

UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

An Investigation into Sustainable Freezers

Sanaz Fotoohi

Scott Hazlett

David Pan

University of British Columbia

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The University of British Columbia
Applied Science 262
Section 201

Technology and Society II

Instructor
Dr Carla Paterson

An Investigation into Sustainable Freezers

by
Sanaz Fotoohi
Scott Hazlett
David Pan
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ABSTRACT

This report investigates available laboratory and industrial freezers on the market in the temperature range of moderate (-20°C) and ultra cold (-80°C) to provide UBC laboratories with greener and more sustainable products. UBC Sustainability Office has created a computer program called 'Virtual Green Lab' which provides lab users with prices and energy ratings of laboratory equipment. This report catalogues useful information on laboratory freezers that was obtained for this program. All freezers have been evaluated based on the triple bottom line assessment. Several manufacturers of freezers were contacted by phone and email. The price, dimensions, volume, as well as features of -20°C and -80°C freezers were tabulated. As well, any energy and material ratings achieved were included.

Since the market for ultra low temperature freezers is niche, and there are high performance requirements by customers for these freezers, it was found that there is not much emphasis on energy efficiency. Almost all of the companies contacted provided price quotes for their models but none provided nominal power ratings. Companies with the most environmentally friendly policies only go as far as satisfying government defined ratings such as UL/ULC, Energy Star, and ETL. The products of two companies were recommended as being the most sustainable for their achievement of additional energy and material ratings and for their manufacturer's practices.

The market for laboratory equipments is consumer driven. Oftentimes manufacturers customize their freezers to meet the unique requirements of their consumers. In order to motivate manufacturers to be more sustainable, it is recommended that the buyers specifically request for energy efficient freezers that achieve additional energy and material ratings from independent certification organizations.

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GLOSSARY

CO₂ / liquid N₂ Backup Systems:

refers to a backup cooling system of carbon-dioxide or liquid nitrogen that becomes active during power outages or freezer malfunctions. It is able to use the cold temperature of CO₂/liquid N₂ to maintain the cold temperature inside a freezer for a certain time. It is often offered as an optional feature by laboratory freezer companies, and it is a useful contingency system (ScienTemp, *Ultra cold, super-cold, moderate-cold freezers*, 2007).

Compressor:

A vital component in refrigerators and freezers. It is used to compress the refrigerant as part of the refrigeration process. Generally, of all the components in a freezer, the compressor uses the most energy. (Garfield, 2002)

Domestic Freezer:

A category of freezer used to store food, most often found in homes.

Laboratory Freezer:

A category of freezer used for storing materials for scientific processes.

Energy Star :

Created as a United States government program in 1992, the Energy Star is an international system for rating energy efficient consumer products. It has been adopted by many countries, including Canada, Japan, Australia and all countries in the European Union. Although there are different standards for different products, in general, products need to be 20% to 30% more efficient than US federal standards in order to be rated as an Energy Star. (Natural Resources Canada, n.d.)

Green:

Green, in the context of this report, refers to services, goods, practices, policies, regulations or laws that are made to be as sustainable as possible, and to have as little impact as possible on the environment.

Regular (Cold) Lab Freezers:

A category of laboratory freezer that operates in the 0 to -40 °C range.

Refrigerant:

A chemical used in refrigerators and freezers as well as air conditioners as part of the refrigeration process. The substances changes from liquid to gas and back during the process to draw heat from the environment. CFCs used to be utilized as a refrigerant until it was banned and replaced with HFCs. (Garfield, 2002)

Ultra Cold Lab Freezers:

A category of laboratory freezer that operates in the -40 to -90 °C range

Montreal Protocol:

An international treaty signed in 1987 designed to phase out substances that are harmful to the ozone layer. Well known for the gradual phase out and banning of CFC's which were commonly used as a refrigerant before the signing of the protocol. (Center for International Earth Science Information Network, 2003)

Warm-up Performance:

Warm-up performance, in context of the freezer industry, is the speed at which the interior of a freezer increases in temperature after power is pulled, and usually reflects on the quality of the insulation. The slower the speed, the better is the warm up performance. (C. Ours, personal communication, 2010)

Pull-down Performance:

Pull-down performance, in context of the freezer industry, is the speed at which the interior of the freezer decreases from room temperature to its desired temperature after power is applied to the freezer. (C. Ours, personal communication, 2010)

LIST OF ABBREVIATIONS

CE:

"CE stands for 'Conformité Européenne', meaning 'conforms to EC Directives'. This indicates that the product may be traded freely within the European Economic Area (EEA) because it meets the requirements of the EC directives. ... The CE mark on a product indicates that the manufacturer or the importer for the EEA has respected the requirements for safety, health and the environment. These requirements are set out in EC-directives." (CE Nordic marking, n.d.)

CFC:

"A chlorofluorocarbon (CFC) is an organic compound that contains carbon, chlorine, and fluorine, produced as a volatile derivative of methane and ethane. A common subclass is the hydrochlorofluorocarbons (HCFCs), which contain hydrogen, as well. The chlorine in these compounds can break off and go on to cause a chain reaction that severely damages the ozone layer." (National Aeronautics and Space Administration, n.d.)

IEC:

"The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes international standards for all electrical, electronic and related technologies. These serve as a basis for national standardization and as references when drafting international tenders and contracts." (International Electrotechnical Commission, 2008)

CEC:

The California Energy Commission established "California's Appliance Efficiency Regulations ... in 1976 in response to a legislative mandate to reduce California's energy consumption. The regulations are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods." (California Energy Commission, 2008)

ETL:

"ETL stands for Edison Testing Labs, a internationally recognized testing lab. Having a ETL label means that the product meets or exceeds various standards of organizations such as UL and CSA." (Edison Testing Laboratories, 2009)

ISPM 15:

"International Standard for Phytosanitary Measures on Wood Packaging (ISPM-15) is the international standard for heat treated and fumigated wood products. The ISPM-15 standard allows for two treatment options of wood products:

Heat Treatment (HT): Wood packaging material should be heated in a schedule that achieves a minimum core temperature of 56oC for a minimum of 30 minutes. The American Lumber Standards Committee (ALSC) administers the US certification program for heat treatment.

Methyl Bromide (MB) Fumigation: The wood packaging material should be fumigated with methyl bromide. The National Wooden Pallet and Container Association (NWPCA) has been tasked by the US Animal and Plant Health Inspection Service to administer the fumigation program." (Priority Worldwide Services, 2009)

kWh:

kWh stands for kilowatt hour and is a unit of energy equal to 3,600,000 joules. It is the amount energy a product rated at 1000 watts or 1 kilowatt uses in one hour.

