Final report

1.1 Project details

Project title	**Cryo Storage Generation B** EUDP 13-I ,Udvikling af lavtemperatur frostlager Generation B
Project identification (program abbrev. and file)	j.nr. 64013-0121
Name of the programme which has funded the project	Energiteknologisk Udviklings- og Demonstrations Program (EUDP). Området: Energieffektivitet
Project managing company/institution (name and address)	HCP innovation ApS Nordlundvej 166 7330 Brande
Project partners	Svend Hansen & Søn A/S Hedema A/S VS Automatic A/S Søborg Køl A/S HCP innovation ApS
CVR (central business register)	29424802
Date for submission	May.2018

1.2 Short description of project objective and results

MABAG´s dialogue with customers identified the need for larger, compact, safe, automated, and energy efficient cryogenic storage. These needs will be met in the new cryogenic storage, which is expected to be unique on the market. The project will reduce the price by 30% compared to Generation A. Energy consumption must be the lowest on the market, it must be reliable, and the capacity must be the same as Generation A.
The last years, energy efficiency is in customer focus. An average size of the product will reduce energy cost by approx. 15,000 Euro / year compared to nitrogen-based systems.
Further the energy consumption for Generation B for compressor driven systems shall be best in class.

HCP innovation: MABAG har via sin indsigt i markedet og dialog med kunder globalt, kunnet konstatere, at der er et stigende behov for større, kompakte, sikre, automatiserede og
energieffektive cryogen lagre. Disse kundebehov vil blive imødekommet i det nye anlæg, og forventes at være helt unik på markedet. Projektet skal reducere prisen med 30 % i forhold til generation A, energiforbruget skal være det laveste på markedet, det skal være driftsikkert og kapaciteten skal være den samme som generation A. Et sådant gennemsnitligt produkt vil reducere energiomkostningen med ca. 15.000 Euro/år i forhold til nitrogen baserede anlæg.

1.3 Executive summary

The need for storage of organic material at low temperature is rising and follows developments in genetic engineering and new medical therapies. Partners have over the last 8 years invested several millions in the project development.

Due to EUDP support it has been possible developing a new, more compact, energy efficient, reliable and modern system Generation B.
Development of the new system has been technically challenging due to new technologies.
However it has been possible to implement several new technologies successfully and develop a system as planned. The new generation B as developed will be the first and only product of this capability on market. (see competitor analysis later as well)
There are actual projects in promise. Distributor network is in development and "The Royal Danish Trade Commission" is searching for distributor in Germany.

1.4 Project objectives

Aim and Goal of project has been development of a technologically modern new cryogenic storage-systems that is best in class in energy efficiency.
Improved materials, technologies and methods shall improve the system to generation B as well as reduce energy demand segnificant. Temperatur distribtion inside the system is important as well.

1.5 Project results and dissemination of results

Before project start is was not sure if the available technologies, methods and components would be applicable for low and ultra-low temperature environment. The area of ultra-low temperature is neither well analyzed nor documented and even material data is not really available.
The main project risks were the needed time and effort to find the right material, process and components for ultra-low temperature if even possible.
Compressor cooling systems for these low temperature are not available, need to be developed.
The project start has been slow due to needed material and process test. Some test failed that demanded new solutions and new tests.
Since components and materials have lead times and not all work can be done parallel, project flow has been interrupted to solve technical issues, find solutions or get new technologies to work.
However, the project succeeded and objectives got fulfilled in general, even so not all detail results was able to archive.

The technical design has been based on newest technology and principles. Being ahead is always challenging and demands special effort.
Technical results – selection:

- 3D print offers new technical opportunities and a new upcoming technology.
- Direct drive is a new energy efficient technology. It has been necessary to get support directly from Siemens Germany
- New technology of compressor cooling system
- Materiale technology, research for data
- Bearing technology, new solutions for ultra-low temperature
- Adhesive technology, solutions and data
- Plenty smaller experiences and technologies that support the project.

Size and price:
The actual system is 41% more compact than the old system Generation A. That means we can store 41% more items within the same volume and at a similar cost. This reduces the cost per item that has been the goal.

