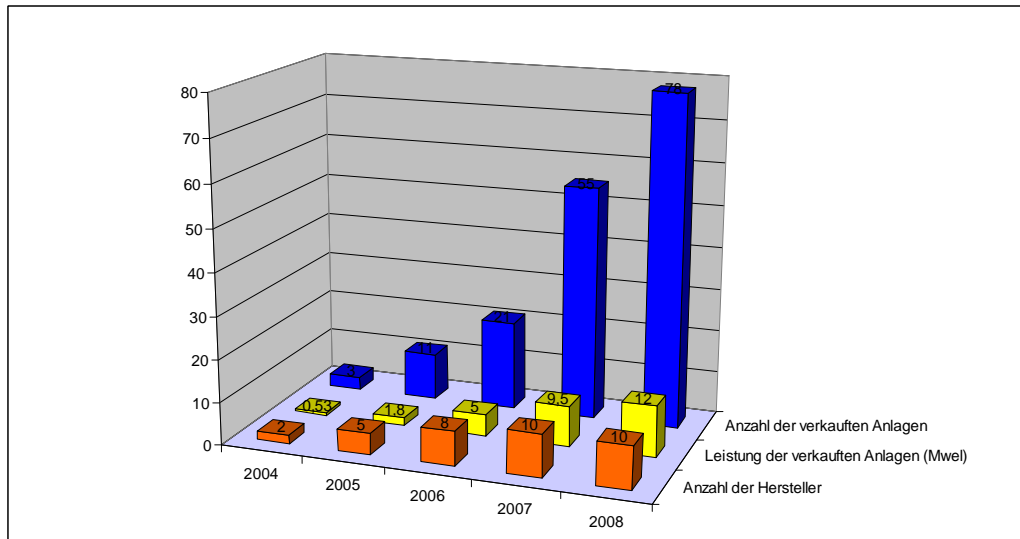


Figure 1 Development of biomass gasification plants for CHP. Source: FEE (12/2008)

By the end of 2008 / beginning 2009 the situation was dominated by following companies offering BGPs in Germany. See table 1:

Table 1. Selection of companies, offering BGP for CHP and dominating the state-of-the-art

	Developer, manufacturer, seller of BGP for CHP (Source of FEE for information) State-of -the-art 12/2008	Range of capacity		Installed electrical power
		Capacity of the module from [kWel]	to [kWel]	Plants built [kWel]
1	Gräbner (Jun.) Behälter- und Apparatebau Holzgasanlagen	10	30	>200
2	B. Joos and partners / licensees, as Sesolution / Baumann / Spanner Re ² GmbH	15	40	>300
3	Qalovis Farmer Automatic Energy GmbH	20		20
4	Schmidt Ingenieurdienstleistungen	30		30
5	Drebe GmbH	40	60	>400
6	ENTEC Corp. & Co. POWER SYSTEMS KG	90		1260
7	Bioenergy systems GmbH	120	220	>1000
8	Kuntschar Energieerzeugung GmbH & Co KG	125	150	>1250
9	(ANKUR-Systems of) Reg-energy GmbH and SCULTURA Engineering & Consulting GmbH as well as plants directly imported form India	250		>750
10	Mothermik GmbH	250		5000
11	Biomass Energiesysteme GmbH & Co. KG and partners	270		1080
12	Bisea GmbH and investor	400		400
Total				>11.500
Increase in capacity compared to 2008				about 2.250

Some of the plants still should achieve the intended nominal power. In several cases they have also to prove yet the availability promised to the clients..

At the end of most projects there are successes but occur also new problems. as dissatisfactions, standstills, but also new bankruptcies. But there is almost no BGP

that had been given up for ever. Even some prototypes, not included into the table, have already reached several hundred hours in operation. At last, some operators became developers by themselves and are advancing to permanent operation.

In comparison to the time when the Gasification Guide Project was drafted, the current situation in Germany is no more characterised by test plants and during recent years even not by demonstration plants but is distinguished by plants in stabilizing development and operation. Some plants exist which already achieved between 3,000 to 7,000 operational hours.

A characteristic feature is almost all plants were privately or by credits financed, almost no plant received federal subsidies in recent years.

Hence it might be concluded, a developing practice is ongoing, characterized by improvement of functionality and taking into account more and more aspects of HSE, too.

The situation in HSE is characterized as follows [3]:

- Many operators and even some manufacturers and sellers do not realize the recognized dangers for human beings that might be caused by carbon monoxide (CO).
- On the contrary, needs for explosion protection are taken serious, at least by the manufactures, but this does not mean they treat it already in every case professionally. Insecurity prevails mainly in defining zones of explosion protection. Frequently, they invest already in countermeasures without having excluded all possibilities for the occurrence of hazardous atmospheres.
- However, protection of skin and respiratory organs against contacts with solid and liquid residues is often underestimated. In many cases up to now ashes are regarded as harmless for human beings and environment and the reactivity of carbon rich residues is underestimated.
- Operators neglect hazards from spores of fungi adhering to wood dust. In rare cases only, they bear breathing masks (f.i. one-way masks) while handling wood chips or working in closed stores.
- Most operators do not know their own specific responsibility that can not be passed to the manufacturer. This applies already to the preparation of the working site. The necessity for instruction and action is acute.

The basic challenge of HSE-issue consists in the multitude of ordinances and regulations on this topic, taking into account that in most cases these subjects are treated to the best knowledge and belief. Strictly spoken, considering HSE-issue duely needs investing into special knowledge, what often is avoided.

Moreover, the personal and financial efforts equal almost each other, notwithstanding the capacity of the plant. It is far more difficult to charge the higher costs to small BPGs.

The current situation prevailing in Germany underlines how urgently a practicable Gasification Guide is still needed, despite or just for the first experiences in HSE-issues collected in operation of BPGs.

1 Since 2008 the 45 MW_{th} plant built by CHOREN Industries GmbH has been put in operation at Freiberg, Saxony. It has been the very single BPG, so far, not dedicated to CHP but for producing synthetic gas. The plant is not included into this paper not only for its thermal and fuel power but of course for its far higher needs to HSE-issues and for the range considered in the Gasification Guide, too.

3 Changes with regard to target groups [9]

During the project time following changes with regard to the most important target groups for the Gasification Guide were necessary:

Developers and holders of technologies, manufacturers and traders

They always have regarded Health, Safety and Environment (HSE)n-needs as part of their work, but in very different dimensions. For the leading persons neither capacity nor complexity of their biomass gasification plants (BGP) were decisive for their attitude to HSE but much more the previous professional path they had chosen before dedicating themselves to thermal gasification. Dependent on their origin from

- energy plant construction or process engineering,
- CHP-branch,
- general reactor or machine manufacturing,
- applied science,

or whether they built their BGP by themselves or became as an operator final developer very different know-how and discipline to observe the regulations could be met. But this differentiation is only true in principle. As at the moment of still very different level of technological development, also technically highly skilled individuals might be encountered presenting simple and useful solutions without having ever been plant manufactures by profession.

Even well established enterprises have to work continuously to comply to important HSE-demands. Elaborating the Guide up to now caused already several developers and manufacturers to keep on working on these issues more systematically.