P-IEC 60335-2-89 {Ed.1.2}:

"This is a standard issued by IEC which deals with the safety of commercial refrigerators with an incorporated compressor, or split systems supplied in two units for assembly together." (International Eletrotechnical Commission, 2008)

RoHS :

RoHS stands for the “restriction on the use of certain hazardous substances in electrical and electronic equipment”. It is a European Directive aiming to control the use of certain hazardous substances in the production of new electrical and electronic equipment (EEE). It is a partner directive to the WEEE Directive (Waste in Electrical and Electronic Equipment) that controls the disposal and recycling of EEE. In the UK the RoHS Directive is implemented through the RoHS Regulations (Statutory Instrument SI2008 No. 37). (National Measurement Office, n.d.)

SSC:

The Standards Council of Canada (SCC) facilitates the development and use of national and international standards and accreditation services to enhance Canada's competitiveness and social well-being. (Standards Council of Canada, n.d.)

UL / ULC:

"Underwriters Laboratories of Canada (ULC) is an independent, not-for-profit product safety organization with a long reputation as a Canadian leader in product safety standards development, testing, and certification. ... ULC publishes and maintains close to 300 Canadian safety standards and other related documents. These standards play an important part in improving public safety. ULC employs a consensus-based process of developing effective product safety standards, using input from consumers, manufacturers, government agencies, users, regulatory authorities and other interested parties." (Underwriter Laboratories, n.d.)

1.0 INTRODUCTION

In an effort to make UBC more sustainable, the UBC Health, Safety and Environment Group, the UBC Supply Management Team, and the UBC Sustainability Office are developing an interactive 3D tool called the “Virtual Green Lab.” The Virtual Green Lab does not allow the user to perform virtual experiments, but rather shows the user how to make their laboratory and its processes more sustainable and to reduce waste. The program assists UBC laboratories do their part to become more energy efficient. One focus of the Virtual Green Lab is on energy efficient laboratory equipment. This should provide the lab manager with information on price, energy and water efficiency, and triple bottom line evaluations on a variety of lab equipment. Providing lab managers with this information empowers them to make sustainable purchasing decisions that meet the lab requirements.

The main purpose of this project is to collect and present data for laboratory freezers at the specific temperatures of -20°C and -80°C . This report attempts to collect the data for price and energy usage as well as safety and usability features relevant to the triple bottom line criteria. The secondary purpose of the project is to inform the manufacturers of the demand for energy efficient freezers.

To facilitate this, we first searched for manufacturers of laboratory freezers, and then studied their websites for available products on the market. Interestingly, we found varying degrees of information that each company was comfortable in sharing on the internet. After the initial visits to these websites, we contacted each company by phone and email in order to obtain comprehensive information on their products, energy and material ratings, and sustainable practices.

2.0 FREEZERS

Similar to regular, domestic freezers, laboratory freezers utilize a vaporized refrigerant. Currently, the most common is HFC or hydrofluorocarbons which replaced the banned CFCs or chlorofluorocarbons of past that were found to damage the ozone layer. The refrigerant starts off in its vapour state and enters a compressor which compresses the gas into a hot liquid. It loses some heat during the process in the condenser tubes while remaining a liquid. The liquid refrigerant then enters the evaporator coils. In the evaporator coils the pressure of the liquid decreases allowing it to suddenly turn into gas. As the refrigerant evaporates, it absorbs a large amount of heat, and allows a freezer to maintain its cold temperature. (Garfield, 2002)

On the other hand, laboratory freezers are designed with very different requirements than regular freezers and are more specific. Laboratory freezers come in a variety of temperatures that are way lower than those of domestic freezers. Temperatures range from moderate (-20°C) to ultra cold (down to -86°C) and even cryogenic temperatures (below -150°C). To accommodate for products that may be temperature sensitive, the freezer allows the operator to set a specific temperature which the freezer maintains closely. (ScienTemp Corporation, 2007).

Depending on the model, the freezer may also have warning or alarm systems as well as CO₂/N₂ back up systems to alert the user of unexpected changes to temperature and provide a contingency cooling system. These changes might be due to power outages or malfunctions. Freezers can be fitted with locks for security. As well, they can be built to be explosion proof. (ScienTemp Corporation, 2010)

Ultra low temperature freezers come in several styles such as: Upright, Chest, Undercounter, Plasma, Blood bank, etc. This report focuses on the two most acceptable types for our purposes: Upright and Chest.

3.0 TRIPLE BOTTOM LINE EVALUATION

The Triple Bottom Line Assessment espouses the evaluation of design decision and policies along not just a cost analysis but also along a social and environmental analysis. We will be applying this evaluation in our investigation.

3.1 SOCIAL FACTOR

We will investigate the social cost of freezers from the standpoint of the operators using the finished product as well as the workers who are involved in the manufacturing process. In addition to this safety wellness evaluation, we will also look at form factors of the product which have an effect on the behaviour of operators.

3.2 ECONOMIC FACTOR

Economic factors greatly influence the purchase decisions for freezers. Unlike many lab equipments which are turned on during experiments, freezers are on 24 hours a day, 365 days a year and are turned off for maintenance checks. Consequently, freezers have a high potential for energy savings compared to the equipment that draw similar amount of power.

3.3 ENVIRONMENTAL FACTOR

There are several environmental factors to consider with freezers.

3.3.1 COMMONALITIES

Most freezers are environmentally safe, and have high density, non-settling urethane foam. For example, by law, the refrigerant line must use CFC-free, non-toxic, non-combustible, non-ozone depleting refrigerant.

There are also ratings issued from standards associations that promote safety and environmental practices such as UL & ULC ratings, Provincial Energy Commission's Efficiency Division, Energy Star Rating, ETL, etc. We will be interested to see how far each manufacturer goes in certifying their freezers.

3.3.2 PACKAGING

While it is important not to overlook packaging in the environmental impact of a product, we feel freezers may deserve some leeway. After all, if this heavy and expensive product is damaged en route, than the increased shipping for a replacement may easily offset the benefits of skimping on packaging.

