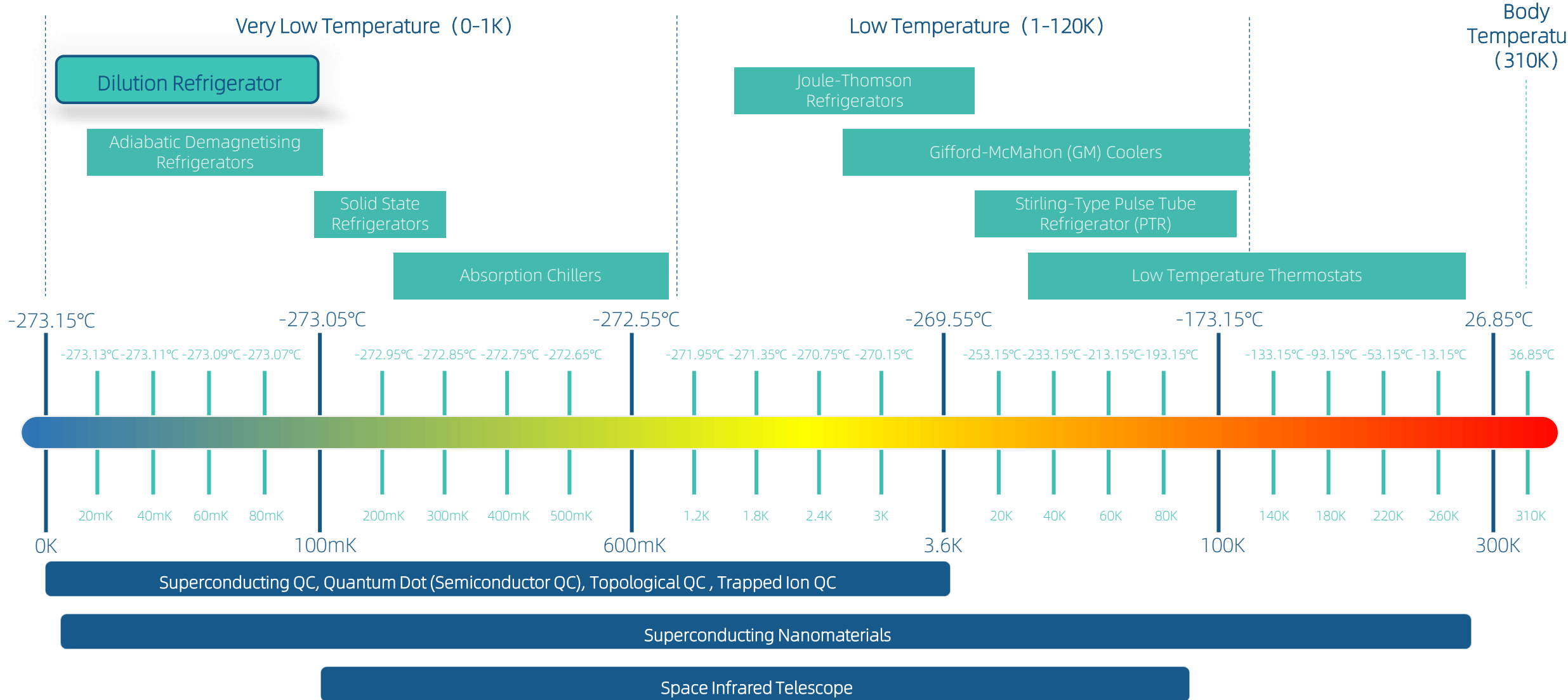


# Dilution Refrigerator

Market Research Report

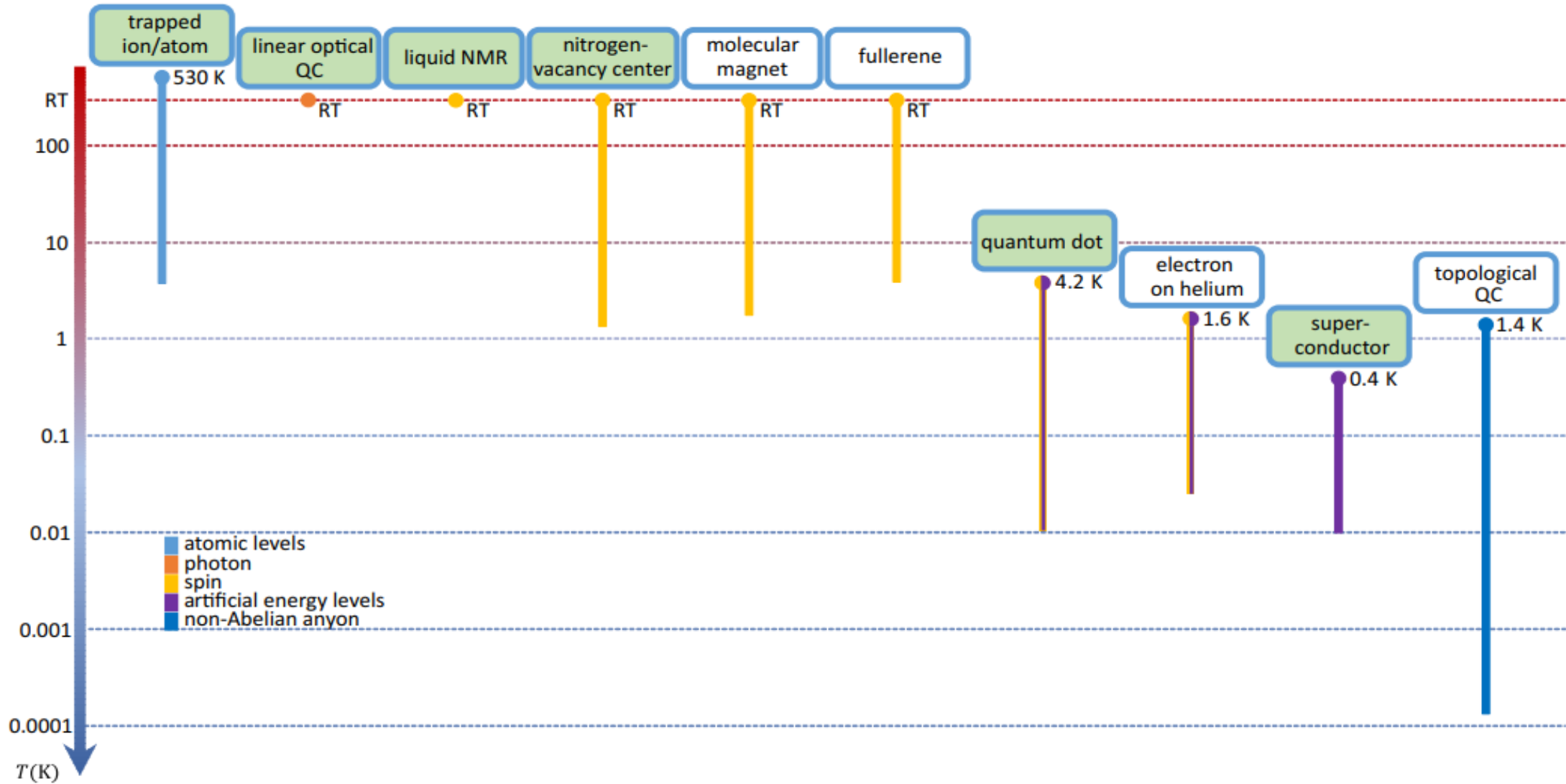
December 2022

# Cryocooler, Temperature & Application



Note: So far, dilution refrigerators are the best solution for maintaining ultra-low temperature environments for quantum computing (QC);  
All cryocoolers capable of operating below 4K can replace the consumption