Report

CoolFish project: final report

Energy efficient and climate friendly cooling, freezing and heating onboard fishing vessels

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SUMMARY
This report is the final report to the research council in the 4-year KPN project CoolFish, financed by the Norwegian research council and industry partners. The main publications, presentations, newsletters and other information can be found in the webpage:
https://www.sintef.no/en/projects/2019/coolfish/
This report gives an overview of the background and objectives, the results and impact, the communication and dissemination, as well as results after the project and further challenges.

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1 Background and objectives

The national and international fishing industry faces major challenges in reducing climate gas emissions. To cope with this, new fuels, and engine technologies for propulsion of fishing vessels are under rapid development. But it is not only the fuel consumption related to propulsion that contributes to the emissions of climate gases. On board there are also energy consuming equipment to keep the catch refrigerated, ensuring product quality and shelf life. There are also systems for producing the hot water on board.

The objective of the project was to contribute to the development of energy efficient and climate friendly systems for cold and heat production onboard fishing vessels and to increase knowledge on these topics. A refrigeration plant contributes to global warming in two different ways; consumption of energy (electricity) to operate the plant, and leakage of the refrigerants. Several refrigerants have a significant global warming impact. Norway is at the forefront of replacing these refrigerants with natural refrigerants, having no negative environmental impact. Further development of these systems has been an important part of the project, as well as transferring of knowledge and technology globally.

2 Research activities and results

The team has had many research activities in the projects, all working towards the goal of the project. The activities have also been linked, to gain experience and to reduce silo thinking. A large part of the activities was related to the industry partners and were conducted within the four industry cases:

- Energy efficiency on board fishing vessels, including both modelling and measurements
- Design concepts for cold utilization from LNG driven ships
- Freeze concentration of hydrolysate from rest raw materials
- Design concepts for integrated thermal energy units, for cooling and heating

In addition, focus was given to work related to sustainability, carbon footprint calculations and traceability. The team also included two postdoctoral candidates and 8 master students.

The partners that contributed to the project were SINTEF Ocean, NTNU, SINTEF Energy Research, MMC First Process, Sørheim Holding, Danfoss, PTG, Bluewild, Gasnor, Ulmatec Pyro, Øyangen and Iso-therm. SINTEF Ocean led the project. The research institutes and the university conducted much of the research work, while the industry partners contributed to the funding of the project and with their time, knowledge, and ideas. The project continued for 4 years, where most of the R&D and collaboration with industry was conducted in the first three years. The last year was dedicated to dissemination and how to bring the results into new project ideas.

2.1 Energy efficiency and refrigerants

Energy efficiency has been a continuous topic throughout the project activities. A pelagic fishing vessel was monitored with sensors, collecting information of the energy consumption and operational pattern. This gave valuable information for dimensioning a new LNG driven pelagic fishing vessel.

Refrigeration systems applying synthetic refrigerant contribute to global warming not only due to the energy demand to operate the unit, however, also due to leakage of the fluid into the environment. Most of these harmful refrigerants are replaced by natural working fluids in Norway. Further development of these natural working fluid systems has been an important part of the project, as well as global transferring of knowledge and technology to encourage others to leapfrog from synthetic refrigerant (HCFC) systems directly to clean cooling solutions. The natural and clean refrigerants CO_2 and NH_3 are excellent working fluids for refrigeration onboard fishing vessels. NH_3 has been used for a long time already and is very efficient. Systems with CO_2 can be compact, the CO_2 cannot burn or explode, and it also offers the possibility to achieve and maintain freezing temperatures below -50°C. This can be a major advantage, as this reduces the freezing time considerably.

2.2 Combined heating and cooling, including thermal energy storage

While the refrigeration plant is providing the cooling capacity, it is also enables to utilize the condenser heat to produce high temperature water (up to 100°C with CO_2 through the gas cooler) at the same time. This kind of surplus heat is valuable as it can replace auxiliary boilers. Surplus heat sources and heat demands was explored to increase thermal integration. Together with thermal storage, this can improve the overall energy efficiency onboard as well as reduce the total green greenhouse gas emissions. The team has investigated the performance of a transcritical CO_2 heat pump chiller (two-stage evaporator: gravity fed/ejector fed), both in the laboratory and with modelling. It is too early in the development to use it on board fishing vessels, but the results show that this combination can result in compact and energy efficient systems, including charging options for cold thermal storage devices. We have also investigated possibilities of improving processes and technology for handling rest raw materials and hydrolysates. These are processes that require a large amount of energy as steam/heat, therefore, alternative methods have been investigated, i.e., freeze concentration. This is gentler on the products, but the technology must be developed to be more robust before it is mature to be included onboard.

