GREENFOODS – energy efficiency in the food and beverage industry

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Keywords
waste heat recovery, industrial energy saving, energy audit, energy analysis

Abstract
Energy efficiency in industry is a key element of the envisioned future of a carbon free society. In order to close the gap from this aspiration to reality, successful implementations of energy efficiency measures must be investigated to evaluate the impact of currently existing energy efficiency policies.

Thus, in the course of the European IEE project GREENFOODS a branch concept was developed that allows the easy, quick and comprehensive evaluation of energy efficiency measures within a company of the food and beverage industry. The user is supported in setting up the energy balance and based thereupon evaluating process optimisation measures (via the GREENFOODS WikiWeb), system optimisation measures (with a Pinch analysis algorithm) and the integration of renewables. The optimisation possibilities are evaluated energetically, economically and ecologically and information on national funding programs is given. The user is strongly supported in all steps of the branch concept with links to the GREENFOODS WikiWeb.

The GREENFOODS branch concept (GF BC) has been developed based on the insights of 204 basic audits that were conducted in 6 European countries. There, a total of 150,000 tCO_2e savings were identified. In a subsequent step, the measures being in consideration for implementation were analysed in 45 detailed audits. This would mean savings in emissions of around 12,500 tCO_2e. Currently, 7 realizations of energy efficiency measures and renewable energy supplies are supported in the course of the GREENFOODS project, which will finally lead to a total of 2,200 tCO_2e. So called Virtual Energy Competence Centres have been installed in the 6 European countries Austria, Germany, Great Britain, France, Poland and Spain and fulfil their role as a one stop shop for energy related questions from industry

Introduction
The European food and beverage industry consumes more than 10 % of the final energy demand of the industry in the EU-28 (Eurostat 2015). The industry consists of more than 287,000 companies of which 99.1 % are small and medium-sized enterprises (SMEs) (FoodDrinkEurope 2014). The overall objective of the GREENFOODS project is to lead this industry to optimised energy efficiency and the integration of renewable energy sources and following 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 GF BC, main output of the project, will guide the user to identify tailor-made solutions for "green production" for SMEs in the different subsectors in the food and beverage industry (focussing on bakeries, breweries, dairies, fruit and vegetable processing and meat processing) by combining technological expertise with knowledge on energy efficiency and renewable energy resulting in clear strategies for SMEs for process optimisation and energy supply towards a production without fossil carbon emissions. Furthermore, the GREENFOODS training module is integrated as a sector-specific training module in existing energy management trainings such as the European Energy Manager (EUREM). Special funding schemes have been developed to facilitate the implementation of identified energy efficiency potentials in SMEs by comparing and analysing existing funding systems. 204 energy audits have been performed including 46 detailed audits and 6 selected SMEs for the imple-

mentation of the concepts. In the participating countries Virtual Energy Competence Centres (VECC) have been installed and work as one stop shop service centre.

Development of the GREENFOODS branch concept

INITIAL POINT

Currently, no simple and user-friendly tools are available that support experts of the food and beverage industry to identify energy efficiency measures and renewable energy integration in their respective sector. Non-energy experts look for low effort tools that can provide them – with very few input data – the depiction of the main energy flows in their company. Thus, the motivation was to design a tool specifically for the food and beverage industry that allows a quick and easy evaluation of the status quo and possible optimization measures. At the same time, the user must be able to quickly expand his knowledge on specific topics of his interest. The GF BC has been introduced in Brunner et al. (2014).

METHODOLOGY

The GF BC was developed, based on the experience of previous activities and projects as the IEE project EINSTEIN I & II and several national projects and the first results of 204 audits performed within the GREENFOODS project. By this, the relevant subsectors and their most common processes were identified and included in the GF BC.

All typical thermal and electrically driven processes with an energy demand in the most common subsectors of the food and beverage industry as well as their energy supply can be determined and evaluated. In order to allow the comprehensive energy balancing of all companies in the heterogeneous food and beverage industry, the entire set of possible unit operations can be defined in the GF BC in a universally applicable way. However, some processes required special attention due to their high share on the overall energy demand in a company. For such processes more detailed flow sheets were designed to represent typical process flows in the companies and thus to raise the accuracy of the energy balancing. Additionally, the GF BC is strongly linked to the GREENFOODS WikiWeb to guide users to relevant information on the current topics. Through this method, it is possible to set up a basic energy balance as well as to go into detail if wished.

