THE UNIVERSITY of EDINBURGH

Cold Storage Facility Policy

Purpose	The purpose of this policy is: • To enable energy, cost and carbon savings while maintaining or improving sample safety, security and integrity within University of Edinburgh facilities housing cold storage (i.e. ULT freezers). • To standardise good practice in the design and operation of cold storage facilities at University of Edinburgh.
Overview	ULT freezers expel a lot of heat and, as such, the rooms in which they are held can heat up very quickly if not well ventilated. As the room becomes hotter the strain on the ULT freezers' compressors increases, which increases energy consumption and the likelihood of failure (risking potentially irreplaceable biological samples). Currently some freezers are located in facilities which have poor natural ventilation, resulting in excessive energy requirements to maintain the appropriate room temperature with fans and air conditioning, and excessive strain and energy consumption of the ULT freezers. The design of facilities to house scientific cold storage equipment can be a major influence on the energy consumption of that equipment and also the energy consumption of building ventilation and cooling services. A well-designed facility will provide more favourable ambient conditions and put less strain upon the components of individual ULTs, reducing risk of failure and associated risk of damage to samples and other freezer contents. Facilities with good natural ventilation, such as the facility at the Roslin Institute, maintain lower room temperatures with very low fan and air conditioning energy consumption. This has a positive compounding effect of lower ULT freezer energy consumption and reduced strain on the compressors, reducing the risk of failure and sample losses.
Scope	For the purposes of this policy, the term "ULT freezer" refers to specialist laboratory Ultra Low Temperature freezers designed to operate at temperatures between -50 and -90^{0}C. Commonly ULT freezers are held at a set point temperature of -80^{0}C, leading to them also being known as "minus eighties". ULT freezer facilities are deemed to be spaces specifically used to house multiple ULT freezers as the primary purpose of the space. Typically numbers of freezers in these spaces is over 10, but can reach over 100. The following areas are considered within this policy: • The air handling mechanisms for maintaining appropriate room temperatures in ULT freezer facilities[1]
The Policy	The overarching principles of the policy aim to maximise the free cooling available from natural ventilation and reduce the energy

[1] Other areas relating to freezer and sample management will be covered in the best practice guide

	consumption of fans and air conditioning in ULT freezer facilities and associated energy, carbon and cost implications. • Natural ventilation should be maximised by fitting substantial controllable openings/grilles/louvers to opposing external walls. When fitted to opposing (rather than adjacent) walls the cold external air can easily enter via one wall, travel through the facility gathering heat, and exit via the opposite wall. • The prevailing wind direction is south westerly so new buildings should maximise their natural ventilation cooling functionality by having the opposing ventilated walls of the freezer facility orientated south west – north east (however, west – east or south – north would also suffice in most scenarios – local wind modelling may be appropriate in highly built-up areas). • To maximise wind speeds available for natural ventilation freezer facilities should be located in as high a location as possible – ideally in a roof-top location, with large lift access to allow easy movement of new/old freezers as well as personnel and samples. • The ambient room temperature should be measured at a suitable number of positions within the room, feeding into the Building Management System (BMS). This should be arranged with the Controls Team within the Energy Office. • The natural ventilation should be designed with 3 escalating functions which should be controlled by Building Management Systems: 1. In cool weather the louvers in the walls should be open to allow cool outside air to flow through the facility 2. In warm weather the louvers should remain open but the air speed should be artificially increased through the use of fans (fans should be fitted to the same walls as the louvers and should move air in the direction of the prevailing wind (i.e. south west to north east, or west to east, or south to north). 3. In hot weather the louvers in the walls should be closed to create a good thermal and draught-proof seal and air conditioning units should be switched on within the facility to control air temperatures. • Temperature sensor(s) should be installed for monitoring and alarm purposes. Careful consideration should be given to the sensor location(s) • Alternative designs which also maximise natural free cooling through other methods may also be acceptable (including, but not limited to: agricultural shed designs, external compressor system, or thermal labyrinth cooling). • It is recognised that retrofitting these design principles into existing freezer facilities may require alternative designs (such as open windows with security grilles fitted if required).

