EnReMilk

Publishable Summary 2nd Periodic Report

Project Title: Integrated engineering approach validating reduced water and energy consumption in milk processing for wider food supply chain replication

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Name of the scientific representative of the project's coordinator and organisation:	Dr. Ana Lucia Vasquez FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V
Tel:	+49 711 970 3669
Fax:	+49 711 970 3994
E-Mail:	analucia.vasquez@igb.fraunhofer.de
Project website address:	http://www.enremilk.eu/

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Project context and general objectives

The food and drink industry is one of the major industrial sectors worldwide and it is known as a heavy user of water and energy. With 13% of the total European Food and Drink industry turnover in 2012, the dairy industry is considered one of the most important sub-sectors as well as and one of the highest energy and water consumers, both overall and per unit production: up to 6.47 MWh (5.55 MWhth and 0.92 MWhel) and an average of 2 m^3 of water per tonne processed milk. EC studies have reported that more than 80% of energy consumed in dairies is related to process heating, pasteurization, sterilization, drying and cleaning operations and that 98 % of the fresh water used is of drinking water quality.

Increasing awareness of the environmental implications of dairy industry's activities has resulted in several initiatives on long-term sustainability strategies to reduce environmental impacts. Dairy companies have recognized the potential economic benefits that can be achieved by implementing water and energy saving strategies as well as waste and waste water management systems. Accordingly, it has been acknowledged that significant saving achievements require investments in technology development and innovation to deliver substantial improvements

The EnReMilk project addresses the need to reduce energy and water consumption along the entire supply chain of the dairy industry. Because more that 70% of wastewater and over 90% of energy consumed along the entire supply chain are generated at the dairy processing plant, this project focuses on milk processing operations. The aim is to achieve significant water (30 %) and energy (20 %) savings in representative dairy processing case studies, namely mozzarella and milk powder production, replicable in both SME and larger dairies. These savings will be validated against a consumption baseline of existing operations, being validated in model simulations and in physical trials. Emerging and novel engineering technologies will be optimised and implemented in key dairy unit operations to provide significant and simultaneous saving of water and energy, while ensuring food quality and safety. The project aims will be achieved by:

- Identifying and monitoring water and energy consumption patterns of along the entire supply chain,
- Modelling and simulations to evaluate savings potential of a vast array of technological scenarios,
- Optimizing selected technologies in case studies with highest water and energy saving potential,
- Optimizing resource supply and use strategies, and
- Ensuring benefits for food producers and equipment manufacturers, while reconciling sustainability imperatives.

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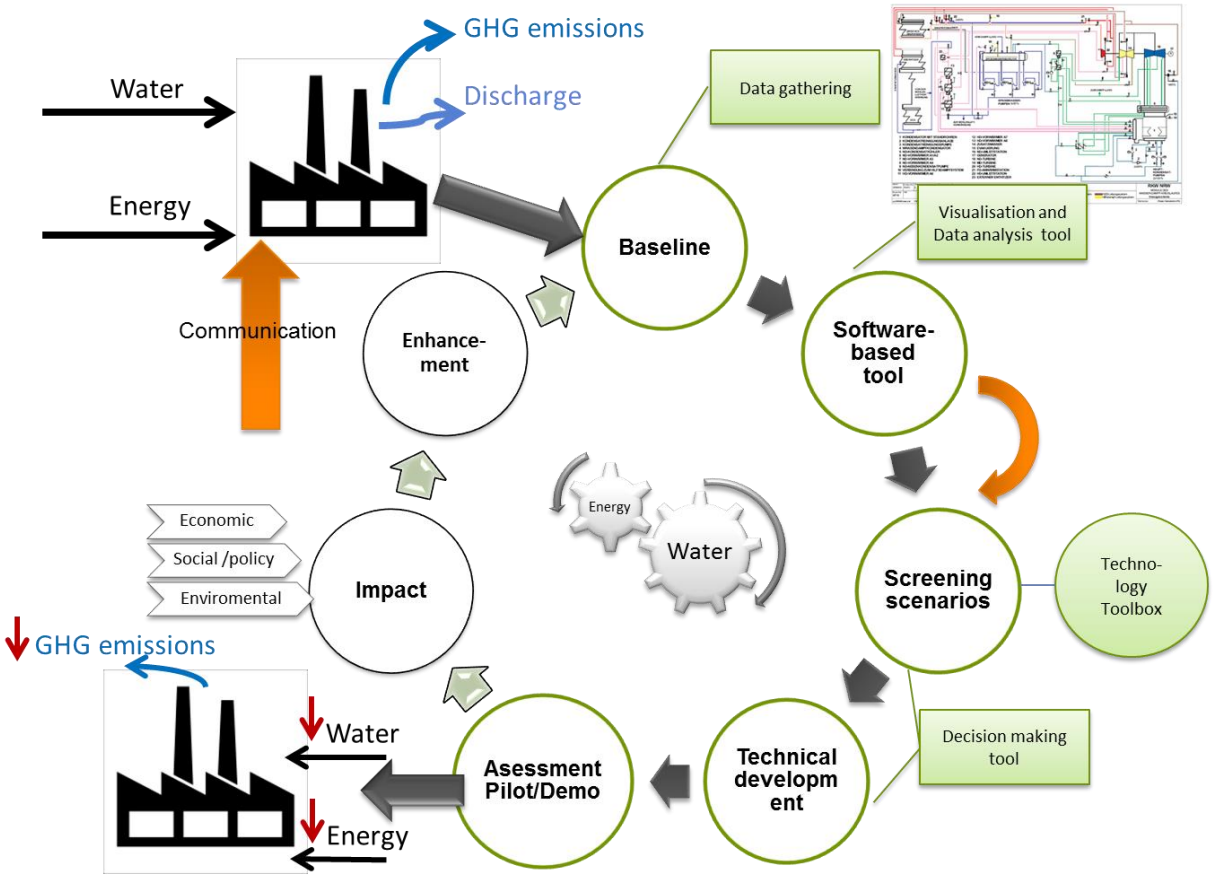
The EnReMilk project will ensure a smooth translation into practical implementation, providing an innovation-driven increase in the competitiveness of the EU dairy sector. In addition, this project will ensure that engineering innovations are verified as environmentally sustainable, economically viable and socially responsible, and that food quality and safety is not compromised.

