

Efficient Use of Energy in the Brewhouse

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ABSTRACT

The brewhouse is the major consumer of thermal energy in a brewery. Reduction of energy usage in the brewhouse requires an integrated approach: improvement of energy efficiency, implementation of energy recovery, and, finally, development of additional energy sources. This article reviews the brewhouse process to identify possible methods of reducing energy input and recovering energy. Measures to reduce energy consumption and optimize the hot water balance can be based on equipment or changes in operation. Both possibilities are reviewed and evaluated. Most of the measures discussed are standard in newly built industrial brewhouses but can also be implemented as upgrades in existing plants. Opportunities for saving energy in specific applications should be identified and evaluated in an energy efficiency audit. A general prerequisite of any energy efficiency audit is that the implemented measures should not compromise beer quality. On the contrary, they should help improve product quality. The return on investment for a consistent energy recovery strategy cannot be measured only in monetary terms. Additional advantages resulting from efficient use of energy in the brewhouse are presented.

Keywords: alternative energy sources, brewhouse, energy efficiency

SÍNTESIS

La sala de cocimiento es el mayor consumidor de energía térmica en una cervecería. Para reducir la utilización de energía en el cocimiento hay que usar un enfoque integrado: mejoramiento de la eficiencia de utilización, implementación de la recuperación de energía y el desarrollo de fuentes alternativas de energía. Aquí se revisa el procedimiento en el cocimiento para identificar posibles métodos para reducir el consumo de energía y para recuperar energía. Las medidas para reducir el consumo de energía y optimizar el uso de agua caliente puede basarse en modificaciones del equipo o en cambios en la operación. Se evalúan ambas posibilidades. La mayoría de las medidas mencionadas son estándar en salas de cocimientos más modernos, pero pueden ser adaptados como actualizaciones en plantas existentes. Se deberían identificar y evaluar las oportunidades para ahorrar energía en aplicaciones específicas mediante una auditoría de eficiencia energética. Un requisito básico es que las medidas a implementar no comprometan la calidad de la cerveza. Lo ideal es que mejoren la calidad. El retorno sobre la inversión para una estrategia consecuente de recuperación de energía no puede medirse únicamente en términos monetarios. Se presentan ventajas adicionales al uso eficiente de energía en el cocimiento.

Palabras claves: cocimiento, eficiencia energética, fuentes alternativas de energía

Introduction

The cost of fossil fuels has increased significantly over the last 10 years worldwide and continues to spiral upward today. From 2004 to 2007 the price of fuel oil for industrial consumers in the European Union soared by approx. 35%, and the price of natural gas increased by approx. 40%. Limited fossil fuel resources, the increasing demand for energy in developing countries, speculation in the fossil energy commodities market connected with globally rising prices, and the ambition of the countries that signed the Kyoto Protocol to achieve the requested reduction in CO₂ emissions has led to the target to par-

tially substitute fossil fuels with renewable energy sources or combustion of energy-rich waste for heat generation.

In 2002, the European Commission (EC), especially the Technical Working Group (TWG) of the European Integrated Pollution Prevention and Control Bureau (EIPPCB), worked out and published best available techniques reference (BREF) documents (documents available at <http://eippcb.jrc.es/pages/FAactivities.htm>). BREF documents can be regarded as guidelines for reduced energy consumption and sustainable production technologies in European industry in general. The BREF for EU food and beverage industries was released in late 2005. For this project, the TWG of the Brewers of Europe provided extensive data regarding energy consumption in European breweries in connection with conventional plants that are often associated with high energy demands. In addition, the report also presents best available techniques (BAT) for the brewing process, with significant improvements in terms of thermal energy and electricity consumption.

The brewing process is energy intensive, especially in the brewhouse, where mashing and wort boiling are the main heat-consuming processes. The imperative to reduce energy consumption has led to the development of new processes and technical solutions that consume less energy (19). Dynamic wort boiling with an internal boiler (13) and use of the Jetstar (Huppmann GmbH, Germany) internal boiler for a simmering boil, with a submerged wort flow and stripping phase to reduce undesired volatiles, is a good example of a sustainable improvement in wort boiling combined with reduced thermal stress and increased wort quality (12).

