PEER-REVIEWED PAPER

GREENFOODS branch concept for enhancing energy efficiency in the food and drink industry

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Abstract

The major output of the European project GREENFOODS will be the **GREENFOODS branch concept**. It is defined as a well-developed comprehensive energy audit and energy management tool as well as a realization guideline for companies of the food and beverage industry. The GREENFOODS branch concept itself will be developed using existing software tools such as MS EXCEL and VBA for two different levels of user input following the same tool structure. It includes the design of the present state production process flow sheet, a mass and energy balance, the calculation of the primary energy use and CO_2 emission as well as heat integration, efficient electricity consumption and efficiency of heat and cold supply. The identification of optimization potentials by the comparison with benchmark data will be supported by the use of renewable energy sources – RES (biomass, biogas, combined heat and power – CHP, industrial heat pumps – HP, solar thermal energy, absorption cooling machines – ACM), the rational use of energy sources, the calculation of profitability and the assessment of suitable technologies.

Guidelines for the implementation of best available technologies and renewable energy sources including information on existing funding systems will complete the offer of GREENFOODS to show potentials for improvements and tailor-made solutions for SMEs in the different subsectors in the food and beverage industry. Furthermore, the guidelines will be supported by best practice examples developed within the project and already existing and identified show cases.

The GREENFOODS branch concept will be closely linked to the GREENFOODS Wiki Web that will be a living document and result of the project. The target groups are energy managers in companies as well as energy auditors and experts, energy suppliers as well as process technology suppliers and associations linked to the food and beverage industry.

Introduction

The overall objective of the GREENFOODS project is to lead the European food and beverage industry to high energy efficiency and reduction of fossil carbon emissions in order to ensure and foster the world wide competitiveness, improve the security of energy supply and guarantee the sustainable production in Europe. The GREENFOODS branch concept will guide the user to identify tailor-made solutions for "green production" for SMEs in the different subsectors in the food and beverage industry by combining technological expertise with knowledge on energy efficiency and renewable resources resulting in clear strategies for SMEs for process optimisation and energy supply towards a production without fossil carbon emissions. Furthermore, the GREENFOODS training module integrated as a sector-specific training module in existing energy management trainings such as the European Energy Manager as well as a stand-alone course will be established. Special funding schemes will be developed to facilitate the implementation of identified energy efficiency potentials in SMEs by comparing and analysing existing funding systems. Applying the GREENFOODS approach, 200 energy audits will be performed including 20 detailed audits and 5 selected SMEs for the implementation of the concepts. In the participating countries "virtual energy competence centres – VECC" will be installed and will work as one stop shop service centre.

Table 1. Typical uses of energy in a meat plant.

Thermal (20–50 % of total energy)*	Electrical (50–80 % of total energy)
Boilers	Refrigeration**
Scalding tanks	Stunning equipment
Singeing (hair removal) equipment	Skinning equipment
Space heating	De-boner
	By-product process equipment
	Ventilation & Lighting

** Pig abattoirs require a lot of hot water so 80 % of its total energy could be in the form of thermal energy.*
*** Refrigeration is the largest user of electricity [5].*

Motivation for Branch Concept

In 2010, food and drinks (and tobacco) manufacturing consumed 29 million tons of oil equivalents of final energy in EU-27 countries which represented a 10 % share of the total energy consumed by the EU-27 industry. This puts the food industry fourth behind iron and steel, chemicals and petrochemicals and non-metallic minerals [1, 2].

Most of the energy consumed by the food and beverage sector is used in process heating (e.g. boiling, drying, pasteurisation, evaporation), process cooling and refrigeration, processing machinery (fans, pumps, ventilation, mixing etc.), and non-process operation (e.g. building and lighting). The majority of companies are supplying most of their process heat using low pressure or high-pressure steam, even if parts of the processes or in some cases the whole systems would not require such high temperatures. This also makes integration of low-grade waste heat very difficult. The processes need to be critically reviewed and alternative strategies for heat supply have to be considered. In this respect, high potentials for reduction of energy demand exist in the food and beverage industry.

