Sustainability Projects Fund

OVER $5,000 APPLICATION FORM

COVER PAGE

PROJECT INFORMATION

Please complete the fields below with information regarding your project.

Project Title Helium Recovery for NMR Facilities in Otto Maass and Pulp and Paper

Brief Description We propose to purchase and install a system for recovering and recycling the limited resource helium, a critical component for the important scientific technique of NMR (nuclear magnetic resonance).

Total Estimated Project Budget $400,000 **Amount Requested from SPF** $330,000

Campus(es) Impacted ☒ Downtown ☐ Macdonald ☐ Gault Nature Reserve ☐ Other

CONTACT INFORMATION

Project Leader

This person must be a current McGill University student, administrative staff, or academic staff.

Name	Robin Stein	Affiliation	Academic Staff
Phone	514 550-8751	Faculty/Unit/Organization	Chemistry
Email	robin.stein@mcgill.ca	Campus	Downtown

Project Team Members

The SPF encourages you to be inclusive, collaborative (especially between staff and students), diverse, and interdisciplinary when possible. To list more members, please complete a second cover page. You may e-mail it to SPF Staff to include with your application.

Name	Tara Sprules	Affiliation	Academic Staff
Email	tara.sprules@mcgill.ca	Faculty/Unit/Organization	Chemistry
Name	Dmitrii Perepichka	Affiliation	Academic Staff
Email	dmitrii.perepichka@mcgill.ca	Faculty/Unit/Organization	Chemistry
Name	Tony MIttermaier	Affiliation	Academic Staff
Email	anthony.mittermaier@mcgill.ca	Faculty/Unit/Organization	Chemistry
Name	Rick Rossi	Affiliation	Administrative Staff
Email	richard.rossi@mcgill.ca	Faculty/Unit/Organization	Chemistry
Name	Weihua Wang	Affiliation	Administrative Staff
Email	weihua.wang@mcgill.ca	Faculty/Unit/Organization	Chemistry

SUBMISSION INFORMATION

In line with the SPF Eligibility Criteria, our team certifies that this project takes place at McGill University, is sustainability focused, is requesting seed funding, and is action oriented. ☒ Yes ☐ No

Our team has read the SPF Terms & Conditions and agrees to respect them. ☒ Yes ☐ No

Our team understands that this application is not confidential and consents to have its contents shared with relevant stakeholders during the review process and, if approved, on the SPF website. ☒ Yes ☐ No

Our team agrees to have their contact information included in the complete and shared application. ☒ Yes ☐ No

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PROJECT OVERVIEW

Instructions: *Please answer the questions below as clearly and concisely as possible. You will be able to detail your project further in Part 2 of the Over $5,000 application process, the Project Plan, as well as submit relevant appendices. Once you have completed this Project Overview, save it and submit it online. SPF Staff will respond with feedback on your application within 2 weeks and send you Part 2. Once all sections are complete, the combined application will be provided to the SPF Governance Council for their review and decision. As a reminder, all SPF applications are assessed using the SPF Eligibility & Evaluation Criteria:*

ELIGIBILITY CRITERIA		EVALUATION CRITERIA		
AT MCGILL	SUSTAINABILITY FOCUSED	ANALYSIS	IMPACT	FEASIBILITY
SEED FUNDING	ACTION ORIENTED	COLLABORATION	SUPPORT	CAPACITY BUILDING

Before starting, you may find it helpful to consult the SPF Sustainability Brief and Vision 2020 Climate & Sustainability Action Plan.

CONTEXT

Criteria assessed in this section: **SUSTAINABILITY FOCUSED, ANALYSIS**

1. **What specific sustainability-related need/issue have you identified at McGill and aim to address through your project? In your response, please describe clearly how the need/issue is related to sustainability.**
   Note: Please wait to detail your project idea in response to Question 5. Limit ~100 Words

Helium is a limited, non-renewable resource extracted from certain natural gas reserves located mainly in the US, Qatar, Algeria, and Russia. It is required to operate nuclear magnetic resonance (NMR) spectrometers, an important tool used by about 30 McGill research groups and 15-20 external groups annually and for undergraduate and graduate teaching. Currently, the NMR facilities in Otto Maass and Pulp and Paper use about 3000 L of liquid helium annually, but without a recovery system, the helium is entirely lost to the atmosphere. We propose to collect, purify, and chill this helium so that it can be reused, thus reducing helium waste while simultaneously reducing CO2 emissions for transportation.

2. **How do you know this is a need/issue? What research have you done (e.g. consultation, observation, survey)?**
   Limit ~100 Words

It is known that helium, once used, evaporates from the NMR instruments and is lost, because it is such a light element. In fact, unlike nitrogen, for example, which is trapped in the atmosphere after usage, helium leaks away from the surface of the planet and cannot be recovered. In order to learn about recovery systems, we have visited the Physics helium recovery system, discussed with recovery system vendors, and liaised with colleagues with similar instrumentation at other institutions with successful recovery systems.

3. **What relevant information and/or best practices have you found that relate to this need/issue? In addition to information from external sources, detail any relevant related initiatives (past or current) that you are aware of at McGill.** *Limit ~100 Words*

At least two possibilities exist to address this issue. The first is helium recovery, where helium is collected as it is used, then purified and chilled before reuse. This is implemented in the McGill physics department in the group of Guillaume Gervais and at many other universities around the world. It costs approximately $350k. Alternatively, more efficient magnets which use less helium or which reuse helium can be used. However, they cost a minimum of $300k each and we have 8 to replace or upgrade.