3.3.3 CARBON FOOTPRINT

The transport of the freezer can contribute a significant amount of carbon dioxide to when compared to the amount contributed by its operation. For example, a freezer running at s ballpark figure of 20 kWh/day for 365 days a year for 10 years will use about 73000 kWh of electricity. In British Columbia, this amount contributes a carbon footprint of 1.46 metric tons of carbon dioxide into the environment, which is extremely low, when compared to Alberta, at 71.93 metric tons and Ontario, at 21.68 metric tons (Carbon Footprint, n.d.). In comparison, delivering the freezer by air from Beijing, China to Vancouver contributes at least 0.72 metric tons, and New York to Vancouver contributes at least 0.36 metric tons. Therefore, assuming that the freezer is to be use in British Columbia, a significant portion of the carbon footprint can be removed by ordering freezers from a closer location. The location of each company is listed in the appendix, and we recommend taking the location into consideration when choosing a freezer.

3.3.4 TOXIC SUBSTANCES

Toxic substance can leach into the environment if not carefully prevented. In an effort to reduce the leeching of toxic substances into the environment, several ratings have been recreated that apply to different geographic regions. Some of these ratings are a requirement by law, while others are from independent standards organizations. We will be interested in seeing how this industry self-regulates by earning these optional ratings.

4.0 INVESTIGATION OF MANUFACTURERS

We contacted all freezer manufacturers in North America that manufactured distributed freezers in the -20°C and -80°C category, and investigated their business practices with an emphasis on their sustainable policies.

4.1 SCIENTEMP

ScienTemp states that they design -20°C and -80°C freezers that have "comfortable, low profile designs" (ie chest freezers). Visual and audible temperature alarms, CFC-free, non toxic refrigerants, and "environmentally friendly" insulation comes standard with each of their freezers. Their freezers are made in the USA and meet UL, ULC and CE standards and "meet many international standards for safety and performance". (ScienTemp Corporation, 2007).

A variety of extra features can be added to their freezers, such as freezer racks, temperature recorder, CO2/liquid N2 backup systems, observation windows, and explosion proofing. Their philosophy emphasizes "single-minded customer service"(ScienTemp Corporation, 2010) that thrives to meet the individual needs of each customers. We feel that this is important, especially for the laboratory freezer market, as each laboratory has their unique requirements.

However it is interesting to note that while their customer service was friendly and replied to inquiries about prices very quickly, we did not receive a reply to several inquires about the energy ratings of their products. It is not known whether this was a result of a communication error or done on purpose. Table 1: Model Chart for ScienTemp Moderately Cold Freezers Table 1 and Table 2 below list their freezer models, and Figure 1 depicts several models. Contact information for ScienTemp can be found in APPENDIX A: CONTACT INFORMATION.

Table 1: Model Chart for ScienTemp Moderately Cold Freezers

Model	Min.Temp (°C)	Capacity (L)	Height (cm)	Length (cm)	Width (cm)	Price	Energy Rating
-------	------------------	--------------	----------------	----------------	---------------	-------	------------------

34-05	-34	142	89	71	61	\$1095.00	D/P
34-07	-34	198	89	88	61	\$1208.00	D/P
34-09	-34	249	89	104	61	\$1311.00	D/P
34-15	-34	433	89	122	76	\$1974.00	D/P
34-20	-34	575	89	157	76	\$2232.00	D/P
34-25	-34	705	89	188	76	\$2515.00	D/P

D/P: Declined to provide

(ScienTemp Corporation, 2010), (ScienTemp Corporation, personal communication, 2010)

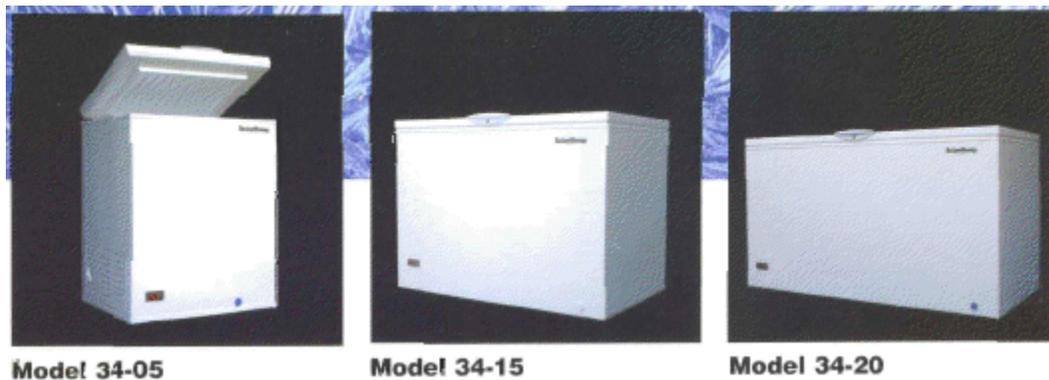


Figure 1: ScienTemp Models (from left to right) 34-05, 34-15, and 34-20

Table 2: Model Chart for ScienTemp Ultra Cold Freezers

Model	Min.Temp (°C)	Capacity (L)	Height (cm)	Length (cm)	Width (cm)	Price	Energy Rating
86-01	-86	28	74	51	55	\$3972.00	D/P
85-1.7	-85	48	91	76	61	\$4127.00	D/P
85-3.1	-85	88	94	104	61	\$4704.00	D/P
85-6.8	-85	193	104	152	71	\$5429.00	D/P
80-9.4	-80	266	104	152	71	\$5829.00	D/P
80-12	-80	340	124	152	71	\$6660.00	D/P
80-21	-80	609	114	213	81	\$9253.00	D/P

D/P: Declined to provide

(ScienTemp Corporation, 2010), (ScienTemp Corporation, personal communication, 2010)



(a)



(b)

Figure 2: ScienTemp (a) 80-9.4, and (b) 85-1.7

4.2 FREEZER CONCEPTS

When we spoke with Freezer Concepts asking about their approach to sustainable design, they referred to the fact that they meet EPA guidelines for safe manufacturing as well as operation of their products (A. Vango, personal communication, 2010). They noted that although none of their products have achieved any additional energy or materials ratings, they nevertheless are very cognizant of the possible exposure of harmful substances and thus are confident in the safety of their products.

They pointed out that they meet the Montreal Protocol of banning the use of CFC and HCFC in their refrigerant. In addition, they feel that they do not need to advertise their environmentally-friendly designs because they meet very clean, medical standards and are thus virtually free of toxic or harmful products.

When asked about recycling services, they replied they have none and pointed out that there is the inescapable issue of bio hazard and non-popularity of second hand freezers. He also said that they only use virgin steel in their products.

Table 3 at below is a quotes list obtained from Freezer Concepts for their Upright and

Chest. Their contact information can be found in APPENDIX A: CONTACT INFORMATION.