There are some general significant challenges, which are highly relevant in the food and beverage sector and prevent the sector from becoming more energy-efficient and competitive: lack of awareness, competition of suppliers and trade companies, problems of data acquisition, evaluation of energy saving measures, implementation, inadequate system design, no common guidelines, no training on optimisation, no one-stop-shop from concept development to implementation, lack of use of alternative sources of heat.

Example Meat and Meat Products

Meat and meat products have the greatest environmental impact of all products in the food and drink area in the EU [4]. In meat plants, energy costs represent the fourth highest cost (after raw materials, waste management and labour) [5]. The most relevant for electrical and thermal demand are refrigeration and steam boilers (Table 1).

A survey by EBLEX (the organisation for English beef and sheep industry) showed that it takes on average about 775 kWh of energy to produce a tonne of beef and 685 kWh per tonne of sheep meat (based on the energy used for slaughtering, cutting and retail packing), although the energy per tonne varied considerably depending upon the type of processes within the plant [5]. None one of the UK companies that participated in the EBLEX survey used renewable energy in their operations, although some companies were considering it.

Scope and Objective of GREENFOODS

In order to overcome these challenges and barriers and to meet the needs of the market, GREENFOODS will offer comprehensive solutions for energy management.

The objective of the GREENFOODS project is to develop and promote a branch concept that allows the assessment of the current energy status of any SME in the food & beverage industry, offer energy-efficiency and RES solutions, and supports their implementation for the food industry. To analyse its energy situation a calculation tool for balancing and optimization will be developed, which builds up on existing benchmarking and energy audit tools elaborated in different European (Intelligent Energy Europe) and national projects:

- The developed solar integration schemes and the calculation nomograms of the SO-PRO project (Solar Process Heat, http://www.solar-process-heat.eu/) will be considered for the solar thermal integration module in GREENFOODS.
- The Austrian Solar Foods project (http://www.solarfoods.at/) developed a branch concept (software tool, guidelines and database) for the integration of solar thermal energy in sub-branches of the food industry. GREENFOODS will use parts of the algorithm of the Solar Foods software tool.
- Benchmarks will be used from the projects BESS and ExBESS (Benchmarking and Energy management Schemes in SMEs, http://www.bess-project.info/), EINSTEIN (Experts System for an Intelligent Supply of Thermal Energy in Industry and other Large-Scale Applications, http://www.einstein-energy.net/), AMETHYST (Integrated benchmarking and self-assessment tool – Wine Industry, http://www.amethyst-project.eu/), and E-CHECK IN CRAFT SME (http://www.eaci-projects.eu/iee/page/Page.jsp?op=project_detail&prid=151).
- Guidelines and tools will be considered from ICE-E (Improving Cold storage Equipment in Europe, http://www.ice-e.eu) and ENGINE (Energy Efficiency in Small and Medium Sized Enterprises, http://www.engine-sme.eu/).

Through these calculation tools, the branch concept will offer a comparison to the current energy status and show potentials for improvements. These calculations will be supported by guidelines for implementation and long lasting energy management in SMEs and the development of a compendium for energy supply technologies, process technologies and best practice examples on a WikiWeb. By means of this instrument, GREENFOODS will be able to provide tailor-made solutions

for SMEs and information for the different subsectors in the food and beverage industry.

The GREENFOODS project covers 6 European member states – Germany, Spain, United Kingdom, France, Poland and Austria – which together account for 59 % of the food and drink industry turnover for EU25 in 2011. (2011 sales, Source: [3].)

The GREENFOODS partners decided to focus on a number of industry sub-sectors for the purposes of this project to provide more in-depth understanding of particular sectors. The sub-sectors were chosen based on their contribution to the overall food and drink industry output and the relative environmental intensity of their production processes.