- Generation A System Kuwait I, size and capacity:
  length outer cell 7,6m, (inner cell 5,1m,) outer cell width 5,3m
  capacity 3024 x 500ml

- Generation B System as tested, size and capacity:
  length outer cell 7,2m, (inner cell 5,6m,) outer cell width 5,4m
  capacity 4116x 500ml

The inner cell contains 12% more items/m², the outer cell contains 41% more items/m²

Work environment:
The new system has been tested and demanded maintenance will be reduced. This will further reduce operational cost.
User will not get in contact with fluid nitrogen or cold climate. All work in cold environment will be done by robots. Health and safety will be improved significant. Work environment will be improved significantly.

Technology:
The project make use of most modern technologies as 3D print, Vacuum Insulation Panels, Direct Drive System and complete new cooling system.
Vacuum Insulation panels reduce the energy consumption of the cooling system.
Further new materials, adhesives and lubrication have been used. Being ahead in technology is important for sale on the marked.
All project participants have stated to have learned and participated a lot from the project and developed their company technologically.

Compressor cooling
Part of project has been development and test of compressor cooling system. Compressor cooling for a large volume at -80°C is challenging and no systems are available. The system had to be developed from scratch. Cooling system contains several demands:

Air drying, ice

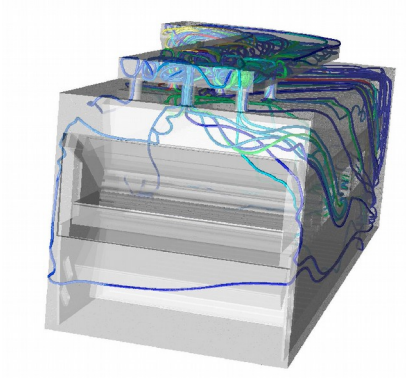
Ice in the system is on of the challenges and largest risks in an ultra low temperature storage.
Ice spoils the mechanical parts and sensors. It can't be removed inside the -80°C area. The necessary drying of air in -80°C has been established and worked fine. Under normal system working condition the system was complete ice free. De-Icing has been very successful.
However, the high air humidity this summer as well as a not well sealed system had loaded the cooling and drying system hard.

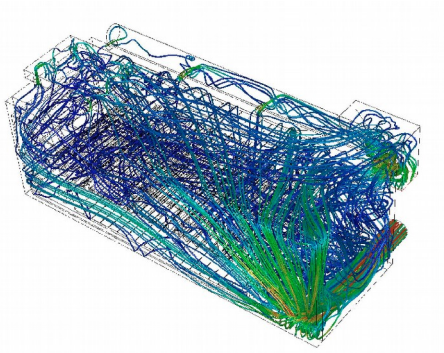
Cooling, distribution of cold air

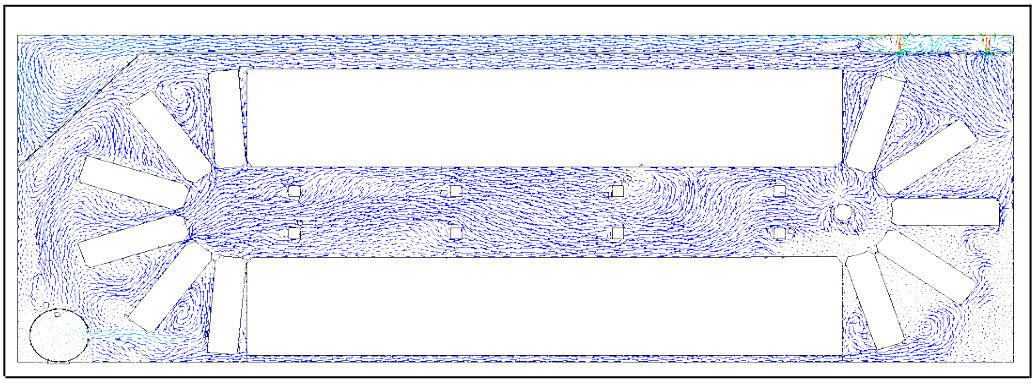
The cooling system relies on air circulation in the storage. Air circulation is essential for equal temperature distribution inside the system. The inner temperature has been measured in 6 points. There has been developed a well working fan system working in -80°C temperature.
The storage has been build as compact as possible to save space. It has been challenging archiving sufficient airflow in the storage. Two strong fans and air guides were not sufficient for an optimal distribution of cold air. Hot areas around the front door were measured.
The inner storage had been rebuild and height increased for more space for airflow. However, more space than now will be needed to transport the cold air sufficient equal and fast inside the system. Temperature distribution need to be improved to fulfill markets requirements.

