ISIS Experimental Operations Cryogenics

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CryoUsers Leeds 2024

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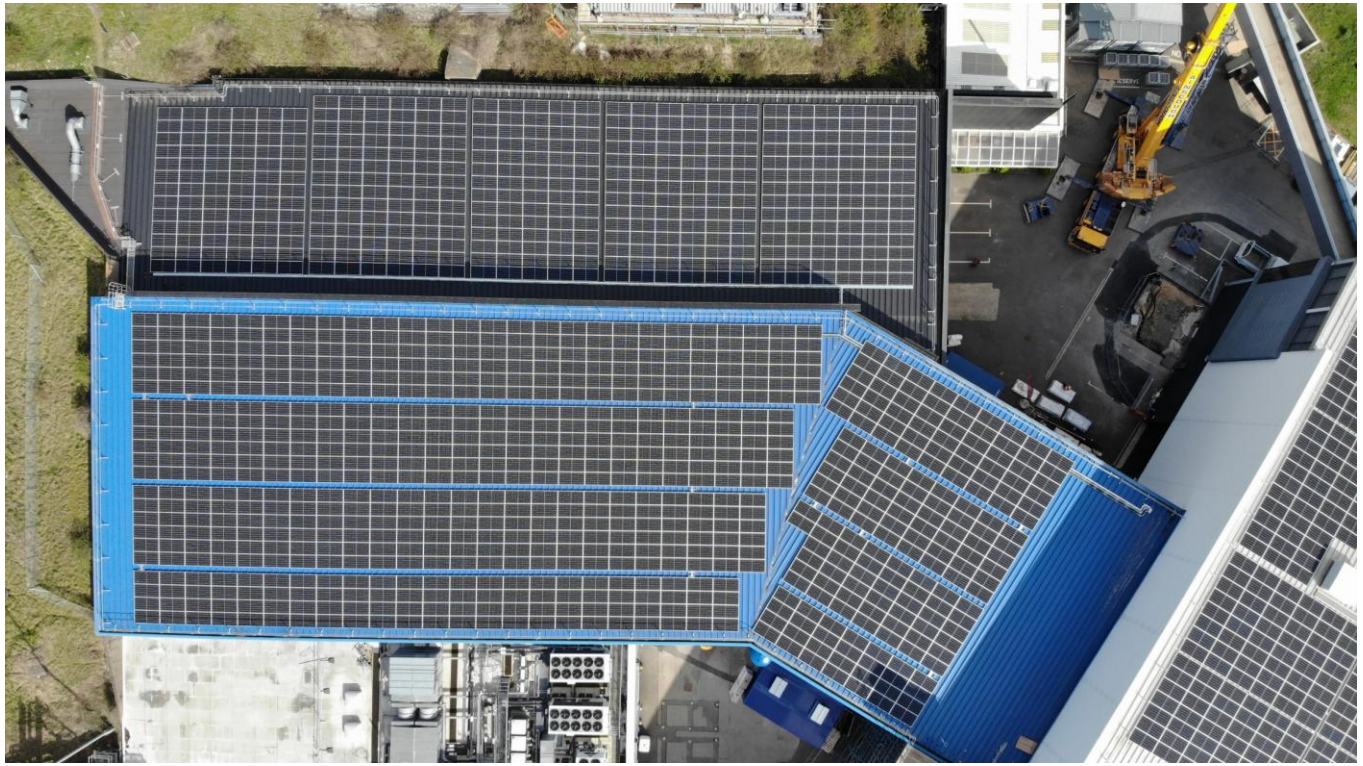
“Wet or Dry”, That’s the question!!

- ISIS Core Cryogenic and Cryogenic Support Equipment and it’s Carbon Footprint
- Carbon Footprint of ISIS Neutron Instrument Cryo Systems
- ISIS Helium Recovery Carbon Footprint with the Addition of LN2 Precool and compare with CCR based Helium Recovery System’s

“Wet or Dry, that’s the Question!!