Table 3: Price Quotes for -20°C and -80°C Freezers from Freezer Concepts in US Dollars

MODEL NO. Price	CU. FT /LITERS	TEMPERATURE RANGE	INTERIOR DIMENSIONS, INCHES, (CM) W x F- B x H	EXTERIOR DIMENSIONS, INCHES (CM) W x F-B x H
CHEST, UPRIGHT				
U85-13 \$6450.00	13-370	-40°C to -85°C	20" x 22" x 51-1/4" (50.8 x 55.9 x 130)	35" x 33" x 79" (88.9 x 90.2 x 200.7)
U85-18 \$6975.00	18-505	-40°C to -85°C	23" x 26" x 51-1/4" (58.4 x 66.1 x 130)	36" x 35-1/2" x 79" (91.4 x 90.2 x 200.7)
U85-22 \$7600.00	22-626	-40°C to -85°C	28-1/2" x 26" x 51-1/4" (72.4 x 66.1 x 130)	41-1/2" x 35-1/2" x 79" (105 x 90.2 x 200.7)
U85-25 \$8495.00	25-710	-40°C to -85°C	34" x 25" x 51-1/4" (86.4 x 63.5 x 130)	49" x 35-1/2" x 79" (124.5 x 90.2 x 200.7)
U80-30 \$9650.00	30-843	-40°C to -80°C	42" x 25" x 49" (106.7 x 63.5 x 124.5)	62" x 35-1/2" x 79" (157.5 x 90.2 x 200.7)
CHEST, HORIZONTAL				
C85-3 \$5530.00	3-83	-40°C to -85°C	24" x 12" x 18" (60.9 x 30.5 x 45.7)	34" x 27" x 47" (86.4 x 68.6 x 119.4)
C85-5 \$5750.00	5-142	-40°C to -85°C	30" x 18" x 16" (76.2 x 45.7 x 40.6)	40" x 35" x 46" (101.6 x 88.9 x 116.8)
C85-9 \$5985.00	9-255	-40°C to -85°C	47" x 16" x 20" (119.4 x 40.6 x 50.8)	57" x 33" x 46" (144.8 x 83.8 x 116.8)
C85-12 \$625500	12-340	-40°C to -85°C	55" x 19" x 20" (139.7 x 48.3 x 50.8)	65" x 35" x 46" (165.1 x 88.9 x 116.8)
C85-14 \$6425.00	14-400	-40°C to -85°C	61" x 20" x 20" (154.9 x 50.8 x 50.8)	71" x 35" x 46" (180.3 x 88.9 x 116.8)
C85-17 \$6975.00	17-480	-40°C to -85°C	69" x 20" x 21" (175.3 x 50.8 x 53.3)	79" x 35-1/2" x 48" (200.7 x 90.2 x 121.9)
C85-22 \$8680.00	22-626	-40°C to -85°C	67" x 19" x 30" (170.2 x 48.3 x 76.2)	95-1/2" x 35-1/2" x 44" (242.6 x 90.2 x 111.8)
C80-27 \$9125.00	27-766	-40°C to -80°C	67" x 23" x 31" (170.2 x 57.2 x 78.7)	95-1/2" x 35-1/2" x 44" (242.6 x 90.2 x 111.88)

(A. Vango, personal communication, 2010)



(a)



(b)



(c)



(d)

Figure 3: Freezer Concepts (a) C85-12, (b) C85-22, (c) U80-30, and (d) U80-15

We found that their freezers employ a timed evaporator flushing cycle and a sequenced compressor startup which minimizes energy consumption (Freezer Concepts, *Ultra low temperature freezers*, 2010). As well, they all have a washable intake filter which is easily removed and keeps the freezer condenser free of dust and dirt. Lastly, they all are equipped with an enhanced sound insulation system to minimize noise and vibration. We felt that these last two features offered a better working environment for operators, and the first feature is both a economic and environmental bonus in reducing its energy footprint.

These freezers also have several standard security and alarm features.

4.3 INDUSTRIAL FREEZERS

IDS has been known for many years as a leading supplier of industrial equipment such as *IDS Brand Freezers*, suitable for a variety of industrial, medical, scientific and commercial applications. IDS products include chest, Upright, under counter freezers at three different temperatures of moderate(-20°C), super(-40°C), and ultra(-85°C) (Industrial Freezers, 2010).

Industrial Freezers is a division of IDS. Its products have ratings such as Energy Star, CEC, and UL&ULC. It has high percentages of recycled steel and aluminum in the freezers. Industrial Freezers uses Aluminum that is made with at least 80% recycled material, Stainless steel that is made with at least 67% recycled material, and Galvanized steel that is made with at least 30% recycled material. They use Environmentally Responsible Packing Materials such as Wood Products – crating, International shipments section uses ISPM15 standard wood products, the Pallet vendors of the company use recycled materials and Chipboard. (Industrial Freezers. *Approval and Certs.* 2010). Industrial Freezers offer a variety of accessories with the freezers and deliver a wide network of support, they offer free consultation with one of their service technicians, and warrant their products for eighteen months.

We have tabulated the prices, features, temperatures, volumes, and part numbers for Chest and Upright Freezers. Table 44, Table 55, Table 6, and Table 67 below summarizes the quotes for Freezers from Industrial Freezers. Figure 4 and Figure 55 depicts their chest and upright freezers.

Table 4: Industrial Freezers Moderate Cold Chest Freezers

Part #	Volume	Operating Voltage	Temperature	Features	Price
2001012	5 CF	115 V	-34C	controller, key lock, casters, alarm	\$ 995.00
2001013	5 CF	230V	-34C	key lock and digital	\$ 995.00

				controller	
2001014	7 CF	115 V	-34C	key lock and digital controller	\$1,195.00
2001015	7 CF	230V	-34C	key lock and digital controller	\$1,195.00
2001016	9 CF	115 V	-34C	key lock and digital controller	\$1,295.00
2001017	9 CF	230V	-34C	key lock and digital controller	\$1,295.00
2001018	15 CF	115 V	-34C	key lock and digital controller	\$1,895.00
2001019	15 CF	230V	-34C	key lock and digital controller	\$1,895.00
2001020	20 CF	115 V	-34C	key lock and digital controller	\$2,195.00
2001021	20 CF	230V	-34C	key lock and digital controller	\$2,195.00
2001022	25 CF	115V	-34C	key lock and digital controller	\$2,495.00

Features

- Thin-wall design
- Urethane foam insulation
- Rugged steel construction
- Baked enamel with textured finish outside
- Magnetic gasket, compartment drain
- Counter-balanced, insulated outer lid.