of liquid <sup>4</sup>He as a thermal bath for pre-cooling the entire system to 4K

# DR in Various Temperature Fields



Resource: Low-temperature environments for quantum computation and quantum simulation, Hailong Fu et al, 2021 Chinese Phys. B 30 020702

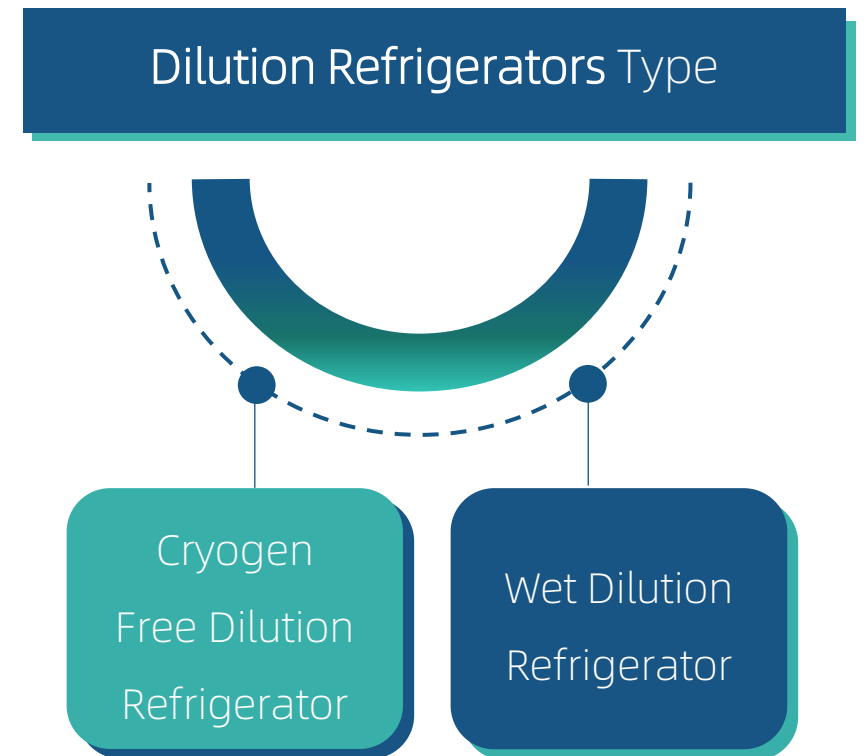
Note: Quantum Simulation experiments have been reported in systems with green color background