4. **What expertise or qualifications does your team have regarding this need/issue, if any?** *Limit ~100 Words*

Robin Stein, Tara Sprules, Richard Rossi, and Weihua Wang all have experience using helium (which is not trivial, as it is a very cold liquid requiring special procedures for transfer). In addition, Richard Rossi and Weihua Wang have backgrounds which would enable us to maintain a recovery system. Our colleagues at other institutions confirm that the systems are ones which we can maintain with our current expertise.

PROJECT IDEA

Criteria assessed in this section: **ALL ELIGIBILITY & EVALUATION CRITERIA**

5. **In context of the sustainability-related need/issue that you previously identified, what is your project idea? Please describe the idea thoroughly and concisely. In your response, share how your project is new or how it is complementary to existing initiatives.** *Limit ~400 Words*

We propose to install a helium recovery system which should allow us to reuse about 90% of the helium required to run the two NMR facilities located in the Pulp and Paper and Otto Maass buildings. The system will be comprised of a compressor, to compress the gas to high pressure; a purifier to clean it; and a liquefier to return it to the liquid state which is necessary for NMR instruments. Also, piping and pressure controllers will be necessary to connect the helium from the NMR instruments with the gas collection bag. Finally, a door linking Otto Maass and Pulp and Paper will need to be widened to permit dewars to be brought from the collection area and the magnets.

The idea of helium recovery is not novel in and of itself, and many commercial providers sell systems which can be used with our instrumentation. In fact, such a system exists within the laboratory of Guillaume Gervais in the Physics Department. However, it is too small to accept the amount of helium used by the NMR instruments in the Chemistry Department, and furthermore, transporting the helium to physics would be logistically difficult (it would be necessary to collect and compress the gas before it could be transported, and require special transportation to be moved). So, the technology would be novel within the context of the Chemistry Department, and complementary to the system in the Physics Department.

6. **Is your project related to the University's Vision 2020 Sustainability Strategy?** ☒ Yes ☐ No ☐ Not sure

7. **If you answered yes to Question 6, how does it relate? Please refer to the strategy category (e.g. Research, Education, Connectivity, Operations, and Governance & Administration) or related action from the 2017-2020 Climate & Sustainability Action Plan in your response.** *Limit ~100 Words*

Reducing helium usage is closely related to actions R-3, institutionalize McGill's sustainable labs practices, and O-3, develop a waste reduction and diversions plan, because it makes using a non-renewable resource efficiently part of institutional culture (we propose to present it to all students in CHEM 392, 532, and 555, and to all trainees using the insturments for research) and it reduces waste of this resource.

TRANSFORMING CAMPUS

Criteria assessed in this section: **AT MCGILL, IMPACT**

8. **In the table below, describe your proposed project's 2-5 main impacts on the McGill campus community or goals to accomplish. Please check the stakeholders that will be impacted. Finally, please list at least one key success indicator for each impact (e.g. # people will be engaged in the project, % waste will be diverted from the landfill, # buildings will be LEED certified, etc.)**

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		Main Impacts/Goals	McGill Stakeholders Impacted (check all that apply)	Key Success Indicator(s)
REQUIRED	1	reduce helium lost to the atmosphere	☐ Undergraduate ☒ Academic Staff ☒ Postgraduate ☐ Admin. Staff ☐ Alumni	reduce the amount of helium purchased annually by at least 80%
REQUIRED	2	publish information about helium recovery on a McGill website and publicize it among other labs	☐ Undergraduate ☒ Academic Staff ☒ Postgraduate ☐ Admin. Staff ☐ Alumni	visits by at least 5 other helium users at McGill University
OPTIONAL	3	inform chemistry and other NMR users about helium recycling	☒ Undergraduate ☐ Academic Staff ☒ Postgraduate ☐ Admin. Staff ☐ Alumni	present system to at least 100 undergrad and 50 grad students annually, in classes and individually
OPTIONAL	4		☐ Undergraduate ☐ Academic Staff ☐ Postgraduate ☐ Admin. Staff ☐ Alumni	
OPTIONAL	5		☐ Undergraduate ☐ Academic Staff ☐ Postgraduate ☐ Admin. Staff ☐ Alumni	

9. Have you considered implementing your project at more than one McGill campus? (e.g. If your project is downtown, could it be implemented at Macdonald Campus as well?)

☐ Yes ☒ No

10. If relevant, please describe your choice(s) of campus(es) and why this choice is best for your project. *Limit ~150 Words*

A helium recovery system must be linked via pipes to the helium source, so for the system requested, only helium used within Otto Maass or Pulp and Paper can be treated. It is not possible to link all helium users on the downtown campus to a single recovery system. The main users of liquid helium at McGill are the NMR facilities housed within the Chemistry Department , and in Physics, who already have a system relevant for their needs. Placing a helium recovery system in Pulp and Paper as proposed would result in the greatest reduction of helium waste, compared with any other location or helium user at McGill. The recovery system is modular, and would have the capacity to recycle more helium than we use in Chemistry. In future, if additional helium consuming instruments were installed in Chemistry, or it became practical to collect helium from other users at McGill and transport it to Chemistry, we could increase the volume that we recycle and reuse.