Simulation

For optimization of air flow, CFD simulation has been used, supported by Vestas Fluid Specialists.







Computer Fluid Design can be used limited only. The extreme heavy air is difficult to simulate. Further effects as sublimation are insufficient known and can't be simulated.
Further analysis for optimization are ongoing.

Energy efficiency:

In this projects new energy efficient technologies have been made use of as:
Direct drive systems that do not need gears and are more energy efficient than gear motors. Efficiency of gear is between 60 and 70%. System without gear so improves energy efficiency.
Vacuum Insulation Panels that have the highest possible insulation today that reduce energy losses significant. The chosen cooling system is designed to be most energy efficient.

Energy balance (based on EUDP request data, calculated of Institute of Technology in Denmark)

The calculated system (SSI) is quite the same as the system build and testet for the EUDP test.

System A) Calculated (SSI) system size:	inner cells length 7,2m, total length 9,5m
	capacity one storage: 4608 x 500ml
System B) EUDP and tested system size:	inner cells length 5,6m, total length 7,2m
	capacity one storage: 4116 x 500ml

All calculation is based on VIP insulation used and therefore lower energy consumption.

Base calculation parameters for Nitrogen cooling:

Cost (DK):	*0,27 €/kg*
Energy consumption for production:	*1kWh/kg*
Nitrogen out blow after use at	*-30°C*

Compressor cooling project results and experiences:

For the given example:
Compressor cooling
System A) Calculated energy consumption per anno:
11.560 kWh/anno; 3083 €/anno for calculated (SSI) system

System B) Compressor cooling as tested in system.
Distribution of air has not been sufficient. Cooling system couldn't reach the defined temperature of -80°C. Energy consumption has been too high. Actual the project team works further on improvement and new concepts to archive the goal. There are started different initiatives to analyze the reasons for energy consumption.

Nitrogen cooling
A part of the energy in fluid nitrogen is not usable and gets blown out.
Further nitrogen vaporizes in tank, tubes, and hoses as soon it is delivered, regardless if used or not. These losses need to be added to the calculated consumption.

System A) Calculated energy consumption: 79.000kg/anno; 15.730€/anno for calculated (SSI) system

System C) Energy consumption measured in project Kuwait generation A, no VIP insulation,
Size: inner cells length 5.2 m, total length 7,6m
Capacity: capacity one storage: 3024 x 500ml
Consumption: 99.070 kg/anno /system

As mentioned before the real consumption of nitrogen is higher than calculated consumption of nitrogen.

Conclusion and Resume
As both calculations made by Danish Institute of Technology as well as measurements show, the compressor cooling system is more energy efficient and cheaper in operation than liquid nitrogen cooling. However, optimization and improvement of compressor cooling system are needed and ongoing.
The needed knowledge and experiences was gained through this project.
Actual performed calculations, simulations and investigations both of flow (CFD) and cooling system (Ebbe Nørgaard, Dryingmate) shall analyze reasons for results as well as areas for improvements.

1.6 Utilization of project results

Ongoing
All partners agree to utilize the project results and commercialize the project. New technologies and the work with new technologies has developed partners companies and improved the know how within these companies as well. These experiences are advantages and will be used in daily operations.

IPR – patents
HCP innovation has be applied for 3 international patents.

Marketing and articles
A *website* is prepared and will be released as soon patents are applied so far.

There has been 2 *articles* in Danish branch Magazines.
http://www.hospitaldrift.dk/content/hospital-drift-arkitektur-44
http://www.danskbiotek.info/content/life-science-2

There are planned articles in German branch magazines.

Near future

Development of investment projects like Cryo storages and systems have a long lead time often over years.
Our sales partner MABAG has actually sold new systems called ”Kuwait II”. We expect to deliver within 2018.
In Denmark has been found a local distributor that works already in the market.
The “Royal Danish Trade Commission” is ongoing finding a German distributor.
Articles and advertising shall support sales work. This is already ongoing.
Work in EUDP project has developed learnings and experiences that are registered in a structured way.
The new system to be sold as System Generation B will be improved compared to the test system. The sold systems will contain all learnings from the test system - that has been listed in a database of known improvements.

Market

The marked for Cryo Systems is relatively new and not large yet. Customers are careful and conservative.
The Cryo Storage will be presented at the most popular conferences that include exhibition areas. The main barriers for successful market introduction are
- timing in relation to competitors,
- technical challenges,
- needed documentation and approval by “lægemiddel styrelsen”
- durability/stability and
- cost of system.