Project overview and specific objectives

The EnReMilk consortium consists of fifteen partners from six different EU-27 states, six high-ranking research institutions, seven SMEs and two large enterprises. They provide complementary and non-overlapping expertise capable of delivering the project objectives and enabling post project the translation of research results into practical industry wide implementation. This project will deliver a technology platform to enable energy and water savings in two representative dairy sub-sectors: Mozzarella and Milk Powder production. An overview of main project activities is shown in Figure 1.

Figure 1: Overview of EnReMilk project activities



Activities comprise the gathering of existing data to create a baseline of the water and energy consumption in the selected case studies. For a systematic data collation and further analysis, a software-based tool is required. The latter enables process modelling

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to evaluate technological scenarios considering the use of novel technologies to replace current process operations at previously identified "hot spots" (in terms of water and energy consumption). Process modelling is based on knowledge-based assumptions and aims at identifying savings potential of a specific technology in a defined context (process step in a production line). Accordingly, technology requirements are specified for the process and the specific conditions defined by each case study. This is a pre-requisite to validate the performance of the selected technologies for the specific process operations, which have been clustered in microbial stabilization, heating, texturizing and drying operations. Furthermore, investigation of a wide array of process effluent treatment and water reuse technologies is conducted. Studies are initially conducted at laboratory level for initial verification, followed by pilot studies for process assessment and implementation of required adaptations. Pilot studies should confirm the performance of the technology for the desired application and enable decision making in terms of further its actual potential for industrial implementation. Consequently, only most suitable technologies and applications will be further demonstrated at industrial sites. Decision-making is not only based on technological assessment but most importantly on the economic validation of them. Moreover, innovations are only justified if economic, environmental and social impacts of the introduction of new technologies are interlinked and assessed in their whole extension.

Description of work performed

WP2 Process Modelling:

During this work package a vast array of technological scenarios to optimise water and energy consumption through the incorporation of novel engineering approaches in the production of mozzarella and milk powder is evaluated through modelling. A software-based tool to create simulation models computing water and energy consumption in two representative dairy processing operations, mozzarella and spray-dried milk production was employed: this tool enabled the innovative water and energy saving technology benefits to be simulated prior to validation in pilot and demonstration activities, allowing iterative enhancements. This work package was completed during the first reporting period.The main results are:

- Baseline scenarios were specified in terms of input, output, and production process
- Mass and energy flows have been characterized, the results of which provided the structure for the database to be developed;
- A database has been developed and filled with data provided by data obtainedfrom sampling points located at case-studies facilities (task 3.1).
- A multi-level hierarchical structure of the production process, including water and energy flows at three aggregation levels, (the highest level being a specific process e.g. pasteurize liquid), was designed;

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- E-sankey was selected as a suitable tool for visualization of mass and energy flows.
- Five alternative scenarios in addition to the baseline scenarios were defined for the milk powder and mozzarella. Each of them was quantitatively modelled and analyzed for its possible energy and water saving potential relative to the baseline scenario.
- Modelling results of the baseline and alternative scenarios were validated, and possible consequences other than energy and water consumption (e.g. economic performance, labour conditions, air pollution, product quality, etc.) were identified.