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PART 2: PROJECT PLAN

Instructions: *Please answer the questions below as clearly and concisely as possible. Once you have completed this Project Plan, save it and submit it online. SPF Staff will respond with feedback on your application within 2 weeks. Once all sections are complete, the combined application will be provided to the SPF Governance Council for their review and decision. As a reminder, all SPF applications are assessed using the SPF Eligibility & Evaluation Criteria:*

ELIGIBILITY CRITERIA		EVALUATION CRITERIA		
AT MCGILL	SUSTAINABILITY FOCUSED	ANALYSIS	IMPACT	FEASIBILITY
SEED FUNDING	ACTION ORIENTED	COLLABORATION	SUPPORT	CAPACITY BUILDING

IMPLEMENTATION

Criteria assessed in this section: **ACTION ORIENTED, FEASIBILITY, IMPACT**

1. **List the key activities for your project and indicate the timing for these on the right. Please be specific and realistic when formulating your activities, ensuring that they are achievable within the indicated timeframe.**

Key Project Activities	Start Date (MM-DD-YY)	End Date (MM-DD-YY)
Installation of a helium recovery system	03-01-20	07-01-20
Installation of piping related to helium recovery system	01-01-20	07-01-20
Widening of door between Otto Maass and Pulp and Paper buildings	01-01-20	07-01-20
Publishing of website explaining purpose and sustainability aspects of helium recovery system	07-01-20	10-01-20
Installation of soundproofing around helium recovery system	07-01-20	09-01-20
Communication of progress via social media	10-01-19	10-01-20
Student research: implementing helium recovery at Royal Victoria Hospital site	07-01-20	07-01-21

2. **Please describe what will happen to your project after the SPF funding ends. Additionally, please share if anything will be produced or installed. (e.g. a workshop guide, equipment, a toolkit, a network, website, etc.) If so, please describe these items and indicate how they will be maintained.** *Limit ~200 Words*

Two aspects of the project, knowledge transfer and technology upkeep, must be considered after funding ends. We intend to disseminate knowledge among members of the McGill community via a website, site tours, and class lectures. The website will include information about the global helium shortage and the CO2 reduction and financial savings achieved with the helium recovery system, and will explain the need for helium in NMR experiments. Site tours will allow us to introduce students, researchers, and science support staff to the facility. In class lectures, undergraduate students will learn about the sustainability aspects of the helium recovery system. As for technology upkeep, ongoing maintenance costs and purchase of small amounts of helium (the recovery system is expected to recycle 90% of helium used, so 10% will still have to be purchased) will be funded through user fees of the NMR facilities participating in the project. User fees have paid about $24000 for helium annually in the past few years. With the new system, the cost of helium and system maintenance are expected to be around $19000, so user fees should pay for all ongoing costs associated with the new system.

3. **Please list any potential risks associated with your project and the measures you will take to reduce their likelihood.**

Main Risks	Preventative Measures
recovery rate of helium is low	talk to colleagues at universities with similar instruments
installation is delayed	communicate with vendor and McGill continuously
power outages	ensure that system cuts off, without loss of helium, as per spec

STAKEHOLDER ENGAGEMENT

Criteria assessed in this section: **AT MCGILL, COLLABORATION, SUPPORT, CAPACITY BUILDING**

4. **Please list all of the key stakeholders involved in your project, indicating their role and support. If the stakeholder has provided a support letter, please indicate so here and attach it as an appendix document.**
Note: Projects involving modifying a space on campus, making a permanent installation, hiring a full-time staff, or adding/modifying a garden, etc., must seek permission from the appropriate stakeholder(s) (e.g. building director, Campus Planning and Development office, staff supervisor, etc.). SPF Staff can help you assess if any key stakeholders need to be added to your list.

Stakeholder's Name(s)	Title	Role in the Project	Support/Permission	Support Letter
Dmitrii Perepichka	Professor	Chair of Chemistry	Confirmed support	Attached
Alice Suarez Kahan	Past-pres, chem	Undergraduate	Confirmed	Yes
David Harpp	Professor	Course coordinator	Confirmed	Yes
Tony Mittermaier	Professor	PI/director, NMR and QANUC	Confirmed	Yes
Jean-Marc Gauthier	Building director	Allocates space	Confirmed	Yes
Graham Currie	Purchasing Mgr	Buyer	Confirmed	Yes
			Choose one.	Choose one.
			Choose one.	Choose one.
			Choose one.	Choose one.
			Choose one.	Choose one.

5. **How will you communicate about your project and share its impacts with your stakeholders and the McGill community? Please describe your tactics (e.g. social media, workshops, tabling, newsletters, etc.) and any related timing (e.g. at the beginning, during, or after the project). Related activities can also be included in Question 1.** *Limit ~200 Words*

Communication about the project and its impacts will be shared with our stakeholders and the McGill community via social media, websites, email announcements, site tours, and course presentations. The Twitter account @MC2McGill will be used to announce all aspects of the project from the awarding of funding to actual helium recovery rates achieved during normal use, with full details presented on the McGill NMR website (https://mcgill.ca/mc2) and/or the QANUC website (http://www.nmrlab.mcgill.ca). Email announcements about the progress of the project will be made to student and postdoc users of the NMR facility and to the PIs of user groups (both at McGill and other universities). Site tours will be offered to our own users and to other helium users at McGill and other universities. Furthermore, various courses touch on NMR or green chemistry (CHEM 180: World of Chemistry: Environment, CHEM 362/392: Advanced Organic Chemistry Lab / Integrated Inorganic/Organic Chemistry Lab, CHEM 462: Green Chemistry, CHEM 493: Advanced Physical Chemistry Lab) and short presentations will be made in those courses as a real-world example of how sustainable design and engineering lead to good environmental stewardship.