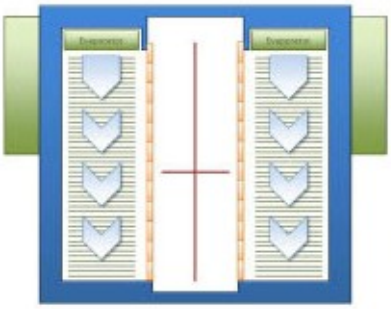
Since this system and technology is new; since many new ideas and solution not seen before are realized, customers need to be convinced about these advantages and the excellence of this new product.
It is planned using the existing system actually as presentation system for potential customers as well as proof of function and reliability.
. MABAG expects that 10 Generation B Cryo Storages can be sold within two years if the concept is matured and tested, which is one of the main purposes of this project. This means that the product is expected to be ready for market introduction by the end of the project. The current sales potential is estimated to be 14,2 million Euro.

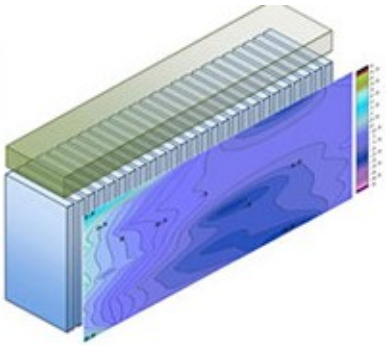
Competition

HCP Innovation and MABAG have a good overview of the competitors as well as the advantages and disadvantages of different systems. It is exactly by means of this insight and dialogue with customers that the idea for the new, more compact system was born. The links below provide a picture of competitor’s solutions:
http://www.brooks.com/products/life-science-systems/storage-systems/ultra-low-temperature-storage-systems
http://www.hamiltonrobotics.com
http://www.liconic.com/products/automated-incubators/automated-incubators.php

Brooks

http://www.brooks.com/products/life-science-systems/storage-systems/ultra-low-temperature-storage-systems





Brooks installed more than 250 system.. Company is US based. Robotsystem runs i -80°C.
Brooks System are variable but mainly for vials, not for bllod banking.
Brooks has required several smaller supplier over the last years.

Brooks was fonded in 1978 as Brooks Automation. In 2015 Brooks aquired ”BioStorage Technologies”.
Revenue (Brooks komplete) 693 Mio $, ca. 65 Mio $ net income. (Wall Street Journal)

Hamilton

http://www.hamiltonrobotics.com

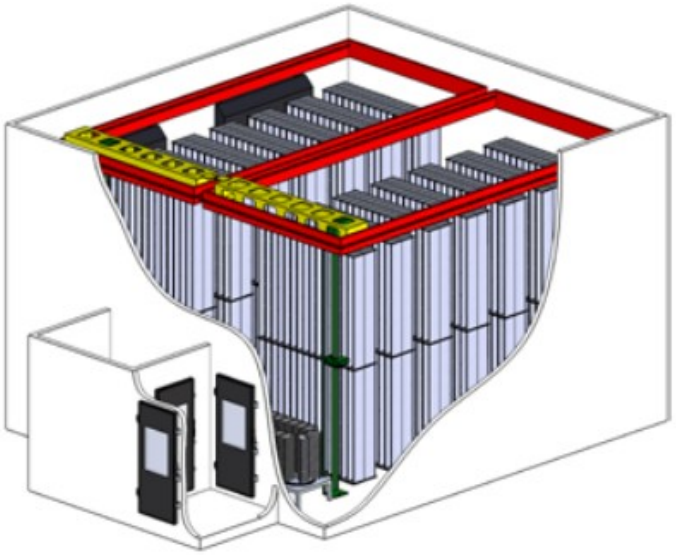
Hamilton uses -20° / -80°C design as well. Systemet is modular. Robot works i -80°C area. Company is based in USA. Hamilton-systemet is mainly made for vials system.
Firmaet is founded in 1947.

Liconic

http://www.liconic.com/products/automated-incubators/automated-incubators.php

STT1k5-ULT

Liconic offer system with vertical cylinder storage, but bad temperature distribution.
Liconic offer automated blood bank systems, but for -65°C.
Company has been founded in 1990.



TAP biosystems

https://www.tapbiosystems.com

smaller semi automated sample-vials-lagre.

Firmaet is based in Storbritannien.