	• All designs should demonstrate that they have prioritised free cooling/avoidance of heat build-up first, then forced air (fans), then air conditioning as a last resort. • A suitable route must be in place between the site of possible freezer deliveries, and the freezer room location. This route should ensure that lifts/elevators have sufficient size and lifting capacity, and each door encountered along the route (including in lifts/elevators) has sufficiently large dimensions to allow for the passage of freezers. • Walls and floors/ceilings between the freezer room and adjoining spaces within the building should be insulated and draught proofed to the same standards as if they were external walls, in order to accommodate the potential temperatures within the freezer room matching outdoor air temperatures on cold windy days.

Date approved	11/12/18.
Approving authority	Sustainable Strategy Advisory Group
Consultation undertaken	Sustainable Labs Steering Group members (January to May 2018) - Including representatives from Medical School, Veterinary School and Roslin Institute, School of Biological Sciences, Estates Development, Estates Operations, SRS, Procurement, Health and Safety Technical Manager, QMRI Health and Safety Manager, Little France Campus Buildings Manager, Little France Campus Centre Technical Manager, SCRM Technical Officer, Chemistry CDBS Centre Manager Technical Services Manager, Chemistry
Impact assessment	TBC
Date of commencement	
Amendment dates	
Date for next review	This policy will be reviewed every two years by university-wide stakeholders including SRS, Estates and lab users to ensure it continues to meet the needs of our lab-based community and university-wide stakeholders.
Section responsible for policy maintenance and review	Estates (Estates Development), SRS With additional input sought from lab users.

Related Policies, Procedures, Guidelines & Regulations	• University of Edinburgh Estates Mechanical Engineering Guidelines • University of Edinburgh Climate Strategy “Zero by 2040” • Health and Safety at Work Act 1974 • Control of Substances Hazardous to Health Regulations 2002 • Provision & Use of Work Equipment Regulations 1998
Policies superseded by this Policy	

Appendix: Cold Storage Best Practice Guide

Cold Storage Best Practice

Executive Summary

This paper summarises the findings of research undertaken by the University of Edinburgh's Department for Social Responsibility and Sustainability into best practice in Ultra Low Temperature (ULT) freezer management. It incorporates international best practice from various research institutions, as well as information gained through lab sustainability and energy efficiency audits across the University of Edinburgh. The term “ULT freezer” refers to specialist laboratory Ultra Low Temperature freezers designed to operate at temperatures between -50 and -90^{o}C. Commonly ULT freezers are held at a set point temperature of -80^{o}C, leading to them also being known as “minus eighties”.

This document describes a number of actions and the potential savings, including:

Replace old freezers (up to £400/year saving per freezer)

Regular defrosting and maintenance of freezers (around £200/year saving per freezer)

Save space by clearing out old samples (save up to £1,000 per year for every ULT freezer you can retire)

Run your freezers a little warmer (up to £300/year saving per freezer changed from -80 to -70^{o}C)

Out with the old, in with new…

The problem:

Older freezers can use as much as £1000 annually in 'plug load' electricity (i.e. not including their impact on room air cooling systems) while new freezers can use less than £600 plug load annually. Investigations at the National Institutes of Health in the United States of America have indicated that for every year of a ULT freezer's life its energy consumption increases by 3%[2].

The solution:

The University of Edinburgh's Sustainable Campus Fund[3] can contribute to the costs of upgrading old freezers.

The Roslin Institute has an ongoing replacement of their oldest ULT freezers, with a requirement that new purchases are energy efficient. This is also an approach being taken by the National Institutes of Health in the USA.

[2] Gumapas & Simons, World Review of Science, Technology and Sustainable Development, Vol 10, No.s 1/2/3, 2013

[3] www.edin.ac/fund

Choked up with ice and dust…

The problem:

Freezers which are not regularly defrosted accumulate frost and ice, reducing internal space (and thus exacerbating the problem of a continual demand for more and more ULT freezers, filling up valuable space in science buildings). In addition to reducing the available space for sample storage, poorly defrosted ULT freezers use more energy to operate as often seals around doors do not operate as effectively. Investigations at the National Institutes of Health in the United States of America have indicated that there is a difference in annual operating costs of the equivalent of around £160 between an ice-free freezer and a severely iced up freezer[4].

Freezers draw air through a filter to cool condenser fins and heat exchange coils, helping the removal of heat from the internal space. If these filters and/or fins are dusty the removal of heat is less effective and the compressor mechanisms for heat removal need to work harder. Investigations at the National Institutes of Health in the United States of America have indicated that there is a difference in annual operating costs of the equivalent of around £230 between a freezer with clean filters and fins and a freezer with severely dusty filters and fins[5].

