Helium Recycling in NMR Laboratory – what's next?

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Sustainable Campus Fund of The University of Edinburgh & School of Chemistry

Helium Recovery at School of Chem. 6x NMR (300-800) + 2x MS

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High Pressure Helium Recovery - components

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Full Helium Recycling – possible scenarios

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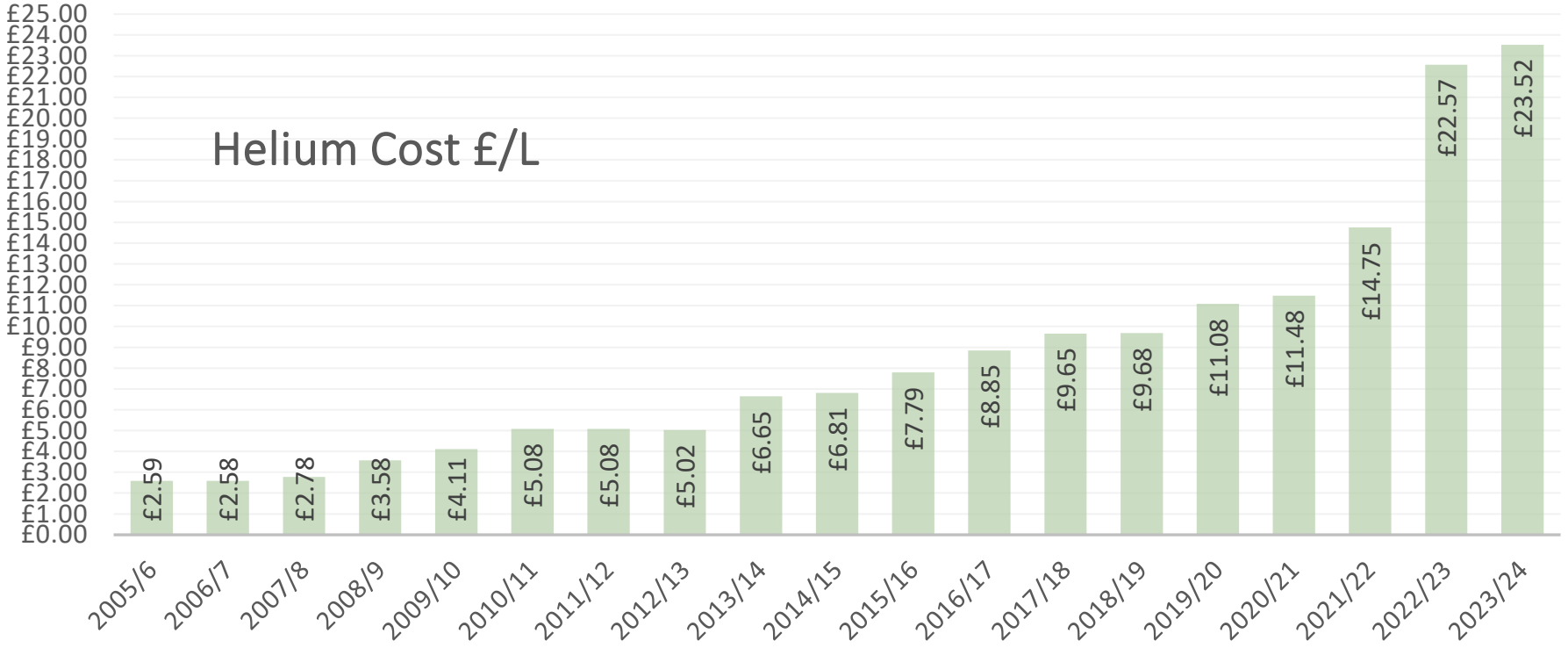
1. **Liquefier on site** – (usually Physics) – huge benefit :

- In proximity – straightforward installation either full recovery (pipes & manifolds, buffer gas bag?) or everyday boil-off only (easy - e.g. 8 mm tubing)
- Far away (depending on distance) – everyday boil-off (easy?) or full recovery system including blowers / vacuum pumps but NO need of (expensive) compressor and MCP

2. **No Liquefier on site** – buy-back contract with BOC, (AL?):

- Full recovery system with complete installation to collect the helium; MCP renting from BOC - loading & uploading from truck (by forklift) – customer responsibility!
- **Small portable liquefier & purifier** – significant purchase cost. Requires complete recovery installation and water chiller.

Why to liquefy locally ? - Liquid Helium cost & returns:



2022/23 NMR Liquid Helium cost £28.22/L * 2,500 L (99% eff. of recovery) ~£71,000.

2022/23 combined (NMR+MS) LHe usage ~£3,300 L / year with cost ~£94,000 + / year.

HR collection ~2,300 m3 / year (~3,000 L). 2023 BOC payback £6.16/m3 ~£14,000 / year.