WP3 Consumption Monitoring and Process Management:

During this work package, a baseline consumption of water and energy of currently employed State-of-the-Art technologies is recorded. A smart metering methodology for water and energy consumption (hardware and software) is developed and implemented. Information will be used to develop a global process management strategy that allows optimizing the consumption of water and energy and to conduct further comparisons with proposed technology innovations. This work package was completed during the first reporting period (June 2015). The main results are:

- Baseline energy and water consumption assessment of milk and mozzarella process were completed.
- Installation of new sensors that allows monitoring the key points for the baseline energy and water consumption was finalized.
- The software tool was developed and successfully applied to both milk and mozzarella processes allowing assessment of the baseline energy/water consumption as well as further comparisons at a later stage.
- A software tool for global process management was developed and successfully applied to the milk and mozzarella processes.

WP4 Milk Processing:

During this work package, the various unit operations and processing conditions identified through the simulations are practically replicated on a laboratory scale. The quality of the outputs is assessed and the water and energy consumption verified. The optimal process parameters and design configurations for a non-thermal microbial stabilization process (Pressure Change Technology, PCT), a microwave pre-heating system for milk concentrates, and a single-screw extruder for plasticization and texturisation of pasta filata type cheese**.** This practical work will feed back and enhance the model developed in WP2. This work package was completed during the second reporting period (December 2016). The main results are:

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Pressure Change Technology

- Screening experiments in existing laboratory batch unit were conducted with focus on Lipase inactivation. Lipases are enzymes present in the milk in sufficient amount (Bovine milk contains 1-2 mg milk LPL/litre) to cause extensive fat hydrolysis and potential marked off flavour. A significant inactivation (>40%) was achieved
- A continuous lab-setup unit was adapted to the requirements of the project and, installed for configuration trials for milk pasteurization and used for further screening and optimization experiments
- Several tests on resistance of different microorganisms and inactivation of enzymes under different conditions (retention time, pressure, gas type, temperature) based on design of experiment approach were developed.
- Validation and optimization of the PCT treatment → physical, chemical and microbiological stability for at least 20 day cold storage was achieved. Shelf life remained similar to thermal pasteurization, fulfilling the EC regulations.
- Requirements for upscaling and validation at pilot scale have been derived

Microwave Heating

- A novel continuous microwave pasteurization system, was adapted for its use as a pre-heating system prior to spray-drying. The technology has been integrated in the factory of Schwarzwaldmilch to be able to run trials on-site. The unit has a capacity up 600 L/h.
- An experimental design for selected products - quark and yogurt- preheating was setup including the parameters microwave power, temperature of inflowing product and flow rate of product. The holding time is determined by the volume of the holding tube and the flow rate.
- Time-temperature raising profiles were monitored and compared with the conventional steam heating. The main finding here is related to the heating performance which was clearly enhanced with the microwave heating. This fact can be explained due to the rapid, volumetric and targeted heating of food products allowed by the microwave heating.
- In terms of process performance the following was confirmed:
    - No significant fouling after microwave heating
    - Rapid, volumetric and targeted heating of food products
    - Very accurate temperature targets
    - Quark powder production throughput was increased by 11% due to the controlled pre-heating.
    - Reduction of CIP cycles (water, electricity, chemicals), saving 75% of CIP (clean in place) consumption for quark and 83% for yogurt. This enables longer production periods between CIP cleaning
    - Overall increase of process efficiency
- In terms of product quality, the following was confirmed:

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- homogenous quality of product after MW heating and subsequent spray-drying
- low level of meso- and thermophile spores

- Based on experiments, modifications of the unit to optimize performance have been delineated and will be implemented in WP7