(Industrial Freezers. *Moderate cold chest freezers*. 2010.), (B. Donohue. 2010. Personal Communication)

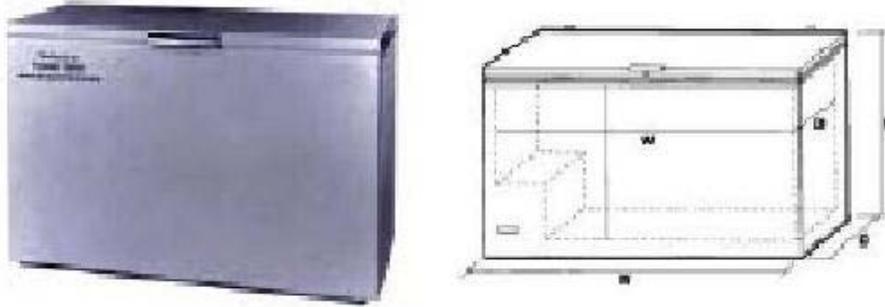


Figure 4: Industrial Freezers Moderate Cold Chest Freezers

Table 5: Industrial Freezers Ultra Cold Chest Freezers

Part #	Volume	Operating Voltage	Temperature	Features	Price
2003006	1.7 CF	115 V	-85C	controller, key lock, casters, alarm	\$4,095.00
2003007	1.7 CF	230V	-85C	controller, key lock, casters, alarm	\$4,095.00
2003008	3.1 CF	115 V	-85C	controller, key lock, casters, alarm	\$4,695.00
2003009	3.1 CF	230V	-85C	controller, key lock, casters, alarm	\$4,695.00
2003010	6.8 CF	115 V	-85C	controller, key lock, casters, alarm	\$5,395.00
2003011	6.8 CF	230V	-85C	controller, key lock, casters, alarm	\$5,395.00
2003000	9.4 CF	115 V	-80C	controller, key lock, casters, alarm	\$5,795.00
2003001	9.4 CF	230V	-80C	controller, key lock, casters, alarm	\$5,795.00
2003002	12 CF	115 V	-80C	controller, key lock, casters, alarm	\$6,595.00
2003003	12 CF	230V	-80C	controller, key	\$6,595.00

				lock, casters, alarm	
2003004	21 CF	230V	-80C	controller, key lock, casters, alarm	\$9,195.00

Ultra Cold (-50 to -86C) Chest Freezers for Industrial use to -86C are Cascade Systems rated for -50C to -86C which include digital controller, alarm and casters are standard on all models. The compact design and tabletop height of the lid make it a perfect choice for any room with close quarters (Industrial Freezers. *Ultracold chest freezers*. 2010.), (B. Donohue. Personal Communication. 2010).

UltraCold Chest Freezers Features

- Whisper quiet
- Available for a wide variety of applications
- Economical operation in laboratory, hospital or industry
- Convenient counter-top height

Table 6: Industrial Freezers Moderate Temperature Upright Freezers

Part #	temperature	Volume	Price
LTF1S22-40	- 40°C	22 CF	\$7,495.00
LTF1S21-30	- 30°C	24 CF	\$6,795.00
LTF2S48-30	- 30°C	48 CF	\$9,795

Standard Moderate to Low Temp Freezer (-30°C on average) features include digital LED Microprocessor control with Hi/Lo visual alarm, adjustable control range from -20°C to -30°C. Factory preset at -30°C. Exterior is white baked on enamel, top and bottoms are galvanized steel, interior liner and interior door panel are painted white. Cabinet and doors are foamed-in-place with CFC Free high density polyurethane Foam insulation. Heavy duty pivot hinges, centered key door locks, full length stainless steel pull handles, four casters (2 locking). 3 epoxy coated wire shelves per door. Refrigerant flow is controlled by a thermostatic expansion valve increasing the ability of the freezer to meet varying load conditions. Air-cooled condensing unit, automatic defrost (Industrial

Freezers. *Moderate cold upright freezers*. 2010), (B. Donohue. Personal Communication. 2010).

Table 7: Ultra Cold Upright Freezers

Part #	Volume	Temperature	Features	Price
2003106	14CF	Ultra Cold(-85)	control, heavy duty casters, alarm	*
2003107	18CF	Ultra Cold(-85)	control, heavy duty casters, alarm	*
2003108	22CF	Ultra Cold(-85)	control, heavy duty casters, alarm	*
2003109	25CF	Ultra Cold(-85)	control, heavy duty casters, alarm	*

*Price available upon request from the company.

IDS Ultra Cold Uprights were designed and constructed for biological product storage. They are equipped with heavy duty hermetically sealed compressors and gravity flow refrigerator cooling systems to maintain vital operating temperatures of -50C to - 86C within a one degree range. These low-cost, extra-duty Ultra Cold industrial freezers feature rugged construction and easy to use and maintain components.(Industrial Freezers. *Ultra cold upright freezers*. 2010), (B. Donohue. Personal Communication. 2010).



Figure 5: Industrial Freezers Ultracold Upright Freezer

4.4 SO-LOW

We discovered that So-Low sells the same model of freezers as does Freezer Concepts. Interestingly, they appeared to have a similar approach to sustainable design in their omission of any such design.

When asked about their achievements of energy standards for their freezers, they replied that there were no such standards in existence, for both -80°C as well as -20°C markets (J. Schum, personal communication, 2010). Meanwhile, in terms of recycling, they use only virgin steel and offer no recycling services to their customers.

When asked about their website claim of energy-efficient freezers and upon which benchmark they evaluated themselves, they replied that they have no internal data on nominal energy consumption. We were told that the major source of power consumption in their products is the compressor, and that the freezer market is a relatively niche market for compressor manufacturers who have billions of dollars in sales from other markets. Thus, freezer manufacturers like themselves do not have any leverage in asking for energy-efficient designs, and are at the mercy of these compressor designs.

We agree that a freezer manufacturer is at the mercy of the performance of the parts they choose to employ. However, we also feel that they are responsible at the very least to benchmark their products' energy consumption, or else they have an unverifiable basis for claiming energy-efficiency.

Table 8, Table 9, Table 10, and Table 11 at below are tabulations by us of the list of quotes obtained from So-Low for their Upright, Chest, and laboratory freezers (J. Schum, personal communication, 2010). Figure 6 has a sample of their chest type freezers. Their contact information can be found in APPENDIX A: CONTACT INFORMATION.

