Integrating renewable energy in the manufacturing processes

In a nutshell

Summary				
Best practice is to integrate the use of renewable energy into the production of food and beverages. Specifically, best practice is to go beyond the use of renewable electricity and to meet the heat demand of production processes (after implementing measures to improve energy efficiency and to reuse waste heat) with renewable heat (i.e. from solar heating systems, biomass or biogas) instead of non-renewable heat. The choice of the source of renewable heat depends on the local conditions, e.g. whether locally produced biomass and suitable feedstock for biogas production are available and/or if annual solar radiation is considerable.				
Target activities				
All food and beverage manufacturing	Processing of coffee	Manufacturing of olive oil	Manufacture of soft drinks	Manufacture of beer
Production of meat products	Manufacture of fruit juice	Cheese making	Manufacture of bread, biscuits and cakes	Manufacture of wine
Applicability				
The principle of this best practice is applicable to all food and beverage manufacturers. However, renewable heat systems rely on the availability of a suitable local renewable energy source and the heat and temperature requirements of the production processes. Additionally, retrofitting an already existing production facility with renewable heat requires a detailed technical feasibility analysis taking into account the current layout and the constraints of the current production processes.				
Environmental performance indicators				
• Percentage of the energy use of production facilities (heat and electricity separately) met by renewable energy sources (%) • Percentage of the energy use of production facilities (heat and electricity separately) met by on-site or nearby renewable energy sources (%)				
Benchmarks of excellence				
• On-site or nearby renewable heat energy generation for suitable manufacturing processes is implemented. • Process technologies are adapted to better match the supply of heat from renewables.				

Description

On-site and nearby generation of renewable energy can be integrated into the production processes of food and beverage manufacturing. The main renewable sources of energy can be divided into:

- Biomass – it can be used for the production of heat or in the combined production of heat and power
- Biogas generated from suitable organic material – it can be employed for generating heat and power.
- Solar thermal systems – they directly generate heat.
- On-site and nearby photovoltaic (PV), small scale wind turbines and other available renewable sources of energy – they can generate on-site electricity

Generation of electricity from renewable sources is already practised and relies on exploiting the locally available renewable energy source to partially or totally meet the electricity demand of the food and beverage manufacturers. The integration of renewable electricity into the existing energy supply is well established and it can be employed directly during the manufacturing of food and beverages, while the excess from production can instead be fed into the electric networks (e.g. national) under certain conditions.

Meanwhile, the integration of renewable heat into the production processes instead is in development but it has large potential in several subsectors of the food and beverage manufacturing sector as its integration is technically state of the art (wherever there is a heating demand, e.g. in beer, wine and cheese manufacturing). Depending on the sector (i.e. the amount of heat and the temperature needed) the renewable heat system (such as solar thermal) can be integrated differently. Firstly, as already highlighted in the best practice on deploying energy management for all products and/or operations, food and beverage manufacturers can identify where the reduction of heating demand by innovative low-energy technologies and the recovery of waste heat (heat integration) can be achieved. Secondly, in order to meet the heat demand which cannot be covered by waste heat, food and beverage manufacturers can employ renewable heat. To do so, they can identify which processes can be fed with renewable heat, replacing which non-renewable energy source and with which renewable heat technology, according to different temperature needs. PV electrical heating is one renewable heat option (e.g. solar). However, this option is associated with low efficiency (about 15%) compared to the solar heating systems which have an efficiency of about 60%. Therefore, PV electrical heating cannot be considered an alternative to solar heating.

Renewable heat can be generated from solar heating systems, biomass or biogas. The choice of the source of renewable heat is made depending on the local conditions, whether locally produced biomass and suitable feedstock for biogas production are available and/ or if annual solar radiation is considerable.

<u>Renewable solar heating systems</u>

Figure 1 shows how a solar heating system can be integrated into a general production process, and is also applicable for food and beverage manufacturing. There are two main options (Muster-Slawitsch *et al., 2014)*.