# Introduction

This report covers dry and wet **Dilution Refrigerators (DR)** in the temperature range of 4K to below 10mK. Cryogen-Free Dilution Refrigerator (CFDR also called Dry DR) based on pulse tube technology, Wet DR mainly use at the extremes of vibration sensitive applications, such as Scanning Tunneling Microscope.

Compared with other mK very low temperature (VLT) zone refrigerators (adiabatic demagnetization refrigerator and sorption cooler), DR can work continuously for longer time, with the advantages of **simple operation, no vibration and electromagnetic interference, stable performance, etc.**, widely used in **condensed-matter, quantum computing, nuclear physics and astronomical observation.**

Dilution Refrigerator mainly divided into 2 types :  
**Cryogen Free Dilution Refrigerator (CFDR)**  
&  
**Wet Dilution Refrigerator (WDR)**



# Comparison of Cryocoolers

Type of Cryocoolers	Temperature	Applications
Dilution Refrigerators	4.1mK-100mK	Quantum Computing, Solid-state Physics, Materials Research, Nuclear Physics, Ultra Ground-Based Research in Cryogenics
Adiabatic Demagnetising Refrigerators	20mK-100mK	Space Applications, Ground Experiments
Solid State Refrigerators	100mK-300mK	Microcalorimetric Detectors in Space, Cryogenics, Cryobiology and Cryomedicine
Absorption Chillers	220mK-800mK	Space Applications, Ground Experiments, Spherical Loads Experiments
Joule-Thomson Refrigerators	1.68K-15K	Large Infrared Space Telescopes, Superconducting Detectors for Astrophysics, Quantum Applications
Gifford-McMahon Coolers	2.5K-120K	Cool for High-Temperature Superconducting (HTS) Magnets, Custom Cryostat Design, Low-Noise Amplifiers (LNA) for Radioastronomy
Stirling-Type Pulse Tube Refrigerators	15K-100K	Space, Underground, Underwater, Special Workface where Room is Extremely Limited
Low Temperature Thermostats	Above 30K	Foodpreservation, Agriculture, Vaccine Storages, Medicalservices, Cooling of Electronic Devices, Quantum Imaging (SPNSPD)

Sources: companies' official website, ICV TAnK

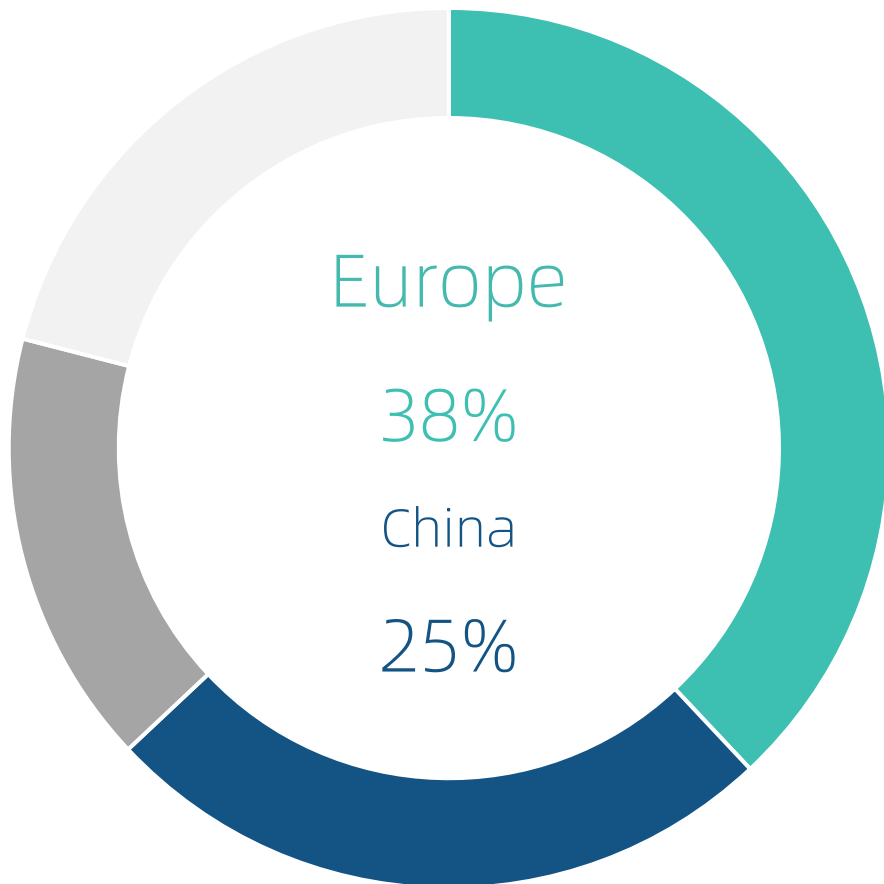
Note: 1K=1000mK; The main operating temperature range of dilution refrigerators is at the mK level, but the actual measurable temperature range can be up to 30K.