The GF BC has been designed in VBA (Visual Basic Application) including userforms of MS Excel. The userforms guide the user intuitively through the GF BC. The development was accompanied by testing performed within the consortium and external users and experts.

The final GREENFOODS branch concept

ENERGY BALANCE – DEFINITION OF THE STATUS QUO

In order to obtain suggestion for improving the energy efficiency of the investigated company, the user must define the status quo of the energy flows within the company. The user is supported in setting up the energy balance. The GF BC includes the whole energy system and energy conversion in an industrial application as the energy input (e.g. natural gas, oil, etc.), the utilities (boilers, chiller, etc.), the distribution and the processes (definition of the energy demand of the most relevant processes) – see Figure 1.

First, the **energy input** has to be defined. Conventional energy carriers such as coal, oil, natural gas and electricity can be defined as well as already existing renewable energy sources like biomass, biogas and solar energy. Mandatory information is the quantity and cost of the energy type. In the subsequent step some parts of the purchased energy is converted in **utilities** into useful energy carriers such as steam, thermal oil, hot water or cold. The definition of the boiler can be done in a basic way where typical boiler efficiency must be assumed, however in an advanced version the boiler efficiency is calculated based on O_2-value and flue gas temperature which are known parameters from boiler service data sheets. Similarly, chillers or CHP (combined heat and power) can be defined in a basic or in an advanced version. The **distribution** sector serves as central hub for the energy flows within the company. All useful energy carriers are automatically listed as well as those final energy sources from the energy input section that have not been converted in the utility section. Distribution losses can be defined preliminary and may be changed later when the energy balance is solved.

The **process** section is the core section of the GF BC. Energy efficiency measure for universally applied technologies like boilers and chillers are easily accessible. However, the specific knowledge on processes is a key advantage of the GF BC. The targeted subsectors of the food and beverage industry are: bakeries, breweries, dairies, fruit and vegetable processing and meat processing. In each subsector various processes are predominant. While the process technologies may differ significantly from one company to another, they can be broken down to a few similar unit operations with similar physical and chemical basics. For instance, the unit operation 'drying' is appearing in almost all subsectors including baking bread, smoking meat and drying fruits.

In the GF BC it is on the one hand possible to define processes in a simple and basic way that follows no particular standards of a specific subsector. On the other hand for certain applications and subsectors an advanced version allows the detailed definition of processes. For instance, the processes in a brewhouse of a brewery are similar in a high majority of cases. While the mashing process could theoretically be defined in the basic version by defining the heating of a product and the cleaning of equipment, it would be much more convenient and accurate to define the mashing process in a specially designed mashing process form. Similarly, a wort boiling form is provided while this could also be done in the basic 'cooking' unit operation. The same applies to several other processes (e.g. baking, cold smoking, curd manufacturing …).

By this approach it is possible to allow the entire process definition of all kind of applications in the highly heterogeneous food and beverage industry. After the user has entered the mandatory data in the four given sections of the energy flow sheet, the energy balance must be solved before the user can advance to the optimization suggestions. Two criteria apply at this stage:

- The 'supplied useful energy' output from the distribution-section must equal the 'supplied useful energy' input to the process-section.

