Newsletter June 2023

Dear CoolFish participant,

The project is in its last phase and the activities now include summarizing what we have completed in the project and ideas for new projects.

Project meetings and workshops

Papers, reports, and presentations from earlier webinars are available here:

www.sintef.no/en/projects/coolfish

International cold chain conference (April 2022)

https://ior.org.uk/ICCC2022

Here is a short summary of the papers presented there:

- Modelling Of Crystallization During Freeze-Concentration of Hydrolysates (Khan, M.U., Tolstorebrov, I., Widell, K.N, Hafner, A., Nordtvedt, T.S.)
    - Dewatering of fish protein hydrolysates is energy intensive process
    - Freeze concentration is an energy efficient solution which provides high quality of concentrate
    - Crystallization of water in fish protein hydrolysates and separation of ice from concentrate were modelled in Modelica and MATLAB, and validated against experimental campaigns and literature review
- Application Of Refrigeration Technologies For Energy Efficient Production Of Fish Protein Hydrolysates (Sherman, P.K., Tolstorebrov, I., Widell, K.N, Hafner, A., Nordtvedt, T.S)
    - Fish protein hydrolysate (FPH) is an efficient and sustainable way to recover valuable nutrients from fish remaining materials and has a widespread application.
    - However, the production of FPH demands intensive heating and cooling loads in the temperature range between 0 and 90 ^{o}C, and stabilization using conventional moisture removal techniques like spray drying and evaporators is energy intensive due to low solid content.
    - This study investigates the use of refrigeration technologies and heat pumps to determine sustainable and energy efficient methods for processing and stabilization of FPH. Techniques such as freeze concentration, vacuum-concentration and freeze-drying were investigated in combination with energy recovery at high temperatures to compare energy savings of different production lines.
- Industry practices for sharing sustainability information in the Norwegian seafood supply chains (Strand, A.V., Thakur, M., Widell, K.N, Gabrielli, C.)
    - Sustainability and traceability of food products have received increased attention due to food safety, consumer demand on knowledge of the origin of their food and reducing food fraud.
    - Most Norwegian fishing vessels capture detailed data on the catch and quality of fish electronically. This information is automatically reported to the authorities while most information regarding the quality and sustainability is not communicated further down the supply chain.
    - Significant data gaps include information on fuel and energy consumption, as well as detailed data on the transport routes and modes used.

Gustav Lorentzen Conference (June 2022)

https://www.sintef.no/projectweb/gustavlorentzen_2022/

Here is a short summary of the papers presented there:

- Evaluation of cold thermal energy storage in fishing vessels (Vingelsgård, E., Svendsen, E.S., Widell, K.N, Nordtvedt, T.S.)
    - Fishing vessels and fish transporting well-boats have varying cooling demands depending on the operational mode
    - Cold thermal energy storage (CTES) can potentially be used for peak shaving and energy saving in these vessels, with a focus on compact and efficient systems
    - In this study, theoretical calculations were conducted to find the requirements of an ice slurry system according to the reference conditions of the studied case, utilizing thermodynamic properties of ice and fish
- Experimental investigation on integrated two-stage evaporators for CO2 heat-pump chillers (Hafner, A., Hazarika, M.M., Lechi, F., Zorzin, A., Pardiãs, A.A., Banasiak, K.)
    - A novel compact two-stage evaporator, i.e. evaporator with one gravity-fed loop and one ejector-assisted circulation loop, is explored in this experimental study
    - Compared to previous heat exchanger models this design allows for less connection work and required space due to the internal connection of loops
    - The experimental campaign proofed that an ejector integration enables the two-stage evaporation configuration, which significantly elevates compressor suction and overall system performance
- Integration of gravity-fed evaporators in CO2 based refrigeration systems (Hazarika, M.M., Bengsch, J., Hafsås, J., Hafner, A., Svendsen, E.S., Ye, Z.)
    - A model of a gravity-fed evaporator for CO2 based heat-pump chillers is studied in this paper
    - Appropriate equations are used and implemented in Modelica to develop a simulation model for this novel heat exchanger design
    - Loop dimensions are critical to the performance; simulations are carried out to predict the optimum dimensions to achieve the optimum circulation rate in the loop