A) Integration at supply level: when high-temperature water networks or steam networks are present, even if the temperature needed at the point of use is considerably lower, the solar heat can be used for heating water at different points of the heat supply system:

- *Heating feed water in an open or partially open heating system:* In the case of open steam systems, the solar thermal system can be integrated just by adding one single heat exchanger to pre-heat cold demineralised replenishing water before process steam generation.

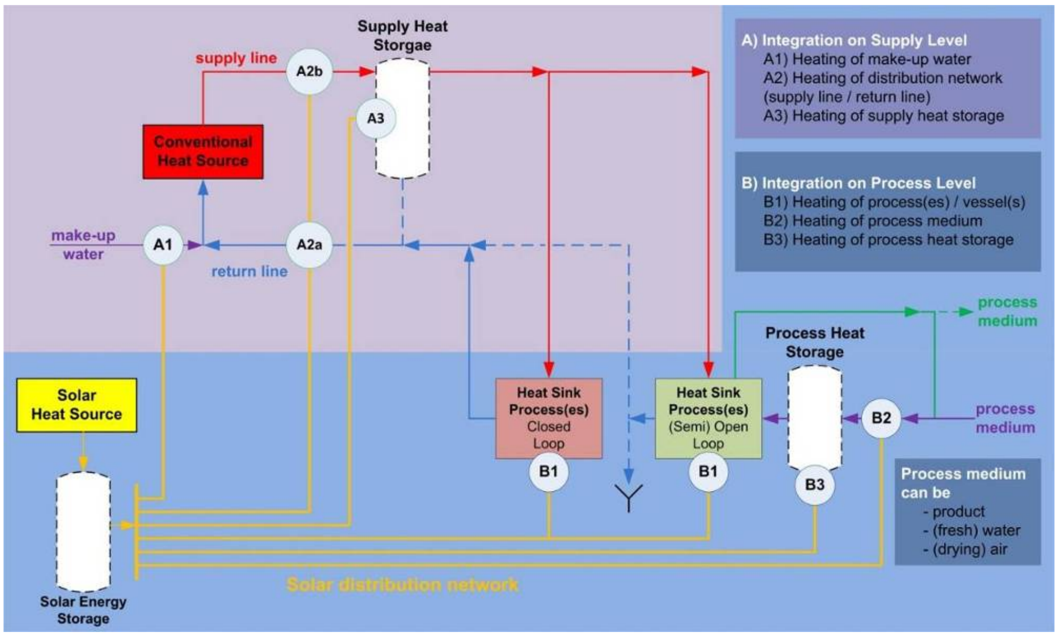
  In the case of partially open steam networks, the demineralised replenishing (make-up) water is usually mixed with the returning condensate before its degasification with steam, before it can enter the steam boiler. In this way, also less steam is required for degasification of the boiler feed water.

- *Heating feed water in a closed heating system:* The integration of solar heat in closed systems needs other solar technologies (e.g. concentrated, evacuated solar heating systems) because of the high temperatures of the condensate return flow.

B) Integration at process level: In this case, solar heat is used directly in process operations, process media or process heat storage.

Figure 1: Integration of solar heating into the industry at the process or supply level

Storage



*Source: (*Muster-Slawitsch *et al., 2014)*

The integration of solar heating in a production plant requires two main systems:

Solar thermal collectors

For temperatures below 100°C, the simplest design is the *flat-plate collector* depending on the location of production. The absorbers are black painted metal (copper, aluminium, steel) or plastic plates with a transparent cover placed on the collectors in order to reduce the convection heat losses. In areas where freezing temperatures are reached, a water/glycol mixture with anticorrosion additives is usually used as the heat-carrying fluid. In Europe, this type of collector is typically for hot water solar heating systems.

