

# Memo

## CREATIV D 4.2.19

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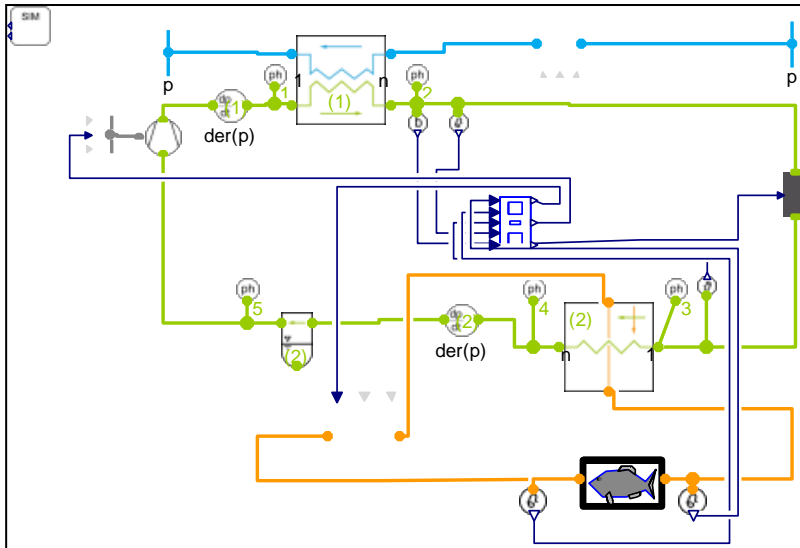
**CLASSIFICATION**

Unrestricted

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# Cases Fish Industry



Michael Bantle, NTNU

Kristina Widell and Trond Andresen,  
SINTEF Energy Research

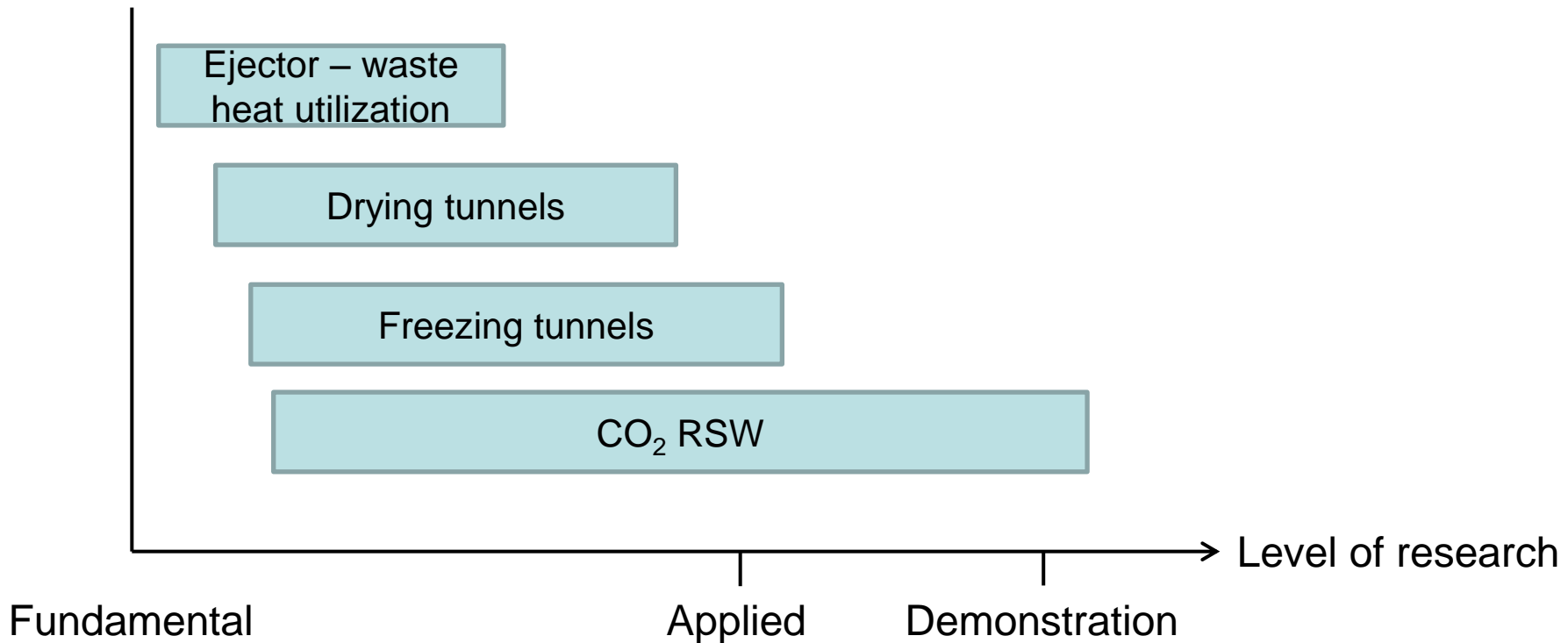
# Outline

- Fish industry research topics in CREATIV
  - RSW systems
  - Freezing tunnels
  - Drying tunnels
  - Waste heat utilization in refrigeration
- Summary

# Topics related to fish industry

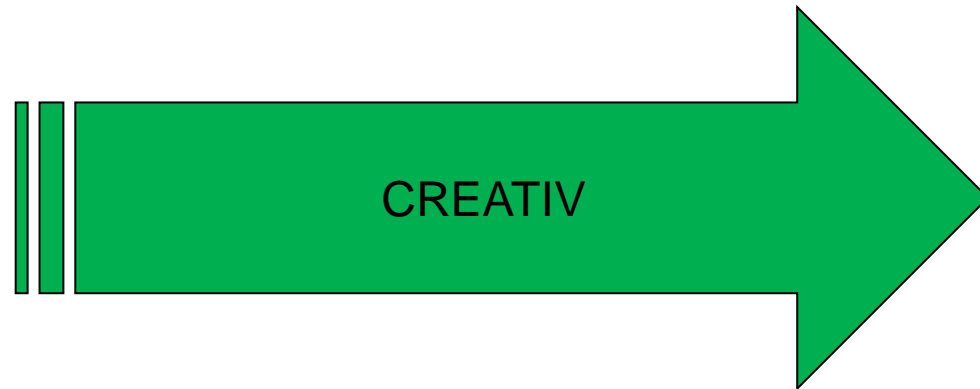
Topic	Content	Status
<b>CO2 RSW</b> (Co-op. applied project)	Modeling, component design and control optimization	Demonstrator on fishing vessel in operation
<b>Freezing tunnels</b>	Ceiling design, product and tunnel modeling, fan control strategies	Ready for demonstration
<b>Drying tunnels</b> (Co-op. industry project)	Product and tunnel modeling, fan control strategies	Ready for lab-scale or industrial verification
<b>Utilizing waste heat for refriger. system improvement</b>	Ejector implementation in refrigeration systems	Laboratory testing and conceptual studies performed

# Level of research



# The “dream team”

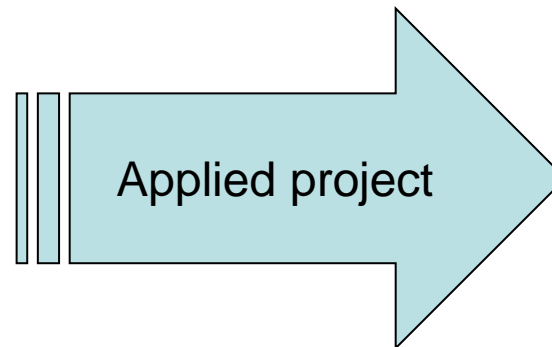
Different activities and tasks but with mutually beneficial cooperation