CoolFish workshop i Ålesund (September 2022)

We had an interesting meeting in Ålesund in the autumn, where many from the project participated and we had presentations from different topics. You can find the presentations here:

https://www.sintef.no/en/events/archive/2022/coolfish-meeting-september-2022/

Workshop on thermal energy storage (November 2022)

Several projects collaborated on organizing a workshop on thermal energy storage. Here is an overview of the presentations that were held:

https://www.sintef.no/en/events/archive/2022/workshop-on-thermal-energy-storage-for-industry-buildings-and-marine-applications/

We are planning a similar event in November this year. Let us know if you are interested in being a presenter there or want to participate.

Ohrid conference (April 2023)

https://www.mf.ukim.edu.mk/web_ohrid2023/ohrid-2023.html

Here is a short summary of the papers presented there:

- Possibilities of ice slurry systems onboard fishing vessels (Widell, K. N., Svendsen, E. S., Nordtvedt, T.S.)
    - Several different methods onboard fishing vessels to keep the temperature of the catch low, including no chilling, ice storage, refrigerated sea water (RSW) and ice slurry chilling.
    - The main working fluid in fishing vessels globally is still R22, but there are efforts for providing systems with natural refrigerants, even if this should be done at a much faster rate.
    - It can be concluded that storing seafood with ice slurry gives longer shelf life, but is not used widely in the industry, mainly because of limited capacities and high costs. Not many of the ice slurry systems are operated with natural refrigerants either. There is clearly a potential for development.
- A comparative study to investigate two configurations of a two-stage evaporator in a CO2 heat pump chiller (Hazarika, M. M., Hafner, A., Bengsch, J.)
    - Two configurations are proposed to implement a two-stage evaporator in a CO2 heat pump. The first configuration is GFES in which the first stage of the evaporator is fed by gravity and the second stage is fed by ejector suction. The second configuration is EDES in which the first stage is fed by ejector discharge and the second stage is fed by ejector suction.
    - Simulation models are developed for these two configurations in Modelica.
    - Simulation results show that the coefficient of performance (COP) of GFES configurations is marginally higher compared to EDES configuration. Results also show how the cooling capacities change in the two stages of the evaporator with a change in compressor frequency.

International congress of refrigeration (August 2023)

Several from the CoolFish project participated in the congress in August and presented results from the project. More information about the conference here: https://www.icr2023.org/

Web sites

CoolFish

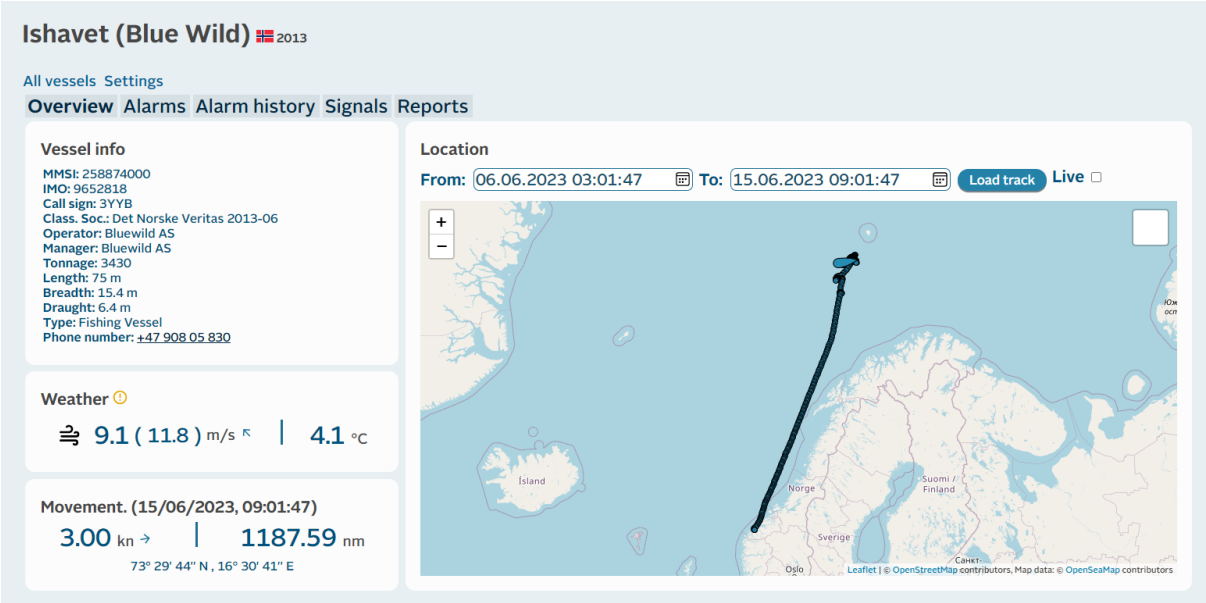
We have always aimed for sharing all results and other public information on our webpage. The page will still be available after the end of the project. Just contact us if you have additional information we can share there.