- Meat
- Beverage (beer and fruit juice manufacturing)
- Dairy
- Bakery
- Cereals & starch products
- Baby food
- Animal feeds (pet food only)
- Fish

Elements of the Branch Concept

The GREENFOODS branch concept is a tool that combines the technological expertise of food and drink production with knowledge on energy efficiency and renewable resources. It was developed, based on the experience of previous activities mentioned above and the first results of the 200 audits performed in the GREENFOODS project. It particularly targets SMEs and their typical knowledge of their respective processes and gives the user a quick and comprehensive insight in the energy efficiency potential of the investigated company. The variable level of detail – as outlined below – allows the individually definition of all relevant processes.

Thus, food and drink SMEs find a tailor-made branch concept that has been developed based on real life situations. Figure 1 outlines the working steps in the GREENFOODS branch concept tool. The user starts with a simplified depiction of his company, by adding multiple predesigned Visio™ shapes to a process flow sheet.

By entering the mandatory required key figures, a first, basic evaluation of the status quo can be generated to allocate the most energy consuming processes and technologies.

However, the GREENFOODS branch concept offers different levels of interactivity between the user and the tool, entailing different levels of results. But for both options the energy and mass flow balance of the status quo is generated. The basic version will roughly calculate the energy consumption of the processes and the efficiencies while in the detailed version the information input over predefined shapes that represent the typical unit operations in the respective branch will generate more significant results.

Over benchmark comparisons the user will get as a result how efficient the whole production as well as several processes are operated and at the same time suggestions how these can be optimized on which level.