- Provide generic knowledge methods and tools
- Educate young professionals



Provide relevant topics, operation data, practical experience



# CO<sub>2</sub> RSW

From fundamentals to industrial prototype



# Motivation

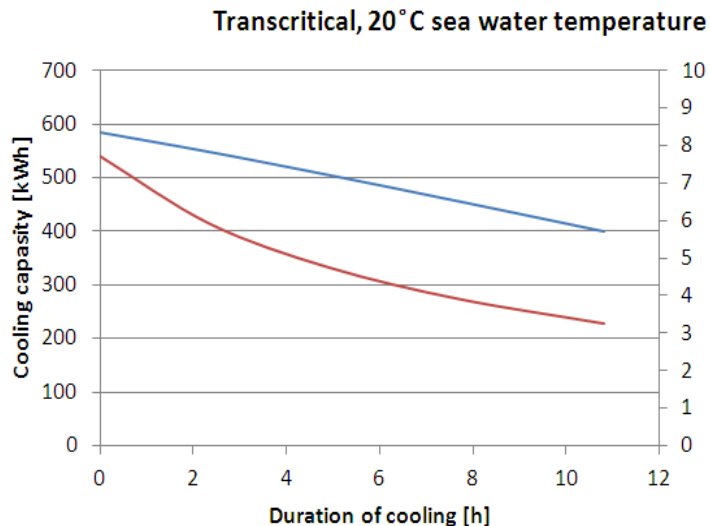
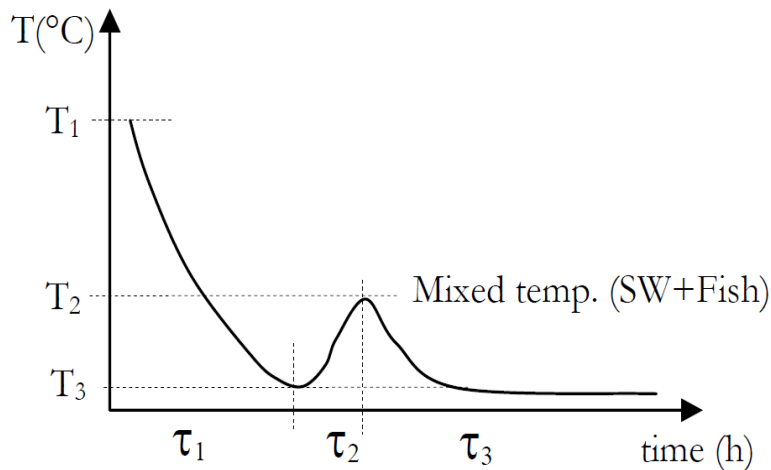
- Refrigerated Sea Water (RSW) refrigeration plants are used on fishing boats to cool and preserve the catch
- Replacement for current, environmentally hazardous fluid required
- NH<sub>3</sub> (Ammonia) is an existing option, but has specific safety issues (toxicity) are challenging for retrofit, and in smaller vessels in general
- CO<sub>2</sub> systems have shown great performance in other applications, but require different solutions



# CREATIV contribution

- Project was facing a design challenge
    - Common design criteria: capacity at 0°C (RSW tank)
    - But RSW operation is dynamic
  - Analyse and improve dynamic operation
    - Develop methods and tools
    - Optimize operation and component design in a transient process
- => Possibility to run high-capacity, high-COP at start up

If the system is designed for it!

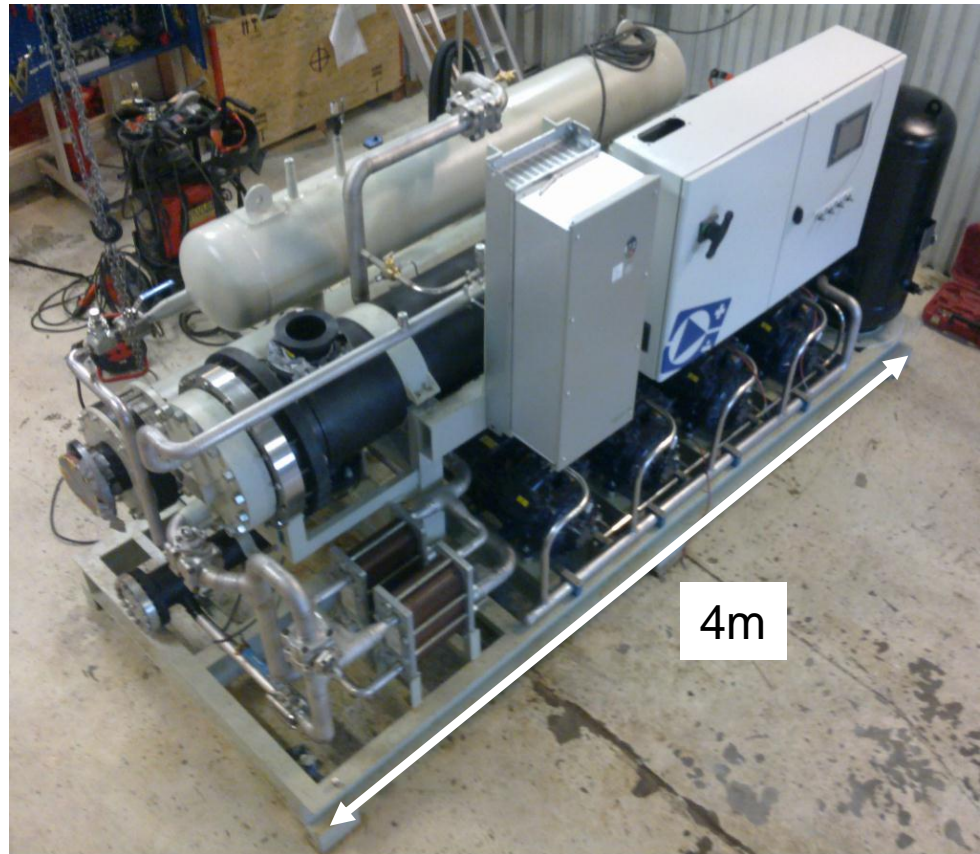


# Result of collaboration

- 250kW prototype, installed on fishing vessel

## Ongoing work:

- Data collection from prototype CO<sub>2</sub> system and commercial NH<sub>3</sub> systems during operation
- Compare CO<sub>2</sub> and NH<sub>3</sub> systems
- Compare operation data to simulation model
- Evaluate current control strategy – recommend improvements