www.sintef.no/en/projects/coolfish

MRTH

MRTH – The Maritime Refrigeration Technology Hub, is a website that was launched last summer and is run by SINTEF Ocean, SINTEF Energy Research and NTNU. All these institutions have been working for a number of years on projects focusing on refrigeration technologies for maritime applications (and the seafood industry in general), but there was a need to bring together and highlight national expertise in this field. MRTH is an attempt to do just that. As of now, there is information on a few selected topics that we have focused on through both the CoolFish project and the 'sister project CruiZE, as well as hosting a number of publications from said projects.

Energy efficiency on board fishing vessels



'If you can't measure it, you can't improve it" is a quote attributed to Lord Kelvin and says something about the importance of having measurable data in order to identify areas for improvement and measures to achieve improvements. In this project, there has been an activity to map energy use on board fishing boats through measurements, precisely to be better able to identify the potential for energy efficiency improvements of the on-board thermal systems. Previously, a cruise has been carried out on the purse seiner Selvåg Senior, which was instrumented with several temperature loggers in a modified RSW tank (in an effort to improve RSW tank design) and resulted in a better understanding of how efficiently the refrigeration system performed during the various phases of fishing (read the report here).

The same task is being carried out on the trawler Ishavet (BlueWild), where, in collaboration with Teknotherm and Ulstein/Bluectrl, equipment has been installed to log energy data from the vessel. The data system has been active and collecting data since autumn 2022 (see picture of integrated dashboard above), while there have been technical challenges with logging signals from the freezer/refrigeration system. Troubleshooting and problem-solving work on this is still ongoing, with good help from technicians/service engineers from Teknotherm and Ulstein, and not least the crew on board Ishavet! When this is solved, the next step is to carry out an energy analysis focusing on the refrigeration system to better understand how it performs during the various phases of fishing. This work has been partly funded by Fiskeridirektoratet.

Master theses (2023)

Development of a concentration process to conserve rest raw materials and process water for circular economy (Faraz Neakakhtar)

Limited fish resources and improved utilization of fish waste have raised sustainability concerns regarding the proper consumption and production of resources. The world's fisheries produce 20 million tons of residual raw material each year. The conversion of these raw materials into higher value products has become a global aspiration. In the farming industry, blood water constitutes up to 9% of the total residual raw material. The discharge of this blood water from slaughterhouses is not permitted by Norwegian law, necessitating the implementation of appropriate cleaning technology. Various concentration processes, such as mechanical vapor compression, thermal vapor compression systems, and freeze concentration, can be utilized as cleaning technology to concentrate the protein obtained from the blood water and recycle the clean water back into the process. An energy and cost analysis of these concentration processes was

conducted. Additionally, experiments were conducted to examine the rheological properties of fish proteins. Subsequently, a lab-scale freeze concentration process was designed, constructed, and experimented upon to enhance the utilization of fish waste, ensuring high purity crystals (up to 99.7%) and protein yield. Separate experiments were performed on two key processes of freeze concentration: crystallization and ice crystal separation. Techniques such as vacuum filtration, centrifugation, and wash column were employed for ice separation. Finally, a theoretical energy system using a CO_2 booster system is proposed to meet the respective heating and cooling demands.