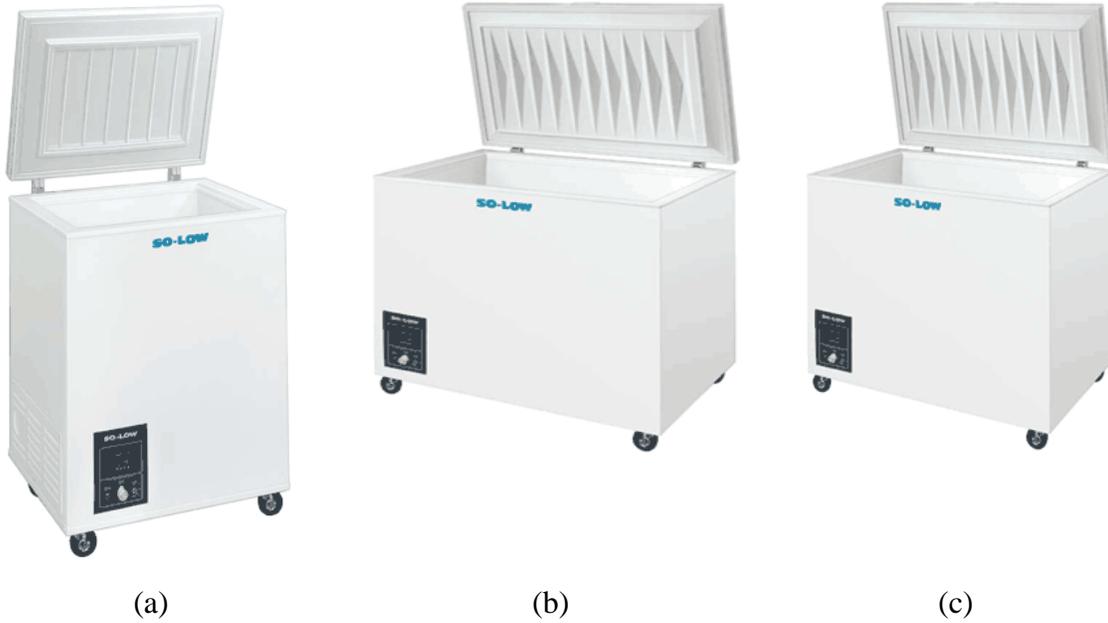


Figure 6: So-Low Chest Style Freezer to -25°C (a) CH25-5, (b) CH25-13, and (c) CH25-9

Table 8: So-Low Upright Freezers to -85°C List of Price (US Dollars), Features, and Available Configurations

MODEL	Upright U85-13	13 Cubic Ft. (370)	-40°C to -85°C	35" x 33" x 70"	20" x 22" x 54"	6095	1095	195	75	85		95
Volume	Upright U85-18	22 Cubic Ft. (626 liters)	-40°C to -85°C	36" x 35.5" x 70"	23" x 26" x 51"	6395	1095	195		80		95
Temperature	Upright U85-22	22 Cubic Ft. (626 liters)	-40°C to -85°C	41" x 35.5" x 70"	28.5" x 26" x 51"	6895	1095	195		80		95
Exterior	Upright U85-25	25 Cubic Ft. (710 liters)	-40°C to -85°C	49" x 35.5" x 70"	34" x 25" x 51"	7895	1095	195		80		95
Interior												
Freezer												
Chart Recorder												
Voltage Safety System*												
17-9-3Rack												
17-12-2 Rack												
23-12-3 Rack												
23-16-2 Rack												
Cryo Gloves												

*Required for 208V system

Table 9: So-Low Laboratory Freezers to -20°C Price and Feature List

MODEL	Laboratory DHW20-20MDP	Laboratory DHW20-30MDP
Volume	19.7 cubic ft. / 558 liters	19.7 cubic ft. / 558 liters
Temperature	0°C to -20°C	0°C to -20°C
Exterior	33" x 27.5" x 76.5"	35" x 32" x 79"
Interior	28" x 16.25" x 56"	32" x 26" x 65"
Freezer	2595	3695
Chart Recorder	1095	1095
Optional Casters	325	

Table 10: So-Low Chest Freezer to -85°C List of Price (US Dollars), Features, and Available Configurations

MODEL	Chest C85-3	Chest C85-5	Chest C85-12	Chest C85-17	Chest C85-22
Volume	3 Cubic Ft. / 83 liters	5 Cubic Ft. (142 liters)	12 Cubic Ft. (340 liters)	17 Cubic Ft. (480 liters)	22 Cubic Ft. (626 liters)
Temperature	-40°C to -5°C	-40°C to -85°C	-40°C to -85°C	-40°C to -85°C	-40°C to -85°C
Exterior	34" x 27" x 47"	40" x 35" x 46"	65" x 35" x 46"	79" x 35.5" x 48"	95.5" x 35.5" x 44"
Interior	24" x 12" x 18"	30" x 18" x 16"	55" x 19" x 20"	69" x 20" x 21"	67" x 19" x 30"
Freezer	4695	4895	5495	6395	7995
Chart Recorder					
Voltage Safety System*			195	195	195
16-5-3 Rack	45	45			
16-7-2 Rack	50	50			
16-6-3 Rack			50	50	
19-9-2 Rack			60	60	
29-9-3 Rack					70
29-13-2 Rack					80
Cryo Gloves	95	95	95	95	95

*Required for 208V system

Table 11: So-Low Chest Freezer to -25° C List of Price (US Dollars) and Features

MODEL	Chest CH25-5	Chest CH25-9	Chest CH25-13
Volume	5 Cubic Ft. (142 liters)	9 cubic ft. / 255 liters	13 Cubic Ft. (370 liters)
Temperature	0°C to -25°C	0°C to -25°C	0°C to -25°C
Exterior	27.5" x 24.5" x 38.5"	42" x 24.5" x 38.5"	43" x 31" x 38.5"
Interior	22" x 16.5" x 28.5"	36" x 16.5" x 28.5"	37.5" x 22" x 28.5"
Freezer	1695	1895	1395
Chart Recorder	1095	1095	1095

4.5 THERMO-FISHER SCIENTIFIC

This company supplies a very wide range of laboratory-related equipment, and markets their products according to basic, premium, and elite configurations. When we spoke to their freezer division (C. Ours, personal communication), we asked them about their opinion of other freezer companies claiming to be green, to which they opined that being green was increasingly becoming a marketing buzzword.

They further opined that there is not much difference in the power performance of -80°C freezers between companies because of physical constraints of operating at that extreme temperature. That explains, they surmised, why there is a dearth of green ratings applicable to the -80°C market. However, they did inform us that they have significant demand for green products in the -20°C market.

