

Helium management at CERN, global resource status and prospect

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Outline

Introduction to CERN & Cryogenics

Helium management at CERN

Main users & applications, prospect Storage, distribution & recycling Procurement & strategy to secure molecules Global resource and prospect (based on public data) Helium sourcing evolution, medium term forecast (up to 2026)

Key parameters

Summary



Introduction to CERN & Cryogenics



CERN, European Organization for Nuclear Research, an Intergovernmental Organization for the High Energy Physics



https://home.cern/about/who-we-are/our-governance/member-states

MEMBER STATES ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP ASSOCIATE MEMBER STATES OBSERVERS



Cryogenics @ CERN: definition

The branch of physics dealing with the production and effects of very low temperatures

https://en.oxforddictionaries.com/definition/cryogenics; Oxford Dictionaries

All scientific and technological disciplines dealing with cryogenic temperatures below 120 K

http://dictionary.iifiir.org/search.php; International Dictionary of Refrigeration

The 120 K temperature limit referring to the normal boiling points of the main atmospheric gases

<u>Krypton</u> (119.8 K), <u>Methane</u> (111.6 K), <u>Oxygen</u> (90.2 K), <u>Argon</u> (87.3 K), <u>Nitrogen</u> (77.4 K), <u>Neon</u> (27.1 K), <u>Hydrogen</u> (20.3 K), <u>Helium</u> (4.2 K)



Cryogenics @ CERN: mandate

- All scientific and technological disciplines dealing with cryogenic temperatures below 120 K; production and effects of very low temperatures
- Design, construction, commissioning, operation & maintenance and upgrade of the cryogenic systems for CERN accelerators complex, detectors, cryogenic laboratory, test facilities and infrastructures
- Low-temperature R&D and tests program at the Cryogenic Laboratory
- Supply of bulk cryogenic fluids CERN-wide (helium, nitrogen, argon, krypton)
- World-wide consultancy and support in cryogenic design and cryogenic instrumentation



The Accelerators at CERN (Injectors upgraded)



THE LARGE HADRON COLLIDER













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The Cryogenics group @ CERN



Status Codes Distribution





Cryogenics @ CERN: large T spectrum





Helium management at CERN



Helium Cryogenics @ CERN: large power (refrigeration, energy & helium inventory)





LHC & HL-LHC timeline updated





HL-LHC CIVIL ENGINEERING:

DEFINITION

EXCAVATION

N BUILDINGS



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Cryogenics equipment (typical)





18 kW @ 4.5 K Warm compressors station

Cold compressors (1.8 K) (IHI-Linde and Air Liquide)



18 kW @ 4.5 K cold boxes (Air Liquide and Linde)



Use of Helium Cryogenics (1/2)

LHC accelerator

Cooling at 1.9 K of the superconducting magnets (36'000 t of cold mass) distributed over the 26.7 km underground accelerator

LHC physics detectors

ATLAS, cooling at 4.5 K of the superconducting magnetic system (1'275 t of cold mass)

CMS, cooling at 4.5 K of the superconducting solenoid (225 t of cold mass)







Use of Helium Cryogenics (2/2)

CERN wide helium refrigeration systems for:
✓ Test benches for accelerator magnets, cables and wires, RF cavities
✓ Detectors' components tests (magnets and sub-detectors)
✓ Large magnetic spectrometers for fixed target physics experiments
✓ Cryogenic laboratory test bench facilities
✓ In situ helium liquefaction for users without dedicated cryogenic plant





HL-LHC civil engineering progress; Shafts & underground galleries and caverns





HL-LHC Surface Cryogenics buildings; mostly completed at Points 1 & 5





Cryogen (helium, nitrogen, argon, krypton)

Helium inventory at CERN: 170 t (today)

- LHC (accelerator & detectors) helium full inventory: 136 t
- Additional strategic permanent storage : 20 t
- In situ helium liquefaction for central services (up to 45 t per year) and distribution by means of mobile containers ranging from 100 to 2'000 liter (users without dedicated cryogenic plant); recycling and purification up to 130 ton/year

Nitrogen liquid for LHC (accelerator & detectors) full cool down: **11'500 t** (equivalent to 500 **ISO-**transportable containers delivered)

Argon liquid for Neutrino platform and ATLAS calorimeter: up to 1'800 t

Krypton liquid for NA62 calorimeter: 24 t



Helium storage capacity at CERN

Storage infrastructure (in brackets: capacity dedicated to LHC)





LHC helium storage & distribution

LHC high grade helium ring line, 2 MPa, 27 km long, for LHC operation)