Picture 1: Microwave heating unit

Single-screw extruder

- Key quality parameters, including dry matter, fat content and optical appearance of the mozzarella were evaluated; first assessment and sensory tests revealed that a good quality of mozzarella was obtained.
- UHOH conducted a series of experiments with the lab-scale single screw extruder. The primary aim of the experiments was to optimize the kneading section, by testing different kneading geometries, residence time and optimal process temperature to obtain adequate product composition and texture.
- Adaptation requirements and implementation of various configurations were evaluated for upscaling. Differently designed screws were built-up and tested in order to optimize the texturization performance

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Picture 2: Production of Mozzarella using single-screw extruder at laboratory level

Further results

- The key variables to be monitored were defined for each technology and a database for data collection and exchange was created
- Mass and energy balance of the process have been collected and updated during this task. E-Sankey Diagrams for visualization have been uploaded to the internal project database
- A preliminary consumption interface system was defined, according to the variables and process parameters identified during laboratory trials.

The findings of this work package are being used to develop corresponding pilot-scale units for WP7.

WP5 Process Effluent Treatment and Water Reuse:

This work package aims to develop an efficient and self-sustained wastewater treatment strategy to close the water cycle by integrating water and management, enabling water to be reused within the dairy production process "fit-to-purpose" (e.g. cleaning operations) and residues to be extracted for further valorisation (e.g. whey proteins). It also aims to ensure that the process effluent treatment and water reuse concept is designed according to requirements of SME and larger dairy operations. As a result of this WP activities, outcome streams from mozzarella and milk powder production collected and characterized. Strategy to treat and recycle selected streams has been elaborated. The most relevant (waste-) water streams from Mozzarella production at G.C.M. were identified according to the following criteria: (i) Amount of wastewater, (ii) current costs for disposal, (iii) potential for re-use as process, drinking water, or for cleaning operations (iv) potential for recovery of valuable materials. Clearly significant results are:

- In mozzarella production a) pre-cooling water which represents about 70% of the total water effluents and; b) the "scotta" effluent from ricotta and cream

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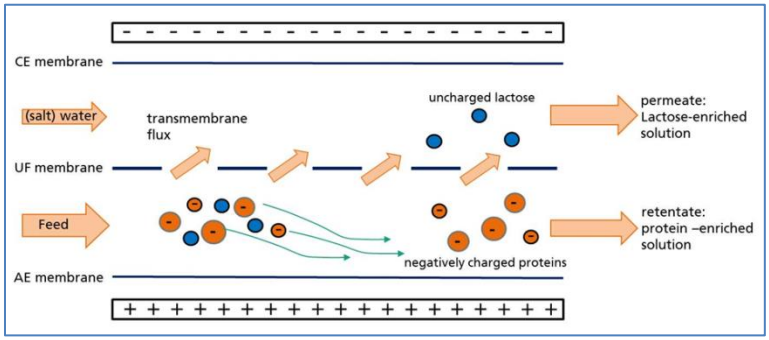
production which is a potential source of valuable protein solutions were identified as most relevant streams to be treated

- Recover whey proteins from "scotta" using electro membrane filtration (EMF) technology: Most promising EMF configuration for the separation of proteins and lactose was identified
- "Pre-cooling was treated using electro-oxidation (EO) technology .The target COD values for recirculation into the process (e.g. for cleaning operations) can be reached with EO. Furthermore, it was confirmed that EO treatment for COD removal is attractive for the case where disposal without treatment is not possible.
- The key variables to be monitored were defined for each technology and a database for data collection and exchange was created
- Mass and energy balance of the process have been collected and updated during this task. E-Sankey Diagrams for visualization have been uploaded to the internal project database
- A preliminary consumption interface system was defined, according to the variables and process parameters identified during laboratory trials.

The findings of this work package are being used to develop corresponding pilot-scale units for WP7.

Figure 2: EMF system for the recovery of protein and lactose-enriched solutions



WP6 Drying:

During this work package the optimal process parameters and design configurations for superheated steam drying (SHSD) and/or inert drying with nitrogen of concentrated milk, enabling the targeted residual moisture content of below 5% and lowest energy and water consumption are defined. An equivalent product quality (microbial and organoleptic) to that achievable by using spray drying technology with hot air will be verified. This practical work will feed back to WP2 for enhancing the process model and to WP3 for refining consumption monitoring. Significant results are:

- Closed-loop inert drying with nitrogen (CL): experiments based on the design of experiments (DoE) approach were conducted at the University of Hohenheim