6. **If applicable, are there any training, volunteer opportunities, jobs, or complementary applied student research integrated in your project? Please describe.** *Limit ~100 Words*

Complementary applied student research could study how effectively helium is being recycled under the requested system and design improvements as necessary. The chemistry department, including some NMR instrumentation, and other helium users will likely move to the Royal Victoria Hospital site. In that case, a helium recovery system will be necessary, and the knowledge gained during installation and use of the requested system will inform the design of the new system. A student dedicated to this study would learn about sustainability and make a genuine difference to the success of the Royal Vic project.

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PROJECT BUDGET

Criteria assessed in this section: **FEASIBILITY**

Revenues

Indicate any funding you will receive or may receive to complete your project, including funds from McGill Departments and Units.

Funding Source(s)	Amount Requested	Request Status
Sustainability Projects Fund (SPF)	$330,000.00	Requested
NMR/EPR Facility	$47,000.00	Confirmed
QANUC	$23,000.00	Confirmed
	$0.00	Choose one.
REVENUES GRAND TOTAL *(must match Expenses Grand Total))*	**$400,000.00**	

Expenses

Indicate your project expenses below. In the Funding Sources column, use the reference number from the first column of the Revenues section, above. You may list more than one source if applicable (e.g. 1,3).

Item Description	Unit Cost	# of Units	Total Cost	Expense paid by SPF?
Helium recovery system	$330,000.0	1	$330,000.00	Yes, fully
Piping	$50,000.00	1	$50,000.00	No
Widening of door	$10,000.00	1	$10,000.00	No
Soundproofing	$10,000.00	1	$10,000.00	No
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
	$0.00		$ 0.00	Choose one.
Expenses Subtotal			**$400,000.0**	

Salaries & Wages

If applicable, please indicate any paid positions needed for your project. Please note: if you complete the Salaries & Wages section, you must also complete the Staff Position Information Appendix.

Position Title	~# Hours per Week	~# Weeks	Hourly Wage	Subtotal	+ 20% Benefits	Total Cost	Funding Sources
			$0.00	$ 0.00	1.2	$ 0.00	
			$0.00	$ 0.00	1.2	$ 0.00	
			$0.00	$ 0.00	1.2	$ 0.00	
			$0.00	$ 0.00	1.2	$ 0.00	
Salaries & Wages Subtotal						**$ 0.00**	

EXPENSES GRAND TOTAL *(must match Revenues Grand Total)*	**$400,000.0**

APPENDIX

Relevant Support Documents

List any appendix documents in order in the table, below.

Please keep the total number of pages as low as possible (recommended max 10). Please include any relevant support letters.

Doc #	Appendix Document Title	# of Pages
1	Helium recovery system for NMR facilities in Pulp and Paper and Otto Maass	4
2	Letter from Prof. Dmitrii Perepichka	1
3	Letter from Ms. Alice Suarez Kahan	1
4	Letter from Prof. David Harpp	1
5	Letter from Prof. Tony Mittermaier	1
6	Letter from Mr. Jean-Marc Gauthier	1
7	Letter from Mr. Graham Currie	1
8		
9		
10	Staff Position Information Appendix, if applicable	

Appendix: Helium recovery system for NMR facilities in Pulp and Paper and Otto Maass

Tara Sprules and Robin Stein

Background

Helium is a non-renewable resource whose supplies are limited and which is of critical importance for medical, technological, and advanced research applications such as MRI instruments, aerospace engineering, semiconductor fabrication, and high-energy physics experiments. It can be found in useful quantities in only a small number of sites worldwide and is difficult to handle, store, and transport. When released into the atmosphere, helium is unrecoverable, and global demand is growing as reserves are shrinking. Thus great care must therefore be taken with its extraction and manipulation in order to ensure its continued availability.[1]

Nuclear magnetic resonance (NMR) instruments are powerful tools for identifying and characterizing molecular identities, structures and interactions and are essential to research in Chemistry, Materials Science, Pharmacy, Structural Biology, and Biophysics, among many other disciplines. They require regular supplies of liquid helium in order for their magnets to operate.[2] Any significant interruption in the supply of helium to an NMR magnet results in an extremely costly "quench", which may cause permanent damage, so that a reliable source of helium is critical.

Two NMR facilities are housed in the connected buildings of Pulp and Paper and Otto Maass. The Chemistry NMR/EPR Facility is an integral part of the McGill chemistry department and also serves the wider McGill community, with some use for external projects. QANUC is a national high-field NMR facility and is open to all users, regardless of affiliation. The majority of usage is by academics at McGill, with most of the rest coming from academics across Canada, many of whom are members of structural biology networks such as GRASP and PROTEO and collaborate extensively with McGill research groups. Together, the two facilities operate eight NMR instruments and serve at least 30 McGill research groups and 150 McGill users annually, in addition to about 140 students in the undergraduate teaching laboratories.