The Solution:

Other than staff time and a little planning, freezer defrosting and cleaning filters and fins requires no additional resources.

Site visits and auditing for the Edinburgh Sustainability Awards indicated that most of the labs involved outsource mechanical maintenance of freezers. Lab groups should check which actions are included in their maintenance contracts to ensure filters, fins and heat exchange coils are cleaned. If not, the lab personnel should include this in their own regular maintenance work. From the findings of the Cold Storage Sustainability Internship in 2018, it is also recommended that the rooms in which freezers are housed should be cleaned regularly, to help minimise the level of dust becoming trapped in freezer fins/filters. Additionally, damage to or physical deterioration of freezers should be regularly checked for, particularly when a full defrost is undertaken and the freezer is empty.

The awards audits also showed that good defrosting practices were in place at The Roslin Institute, the Biology Teaching Organisation, the Wellcome Trust Clinical Research Facility, SynthSys labs, and the Institute of Genetic and Molecular Medicine. Typically these labs undertake regular and planned defrosting schedules, and/or audits from senior lab staff.

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[4] Gumapas & Simons, World Review of Science, Technology and Sustainable Development, Vol 10, No.s 1/2/3, 2013

[5] Ibid.

Best use of valuable space…

The problem:

ULT freezers are expensive to purchase and have high operational costs due to their plug-load and air conditioning energy consumptions. However the number of ULT freezers across the University of Edinburgh is growing, adding strain to departmental budgets and diverting money away from other uses.

The solution:

Lab users/lab groups should ensure they only use ULT freezers to store items which absolutely must be stored at these temperatures. There are three factors to consider here:

Firstly, do you need to keep all of those samples?

If you are a lab user who stores samples in ULT freezers you can help to reduce significant departmental costs of purchasing and running ULT freezers by regularly checking the samples you are storing and removing those which are now redundant/no longer needed. ULT freezer storage, of course, does not stop sample degradation - it merely slows it down - so those samples you have been holding onto for years and years may not even be of any scientific use to you if you did decide to use them again.

N.B.: unless there is absolute certainty regarding the contents of sample containers, they should be handled, managed and disposed of with some caution in case they are more hazardous than they seem.

A well maintained database of the freezer contents can also help lab users find their samples quickly and easily rather than searching for a long time with the door open, risking warm air entering and damaging freezer contents and excess energy consumption to draw the temperature down again once the door is closed.

Secondly, do your samples need to be stored in ULT freezers?

There is a growing body of evidence which suggests that some sample types can safely be stored in non-ULT freezers (i.e. at -40°C, -20°C, +4°C or even room temperature)[6] [7] resulting in significant energy savings. Stanford University found that up to 25% of their biological samples (DNA/RNA/bacteria) could be stored at room temperature after a successful trial.[8] The University of Colorado - Boulder and University of California - Davis have developed a freely accessible database of over 200 biological sample types which they are storing at -70°C or warmer[9] with no ill effects. More details on this later in this document. Have a look for yourself!

Typically the suitability of a temperature for sample storage depends on the length of the storage time - if you are storing samples for only a short amount of time it may be safe to store them at a

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[6] Colins et al, (1993), "Storage temperature and differing methods of sample preparation in the measurement of urinary albumin" Diabetologica, vol 36, issue 10, pp 993-997

[7] http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/ulf_freezer_user_guide.pdf (U.S. Dept of Energy "Store Smart" ULT freezer guide)

[8] http://www.goodcampus.org/uploads/DOCS/106-case_10_-_uni_california_final_25_2_11.pdf and http://sustainable.stanford.edu/sites/default/files/documents/Stanford_Room_Temp_Pilot_May09.pdf

[9] https://docs.google.com/spreadsheets/d/13UvBeoXAhwSHshSYoUDHwcxWiW7qYLnUb-eLwxJbCYs/pubhtml

higher temperature. Freeze-thaw cycles may be more important than the storage temperature for degrading samples[10] [11] [12] [13].

If samples are valuable and vulnerable enough to require ULT freezer storage the freezer should also be fitted with additional temperature sensors linked to an alarm system which would alert individuals in the event of rising internal temperatures. Careful consideration should be given to the sensor location(s) to ensure it is representative of the conditions surrounding the samples, and not impacted by localised conditions.