Although Thermo-Fisher Scientific was only able to provide a nominal power rating for their largest upright and largest chest freezers in the -80°C category, they were nevertheless the only company able to provide any concrete numbers on nominal lower consumption. They cited their a power rating of 22.7kWh per day for their 25 cu.ft upright model and 19.2kWh per day for their 20 cu.ft chest model. We while trusted

their values over the phone, we were pleased to confirm these values from detailed performance documents that we subsequently received from them.

Despite their mention of the lack of ratings in the -80°C market, we found that both their -80°C and -20°C freezers all meet this list of ratings (C. Ours, personal communication, 2010):

- UL/ULC
- CE
- P-IEC 60335-2-89

In addition, we were informed that their -20°C freezers also achieved Energy Star rating.

While we appreciated time spent with two of their representatives over the phone and via email over several occasions, as well as receiving detailed performance documents and product pamphlets, we unfortunately did not eventually receive any quotes from them in time for this report. We should note that one of their representatives contacted us to reiterate that they have a large line of laboratory equipment that has an emphasis on green design.



Figure 7: Thermo-Fisher (a) Revco Elite PLUS -86°C Upright Freezers, and (b) Ultra-Low Temperature Chest Freezers

The contact information for Thermo-Fisher can be found in APPENDIX A: CONTACT INFORMATION.

5.0 DISCUSSION

Through the course of research for this project, we discovered patterns and concepts that we felt deserved special mention.

5.1 GREEN DESIGNS FOLLOW GREEN DEMAND

We deduced that the freezer market is a highly-consumer driven market. On the one hand, we learned from our interviews with freezer manufacturers that the -20°C freezer market sees high interest for green designs. This they say, in combination with this market's high volume, is good reason for why many freezers in this market meet green ratings as well as strive for environmentally-sustainable practices (C. Ours, personal communication, 2010), (A, Vango, personal communication, 2010).

On the other hand, freezer manufacturers note that -80°C freezers operate at relatively extreme temperatures, and have strict performance demands from customers, and thus there is little or no incentive to prioritize sustainable designs (J. Schum, personal communication, 2010). Our conclusion is that the -80°C market completely ignores sustainable designs except where economically attractive. That is, a product would usually only opt for a green design if that design happened to be a side-effect of lowering the product's cost.

Tellingly, we found it much more difficult to find information relating to energy use of the freezers in the industrial market than the residential market, and we concluded that this reflects the lack of interest in efficiency in the laboratory freezer market. Woolliams research reinforces this when she concluded that there is more confusion in the laboratory freezer market than the domestic freezer market in regards to "applications and interpretations of current lab guidelines, codes and standards, particularly addressing sustainable performance" (2005).

5.2 INDUSTRY'S GREEN SOPHISTRY

While it is good for the environment that each company meets the Montreal Protocol (Center for International Earth Science Information Network, 2003) of banning certain refrigerants from their products, we realize that this is a requirement of doing business. It

is safe to say that for all the freezers we researched, they all met regulations and standards required by law. (ScienTemp Corporation, *Ultra cold, super-cold, moderate-cold freezers*, n.d.), (Freezer Concepts, *Freezer Concepts*, n.d.), (So-Low Environmental Equipment Co., *Ultra Low Freezers*, 2010). Thus, the argument that being CFC- and HCFC-free is being green is misleading, and actually obfuscates the reality of whether a company is green or not.

We feel that a green manufacturer is one who either through sheer technological ingenuity uses a technology that is inherently cleaner for the environment, or uses a comparable technology as to their competitors' but is willing to make design decisions that their competitors are not willing to make that are sustainable at the sacrifice of another aspect of their product.

For example, a typical compromise would be to choose a more expensive insulation for their design despite not being legally required to do so but rather because there may be controversial health issues with the cheaper insulation. Another typical compromise would be to lower the "pull-up" and "pull-down" performance of their freezers so as to be able to use less power-hungry compressors in their design, thereby reducing their energy footprint (C. Ours, personal communication, 2010).

Of the companies that we contacted, none were able to make either of the above claims. Rather they all merely abided to government regulations of allowable insulation, and designed their freezers to have a steep "pull-down" time and shallow "pull-up" time. This is not an indictment against any manufacturer, rather it is just to clarify what justifies earning a green label.

For comparison, in the building industry, to be a "green" designer requires making many costly provisions and compromises.

While the argument of some manufacturers that they designed for clean, medical standards generated confidence in the sterility of their products, we do not feel that this in any way addresses the issue of whether the freezer was made in a sustainable way. In

fact, a Cynist may even reason that to create this sterile environment the manufacturer could easily choose to use a potentially more hazardous material or process as a means for an easier or cheaper route to achieve these extreme standards. However, despite the obvious, we commonly heard this argument when a manufacturer was asked if they thought of themselves as a green manufacturer.

Indeed, none of the manufacturers contacted volunteered information into the manufacturing process of their freezers, other than that they adhered to government regulations for workplace safety.

5.3 NON-RECYCLING OF FREEZERS

None of the manufacturers contacted had any form of recycling program in effect for their finished products. Once a manufacturer has shipped a freezer, they offer some services in the form of preventative maintenance or repair, but no services with regard to recycling or reusing the freezer even if that customer is seeking to upgrade their existing freezer with a newer model.

We are concerned because this leaves accountability for the responsible disposal of freezers in the hands of the consumers, whom have less incentive to be responsible when that entails more cost to them. In addition, we feel that there are likely many reusable parts of a failed freezer that should be salvaged, if not as raw materials, then as complete components.

While we feel the reuse of functional components would be ideal, we doubt that there is a serious market demand for refurbished freezers in the -80°C market.

5.4 WHERE IS THE GREEN FREEZER?

So who do we feel among those contacted deserves to be considered as a green company? We found that there is not much design to be sustainable. However, some manufactures deserve being mentioned as being "greener" than others.

Thermo-Fisher Scientific has a webpage dedicated to their company's green initiatives, which includes using recycled corrugated cardboard in their full-paper packaging (Fisher

Scientific, *Because we all play a part*, 2010). As well, they have a "Think Green" publication (Fisher Scientific, *Think green*, 2010) which demonstrates at the very least that they have spent considerable effort in evaluating the full life cycle analysis of their products. In addition, they have achieved additional energy and material ratings voluntarily.

As mentioned above, Industrial Freezers uses 30-80% recycled steel, which is about 90% of the material that goes into their freezers (Industrial Freezers, *Approvals and Certs*, 2010). Some of the other manufacturers mentioned that they recycled excess steel in their production, but none of them used anything but virgin steel. We recognize that steel loses a lot of its properties the more that recycled steel is introduced to it, and so we commend Industrial Freezers for designing to accommodate for this. This manufacturer also achieved additional energy and materials ratings voluntarily.