For temperatures above 100°C, *evacuated tube collectors or concentrating collectors* have been developed. Evacuated tube-collectors achieve a superior performance because the vacuum surrounding the absorber drastically cuts heat losses to the atmosphere. Outlet temperatures above 100°C are easily achieved with a higher conversion efficiency compared with a standard flat-plate collector (AEE INTEC, 2008).

Thermal storage

Thermal storage is generally required when the load profiles of heat availability and demand are different due to the fact that heat supply does not always meet heat demand or there is a need to store the excess heat provided by the solar heating system. The need for thermal storage in solar hot water systems is often short-term and, for this, water tank storage technology is mature and reliable. Thermal storage can also accumulate waste heat generated in certain production processes which can then be employed at a later stage.

The water storage tanks' capacity is calculated according to the supply and demand requirements and storage temperatures.

Renewable heat from biomass

In addition to solar heating systems, another source of renewable heat is biomass in the form of forest residues or waste streams from production. When biomass is available (e.g. in wineries which can use the pruning residues from the vineyard or in a food and beverage production site where forestry residues are easily available), renewable heat can be obtained from the combustion (in a grate furnace or fluidised bed) of the biomass in a heating or CHP system. Depending on the technology used, hot water or steam can be produced and integrated at different levels of the food and beverage production process, as for the heat produced by solar heating systems.

When a food and beverage manufacturer installs a biomass combustion plant, there are two technologies that can be used for the combustion process: fixed bed (including grate furnaces and underfeed stokers) or fluidised bed (Van Loo et al., 2012). The choice is based on the type of fuel and nominal capacity of the system. The following main elements are included in a biomass plant:

- Biomass storage area.
- Feeder: a conveyor system which feeds the furnace.
- Furnace: the furnace is the key element of the whole system and it should ensure proper biomass combustion. Its design affects the system efficiency and the characteristics of the biomass which can be used.
- Boiler: it should ensure an efficient exploitation of the radiant heat by the generation of hot water/steam. The boiler should be insulated to minimise undesirable heat losses and heat recovery systems can also be installed.
- Flue-gas cleaning system: the aim of the system is to reduce gaseous emissions and pollutants and particles emitted from the combustion.
- Ash disposal system.

Another option for employing biomass is the generation of biogas from suitable feedstock (e.g. citrus waste as presented in the best practice on value added use of fruit residues). Food and beverage manufacturers can use suitable organic residues from their production processes (solid waste and waste water) or from nearby sources to produce biogas in an anaerobic digestion plant. Gas produced can then be burned in a gas turbine for the generation of electricity and heat.

Renewable cold production

In some cases, when food and beverage manufacturing necessitates cooling, renewable heat (from solar, biomass or biogas or waste heat streams) can be used in an absorption process able to meet a part or all of the cooling demand of the process. An absorption process consists mainly of an evaporator, an absorber, a generator and a condenser and can use refrigerants such as NH_3 or CO_2 or combinations like NH_3/H_20 or H_2O/LiBr. A simplified scheme of the absorption process is presented in Figure 2.

Figure 2: Refrigeration by absorption process to meet cooling demand

.

Image not found or type unknown

Environmental benefits

The use of renewable energies for production processes primarily replaces fossil fuels (e.g. natural gas or coal), therefore emissions to air generated during their combustion are reduced.

In the case of solar heating, the efficiency is affected by the energy yield of the solar heating systems, which depends on its geographical location, the season and meteorological conditions, but also on the technology of the solar heating system. The solar radiation on the earth's surface has seasonal variations, which can be 1:2 in the tropics and up to 1:10 in the higher latitudes (IEA, 2010).

Side effects

There is no environmental cross media effect from implementing the use of renewable energy sources in the food and beverage production processes. For instance, the life-cycle environmental impact of solar thermal systems calculated in several studies is low, especially if collectors are constructed with recyclable materials. Ardente et al. (2005) calculated the energy and CO_2 payback times of solar thermal systems. These indicators resulted in very short payback times (less than two years) showing the great environmental convenience of this technology. Pehnt (2006) shows that the inputs of finite energy resources and emissions of greenhouse gases are extremely low compared with the conventional system. LCA results for renewable energy systems reveal that the use made of the material resources investigated (iron ore, bauxite) is less than or similar to that made by conventional systems.

