ARTICLE

Environment and Energy in German Breweries

Gerritt Blümelhuber, Doemens Brewing and Malting Academy

The following article reviews the environment and energy situation in German breweries. First, the legal situation is described, in order to get an idea of developments in the technical area.

Legal Basics

In the 1970s and 1980s the German legislature reacted to the increasing pollution of the environment caused by industry and households and enacted laws to improve the environmental situation. Certainly, the German brewery industries were not the main environmental polluters; nevertheless, they were affected by the new legislation. The German environmental law does not only consist of a central law/act of environment, there are series of acts and continuative regulations, partially installed only for environmental protection and partially focused on other fields of law having a partial impact on environmental law. There are estimates that more than 300 legal directives of German legislation will affect directly or indirectly the environmental law. To discuss all would go beyond the scope of this article. Therefore, the article will focus on a few important laws and regulations.

The Federal Emission Control Law (Bundesimissionsschutzgesetz (BimschG)) and the Federal Emission Control Regulation (Bundesimmisionsschutzverordnungen (BimschV))
The Federal Emission Control Law is the superior law dealing with the environmental impact of industrial and private facilities. It is replenished by the so-called Federal Emission Control Regulation, which is responsible for the detailed rulings. The purpose of the BimschG is "to protect humans; animals and plants, land and water, atmosphere and cultural and other real assets against detrimental effects on the environment and prevent against new detrimental effects on the environment" (1). The Federal Emission Control Law basically regulates the requirements for operators, licensing procedures, and facilities in regard to an environmentally relevant background. Within the scope of a licensing procedure, the environmental impact on a planned factory/location will be evaluated. Here, the legislation distinguishes as follows:

Facilities exempt from approvals: An approval is not necessary, the interests of the BimschG will be considered by continuative authorities in the scope of other approval processes (e.g., building license; final inspection of a combustion plant by a chimney sweep).

Simplified approval procedure: In this connection, the appraisal is done exclusively by the responsible authorities.

Complete approval procedure: Here, it is possible for the public to comment on the project.

The 4th BimschV of the continuative Federal Emission Control Regulation is particularly relevant for breweries and malthouses as it includes the facilities for the simplified or complete approval procedure. Breweries with a daily production volume of 200 hL/day (calculated on the quarterly average) are exempted from approval. Breweries with a production volume between 200 and 3000 hL/day are approved by the simplified approval procedure. Breweries producing more than 3,000 hL/day have to pass the complete approval procedure. Malthouses with a production volume of 300 t of malt or more (calculated on the quarterly average) have to undergo the complete approval procedure. A simplified approval procedure is not intended for malthouses.

With an approval procedure according to BimschG, all operational areas will be considered in regard to environmental impacts. Accordingly, all substantial operating changes (e.g., major reconstruction or extensions) have to be reported to the appropriate authorities; under certain circumstances, a new approval is necessary. If the operator meets all the mandatory requirements, the respective authority is obliged to issue the license. In order to fulfill the requirements, all facilities with an environmental impact have to meet the state-of-the-art. Particularly relevant in malthouses are the following operational areas or facilities because of their environmental impact:

- Combustion plant
- Refrigeration plant
- Sewage system, respectively (if existing) wastewater treatment
- Brewhouse (due to odor impact of vapors)
- Bottle filling (due to noise development)
- Chemical store
- Car pool

Individual areas of the facilities are subject to other BimschV's. Listing all 38 BimschV's would exceed the limit of this article. A control of exact limitation for a defined facility does not exist in a BimschV. In those cases legal regulations, as for example technical instructions (TA) for air or noise, become effective accordingly.

"Technical Instruction Air" (TA Luft) and "Technical Instruction Noise" (TA Noise)
The technical instructions are directive acts for supervising authorities. They include exact limitation values and details for the approval procedures, as well as for the supervision and the responsibilities of the operators. The technical instructions also contain detailed instructions for measurement systems in order to verify the relevant facilities.