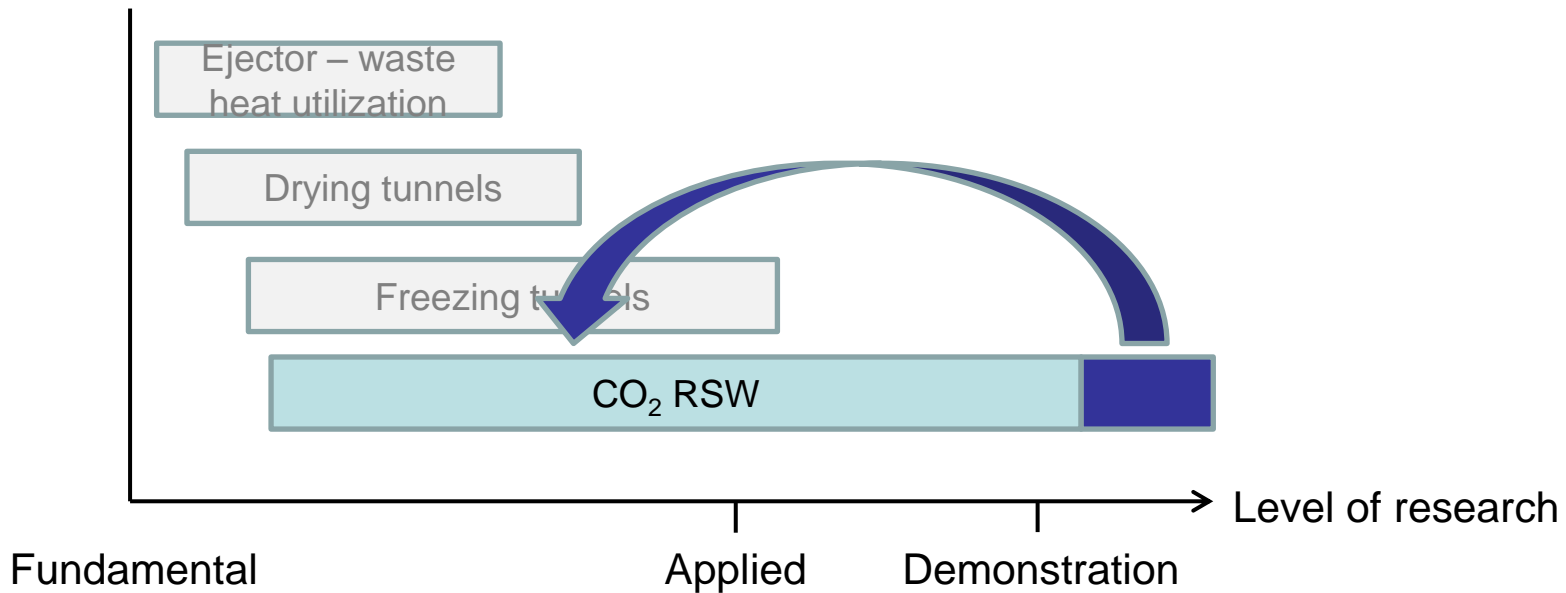
# Summary

- CREATIV and applied project "*Fremtidens RSW anlegg på fiskebåt*"\* with co-operation on CO<sub>2</sub> RSW development
- Applied project designed and installed demonstrator on fishing vessel, currently in operation
- CREATIV supported with more fundamental basis;
  - Modeling of components and dynamic model of system
  - Steady state simulations to aid in novel heat exchanger design
  - Dynamic simulation of various operation modes and conditions to determine efficient and secure control of system

\* *Next-generation RSW systems on fishing vessels*

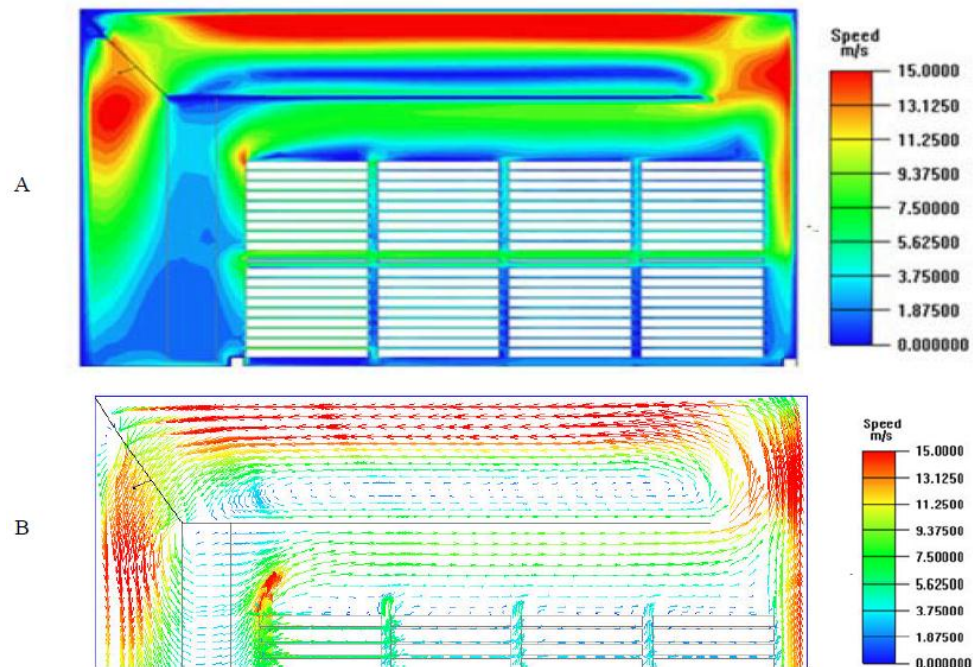
# Ongoing/further work

- CREATIV plans:
  - Together with industry project acquire logged data for CO<sub>2</sub> prototype and commercial NH<sub>3</sub> system in operation
  - Use logged operation data to verify models and suggest improvements