In a reflection of the limited quantities of helium available, reports of helium scarcity and high helium prices have been increasing across the globe over the past few years.[3] At McGill, very few helium supply problems have been encountered, but prices have increased almost four-fold since August 2018.

We propose to use helium sustainably, alleviate concerns about helium supply, and keep the NMR facilities financially viable by installing a helium recovery system for the QANUC and Chemistry NMR Facilities.

Helium and sustainability

Helium can only be extracted from certain natural gas deposits, almost all of which are located in Qatar, Russia, Algeria and the US. Supplies of helium are finite and are often difficult to extract from the natural gas in which they are trapped. The helium atom is so light that if it escapes into the atmosphere at any point during extraction, storage, or use, it will make its way into space.[4] Thus, the element illustrates the very definition of non-renewability – once used, it is lost forever. In contrast, even the carbon of hydrocarbons survives in the atmosphere as carbon dioxide after it is burned and could, in principle, be reused.

The process of extracting, purifying, liquefying, and transporting helium is energy intensive. The McGill NMR facilities currently purchase 3000 L of liquid helium a year. The CO_2 emissions produced when extracting and liquefying this volume of helium are estimated to be 5.97 metric tons (assuming that 50% of the required power comes from clean energy and ignoring helium losses during the manufacturing process).[5] At McGill, we believe that the majority of our helium comes from the United States Bureau of Land Management facility in Amarillo, TX, USA. The helium is shipped to Brampton, ON,[6] then packed into smaller dewars and trucked to Montreal in several shipments. Assuming that trucking generates

161.8 g CO_2 per ton mile,[7] then a minimum of 0.77 metric tons CO_2 per year are generated in bringing helium to McGill under the current arrangement, for a total CO_2 cost of 6.74 metric tons to supply us with 3000 L of helium each year.

A helium recovery system is expected to allow us to recycle 90% of the helium we use, requiring us to expend one-tenth the CO_2, or 0.67 metric tons CO_2 per year, in extraction, liquefaction and transportation of the remaining 10% to the NMR facilities. The proposed recovery system itself requires 15 kW of power. If it is in constant use, then Hydro-Québec average CO_2 generation figures[8] mean that we will generate 0.07 metric tons CO_2 per year to keep the system running. The reduction in annual CO_2 generated, from 6.74 to 0.74 metric tons CO_2 per year (90%), is substantial.

Details of the helium recovery system

The goal of a helium recovery system is to collect helium and cool it so it can be reused. In our case, the helium comes from the NMR magnets: it evaporates ("boils off") as gas and needs to be liquefied before it can be redistributed to the magnets. The major components of the system are a compressor to pressurize helium that boils off, so that it can be stored in compressed gas cylinders, a purifier to remove any contaminants from the helium, and a coldhead for refrigerating the gas to liquid. The liquid is collected in helium dewars which can be transported to the NMR machines and used to refill them.

Such a helium recovery system can be purchased as a standardized product from suppliers such as Quantum Technology (Squamish, BC) or Quantum Design (San Diego, CA) for approximately $330,000 CAD. Similar systems have been installed in NMR facilities at the University of Lethbridge in Lethbridge, AB, Memorial University in St. John's, NL and at an increasing number of sites in the United States and Europe. At McGill, the Physics Department has a unit (technical and logistic details prevent it from being shared with the NMR facilities). Financing has come from various sources, including federal grants, private donations and sustainability funding.

The system can be sited indoors and requires cooling water and high voltage power. Pulp and Paper 023, a large room which houses one of the QANUC NMR spectrometers, already has chilled water lines and a high voltage power supply in place, as well as an oxygen detector. There is ample space in the room to place the components of the recovery system, and they will not interfere with operation of the spectrometer. Its use has been approved by the Department.

It is expected that the helium recovery system will allow us to recover 90% of the helium used. Furthermore, the helium supply will be reliable. The remaining 10% that must be purchased annually can be obtained as liquid or as gaseous helium, making supply issues even less of a problem.

Related work

The commercial helium recovery systems do not include wide bore copper piping to bring the helium from the magnets from which the helium boils off to the gas compressor. To link the chemistry NMR facility with the Pulp and Paper building approximately 80 m away is expected to cost approximately $50,000 CAD. The cost of designing the piping system is included in the purchase of the recovery system, and the plans will be made in collaboration with McGill Facilities, who will then be responsible for purchase and installation of the piping. Final connections between the piping and the spectrometers and recovery system will be made by the recovery system manufacturer.

Liquid helium from the recovery system will be placed in a 250 L helium dewar for transfer to the NMR magnets. The underground tunnel between Otto Maass and Pulp and Paper is constricted by a door which is too small for standard 250 L helium dewars to pass between the two buildings. A 250 L dewar is required as the next largest dewar size commercially available is 100 L, which is too small for use with the 800 MHz QANUC magnet. This cost of this enlargement is estimated to be $10,000 CAD and McGill Facilities can do the work needed.

The system may generate substantial noise at times and because some NMR experiments require operators to sit at the NMR spectrometer for many hours at a time, we are requesting $10000 for a soundproofing curtain.

Effect on NMR facilities

Guaranteed helium supply is crucial for the running of the NMR facilities: an unexpected lack of helium will lead to superconducting magnets warming up and can cause catastrophic failure. This leads to significant downtime, as reinstallation is not instant, forcing gaps in research lasting months or even years, and potentially requiring the replacement of instruments costing between $300,000 and $1,500,000. Although we have not heard reports of supply problems in Quebec serious enough to compromise the NMR facilities, our colleagues in Ontario have reported helium rationing over the past year.