"Technical instruction air" regulates the limitation values for the emission of harmful substances from combustion plants, as well as from combustion engines. It also issues detailed rulings for respective trades on how to proceed with problematic emissions. Breweries and malthouses are not mentioned specifically.

The "technical instruction noise" defines the limits of noise emission within operations. These limits depend on where the operation is located. For example, the limit of noise level outside a building in industrial areas is defined as 70 dB(A), whereas the limit in mixed zones (residential buildings combined with commercial zones) is defined during the day as 60 dB but during the night only as 45 dB(A). This is relevant for traditional breweries in Germany as they are mostly located in mixed zones.

Renewable Energy Sources Act
The Renewable Energy Sources Act has been legislated by the German government in order to encourage the employment of renewable energy sources. The central statement of this law, which has extensive importance, is that the suppliers of electricity are liable to use electricity produced from renewable energy sources and to pay fixed refunds to the producer of the electricity. With the commencement of the act in 2004 different refunds for different renewable energy sources have been established, which will be reduced annually. According to the act, the amount of the buyback price has to be guaranteed for 20 years.

Table 1. Buyback price for facilities implemented in 2008

Renewable energy source	Buyback price (€/kWh)
Solar radiant energy	0.35–0.51
Biomass	0.08–0.19

Water power	0.06–0.10
Landfill, sewage, and mine gas	0.06–0.07
Geo therm	0.07–0.15
Wind power	0.05–0.08

Recently, the law incurred increasing criticism as the reinforced utilization of biomass for production of energy particularly caused many problems. The revenues of those cultivating energy crops like corn and oilseeds were higher than the revenues of aliment production, as well as for brewing barley; this resulted in a considerable decrease in areas under cultivation of brewing barley in Germany and, consequently, to a significant price increase leading to higher raw material costs for breweries. There are critical considerations pertaining to the development of renewable biomass from tropical or third world countries. For example, palm oil can be used in BHKW to produce electricity according to EEG and achieves a respective refund. Therefore, a rising demand for palm oil in Germany occurred, leading to increased cultivation of oil palms in tropical countries. The consequences are this: on the one hand, there is partial deforesting of tropical rain forest for the required acreage; on the other hand, the use of cultivated areas formerly used for alimentation of the local population. Hence, one has to challenge the ecological as well as the economical sense of the EEG. At present, these weak points are the reasons for an amendment of the EEG.

Status Quo Concerning Energy Benchmarks in German Breweries

Schu collected in 1998 specific data on the energy and water consumption of different German breweries, graded on their production volume (2). Table 2 is a summary of this comparison.

Table 2. Specific consumption of energy and water depending on size of brewery (average values) (2)

Area	Total average	Class 1	Class 2	Class 3	Class 4	Class 5
Specific heat requirement (MJ/hL)	175.5	226.2	211.3	190.7	154.5	102.5
Specific electricity consumption (kWh/hL)	14.03	18.23	15.58	14.12	12.53	10.87
Specific water consumption (hL/hL)	6.44	7.84	6.76	6.50	3.86	4.95

a Class 1: 0–20,000 hL; class 2: 20,000–50,000 hL; class 3: 50,000–100,000 hL; class 4: 100,000–500,000 hL; and class 5: >500,000 hL.

Energy consumption is divided in the average of the several departments mentioned in Tables 3–5. Attention should be paid to the fact that these are only average values, influenced to a certain extent by the brewery size and to a great extent by the degree of automation, as well as by the percentage of distribution of the production volume per bottle and barrel.