In practice, manufacturers have to accumulate higher knowledge as demanded in the Guide and adopt it. This applies already to a part of them. For them, f.i. chapter 5 regarding observations on potential sources of hazards delivers no more than hints. Some of them dominate protective technology already better than it has been formulated in the Guide, so far. Others just started the process of systematically elaborating HSE-needs. However, for both of them the abundance of regulations to be observed stays unclear.

The Gasification Guide should keep both groups in mind and help to find juridical reliable paths through the numerous regulations concerning or touching HSE.

Project consultants, planning engineers and intermediaries

In Germany, they almost do not exist in this special field of thermal biomass gasification. In most cases manufacturers or future operators (individually or with partners) deliver the necessary services.

Reasons for this consist in the features of biomass gasification technology and the fear of the manufacturers to give away special know-how. Therefore, mostly

manufacturers are the only ones to provide permitting engineering with regard to the technological part. Moreover, external planners need a lot of time to get acquainted to the special conditions of the various technologies of biomass gasification. On the other hand, they might find out faster than others the still existing technical and economical risks and liabilities linked to them. However, the balance of efforts, remuneration and chances to get follow-up orders has been for them still ineffective. Integrating planning engineers would improve perspectives of success for realizing BGPs

essential. Completing many systems by operators as frequently done to bring down the costs has been proved without any doubt as an obstacle and risk factor.

For planning engineers the Guide might serve as a manual, but one that should go beyond a basic guideline.

Permitting authorities and experts

In Germany, professionals are responsible for the permitting process for BGPs with > 1 MW energy equivalent of the gas before inlet of the engine. They have to assert immission protection legislation. They are familiar with different emitting technologies and they have to follow their instructions how to treat BGPs (for details see chapter 7). But now and for the foreseeable time being, the majority of BGPs in development and operation in Germany have a capacity of < 1 MW energy equivalent of the gas before inlet of the engine.

Currently, the construction experts in the municipalities are the responsible authorities for giving permits for their operation. For these specialists BGPs are “plants of technical appliances of buildings”. In rare cases only, these experts are qualified on thermal gasification. Mostly, they are building engineers and have to prepare and take their decisions by involving other specialists (say for technical security, keeping air clean, protection of lakes and rivers, ground water and soil). In exceptional cases only, they may count on partners of offices of the Federal Länder (administrative units constituting the Federal Republic) for consultations.

Therefore, the know-how to elaborate permits on applications has to be established yet.

Repetition for reuse might have been excluded, so far. It is common practise that most authorities take care for their own certainty by external evaluations. This is time consuming and expensive. Time and costs were mostly not planned for. Even evaluating experts frequently are not familiar with biomass gasification technologies. It leads to additional measuring and testing and once again rising costs.

Applicants for permits (still as a rule the manufacturers) should establish confidence with the authorities, contact and inform them as early as possible.

Hence, the Gasification Guide might become for manufacturers and permitting authorities a valuable supporting tool. As long as a vast variety of biomass gasification technologies exist the Gasification Guide should propose fundamentals and less details as possible to facilitate understanding between authorities and applicants / manufacturers.

Potential applicants, investors, operators

Up to now, they form the largest individual group in Germany, busy in the field of thermal biomass gasification which collects information and is dedicated to the matter in such a manner that some of them became buyers, operators, even developers by themselves. At this stage, problems of HSE play a decisive role, only rarely.

But it is a matter of fact that several operators can already rely on some thousands of operational hours. Some of them accumulated more expertise as several

manufacturers, exempting mainly those who are integrated directly into the operational companies. This applies to HSE-issues, too. Additionally, the amount of operators grows who became developers even without any or with only loose links to the original manufacturers. Most of them limit themselves to mature their own plant. But there are efforts to recognise to build new plants. The exchange of experiences with operators gains more and more sense given to surmount individual hurdles and to keep attention to juridical disputes with the sellers.

The final version of the Gasification Guide should consider that at one side even experts might learn from operators and despite of this at the other side especially with operators high backlog demand concerning HSE-needs exists.

4 Terms concerning biomass gasification plants (BGPs)

Most of the guidelines and instructions were adopted when development of BGPs was hardly expected. But step by step these plants are becoming reality. To establish relations to the effective framework of rules in Germany mainly similarities with existing other technologies and plants are used which are mentioned in these legislative instructions. These “bridges” and interpretations apply to almost all Health, Safety and Environment (HSE)-subjects on BGPs currently. Their handling getting increasingly more complicated.

Up to now, in the renaissance period of thermochemical gasification of biomass the term “wood gasification” was established in the German technical language usage, for most language users. They mean *expressis verbis* gas cleaning and a prime-mover-generator unit as well as the appliances for the transport of electrical energy and heat. The draft of the Guide follows this line, too. It emphasizes biomass instead of wood but implicates also mainly the gas utilisation by engines.

The technological component gasification never exists in practice alone. It is always embedded into process chains. Regarded as a black box the gasification reactor depends on the input side from kind and quality of the biomass (see beneath: “gasification fuel”) and on the output from the purpose to the use the generated gas (see beneath: “gasification gas”). These well-known relations should lead to consequences in the generally accepted use of uniform terms.

Derived from the daily practice and confirmed by elaborating projects it seems to be justified to regard biomass gasification in future also in the governmental regulations. Again, simplifications are en vogue in common language terms like “wood gasification” and “wood gas”.

Operators have dealt up to now mainly utilised wood in plants and its gas. But wood is ONE technological variant in order to generate products on the base of biomass by gasification based on heat. What the input is concerned, first plants use further lignocellulosic biomass like residues from composting or landscaping. Gasification of digestates (residues from digestion) is tested. Plants for gasification of straw are being developed. On the side of prime movers the first turbine driven by gasification gas is being put into operation, alike counter-current gasification plus stirling engine. First combinations of biomass gasification and fuels cells are ongoing. Concepts to produce Bio-synthetic natural gas (SNG) gain more and more attention.

It is proposed, thus, to discuss within the Gasification Guide Project group and the branch to use uniform terms, such us

- “thermochemical biomass gasification” (short: biomass gasification, BG or th/ch BG) meaning the complete technological process from diverse biomass input into the reactor to the cleaned “gasification gas” output for different gas applications,
- “thermochemical biomass gasification plant” (short: biomass gasification plant, BGP or th/ch BGP) meaning the whole technical plant from feeder to gas outlet,
- “thermochemical biomass gasification combined heat and power plant” (short: biomass gasification combined heat and power plant, BGP for CHP) meaning the BG for the purpose of producing gasification gas for the purpose of generating electrical power and heat by different prime movers as engines, Stirling engines, micro-turbines, fuel cells (and in some cases convert the heat into cold).

This fundamental basis would make it easy to be expanded similarly to further applications “thermochemical biomass gasification for different utilisation of the gasification gas” as BioSNG for feeding into the natural gas grid or its use as automotive fuel or synthetic gas for biofuels or as basic compound for chemical applications, thus creating a comprehensive and logical structure of terms and meanings, including the above mentioned term “gasification fuel” meaning all possible biomass dedicated to th/ch BG (different types of wood, like natural wood, industrial or other waste wood, energy wood from the forests, wood from landscaping, short rotation forest, agrowood, other lignocellulosic plants, as industrial biowaste, municipal solid waste) that might be gasified.

