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SUSMILK; Re-design of the dairy industry for sustainable milk processing

Industrial food production is necessary to serve human needs. In Europe, the dairy industry accounts for 13% turnover in the entire food and beverage industry. In order to guarantee a persistent competitive dairy industry in the future it is necessary that this industry foster resource efficient food processing. Therefore, a redesign of dairies needs to be initiated in order to save water and energy, and to implement an increasing use of renewable energy resources. In principle, technologies for energy and water saving are available, but they lack adaptions and developments to meet the requirements in a dairy. So far dairies have been built under the constraint of using fossil fuels. Thus, the implementation of innovative technologies is now a key to save CO_2-emissions for the next decades. The system change is overdue and can only be accomplished by novel suitable technologies. The aim of SUSMILK is to deliver a toolbox of such suitable technologies and concepts. The single aspects of SUSMILK will be explained in more detail within this article.

The SUSMILK project is a running FP7 project that is funded in the call KBBE.2013.2.5-02: 'Saving water and energy for resource-efficient food processing' within Theme two: 'Food, agriculture and fisheries, and biotechnology' of the European Commission. The project started on the 1st November 2013 and will last three years. 21 partners (seven from research and development, four from industry, five dairies, five for assessment and dissemination tasks; thereof eight small and medium companies) from nine different countries work in SUSMILK together. **Figure 1** (page 45) gives an overview.

Within SUSMILK milk production and consumer behaviour is not considered. Thus only milk transport and milk processing lie within the boundaries of SUSMILK. This is illustrated by **Figure 2** (page 45).

Milk processing is characterised by a large variety of processes to obtain different products like pasteurised milk, cream, yoghurt, curd, cheese, etc. But all steps of milk processing have in common is that they require several heating and cooling steps. In addition, cleaning by CIP (clean-in-place) processes is mandatory at least on a daily basis. Thereby, a lot of wastewater is produced and chemicals are consumed. Within the SUSMILK boundaries, three different pillars have been identified that include large potential saving in energy and/or water. These three pillars cover the product (milk) processing itself, energy converting and generating technologies and finally waste (water) processing technologies. They encompass development and analysis of different aspects for the dairy. The outcomes serve as single stand-alone modules, but with the option to combine them altogether. The collaboration of all technologies and concepts or reasonable combinations thereof will be evaluated in a green dairy model which is being developed in SUSMILK. At project completion the three assessed pillars with the single technologies will be available as online tools for dairies to enable a quick assessment of their optimisation potential.

Figure 1: Overview of SUSMILK partners

Pillar 1: Product processing

The pillar of product processing covers pre-concentration of milk as a measure to save water and energy. The biggest savings are expected within the milk transport. 140 million tons of raw milk is transported to dairies within the EU for further processing with an average transportation distance of 100km for each litre of milk. But milk has only an average dry substance content of 13% (see **Figure 3**). By removing a significant amount of water directly at the farm or at milk collection points the number of trucks could be reduced significantly. This immediately saves on transportation emissions and also cleaning of trucks. Within the proposed technology of SUSMILK, it is expected that approx. three out of four trucks could be saved, because the milk will have been concentrated. This also offers the possibility to reduce the tank sizes and machines in the dairy, and to increase the efficiency of production processes for cheese, yoghurt and other such products. Furthermore, concentrated milk itself is increasingly becoming a tradeable product.

> "The pillar of product processing covers pre-concentration of milk as a measure to save water and energy"

Concentrated milk is already a tradeable product; the difference in SUSMILK is that here the milk is concentrated with membranes instead of the generally used evaporation technique. This is to avoid several disadvantages related to evaporation including the fact that the milk quality is affected when a temperature of 70°C is exceeded. Furthermore, evaporation consumes large amounts of energy and is cost intensive. Hence, SUSMILK will take advantage of the application of membrane technology with just 40°C. The membrane technology may further selectively concentrate certain components of the milk by different stages of filtration techniques. Here, micro filtration (MF), ultrafiltration (UF), nano filtration (NF) and reverse osmosis (RO) may be combined.