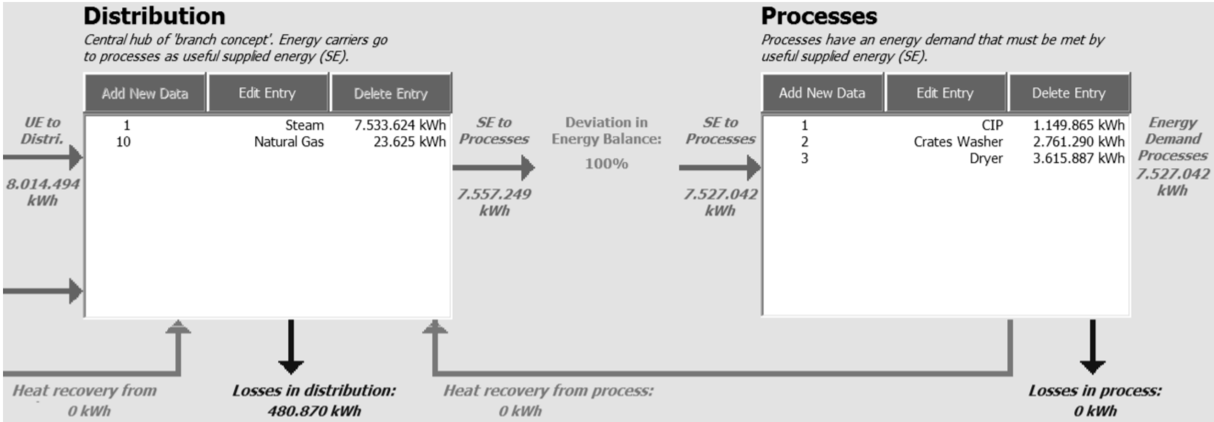

Figure 1. Energy balance in the GREENFOODS branch concept (distribution and process section are shown).

- The energy carriers defined in the input-section must be fully assigned to utilities and processes.

The user is supported in the process of solving the energy balance by guiding him to the respective free variables of the energy balance as the efficiencies of utilities (boilers, chillers) and processes, part load factors and running hours of utilities (boilers, chillers) and processes, product input in processes, heat recovery rate and distribution losses.

DEVELOPMENT AND EVALUATION OF OPTIMISATION ALTERNATIVES

Optimization alternatives are suggested based on the definition of the status quo and include one of the following 3 steps: technology or process optimization, system optimization, integration of renewable energy sources

Technology or process optimisation

Technology and process optimizations will be linked to the WikiWeb were relevant information is available on each unit operation specifically for each sub sector of the food and beverage industry (e.g. innovative technologies, information on flow sheets, integration concepts of solar thermal, etc.). Technology optimizations cannot be evaluated within the GF BC, however vast and detailed information is given for possible alternatives in the WikiWeb. Likewise process optimizations cannot be economically and ecologically evaluated, but the user can compare different process configurations within the process definition and gets insights in possible energy savings by changing key parameters.

System optimisation – waste heat recovery

System optimisation refers to the intelligent waste heat recovery within a company. In the phase of depicting the status quo, all possible process streams that need to be warmed up (cold streams) or cooled down (hot streams) are saved, as well as waste heat from utilities such as boilers, chillers and air compressors (also hot streams). An advanced Pinch analysis algorithm has been developed that automatically suggests feasible heat exchangers by combining the previously defined hot and cold streams within the boundary of the company. All feasible heat exchangers are automatically ranked depending on the size, the transferred energy and the exergy loss. In a related feature, the user identifies possible implementations of high-temperature industrial heat pumps. Hot streams with a too low temperature for utilization in a heat exchanger might be used as heat source of a heat pump.

Integration of renewables

Finally, the integration of renewable energy sources is evaluated. Besides the already mentioned heat pump integration, the user can evaluate the feasibility of 1) biogas production and utilization, 2) solar thermal integration, 3) photovoltaic, 4) combined heat and power and 5) absorption chiller machine. All options are evaluated technically, economically and ecologically. The technical evaluation is in all cases dependent on the previously defined status quo and its structure of heating, cooling and electricity demands. Additionally, available space, biogas potentials and existing equipment is influencing the outcome of the technical feasibility check.

During the definition of the status quo, waste streams are identified and its biogas potential calculated. This includes sewage waters and solid wastes from food processing. In a second step the production of biogas in a fermenter and the utilization of the biogas in a CHP plant is calculated, considering own heat and electricity demands. The solar thermal tool identifies interesting process streams where solar thermal heat can be integrated.

Alternatively, solar heat is integrated on the supply level. Four different collector technologies can be compared as well as 10 climate regions in the GREENFOODS countries. The tool considers heat losses and temperature differences in heat exchangers and storages. Based on this data a maximal size of the solar thermal plant is suggest to the user which can be altered (however is limited with the previously defined available area) and then used in the final evaluation. The photovoltaic tool takes the internal electricity demand into account which affects, depending on country specific policies, the profitability of the plant. The size of the photovoltaic plant is limited by the available area.

Combined heat and power and the absorption chiller machine are suggested if conventional boilers or chillers can be replaced. In the latter case this has restrictions like temperature levels of the cooling medium and availability of waste heat to drive the ACM (absorption cooling machine). A CHP is suggested for two different fuel types: solid biomass and natural gas.