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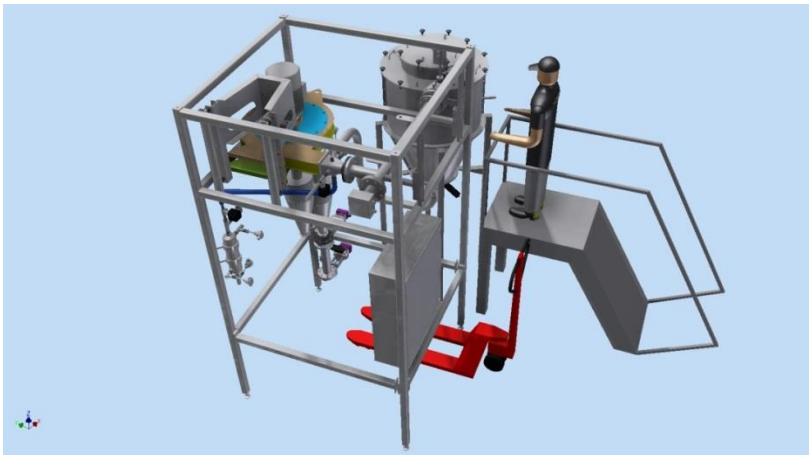
- Necessary modifications on the laboratory-scale CL drying unit were undertaken to achieve the desired product quality attributes
- A chamber for spray drying of concentrated milk with superheated steam at atmospheric pressure was designed and built
- Trials have been conducted and results compared to a standard powder provided by S-Milch
- Data acquisition system to evaluate energy consumption have been implemented
- Technology scenarios have been configured based on key technology parameters using Sankey-diagrams for mass and energy flows to enable subsequent data collection during validation studies at pilot level.

Figure 3: Laboratory SHS- Spray-Dying Unit



The findings of this work package are being used to enhance the design of the units for WP7.

WP7 Pilot study:

This is an ongoing task. Pilot units have been up-scaled to a relevant size. In most cases, existing pilot units have been modified according to process requirements and findings of configuration studies conducted at laboratory level in previous work packages. In other cases, learnings from test runs for improved construction have been identified

WP9 Economic Validation:

This work package will ensure the development of an economically sustainable business and exploitation strategy of the project results (WP12). The Opex (operating expenditure) and Capex (capital expenditure) of the various milk processers (technology implementers) and the revenues generated by the equipment suppliers (technology providers) will be validated. An optimal business deployment strategy (size and localisation) will be prepared. Financial mechanism that can be applied in different

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regions of Europe will be selected. To prepare an integrated financial and business package to support the wider deployment of the innovations.

A flexible financial toolkit will be developed that is able to show the economic benefits of the implementation of the EnReMilk technology to secure additional investment funding and enable widespread replication of the EnReMilk technology across Europe.

This work package is still in progress:

- A Worksheet for collecting and reporting key indicators including most relevant categories, like environmental performance, operational performance, process performance, human resources and equipment use have been prepared and sent to technology developers
- Preliminary data has been received and is being analyzed
- A large survey amongst potential technology adopters is being conducted in order to gather data for the financial risk assessment, business plan and assessment of post-project financing.
    - Survey fully has been developed and validated by representatives from the two model companies
    - According to the sampling criteria, the whole sample of companies identified is the following: 494 Milk companies: 145 in Germany, 114 in Spain and 234 in Italy.
    - Data collection in progress: survey has been translated into Spanish, Italian and German and has been sent to representative firms in Spain, Germany and Italy.

WP10 Social Impact and Policy:

During this work package, widespread knowledge an evaluation of the acceptance of the EnReMilk innovations as good environmental practices at policy makers and consumers levels will be promoted. In order to understand the acceptance of new technologies in relation to environmental performances, health and safety issues social and market dynamics with regard to the adoption of innovation at firm level are being analyzed.

Data from Community Innovation Survey (CIS) for the agrifood sector is being used. This is a Eurostat harmonized survey of innovation activity in enterprises. In order to address the sector of mozzarella production we are complementing this data with the result a specific survey on mozzarella producers in southern Italy (four regions). The survey is finalized to analyze energy consumption, main innovation adopted in order to reduce energy and water consumption and waste production, the adoption of environmental management tools and certifications, main investments realized in the field of energy and water management. The questionnaire has been tested and interviews are ongoing.

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Labelling/branding tools for the products in order to increase awareness of the consumers and to achieve price premiums to the environmental innovations are being assessed. It will be ensured that the innovations are also compliant with regulatory requirements in all EU-27 member states. Accordingly, policy measures in order to spread the innovations in food industry will be defined. Activities are still ongoing Data requirements to study social factors, market dynamic and tools and policy tools have been identified.