Applicability

The principle of this best practice is applicable to all food and beverage manufacturers. However, renewable heat systems are applicable in new and existing food and beverage productions sites with a relevant heat demand. In the case of new plants, the integration of renewables can be part of the overall energy concept. Furthermore, the installation of the renewable heat systems should take into consideration factors such as heat and electricity demand, size of the available space for mounting solar panels/collectors (ground mounted/roof mounted), location of the company, solar collector technology or temperature at which the energy is needed (AEE INTEC, 2013 pers. comm.).

Technically there are no limitations regarding the implementation of renewable heat systems in food and beverage manufacturing. However, the technical feasibility should be analysed in each particular case, given that it will depend, among others, on existing boundary conditions, production process technology and heat distribution network characteristics (e.g. heat exchangers and hydraulic connections for solar heat). This is because it is highly recommended to carry out a preliminary analysis to assess the suitability of solar heat systems prior to decide if it is a possible option (SO-PRO project, 2010).

Preliminary analysis should include the analysis of existing boundary conditions to evaluate if there is any technical restriction (i.e. the available area for collectors or storage tanks, the distance from collector area to storage tanks, the distances from storage tanks to potential supported process, etc.). Moreover, the process characteristics and the heat distribution network should be analysed to determine the feasibility of coupling renewable heat systems with thermal processes and the compatibility with the heat distribution network. The technical suitability of renewable heat systems should also be considered when modifications in the production process, affecting either the thermal load or the load profile, or in the heat generation network are planned.

The applicability of renewable heat systems relies on the availability of the renewable energy source identified. For example, the choice of solar thermal collectors depends on the location of the production site as in southern European countries, for example, direct solar radiation is higher. There, concentrating collectors can achieve higher efficiencies while in central or northern European regions flat-plate or vacuum tube collectors are used. However, solar heating systems can be combined with other heat sources available in the installations, as is the case of biomass CHP.

Economics

The economics of the renewable energy system are based on analyses of the installation costs and the energy generated. Therefore they depend on local conditions and the type of renewable energy source.

In the case of solar thermal systems, the economic analysis is presented below (SO-PRO project, 2010).

- *Investment cost:* The costs of solar thermal process heat installations (i.e. including planning, collectors, piping, buffer storage and heat exchanger) in Europe range from EUR 180 to EUR 500 per m^2, depending on the technical and country-specific factors. (SO-PRO project, 2010). Data from the Hütt Brewery mention an investment of around EUR 95500 in a 155 m^2 solar thermal system and 10 m^3 buffer storage tank, which amounts to around EUR 600 per m^2 of collector surface area. The Neumarkter Lammsbräu plant made an investment of around EUR 32000 in a 72 m^2 of single-glazed air solar collector, which amounts to around EUR 444 per m^2 of collector surface area (without storage tank).

- *Maintenance cost:* The annual maintenance is approximately 2% of the total investment cost.
- *Life-time:* Properly planned and maintained solar thermal systems can have a lifetime of more than 20-25 years (Comunidad de Madrid, 2010).
- *Cost of fuel avoided* considering the efficiency of the fuel heat system and the fuel price rising.
- *Financing*. In some EU countries there exist national and regional subsidy programmes for funding solar thermal investments.

Table 4 shows cost figures (low and high) of various solar heating systems in industrial processes in southern/central Europe

Table 4: Examples of cost range (low and high) for solar heating systems in industrial process.