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Another task detailed in the BREF document is the reduction and limitation of emissions and waste from the production process. This article focuses on the following topics:

- EC environmental and industrial guidelines
- Impact on breweries
- Energy-related technology in the brewhouse

International retail groups are increasingly concentrating on the carbon footprint of their food and beverage producers, and consumers are increasingly more aware and interested in the energy consumption of the products they use in their daily life (more information is available at www.tesco.com/greenerliving/ and www.walmartstores.com/sustainability/). For some global brewers, private medium-sized breweries, or even small-scale breweries, the carbon footprint is already a significant part of their business philosophy and their sustainable environmental policy.

Discussion

Beer, Energy, and the Environment

Brewing is an energy-intensive process, and the target for every brewing company should be the development of a sustainable process with efficient energy consumption to achieve savings in fuel and energy costs. Fuel oil was considered a very interesting commodity at the end of 2007, and its price has been pushed continuously to higher levels by speculative investments. The situation remains the same in 2008, and there is no sign of a significant price decrease in the future. The conservation of fossil fuel resources will help reduce CO₂ emissions from fossil fuel combustion, greenhouse gas emissions, and possible climate changes due to these emissions.

The demand for heat energy in the brewery can be reduced through the use of waste heat as process heat or energy-rich by-products or waste material for thermal energy (11). The combustion of spent grains is one possibility for generating thermal heat and electrical power (9,16). Two installations for heat generation through spent grain combustion are currently in operation, but the technique for partial dewatering of spent grains and design of the combustion box must be improved. Huppmann is cooperating with experienced partners on this process, and the development of a reliable system is underway.

Another possible substitute for fossil fuel is the anaerobic fermentation of brewery wastewater and biogas production (1). This biofuel can be utilized in efficient combined heat and power (CHP) units (14). The electricity produced can be used in the brewery, and any surplus can be sold to the local electricity provider. Electricity from renewable sources is often subsidized by governments through the payment of special bonuses.

Fuel cell cogeneration is useful for the generation of electricity and process heat. In 2002, the first trial installation was set up in Germany in a small-scale brewery to supply the brewery, a pub, and the brewery offices with electricity and hot water (Vaillant Group press release, www.vaillant.de). The system was not stable enough for regular daily use, and the maintenance requirements were quite high. The trial was completed in 2006, and the equipment is now continuously improved by the manufacturer and running in other trial applications in the German food industry. Sierra Nevada Brewery (Chico, CA) invested in a direct fuel cell/CHP system in 2005. The capacity is 1 MW, and system efficiency is estimated to be 50% for generating electricity and probably 75% using CHP (17). This pilot project

received financial support from the U.S. Department of Defense Climate Change Fuel Cell Program and the Pacific Gas and Electric Company as part of its Self-generation Incentive Program (more information is available at www.fuelcellworks.com).

The sun can be seen as the lowest cost energy provider. In past years, many manufacturers have put great effort into the development of photovoltaic and thermal energy collectors (21). Current medium-temperature collectors contain flat-plate, compound parabolic concentrator, parabolic trough, and linear concentrating Fresnel collectors. With the new type of vacuum collectors developed for solar thermal energy collection, not only can hot water up to 90°C be generated, but hot water up to 160–300°C and live steam for process heat also can be produced (22).

Many breweries worldwide are located in sunny regions where it makes sense to think about the installation of solar collectors to take advantage of cheap solar energy (2). In the European Union, some small-scale and medium-sized breweries have invested in such systems, and the EC plans to subsidize a few pilot installations in the brewing industry in the coming years (5,6,18). It is expected that the cost and installation of such solar collector equipment will decrease rapidly to approx. 50% of the present cost in the next five years, because demand for this technology will lead to an increase in production volume, better use of installed manufacturing capacity and, therefore, lower fixed costs. Solar thermal energy can be used for heating processes in CIP plants, bottle washing machines, and pasteurizers or for cooling processes with absorption chillers (10,22).

