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Comments to Potential Future Solicitation(s) on Advanced Energy Management and Monitoring of the Dairy Industry

Additional submitted attachment is included below.

MINISTRY OF
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THE DANISH TRADE COUNCIL

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COMMENTS TO POTENTIAL FUTURE SOLICITATION(S) ON ADVANCED ENERGY MANAGEMENT AND MONITORING OF THE DAIRY INDUSTRY

The following comments are targeted at potential future solicitations on Advanced Energy Management and Monitoring of the Dairy Industry being prepared by the California Energy Commission (CEC). The purpose of the comments is to present relevant and recent research, development and commercial activities for technologies within this field in Denmark that are not currently widely deployed or available in California. Therefore, these comments can provide valuable input on some of the European RD&D working areas, trends and best practices that could be considered in the development of future CEC solicitations. The main aspects of the comments are in the field of efficient electrification of processes[1] and process optimization through advanced control and digitalization in the food and beverage industry. These are currently a major focus area in Denmark and Europe.

The comments are compiled from input from both Danish and US based companies, consultants, relevant authorities and academia within this field.

ELECTRIFICATION OF DAIRY PROCESSES

The energy supply of thermal processes in dairy processing plants relies heavily on the combustion of fossil fuels, i.e. natural gas. Decarbonization efforts have been primarily targeting energy efficiency measures. The increasing share of renewable energies in the electricity mix in Denmark and California presents the opportunity to decarbonize the dairy industry through electrification of process heat supply.
Heat pumps[2] play a major role in the electrification of dairy processes, as they upgrade low quality heat sources through electric energy, to supply process heat. This means heat pumps provide a multiple of the electric energy invested as process heat, making them a competitive alternative to natural gas boilers. Heat pumps have been limited by their process heat supply temperature of maximal 90

[1] In this context, electrification is defined as the conversion from a fossil fuel-based to a renewable electricity-based process heat supply.
[2] Heat pumps of the type vapor compression move heat from a low temperature to a higher temperature by use of electric energy in a compressor.

degree Celsius. Recent developments however show that heat pumps can also provide high temperature process heat.

COMMERCIAL INSTALLATIONS IN DENMARK

At a Danish milk powder factory, heat is recovered from the evaporators' cooling towers and used to preheat injection air for one of the spray towers. The heat is utilized partly through direct exchange and partly through a hybrid heat pump. The project resulted in annual natural gas savings of 16.4 GWh through an electricity consumption of 1.4 GWh per year in the heat pump. The investment had, after energy subsidies, a simple payback time of 1.6 years[3].

R&D PROJECT EXAMPLE FROM DENMARK

GEA[4] has developed a heat pump solution for spray dryers in the dairy industry. This solution allows the complete electrification of the spray drying process and at the same time increases production throughput by dehumidification of drying air. The heat in the spray dryer exhaust is recovered in a heat pump. This system was proven successful in a pilot scale installation and is now being rolled out to commercial dairy factories.

RESEARCH ON INDUSTRIAL ELECTRIFICATION IN DENMARK

The Technical University of Denmark (DTU) has been active in the research of electrification options and scenarios in the food and beverage industry. A research project has developed and performed techno-economic analyses of different options for fully electrifying a dairy processing factory[5]. The work showed that electrification can reduce primary energy use for thermal processes by up to 65 %. Currently, a demonstration project launched in 2020 is investigating the integration and implementing electrification solutions in the food industry.

WORKING AREAS AND DEVELOPMENT TRENDS FOR DECARBONIZATION AND ELECTRIFICATION IN DAIRIES

Based on the projects currently ongoing in Denmark the following working areas with respect to electrification in dairies were identified:

- Demand side flexibility: The opportunity to shift electric loads through heat pumps and other electric technologies in combination with thermal energy storage is a relevant area of investigation. Thermal energy storage at low to medium temperatures, e.g. hot water storage, is a very cost-efficient type of energy storage compared to electric energy storage. Increasing the use of electricity at the dairies when power prices are low or have a high share of renewables could help reduce curtailment of renewables and reduce operating costs at the dairy.

[3] Danish Energy Agency (2019). Preheating with a hybrid heat pump secures large savings for spray drying facility.
[4] GEA (https://www.gea.com/en/index.jsp)
[5] Bühler, F., Zühlsdorf, B., Nguyen, T. V., & Elmegaard, B. (2019). A comparative assessment of electrification strategies for industrial sites: Case of milk powder production. Applied Energy, 250, 1383-1401.

- Heat pump framework: Investigation of framework conditions in California for the use of heat pump technology for decarbonisation of the process heat supply. In particular, identifying the economic conditions for profitable investment and environmental benefits is required to steer policies and regulations towards increased electrification.
- Combined heating and cooling from vapor compression machines in dairy processing.
- Electrification of thermal processes, through heat pumps, electric heaters and alternate activators (e.g. infrared, microwave), provides new opportunities in the control, data collection and monitoring of the dairy production system.

MONITORING AND DIGITALIZATION IN DAIRY PROCESSING

COOLING AND REFRIGERATION EQUIPMENT

A 2006 study reported that 31 % of the electricity use in dairy processing in the U.S. can be allocated to refrigeration and cooling[6]. Cooling and freezing can typically be the highest energy cost in some facilities and is typically not managed well. Danfoss Controls provides supervisory control systems for the cooling and freezing systems utilized in Dairies. The supervisory control systems actively manage accurate cooling and freezing processes for milk, cheese, ice cream and associated products while reducing energy usage. This system provides superior energy management by operating equipment efficiently and employing Variable Frequency Drives (VFD's) to reduce energy consumption. Temperature monitoring, data logging and reporting are key elements of the system. The system is flexible and adaptable to any process. The solution from Danfoss Controls was developed relying on over forty years of experience in the dairy industry. A screening of state of cooling and freezing equipment in Californian dairies, as well as the use of the thermal energy in the processes could give valuable insights into the areas for optimization. As there are already reliable and efficient technologies for optimizing operation of refrigeration equipment available on the market, barriers and drivers to their implementation should be evaluated for the future solicitations.

DIGITAL TWINS FOR HEATING, COOLING AND PROCESS OPTIMIZATION IN DAIRIES

The digitalization of heat pumps, refrigeration systems and dairy processes improves performances and enables sophisticated controls, which amongst others support the integration into smart grids. However, this requires increased knowledge about the system during operation. This may be obtained by the use of digital twins. Digital twins are sets of numerical models, which are virtual representations of a physical system. These representations adapt continuously to the physical system, monitor its operation, and can be used for detailed analyses.

[6] Masanet, E., Brush, A., & Worrell, E. (2014). Energy Efficiency Opportunities in the U.S. Dairy Processing Industry. Energy Engineering. 111.

Application of digital twins in the dairy processing industry can enable:

- Advanced system monitoring
- Fault detection and diagnosis
- Optimized system operation.

The Danish project 'Digital twins for large-scale heat pump and refrigeration systems' covers research, development, and demonstration of digital twins in industrial practice[7]. The partners are, amongst others, the Danish Technological Institute and Danfoss. The project is funded through the EUDP (energy development and demonstration program).

[7] Project website: http://digitaltwins4hprs.dk/