This proposal seems to be logical and to a necessary manner distinctive as gasification gas hardly in its first steps of creation is a “pyrolysis gas”, chemically by far nearer to “town gas” from hard coal or lignite or “generator gas” (a mainly in German used synonym) or “water gas”[10], but in no way a biogas (this term should be restricted to fermentative gases produced by digestion processes of micro-organisms).

This would be also in line with the proposal of Prof. em. Dr.-Ing. Erhard Klose, member of the Scientific Board of FEE, to introduce the collective term “gasification gas” summarising all types of gases of BG like “synthetic gas”, “producer gas” or “raw gas”, of course combined with characterising the different gas components, if needed. This is in no way a linguistic problem only, it may contribute to equal technological understanding in the industrial and authoritative branches, notwithstanding the country or language and make the permitting process easier to define. It may even help to surmount obstacles if f.i. for the definition of emission limits it becomes necessary to fix links with regard to BGP and HSE. Moreover, contradictive discussions between producers of CHP and feeding-in power to the electrical grid and the owners and operators of these grids might be avoided for recognition of the biomass gasification and its just remuneration. These gas compounds might be defined more exactly with regard to their HSE needs as now by benchmarking them to “biogas” or “water gas” as often done. In Germany only, between 2004 and 2007 many permitting processes were bound to time consuming finding and general recognition of terms and meanings. Since then, there has been accepted a compromise (see chapter 7).

This chapter wants to start a discussion on the subject and find commonly accepted solutions.

5 Safety

Discussions of safety issues of gasification frequently are limited very specifically to challenges of explosion protection. This chapter deals beyond that with principal problems of safety, basically as a unity of safety for technical plants and for life and limb of the employees at biomass gasification plants (BGPs) and the neighbours living nearby.

5.1 Special features of BGPs with regard to controlling general and acute hazards

Supply of oxidizable gas compounds that are inflammable is likewise aim and subject of thermochemical biomass gasification (th/ch BG). But gasification gas is under certain conditions also explosive and at least one component of the compound (CO) is human toxic, accompanying dust even extends the hazards. Essential differences to other thermal conversion technologies consist in its reactions dominated by kinetics and the property that balances might not be established slowly but go on locally very differentiated by transporting processes of solids and flow of gases. Reactions are to be controlled by vessels, management of the flow of matters, human knowledge and actions, in most cases by automatic control.

Physico-thermal control of the reactions as an inherently safe process is a basic precondition of safety of BGPs. This is a truism but with the manner to solve it many of HSE-challenges start and end.

History of wood gasification of the 1940s had shown it is principally possible to operate these plants safely. This is proved currently also by most of the operators of BGPs for combined heat and power (CHP) generation (of wood gasification of the second generation) day after day. To state clearly, BGPs are in no way potentially unsafe plants but in comparison to wood chip fired boilers or natural gas fired CHP-plants operation of BGPs is more complicated and takes more pains to be realised and operated safely. Finally, the achieved state-of-the-art with regard to safety might be evaluated as achievable but not yet optimised. The ten plants that having caught fire during the Gasification Guide Project time might be taken as an alarming proof.

It is well known that special attention has to be put to starting-up and shutting-down processes in most of the autothermal BGPs that have been put into operation so far. Foremost, the phase of conversion from oxidation to reduction and the supply of necessary reaction heat by combustion for the actual gasification has to be controlled.

How to realise it step by step at divers BGPs is not common knowledge to be studied in books, but constitutes special know-how of developers and manufacturers. Notwithstanding, citing a paper of Dr. Dietmar Bendix [11] special attention has to be drawn to passing of one of the most critical phases, taking a phased gasification process as an example:

“The readiness to intake inflammable gas has to be controlled before **crossing from the oxidizing to reducing atmosphere**¹. That means in case of using an injection engine, starting-up the engine, reaching the point of operation parallel to the grid and achieving a point of capacity that adding the gas flow (...) from the reactor should not causing large fluctuations. Utilizing gas engines² the torch has to be put into operation. By reducing process air, switching to the ignition engine or to the torch will become easier. After having reached again the process air mass flow before switching over to the used process air mass flow, fuel input or fuel dynamics should

slowly be increased. Because of the unbalanced scarcity of oxygen availability, the residual oxygen content is slowing down to zero, CO-content of the gas is growing and the reactor temperature is decreasing. Parallel to the increased material input the mass flow of process air should be risen to a degree that the temperature in the high temperature zone is augmented slightly until the normative temperature is reached. If necessary, the gas engine will be started as soon as the normative point for CO is reached, and the torch will be turned off. In the quasi-stationary state engine power is regulated by fuel dosage, the temperature by addition of air and the internal pressure by induced-draught.“

In practice results of those and similar follow-up steps have already been implemented in different plants. They usually run smoothly, but always in interaction between a well defined gasifier and a specific engine. Presumably, these considerations are late for the first 75 installed plants. However, because of so many instabilities all those concepts already realised should be checked again and again and step by step with the present experiences, starting with the thermochemical and thermophysical basic processes. All efforts to improve (plant-) safety should start with the basics and consider the in the meantime continuously improved HSE-aspects and -tools. Developers, who so far have tried to solve many problems by themselves, are advised to check their processes jointly with their colleagues by profession. Best choice for the technology owners would be to scrutinise their plant down- and back-stream jointly with a chemical / process engineer, mechanical engineer, measuring and controlling expert as well as a safety specialist. As several companies might encounter difficulties realising it, FEE offers itself as a mediator.

- 1 It is assumed, that dependent on the different construction of the gasifiers suitable pre-heating of parts of the plant and a safe bringing up of gasification fuel to combustion (oxidation zone) up to the desired „gasification“ temperature was realized before.
- 2 Subject to no other solution specifically for the plant for starting the engine (without gasification gas) and for environmentally friendly combustion of the gas still unsuitable for the engine is available.

5.2 Legal aspects

Gasification Guide exposes under point „3 legal frames of the biomass gasification“ generally applicable guidelines, which are published in Europe and which are valid for HSE and, hence, to relevant safety issues for biomass gasification plants (BGPs). It is pointed out, that consequently the manufacturers have to find on their own responsibility the path through the abundance of guidelines to meet the appropriate requirements certainly. References to EU-guidelines are given in the following table:

Directives: Number, Range	Examples for Application (with reference to BGPs)
73/23/EEG: Low voltage [2006/95/EG]	Electrical equipment, drives, automatic controls and controllers, generators
89/336/EEG: Electromagnetic compatibility [2004/108/EG]	electrical installations, internal combustion engines, drives, blowers, turbochargers, controlling units, controllers
98/37/EG: Machines [2006/42/EG]	drives, pumps, blowers, moved mechanical parts, gas engines, fuel supply systems, ash removal systems
94/9/EG: Devices and protective systems used in hazardous areas (ATEX directive)	Blowers, measuring instruments, flame lockers
97/23/EG: Pressure equipment	Heat exchangers / boilers, compressed air system
2000/14/EG: Noise emissions for outdoor equipment	Conveyor belts
Council directive 98/24/EG of 7 April 1998 for the protection from risks of health and safety of workers from the risks related to chemical agents at work Council directive 85/374/EEG of 25. July 1985 to the adjustments of laws, regulations and administrative instructions of Member States about the liability for defective products (German), official journal no. L 210 from the 07/08/1985 p. 0029 - 0033	when dealing with tars, aerosols

Tab. 5.1: European directives, which can be applied on BGPs or parts of such a plant (additions to table 3.1 of the draft of Gasification Guide [7])

Aspects of liability for products are related to these rules and are to be considered. They are regulated in application of European directives to Germany by the Act on Liability for Defective Products – Product Liability Law (ProdHaftG) in the version from the 15th of December 1989 (BGBl. I 1989 p. 2198; in 1993 p. 512, 2436; in 1994 p. 2658, 3082, 3117; in 2000 p. 1487; 19.7.2002 p. 2674 02).