Cryomech/Bluefors LHEP22 liquefier (20+ L/day) ~5,500 m3 of gas / year ~£250,000 +

Running cost & servicing ~ £2,000 / year + optional LHe dewar ~£20k.

Pay back time ~3 years. Disadvantage: No BOC “priority” contract for LHelium deliveries.

Helium recovery – Bruker / Quantum Design – not available directly

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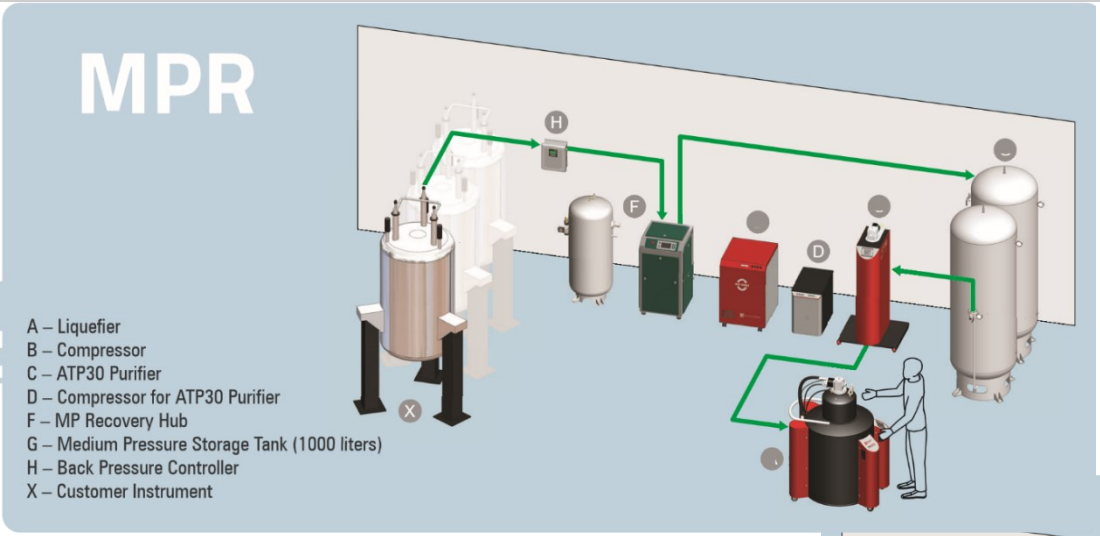
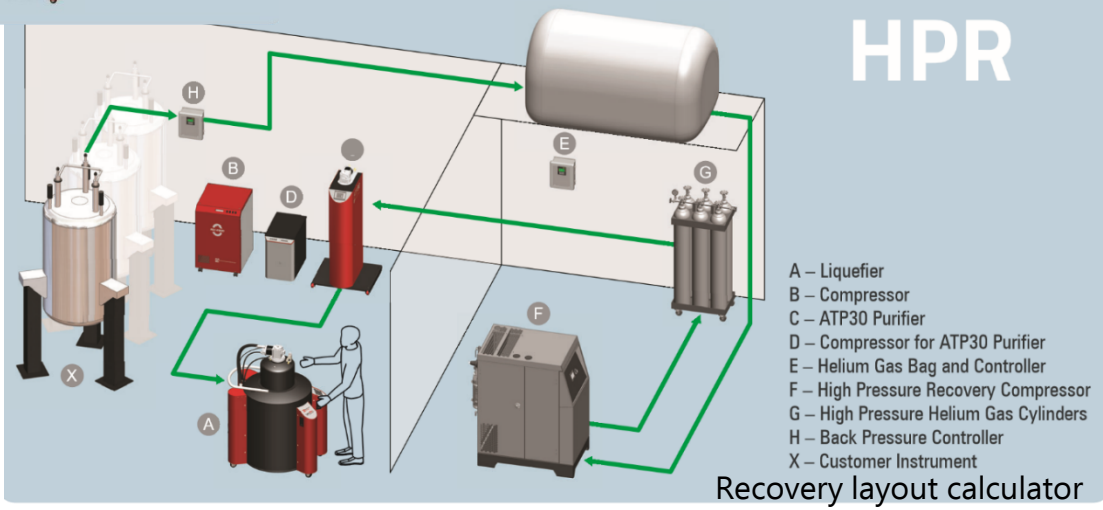


Medium Pressure Recovery
Up to 3 NMR magnets
Recommended max. 5 storage tanks @ 5 bars = 25 m3. (~100 L He refill)
High Pressure Recovery (HPR)
For large systems / laboratories
Customisable gas bag
Compressor speed ~15 m3 / hour