Table 3. Heat consumption in a brewery, separated by departments

Department	% of total heat consumption
Brewhouse	46
Hot water of the operating facilities	8
Bottle cellar	25
Barrel cellar	10
Administration	5
Other heat requirements	6
Total	100

Table 4. Electricity consumption in a brewery, separated by departments

Department	% of total energy consumption
Water supply	5
Boiler house	9
Refrigerating plant	30
Air supplying device	8
CO_2 facility	5
Brewhouse	8
Fermenting cellar	14
Filtration	3
Barrel cellar	3
Bottle cellar	12
Facilities	1
Administration	2
Total	100

Chart 5. Water consumption in a brewery, separated by departments

Water consumption	% of total water consumption
Raw material receipt	2
Brewhouse	30
Fermenting cellar	8
Storage cellar	8
Filtration cellar	10
Filling and cleaning of bottles	25
Filling and cleaning of barrels	10
Full goods	7
Total beer production	100

Technical Aspects of Environmental Subjects and Possibilities of Energy Savings in Breweries

Exhaust Vapor Condenser

The exhaust vapor condenser (Pfaduko) represents one of the oldest systems of energy recovery in a brewery. The vapors resulting from flavor cooking are condensed and cooled down by a heat exchanger (Pfaduko). Water is used as a coolant solution; it is heated in the process and subsequently stored in the hot water rack. It can be used either as hot water for the operating facilities or for the next suitable brewing step to heat the flavor, so that flavor temperatures up to 92 degrees can be achieved, which reduces the necessary heating energy considerably.

Thermal and Mechanical Vapor Compression

If the supplied hot water from the heat exchanger (Pfaduko) is used for operational purposes, combined with additional hot water from the flavor cooling process, this could result in an excess of hot water in a brewery. One possibility to recover flavor energy and simultaneously implement it is to compact the flavors. Thermodynamically, the process of compacting flavor works as a heat pump. The basic principle is to get the vapors of the flavor to a temperature high enough to heat the flavor pan again. In this way the energy, which was inserted into the flavor cooking can be reused directly in the next process. The increase in pressure (0.3–0.4 bars) leads to a temperature increase in the flavors to 107–110 degrees. The pressure increase can either be achieved mechanically by a compressor or thermally by using main steam, which will be mixed in the thermal vapor compressor with the vapor of the copper. The costs for the mechanical energy of the compressor have negative impacts on mechanical vapor compression. A disadvantage of thermal vapor compression is the creation of condensate, which cannot be returned to the steam cycle because of the contaminated vapor. Nevertheless, the advantages of vapor compression are significant compared to the negative impacts. The energy savings from thermal vapor compression is about 50–60% and from mechanical vapor compression is about 40–50% compared to conventional cooking systems without heat recovery. While “Pfaduko” and vapor compressions use systems that deal with heat recovery, an increased number of cooking systems with the objective to reduce the application of primary energy have entered the market over the past years. Total vaporization is playing a decisive role in this matter. Whereas the total vaporization of classical systems is usually approx. 8%, new systems can manage with 3–4% of the total vaporization. This occurs frequently with the assistance of a coating in the vaporization process, which does not necessarily accelerate the vaporization of water, but significantly supports the evaporation of unwanted flavors such as DMS. These cooking systems work partially atmospherically, but also with slight depression.

Heat Exchanger

In a brewery, heat exchangers play a considerable role in regard to energy consumption and energy saving potential. Hence, the need to maintain and verify the efficiency of the heat exchangers is mandatory. A frequently occurring problem is the relocation of heat exchange areas resulting from lime deposit or fouling. At the lime deposit process, mineral ingredients of the mediums/materials are sampled out due to high temperatures, thus causing a crust on the heat exchange areas. Within the fouling process, deposits of organic material on the heat exchangers occur. They reduce, as well as at the lime deposit process, the so-called k-value (K-Wert). This is the value that expresses the efficiency of the heat transfer at both sides of the heat exchange area, as well as the heat conduction by the material of the heat exchange area. Reducing the k-value leads to a significant deterioration of the heat transfer and consequently to a reduced efficiency of the heat exchanger. Increased energy costs for the brewery are the consequence. In order to prevent fouling and lime deposit, it is essential to clean and maintain the heat exchangers. In order to check the effectiveness of the cleaning processes, it is necessary to ensure the ability to define the efficiency of the heat exchangers. To calculate the efficiency ratio of the heat exchanger one has to know the input and output temperatures of the individual mediums, the enthalpy of evaporation and condensation, and the mass flow. The efficiency ratio should not be considered an absolute value. It serves as a measure for verification of the heat exchanger. If the efficiency is degrading over the course of time, it indicates a relocation of the heat exchange areas caused by fouling or lime deposit, which leads to the conclusion that the heat exchanger was insufficiently cleaned.