Some collection tubes are designed for room temperature storage such as saliva collection kits from Isohelix or DNA Genotek, used for extracting DNA. This means they can be stored and shipped at room temperature without the need for using dry ice.

Thirdly, are you making best use of storage space?

Efficient use of space in ULT freezers can help to reduce the demand for additional units. Ensuring that your samples are neatly stored in appropriate storage solutions (racks/boxes) for the type and size of material will allow more items to be stored in the existing number of freezers. Where possible try to avoid storing bulky items in freezers if you can divide them up into more easily stored small samples/aliquots. An example might include extracting DNA from tissue and storing only the DNA, rather than a large bulky tissue sample. Storing your samples in racks/boxes can also make them easier to quickly transfer in the event of a freezer failure.

Best practice would be to use high quality steel racking as this makes best use of space and retains cool surface temperatures better. This is better for samples and ensures freezers warm up more slowly when users open the door. When purchasing a new freezer you should budget for spending about the same amount on racking as you do on the freezer.

Good practice has been observed around the University of Edinburgh including:

Hugh Robson Building charge for space in the Hotel Freezer.

BTO consolidate their materials into fewer fridges/freezers over the summer holiday and switch off extraneous ones.

Wellcome Trust Edinburgh Clinical Research Facility have good racking to make best use of space, and control samples using a LIMS (providing Biobank storage for researchers).

IGMM consolidated the contents of c.40 small LN2 storage tanks into 2 large ones saving c.£18k annually in LN2 refill costs.

The mass spectrometry facility at the IGMM have a very good database of their ULT freezer contents.

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[10] http://bitesizebio.com/19700/freeze-thaw-cycles-and-why-we-shouldnt-do-it/

[11] M. S. Charde et al. (2014) "Review: The procurement, storage and quality assurance of frozen blood and tissue biospecimens" International Journal of Pharmacological Research Volume 4 Issue 2 (2014)

[12] Brand, J.J., "Cryopreservation of Cyanobacteria" http://www-cyanosite.bio.purdue.edu/protocols/cryo.html

[13] B. L. Mitchell et al., (2005) “Impact of Freeze-thaw Cycles and Storage Time on Plasma Samples Used in Mass Spectrometry Based Biomarker Discovery Projects”, Cancer Informatics 1(1): 98–104.

SynthSys allocate specific shelves/space in ULT freezers to lab groups.

QMRI biobanking is done on a ‘cost recovery’ basis.

Chancellors' Building are investigating room temperature storage of DNA.

Space to breathe…

The problem:

ULT freezers operate by removing heat from inside the freezer cabinet and expelling it (usually through heat exchangers at the back of the freezer). In an enclosed space this quickly results in the air temperature of the room rising to temperatures which are uncomfortable for the users and cause the freezer to work harder to maintain a set internal temperature (“Each 1°C drop in ambient temperatures from 32°C lowers the energy consumption for a ULT freezer by approximately 2%”[14]). To counteract this, energy intensive air cooling/mechanical ventilation equipment is installed and operated, adding to the energy consumption of operating freezers.
Some ULTs do not have enough space around them for air to circulate adequately (i.e. they are up against a wall and/or have boxes on top of or around them). This reduces the ability of the freezer to dissipate the heat from inside to outside.

Some labs keep numerous ULT freezers in the lab or in surrounding corridors. Sometimes the air handling and natural ventilation options in these areas are not able to deal effectively with the extra heat gain from the ULT freezers, leading to overly warm spaces which are uncomfortable to work in and also increase the strain on the ULT freezers (increasing energy consumption and wear and tear on components).

Some labs keep ULT freezers adjacent to heat sources such as radiators, drying ovens, incubator shakers, etc. This increases the strain on the ULT freezer, and can also speed up the process of ice accumulation, leading to more work for those responsible for de-icing the unit and a greater threat of freezer failure.