# Freezing tunnels

Improving operation based on advanced simulation models

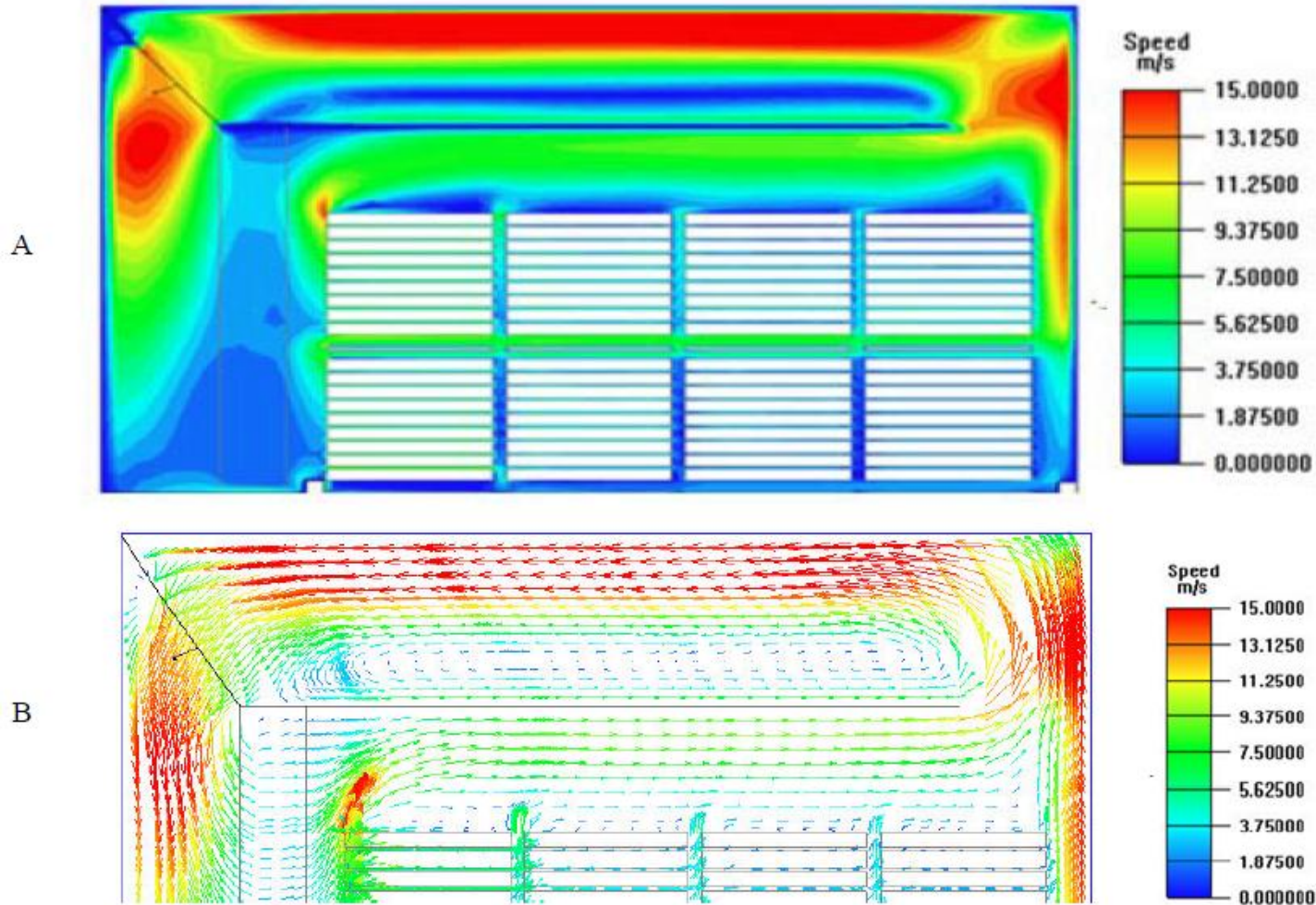


# Motivation

- Freezing tunnels are energy demanding industrial processes
  - Energy use may be minor part of turn-over, but significant to margins
- Studies have shown great potential for improvement to energy efficiency
- The industry is generally aware of possibilities for improvements
  - Challenging and risky to test, disturbs core processes => sticks to "normal practice"
  - Still: Different solutions for improvement have been implemented by the industry, effect is largely un-documented
- **CREATIV** role: Methodic approach; evaluate existing solutions and suggest improvements.
  - Focus on fan power and control: Fan power is significant, and adds heat to the freezing tunnel air. Improvements have multiple effects on system power consumption

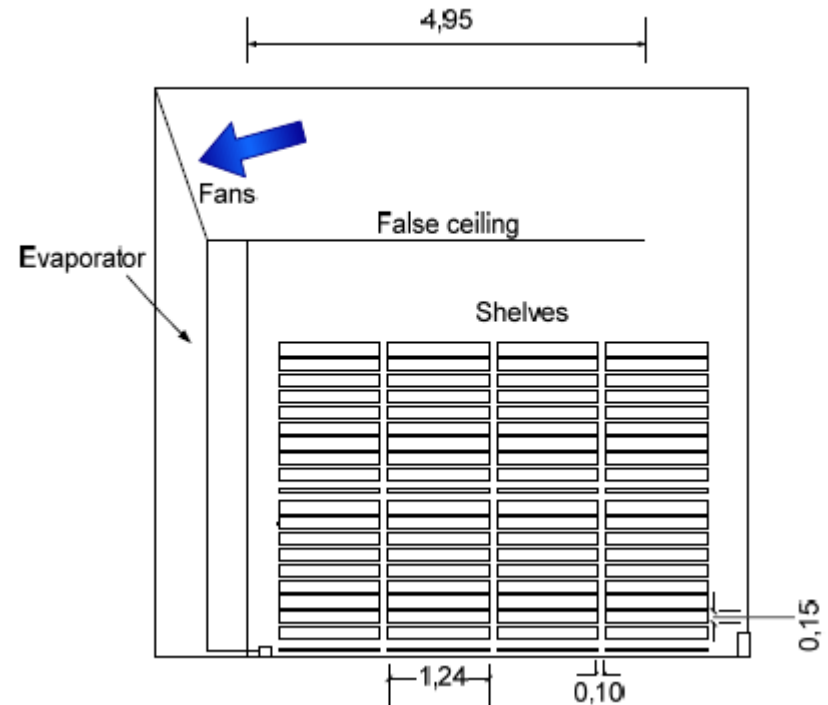


# Model Freezing tunnel



# Scope

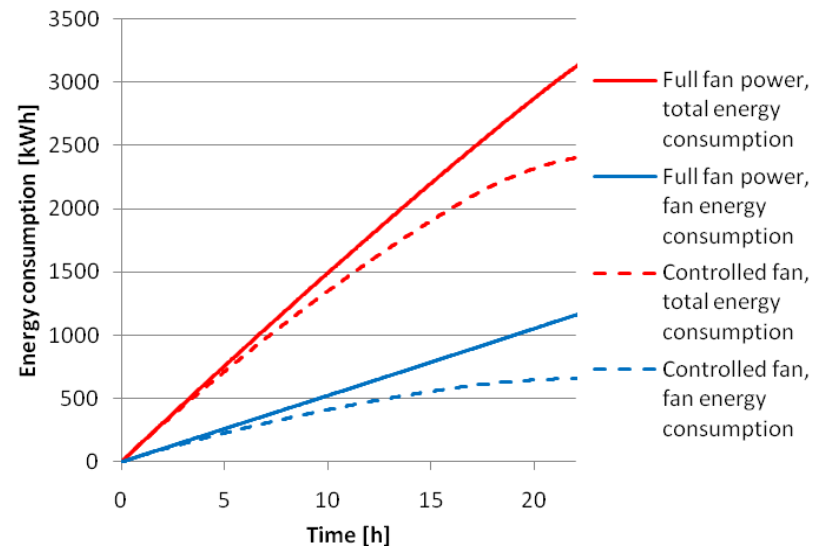
- Investigation of air flow in tunnels
- Optimization of ceiling design to improve air distribution and reduce fan work
- Investigate control strategies for fan control to reduce power consumption of fans and refrigeration system
- Industry-scale measurements and evaluation of different fan control strategies