 Very Low Temperature (VLT)

 Low Temperature

# Market Share & Industry Analysis

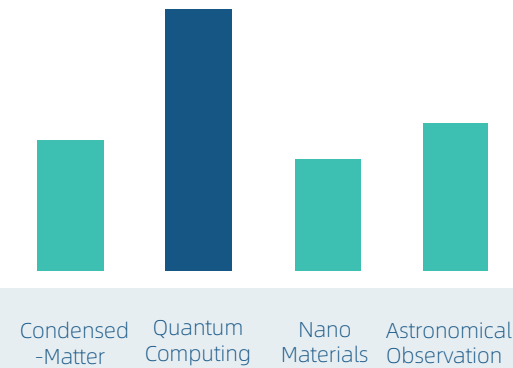
## Market Share (by Region) (2025E)



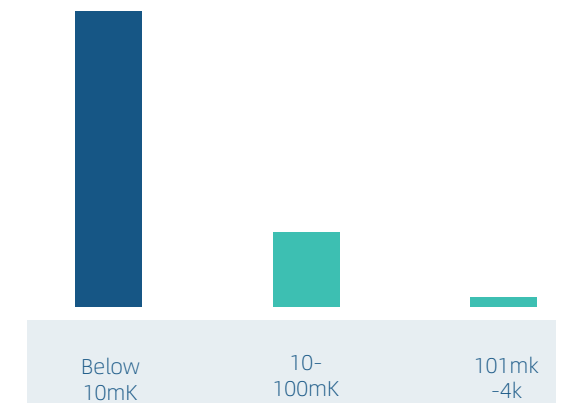
Regions are divided into North America, Europe, China and others.

Temperature divided into Below 10mK, 10-100mK, 101mK-4K.