The major consumers of electricity in breweries are refrigeration (44%), packaging (20%), and compressed air (10%). In general it is recommended that producers invest in insulation and check whether insulation is dry. Regular inspection of the pipe system for the compressed air supply and installed valves is necessary to avoid losses and will help reduce electricity costs with little effort.

In addition to fossil fuels, water is the other resource that is limited in quantity and good quality. Therefore, brewers always aim at efficient water consumption for cleaning and cooling purposes, the prevention of losses, and the reuse of treated wastewater (20).

There is also an increasing demand for reductions in odor emissions from brewing facilities. Legal requirements, residents in the vicinity of production sites, and media pressure are forcing breweries to address pollution control; additionally, it is good common sense to do so (7). The sources of odor volatiles in brewhouse are well known, and some studies have been published on odor control in the brewing and food processing industries or, as the final target, the “zero emission brewery” (15). In addition to installing condensing systems for brewhouse vapors, some breweries in the European Union have invested in equipment that incinerates collected exhaust air or uses ionized air to reduce odor volatiles (3,8).

Impact on Breweries

The German Federal Environment Agency published a BREF document on integrated pollution prevention and control in December 2005. The guideline is based on the general European directive on waste prevention and reduction of emissions. The document contains useful information for breweries and beverage manufacturers relative to recommended BAT and defines target values for energy consumption, quantity of by-products generated, and waste per hectoliter of beer produced. The guideline is regarded as a recommendation with normative proposals and values and is not a statute with fixed limit values. However, plant operators and licensing authorities are requested to

follow these directives and target values for the planning and operation of brewery plants. The benchmark values for European breweries shown in Table 1 were collected and summarized for the EC by the Brewers of Europe in 2002.

The directives define consumption and emission values that are considered adequate, but the values have no legally binding limit parameters. However, new plants should be designed to meet or exceed the specified values through the use of BAT. The consumption and emission values serve as orientation values for industries, authorities, and the public in EU member states. EU member states must ensure that their regulatory authorities keep up-to-date with the development of BAT and are informed about them. When regulatory authorities issue permits and establish permit conditions, they must consider emission limit values that are based on BAT, irrespective of compliance with environmental quality standards. Figure 1 shows Brewers of Europe consumption figures (2002) for German breweries with an output >1 million hL/year.

Energy-Related Technology in the Brewhouse

The power consumption of European breweries (Table 2) with conventional equipment is approx. 13.1–14.3 kWh/bbl (11–12 kWh/hL); the BAT minimum benchmark value is 8.9 kWh/bbl (7.5 kWh/hL). Breweries with conventional systems for process heat (Table 2) have consumption figures between 42.9 and 47.7 kWh/bbl (36 and 40 kWh/hL); the BAT minimum benchmark is 28.6 kWh/bbl (24 kWh/hL).

The installation of a vapor recompression system can help reduce heat demand during wort boiling; however, the disadvantage of a mechanical recompression system is its high electrical power consumption. To lower consumption, the BREF document recommends a wort kettle with internal boiler and heat

recovery from wort boiling using a vapor condenser in combination with an energy storage system.

In Germany, a few large-scale breweries equipped with the abovementioned technology require much less heat energy per barrel of beer produced. For example, one brewery with a production volume of approx. 2.8 million hL requires less than 17.9 kWh of thermal energy per bbl (15 kWh/hL) in combination with approx. 5.4 kWh of electrical power per bbl (4.5 kWh/hL) (Huppmann, unpublished data). The equipment used is the state-of-the-art in new greenfield plants. The use of heat energy with a Jetstar internal boiler is very efficient, and the recovery of waste heat through condensation and use as process energy for heating wort during transfer to the wort kettle is vital. This equipment is Huppmann’s standard brewhouse technology (Fig. 2), and the equipment and applied technology are in line with the BREF document recommendations.