For developers, manufacturers and suppliers of BGPs it is in general indisputable, that they can introduce their products onto the market, if „... the safety and health of the user or third parties, (...) are not endangered with its intended use or predictable misuse.“ This excerpt (from § 4 (2)) is cited from the Act on Safety of Technical Equipment and Consumer Products (Geräte- und Produktsicherheitsgesetz - GPSG) [12], which regulates the „marketing (...) of products“, including also marketing of BGPs.

The question is, which requirements from which regulations are related to BGPs, have to be considered and solved in order to being documented and demonstrated by the CE-mark declaration of conformity, that the facility was constructed in accordance with applicable guidelines and shall be operated safely .

5.3 Proposal for methodology

In difference to actors in technical adjacent crafts, for example from gas- and heating technology or steam boiler technology, manufacturers of BGPs can not rely on specific rules and regulations [e.g. 13].

They are obliged to hand over to their clients in every imaginable aspect safe plants. Otherwise they have to determine the degree of freedom and combined with it, having the trouble to derive their obligations from the abundance of directives, guidelines and regulations in order to check which of them might be applied to their plant or its components. Meanwhile, several German manufacturers and suppliers have taken the pains of this expensive and not very clear process, not surprisingly they abstain from publishing their experiences gained.

An approved suitable proposal was made by the engineering company TOC, Berlin, by Dipl.-Ing. Thomas Otto. He bases all safety related issues on the Machine directive 2006/42/EG¹ [14] and its German equivalent [15]. The guideline is indeed more focused on products in the mechanical and thermal engineering, but it compels in correspondence with its appendix I „Basic health and safety requirements for design and construction of machines" to quite a systematic iterative risk evaluation and decrease of risks. Moreover, the Machine guideline defines every installation containing moving parts as a "machine". This is an aspect to be adopted obviously on a complete BGP system. Transforming all headlines of the content of the guideline² into lines and all "life phases" or process stages of the plants into columns leads to a matrix, which is better than the frequently postulated checklists for providing an overview over all related aspects. In this manner fire and explosions hazards are taken into account and the other areas mentioned in Table 5.1 (low voltage, electromagnetic compatibility, etc.) are integrated. Even if some experts disagree to mandatory treating of BGPs as "machines" but prefer alternatively to regard the as „process plants“, they share the opinion in their assessment that treating safety issues based on the principles of machinery directive, the tools and the standards developed for this purpose is comprehensive, practical and effective.

This handling would also provide a good basis for the use of the in the Gasification Guide project compiled "software tools" [16]. It should be considered in a second check for further risk assessment of the tool and the guide.

- 1 One of the six basic EU guidelines to be applied for on biomass gasification, summarized in the table of section 5.1
- 2 Describing the type of operation with exception of chapter 1.2.3 Putting into operation and 1.2.4 Shut-down

5.4 Recommendations on components

In this chapter only aspects will be treated which are connected with safety issues. Although already several plants were being put into the market, the discussion is still ongoing about f.i.

- best solutions for fire protection equipment with fuel feeding at the top of gasifiers,

- safe construction of pressure relief of divers types of gasifiers or of complete biomass gasification systems,
- safe and equally environmentally friendly outlet of the produced gasification gas which temporarily can not be converted or instantaneously is not required any more and
- practicable back fire protections in engines,

Before kick-off of the Gasification Guide project, there was no mandate at all for clarifying such aspects. During the project, it has become quite clear, that basic work is needed, but for doing it the project was not designed for. Hence, the contradiction still prevails, that to realise the above mentioned obligations mandatory technological solutions are provided although the means for safety provisions might be deliberately chosen, as described earlier in this chapter.

This is already common rule in permitting procedures as f.i. the general requirement for installing torches, being derived from application of biogas technology.

Also the draft of the Gasification Guide contains inflexible narrow technological recommendations for the prevention of hazards.

Notwithstanding, the conviction that impulses for further clearance should be given by people concerned and should be treated in a subsequent project, the authors take themselves the freedom of giving some principal and practice related proposals and recommendations.

All safety solutions should be inherent, that

- they have to be adapted to the nature of thermochemical biomass gasification, that means, they have to meet challenges of a raw gasification gas loaded more or less with tar, aerosols, condensates and dust,
- they should be directed always primordially to the causes of hazards and consider, that although BGPs present at one hand process chains but at the other hand their components are not in any case one after another interrelated but by many interactions and back couplings linked (how above citation in point 5.1 emphasised)
- additionally, they should be based primarily on the most simple physicochemical principles and also be technically robust and easy to maintain.

Returning to the three above referred requirements it is recommended:

- while selecting components for feeding of gasification fuel to pay attention to their close gas tightness,
- in the realization of pressure relief in and at gasifiers, to prefer exhaust cross sections with wide areas and to use as counterforce either gravity of a locking body or the calculated water column,
- for controlling of gases, which are not convertible for engines or are not otherwise being used, application of torches might only be dispensable, if

there are other environmentally friendly solutions available for leading-off the gasification gas,

- for realising back fire protection at the engines, preferably the use of technological measures to regulate the flow or the installation of barriers interrelated with wet gasification gas cleaning should be checked before considering thermal or mechanical protecting devices.

It should be noted that security tasks can only be executed by safety proofed components. These have to be tested and certified by a recognized authority. In most cases, solutions known from the gas technology have to be excluded, because they were not developed by the manufacturer for the intended purpose of application for BPGs and, hence, can not be implemented for the special medium gasification gas.

5.5 Conclusions

For developers, manufacturers, suppliers and operators of BPGs the challenge remains unsolved, that only a technically safe facility might be placed in the market, but most guidelines, rules and regulations have to be determined only by the stakeholders themselves and being adapted to application to BPGs. That means, these propositions are unbinding recommendations in most cases.

Therefore, it is proposed to the manufacturers to test the usefulness of methods of both the Machine Directive and the elaborated software tool, and use the nation-wide network of FEE for exchange and evaluation of their findings and experiences.

Another proposal is aimed at elaborating "BGP-HSE-work sheets" for interested stakeholders. The work sheets could be compiled and updated by FEE for a charge. It might be started, for example, with sheet No. 1 "Overview, concerning legislations, rules, regulations, norms and standards related to BPGs".

For the final period of Gasification Guide is recommended, to define more exactly the standards for protective devices, as equipment versus backfiring (see chapter 5.2 valid as well as for the whole plant or for main safety components, instead of already proposing "technical safety components". These proposals might be treated in an extra chapter 5.3.3. "Safety components".

6 Health

This chapter treats health issues related to biomass gasification plants (BPGs) under the imperative condition that all has to be done to exclude any harm to employees (and residents in the neighbourhood) caused by any effects of plant operations, whatsoever.