Furthermore, helium is a major component of the budget of the NMR facilities, with the 3000 L of helium used by the two NMR facilities recently increasing in cost from about $24,000 for helium to $90,000 annually. Research grants, the major source of revenue for the NMR facilities, have clearly not kept pace with the increase in helium cost. Shutting down instrumentation temporarily to conserve helium is not an option, for three reasons: there is no redundant equipment in the university, NMR magnets require large amounts of helium (approximately 2-3 times their yearly consumption) during deenergizing (shut down) and then subsequently during recooling and reenergizing, and because they are sensitive instruments not guaranteed to return to their original performance quality after a shut down.

A helium recovery system would guarantee a supply of helium at a price that could be covered by user fees, allowing research to continue unimpeded.

Ongoing maintenance and costs

After the system is installed, it will need to be checked for proper functioning, measured in terms of helium recovery rate. Once McGill staff (the managers of the NMR facilities and the electronics technicians) are familiar with the system, a student could be trained to help with these tasks.

The coldheads and compressors used in the compression, purification, and liquefaction of the helium require annual maintenance at a cost of approximately $10,000. As the recovery is not 100% efficient, 300 L of helium will need to be purchased each year for approximately $9000. Therefore, the NMR facilities liquid helium needs will be supplied at a cost of $19,000 per year, a savings of $71,000 per year in comparison to the current spending of $90,000 per year to purchase 3000 L of liquid. Given that the overall cost of purchasing and installing the system will be approximately $400,000, the cost-recovery time is on the order of 6 years.

The aim of the maintenance is to prolong the life of the components of the system. Generally speaking, the components are either regenerated (cleaned) or exchanged – but the exchanged components are returned to the manufacturer for refurbishment and future exchange. So recycling is integrated into the ongoing maintenance of the system.

The NMR facilities collect user fees, which up until the large helium price increase were sufficient to pay for $24,000/year of liquid helium and other consumables required to keep the instrumentation operational, with excess set aside to pay for repairs or other costs. As the effective cost of liquid helium will be lower than in the past and user fees have been raised to help offset the increased cost of liquid helium, the facilities will have sufficient funds to cover the annual maintenance of the recovery system, with the surplus set aside in the event that the system requires repairs in the future.

Futureproofing

It appears likely that some or all of the NMR Facilities will move to the site of the former Royal Victoria Hospital. At this time, the equipment can move with the NMR instruments without degradation to its performance. In the meantime, if the helium recovery system is used for 6 years before it is moved and it

functions at 90% efficiency, it will save 16,000 litres of helium, about $480,000 at current pricing, and 37.5 metric tons of CO_2.

Ongoing community engagement

In order to educate the NMR and wider McGill community about the benefits of thinking about sustainability when a research facility faces challenges, the NMR facilities will make information about the recovery system widely available via a website and social media. The Chemistry NMR Facility is part of a wider instrument facility, the McGill Chemistry Characterization facility, or MC[2]. A set of pages detailing the technology and benefits of the helium recovery system will be added to the facility website, https://mcgill.ca/mc2, as the project progresses. The QANUC website, http://www.nmrlab.mcgill.ca/, which reaches an audience spread across Canada, will also monitor progress. At the same time, day-to-day progress will be announced via the Twitter handle @MC2McGill.

Site visits will be offered to helium users on campus and to other interested parties, such as nearby NMR facilities.

In order to engage students with the recovery system, all undergraduate and graduate students and postdoctoral researchers who use the NMR facilities will be introduced to the system. About 100 students use the facility each year as part of the CHEM 362, 392, and 493 courses, and about 80 students and postdoctoral researchers are trained annually to use the facilities for their research. A description of the instrumentation is part of the training courses, and as the helium recovery system will be an integral part of the spectrometers, information about it will be added to the course material.

To spread information to the wider community, a presentation will be made as part of the CHEM 180 World of Chemistry: Environment course, which usually attracts at least 80 students. Finally, a project investigating the availability of elements including helium will take place in CHEM 462, Green Chemistry.

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[1] S. R. Bare et al., "Responding to The U.S. Research Community's Liquid Helium Crisis: An Action Plan to Preserve U.S. Innovation" (2016), report issued by American Physical Society, Materials Research Society, and Materials Research Society, https://www.aps.org/policy/reports/popa-reports/upload/HeliumReport.pdf.

[2] M. Ewald, L. Elmar, S. Franz, K. Georg, "Ultra-High Field NMR and MRI—The Role of Magnet Technology to Increase Sensitivity and Specificity", *Frontiers in Physics* **5** (2017), 33, https://www.frontiersin.org/article/10.3389/fphy.2017.00033.

[3] D. Kramer, https://www.aip.org/fyi/2019/helium-users-grapple-supply-crunch, accessed July 2, 2019; email list of Association of Managers of Magnetic Resonance Laboratories (AMMRL, http://www.ammrl.org).

[4] S. Hayes, W. Halperin, W. Hartwig, https://www.acs.org/content/acs/en/acs-webinars/popular-chemistry/helium.html, accessed July 2, 2019.