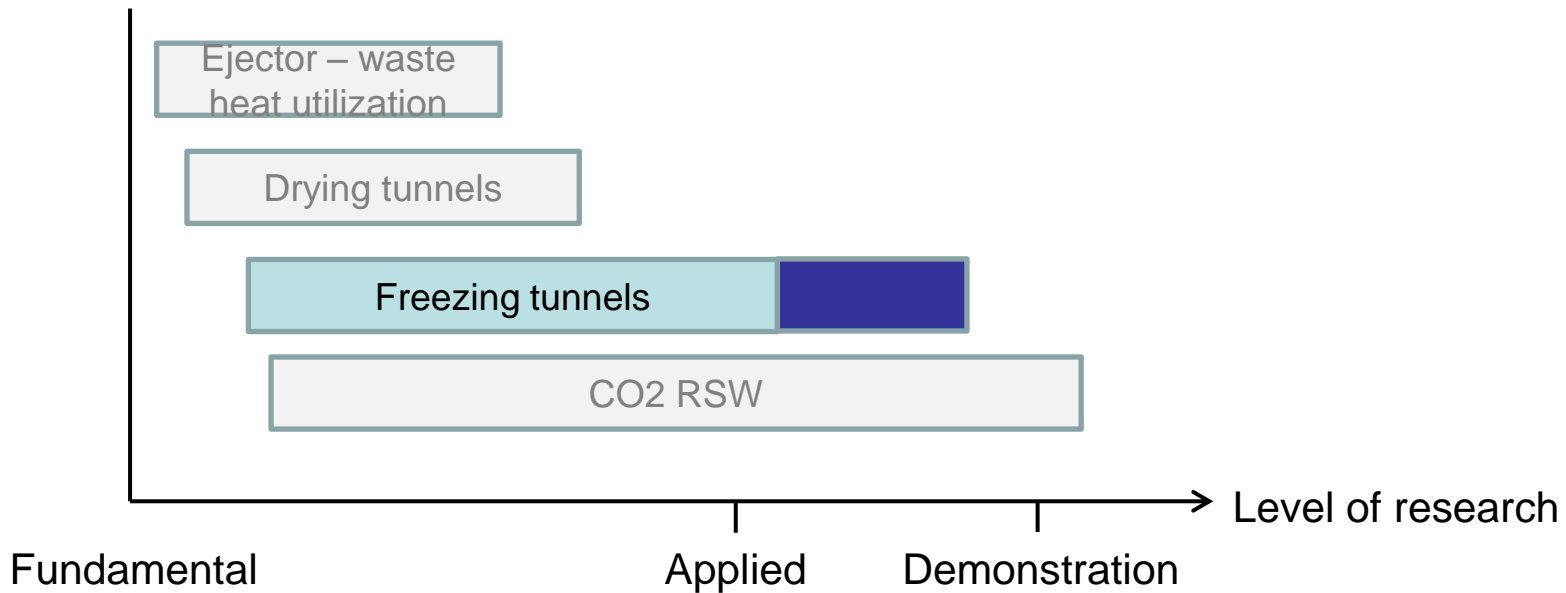
# Summary

- CREATIV sub-topics
  - Optimization of ceiling design to improve air distribution and reduce pressure drop
    - Equalize freezing times for products across tunnel
    - Reduce the significant energy consumption to fans and refrig. system
  - Investigate control strategies for fan control to reduce power consumption of fans and refrigeration system
    - Shown great potential for increasing energy efficiency



# Ongoing/further work

- Desirable to evaluate fan control strategies in industrial environments:
  - Challenging due to risk of disturbance on core process
  - Coupled and complex systems
  - Requires instrumentation of refrigeration system and products
  - Several sites contacted; found interest, but systems unsuitable



# Drying tunnels

Methodic approach towards knowledge and system improvement



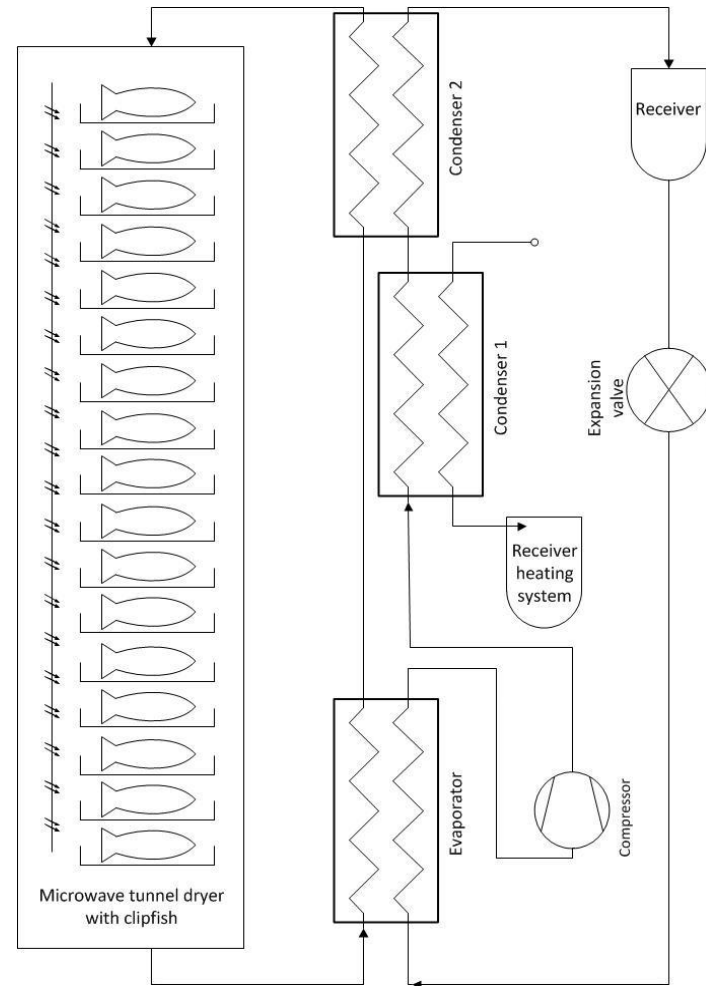
Fluid bed chamber

# Motivation

- Drying tunnels are energy demanding industrial processes
  - Energy use may be minor part of turn-over, but significant to margins
- Studies have shown great potential for improvement to energy efficiency
- The industry is generally aware of possibilities for improvements
  - Challenging and risky to test, disturbs core processes => sticks to "normal practice"
  - Still: Different solutions for improvement have been implemented by the industry, but effect is largely un-documented
- CREATIV role: Methodic approach; evaluate existing solutions and suggest improvements.
  - Focus on fan power and control
- two approaches:
  - Improvement of existing drying technology (HPD)
  - Fundamental research on hybrid drying technology (ultrasound and microwave)

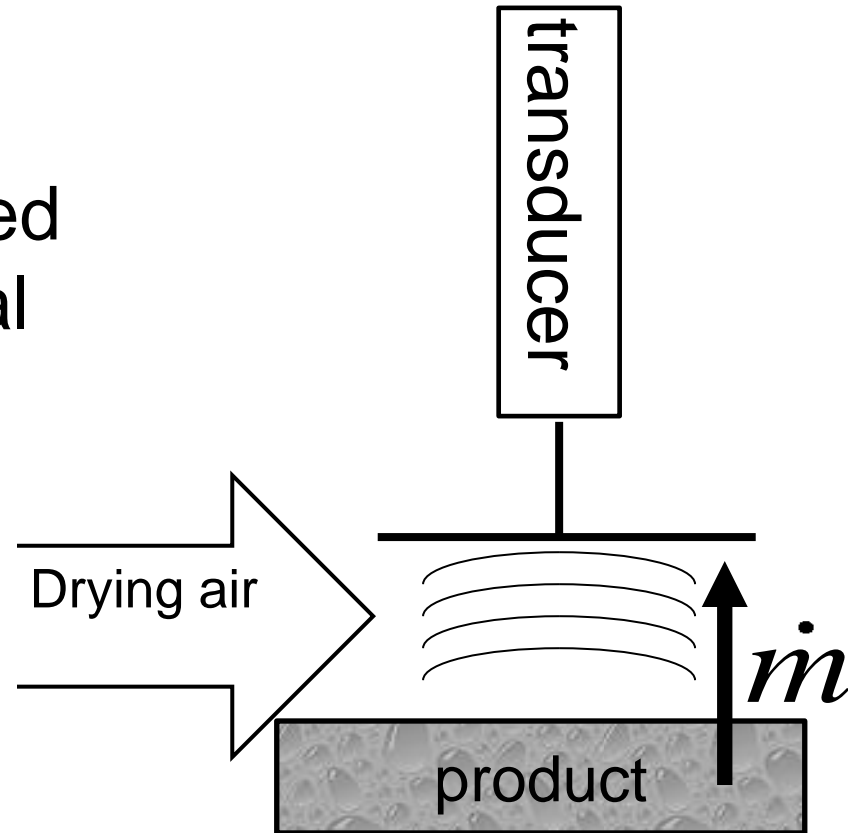
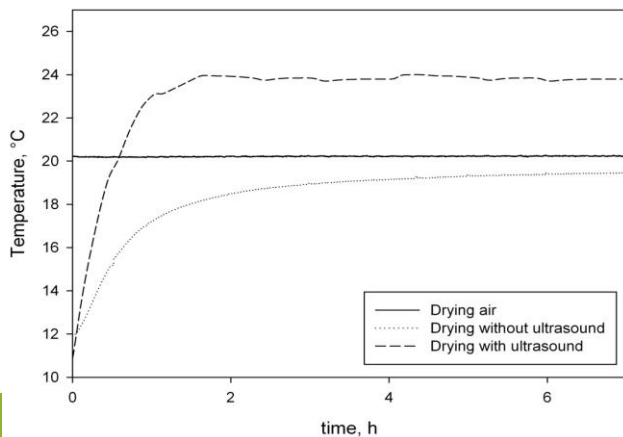
# Existing heat pump drying