## Market Share Application



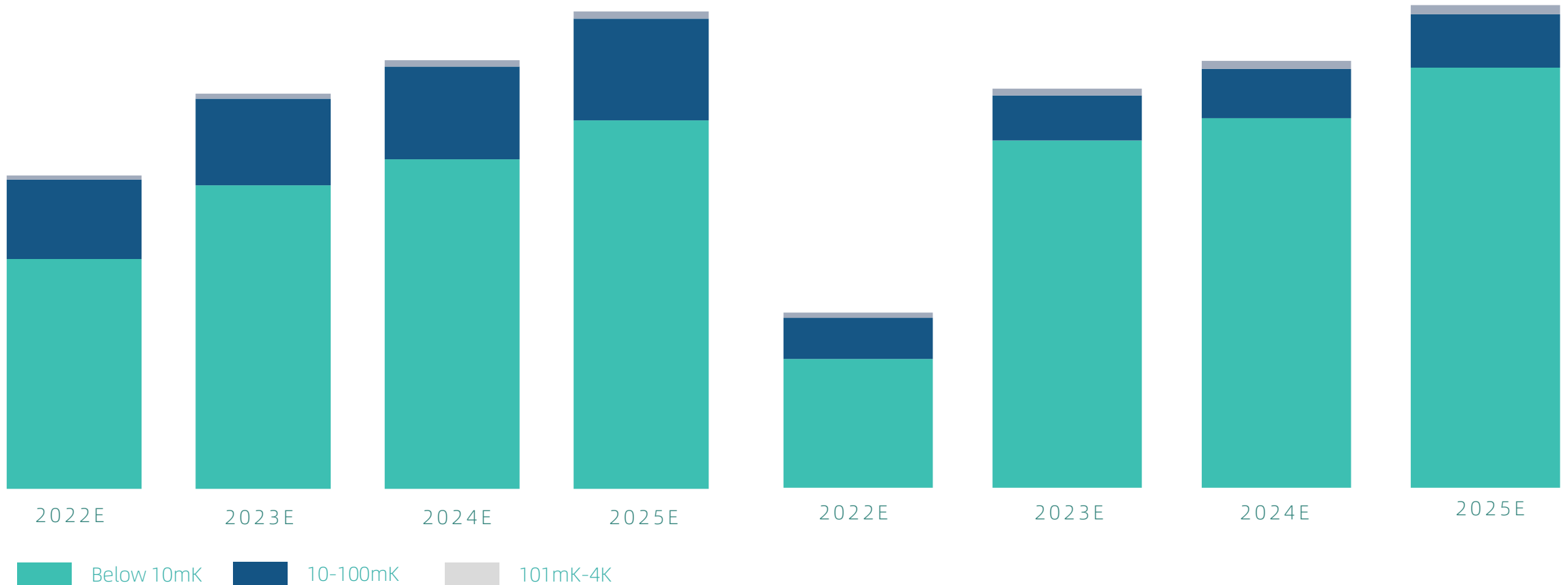
## Market Share Temperature



# Market Share & Industry Analysis

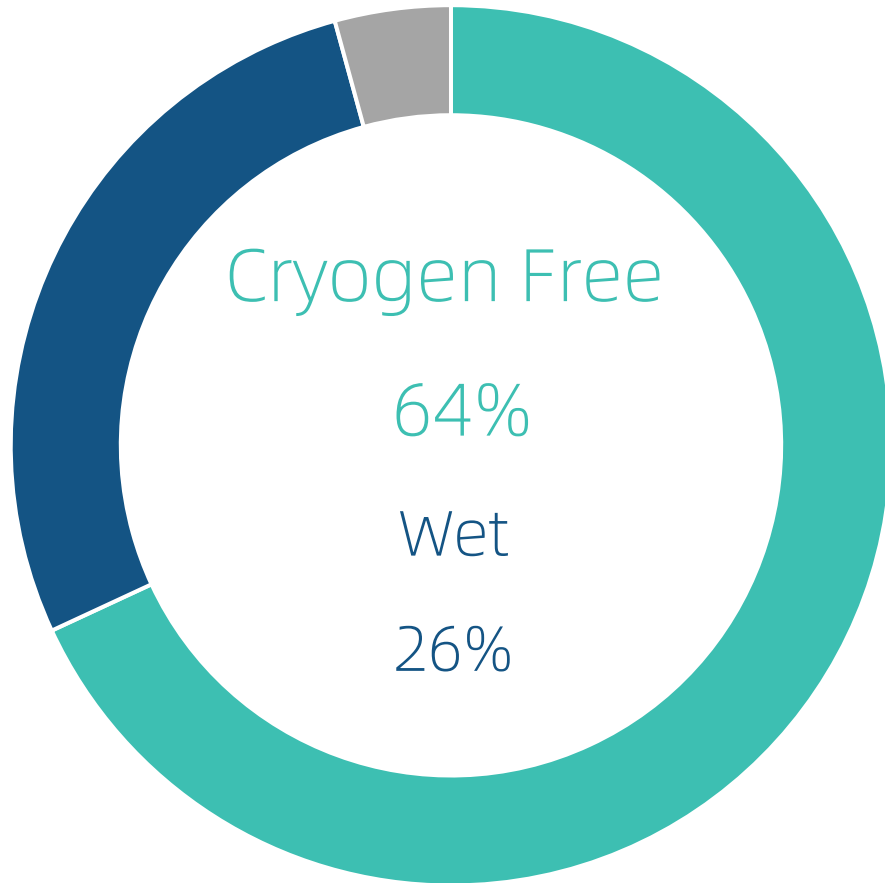
Market Share by Temperature (Europe)  
(2022-2025E)

Market Share by Temperature (North America)  
(2022-2025E)