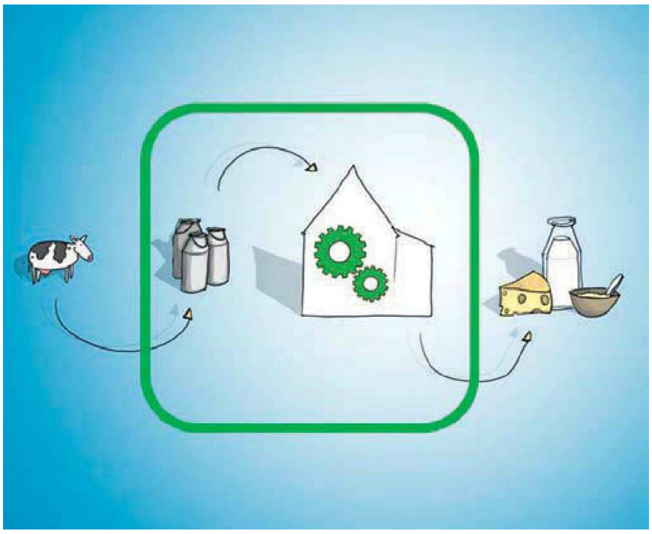

Figure 2: Boundaries of SUSMILK (indicated by the green box)

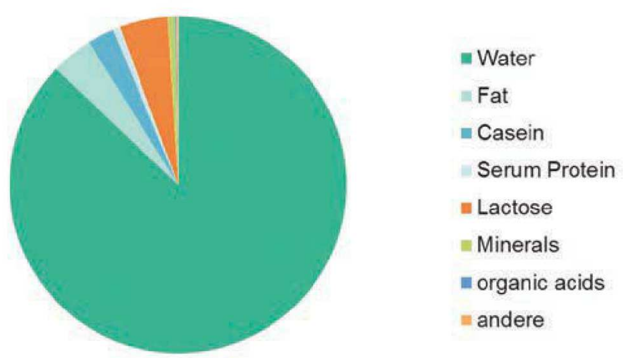

Figure 3: Composition of milk

A redesign of dairies needs to be initiated in order to save water and energy

A preferred option would be to combine UF which concentrates the proteins in the milk, followed by a subsequent NF or RO stage for the UF permeate (Figure 4). The concentrates of both stages can be used separately or could be mixed to receive another suitable concentrate from this process.

A prototype has been developed in SUSMILK which will be tested in the final phase of the project under realistic conditions in a dairy. Compared to existing processes it is innovative that higher concentration factors with 3.6 can be achieved on average.

Pillar 2: Energy converting/generating technologies

The pillar of energy (converting/generating) technologies, that are adapted in SUSMILK, span heat pumps, absorption chillers, and solar heat technology in combination with biomass heating for a 24h supply of heat. Heat pumps and absorption chillers can utilize waste heat in a dairy. A heat pump can raise waste heat up to a temperature level that can be used in a dairy. The SUSMILK processes achieve output temperature on an industrial level. Thus, the developed heat pump is not comparable to heat pumps in households. This new heat pump may deliver a temperature of up to 120°C. It is hence suitable to substitute steam, which consumes a lot of energy when generated. The heat pump can run by using waste heat from a cogeneration unit. Another possibility to utilise waste heat is to feed it into an absorption chiller which then delivers a cold stream. Cooling also normally requires high energy demands. By substituting a part of this with an absorption chiller the dairy could be more resource efficient. A 50kW unit will be developed in SUSMILK. This particular performance level is currently not available on the market and could thus serve so far for unused niches in the dairy. The new absorption chiller as well as the new heat pump is going to be tested in the final phase of SUSMILK.

> “The developed heat pump is not comparable to heat pumps in households”

Another technology of SUSMILK is a combined solar heat and biomass system that can supply the dairy continuously with heat. This could make the dairy principally independent from fossil fuels. In one of the SUSMILK dairies the system is used for three internal processes. First demonstration results show that approx. 27% of the total produced energy can be delivered by solar heat panels. The remaining 73% are generated by a biomass pellet boiler (Figure 5). The washing street for boxes and moulds and the climatisation of the production hall was totally changed to renewable energy.