UKRI STFC’s goal = Zero Carbon Footprint by 2040

- ISIS has 6000 solar panels
- Generating over 2.4 million kWh per year
- Cutting carbon emissions by over 550 tonnes



Core Cryogenic Equipment

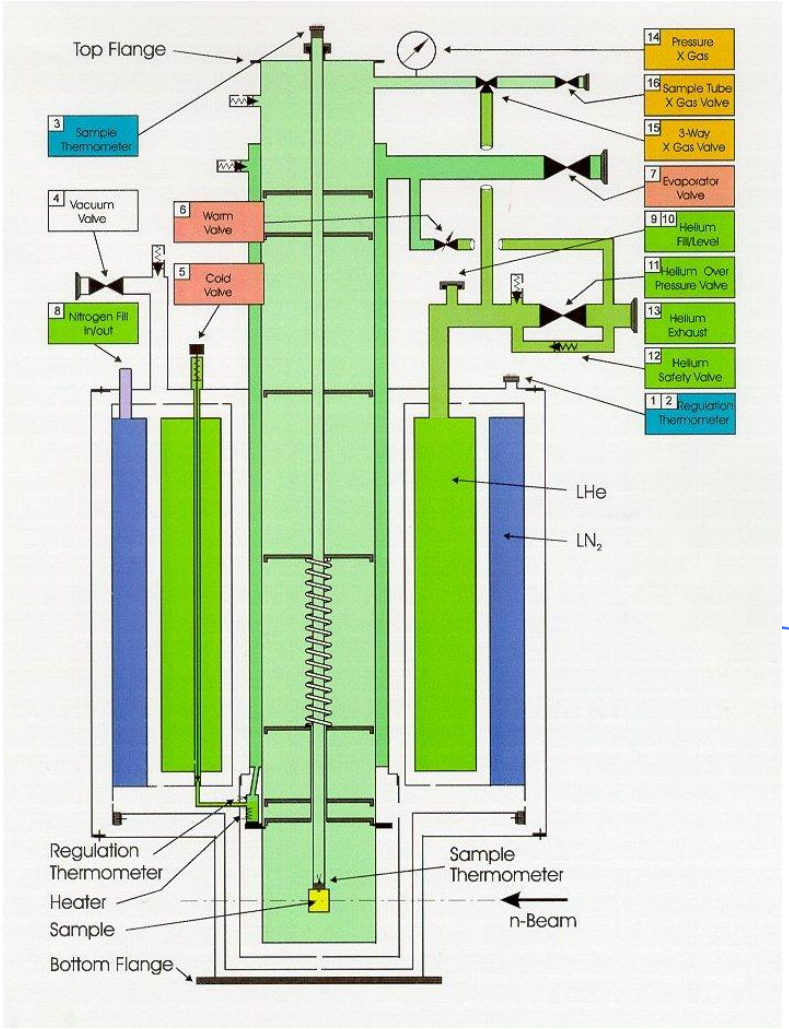
Dry systems

CCR Top Loading Systems

PR-082B (8) & SRDK 415 (6) CCR T/L
145W (2x2 wired in parallel)

Wet systems

ISIS Cold valve / Temperature Controller	Flow	Temperature	Power
	5 mBar	Static	19.5W
	5 mBar	200K	101W
	5 mBar	Max Power	180W



Support systems

Scroll & Multistage Roots Pumps

- Edwards XDS 35i
- Leybold Ecodry 65 (55m3/h)
- Edwards NXR 90 (90m3h)

	0 mBar	1000 mBar
Sample Volume Pump (XDS 10)	275W	355W
Cryogenic Vacuum Pump (Turbo + XDS 10)	490W	800W

	0 mBar	6 mBar	60 mBar
VTI Pump XDS 35i	395W	452W	696W
VTI Pump Ecodry 65	536W	675W	863W
VTI Pump NXR 90	475W	585W	930W