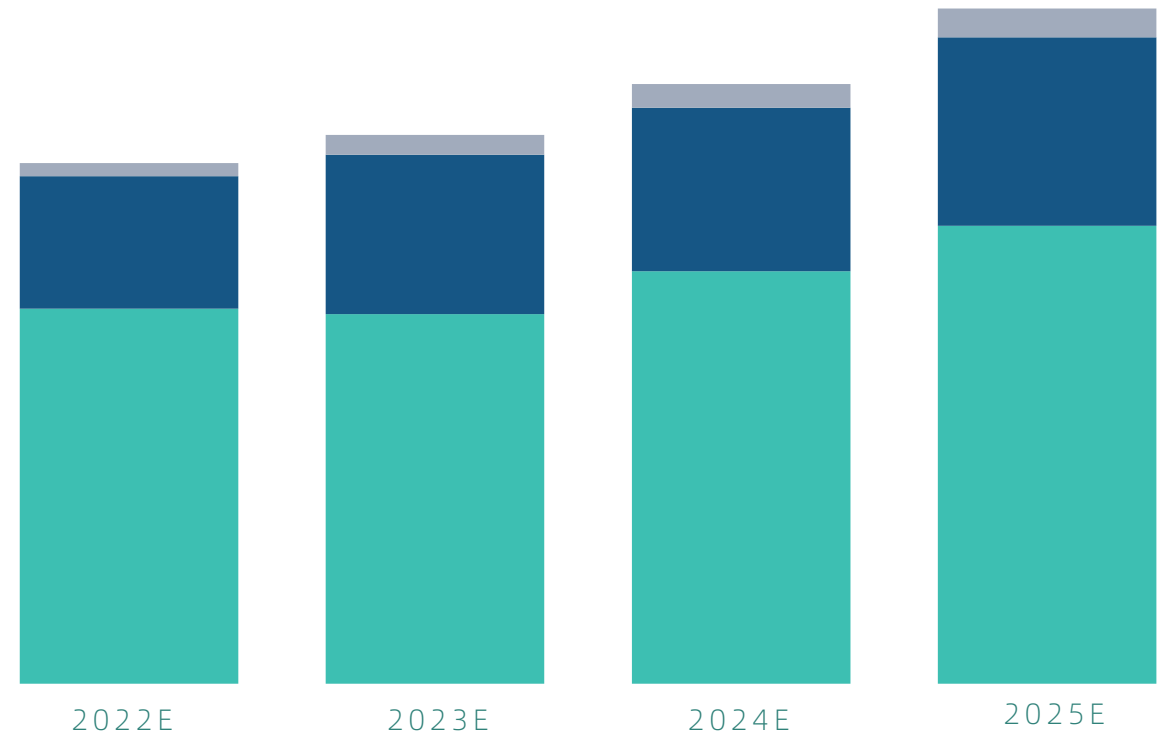


# Market Share & Industry Analysis

Market Share (by Type, %)  
(2025E)



Market Size (by Type, Million USD)  
(2022-2025E)