- Determination of performance
    - Energy
    - Drying
  - Develop dynamic process simulation tools
  - Verification
- New drying concepts
- Storage drying for clipfish
  - New design of tunnel
  - Controlled volume flow



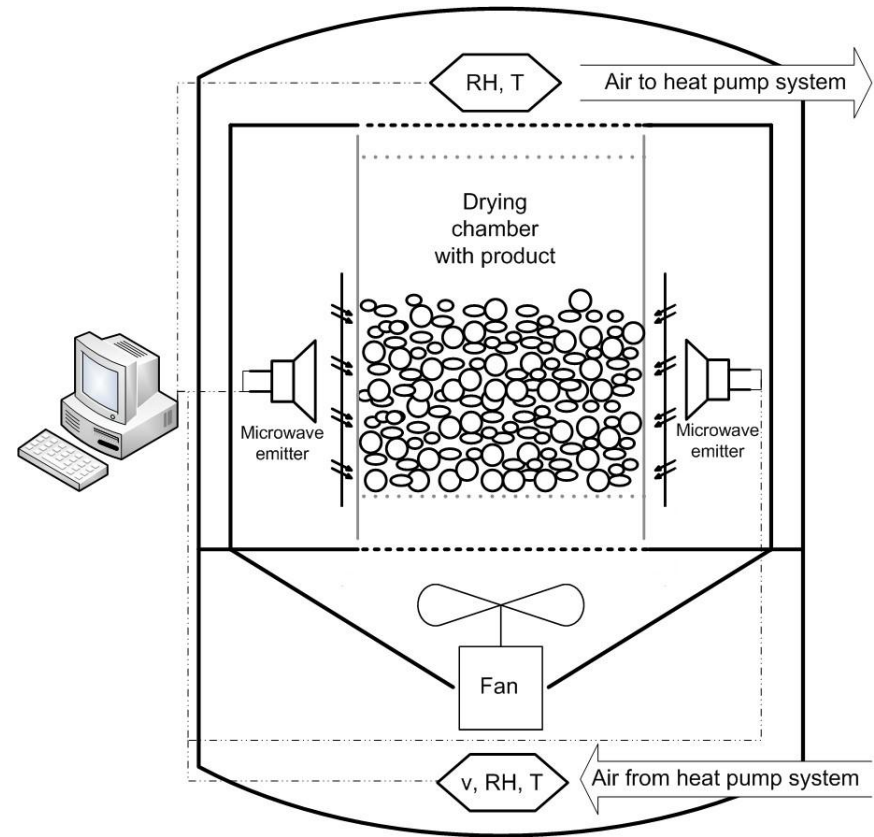
# Fundamental research

- Ultrasonic drying:  
→ Kinetic energy used to accelerate thermal process



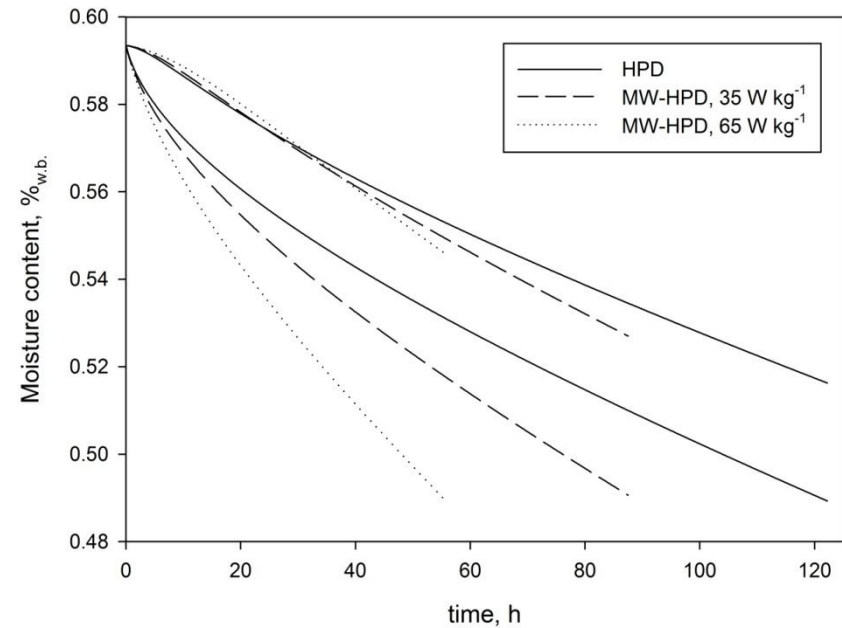
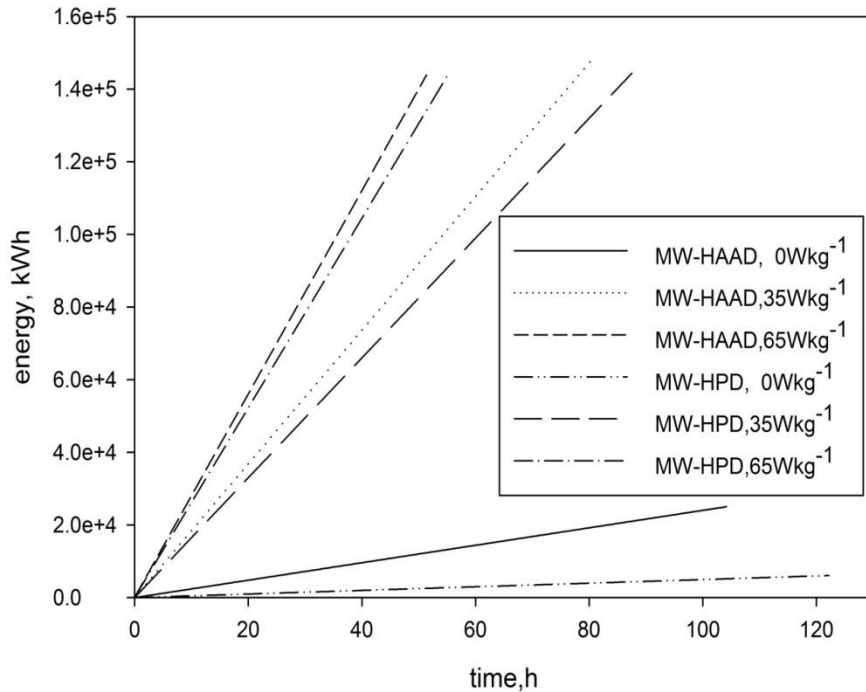
# Fundamental research