2.3 Utilizing surplus cold onboard LNG fuelled vessels

A few fishing vessels with LNG as fuel have been launched in Norway and a few more are being planned and built. LNG is a fossil fuel, but with less carbon footprint than conventional fuels. It also facilitates a change to bio-based fuels (biogas) when available and hydrogen or ammonia in the next step. In the project we have analysed the potential of utilizing surplus cold from the LNG fuel system for active cooling of fish. One of the projects industry partners have now launched their new LNG fuelled vessel which has a system for recovering coolth from the LNG system. Together with the activity on measuring onboard energy use for different operations, we see that there is a potential to reduce energy use for cooling onboard fishing vessels, for example for cooling of the catch on the way back from the fishing fields. However, there are still challenges related to a robust design of these systems.

2.4 Carbon footprint and environmental impact of refrigeration systems

The CoolFish team has provided two reports which gave an overview of alternative fuels and propulsion systems for fishing vessels and a review of standards, methods and tools related to carbon footprint assessment of fisheries. We have also systemized industry practices for sharing sustainability information in the Norwegian seafood supply chains to evaluate how traceability can be used to improve sustainability information in this sector.

2.5 Postdocs and MSc candidates

Two Postdoc candidates were involved in CoolFish, primarily working on the simulation development and laboratory validation of the models. NTNU has also educated eight master students, who have presented their work at meetings and conferences. There has been a large interest from the students in working within this topic, which also may continue beyond the project as some of them have been employed by the CoolFish partners.

3 Impact of results

CoolFish have had impact on national knowledge base, especially within the fishing sector and equipment vendors for this industry. However, other shipping sectors can also benefit, especially those having large thermal demands, such as cruise/passenger ships, and certain cargo ship. The knowledge and understanding have also increased among the participants, who were industry participants, students, and the scientific community. The results from the project, as articles, measurement data, presentations, and other dissemination, also reach(ed) a wider audience, since it is available online.

CoolFish has also had impact on international knowledge base. Presenting at international conferences and discussing with actors from other countries have led to collaboration with other countries, for example with India in the project INDEE+. Findings from the project have shown that many fishing vessels around the globe still use R22 (HCFC) in their refrigeration systems. This must change towards natural refrigerants, which has been shown to be a success story for the owners of the vessels in Norway. We will continue to bring forward this message until we see a change, for example in the feedback to the European Commission.

The eight master students that have participated in the project will bring both their work and other input from the project to their existing or future collaborations.

CoolFish has collaborated with other projects and has also brought forward ideas for new projects, some of which have already been applied for, for example low temperature thermal energy storage with CO_2 and development of very small RSW systems for fishing vessels.

The project has contributed to value creation and increased competitiveness for the Norwegian industry, where this technology results in fish products of high quality and produced with low energy use and low climate and environmental impact.

4 Communication and dissemination

Communication and dissemination have been high on the agenda throughout the project and that can be seen from the long list of publications in Cristin (about 100 posts). The project also has a webpage which gives an overview of the project and where publications can be found and downloaded. News of the project have been shared in newsletters, which were sent to all partners and are also available online.

We have had nine workshops in the project, where the first was with Norwegian industry in 2019 and the following three (2020 and 2021) were conducted as Teams meeting, including international participants. We had a project meeting in November 2021 where all industry partners were invited. In November 2021 we had a workshop on thermal energy storage, which was a collaboration between 4 SINTEF/NTNU projects. A similar workshop was held at the end of 2022. We had a workshop in Ålesund in September 2022, which summarised most of the activities in the project. Many industry partners participated there. Another workshop was organized during the international Congress of Refrigeration (Paris, August 2023), which was on the topic "Training on clean cooling and heating solutions". We have had many other meetings in the project, especially within the industry cases.

Seven reports have been published during the project, for example: "Alternative Fuels and Propulsion Systems for Fishing vessels", "Carbon Footprint of Fisheries - a review of standards methods and tools" and "Equipment and systems onboard fishing vessels". We have published 18 journal and conference papers, in for example International Journal of Refrigeration, IIR conference on sustainability and the cold chain, IIR Gustav Lorentzen conference on natural refrigerants, and IIR Conference on Ammonia and CO_2 Refrigeration Technologies.

5 Results after end of project and further challenges

Norway has come a long way in implementing natural refrigerants onboard fishing vessels, but this is not the case for many other countries, where for example R22 still is in use. R22 has both high global warming potential (GWP) and ozone depletion potential (ODP). There are synthetic alternatives without ODP and with low GWP, but it has been shown that they decompose to PFAS substances, which have both health and environmental issues. This is a topic that goes far beyond this project and is something we continuously work with. Our information and knowledge will be shared in upcoming national and international events.

Fishing vessels have refrigeration onboard to cool the fish, which maintains the product quality and ensures shelf life. However, many small fishing vessels (<11 m) doesn't have active chilling, even if they could benefit from it. One reason for this is the lack of very small, robust systems with natural refrigerants, so this is a technology we want to develop further with industrial partners.

Another challenge within the topic of CoolFish is the low availability and quality of operational data for fishing vessels, making it difficult to perform proper energy analyses. For example, disaggregated data on fuel usage between propulsion and refrigeration are required, as well as reliable temperature measurement for the cooling system. In this context, research cruises with detailed data collection are essential and something we want to continue to work with.