Sample Environment Equipment Carbon Footprint

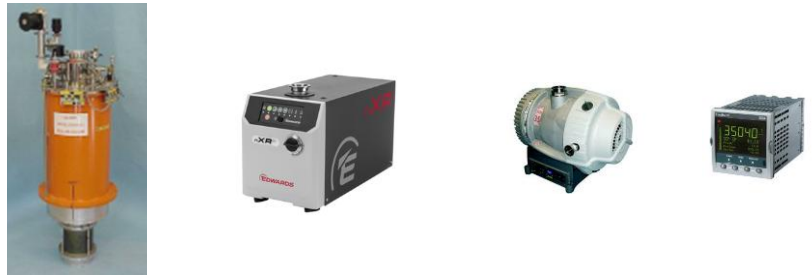
CCR Power Consumption

Gifford McMahon (GM)
Operation 6.8 kW @ 50Hz
Pulse Tube (PT)
Operation 6.9 kW @ 50Hz
Start-up < 8.5kW @ 50 Hz

CCR Top Loader 300 – 4K = 6.8 kW
SE Pump 275W
Temperature Controller 100W

7.175kW *24(233.14) = **<u>40.2 Kg CO2 per day</u>**

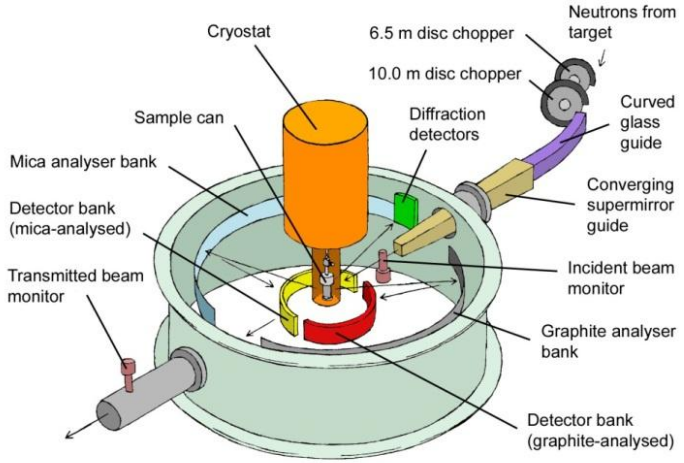
Wet Cryostat Power Consumption



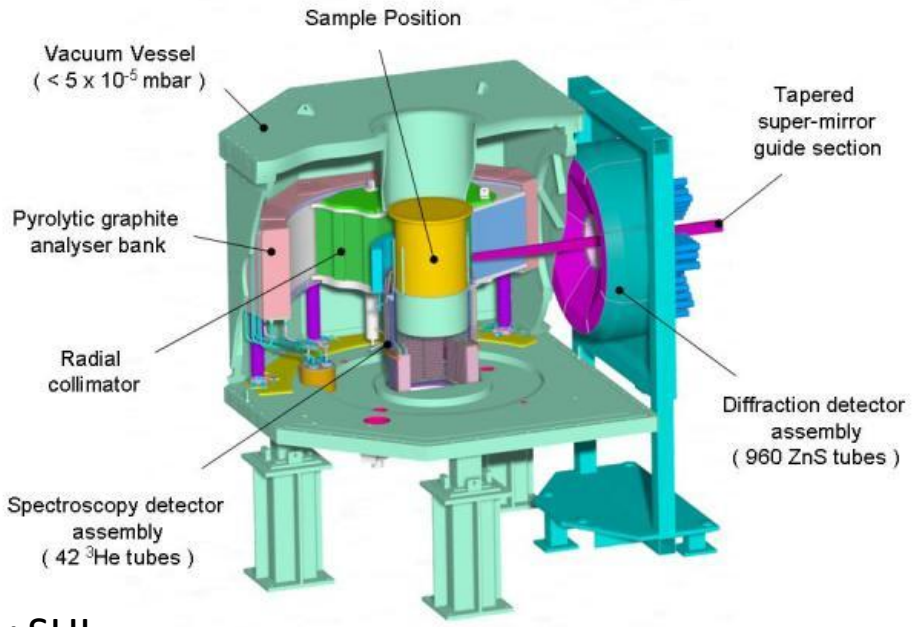
Cryostat 300 – 1.5K
10LL Helium Usage per day 5Kg CO2
VTI Pump 585W
SE Pump 275W
Valve / Temperature Controller 100W
0.960kW *24(0.23314) + 5 = **<u>10.4 Kg CO2 per day</u>**