- Microwave drying
  - Drying time reductions of 90% possible





# Interaction: new vs. existing technology





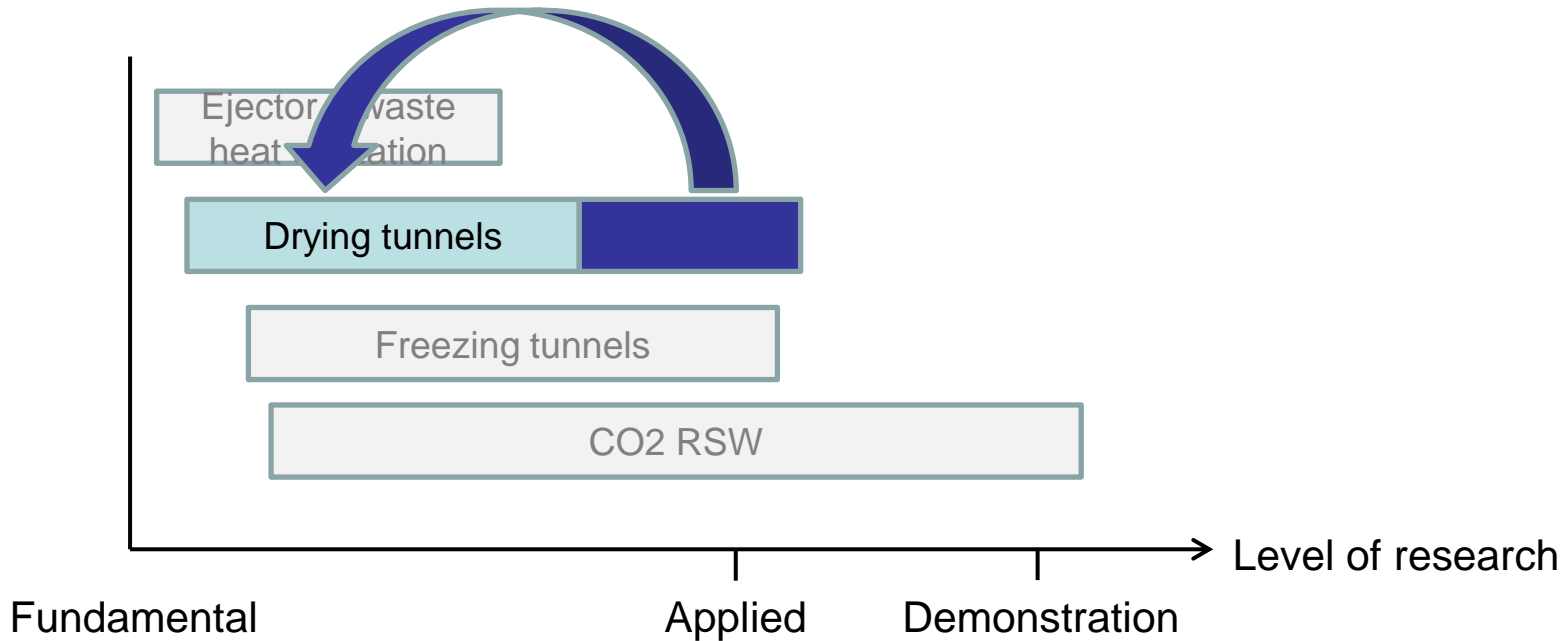
# Summary

- Co-operation with industrial project "Rasjonell klippfisktørking"\*
- Shares problems, solutions and methods that are analoge to freezing tunnel application
- CREATIV sub-topics
  - Dynamic modeling of the drying process
    - Product modeling; describe behaviour of product during drying (very complex)
    - System modeling; describe behaviour of refrigeration system and air circulation
  - Investigate control strategies for fan control to reduce power consumption of fans and refrigeration system

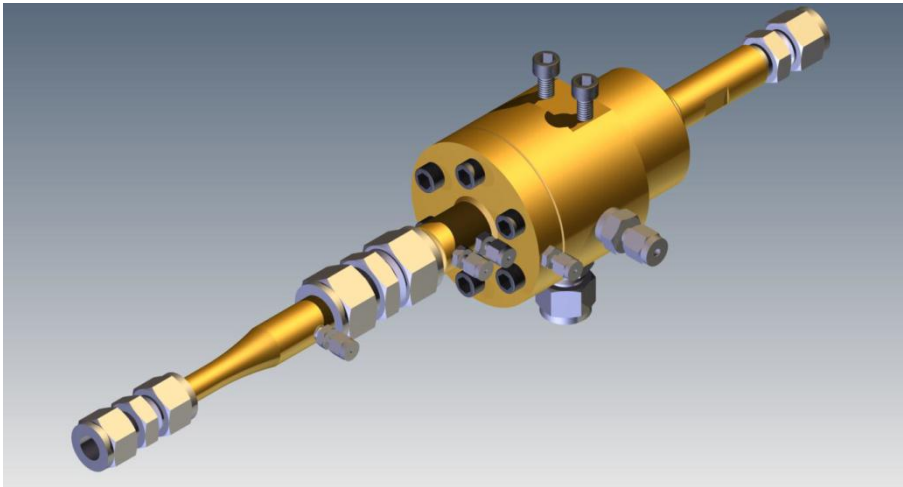
\* *Rational clip-fish drying*

# Ongoing/further work

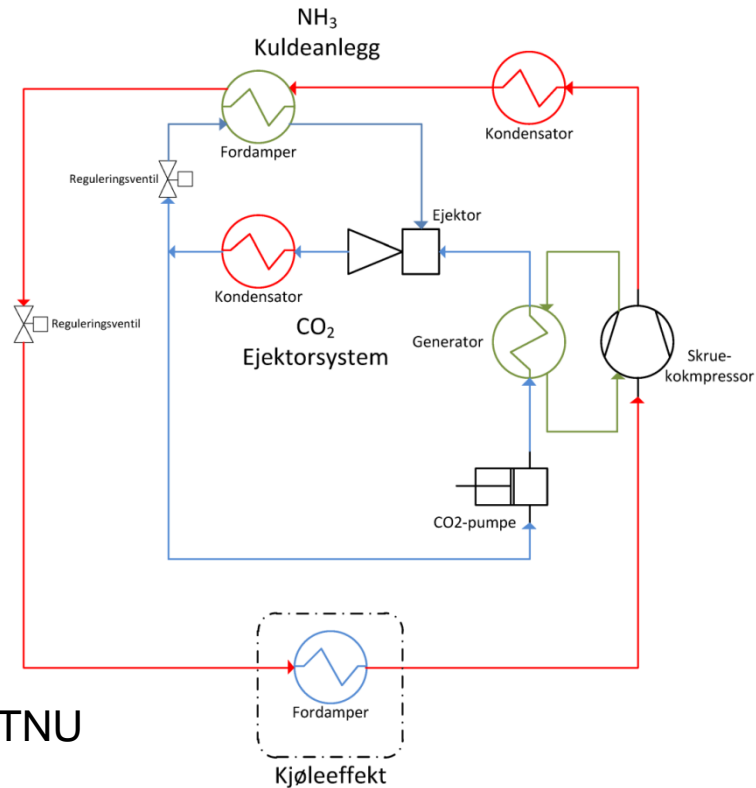
- Verification of models through lab/industry-scale measurements and evaluation of different fan control strategies
- CREATIV models and methods planned used in industry project tasks – natural platform for bringing the results out to the industry