NCC_MED

http://www.nnc-med-consulting.com

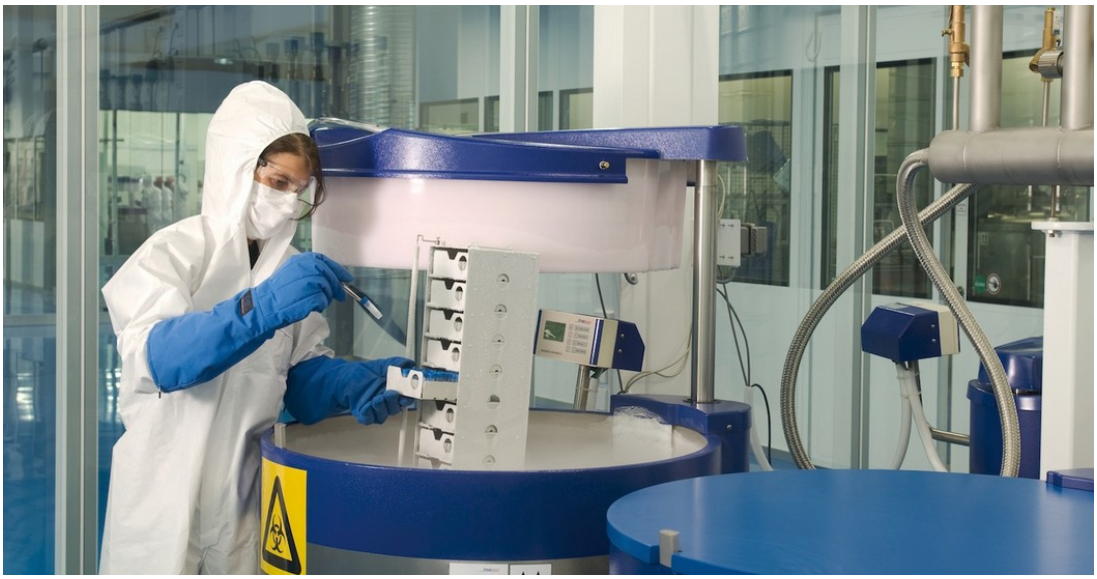
NCC is a spinn off Mabag and build vertical cylinder blood bank storage systems based on nitrogen cooling.

Other freezer

There are a large number of supplier using refridgerator for storing of organic pamterial. These systems has a large energy consumption, issues with Ice and temperatur distribution and user need to work in ultra cold area.

Freezer demand lot of space and energy (picture: Brooks)

Several companies buidling semin automated systems for nitrogen cooled storages as shown below. Today, hospitals uses usually freezer or liquid nitrogen systems as shown below. User work here in ultra cold and nitrogen enviroment.



1.7 Project conclusion and perspective

The project fulfilled expectations, aim and goal. On technical area, experiences and acquired know how has been generated even more than expected.
There has been generated valuable knowledge that is needed and basis for further optimization.
The team expects a reasonable sale as soon as customers see the product on market and get confident in function and capability.