VISUALISATION AND EVALUATION OF RESULTS AND RECOMMENDED MEASURES

Both the system optimization as well as the integration of renewables can be evaluated economically, energetically and ecologically at one glimpse. Figure 2 shows how all alternatives can be individually or jointly be evaluated. The alternatives are compared with the reference which is the status quo of the company. Depending on the energy carrier that is in the focus of the user, the reference can be either only electricity or only thermal energy or both of them.

The energy costs are calculated dynamically, depending on discount rate, projected system life time, investment costs and operating costs. The effects of additional electricity demand due to the implementation of renewables are also considered economically and ecologically. The charts show the energy costs, final energy, primary energy and tCO_2e emissions.

The GF BC is connected with the IFC (International Finance Corporation) database for benchmarks referring the energy demand on product amounts or raw material (e.g. MJ/hl beer, kWh/t flour, etc.). 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.

TARGET GROUP

The target group of the GF BC are in particular SMEs that have different levels of knowledge on the processes and energy efficiency. Thus the GF BC is designed to be an easy handling tool where a closed energy balance can be achieved in a basic version with little input parameters and optimisation suggestions can be obtained. However, much more detailed technical parameters can be added to improve the accuracy of the depiction of the company in question. In this way a wide range of companies with different levels of knowledge on processes can be reached.

Application of the GF BC and following implementation of energy efficiency measures

In total, 46 detailed audits were performed within the GREENFOODS project using the branch concept and focussing on the sub-sectors meat processing, beverages, bakeries, fruit/vegetables processing and dairy products. Most of these audits have been performed in Austria (19), followed by Spain and the UK (7 each), Germany (6), Poland (4) and France (3).

29 companies have been selected for a detailed audit evaluation, consuming nearly 534,000 MWh of energy per annum. The most common energy source used was natural gas, with 41 % of total energy consumed. Following this was electricity at 27 %, coal at 25 % and oil at 5 %. Biogas and biomass were the least popular fuels, contributing less than 2 %. It should be noted that while coal consumption was 25 %, it was only used by two companies in the audits, both from large companies in Poland (dairy and meat). The consumption of the other main energy sources was more uniformly spread between the sectors and countries.

The identification and quantification of potential measures used to decrease energy consumption in order to mitigate CO_2e emissions was a key focus of the project including different recommended measures. From these, process optimization and heat recovery were the most popular methods to decrease energy or fuel consumption, followed closely by solar process heat, then cold supply optimization and biomass use, and finally heat supply optimization and CHP utilization.

In total, feasible measures with the potential to reduce the energy consumption by over 120,000 MWh were identified, resulting in a large reduction of CO_2e of 30,500 t. To provide an estimation the quantity of potential tCO_2e mitigation for all measures (except CHP), the gross quantity of MWh identified was multiplied by the average t CO_2e emissions from oil and natural gas (0.261 t CO_2e/MWh), provided by "Greenhouse