[5] Communication from Joey Heider, Quantum Technology, June 17, 2019.

[6] V. Chrz, "Helium Storage and Transport", 2010, European Graduate Course in Cryogenics, https://indico.cern.ch/event/90787/sessions/113901/attachments/1093425/1559937/Helium_Storage_and_Transport.pdf, accessed July 2, 2019; conversations with Stan Theberge (MEGS), 2018-2019.

[7] J. Mathers, "Green Freight Math: How to Calculate Emissions for a Truck Move", 2015, http://business.edf.org/blog/2015/03/24/green-freight-math-how-to-calculate-emissions-for-a-truck-move, accessed July 2, 2019.

[8] "Hydro-Québec's Electricity Facts: CO_2 Emissions and Hydro-Québec Electricity, 1990-2017", https://www.hydroquebec.com/data/developpement-durable/pdf/co2-emissions-electricity-2017.pdf, accessed July 2, 2019.

McGill

Faculty of Science | Faculté des sciences

801 Sherbrooke St. W.
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August 10, 2019

Sustainability Projects Fund
McGill Office of Sustainability
1010 Sherbrooke St. W, Suite 1200
Montreal, QC H3A 2R7

Dear SPF,

As chair of the chemistry department, I would like to express my support for the helium recovery system proposed by Dr. Tara Sprules and Dr. Robin Stein. NMR is a critical technique for chemistry research. My group and about twenty others in the chemistry department use NMR nearly every day of the year. The chemistry department NMR/EPR facility has traditionally met its costs (including helium costs) by levying user fees. The recent increases in the price of helium, which began last fall and have continued, have made NMR a more expensive technique than the grants of our PIs can support. Furthermore, our department has a clear commitment to sustainability. We recognized that Green Chemistry and Sustainability was a principal research theme of the department two years ago and now have seventeen research groups in the department performing research related to this theme. We are part of the FRQNT Centre for Green Chemistry and Catalysis (CGCC) and until recently were part of the NSERC CREATE in Green Chemistry. Thus, a helium recovery system will be a wonderful addition to our department, both because it enables NMR experiments to be performed and because it fits so well with our values. I am pleased to support this application by confirming that the department can provide the necessary space and funding via the chemistry NMR facility ($47000) and QANUC ($23000). I hope that you will consider this proposal seriously.
Please do not hesitate to contact me if I can provide any further information.

Sincerely yours,

Dr. Dmitrii F. Perepichka
Sir William C. MacDonald Professor of Chemistry
Chair, Department of Chemistry
Dmitrii.perepichka@mcgill.ca

Holmevej 171

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Denmark

July 3, 2019

Sustainability Projects Fund
McGill Office of Sustainability
1010 Sherbrooke St. W, Suite 1200
Montreal, QC H3A 2R7

Dear SPF,

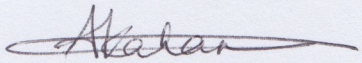
I am writing to support the proposal for a helium recovery system for the NMR instruments in the Chemistry Department and at QANUC, from a student perspective. I have just finished my term as president of the Chemistry Undergraduate Student Society (CUSS) and graduated with a degree in chemistry. NMR formed part of our curriculum; we performed hands on experiments during the advanced organic lab (CHEM 362, for which I was TEAM TA) and in the advanced physical chemistry lab (CHEM 493). Also, along with many other students in my year, I used NMR during my research project, which in my case was on liquid crystal materials and was supervised by Prof. Linda Reven.

I understand from Dr. Stein that helium costs are a significant part of an NMR lab's budget, so rising costs concern me as an undergraduate. The hands-on experience I gained using NMR has made me a better chemist - I have learned to prepare samples and operate expensive equipment carefully. This will serve me well not only in graduate school, but also in other areas where using instrumentation properly is critical. Thus, I would support any proposal that makes it more likely that undergrads such as myself could continue to have access to this instrumentation. Apart from anything else, the importance of NMR as a characterisation technique means that it's crucial for anyone with a chemistry degree to have a clear understanding of it - regardless of the field they go into.

Furthermore, the sustainability aspect of the project is very important. Green chemistry and sustainable practises are emphasised throughout our degree, and in light of the climate crisis it is our responsibility to address issues of wastage etc. where we can. We learn to close fume-hoods from day one in the labs and to think about the amount of solvent we use - conserving helium is not only a logical extension of this thought process, but a particularly important example of resource management. Helium is a non-renewable, increasingly scarce material, with crucial applications in e.g. healthcare. If the chemistry department at McGill doesn't implement a helium recovery system sooner rather than later, we risk being left behind, with damaging restrictions placed on the science that undergraduates (chemistry, and others such as biochemists who use the facilities) can learn and do, in research and classes.

As such, I fully support the implementation of a helium recovery system for the Chemistry Department.

Yours sincerely,
Alice Suarez Kahan



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Sustainability Projects Fund
McGill Office of Sustainability
1010 Sherbrooke St. W, Suite 1200
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July 5, 2019

Dear SPF,

Dr. Tara Sprules and Dr. Robin Stein contacted me about bringing a lecture about helium recovery into the curriculum of CHEM 180, World of Chemistry: Environment. This is an exciting initiative that fits very well with the themes of the course. I believe that the real-world example of improving sustainability in a research laboratory by recycling a non-renewable resource will be of great interest to the 80+ chemistry and non-chemistry students in the class.