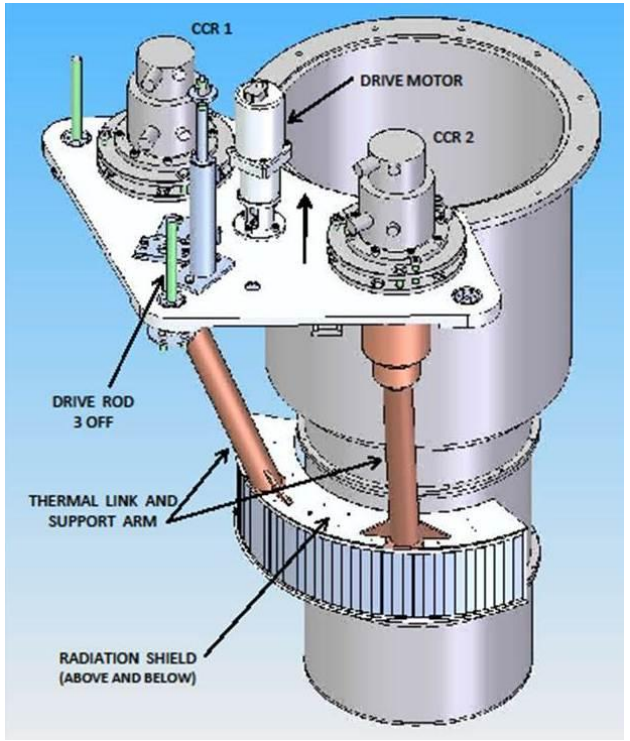
Instrument Based Cryogenic Systems
“The Molecular Sciences Group”

IRIS



OSIRIS

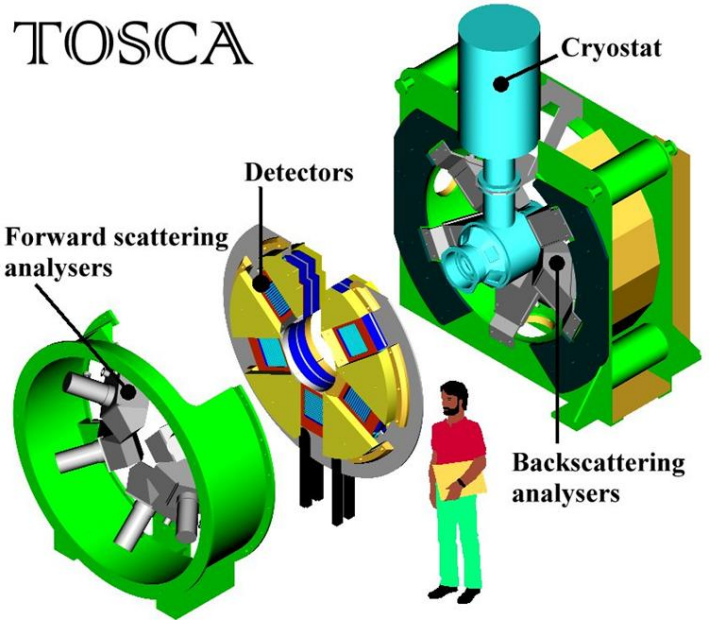




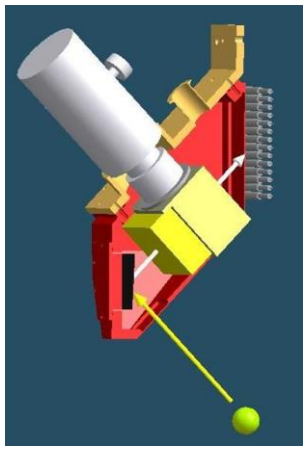
Graphite Analysers & Be Filters cooled by SHI
RDK 415 & SHI CH-110 GM CCR’s