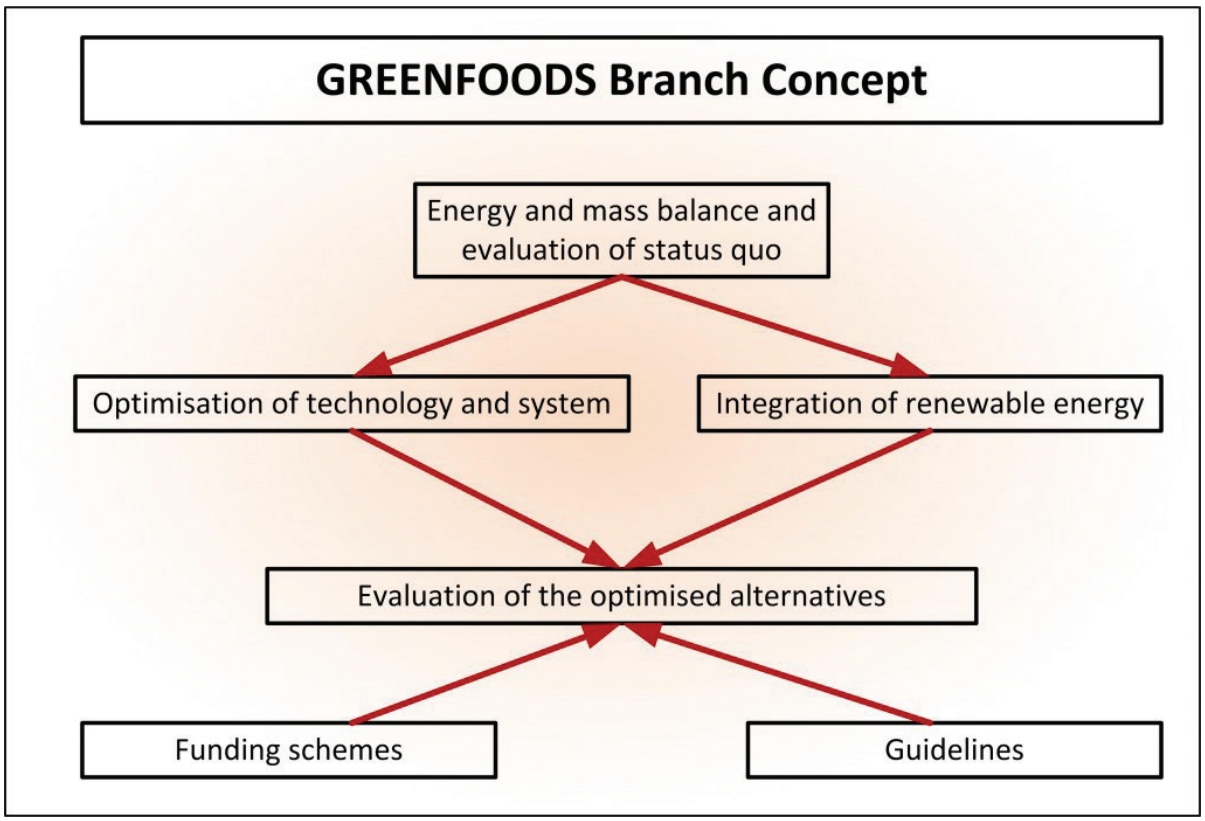

Figure 1. Main Elements of the GREENFOODS Branch Concept, Source: GREENFOODS.

For the optimization of production and processes different alternatives are suggested based on the status quo. These alternatives may refer to one of the following 3 areas:

- Technology optimization.
- System optimization.
- Integration of renewable energy sources.

Technology optimization will be suggested if key figures of the status quo suggest a potential technology upgrade. This step is based on a documentation of and guidelines for the implementation of best available technologies (BATs).

System optimization concerns to the areas of heat integration, either directly via heat exchangers or indirectly via heat storage units. Therefore, advanced Pinch analysis algorithms (developed within the GREENFOODS consortium) will be executed to identify the heat integration potentials. In addition, the efficiency of heat and cold supply, as well as optimization approaches for the reduction of electricity consumption, e.g. by electric motor system optimization (e.g. compressed air systems) will be accounted for.

Finally, the **integration of renewable energy sources** can be calculated on a preliminary basis. Two major technologies are currently implemented in the GREENFOODS branch concept:

- The *biogas potential* is evaluated based on the previously identified typical waste streams of the respective branches (e.g. spent grain in breweries).
- A *solar thermal simulation tool* has been implemented that allows the definition of a variable heat load that can be linked to a previously defined heat sink of the Pinch analysis. The solar tool considers collector efficiency of different technologies as well as storage and heat exchanger performances and allows a quick but detailed analysis of the collector field size.
- CHP (Combined Heat and Power), ACM (Absorption Cooling machines) and heat pumps are proposed and sized if key energy figures after status quo and the first two optimization steps (technology and system optimization) suggest a practical implementation.

Thus, the tool shows integration possibilities of renewable energies in an uncomplicated manner and demonstrates immediately the effects on the energy balance in order to facilitate decision-making.

The optimized alternatives are visualized on a predefined user interface developed with VBA including necessary process information like mass flow, temperature, medium and load profile. The comparison of status quo and optimization are easily assessable in a graphically prepared energy balance.

All proposed alternatives have to be evaluated on an environmental and economic basis (see Figure 3). These calculations will be supported by guidelines for implementation and long lasting energy management in SMEs and the development of a compendium for energy supply technologies, process technologies and best practice examples via GREENFOODS WikiWeb. This free tool will be on-line available through the GREENFOODS web (www.green-foods.eu) from 15/03/2014.