NexGen160, 250 & ATL160 liquefiers using (GM) cryo-cooler / cold head:
Liquefaction Rate 20+ L/day @ 50Hz = 0.83 L/hour = 0.63 m3/hour of gas
ATL160XL: 28+ litres/day @ 50Hz
Dewar Capacity 160 resp. 250 litres
250L=189 m3 requiring 21 cylinders
Water cooled indoor compressor
Requires 99.999% He purity
ATP cold head based purifier



Recovery layout calculator

Quantum Design EUROPE

Quantum Design GmbH
Im Tiefen See 58, D-64293 Darmstadt
www.qd-europe.com

Dr. Marc Kunzmann
David Appel
Dr. Tobias Adler

Helium recovery & liquefaction – commercial solutions:

- Companies offering either full recovery including helium liquefaction or just collecting the gas suitable for NMRs':
- Cryomech (US) recently acquired by Bluefors (EU/Finland): bluefors.com/products/liquid-helium-management-products/
- quantum-technology.com/helium-products/
- Quantum Design (EU) stopped offering small liquefiers but apparently Bruker continues to supply their products (HelioSmart?) but impossible to find on their web page.
- www.724pridecryogenics.com/en/product2.asp?bigid=105
- cryogenic.co.uk/products/re-condensing-zero-boil-cryostats
- www.motivair.co.uk/products/special-services-products/helium-recovery

Procurement struggle

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- Project awarded in November 2023
- PIN (Prior Information Notice / Early Market Engagement) beginning of December:
- Cryomech & Gas and Liquids Control – no liquefier available – development
- NCA – Non Competitive Action / single source attempt unsuccessful
- Full EU Tender beginning of February 2024:
- Cryomech & Cryogenic – GM liquefier not suitable for High Pressure Recovery
- Contract awarded to Cryomech/Bluefors at beginning of June
- PO placed at mid June 2024
- Delivery & installation (28 weeks) – Sept. / Oct. ???
- All auxiliaries – HR modifications, MCP & water chiller preferably sourced by Motivair (HR upgrade)

Cryomech – Bluefors medium pressure with Automatic Purifier

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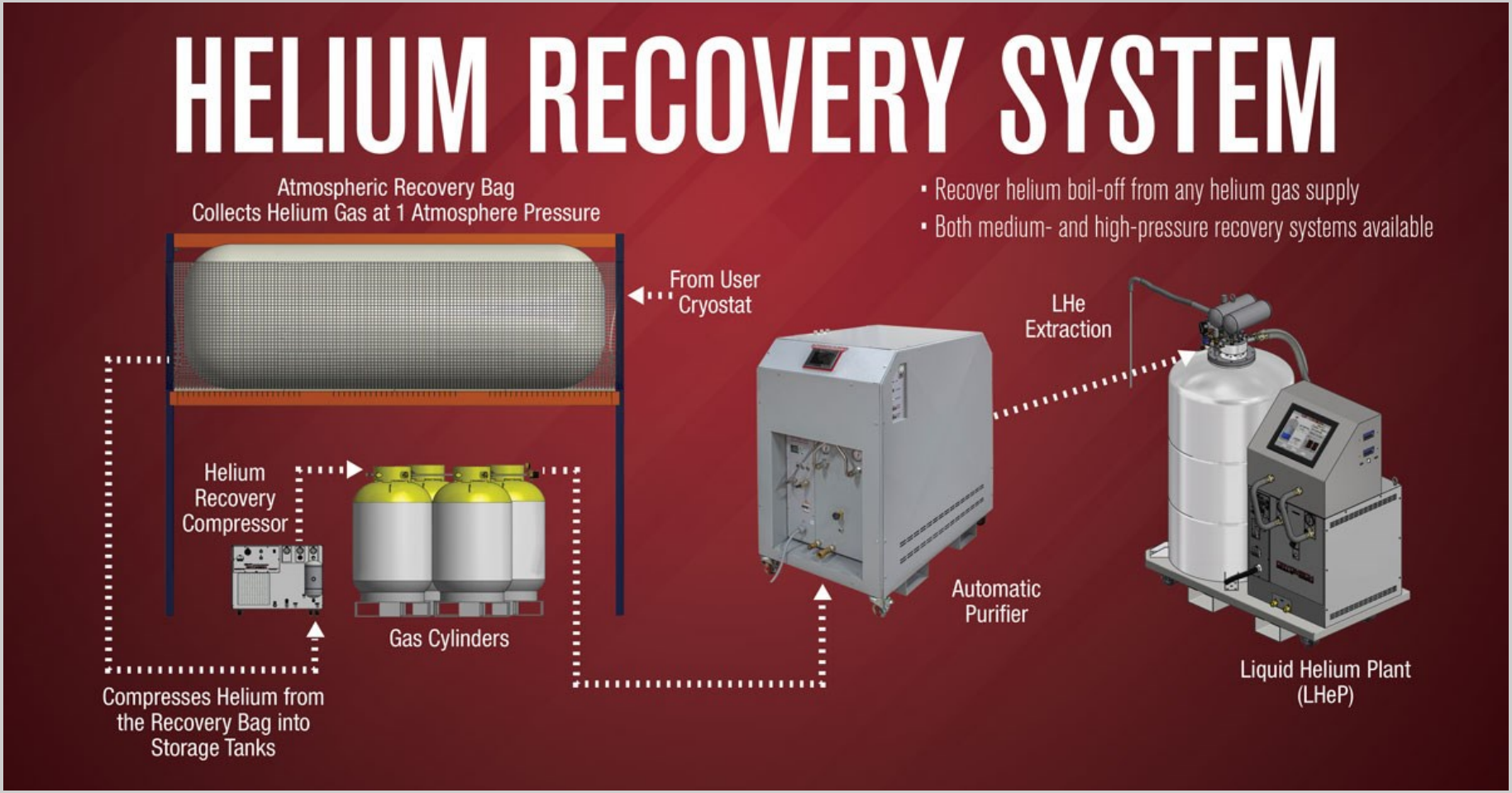