# Utilizing refrigeration waste heat with ejector



Source: Øystein Hundseth, MSc Thesis, NTNU

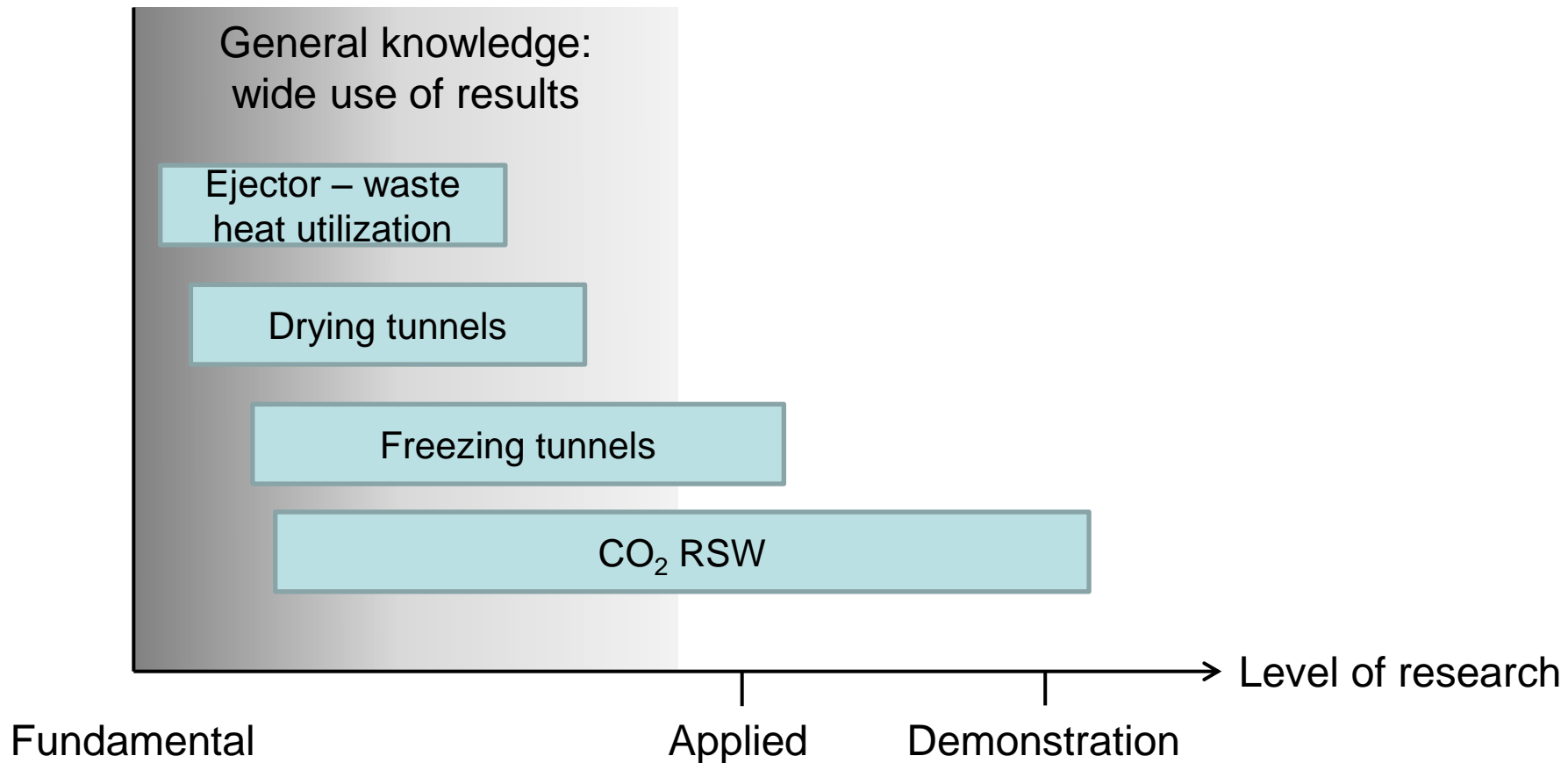


# Motivation and summary

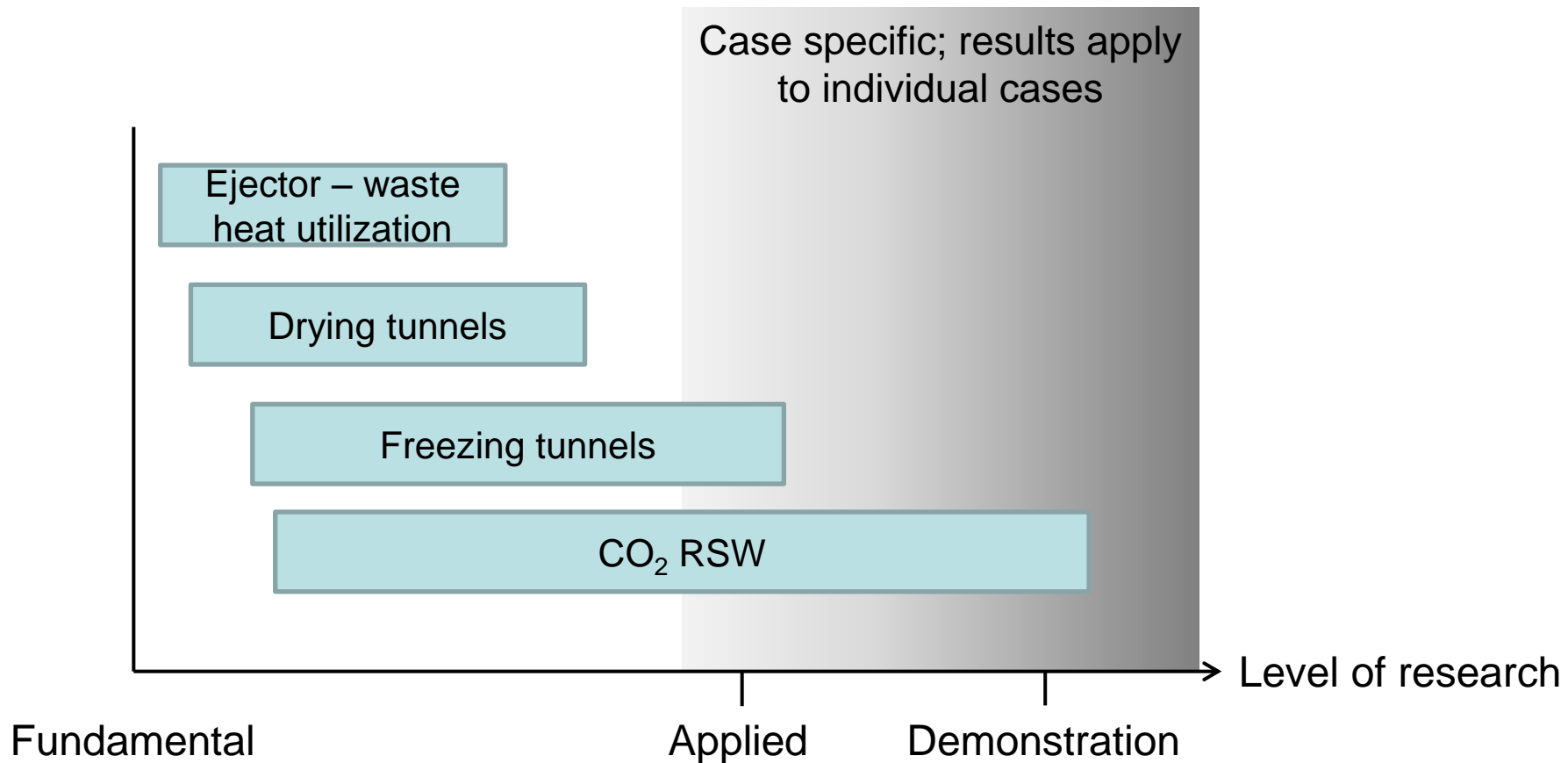
- There are significant unused waste heat from refrigeration systems
- This energy can be used to improve system efficiency or converted to cooling using ejector cycles.
- MSc Student Øystein Hunseth investigated opportunities through conceptual studies and laboratory experiments
- Heat source: Screw compressor oil cooling (60-90°C)
- Gains in efficiency was found with current setup, no further activity



# Level of research - Summary



# Level of research - Summary



# Summary and conclusions

- Topics with industry project co-operation experiences significant synergy
- Significant progress on important topics
- Work spans from near-fundamental level to demonstration and prototypes
- Some challenges to demonstrate concepts in industrial environments

# Thank you for your attention!