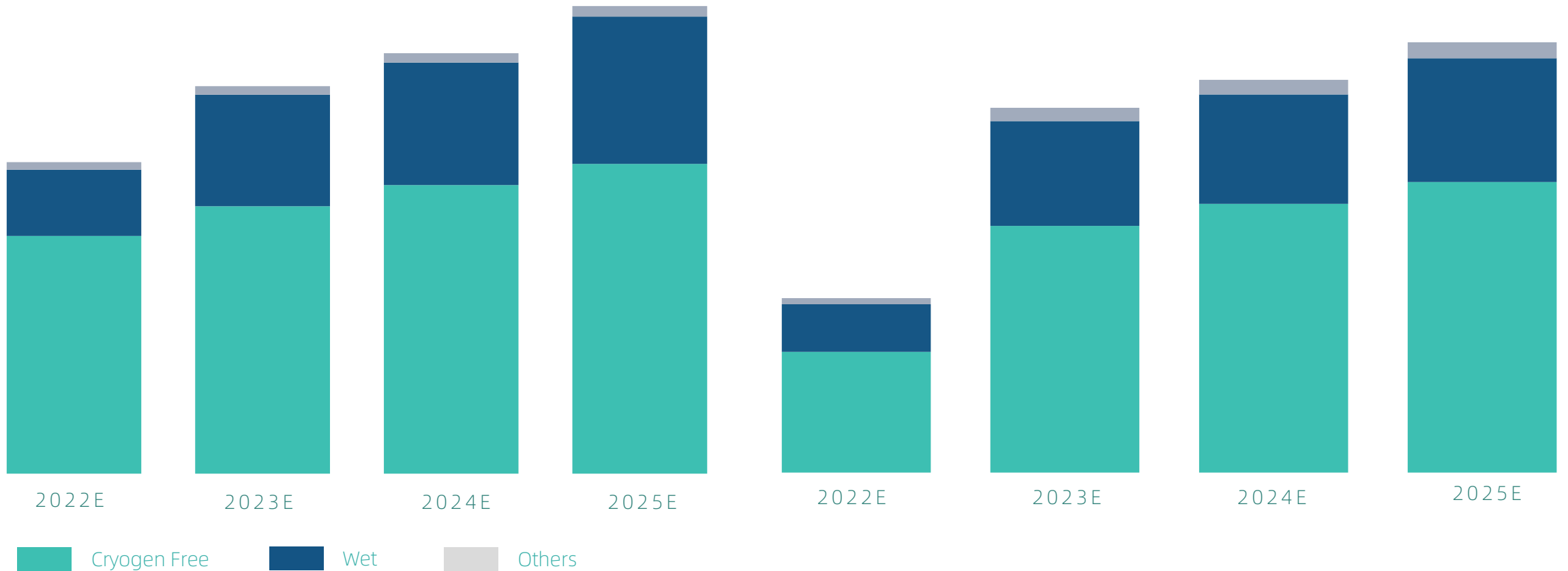




# Market Share & Industry Analysis

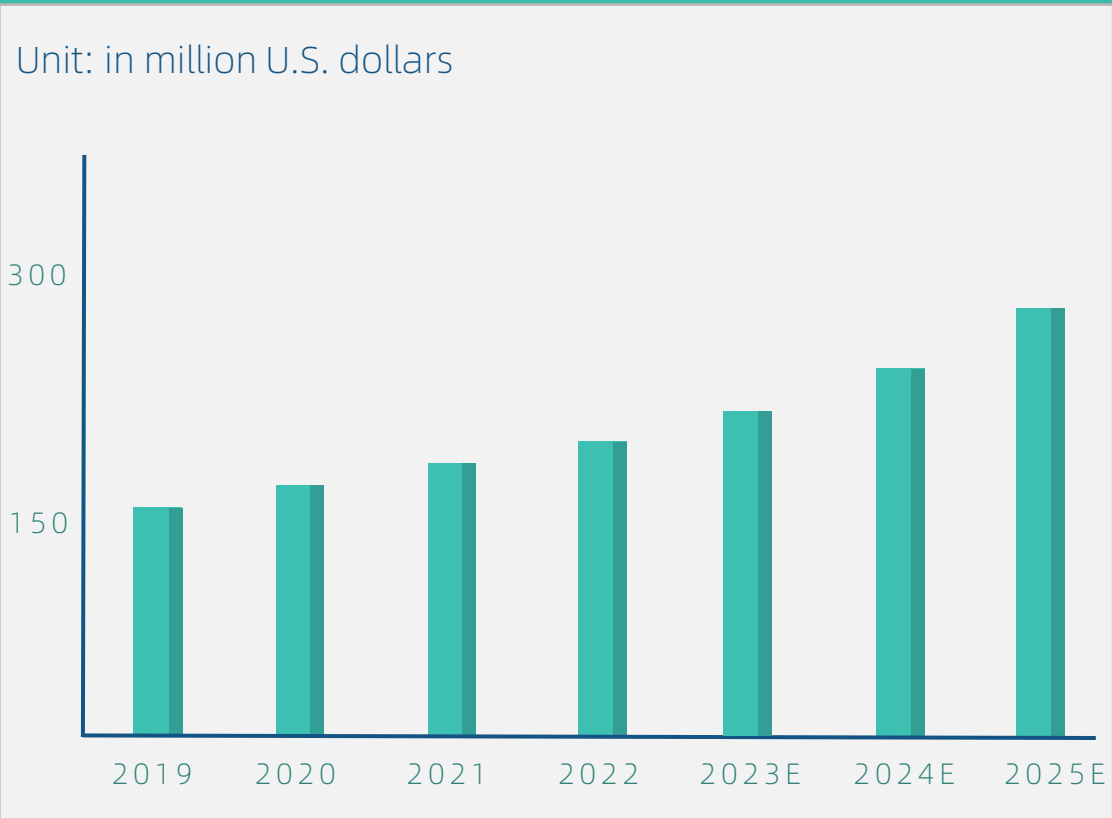
Market Share by Type (Europe)  
(2022-2025E)

Market Share by Type (North America)  
(2022-2025E)