The solution:

Dedicated spaces with abundant natural ventilation have been constructed at the Roslin Institute to house the majority of their ULT freezers. These spaces have large louvered vents and fans which allow external air to be used either passively (fans switched off, air moves with convection and pressure differentials/wind) or actively (fans switched on to drive air through the space) to remove hot air from the freezers. If external air temperature rises above a certain level the louvers are closed and the room cooled with air conditioning. This is currently not required very often in the Edinburgh area but climate change forecasts suggest more frequent warm weather. This design significantly reduces the amount of air conditioning required to keep the air temperature of the freezer space at a level which allows the freezers to operate safely and with low energy consumption. Designs incorporating methods for free cooling and more ‘passive’ design while incorporating active cooling for when required will be better able to adapt to future climate changes.

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[14] Gumapas & Simons, World Review of Science, Technology and Sustainable Development, Vol 10, No.s 1/2/3, 2013

Freezers (especially ULT freezers) should have 15cm space on the back, sides and top. When checked, some freezers will need to be pulled out away from walls in order to achieve this. No objects should be stored on top of the freezer.

Freezers should not be located in large numbers in labs or corridors. One or two in a large lab or corridor may be acceptable, but this is not ideal - locating the freezer in a dedicated facility would have substantial benefits in terms of energy consumption and freezer failure rates.

Where a ULT must be kept within a lab or corridor it should always be located in the coolest point of the room, away from heat sources such as radiators, drying ovens, incubator shakers, etc.

Too Cool…?

The problem:

Fifteen or twenty years ago the lowest temperature achievable by most lab freezers was -70^{o}C. Technology improved and newer freezers were able to achieve temperatures of -86^{o}C. The lower temperature (often -80^{o}C) was then adopted by many lab users/groups as a new standard operating practice. The technological advance which led to freezers achieving lower temperatures came at a price - higher energy consumption in terms of both plug-load and impact on air conditioning loads.

The solution:

There has so far been little evidence produced which shows that operating ULT freezers at -80^{o}C has substantial benefit for lab research, in fact some sources show that a variety of samples are stable at

-70^{o}C[15] [16] [17] [18] [19] [20] [21] [22] [23]. The University of Boulder Colorado and University of California - Davis have developed a database which details a wide variety of samples being stored at -70^{o}C[24]. Some samples will benefit from being stored at -80^{o}C so it is worth checking the literature first, or even doing your own tests. Even if your samples do benefit from being stored at -80^{o}C it is a good idea to run your back-up freezers ("hotel freezers") at -70^{o}C or even -60^{o}C to reduce energy consumption, and then adjust them to -80^{o}C when required. Many freezers around the campus have temperature monitors connected to remote alarms which are activated if the temperature rises above a threshold and alerts a nominated member of staff. This reduces the need to store samples at a lower temperature in order to have a 'buffer' to give more time between a freezer failure and the internal freezer temperature exceeding a threshold temperature.

Running a freezer at -70^{o}C instead of -80^{o}C can produce almost 30% plug-load energy savings[25] equating to **up to £300 annually**, as well as further savings on room air conditioning. A number of lab users around the University are running freezers at -70^{o} including Roslin, IGMM and BTO.

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[15] http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/ulf_freezer_user_guide.pdf (U.S. Dept of Energy "Store Smart" ULT freezer guide)

[16] Tedeschi, R. & De Paoli, P; (2011) "Collection and Preservation of Frozen Microorganisms"; Methods in Molecular Biology Volume 675, pp 313-326

[17] Marino, D, (2013) "Best practices for storing biological samples in ULT freezers" http://www.biocompare.com/Bench-Tips/137747-Best-Practices-for-Storing-Biological-Samples-in-ULT-Freezers/

[18] Colins et al, (1993), "Storage temperature and differing methods of sample preparation in the measurement of urinary albumin" Diabetologica, vol 36, issue 10, pp 993-997

[19] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Reimer, L. and Carroll, K. (2004) Procedures for the storage of microorganisms In: Manual of Clinical Microbiology (Murray, E., Baron, E., Pfaller, M., Tenover, F. and Yolken, R., Eds.), pp. 67–73. ASM Press, Washington, DC

[20] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Michel, C. and Garcia, C. (2003) Virulence stability in Flavobacterium psychrophilum after storage and preservation according to different procedures. Vet. Res. 34, 127–132.

[21] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Harbec, P.S. and Turcotte, P. Preservation of Neisseria gonorrhoeae at 20 C. J. Clin. Microbiol. 34, 1143–1146.