WP11 Environmental Sustainability:

This workpackage aims at verifying the full life environmental viability of EnReMilk using a recognised LCA (life-cycle assessment) approach based on ISO14040/44 (2006). This study will provide detailed insight in the environmental hotspots producing milk powder and mozzarella, and it will compare the environmental aspects of different innovations in mozzarella and milk powder production. It will, in a quantitative way, broaden the view on the sustainability effects of the innovations tested in the EnReMilk project from Energy and Water consumption alone to a broader selection of environmental impacts. Significant results at this stage include:

- Goal and scope: All methodological choices have been coordinated with developments in the field, in which the PEF Dairy Pilot and the release of the IDF standard on GHG reporting are important contributions.The allocation approach was revised, and the findings of the study
- Life cycle inventory: Data from questionnaire responses from process experts and secondary data from EcoInvent has been completed.
- Life cycle impact assessment: **:** A draft LCA model was filled with inventory data to determine a first baseline LCI for both mozzarella and skim milk powder, which enabled a first hotspot identification.
- The LCA model was fully parameterized, so that sensitivity and uncertainty analyses are enabled. Through the (parameterized) Process Model and the defined output format to the LCA model, a robust interpretation will be facilitated

WP12 Dissemination and exploitation:

This work package will enable project results to be protected and then widely disseminated for maximum impact: Dissemination will include international industry seminars, scientific and technical papers, publications and conference proceedings and a dedicated open access web site to publicise project achievements during the project and five years post project. During the second periodic report, the project website has been updated. Target groups for dissemination and locations have been addressed and dissemination protocols have been updated. This is an ongoing activity.

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Expected final results and potential impacts

EnReMilk will achieve significant and quantifiable savings at pilot and industrial demonstration levels. These savings will be achieved during the project life and will be at least: 20% in energy and 30% in water consumption compared to the current production of mozzarella and milk powder. Data acquired on water and energy consumption, necessary to quantify savings and asses environmental and economic impacts from the EnReMilk's engineering solutions will be carried out through the implementation of management strategies. This will also enable the dairy processors to pursue continual and dynamic refinement of their sustainability strategy. The full life cycle assessment will be verified across the entire supply chain through an approach based on ISO 14040/44, with minimum rebound effect and in compliance with food legislative requirements, to enable widespread trans-European market acceptance by SME and large dairy operations.

The potential impacts of final results and use are:

I) European added value through an innovation-driven increase in the competitiveness of the European dairy and other food processing sectors. This will be achieved in the EnReMilk project by involving nine industrial participants (seven SMEs and two large enterprises) in the research and development activities.

II) Notable reductions in water and energy consumption, while at the same time ensuring sustainable economic growth: The EnReMilk project will not only provide innovative engineering solutions enabling significant and simultaneous saving of at least 30% water and 20% energy at the dairy processing level, but also offer accompanying software-based tools for the monitoring and management of water and energy consumption and the improvement of resource-efficiency with respect to individual needs and sustainability strategies along the dairy supply chain, enabling notable reduction in associated economic burdens.

III) Research contributing to resilient, sustainable and productive food chain in line with the EC Strategy "Innovating for Sustainable Growth: A Bioeconomy for Europe": Software-based tools and smart-metering strategies will be developed to enable natural resources to be managed sustainably.

IV) Specific resource-efficiency objectives for 2020 and beyond as planned in the "A resource-efficient Europe": This initiative highlights the needs to "boost economic performance while reducing resource use, identify and create new opportunities for economic growth and greater innovation for the EU's competitiveness, ensure security of supply of essential resources, and fight against climate change and limit the environmental impacts of resource use". The EnReMilk project responds to these needs by:

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- Supporting sustainable growth of the European food industry by means of providing innovative engineering solutions to enable significant water and energy saving in the manufacture of dairy products with among the highest potential for exports (€7.68 exports and €7.01 net trade).
- Contributing in the reduction of energy consumption and thus greenhouse gas emissions from processing through the development of low-carbon technologies
- Offering a significant potential for further resource-efficiency gains through valorisation of process effluents, which are currently otherwise wasted: EnReMilk's innovations to be tailored in WP4, WP5 and WP6 for dairy processing will support the reuse of treated process effluents in process stages and cleaning operations, the recovery of valuable byproducts (e.g. proteins from whey), and the reduction of pressure on non-sustainable resources (e.g. fossil fuel).

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Partners

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End User
Case studies

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Mozzarella Manufacturer (IT)

Schwarzwaldmilch FREIBURG
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