Best Practice Examples

There are a lot of possibilities to integrate renewable energy sources in the production of companies within the food-industry, the following are some cases already collected within the GREENFOODS project:

Fleischwaren Berger GmbH is a meat-processing company (Sieghartskirchen, Austria) producing approximately 80–90 tons of meat and sausage products per day. At Berger solar flat plate collectors with an overall area of ca. 1,067 m² are installed on a field next to the production facility including a storage tank (60 m³). The produced thermal energy is used for feed water preheating (30 °C up to 95 °C) for steam production

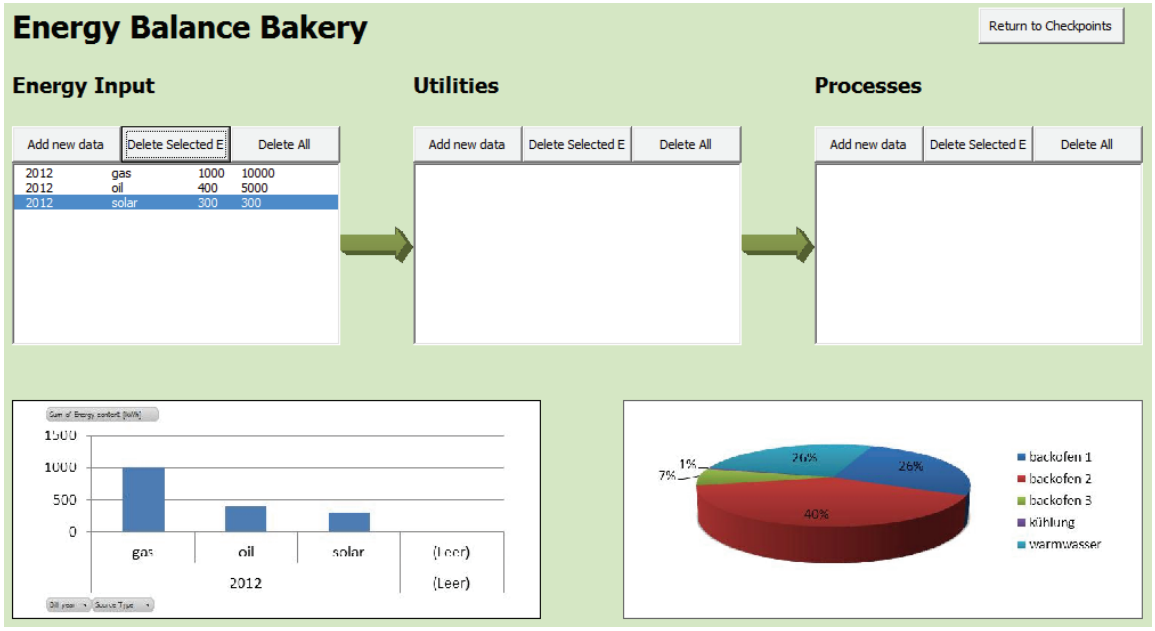

Figure 2. Preliminary Screenshot of the GREENFOODS Tool, example energy balance, Source: GREENFOODS.