[22] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Sebire, K., McGavin, K., Land, S., Middleton, T. and Birch, C. (1998) "Stability of human immunodeficiency virus RNA in blood specimens as measured by a commercial PCR-based assay". J. Clin. Microbiol. 36, 493–498. And Winters, M.A., Tan, L.B., Katzenstein, D.A. and Merigan, T.C. (1993) "Biological variation and quality control of plasma human immunodeficiency virus type 1 RNA quantitation by reverse transcriptase polymerase chain reaction". J. Clin. Microbiol. 31, 2960–2966.

[23] Mitchell, B.L. et al, (2005) “Impact of Freeze-thaw Cycles and Storage Time on Plasma Samples Used in Mass Spectrometry Based Biomarker Discovery Projects” Cancer Informatics 98–104

[24] https://docs.google.com/spreadsheets/d/13UvBeoXAhwSHshSYoUDHwcxWiW7qYLnUb-eLwxJbCYs/pubhtml

[25] Farley M., et. Al., (2013) "Freezer Energy Consumption Report"

Sharing has benefits for all…

The problem:

Where freezers are individually owned and space is not shared this can lead to scenarios where a large ULT freezer may not be full of useful samples, and may have empty space, but this space is not made available to neighbouring scientists. The neighbouring scientists are then required to purchase and operate an additional ULT freezer - doubling the cold storage energy consumption.

This problem is facilitated by individual ownership of ULT freezers. Where individual freezer ownership is the model this can encourage those with small ULT storage needs to purchase a small under-bench ULT freezer. These types of ULT freezers have the highest energy consumption per volume of cold storage space, and can use almost as much energy as a unit twice their size (9kWh/day[26] for a new 100litre underbench unit, versus c.12-15kWh/day for a new 600-800 litre unit[27]).

The solution:

Sharing freezer space, combined with maintaining a good database of freezer contents and regularly throwing out redundant samples can lead to great cold storage space efficiencies, reducing the need to purchase additional ULT freezers, saving capital and operational costs as well as freeing up space within the lab making it a more pleasant space to work in.

Where the ULT freezers are owned by the institute and cold storage space allocated to lab groups on a needs-assessed basis (possibly involving re-charging) better sample storage and inventorying practices are encouraged and rewarded.

Under bench ULT freezers should be avoided and discouraged unless absolutely necessary, due to their high energy consumption per cold storage volume.

Medium and large institutions across the University of Edinburgh should be aiming to move towards a model where the institute provides the cold storage facilities to the scientists rather than having private ownership of individual ULTs.

Hotel/Spare freezers should be shared among multiple users (and set to a higher temperature, e.g. -60degreesC, when empty. Modern ULT freezers advertise that they can pull down from +20°C to -80°C in c.5hours. Pulling down from -60°C to -80°C would take substantially less time than this.)

Alternative technologies

The Problem:

Standard ULT freezer design expels heat into the room in which the freezers are located. This heats up the room putting a strain on the compressors of the ULT freezers and also adding load to building air conditioning and ventilation systems in an effort to maintain a stable room temperature.

[26] https://labcold.com/wp-content/uploads/2016/04/Labcold-ULT-FreezerLULT80100-1.pdf
[27] https://www.thermofisher.com/uk/en/home/life-science/lab-equipment/cold-storage/lab-freezers/ultra-low-temperature-freezers-minus-80.html

The Solution:

A new design of cold storage device exists, branded as 'Nordic'[28] and sold in the UK via LabMode. Nordic consists of terraces of highly insulated cabinets which are served with cooling from a compressor held in a different room/outside the building. The terracing of the cabinets leads to reduced heat gain as the ratio of internal volume to external surface is improved. The location of the compressor away from the temperature sensitive materials removes a degree of risk from cold storage. In addition, the insulated cabinets can be built within the room and configured to make best use of the room space and height, and thus there may be potential to increase the cold storage capacity of the room. Finally, energy savings advertised for this technology are very substantial at well over 50% - these are achieved by reducing or eliminating the need for air conditioning, and ensuring the compressor is situated in a well ventilated room without heat sources (unlike the situation with multiple freezer compressors within a standard ULT freezer facility). With multiple freezer-sized cabinets served by the same compressor there is the concern of impact of compressor failure – this is countered by the system having 2 separate compressors with 2 separate pipe-runs in order to insure against the failure of either system.