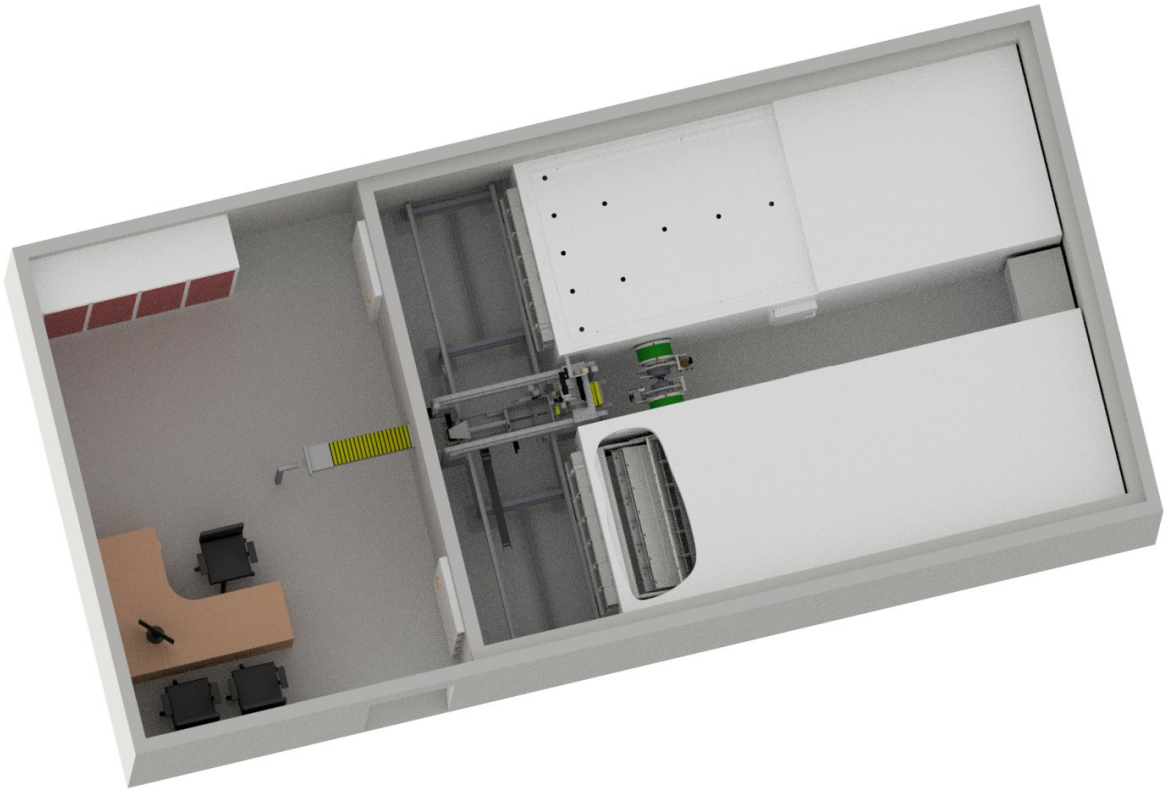
Employees:
Companies have increased number of employees as planned under project and we expect, when sale of project begins, further increase of employees will happen.

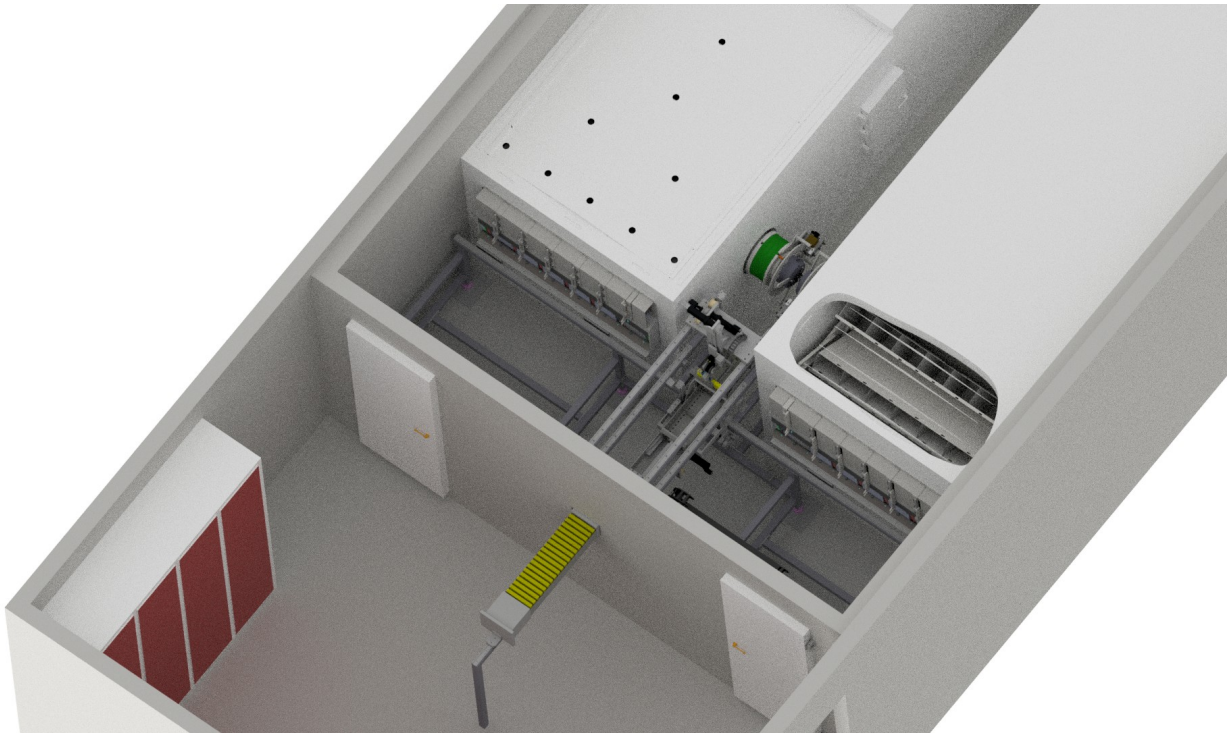
Results, expected and not expected:
A large part of the project work and delay are based on finding the right materials, components and methods.
However the technical knowledge and technical results has been even better than expected. In some areas further improvements are needed to archive the final and needed results. This work is actual ongoing based on learnings from EUDP project.