	Unit	Low cost	High cost
Typical system price (installed)	*EUR/system*	175000	400000
Collector area	*m^2*	500	500
Effective system price	*EUR/m^2*	350	800
System O&M Cost	*%*	2	2

System O&M Cost during lifetime	*EUR/m²*	140	320
Total cost- investment and O&M	*EUR/m²*	490	1120
Expected life time of the system	*year*	20	20

Source: (ESTTP, 2012)

Driving forces for implementation

The main driving force for integrating renewable energy systems into food and beverage manufacturing is the reduction in cost related with energy use in a scenario of continuous fuel price increases. Another related driving force is the reduction in CO_2 emissions, which allows the carbon footprint at corporate and product level to be reduced. Investments in solar energy improve the company's market image and can add value to certain special “green” products.

A third driving force is the increased security in energy supply achieved thanks to the use of renewable energies on site and nearby.

Reference organisations

- Miguel Torres S.A.: Winery which uses biomass for renewable heat and cold production.
- Lesa Dairy (Switzerland): Implemented solar heating system in their production process.
- Emmi Dairy (Switzerland): Implemented solar heating system in their production process.
- Göss Brewery (Austria): First solar brew relying only on renewable heat for mashing .
- Hütt Göss Brewery: Solar energy used to heat the cold brewing water from the supply tanks.
- Hofmühl Brewery: Supplies hot water to various process stages thanks to a solar heating system.
- Neumarkter Lammsbräu: Solar energy is used to preheat ambient air for the drying process in the malt house.
- Neuwith Brewery: The solar thermal energy is used for bottle washing, pasteurization and sterilization.

Literature

- AEE INTEC, 2013. Comments on preliminary drafts (Christoph Brunner personal Communication, October-December 2013).
- AEE INTEC. 2008. Process Heat Collectors. State of the Art within Task 33/IV. IEA SHC-Task 33 and SolarPACES-Task IV: Solar Heat for Industrial Processes. Ed.:Werner Weiss Matthias Rommel. 56pp. Published by AEE INTEC, Gleisdorf, Feldgasse 19, Austria, 2008
- Ardente F., Beccali G., Cellura M., Lo Brano V. 2005. Life cycle assessment of a solar thermal collector. Renewable Energy. Volume 30, Issue 7, June 2005, pp. 1031–1054.
- B. Muster-Slawitsch, B. Schmitt, P. Krummenacher, A. Helmke, S. Hess, I. Ben-Hassine and H. Schnitzer. 2014. Integration Guidelines, B. Muster-Slawitsch, Ed., IEA Task 49/IV