6.1 Singular emissions of BPGs causing diseases

Previous chapters were focused on endeavours to avoid any accidents. Now, the letter H, standing for "health" in the abbreviation HSE will be dealt with more in detail with regard to influences from BPGs that might trigger diseases.

According to observations and discussions with experts, it is common knowledge that

- biomass dusts, because of their combination with spores,

- ashes, because of their alkaline characteristics and adhesive hydrocarbons, and also
- vapours, condensates, aerosols, tars, solid tar residues, soot from the processes of gas generation and gas conversion as well as the hydrocarbon loads of gases

might trigger diseases in case of contact with or absorption by the respiratory organs or skin.

Compared with the years 2004 and 2005, it should be recognized, that developers and manufacturers are much more aware of these facts and handle such media carefully. The already mentioned works of Lettner and Timmerer [4], problems presented by Unger [2] and constant activities of FEE have contributed to the change of attitude.

The situation is much more critical with the totality of all matters contained in exhaust gases of BGPs. For a long time, they primarily have been discussed under the aspect of slip of carbon monoxide, only, respectively interpreted as a problem of decreasing CO and nitric oxides sufficiently and simultaneously. Since 2007 the Bavarian State Office for Environment, mainly in person of Mr. Gerhard Schmoeckel [17], has drawn attention to a more differentiated view on air pollutions in the installation spaces of and in the seemingly purified exhaust gas from biomass gasification combined heat and power plants. Mainly benzene emissions have to be brought down to the limits.

The advise to the limitation of air pollution directly at the working places corresponds with several other requirements, one of them is that the plants have to be built absolutely gas-tight. As a rule, manufacturers and developers are working on complying to these requirements. But the task to limit the benzene values in exhaust gas flows of the engines now being public knowledge is not yet broadly adopted, hitherto.

6.2 Reducing benzene in the exhaust gas from biomass gasification CHP

Benzene dissolves fats and proteins and in consequence parts of the human body and its nervous system, it does cause cancer. Hence, the limits set in regulations as the German Technical Guide for Air (TA-Luft) [22] have to be observed. Because of progress in developing engine technology and measuring devices it became at last possible to measure more components of the total air pollutants that probably occur. Thus, benzene in the exhaust gas of several BGPs was detected as a hazard for preserving the health of employees and neighbourhood.

First measurements confirm most of the limits fixed by the Technical Guide for Air might be observed. Nevertheless, the rate of benzene in exhaust gas of gasification gas fired engines¹ exceeds the limits. Whereas, meanwhile measurements at other sites and different systems indicate that other or equal systems come close to the limiting value of 1mg/m. However, there are still systems with enlarged benzene emissions.

The challenge might be solved subject to finally being worked on systematically.

The benzene problem resembles to the formaldehyde challenge for the biogas branch with regard to the manner becoming public knowledge, the significance and the process from understanding to final impact to look for solutions. But in difference to biomass gasification at the time as solutions became indispensable the biogas branch disposed of its own dynamics, the attention of farmers and politicians as well as strong partners like the gas engine industry.

Whereas, the biomass gasification branch has to help itself.

The reason for formation of benzene is inherent to the process. Aromatics in form of lignin in the biomass get into the conversion process. Dependent on temperature they are split up and with changing reaction conditions might be again partially synthesized. Regarded over the complete chain of process, various benzene formation and deformation processes interact among each other. Apparently, these factors of reactions might be similar to those of tar formation and reduction. But this has to be investigated more profoundly especially what is going on inside of the engine. The concentration of benzene is shown in figure 6.1

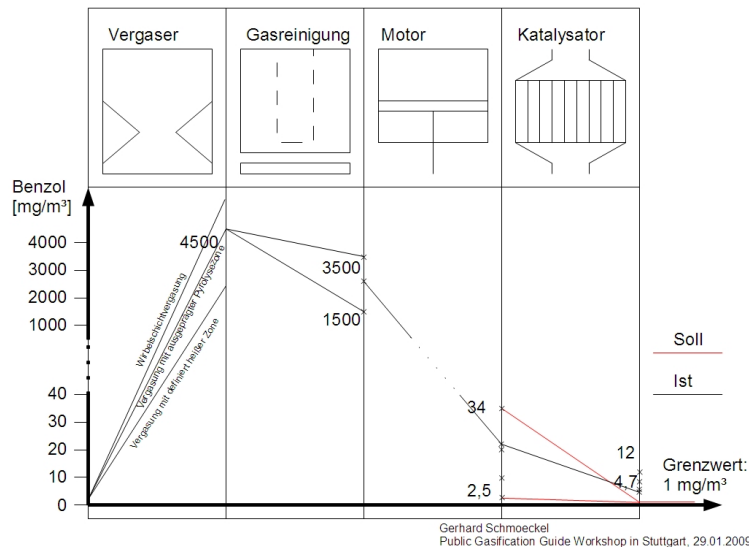


Fig. 6.1 Course of the benzene concentration in the process chain of a BGP
Source: cand. Dipl.-Ing. Christoph Hirschmeier [18, 19]

Up to now, only some clear differences are known in benzene formation during the gasification. It depends on whether the gas is generated by relatively low temperatures or in connection with defined flow through hot zones. The influence of the gas cleaning is hardly investigated. It is known in the internal combustion engine technology, that by a few changes in filling the cylinder capacity and in ignition, the benzene output can be varied. Major expectations for the reduction of benzene are anticipated in the combination of engines with oxidation catalysts.

It seems to be necessary to reconsider the limitation of benzene emissions as a part of the whole process engineering and its emissions and investigate the whole biomass gasification system.

At the same time it is also imperative

- to find a compromise in the branch about measures to be taken immediately and - based on them –
- to develop a strategy basically supported by applied science for elaborating different solutions separated into principles of gasification and gas cleaning as well as for engines.

Afterwards, the divers stakeholders of technologies should put the results into practice, from then on competing again with each other to find out best technology engineering practice.

For both phases is important to organise affordable and comparable measuring.

First steps might be:

- understanding the problems by using the thesis of Mr. Christian Hirschmeier „Emission bei der Verbrennung von aus Holz thermochemisch erzeugten Gasen im BHKW“ [working title: „Emission by combusting gases generated thermochemically from wood in a CHP plant”]
 - agreement of stakeholders on common actions
 - drafting a project proposal with various interested partners, as University of Applied Science Zittau / Görlitz and FEE who already have taken the initiative and Dr. Günter Herdin (formerly for about 15 years head of research & development of GE Jenbacher, Austria, now, CEO of agnion technologies GmbH)
- 1 Measuring potential benzene emissions with micro-turbines and stirling-engines fired by gasification gas has still to be conducted

6.3 Conclusions

It is recommended to developers, manufacturers, suppliers and operators of BGPs to follow the example of the biogas industry and solve serious and general problems jointly as an upcoming branch. Even if it seems to be possible, to draw market advantages from gaining know-how on benzene, but clarification of nature, interrelations and the complete solution of these serious problems might exceed the strength of a single enterprise.

To the Gasification Guide project group is recommended in its final phase to take up the challenge connected to limiting benzene emissions and finding solutions. The topic should be involved into in the guideline in point 6.2.