Refrigeration Plant or Cooling Device

The refrigeration plant is by far the largest electricity consuming department in a brewery. As a result, a high potential savings is expected. The heat exchangers in the refrigeration plant play a decisive role. For this reason, again, the need for maintenance and cleaning of the heat exchangers is mandatory. Next, the operating procedure has to be checked thoroughly on the actual required minimum temperature. In a lot of breweries the vaporization temperatures for operating the refrigeration plant are significantly lower than actually needed. Vaporization temperatures under –5 degrees are not necessary in most instances.

Breweries operating with lower vaporization temperatures should elevate the temperatures accordingly. It should be considered as a rough rule of thumb that a vaporization temperature increase of 1 K leads to a 3% savings in electricity. Another way of saving costs is the condenser of the cooling device. A few years ago, the dissipation und condensation heat conducted at the condenser emerged mostly unused into the atmosphere. Today, due to continued energy price increases, the implementation of heat recovery systems at cooling devices is practiced. The particular interest of Blümelhuber is the heat of the superheater at the refrigerating agent, i.e. the energy conducted at the refrigerating agent before condensing. Depending on the final pressure of compression, temperatures range between 110 and 140 degrees at this stage. This is a temperature level suitable for operating processes in breweries. The heat recovery is realized here with tube bundle heat transformers, raising the water temperature with the reverse flow. In order to reduce the power requirements, it is recommended that the facilities be operated at the optimum working point. It can be reached under full utilization and long-term operation. Therefore, the effective need of refrigeration should be considered already in the planning and installation phase.

In most of the cases, refrigeration plants are oversized. Mostly, this is caused due to higher expectations of production volumes or simply due to insufficient calculations of required cooling, resulting in enormous excess charges on the installed refrigerating capacity. As the refrigerating capacity is normally calculated based on the highest required cooling, mostly the flavor cooling, one has to consider that flavor cooling (especially in smaller breweries) is only necessary 2–3 times per day. Therefore, it is not reasonable to calculate the requirements in regard to flavor cooling. In fact, one has to consider heat accumulators, e.g., like a container filled with ice water or an ice accumulator, which can be filled up overnight, in order to be unloaded during flavor cooling and thus lowering peak power. Facilities with lower capacities can be installed accordingly; they run more effectively due to longer run times than bigger facilities running only a few hours per day.

Another point which should be mentioned is the number of refrigeration plants, especially for breweries that become bigger over the years. Quite often, each department requiring cooling, has its own cooling device. A central refrigeration plant would be preferred, as long as distances among the different departments would allow this.

Compressed-Air Supply
The compressed-air supply facility is the second largest electricity-consuming department in a brewery. But, a lot of saving potentials can be achieved here. First, it has to be guaranteed that the compressed-air supply is free from leakage. A hole with a diameter of 1 mm in a compressed air line with a net pressure of 8 bars causes a loss of compressed air and has to be compensated by approx. 0.4 kW of electrical power input at the compressor. Assuming that the compressed-air supply is out of order during the weekends, the plant runs 260 days, i.e. 6,240 h under pressure, a hole of 1 mm would require an additional 2,496 kW. Considering 0.08 US$/kWh energy price, this results in a loss of approx. US$200/year caused by just one single hole! Taking into account that no compressed air is required, a leak can be inspected by running the pressurized tank under operating pressure and the compressor switched off. If a pressure loss at the pressurized tank is monitored in the next couple of hours, this is an indication of leak(s) in the compressed-air supply. In order to locate these leaks, the operating process should be switched off, as most of them are audible. An inspection of the total grid network is necessary. It is also possible to cut off single departments from the compressed-air supply in order to monitor a pressure decline in the affected department at an installed manometer.