- BINE. 2010. Brewing beer with solar heat. [pdf] Publisher: FIZ Karlsruhe 76344 Eggenstein-Leopoldshafen, Germany. Available at: http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/projekt_1310_engl_internetx.pdf Accessed October 2013
- Celma A.R., Rojas S., López-Rodríguez F., 2007. Waste-to-energy possibilities for industrial olive and grape by-products in Extremadura. Biomass and Bioenergy, 31, pp. 522–534.
- Comunidad de Madrid and FENERCOM 2010. Manual técnico de energía solar para procesos industriales. [pdf] Madrid, 2010. Available at: www.fenercom.com Accessed September 2013
- Cotana F. and Cavalaglio G., 2008. Recovery of vineyards pruning residues in an agro-energetic chain. 16th European Biomass Conference & Exhibition, Valencia, Spain, June 2 - 6.
- Cotana F., Cavalaglio G., Rinaldi S., 2009. Energy and environmental performance of a polygeneration plant from vineyard pruning residues. 17th European Biomass Conference & Exhibition, Hamburg, Germany, June 29 - July 3.
- ESTTP (European Technology Platform on Renewable Heating and Cooling). 2012. [pdf] Strategic Research Priorities for Solar Thermal Technology "Available at: www.rhc-platform.org/structure/solar-thermal-technology-panel/downloads Accessed October 2013
- European Commission. 2006. Reference Document on Best Available Techniques in the Food and Drink sector. [pdf]. August 2006. Available at: http://eippcb.jrc.ec.europa.eu/reference/ Accessed September 2013
- Fernández R.G., Pizarro García C., Gutiérrez Lavín A., Bueno de las Heras J.L., 2012. Study of main combustion characteristics for biomass fuels used in boilers. Fuel Processing Technology, 103, pp. 16–26.
- Gómez A., Zubizarreta J., Rodrigues M., Dopazo C., Fueyo N., 2010. An estimation of the energy potential of agro-industrial residues in Spain. Resources; Conservation and Recycling, 54, pp. 972–984.
- IEA – International Energy Agency, 2010. The Potential of Solar Thermal Technologies in a Sustainable Energy Future.
- Marcelescu C, Ciuta S. Wine industry waste thermal processing for derived fuel properties improvement. Renewable Energy, 2013, vol. 57, issue C, pages 645-652.
- Mauthner F., Hubmann M., Brunner C., Fink C. 2014. Manufacture of malt and beer with low temperature solar process heat. Energy Procedia 48, 1188 – 1193.
- Mescalchin E, Cristoforetti A, Magagnotti N, Silvestri S, Spinelli R. 2009. Utilizzo dei residui di potatura della vite a fini energetici. Fondazione Edmund Mach.
- MIGUEL TORRES, S.A. Description and Technical specifications on the system for heat and cold production from biomass placed in Miguel Torres winery (Personal communication, 2013).
- Muster-Slawitsch B., Weiss W, Schnitzer H., Brunner C. 2011. The green brewery concept - Energy efficiency and the use of renewable energy sources in breweries. Applied Thermal Engineering 31, pp. 2123-2134
- Pehnt M. 2006. Dynamic life cycle assessment (LCA) of renewable energy technologies. Renewable Energy. Volume 31, Issue 1, January 2006, Pages 55–71.
- Scheller L., Michel R., Funk U. (2008), Efficient use of energy in the brewhouse, MBAA TQ, 45(3), 263-267.
- Solar Heat for Industrial Processes (SHIP) database. Available at: www.ship-plants.info Accessed October 2014
- SOLÉ L., S.A. Description and Technical specifications on the system for heat and cold production from biomass placed in Miguel Torres winery (Personal communication, 2 June 2013).
- SO-PRO - Solar Process Heat Project 2010. Solar Process Heat Generation: Guide to Solar Thermal System Design for Selected Industrial Processes. [pdf] Published by: O.Ö. Energiesparverband. Available at: http://www.solar-process-heat.eu/fileadmin/redakteure/So-Pro/Work_Packages/WP3/Planning_Guideline/Techn_Bro_SoPro_en-fin.pdf Accessed May 2015

- Spinelli R., Nati C., Pari L., Mescalchin E., Magagnotti N., 2012. Production and quality of biomass fuels from mechanized collection and processing of vineyard pruning residues. Applied Energy, 89, pp. 374–379.
- Tecnolimpia, 2009. Guía de Valorización de Residuos Sólidos Vitivinícolas. Programa de Tecnologías Limpias para Empresas de Menor Tamaño (Tecnolimpia). Consejo Nacional de Producción Limpia de Chile
- The Brewers of Europe. 2012. The Environmental Performance of the European Brewing Sector. Available at: http://www.brewersofeurope.org/uploads/mycms-files/documents/archives/publications/2012/envi_report_2012_web.pdf Accessed May 2015
- Toscano G., Riva G., Duca D., Foppa Pedretti E., Corinaldesi F., Rossini G., 2013. Analysis of the characteristics of the residues of the wine production chain finalized to their industrial and energy recovery. Biomass and Bioenergy, 55, pp. 260-267.
- Van Loo S., Koppejan J., 2012. The Handbook of Biomass Combustion and Co-firing. Earthscan publisher. 464 pages.
- Velázquez-Martí B., Fernández-González E., López-Cortés I., Salazar-Hernández D.M., 2011. Quantification of the residual biomass obtained from pruning of vineyards in Mediterranean area. Biomass and Bioenergy, 35, pp. 3453-3464.