7 Environment protection

Hitherto, the considerations were mainly focused on the process inherent features of biomass gasification for combined heat and power generation (CHP) and its more direct effects on human beings. In this chapter now attention will be drawn more to environmental aspects of German state-of-the-art and first best practice as well as how society reacts by emission legislation and administrative behaviour in permitting practise on thermochemical biomass gasification to contribute protecting neighbourhood and environment from potential short- and long-term effects of harmful emissions.

7.1 Position of BGPs in relation to environment legislation

As discussed, the operation of biomass gasification plants (BGPs) is linked by different material flows with the environment. These relations are summarised and illustrated in fig. 7.1.

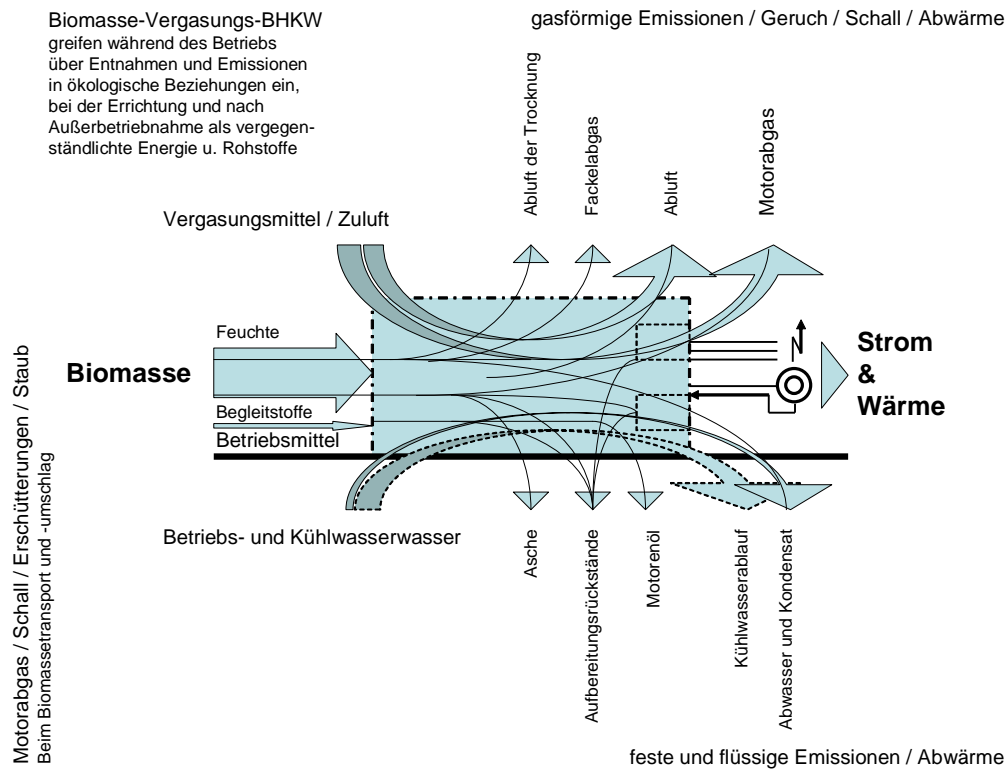


Fig. 7.1 Manifold bounds between biomass gasification CHP and environment

Analysing these interactions it is obvious without due planning, production and operation of BGP's it might not to be excluded that "the release of substances, vibrations, heat or noise into air, water or soil is caused directly or indirectly by human activities, which might harm human health or environmental quality or material property or lead to interference or disturbance of comfort and other legitimate utilisation of the environment¹." Because such interferences might be caused by BGP's, it seems reasonable to look at them from the point of view of the Directive to the Integrated Avoidance and Decrease of Environmental Pollution (IVU) [20], adopted in Germany mainly by Federal Act on Immission Protection (BImSchG) [21] and several related ordinances (e.g. 4th BImSchV). In Chapters 5 and 6 of IVU guideline, the view had already been directed to meet such effects "preferably at the source itself".

Even if the IVU directive (according to its annex I) is valid only for "firing plants" of a "total thermal capacity" of > 50 MW it is recommended to the biomass gasification branch to keep it in mind², as the directive

- urges for the main principle of overall consideration and of integrated treatment of all emissions in air, water, soil, waste in form of residues to be disposed and counteracts against the shift of problems of one material flow to another,
- enumerates (in its appendix III) important "pollutants", also produced³ by operation of BGP's that have to be encountered,
- mentions (in appendix IV) „best available technology“ which is to be considered e.g. in view of any definition of limits in all permitting procedures of

BGPs in light of the chance for the applicant to be elevated from charges considering the relation of costs to profit.

The permitting phase might be used preferably for plants in planning. Just in this phase the general and interested public might exercise concrete influence most effectively on BGPs. Many actors of the branch often consider it still as a hurdle or phase of interference. But more and more manufacturers recognise the possibility to avoid conflicts with neighbours at an early stage before main investments are done and alternations are difficult to execute.

- 1 Definition of „environmental pollutants“ as meant in the IVU-directive of 15.01.2008
- 2 Cancelling the word "coal" in point 1.4, appendix I, as it discussed currently, would also mean involving BGPs as (coal) "gasification and liquefaction installation" without defining any limiting value of capacity, without differentiating for the biomass fuel used and would put them into the range of validity of the directive
- 3 As enumerated (...) 2nd Nitrogen oxide and other nitrous compounds, 3rd carbon monoxide, 4th volatile organic compounds, (...) 12th materials and compositions transported by air with proven carcinogenic, mutagenic properties or possibly affecting reproduction

7.2 Permitting BGPs in Germany (as of 2009)

In principle, no developer, manufacturer, supplier and operator can escape the observance of measures of environmental protection in Germany. But this does not mean that it has not been tried in the self-construction sector, that might hardly be controlled and where other regulations are valid as f.i. the Machinery Directive.

Building and the commercial operation of BGPs is always connected with several legally regulated duties¹, which allow an intervention of the general public, also for environmental purposes.

A leading function occupies the Federal Act on Emission Protection (BImSchG) [21]. It serves to the purpose „to protect people, animals and plants, soil, water, atmosphere, cultural values and material commodities against harmful environmental influences and to prevent the forming of harmful environmental influences“ (citation according to §1).

The majority of the manufacturers of BGPs is aware, that damaging environmental influences without taking countermeasures might be caused by their plants and „are able according to their kind, dimension and duration to precipitate dangers, considerable disadvantages or considerable annoyances for the general public or for neighbourhood.“ (citation according to §3).

Therefore, forerunners of the branch have already orientated themselves since beginning of the 1990s to the BImSchG and the ordinances emitted for its enforcement, such as 4th BImSchV [10] and related technical instructions such as the Technical Instruction for Air [22]. Nevertheless, up to 2005 this happened mainly in individual cases. Moreover at that time, most plants were test or demonstration projects by property. That was one reason why the phase of the clarification how to apply the BImSchG on BGPs lasted till 2007.