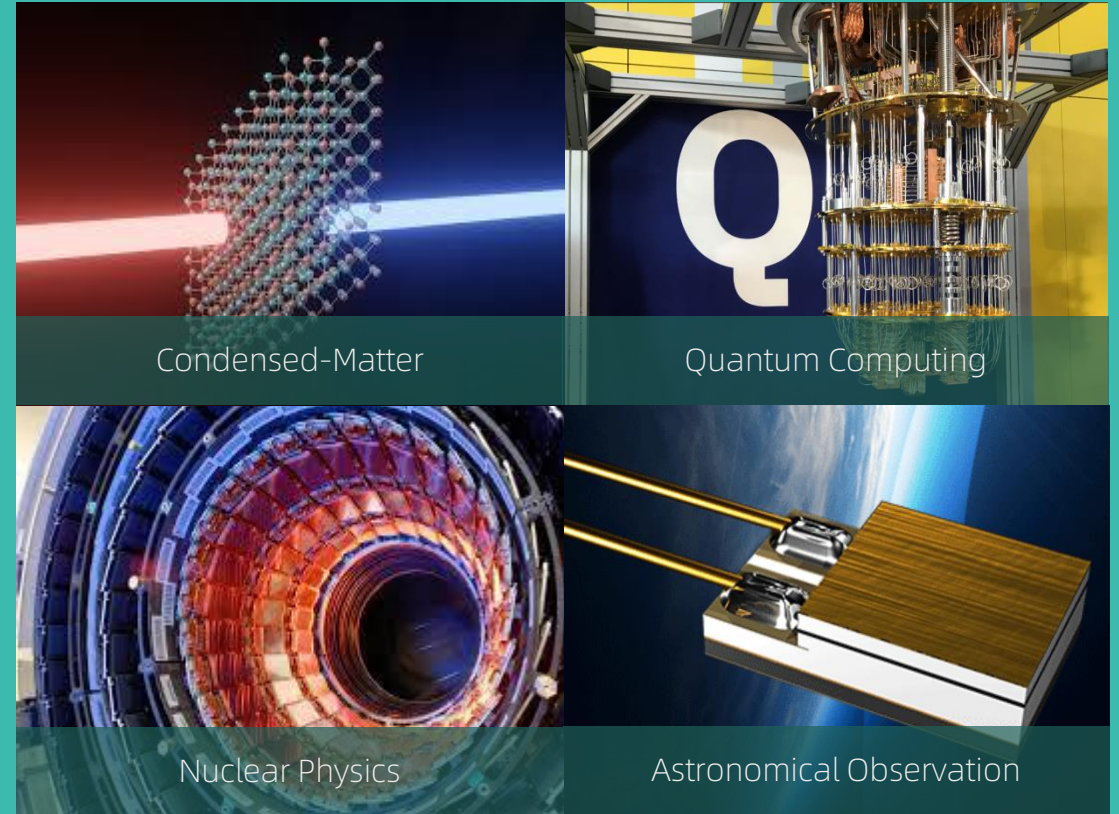


# Market Prediction and Applications

## Global Dilution Refrigerators Market Prediction (2019-2025E)



## Applications of Dilution Refrigerator



# Comparison of Dilution Refrigerators

Manufacture/Model	Type	Base temperature	Temperature control range	Cooling power at 100 mK	System cooldown (From room temperature)
Oxford Instruments/Kelvin oxJT	Dipstick-style	25 mK in a VTI or Teslatron 40 mK in a helium dewar	25 mK to 300 K in cryogen free system	≥ 20 μW	From room temperature to < 100 mK typically 6 hours
Form Factor/ Wet DR 500-TL	Optimized for STM	10 mK	n/a	300 μW	n/a
Leiden Cryogenics/CF-2000 Maglev	Cryogen Free	< 8 mK	n/a	1400 μW	24 hours
Oxford Instruments/Proteo x5mK	World's coldest commercially available continuous operation Cryofree	< 5 mK	5 mK to 30 K with magnet at full field	850 μW	4 hours (From 30k to Base Temperature)
Form Factor/ JDry-500	Optimized for quantum computing	10 mK	n/a	≥450 μW	With LN2 precooling: ≤28 hours
Bluefors/LD400	Top Sales	10 mK	10 mK to 50 K	400 μW	24 hours
Bluefors/LH250	For beamline, telescope or detector experiments	10 mK	10 mK to 50 K	250 μW	24 hours
Bluefors/LX900	Greater experimental capacity and adaptability.	< 7 mK	7 mK to 30 K with magnet at full field	> 850 μW	n/a

Sources: companies' official website, ICV TANk

 Wet Dilution Refrigerator

 Cryogen Free Dilution Refrigerator

# Timeline of DR Core Event



Janis Research (renamed as Janis ULT) established



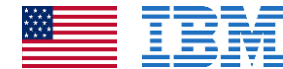
World's first commercial DR (200mK)



Cryo Concept (SPEC laboratory part of IRAMIS CEA) established



Co-founded by Chief Technology Officer John P. Davis at the University of Alberta.



'Super fridge' known as Project Goldeneye (~25mK, 1.7m<sup>3</sup>, 7ton)



1961

World's first prototype DR (mixing of 3He and 4He isotopes, 220mK)



1965

1966

1992

Leiden Cryogenics established. (Leiden University)



2000

Bluefors (Low Temperature Laboratory of Aalto University) established



2008

2017

IOP CAS developed a liquid helium-free DR prototype (10.9mK)



2021

2022

Form Factor acquired Janis ULT's DR product line



2022

# Key Players



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# Ordering Information



Dilution Refrigerator  
Market Research Report

- |                                  |  |              |
|----------------------------------|--|--------------|
| <input checked="" type="radio"/> | Electronic (1-5 users)                 | 6,500.00 USD |
| <input type="radio"/>            | Electronic (6-10 users)                | 9,200.00 USD |
| <input type="radio"/>            | Electronic and 1 Hardcopy (1-5 users)  | 7,250.00 USD |
| <input type="radio"/>            | Electronic and 1 Hardcopy (6-10 users) | 9,950.00 USD |

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