Cryomech – Bluefors
Integrated / Non-Integrated

Cryomech – Bluefors Integrated with LN2 purifier / trap

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Cryomech – Bluefors / Haskris water chiller options

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CRYOMECH COMPRESSOR			HASKRIS MODELS			
Model	Max Heat Load	Min Flow Rate	Non-Refrig.	Refrigerated	Refrigerated	Refrigerated
			Indoor	Indoor	Indoor	Outdoor
			Water-Cooled	Air-Cooled	Water-Cooled	Air-Cooled
CP810	1.3 kW	0.5 GPM 2.0 LPM	WW1	LX1-A R050	LX1-W R050-C	OPC1
CP820	2.0 kW	0.5 GPM 2.0 LPM	WW1	LX1-A R075	LX1-W R075-C	OPC1
CP830	3.4 kW	1.2 GPM 4.5 LPM	WW1	LX2-A R175	LX2-W R175-C	OPC2
CP2850	5.4 kW	2.3 GPM 9.0 LPM	WW2	LX3-A R250	LX3-W R250-C	OPC2
CP2870	7.3 kW	2.3 GPM 9.0 LPM	WW2	R250	R250-C	OPC3
CP289C	8.4 kW	2.3 GPM 9.0 LPM	WW2	R300	R300-C	OPC3
CP1110	10.7 kW	3.0 GPM 11.5 LPM	WW2	R400	R400-C	OPC4
CP1114	12.5 kW	3.0 GPM 11.5 LPM	WW2	R400	R400-C	OPC4

ISIS / SoC Helium Recovery Carbon Footprint

For 1L of Liquid Helium

Recovery compressor speed: ISIS = 44m3/Hr eq. of 58 L/Hr liquid / SoC = 13m3/Hr eg. 17 L/Hr
Liquefier speed: ISIS Linde TCF 20 = 20 L / Hr (data plate) / SoC = 0.875 L / Hr (specs)
Grid CO2 (g CO2/ kWh) = 233.14 (Carbon Trust)
Helium expansion rate = 757:1 (physical constant)

ISIS / SoC	Power (kW)	Time (Hrs)	Energy (kWh)	CO2 (g)
Sauer Recovery Compressor (ISIS)	25	0.017	0.43	100.277
Paramina (SoC)	7.5	0.058	0.44	102.6
R108 Liquefaction Components (ISIS)	30	0.050	1.50	349.71
LHe22P Cryomech Liquefier (SoC)	9.2	1.143	10.51	2,451.3
Total ISIS	55	0.067	1.93	449.987
Total SoC	16.7	1.201	10.95	2,553.9

Co2 Produced per Liquid Litre: ISIS = 450g / SoC = 2,554g

Is local liquefaction CO2 sustainable?

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ISIS Helium Recovery:

- **CO2 / litre supplied:** **450g**

Supplied Helium production Totals:

- **CO2 / litre He produced: 790g** (= 730+39+4.5+16.5)
- **CO2 / litre He supplied:** **1319g** (= 790*1.67)

School of Chemistry Helium Recovery:

- **CO2 / litre supplied:** **2,554g**

BOC Supplied Helium production Totals:

- **CO2 / litre He produced: 1,667g** (= 730+39+4.5+893.3)
- **CO2 / litre He supplied:** **2,784g** (= 1,667*1.67)

Despite of 5.6 (2,554/450) fold less efficient liquefaction at SoC site comparing to ISIS, still marginal 1.1 (2,784/2,554) fold benefit comparing to BOC production including deliveries.

Scottish renewable energy 90%+ hasn't been considered in this projection.

Helium recovery – summary & acknowledgments

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- Richard Down – ISIS Neutron and Muon Source
- Google photos - https://photos.app.goo.gl/wbBbAVSzeeBnrYY97