Although, the complete legislative framework has not mentioned up to now the term “biomass gasification CHP plant”, in practise a way was developed for the consideration of these plants. The Länderausschuss für Immissionen (LAI) [Committee of Federal States for Pollution Control] called plants for the gasification of natural wood „plants for the production of generator gas or water gas from solid fuels“

(cf. No. 1.13 in the appendix of 4th BImSchV) and recommended permitting them in connection with „internal combustion engine plants“ according to No. 1.4 (ibid.) [23]. But despite of this advise BGPs could be assigned to suitable permitting procedures according to their thermal power. But by amending the 4th BImSchV from the 23.10.2007 [24], plants “for the generation of wood gas“ to generate a maximum gas amount with an energy equivalent of less than 1 MW, were again exempted from the need to be approved by legal emission control.

The following figure 7.2 illustrates the current classification of the obligation for permission of BGPs in relation to installed thermal power, energy equivalent and installed electrical power. It was elaborated by FEE and shows the state of discussion by June 2009.

It means for plants up to 5 MW_{th}, which are subject of the Gasification Guide-project, according to current legal situation only few BGPs, realised for being fired with natural wood, have to be controlled¹ or have to be permitted in Germany for their emission protection relevance by applying the permitting procedure for legal aspects of environment protection.

It has to be proved, that plants can be constructed and operated in a manner that

- „firstly, harmful environmental influences are prevented, which are avoidable according to the state-of-the-art³
- secondly, unavoidable influences on environment have be limited to a minimum according to the state-of-the-art, and
- thirdly, residues resulting from operation of the plants can be removed properly.“ (citation from §22 of the BImSchG, paragraph (1))

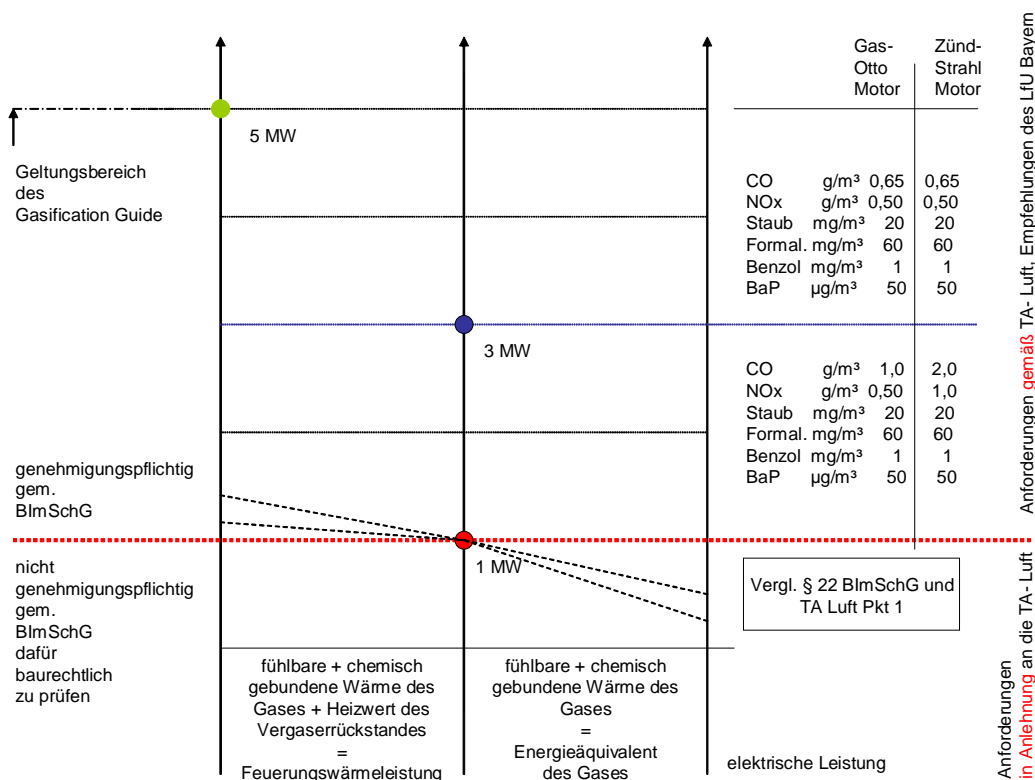


Fig. 7.2: Classification of BGPs according to permitting procedures

As already described in Chapter 3, as a rule officers of the building authorities of the districts are responsible for granting permits. Their working and decision bases are the Baugesetzbuch (BauGB) [Building Code] and the individual building regulations of each separate federal state.

They are expected to know the just emerging dynamic “state-of-the-art“ of more than 75 plants in Germany, almost all of them first of its kind, recognise best practise solutions, evaluate them for making them for the applicants as conditions. A first support is to be expected by the Federal Environment Office (UBA) for autumn 2009. It may allow an approach to the state-of-the-art by „stationary internal combustion engines“ taking into account also the use of „wood gas“[25].

Difficulties might arise if for the official permitting information exact emission limits have to be established. Simplified, frequently the officers responsible for plants that are not obliged to get a formal permit use TA-Luft as source of knowledge. But, notwithstanding, they have to enforce protection against harmful effects on environment and take care against damages⁴. But also under these circumstances a permitting practise is emerging. Experiences of the Bavarian State Office for Environment are often taken over. The Office recommends to apply for BGPs fuelled with natural wood that are not obliged to apply for permission the requirements the proposals elaborated in fig 7.2 for combustion plants of < 3 MW installed thermal power if not otherwise harmful effects on environment might be caused.

According to Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) [26] and Federal Office for Environment (UBA) [27] general legal regulations for emissions of BGPs will be elaborated soon.

- 1 As those derived f.i. from the legislation of building and trade
- 2 As there are some plants which had been classified before 2007 according to 4th BImSchV and got their permission in a simplified procedure.
- 3 With regard to more than 75 biomass gasification plants, most of them first of their kind
- 4 See chapter 6. It might be possible that for the sake of protection of human health the emission values will be taken from TA-Luft and will be established f.i. for benzene at 5 µg/m³

7.3 Conclusions

Developers, manufacturers, suppliers and operators of BGPs are well-advised for taking into their account requirements of environment protection, with the aim to accelerate the permitting processes. They should consider requirements, which are relevant for environment and

- always orientate themselves to the BImSchV and deal intensively with all requirements of TA Luft and handling of hazardous materials,
- take the often repeated advice very seriously and look for early contacts to the locally responsible permitting authority,
- present for application complete and meaningful documents, if possible, supported by measured data,
- especially in case of permitting according to the Building Code provide the

officers information based on heating and combustion technologies and explain to them the specific properties of technology of biomass gasification and of all integrated components,

- contribute proactively to ongoing definition of the „state-of-the-art“ by publication of comparable data and
- participate in establishing an organisation for joint lobbying for common interests as it had been done f.i. by the biogas branch.

To the Gasification Guide project group is recommended for the final phase:

- to recognize, that in Germany the overwhelming majority of marketed BGPs in operation have not been installed as plants that required permit according to emission protection legislation but were built according the provisions of TA Luft,
- to notice that for this reason in almost any new application again and again new emission limits might be risen by authorities and in detail different administrative rules might prevail.

That means both are unfavourable conditions that should be treated by Gasification Guide to get to clear, easy to handle and reliable uniform conditions facilitating the dissemination of biomass gasification technology.