Breweries use different setpoints for wort boiling regarding time and evaporation rate. Formerly, the standard evaporation rate for acceptable wort quality was 10–12%. A homogeneous boiling temperature in the kettle was often difficult to achieve due to the design of the wort kettle and agitator or inadequate heating surfaces on the bottom or shell of the wort kettle, which causes insufficient heat transfer to all wort particles. The installation of an internal boiler or the pumping of wort through an external boiler can reduce the problem of low homogeneity, but even with this equipment, the thermal stress on specific wort particles is obvious. Low coagulable nitrogen and poor beer foam quality on the one hand and insufficient stripping of unpleasant flavor volatiles and DMS from the beer on the other hand re-

Table 1. Benchmarks for European breweries

Parameter	Per barrel	Per hectoliter
Fresh water consumption	3.7–4.7 bbl	3.7–4.7 hL
Thermal energy consumption	28.2–39.3 kWh	23.6–33 kWh
Electricity consumption	8.9–13.7 kWh	7.5–11.5 kWh
Kieselguhr consumption	3.78–6.73 oz	90–160 g

Table 2. Energy consumption in the brewhouse as published in the best available techniques reference document

Energy consumer	Electrical power		Thermal energy	
	kWh/hL	kWh/bbl	kWh/hL	kWh/bbl
Wort production in brewhouse	0.84	1.0	10.2	12.2
Wort production (%)	10.4	10.4	36	36
Total consumption in brewery	8.1	9.7	28.3	33.7

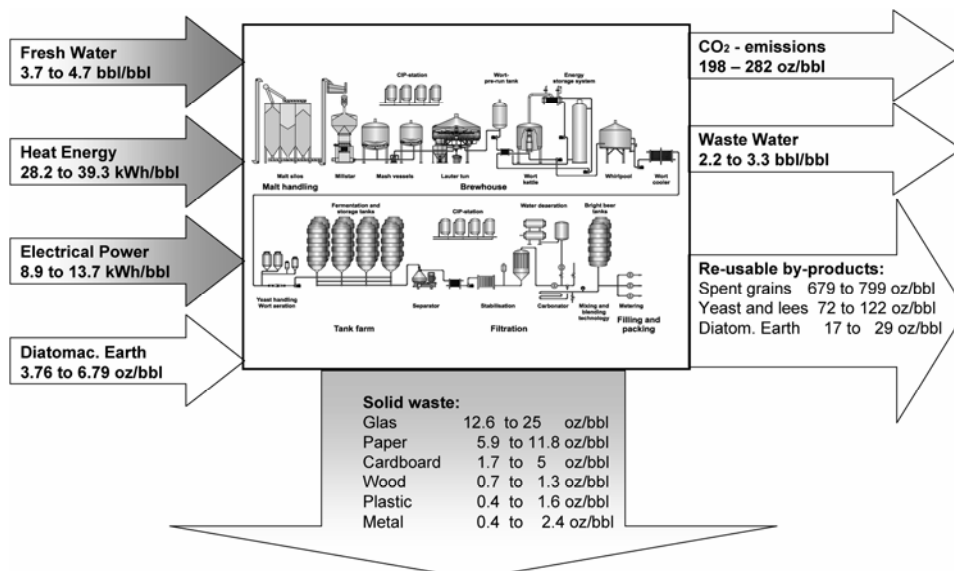


Figure 1. Consumption figures (Brewers of Europe, 2002) for German breweries with an output >1 million hL/year.

main unsolved. The design of Huppmann’s Jetstar internal boiler, in combination with dynamic low-pressure boiling, has proven to have a remarkable influence on wort homogeneity during boiling and the subsequent high quality of the finished beer (4).

The energy demands for wort boiling under different pressure conditions and evaporation rates are summarized in Table 3. The recovery of heat energy is achieved by a vapor condenser in combination with an energy storage system. For wort preheating during transfer from the wort collection tank to the wort kettle, the recovered and stored heat energy is applied in a closed hot water circuit with a plate heat exchanger. The recommended total evaporation rate for dynamic low-pressure boiling is 4.5%. Compared with atmospheric boiling, with its 7.5% total evaporation rate, the energy saving is approx. 19%; the equivalent reduction of CO₂ emissions is 18 oz/bbl (0.43 kg/hL) of cast wort. A production volume of 2 million hL/year results in a reduction of CO₂ emissions of approx. 1,044 metric tons. An additional benefit is provided by the recommended installation of a vapor condenser, energy storage system, and plate heat exchanger, as specified in the BREF document. The recovered thermal energy is sufficient to preheat the collected wort during transfer from the wort tank to the wort kettle; a temperature increase from 74 to 95°C can be achieved.