A further saving potential is the amount of the net pressure of a plant. Most of the time breweries operate with a too high net pressure. With respect to energy savings, kneeling of compressed-air supply is not only possible but absolutely necessary. In fact, producers of compressed-air controlled devices recommend specific working pressures, but mostly these recommendations are given by way of security. In order to identify the ideal economical net pressure, decreasing pressure should be done step by step (approx. 0.1 –0.2 bars per step). During the following week, the operating performance should be monitored. If no compressed-air related failures occur, another decrease in pressure can be considered within the following week. If errors are reported, the pressure should be increased by one step and the minimum net pressure should be obtained again. It is also important to not operate too many compressed-air loads with high net pressure at once, as this could lead to a heavy pressure decline in the compressed-air system.

Insulation
It is well known that insulation can save a lot of money. However, insulation faces a shadowy existence. Due to repairs, insulation is removed at already insulated steam pipes and is not re-installed again afterward; in addition tank insulations are not re-installed due to convenience aspects. This list could be continued. Furthermore, insulation is considered very expensive and does not depreciate accordingly. In regard to actual energy costs, this is not the case nowadays. Therefore, all areas in a brewery should be insulated if there are differences in temperature vs. ambient air of at least 20 K. Insulation is essential, particularly at steam and condenser pipelines, as well as at their corresponding fittings. Until now, the fittings especially have not been insulated. The reasons are obvious at first glance. In case a steam-isolating valve is insulated, it is not directly accessible for maintenance and repair checks. Another argument against insulation is the assumption that an insignificant loss of heat on a short part of a fitting does not pay for the

effort of insulating it. Neither argument is convincing. Operational experiences should be considered. Steam fittings especially are maintained usually only once a year (in some plants steam fittings are never maintained). Insulation is efficient even in a yearly maintenance routine; the additional effort of removing and re-installation of insulation are kept within a limit, especially by using preconverted insulation already existing in the market. There are insulations for all current fittings that area wire-fastened and, therefore, easy to install and re-install. Normally, the costs for these insulations depreciate within a period of 8–16 months. Insulation devices for buildings should be completely inspected, especially in the fermenting and storage cellars. Savings potentials up to 20% of electricity costs for the cooling device, especially in older plants, can be achieved. Taking these potential savings into account, it is clear that insulation will save a lot of money.

Aspects for the Future – Regenerative Energy Sources and Applications

Solar Heating/Cooling

At present there are some efforts to merge solar energy in breweries. In particular, modern vacuum tube collectors offer the possibility of reaching a high usable temperature level, which would be of interest for breweries. Due to the fact that most breweries have a surplus of warmth within the range of 80°C, only those collectors with temperatures above 80°C are interested. These collectors are always installed in combination with heat storage tanks to adjust the fluctuations of sun exposure and ensure a normal course of operations. Bottle-filling solar plants are of particular interest, especially for the bottle-washing machine. Another possible application is a combination of collectors with an absorption chiller, which provides cooling energy from solar heat. A disadvantage of solar thermal energy is the need for a large area for installation of collectors, especially when the total heat demand should be covered by solar energy.

A further point of critique is the cost/benefit ratio. With invest costs for installation from approx. US$800 up to 1,000, with annual proceeds between 400 and 600 kWh/m^2 (on 50° northern latitude) long amortization periods are the result at present. Nevertheless, solar thermal energy is a promising technology, especially because not only the costs for fossil fuels will continue to increase, but also the costs for collectors will decrease if there is a higher demand for them.