Figure 6 (page 47) shows how much greenhouse gas emissions (GHG) have been saved with the solar heat and biomass system compared to a conventional Diesel boiler. Installing such systems widely

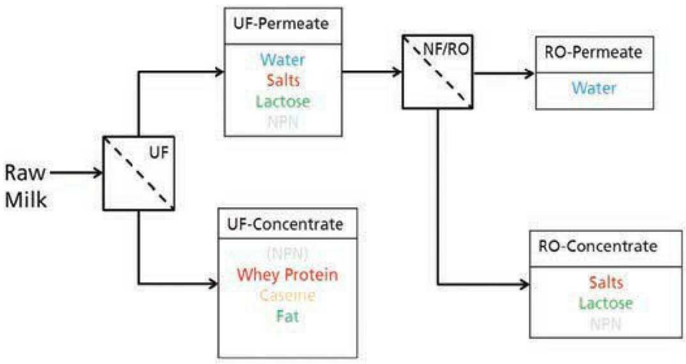

Figure 4: Suitable membrane process scheme to get milk concentrates

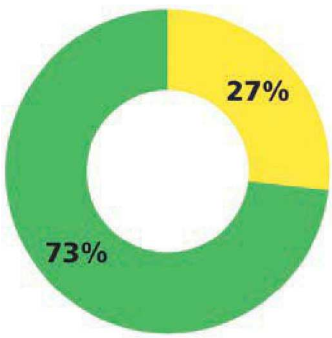

Figure 5: Total energy production distribution (green = biomass, yellow = solar)

in Europe could significantly contribute to reduce the overall CO_2 emissions. In addition, this system is more cost-effective than using fossil fuels. The dairy becomes subsequently independent from energy prices for fossil fuels, which enhances its competitiveness.

Moreover, new solar heat panels developed in SUSMILK could principally deliver a temperature output of 150°C. This offers the possibility to use them also for steam generation in a dairy.

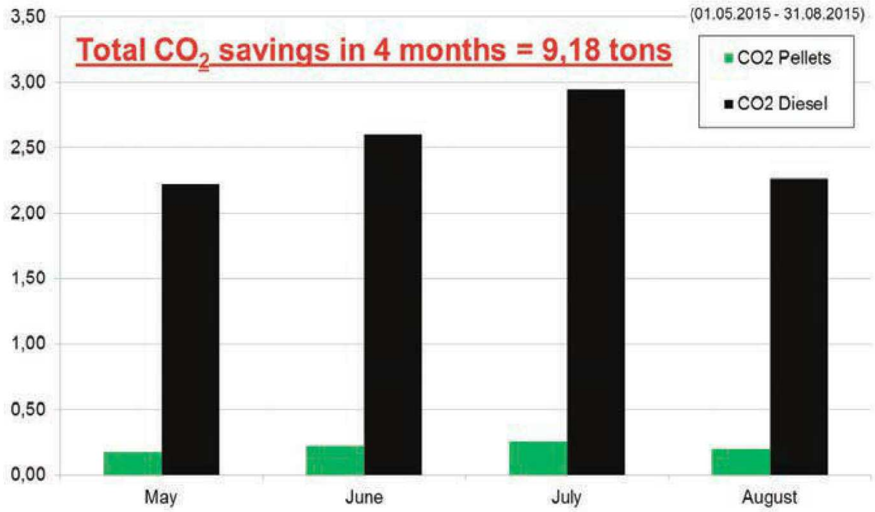

Figure 6: Calculated GHG (CO_2) emissions of fuels

Pillar 3: Waste (water) processing

The third pillar of SUSMILK focuses on improvements in the waste water handling and management. Here, two main strategies are analysed. The first one relates to recycling water and chemicals of clean-in-place (CIP) processes. The second strategy, maybe even combined with the former, analyses waste water from dairies as a potential raw material source for biogas, bioethanol or lactic acid production.