The recommended installation with wort boiling at low pressure and 4.5% total evaporation compared with conventional wort boiling under atmospheric conditions without an energy

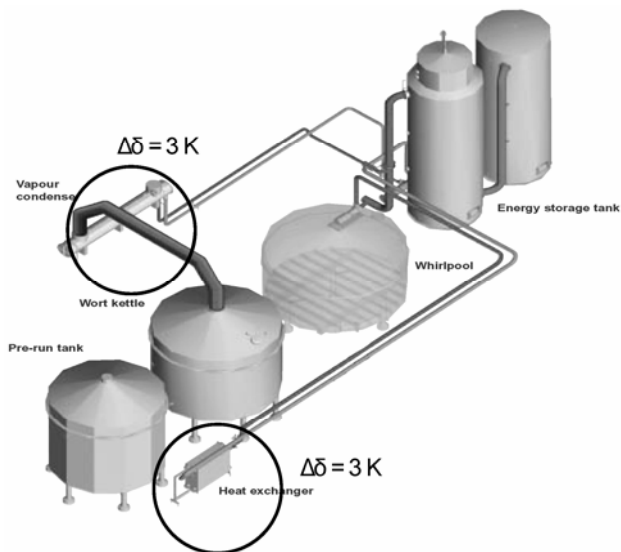


Figure 2. Huppmann energy storage system.

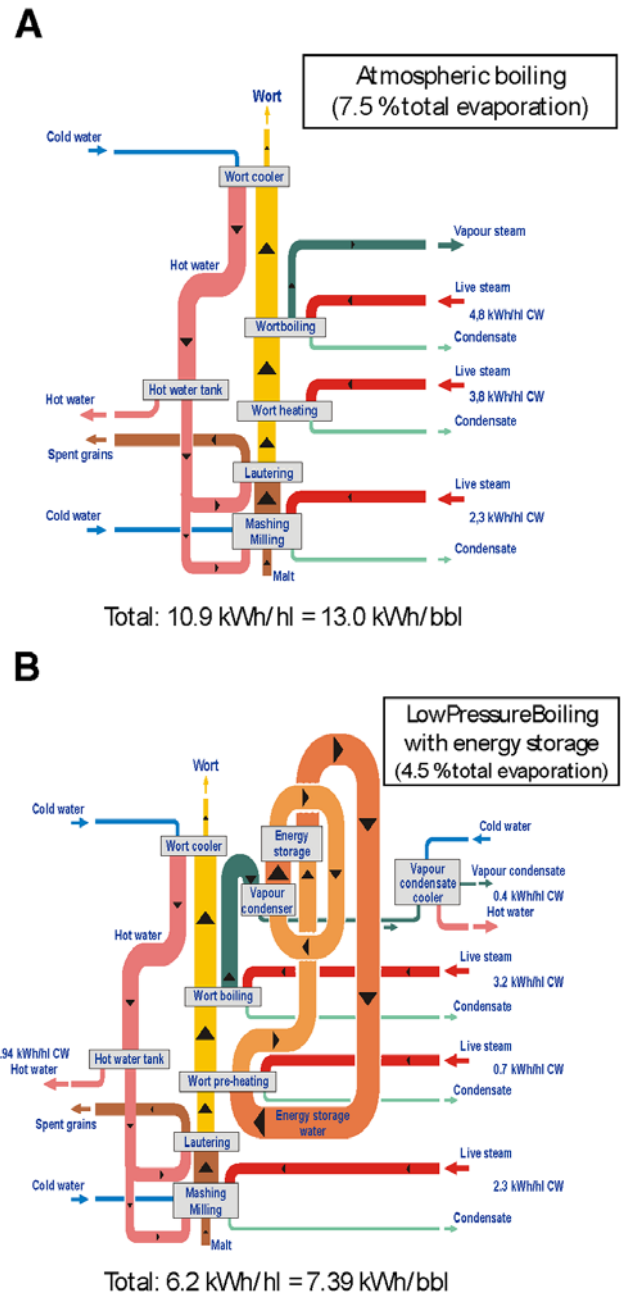


Figure 3. Heat flow in the brewhouse A, without and B, with an energy storage system.