Outlook
It seems to be possible to extend the use of the Cryo System to an even lower temperature. Hence here is a new marked with nearly no competitors, part of the team will analyze and try to improve the system to cover lower temperatures as well.

Based on ongoing work regarding distributors, the team expect sales results as planned.

Annex 1
Graphics



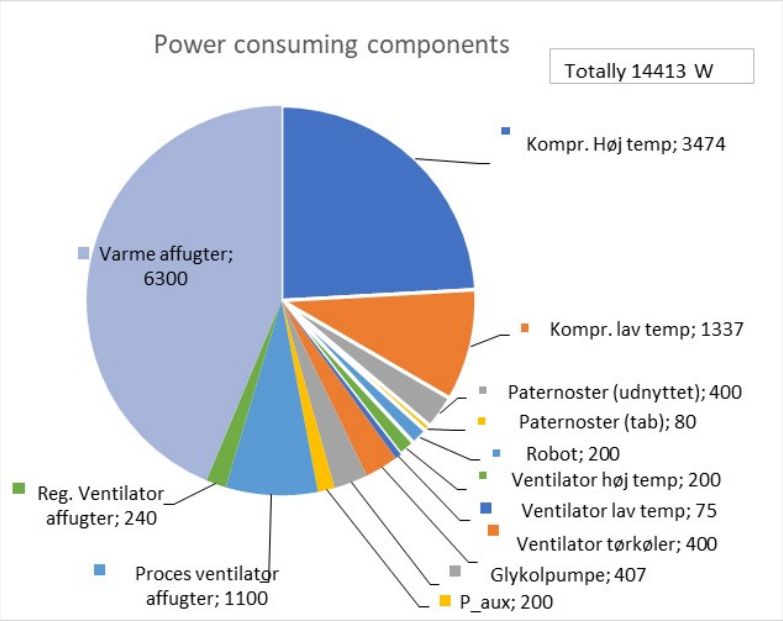


Annex 2

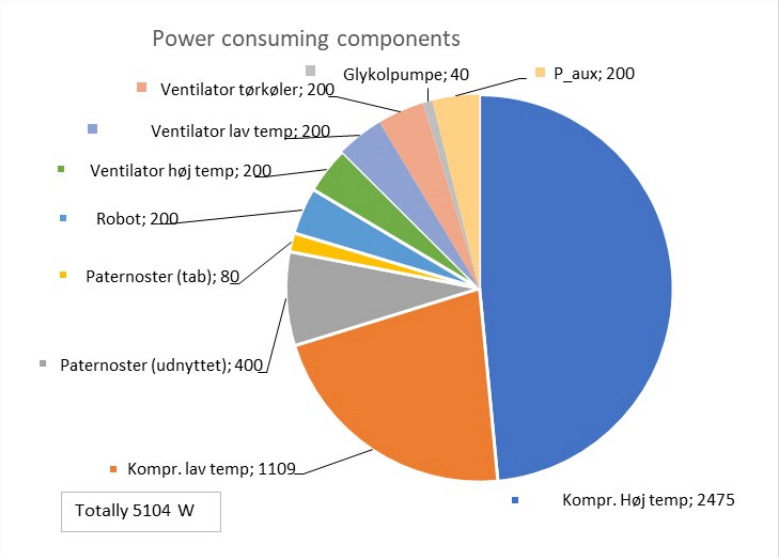
Calculations done in 05-2018 regarding cooling system

The reason for colling failuer has been:
- drying system and energy in the system
- motors and drives as energy source
- lack of sealing and insufficient insulation