CIP processes are needed at least on a daily basis to clean machines and pipes. Therefore several different chemicals are required to achieve a sufficient cleaning. Bases are indispensable to remove fats and sugar, acids for displacement of mineral deposits and detergents for protein removal. CIP processes work generally in the same way, but employ various chemicals depending on the manufactured products. An inherent characteristic of CIP systems is that the washing solutions are concentrated and reused to a certain extent before they are disposed. But this disposal also means that chemicals are lost and that new chemicals have to be added to maintain the CIP efficiency. In SUSMILK it is analysed if a recovery of chemicals with membrane technology could be realised and if it is economically feasible. The results show that it is possible to retain chemicals, but the economic feasibility is highly dependent on the prices of the used chemicals. Test calculations reveal that the ROI is highly dependent on the amount of processed CIP water. The ROI is approx. five years for small dairies (less than 50t of processed milk/d), 1.5 – 2 years for medium dairies (50 – 300t of milk/d) and six months for big dairies (over 300t of milk/d).

The second strategy in terms of producing valuable products such as lactic acid, biogas and bioethanol is currently still ongoing. Preliminary results disclose that specific types of waste water have a big potential as raw material source. An overall concept for dairy waste water treatment is being worked on now and as a result guidelines for dairy waste water treatment will be published by the end of April 2016. This guideline will be also available through the SUSMILK website (www.susmilk.com).

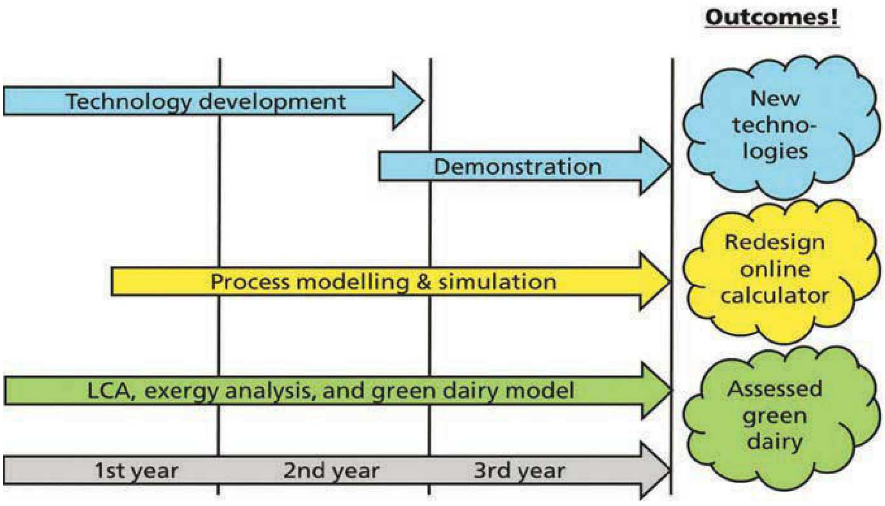

Figure 7: Overview about SUSMILK goals and outcomes including a timeline

Green Dairy Model and online tools:

All aforementioned methods and concepts will be assessed and evaluated. The developed technologies are going to be installed and tested in the SUSMILK partner dairies, in order to obtain real life data. All modules of SUSMILK will be theoretically summarized in a Green Dairy model. This model will deliver an overview about sustainable solutions with regard to re-designing existing dairies. By the middle of 2016, the SUSMILK website will provide special online tools helping the dairies to derive benefit from this useful model. These online tools will allow quick assessments for any optimisation potential related to water and energy savings by implementing one or more of the proposed measures. The aims, ideas and visions of SUSMILK are summarised in **Figure 7** containing also a timeline (SUSMILK will end in October 2016). SUSMILK will eventually lead to a more resource efficient food production in Europe.

About the Author

Dr. Christoph Glasner finished his studies of mechanical engineering with a specialisation in process engineering in 2005. He got his PhD in the field of oil filtration with several separation/membrane technologies in 2009. The PhD thesis was carried out within the framework of two FP6 projects (TRANSMAN, SAFELUBE). Since 2009 he is senior scientist at the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT (Germany) in the field of biomass conversion and water treatment/management in combination with heat recovery. Currently, he coordinates two European projects in the area of food processing (FP7 – SUSMILK; ERA-Net SUSFOOD – BioSuck).