One of the most attractive aspects of the problem from a pedagogical point of view is that the material in question is not one which is commonly considered when discussing sustainability, such as solvents, a major topic in green chemistry, nor is it a traditional consumable such as glass pipets.

As a chemist myself, I know how important NMR research is to many areas of science, and many of the topics which we discuss in the course relate to problems which NMR has helped solve. I am pleased that a helium recovery system is being considered by the NMR facilities to ensure their future viability in a sustainable and economical manner. I am very much in favour of funding a helium recovery system and I would be pleased to have Dr. Sprules and Dr. Stein present the topic as one of the lectures in CHEM 180 this winter.

In fact, such a lecture, (or derivative) could be an important addition to any other course in the department that deals with NMR- and there are several, large-enrolment venues where this important concept would be highly applicable.

Sincerely,

David Harpp

David N. Harpp
Professor of Chemistry
Tomlinson Chair in Science Education

McGill
Faculty of Science / Faculté des sciences

Department of Chemistry
801 Sherbrooke Street West
Montreal, Quebec H3A 0B8
August 18, 2019

Sustainability Projects Fund
McGill Office of Sustainability
1010 Sherbrooke St. W, Suite 1200
Montreal, QC H3A 2R7

Dear SPF,

As director of the QANUC high-field NMR facility and chair of the McGill Chemistry Characterization Facility committee (which is responsible for NMR), I enthusiastically support the acquisition of a helium recovery system for the QANUC and Chemistry Department NMR facilities. QANUC has provided exciting results for researchers in the Department of Chemistry and other departments affiliated with the Faculty of Science, such as Biochemistry and Pharmacology and Therapeutics, as well as for researchers across Quebec and Canada. The Chemistry NMR Facility has been used by Chemistry Department members and by many other departments, including materials sciences-oriented departments such as Atmospheric and Oceanic Sciences, Chemical Engineering, and Biomedical Engineering. Researchers at McGill hospital institutes such as the Research Institute of the McGill University Health Centre, the Lady Davis Institute at the Jewish General Hospital, and the Montreal Neurological Institute also benefit from these facilities.

The availability and price of helium have always been a major concern for NMR facilities and the recent rise in prices has been a headache at the departmental and faculty levels. Research grants have not kept pace with these increases. A helium recovery system seems to be the only reasonable strategy to keep the facilities going. Plus, it conserves a critical non-renewable resource, which is in many ways the most important criterion for deciding what technology to invest in. Thus, I have no hesitation in recommending that the SPF contribute to the cost of installing a helium recovery system. To support the project, the Chemistry Department NMR Facility and QANUC will gladly contribute $47,000 and $23,000 respectively, for a total of $70,000.

Thank you for your consideration.

Sincerely yours,

Anthony Mittermaier
Associate Professor
Department of Chemistry
McGill University

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Montreal, August 21, 2019

Sustainability Projects Fund
McGill Office of Sustainability
1010 Sherbrooke St. W, Suite 1200
Montreal, QC H3A 2R7

Dear SPF,

As Building Director for the Maass Chemistry Building and the Pulp and Paper Building, I hereby confirm my support for the helium recovery system proposed by Dr. Tara Sprules and Dr. Robin Stein. Room 023 in the basement of Pulp&Paper, was identified as the most appropriate location for the system. Not only does it have available space, it has chilled water and electrical connections already in place.

I would also like to express my support to the project for its contribution to sustainability and insist on the importance of running the NMR facility in an economically viable manner. As Director of Undergraduate Teaching Laboratories for the Department of Chemistry, I can confirm that NMR is an important and necessary component of the Chemistry and Biochemistry teaching curricula. We introduce and use NMR techniques in several courses, but more specifically in the lab components of CHEM 362 (Advanced Organic Chemistry Laboratory), 392 (Integrated Inorganic/Organic Laboratory), and 493 (Advanced Physical Chemistry Laboratory), where practical exercises are performed on the NMR spectrometers.

Please do not hesitate to contact me if you need any further information.

Best regards,

Jean-Marc Gauthier
Building Director - Chemistry
Director of the Chemistry Undergraduate Laboratories
T.514-398-6180, E.jean-marc.gauthier@mcgill.ca

Procurement Services
3465 Durocher Street, Suite 101
Montreal, QC H2X 0A8

July 2, 2019

Sustainability Projects Fund
McGill Office of Sustainability
1010 Sherbrooke St. W, Suite 1200
Montreal, QC H3A 2R7

Dear SPF,

I would like to write in support of the proposal for a helium recovery system for the NMR facilities located in the chemistry department. Procurement Services has been involved with purchasing helium and other cryogens for many years. Luckily, the NMR Facilities have been able to purchase helium at low prices, ranging between $4.77 and $8.15 per litre, for at least 14 years, ending in late 2018. However, it has not been possible to keep helium at reasonably low rates since then and helium currently costs $30 per litre. Worldwide market forces including increased demand in emerging markets such as China and India and efforts of the Bureau of Land Management (US) to reduce their stock of helium have caused prices to increase rapidly, and there is little prospect of new helium sources coming online soon. Thus, it is in the best interest of McGill University to support its helium users by making it possible for them to reuse as much helium as possible.

I would like to wish the best of luck to the proposal for a helium recovery system for the NMR facilities.

Sincerely yours,

Graham Currie

Procurement Manager - Faculties