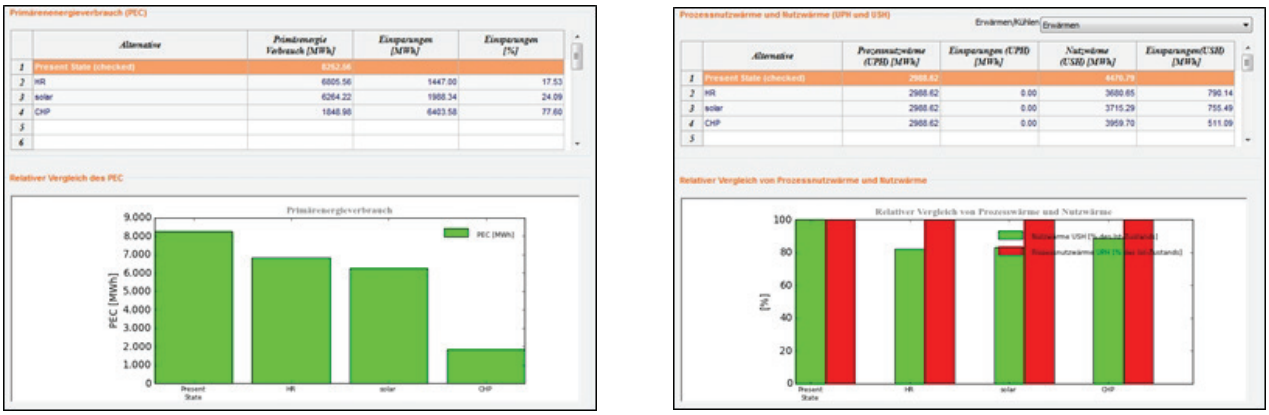

Figure 3. Evaluation of the optimization potential (example from Software EINSTEIN).

for ham cooking and hot water preheating from about 40 °C up to 70 °C required for drying the air conditioning systems (climatic chamber and maturation room for production of long-lasting sausages). The implementations at Berger concentrate on centralized water and steam production facilities that can be found in almost any industrial production site that uses thermal energy. It therefore easily can be copied to other sites and therefore offers a high replication potential. The fossil energy saved amounts to 500 MWh per year leading to CO_2 emissions savings of 150 tons per year.

In the *brewery in Goess* (Austria) the mashing process has been changed to a low-temperature-process by integrating additional heat exchanger plates. Hot water is now used instead of steam, which allows better renewable energy integration. A 1,470 m² solar thermal collector field provides hot water for the mashing process. A vapour condenser recovers the waste steam, which occurs during the start-up of the wort boiling process. The produced hot water is also integrated into the hot water distribution network of the brewery. A storage tank of 200 m³ is used. 400 MWh/a of fossil energy saved (solar gains based on feasibility study) leads to reductions in CO_2 emissions of 196 t/a.

Food industries have typically a high potential for solar process heat at low temperature due to specific washing and cleaning needs. The company *Montesano* had done the installation of a solar thermal system in Jerez de los Caballeros with good results. The preliminary wishes of the factory owners directed to improving the environmental data of the factory, as well of the previous energy diagnosis made by SOPRO pointed out the possibility of this renewable energy source. The processes demanding an important amount of heat are the raw product reception washing, first and second product treatments, washing of final products and cleaning of vessels and machinery. The temperature level is 40–50 °C for all processes and the total heating demand is 360,000 kWh/a. The existing heat supply has been partially substituted by 120 solar thermal collectors with a surface area of 252 m². 172 MWh of fossil energy and 52 tons CO_2 emissions could be saved per year.

Conclusions and Next Steps

The project has confirmed so far that GREENFOODS is focusing on the correct sub-sectors of the industry, with meat, beverage, dairy and bakery being four of the top five sub-sectors with regards to turnover, number of companies and energy consumption. The most energy consuming countries in the European food and drink sector are Germany, France, Italy, UK and Spain. Four of these five countries are GREENFOODS participants.

The energy audits done within the GREENFOODS project are the basis for the branch energy concept. To date 188 basic energy audits have been carried out in the 5 partner countries and France.

The project so far has shown that companies in Austria and Spain are particularly interested in participation in the project as they are aware of their situation and potentials for increase of performance. In other countries, particularly the UK, this awareness is only slowly growing. The evaluation of the basic audits to date has shown, that there are a large number of companies that would be suitable for detailed audits (100). Out of these 100 cases 30 were classified as suitable for implementation by the auditors. Currently the basic audits are finalized and the detailed audit phase has been started. It is expected, that the 5 implementation cases will be chosen by end of April.

Energy is an area where substantial savings can be made almost immediately with little or no capital investment, through simple housekeeping efforts. In addition to reducing a plant's demand for energy, there are opportunities for using more environmentally benign sources of energy. Opportunities include replacing fuel oil or coal with cleaner fuels, such as natural gas, purchasing electricity produced from renewable sources, or cogeneration of electricity and heat on site. For some plants it may also be feasible to recover methane from the anaerobic digestion of high-strength effluent streams to supplement fuel supplies.

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Endnotes

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