8 Final reflections and conclusions

Thermochemical biomass gasification is an urgently needed cornerstone for a future system of covering the need for energy completely by renewable energy sources (RES). It offers the potential to generate gasification gases as a secondary energy carrier that might be converted in electrical energy, heat, refrigeration (CHPR) and as one the few existing renewable carbon carriers into numerous matters.

The total efficiency of energetic conversion is higher than in biomass combustion, the conversion rate of the energy content of original lignocellulosic biomass higher than as all other technologies that so far have been known. It is fuel flexible, might be stored, used as transportation fuel, substitute natural gas for both near and distant CHPR as well as in several industrial processes where additional to the heat the carbon content during the combustion process is needed.

Not to forget that biomass itself is becoming a valuable commodity, in some regions even first signs of scarcity are to be observed. This conclusive remark and insight look in to German reality coincide with final results of the 16th European Biomass Conference (2 –6 June 2008, Valencia, Spain) that biomass becomes a scarce commodity. All sustainable sources should be mobilized. They have to be used with clear priority criteria, in cascades and without exergetic losses and with the highest possible energetic efficiency. [28] It means, to look for plants being economically operated with the lowest throughput of biomass fuel and highest total energetic efficiency possible. This demand also in line with the reality of the low energy content of biomass in comparison to fossil primary energy or secondary carriers, consequently biomass should benefit from short logistic distances of supply.

Considering these benefits and features it should be done much more in research, development and – often neglected to the detriment of global competition - facilitating application of small and medium scale BGPs. This does not mean that in the past nothing had been done or even no financial means were spent.

How the situation might be changed and progress achieved by concentrating forces and means is shown impressively by Austria in the Güssing research, development AND production competence centre for various applications of biomass gasification, some of them very innovative.

Keeping these in most countries overwhelmingly unsatisfactory conditions in mind, it is really admirable how in recent five years the small and medium scale biomass gasification branch has advanced to more than 75 plants in operation with their customers. The first systems running up to about 6,000 hours per year. Thanks to the entrepreneurs and companies who had proved enormous dedication and readiness to bear economic risks and thanks to the favourable conditions of the German exemplary Act on Granting Priority to RES.

They and biomass gasification technology earn much more priority, legal, administrative, scientific, financial and further economic support apparently not only in Germany but in the European Union and almost all Member States. This might be done on the base of the just adopted new version of the SET program.

What HSE issues are concerned, most developers, manufacturers and operators of biomass gasification plants (BGPs) are well aware, that their plants and activities exercise a main influence on plant safety, health of the workers operating it, people living nearby and, last, but not least, on environment protection. Mostly for years, they have exposed themselves to dangers and hazards which were posed by BGPs to push the technology forward. They have a strong self-interest for finally selling safe and environmentally friendly systems and components, regardless of their legal liability. Without any exception known by FEE all German manufacturers are operating a plant by themselves or at least have been operating a system or main components for a long time.

On the other hand, growing knowledge by research, new facilities of measuring, know-how having been accumulated during development, testing, demonstration and in recent years by operating plants in the market have contributed to better understanding on possible hazards, like fires, the damage to human health originating from gases, aerosols / tars, washing waters, charcoal and ash. Despite of risen attention, it is still to be observed, that serious risks are taken.

That was one of the main reasons why FEE has organised during the Gasification Guide project, among other actions taken, six meetings with manufactures from German speaking countries, to all of them project partners had been invited. All of them had been used for the benefit of the in our view two main functions of Gasification Guide, namely, contribute to start creating uniform conditions for permitting procedures all over the European Union, within its Member States and not to forget often within these countries in their administrative entities and raise awareness and help to surmount deficiencies in HSE issues as a major obstacle, in worst case even as barrier that might block utilisation of biomass gasification despite all its advantages above mentioned.

Gasification Guide has proved itself not only as an investigator but also an mediator between different, sometimes even contradictive interests in particularly what the discussion on HSE aspects is concerned but also as a guide against encountered ignorance.

Concluding,

developers, manufacturers, suppliers and operators should organise themselves as a professional branch and take as a starting point common concern on realisation of best solutions of HSE issues in BGPs. Solving the benzene emission challenge should serve as a major and most urgent task and at the same time as adhesive for all interested parties from administration via science to industry, craft and plant operating market. Next objectives might be given priority to the common development of specific safety rules and equipment, to joint research, development and testing, including reliable, robust but inexpensive measuring devices, and most important to lobbying in public, administration and governmental bodies at all levels for justified interests of the biomass gasification community.

Taking into account the results of two special workshops, three annual international conferences for application of biomass gasification, six special meetings only with manufacturers, almost all four meetings per year of the national working group of FEE on "Gasification of Biomass" and numerous individual talks with stakeholders from ministries to industry and craft, all of them used for issues to be treated in Gasification Guide, for establishing close contacts to the stakeholders, putting main emphasis on analysing needs, preferences and achievements of partners from industry and craft for the final phase, the Gasification Guide Project team is requested:

- to decide on practical solutions for HSE well-balanced between requirements, unavoidable measures and economic and technological realism,
- to give a strong impulse to the European Commission for unified permitting procedures,
- to resist against the undifferentiated opinion that biomass gasification technology had not made any progress at all, in this relation start with a detailed description of the European or at least Gasification Guide partner countries state-of-the-art of application showing the diversity and the opportunities of biomass gasification technologies and -components and their different maturity,
- to contribute to raise better understanding for the needs of research and development but also the knowledge that both are no more than service partners in, first, international competition for industrial implementation and, second, in finding the right position and priority for application of thermochemical gasification of biomass be it from natural or waste sources in an overall strategy for energy efficiency and complete energy supply by RES.

It should be clear, this project is only the first step of a process to solve comprehensively, but without any delay HSE-issues. Gasification Guide should be further updated, kept in course with ongoing developments and further intensive contacts with the stakeholders and continued to draw attention to really existing problems, which could be disclosed only with this project and should strive for solving them in future.

As a matter of fact, since the end of the EU-ThermalNet two years ago there has been no European network for information, consulting stakeholders, finding common points of view, preparing joint research, development and dissemination projects and organising activities in favour of biomass gasification, anymore.

Gasification Guide served as a mean trying to fill this ever more sensible gap. It might be developed to a new European network.
 FEE is not only ready to participate in both important tasks but play an active role.

Abbreviations

BG	biomass gasification
BGP(s)	biomass gasification plant(s)
BImSchG	Bundes-Immissionsschutz-Gesetz [Federal Act on Immission Prevention]
BimSchV	Bundes-Immissionsschutz-Verordnung [Federal Ordinance on Immission Prevention]
CEP®	Clean Energy Power (congress and exhibition)
CHP	combined heat and power
CHPR	combined heat, power and refrigeration
CO	carbon monoxid
e.V.	eingetragener Verein [registered association]
EIE	Europe Intelligent Energy
el	electrical (installed electrical power)
EU	European Union
FEE	Fördergesellschaft Erneuerbare Energien e.V. [Society for the Promotion of Renewable Energy]
GG	Gasification Guide
HSE	Health, Safety, and Environment
jun.	junior
kW	kilowatt
MW	megawatt
RES	renewable energy sources
EEG	Erneuerbare-Energien-Gesetz [Act on RES]
SNG	synthetic natural gas
TA-Luft	Technische Anleitung Luft [technical instruction on air]
th	thermal (installed thermal capacity)
th/ch	thermochemical

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