IRIS Graphite analysers initially cooled with LHe
500L / Day
£35K - £70K Per Year £1000K at today's Costs

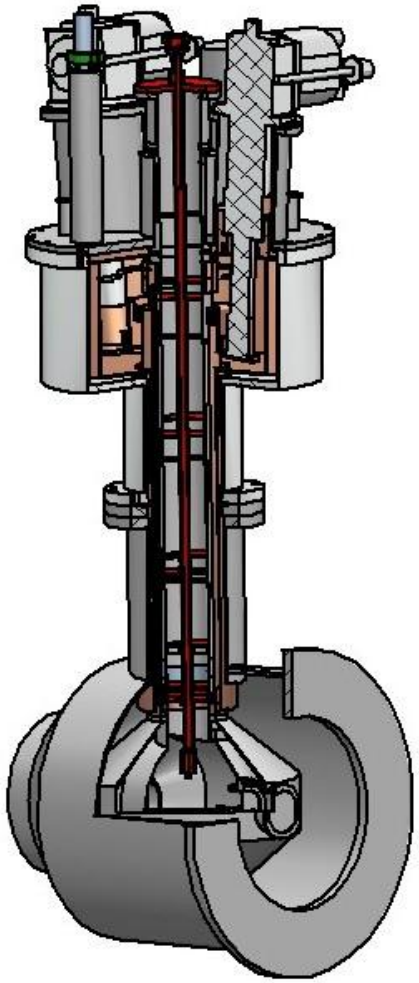
Tosca & Tosca Duplex



12x GM CCR's
7x F70 Compressors
RT to base in 7Hours
Sample Change RT – 20K 45mins
LHe Fast cool 10Mins



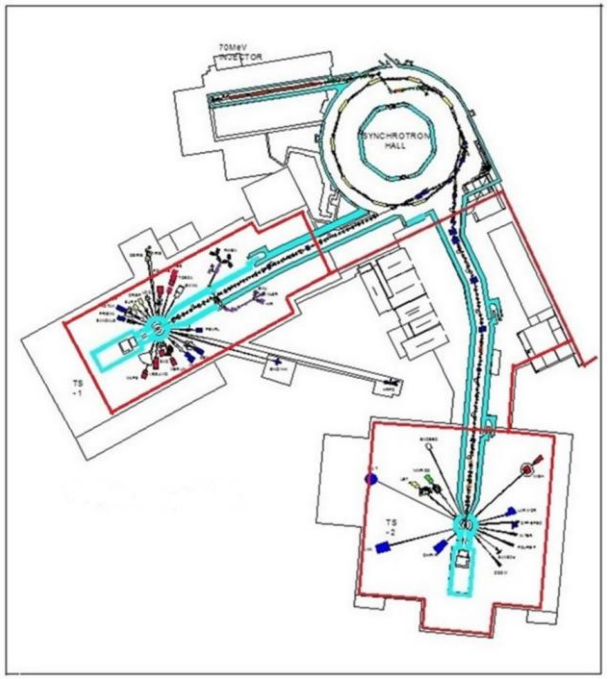
7x F70 Compressors
7x F70 Compressors * 6.8 kW = 47.6 kW
SE Pump = 275W
Temperature Controller = 100W
48 kW *24(0.23314) = **<u>269 Kg CO2 per day</u>**