The Nordic system is quite expensive, and also requires a fairly expensive maintenance contract, and as such it was not found to make financial sense for a retrofit project (i.e. getting rid of the ULT freezers in an existing freezer facility and replacing them with Nordic). However, it may be a more attractive financial option when compared to the costs of setting up a new freezer facility from scratch (comparing against the cost of purchasing new ULT freezers).

[28] https://www.youtube.com/watch?v=USVCJdyVyYA

Appendix

Lab contacts who can help you with these projects:

Freezer replacement

Andrew Arnott, Department for Social Responsibility and Sustainability, andrew.arnott@ed.ac.uk

Brian McTeir, Roslin Institute, brian.mcteir@roslin.ed.ac.uk

Defrost and maintenance

Brian McTeir, Roslin Institute, brian.mcteir@roslin.ed.ac.uk

David Hills, Biology Teaching Organisation, david.hills@ed.ac.uk

Lee Murphy, Wellcome Trust Clinical Research Facility, Lee.Murphy@ed.ac.uk

Eliane Salvo-Chirnside, SynthSys labs, Eliane.Chirnside@ed.ac.uk

Stewart McKay, Institute of Genetic and Molecular Medicine, Stewart.McKay@igmm.ed.ac.uk

Efficient use of space

Carol Wollaston, Hugh Robson Building, C.Wollaston@ed.ac.uk

Lee Murphy, Wellcome Trust Clinical Research Facility, Lee.Murphy@ed.ac.uk

Stewart McKay, Institute of Genetic and Molecular Medicine, Stewart.McKay@igmm.ed.ac.uk

Jimi Wills, IGMM Mass Spec facility Jimi.Wills@ed.ac.uk

Eliane Salvo-Chirnside, SynthSys labs, Eliane.Chirnside@ed.ac.uk

Moira Nicol, QMRI, Moira.Nicol@ed.ac.uk

Steve McLean, QMRI, Steven.Mclean@ed.ac.uk

Heather Anderson, Chancellors' Building, Heather.Anderson@ed.ac.uk

Reducing the requirement for air con in freezer rooms

Brian McTeir, Roslin Institute, brian.mcteir@roslin.ed.ac.uk

Running freezers at higher temperatures (e.g. -70^{0}C)

Brian McTeir, Roslin Institute, brian.mcteir@roslin.ed.ac.uk

Stewart McKay, Institute of Genetic and Molecular Medicine, Stewart.McKay@igmm.ed.ac.uk

Useful links and resources

Impact of age, dust, ice, freezer temperature set point and size on energy consumption of freezers

Gumapas & Simons, World Review of Science, Technology and Sustainable Development, Vol 10, No.s 1/2/3, 2013 http://www.inderscience.com/info/inarticle.php?artid=50786

Impact of ventilation on freezer energy consumption

http://www.triplered.com/downloads/pdf/Sterling%20Freezer%20Efficiency%20paper.pdf

General energy consumption of freezers and impact of ambient air temperature

www.eventlink.org.uk/.../103-Arthur_Nicholas_-_Cold_Storage_at_the_University_of_Manchester

Pardise, A. et al., "Ultra-Low Temperature Freezes: Opening the door to energy savings in laboratories", Centre for Energy Efficient Laboratories

Freezer energy savings

http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/ulf_freezer_user_guide.pdf (U.S. Dept of Energy "Store Smart" ULT freezer guide)

Impacts of cold storage conditions on sample integrity

De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910

Mitchell, B.L. et al, (2005) “Impact of Freeze-thaw Cycles and Storage Time on Plasma Samples Used in Mass Spectrometry Based Biomarker Discovery Projects” Cancer Informatics 98–104

Colins et al, (1993), "Storage temperature and differing methods of sample preparation in the measurement of urinary albumin" Diabetologica, vol 36, issue 10, pp 993-997

Tedeschi, R. & De Paoli, P; (2011) "Collection and Preservation of Frozen Microorganisms"; Methods in Molecular Biology Volume 675, pp 313-326

Marino, D, (2013) "Best practices for storing biological samples in ULT freezers" http://www.biocompare.com/Bench-Tips/137747-Best-Practices-for-Storing-Biological-Samples-in-ULT-Freezers/

Wu, J et al., "Stability of Genomic DNA at Various Storage Conditions", International Society for Biological and Environmental Repositories (ISBER) 2009 Annual Meeting, Poster QAC 03