Application of a novel two stage evaporator within AC applications including TES (Lukas Köster)

The previously investigated two-stage evaporator system configuration was applied with a hydronic subsystem to meet the AC demand of for example fish production facilities. The hydronic subsystem uses cold thermal energy storage by means of a cold water tank and an ice tank. The system setup allows the hydronic system to operate in 15 different operation modes, providing great operational flexibility. As a proof of concept, the hydronic system, including the novel two stage evaporator, is modelled in Modelica and simulated for an exemplary AC load. The results show that the implementation of the cold thermal energy storage in combination with the two-stage evaporator configuration allows the AC load to be shifted from the on-peak period to be covered within the off-peak period. Thus, the system achieves both peak load limiting and load shifting by using the novel two stage evaporator in combination with thermal energy storage.

Ideas for new projects

Low-temp TES

Earlier this year we sent an application to the research council of Norway regarding development of thermal energy storage systems at low temperatures (-50°C). We were not granted this time, unluckily, but will update and send in again at next suitable option in Norway. We did a simmilar application towards EU, answer is expected after Christmas.

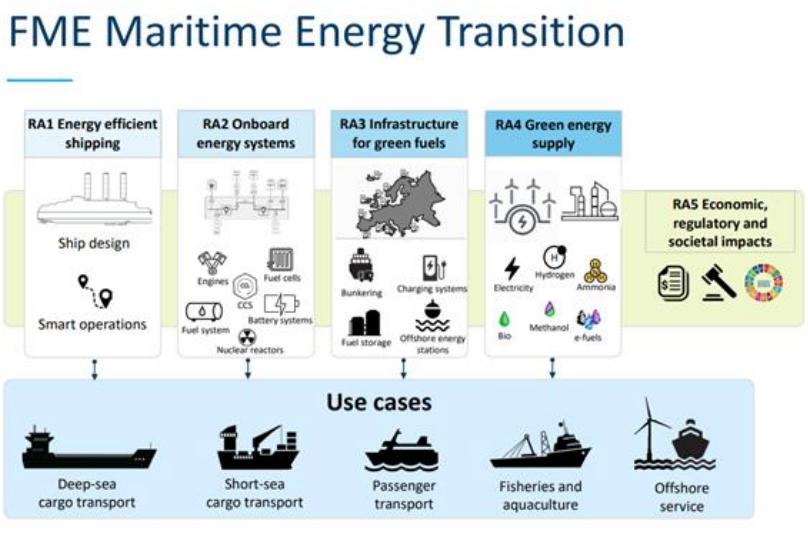
Slurry/RSW om bord i små fiskebåter

We have done some investigations regarding possibilities of slurry or RSW systems onboard small fishing vessels. Not many of the smallest vessels have refrigeration systems onboard, but the shelf life of the fish could be extended several days if they had. This has for example been shown in the project , where among others PTG was participating. SINTEF Ocean has also sent a suggestion to next years action plan for FHF.

Research centre on maritime energy transition

SINTEF is currently working on several proposals to establish new FMEs, centres for environment-friendly energy research (FME). The application deadline to the Research Council is in November and we have started collecting input on what the industry considers to be important issues. Two of these initiatives are relevant for the actors within fishing or aquaculture industry:

- *Energy transition in the maritime sector*. As shown in the figure below, fishing vessels will be one of the "user cases". For more information, contact Cecilia: cecilia.gabrielii@sintef.no or 40623710.



- cEFF - Norwegian research centre for industrial energy efficiency. This is a continuation of FME HighEff. It includes improving energy efficiency in land-based industry but will have many synergies for maritime industry. For more information, contact Tom Ståle: Tom.S.Nordtvedt@sintef.no or Kristina: Kristina.Widell@sintef.no.

Project participants

Management group

- SINTEF Ocean
- NTNU
- SINTEF Energy

Industrial reference group

- MMC First Process
- Selvåg Senior/Sørheim Holding
- Danfoss
- Perfect temperature group (PTG)
- Gasnor
- Bluewild
- Isotherm Inc. (USA)

Scientific reference group

- International Institute of Refrigeration
- London South Bank University
- Johnson Controls Denmark

Project funding

- Norwegian research council ENERGIX
- Industrial partners are contributing with 20 % of total budget

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