45 CCR systems in front line Operation

The ISIS Helium Recovery System

- Evaporated Low pressure gas collected from instruments into gas bag
- Compressed by 3x Sauer WP4341 44m³/hr to 200 Bar
- Directed to HP storage by PLC controlled manifold
- Linde TCF 20 Liquefier Produces 480 L /Day



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Carbon Footprint of the ISIS Helium Recovery System

For 1L of Liquid Helium

Helium expansion rate = 757:1 (physical constant)
Recovery compressor speed = 44m3/ Hr (data plate)
Grid CO2 (g CO2/ kWh) = 233.14 (Carbon Trust)
Linde TCF 20 Liquefier speed = 20 L/ Hr (data plate)

Item	Power (kW)	Time (Hrs)	Energy (kWh)	CO2 (g)
Sauer Recovery Compressor	25	0.017	0.43	100.277
R108 Liquefaction Components	30	0.050	1.50	349.71
Total	55	0.067	1.93	449.987

Co2 Produced per Liquid Litre = 450g

Helium Recovery is Green but is by No Means Carbon Neutral!!

Helium Production & Delivery

- Natural Gas extracted with minor concentrations of Helium
- Crude Helium produced from the LNG Trains (-160°C)
  (~50% by volume He,+50% N2, with minor amounts of H2, CH4, Ne)
- Purification
  - Compression / condensation
  - Partial Nitrogen Removal
  - Catalytic Hydrogen Removal
  - PSA Purification (~150ppm)
- Liquefaction
  - Compression
  - Final Purification (~5ppm)
  - Liquéfaction
  - Transferred into ISO containers
- Storage / Loading / Delivery

Pascale Dauguet Air Liquide Advanced Technologies – Technologies Campus Grenoble France

Where does it come from and how does it get here?

Qatar to UK is 7200 Miles, 15 days at sea!!

Sea

Container Ship carrying 5000 containers, travelling at 15 Knots, burning 170t of fuel will use **43.3 CO2 g / LL of Helium transported**

ISO Road

Helium ISO container transported by road from port for 250km using 89L of diesel fuel will use **6.2 CO2 g / LL of Helium transported**

Dewar Road

Helium transported to RAL from a local depot for 65km using 15L of diesel fuel will use **38.2 CO2 g / LL of Helium transported**

More Carbon emission!!

Green Helium Production is on the UP!!

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Port of London, United Kingdom to Port of Ras Laffan, Qatar - Sea route & distance - ports.com
Fuel Consumption by Containership Size and Speed | The Geography of Transport Systems (transportgeography.org)
UN-portable-tank-for-helium_tcm20-281285_tcm19-588803.pdf (linde-engineering.com)
Assumption that Heavy Fuel Oil (HFO) is C4OH82
What fuel economy (MPG) does a lorry get? (mwtruckparts.co.uk)
Thanks to Alex Jones, Chris Lawson & Oleg Kirichek for assistance with the figures

Boil off Losses

Loss per day: 1% *ISO hold time 48 days (Estimate 1/2 lost after this).*
Loss per transfer: 10% *ISIS transfer estimation.*

Description	Units	Fraction Remaining	Loss %
Road Transport	2	0.98	2.0
Wait at ISIS	5	0.95	4.9
Dewar Transfers	2	0.81	19
Amount Remaining/ Lost		**0.75**	**25**

For every Liquid litre used, Gas company need to transport: **1.32L**

Liquefaction

Process	CO2 / L	Comments
Liquefy LNG	440 Kg's	See links
Liquefy Helium	450 g's	Based on ISIS Linde TCF 20

ISIS Helium Recovery
CO2 / litre supplied: 450g

Supplied Helium production Totals
CO2 / litre He produced: 540g
CO2 / litre He supplied: 710g

CO2 of LNG extraction is much higher!!