Table 3. Energy demands for heating and wort boiling under different pressure conditions and evaporation rates^a

Energy consumer	Atmospheric boiling (7.5% total evaporation)			Dynamic low-pressure boiling (4.5% total evaporation)			Atmospheric boiling with internal boiler (3.0% total evaporation)		
	kWh/hL	kWh/bbl	%	kWh/hL	kWh/bbl	%	kWh/hL	kWh/bbl	%
Mashing, 52/78°C	2.21	2.63	19.8	2.21	2.63	24.3	2.21	2.63	27.9
Heating, 74/99°C	3.38	4.03	30.2	3.29	3.92	36.3	3.24	3.86	40.8
Wort boiling	5.03	6.0	45.0	3.02	3.60	33.2	2.01	2.40	25.3
CIP	0.28	0.33	2.5	0.28	0.33	3.1	0.23	0.27	2.9
Hot service water	0.28	0.33	2.5	0.28	0.33	3.1	0.25	0.30	3.1
Total consumption, brewhouse	11.18	13.33	100	9.07	10.82	100	7.94	9.47	100
Consumption at boiler house	13.84	16.50		11.23	13.39		9.81	11.70	

^a CO₂ emissions for atmospheric boiling, dynamic low-pressure boiling, and atmospheric boiling with internal boiler were 2.8, 2.2, and 2.0 kg/hL of cast wort, respectively.

storage system and with 7.5% total evaporation leads to an energy savings of approx. 43% or 5.6 kWh/bbl (4.7 kWh/hL) (Fig. 3). This change in wort boiling technology can result in a reduction of 1,880 metric tons of CO₂ for a production volume of 2 million hL/year. Another advantage of low-pressure boiling and internal boiler installation is an optimum hot water balance due to complete heat recycling in the brewhouse. There is no need to store surplus hot water, probably at a lower temperature, and no need to transfer hot service water to any other consumer in the brewery. The installation of storage tanks, pipes, and pumps is not necessary. In addition, there is no extra power consumption needed to supply surplus hot water to consumers. Condensation of wort kettle vapor in the condenser guarantees minimum vapor emissions into the atmosphere, which will help the brewery to meet the target of a “zero emission brewery.”

The Jetstar internal boiler can work with a minimum total evaporation of approx. 3–5% for kettle-full wort and, in a best energy balance scenario, at 4.5% for heating collected lauter wort to near boiling. The boiling procedure is characterized by a very even treatment of the total wort and excellent evaporation of undesired odor volatiles due to vapor bubble stripping of the entire kettle contents.

Conclusions

In a BREF document, the EC defines the BAT for the food and beverage industries in the European Union. Recommended techniques for sustainable process technology in breweries and benchmark values for energy consumption are part of this document. This article discussed energy consumption in the brewhouse and proposed technical installations that could result in heat energy savings of up to 5.60 kWh/bbl (4.7 kWh/hL) of cast wort. Energy recovery in the brewhouse is regarded as state-of-the-art according to the BREF document, and plant managers and licensing authorities are asked to take published benchmark values into consideration when modernization of techniques or approval planning and licensing of a new brewery take place.

The reduction of heat energy consumption in the brewhouse by means of the technology discussed in this article is an important contribution to the preservation of fossil fuel resources and to significantly reducing CO₂ emissions. The carbon footprint of a brewery can be optimized further with spent grain combustion and the use of solar thermal energy. The technology and applied technique of biomass combustion must be improved for use in the brewing industry, and an appropriate technique should be made available in 2008.

An additional request mentioned in the BREF document is the condensation of vapor, which would minimize odor emissions into the atmosphere within the vicinity of a brewery. The ionized air technique should be applied to remaining and collected vapor emissions if the intent of the brewer is to meet the benchmark target of a “zero emission brewery.”