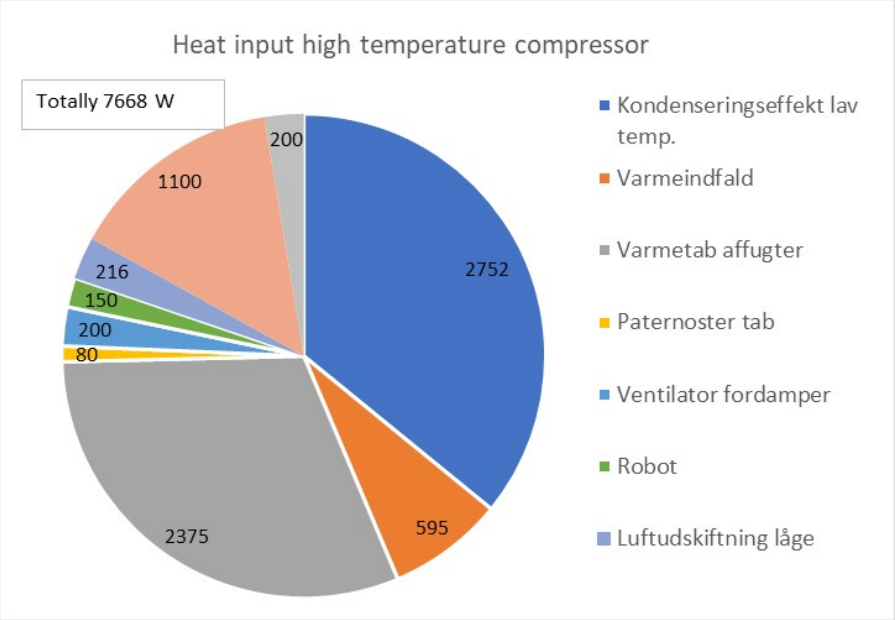
Calculation are made by Dryingmate, Ebbe Nørgaard



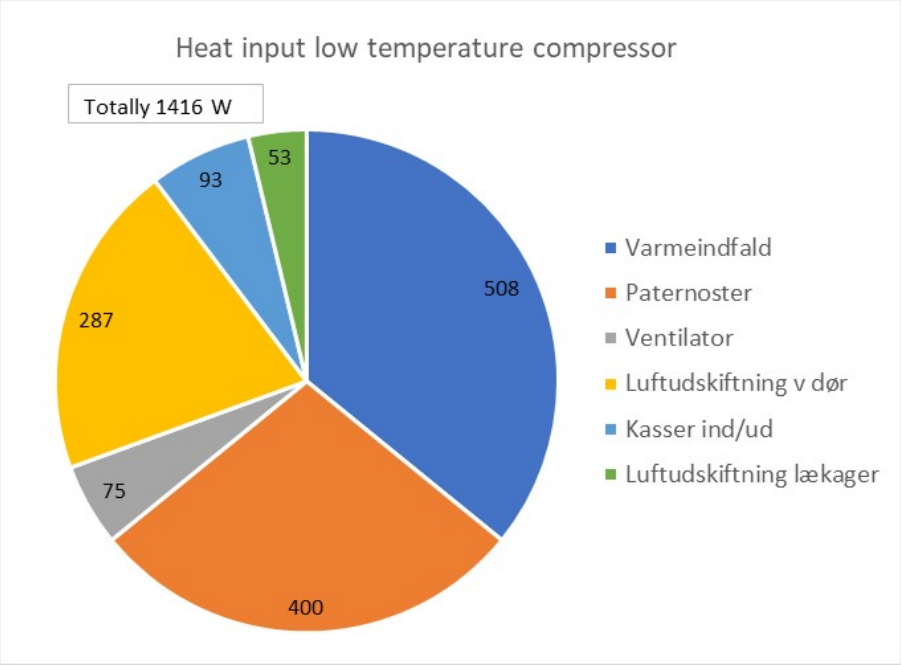
The dryer is very energy consuming and a large part of that heat get emitted insite the outer cell.



Without dryer, the compressors has the largest power consumption where the high temp. comressor need to take the laod of low temp. comprressor as well.



The high tempertur compressor need to absorbe the heat from dryer as well as the low temperatur compressor - as mentioned before



Inside the low temperatur area, the moving parts and insulation have largest influence.

Improvements need to be done in area of:
- door insulation (done)
- insulation (next prototype)
- new way of drying air (in work)
- reduction of power due to motors (to be done)
- reduce pumps etc.m (to be done)
- improved cooling aggregat (to be done)

Calculations show we can be able reducing the demanded power form 14.4kW to less than 6kW.