If production of LNG is factored in
CO2 / litre He produced: 440Kg
CO2 / litre He supplied: 580Kg

From https://www.linde-engineering.com/en/images/UN-portable-tank-for-helium_tcm20-281285_tcm19-588803.pdf
https://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx
http://www.kosancrisplant.com/media/5648/1-lng_basics_82809_final_hq.pdf

ISIS Liquid Nitrogen Precool Carbon Footprint

+

LN2 Precool (40 LL/Hr)

= 960 L / Day

Doubles Liquefaction

- LN2 carbon footprint = 0.06 CO2 /Kg
- 1L LN2 = 0.8083 Kg
- LN2 CO2 LL = 48.5 g
- Distance from LN2 source to RAL 277Km, transporting 6000L CO2 / LL N2 = 27.1 g
- LN2 Precool ½'s CO2 / LL He

Item	CO2 (g)
1 L LN2	48.5 + 27.1 = 75.6
1 L LHe	450/2 = 225
Total	300.6

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F1 Finland Verified by CarbonCloud
https://apps.carboncloud.com/climatehub/product-reports/id/42847031980

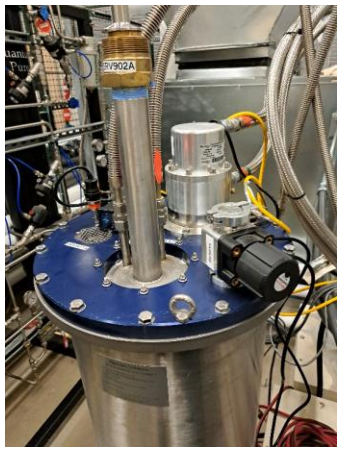
CCR Based Helium Recovery Carbon Footprint

Quantum Design ALT 160+

ALT 160+ = 1.25 LL He / Hr
5 kW + 7 kW = 12 kW
12kW *24(0.23314)
= 67.14 Kg CO2 per day
= **<u>2.2 Kg CO2 per LL He</u>**

NIST Type System

16x SRDK 415
= 300 LL He / 24Hrs



16x 6.8 + 5 kW = 113.8 kW
113.8 kW *24(0.23314)
= 636.75 Kg CO2 per day
= **<u>2.1 Kg CO2 per LL He</u>**

Comparison Conclusions

CCR Top Loader 300 – 4K = **40.2 Kg CO2 per day** He4 Cryostat 300 – 1.5K = **10.4 Kg CO2 per day**

Carbon footprint of ISIS Helium Recovery Plant is: 450 g CO2 / LL

Introduction of LN2 Precool: Increases the carbon footprint to 300.6 g CO2 / LL but doubles production.

Therefore: **producing 960L per day reduces ISIS Helium Recovery Plant carbon footprint to 300.6 g CO2 / LL**

A similar CCR based Helium recovery system using 48 compressors would have a carbon footprint of 2 Kg per LL He

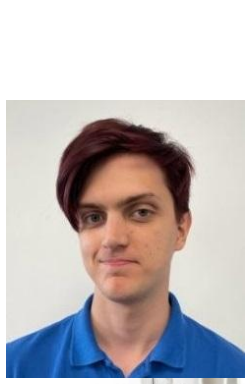
But

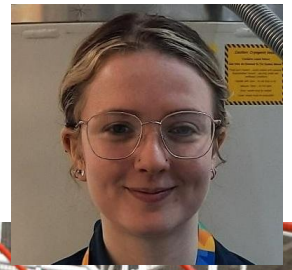
CCR systems are not as Green, but can be half the capital cost of a Brayton Cycle Liquefier

Conclusion

CCR Systems may have a higher carbon footprint than Liquid Helium based systems, but without them forming the backbone of our ISIS Sample Environment we could not offer the extreme conditions that we do.

There'll always be a requirement for CCR in areas with less Helium usage for liquefaction, they can reduce Helium boiloff to zero in recondensing systems, are extremely useful in Vacuum systems and core Sample Environment.





Cryogenic (10+1SS+ 1APP) & Helium Recovery (3) Team

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Thank you!!