REFERENCES

- Ahrens, A. (2007). Stabile Prozessführung und Biogasgewinnung bei anaerober Abwasserklärtechnik. *Brauwelt* 38/39:1050–1051.

- Buchhauser, U. (2006). Alternativen zu Öl und Gas. *Brauindustrie* 6: 55-57.
- Bühler, T., and Michel, R. (2006). Zero emissions in the brewhouse. *Tech. Q. Master Brew. Assoc. Am.* 43:115-120.
- Bühler, T., Michel, R., Kantelberg, B., and Baumgartner, Y. (2003). Dynamic low-pressure boiling—Systematically optimized for top quality. *Brauwelt Int.* 21:306-313.
- European Commission. (2008). Proposal for a directive of the European Parliament and of the council on the promotion of the use of energy from renewable sources. Published online at www.ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf. Commission of the European Communities, Brussels.
- European Commission. (2008). Progress on EU sustainable development strategy: Final report. Published online at www.ec.europa.eu/sustainable/docs/sds_progress_report.pdf. Commission of the European Communities, Brussels.
- Evers, G., and Bühler, T. (2005). Design and first practical experience: The new Grolsch brewhouse. *Tech. Q. Master Brew. Assoc. Am.* 42:319-323.
- Hofmann, A., and Michel, R. Erfolgreiche Geruchsreduzierung in einer Innenstadtlage. *Brauwelt*. In press.
- Keplinger, W. L., and Zanker, G. (2001). Use of spent grains. In: *Proc. Congr. Eur. Brew. Conv.* Budapest 28:107. Fachverlag Hans Carl, Nürnberg, Germany.
- Krüger, D., Pitz-Pall, R., Lokurlu, A., and Richarts, F. (2002). Heating and cooling supply of a hotel with parabolic trough collectors. In: *11th SolarPACES Intl. Symp.*, Zurich, Switzerland.
- Ledwig, J., Hilser, M., and Scheller, L. (2007). Stillstand ist Rückstand—Optimierung der Energieeffizienz in der Brauerei. *Brauindustrie* 9:34-36.
- Michel, R., and Vollhals, B. (2002). Reduction of wort thermal stress—Relative to heating methods and wort treatment. *Tech. Q. Master Brew. Assoc. Am.* 39:156-163.
- Michel, R., and Vollhals, B. (2003). Dynamic wort boiling. *Tech. Q. Master Brew. Assoc. Am.* 40:25-29.
- Raabe, E., and Henkel, I. (2003). Regenerative Energien. *Brauindustrie* 12:31-33.
- Robbins, L., and Brillat, B. (2002). Control of odors in the brewing and food processing industries. *Tech. Q. Master Brew. Assoc. Am.* 39: 29-31.
- Russ, W., and Meyer-Pitroff, R. (2002). The wastes of the food industry. In: *The Future of Waste Management in Europe*, pp. 341–344. Funck, Koblenz, Germany.
- Sierra Nevada Brewing Company. (2008). Our environment: Fuel cells. Published online at www.sierranevada.com/environment/fuelcells.html. Sierra Nevada Brewing Company, Chico, CA.
- Meyer, J.-P. (2007). Prozesswärme: Waschen, kochen, trocknen. *Sonne Wind & Wärme* 1:46-53.
- Unterstein, K. (1992). Integration des Würzekochkreislaufes mit unterschiedlichen Rückgewinnungssystemen in den gesamten Energiefluß der Brauerei. *Brauwelt* 22:1024-1043.
- Walter, S., Glas, K., and Parlar, H. (2005). Wassermanagement in der Getränkeindustrie. *Brauwelt* 33:972-976.
- Weiss, W., and Müller, T. (2005). Solare Prozesswärme—Entwicklungen im Rahmen der IEA Task 33/4. Published online at www.aee-intec.at/uploads/dateien67.pdf. AEE – Institute for Sustainable Technologies, Gleisdorf, Austria.
- Weiss, W., and Rommel, M. (2005). Solar Heat for Industrial Processes: Medium Temperature Collectors. Published online at energytech.at/pdf/medium_temperature_collectors_task33.pdf. AEE – Institute for Sustainable Technologies, Gleisdorf, Austria.