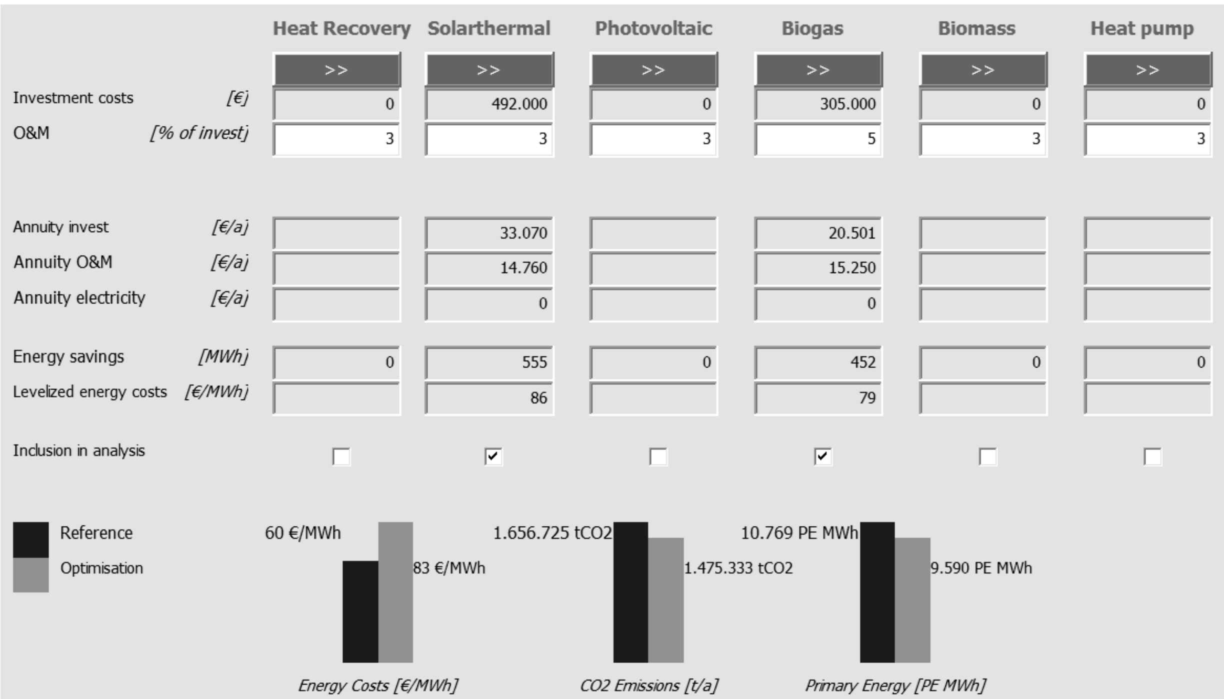

Figure 2. Economic evaluation of energy efficiency measures in the GREENFOODS branch concept.

Gas Conversion Factor Repository", since these energy savings directly reduce the amount of energy necessary to be burned or used, and thus CO_2e mitigated. This conversion factor was used as a fairly conservative estimation of the average potential savings, as most thermal energy was derived from oil and natural gas, and most measures provided a means of thermal energy savings and not electrical. The CHP recommended measure was slightly more difficult to estimate, as the identified amount of energy does not directly correlate to the tCO_2e savings since fuel is still burned to operate the machine. To calculate this, a comparison was done between the current electrical and fuel use per plant (and their respective tCO_2e emissions), to the new gas fired CHP plant, which was assumed to produce 40 % electrical and 50 % heat energy per unit input. As expected, the largest effect of this was in Poland, which currently uses coal for both electricity and heat, at a savings of about 0.326 tCO_2e/MWh. The opposite was seen in France. Since carbon emissions are already quite low due to nuclear produced electricity, converting to a CHP provides nearly no CO_2e reduction when converting from an oil boiler and actually produces more carbon emissions when converting from a gas boiler.

The audit results prove the very high potential of energy efficiency measures and the integration of renewables in the food and beverage industry and it is essential to mention that the suggested measures are in most cases easy to reach steps with a very high multiplicity in other SMEs of the sector.

In order to minimise the barriers for realisation by Best Practice Examples and to show that the suggested measures do have a very high impact on energy efficiency and the reduction of fossil CO_2e emission, based on the detailed audits and their evaluation 7 projects have been selected to be accompanied during the realisation of the identified measures within the project. It is essential to mention that no investment funding is included in the EU funded project. The measures are feasible based on the energy and cost savings and reach payback periods less than 7 years each. The companies have been supported in the detailed evaluation of the measures, the basic and detailed engineering, and discussion with realising companies and manufacturers and the acquisition of existing national funding systems in one case.

In all participating countries at least one realisation is accompanies, in Austria even 3 companies could be convinced to participate in this project phase. Furthermore, a strong focus has been set to cover different measures in order to be able to cover a broad range. In Austria two bakeries and one brewery are in the implementation phase covering process optimisation (e.g. full load operation of baking ovens) and system optimisation (waste heat recovery from cooling machines, baking ovens and wort cooling). Furthermore, in one bakery the use of ground water for cooling is realised and in the brewery solar thermal heat and a special ice storage are integrated in the existing energy supply system. In the UK a meat processing company will install a dusty condenser, solar thermal panels and an anaerobic digester supported by easy to reach measures as de-icing and insulating the pipes.

In Germany a meat processing company replaces an existing heavy-fuel steam boiler by an efficient gas-fired boiler and by this substitutes partially the steam distribution system to a hot water distribution system in order to reduce losses followed by a total re-design and reinstallation of the heat recovery network. In Spain a dairy installs an optimised heat recovery system including waste heat from chillers and the air compressors. Finally in Poland a dairy re-designs the energy supply system switching from a coal-fired to a gas-fired system and by this targeting a hot water distribution system and a re-design of several processes and their energy supply (switch from steam to hot water). In total it is envisaged to save more than 10,000 MWh/a final energy and more than 2,500 tCO_2e/a. Results, concepts and the evaluation will be available on the project website as well as in public reports by autumn 2015.