[Completing the existing CERN helium recovery system: high grade, 20 MPa, 5 km long and low grade, 3 kPa & 20 MPa, 3 km long each]





Helium management in LHC accelerator



LHC He consumption since 2007



Helium recycling & purification (kg/year)



CERN

Procurement & strategy to secure molecules

Procurement: Helium supply contracts at CERN for 2022-2026

- Liquid helium supply 200 ton to compensate helium losses
- Helium management 140 ton temporary sent out from CERN to contractual suppliers and returned on demand (virtual storage) during yearly or long shutdowns (next slide)
- Gaseous helium supply 6 ton for LHC machine pressure tests
- Strategy: CERN places renewable contracts with world-wide leading industrial partners operating in Europe
- Helium is considered strategic product for CERN, procurement shall be secured
- International standards for the management of helium facilities including production, trading, transport and delivery
- In order to secure logistics and deliveries, CERN has always promoted the selection of several contractual suppliers (from two to three) with direct access to several worldwide sources closely following the market (geopolitical situation, major events)



CERN High Grade Helium supply 1998-2021 (and 2022-2027 forecast)



Year



FCC, Feasibility Study launched



•Stage 1: FCC-ee (Z, W, H, ttbar) as Higgs factory, electroweak & and top factory at highest luminosities kW @ 4.5 K (nb of plants) 4 (1), 33 (1), 41 (2), 55 (4), 63 (4)

•Stage 2: FCC-hh(~100 TeV) as natural continuation at energy frontier, with ion and eh options

10 cryogenic plants 110 kW @ 4.5 K including 15 kW @ 1.8 K; 880 t of helium inventory^p cryogenic distribution line

2018 CDR (studies in collaboration with industry) 2020 European Strategy recommendation: Feasibility, impact & sustainability studies (2021-2025)



Global resource and prospect

- based on public data
- focus on securing molecules (CERN view)
- helium market is considered highly volatile, strongly linked to geopolitical aspects

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Main Helium sourcing evolution, medium term forecast Helium as a by-product of natural gas



Main sources of helium extracted from natural gas in 2020 according to US Geological survey in quantity of ISO container of 4.5 ton

Tentative forecast in 2026 based on public announcements of new capacities available in quantity of ISO container of 4.5 ton

Liquid Helium at CERN is exclusively transported and delivered by means of thermally insulated ISO containers of approx. 4.5 ton, operated by world-wide specialized industrials partners operating in Europe



Key parameters, past, present and near future (1/2)

Experience from the past:

- Helium shortage (2006 & 2013), unbalanced production/demand
- Geopolitical (Qatar 2017) & Logistics complexity (Suez Channel 2020)
- Maintenance shutdown and/or technical event impacting market (several sites world-wide)

This year:

- US BLM temporarily closed for procedures of safe handling of chemical materials (Gasworld); Outsource of BLM operations to private contractor
- Incidents at AMUR site in Russian production site in January leading to slow-down of the commissioning (Gasworld); Expecting ramp up of the production postponed
- Commercial limitation with Russian production due to conflict in Ukraine; Impact on the AMUR project repair and recommissioning of the helium plants
- Restart of industrial activities after Covid period; Market shortage is affecting industrial and scientific customers; average allocation to customers 60-70%



Key parameters, past, present and near future (2/2)

Helium market remains volatile in 2023 and for the coming years

- Uncertainty on the effective Russian production capacity ramp-up and market access
- Seen from Europe, no more back-up from US, Cliffside for sale (<u>C&en News</u>)

Prospect of new helium production capacities

- Qatar IV in service by 2026; Qatar V in approach
- Canada (Gasworld <u>article 1</u> & <u>article 2</u>): production objectives 10% word-wide capacity by 2030
- Tanzania (The Citizen) production of 54 bcf announced by 2025 at Lake Rukwa
- South Africa, draft estimate 900 Mm³



Summary

Helium management at CERN:

- Large helium inventory (170 ton) on-site; storage in liquid and gas phases
- Very important effort to reduce helium operational losses & improve recycling by purification
- To secure logistics and deliveries, CERN has always promoted the selection of several contractual suppliers (from two to three) with direct access to several world-wide sources : key strategy

Global resource and prospect:

- Unbalanced production/demand (US BLM strategy, Technical and Geopolitical issues) affecting industrial and scientific customers, allocated to 60-70% of their demand
- Strong activities restart post Covid-19 pandemic
- Uncertainty on the effective world-wide production capacity and market access (countries restrictions)
- New helium production capacity (Qatar IV-V, Canada, Tanzania, South Africa) but for after 2025-2026





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