Photovoltaic

The situation concerning photovoltaic energy in breweries is very similar to the solar thermal energy in breweries. There is a need for large areas to install solar cells, and the costs for investing are still too high for an economical application. Because breweries normally have no ability to storage electrical energy, its only reasonable to sell electricity to the local electric utility. Only if there are guaranteed prices for selling the electricity, as there is in Germany, will this method of “energy saving” be economically arguable. In this case, the electricity is not produced for the plant but for the public network. The electricity that is used in the brewery has to be taken from the public network as well, but for a lower price than the brewery can get for its own electricity.

Biogas

Biogas plants are a meaningful extension for breweries concerned with energy production. Due to their composition sewage water from breweries is an especially good raw material for biogas plants. In an anaerobic process the organic compounds of sewage water are decomposed to methane, carbon dioxide, and further trace elements. The content of methane in biogas can reach up to 80%. With biogas it is possible to operate a steam boiler to get heat energy, but it’s also possible to operate a cogeneration unit to get heat energy as well as electricity.

Another advantage of biogas plants is that wastes like spent grain or claimed beer can be utilized for energy production. Therefore, there is a reduction in costs for sewage and waste. A major disadvantage of biogas plants is the high invest cost, which is the reason why only bigger breweries are normally able to run biogas plants in an economical way.

Heat Pumps

Heat pumps work according to the same principle as refrigerant plants. They take up heat on a low temperature level and deliver heat on a higher temperature level as usable energy. Therefore, they need electricity. But, the ratio between electricity and heat is about 1:4 up to 6, which means for each kWh of electricity you'll get 4 up to 6 kWh of heat. In breweries there are many processes that deliver heat for operating heat pumps, which is not usable for other processes in the brewery. The main problem with heat pumps at the moment is that the delivered temperature level is to low. Of course, there are a few heat pumps that are able to deliver temperature levels above 100°C, but those are expensive to invest in and not fully developed. Nevertheless, because of further development, heat pumps should be available in the next few years, because they offer a good possibility for energy recovery in breweries.

Cogeneration Units Operated with Plant Oil

Cogeneration units operated with plant oil are found more frequently in breweries. Therefore a combustion engine, which is operated with plant oil, powers a generator. The electricity that is earned in this way can be inducted to the public network or can be used in the plant. The heat that is generated in the combustion engine can also be used in the plant. All-in-all a cogeneration unit has an efficiency of more than 90%, divided into about 33% electricity and 66% heat. Another advantage of cogeneration units is the relatively low invest cost. A disadvantage is the actual fuel used, especially palm oil. The prices for palm oil have increased over the last two years, very similar to those of petroleum. Another ecological disadvantage of some plant oils is that cultivation has to take place in a tropical climate, which is one reason why many primeval forests are being cleared.

Biomass

A reasonable alternative for the classic total heat supply is heating with biomass. Renewable prime products are used for this, for example miscanthus on grate firings. The heat is used for steam production. Because the cost for renewable biomass is much lower than those of fossil fuels, the amortization period for these systems is very short. A disadvantage is the difficulties in converting combustion plants. The plant has always driven at least on minimal demand; if the plant is switched off completely, the initiation would last to long. Another disadvantage is the problem of fumes, because even small combustion plants need a dust filter to avoid too many emissions. Nevertheless, the biomass combustion plant is one of the most promising possibilities for generating energy in the brewery.

The measures mentioned above and the new "energy sources" are only a short list of possibilities. Increasing energy costs, a changed ecological awareness of the consumer are forcing breweries to a new way of thinking about energy and energy consumption. However, while renewable energies are very important, it is much more important save energy in the brewery.

References

1. Bundes-Immissionsschutzgesetz in der Fassung der Bekanntmachung vom 26. September 2002 (BGBl. I S. 3830), zuletzt geändert durch Artikel 1 des Gesetzes vom 23. Oktober 2007 (BGBl. I S. 2470).
2. Schu, G. F. et al: Betriebevergleich Energie 1998. Brauwelt Nr. 4, Hans-Carl-Verlag, 2001.
3. Hackensellner, T. Umwelttechnik für Brauereien. Firmenveröffentlichung, Unternehmensgruppe Huppmann, 2001.