Virtual Energy Competence Centres

Within the project national Virtual Energy Competence Centres (VECC) have been established as one-stop-shop service centres offering the possibility of renting equipment, exchange of know-how, trainings, etc. and connected to a European network. It is known that especially SMEs face the lack of information and often just don't know where to get adequate information. By this the energy management will be supported covering the whole spectrum of services and guides them from the use of the branch concept to the implementation. The structure and the network of the chambers of commerce in the participating countries are supporting these activities. Thus it will be ensured that the target groups like the SMEs have a smooth support in the energy related issues. These efforts will tackle the current problem of lack of financing and boost investments in energy-efficiency and RES technologies in the food and beverage sector.

The Virtual Energy Competence Centres offer interested people of the project's target group information and support for steps to increase energy efficiency in the European food and beverage industry. They will be the first address/entry point for request related to energy in the food and beverage industry. In the beginning the energy competence centres function as networks for the target groups. Due to the fact that these centres are integrated within a European network of experts, the food and beverage industry should receive fast and high quality support. Contact data of the VECC can be found on the website of the project (www.green-foods.eu).

Conclusions

The target of the IEE project GREENFOODS was to develop a branch concept as an easy-to-use tool supported by information linked to the GREENFOODS WikiWeb as a basis for the identification and evaluation of energy efficiency measures and the integration of renewable energy in the European food and beverage industry. The target group of this branch concept are energy managers, consultants, etc. of SMEs, so it was essential to create a user-friendly interface. Furthermore, the approach was to support the user with information and default values as well as automatic background calculation so that minimal data is sufficient for the basic evaluation of the status quo and especially the identified optimisation measures. The GF BC will be further developed within the consortium and can be accessed from the VECC beyond the project.

Included steps are the definition of the existing energy supply (used energy carriers as natural gas, coal, electricity, etc. and their costs), the utilities (boilers, chiller, etc.) and the distribution system. Core part of the branch concept is the definition of the main energy consuming processes and unit operations supported by a wide range of information and background calculation in order to be able to perform the mass and energy balance based on minimal process parameters and information. As a next step the user is guided through potential process and technology optimisation closely linked to the compendium summarised in the GREENFOODS WikiWeb.

The system optimisation module leads the user to more energy efficiency where an optimised heat recovery system is suggested automatically based on an integrated Pinch algorithm. The user defines heat exchangers based on the suggestions and can evaluate the energy savings and resulting payback periods. Finally, the tool offers the evaluation of different renewable energy sources as solar thermal, photovoltaic, biomass, etc. in order to reduce fossil CO_2e emissions. In the overview section the final evaluation of all identified optimisation measures are summarised, once again linked to the GREENFOODS WikiWeb for more and detailed information.

The project has confirmed 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 beverage 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. 204 basic and 46 detailed energy audits have been carried out in the 5 partner countries and France. The project so far has shown the high interest of companies especially SMEs in all partner countries and the evaluation of the basic and the detailed audits highlighted the significant potential for energy savings, energy efficiency and the integration of renewables in the European food and beverage industry with in most cases little effort. This will be shown within the project based on at least 7 realization cases in companies of the relevant sub-sectors where the implementation of the identified measures is accompanied by the project partners. These measure cover easy process optimization steps (pipe insulating, de-icing), heat recovery from processes, chiller, compressors, etc. and the integration of renewable energy as solar thermal, biogas or efficient boilers. This will include basic and detailed engineering and the evaluation of the measures. These Best Practice Examples will help to reduce the barriers for realization and will push further investments in SMEs of the food and beverage industry.

Energy is an area where substantial savings can be made almost immediately with little or no capital investment, through simple housekeeping efforts. The lack of knowledge and available information often slow down the motivation and willingness of especially SMEs to invest in these measures. The offered branch concept, the linked compendium in the GREENFOODS WikiWeb, the identified optimization measures and the implemented concepts will further push these initiatives. All these steps are supported by the developed GREENFOODS training (envisaged to be part of EUREM) and the identified and evaluated funding and financing systems in all partner countries.

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Endnotes

This paper is based on the project website www.green-foods.eu and the corresponding work.

Acknowledgements

The sole responsibility for the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EACI nor the European Commission are responsible for any use that may be made of the information contained therein.

Co-funded by the Intelligent Energy Europe Programme of the European Union

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