Table 12 below summarizes the green features from each manufacturer contacted.

Table 12: Summary of Freezer Manufacturers and "Green" Features

Manufacturer	Green Features
Labrepc	CFC free insulation
Industrial Freezers	Energy Star rated, California Energy Commission Compliant, UL&ULC, CFC free high density insulation, Urethane foam insulation
So-Low	ETL certified, CFC & HCFC free refrigerants
Freezer Concepts	CFC free insulation
ScienTemp	CFC free insulation, non-toxic refrigerant, UL & ULC, CE standards
Thermo Fisher	UL, CE, P-IEC 60335-2-89 {Ed.1.2}

5.5 CHOOSE APPROPRIATELY SIZED FREEZER

Although there are differences in price and energy efficiency for different suppliers, the largest difference in price and energy ratings occurs between freezers of different sizes. (ScienTemp Corporation, personal communication, 2010) The most important action a lab operator can take to save money in energy usage of the freezer over its lifetime is purchasing the correct size for the laboratory. Buying a freezer of the appropriate size will not only save money due to its lower energy use, but also purchase price is cheaper

as well. However, due to lower energy costs in British Columbia, the price of energy savings by purchasing a more energy efficient freezer or a smaller freezer will not be as significant as provinces with higher energy prices.

6.0 CONCLUSION

Our group was able to compile information on price, geometry, and features for a variety of freezers from several manufacturers of laboratory freezers for the Virtual Green Lab. We were not able to collect any meaningful data in terms of energy use. The companies we contacted either did not have information regarding energy use, or declined to provide it only to say they meet all required environmental and energy regulations.

Through our research of the -20°C and -80°C laboratory freezer market we discovered that there is limited interest for energy efficient and sustainable freezers from both the manufacturers and consumers.

The laboratory freezer market is a very consumer driven market. Each laboratory has their own unique requirements, and the freezer manufacturers have to work with consumers to meet these individual needs to remain competitive. The scarcity of information on energy usage of freezers and a lack of “environmental responsibility” from manufacturers proves the lack of consumer demand.

We recommend that to motivate the laboratory freezer market towards energy efficient and sustainable practices and designs, it is vital that the buyers of these freezers expressively demand energy efficient freezers. We believe that by doing so, a market for energy efficient freezers is created, and there would be an incentive for the manufacturers to produce greener products. We also recommend that each laboratory manager put more emphasis on the triple bottom line criteria we listed when making purchasing decisions for new freezers.

APPENDIX A: CONTACT INFORMATION



Scientemp Corporation

3565 S. Adrian Highway

Adrian, MI 49221 U.S.A.

1-800-968-2653

Ph: 1-517-263-6020 Fax: 1-517-263-5492

<http://www.scientemp.com>

Freezer Concepts

Freezer Concepts

P.O. Box 863

Southbury, CT 06488 U.S.A.

Phone: 203-405-1455 Phone 203-405-1455

Fax 203-262-8714

email: info@freezer-concepts.com

www.freezer-concepts.com



Industrial Freezers

5311 Derry Ave

Building D

Agoura Hills CA 91301 U.S.A.

818-597-4300

<http://www.freezerlink.com/>

SO-LOW

So-Low Environmental Equipment Co., Inc.

10310 Spartan Drive

Cincinnati, Ohio 45215-1279 U.S.A.

513-772-9410 / Fax: 513-772-0570

<http://www.so-low.com>

sales@so-low.com

Thermo
SCIENTIFIC



Fisher Scientific
Part of Thermo Fisher Scientific

Thermo-Fisher Scientific

308 Ridgefield Court

Asheville, North Carolina 28806-2210 U.S.A.

United States

Tel: (866) 984-3766

Fax: +1 828-645-4225

<http://www.thermo.com/>

LABREPCO

LabrepcO

101 Witmer Road, Suite 700

Horsham, PA 19044 U.S.A.

P: 1-800-521-0754

F: 215-442-9202

<http://www.labrepcO.com/>

REFERENCES

- California Energy Commission. (2008, July 7). *California's Appliance Efficiency Program*. Retrieved April 5, 2010 from <http://www.energy.ca.gov/appliances/>
- Carbon Footprint. *Carbon Footprint Calculator*. Retrieved April 5, 2010 from <http://www.carbonfootprint.com/calculator.aspx>
- CE Marking Nordic. *What is CE marking?* Retrieved April 3, 2010 from http://www.cemarkingnordic.se/pdf/english/what_is_ce_marking.pdf
- Center for International Earth Science Information Network. (2003, February 5) *Montreal Protocol*. Retrieved April 5, 2010 from <http://www.ciesin.org/TG/PI/POLICY/montpro.html>
- Edison Testing Laboratories. (2009, September 10). *Welcome to the ETL Movement*. Retrieved April 5, 2010 from <http://www.etl.com>
- Fisher Scientific. *Because we all play a part*. Retrieved April 5, 2010 from <https://www.fishersci.ca/aboutus.aspx?id=6258>
- Fisher Scientific. *Think green*. Retrieved April 5, 2010 from <https://www.fishersci.ca/uploadedFiles/thinkgreencLowREZfinalv2.pdf>
- Freezer Concepts. *Ultra low temperature freezers*. Retrieved April 5, 2010 from <http://www.freezer-concepts.com/html/commercial.php>
- Garfield, S. (2002, April 12). *How does a refrigerator work?* Retrieved April 5, 2010 from California Energy Commission website: http://www.energyquest.ca.gov/how_it_works/refrigerator.html
- Industrial Freezers. (2010, February 6). *Moderate cold chest freezers*. Retrieved April 1, 2010 from http://www.freezerlink.com/moderate_cold.htm
- Industrial Freezers. (2010, February 6). *Moderate cold upright freezers*. Retrieved March 31, 2010 from http://www.freezerlink.com/moderate_uprights.htm

Industrial Freezers. (2010, February 6). *Ultra cold upright freezers*. Retrieved April 1, 2010 from http://www.freezerlink.com/ultracold_uprights.htm

Industrial Freezers. (2010, February 6). *Ultra cold chest freezers*. Retrieved April 1, 2010 from http://www.freezerlink.com/ultra_cold.htm

International Electrotechnical Commission. (2008, July 23). *Mission and Objectives*. Retrieved April 5, 2010 from <http://www.iec.ch/about/mission-e.htm>

National Aeronautics and Space Administration. *Ozone History*. Retrieved April 5, 2010 from <http://www.nas.nasa.gov/About/Education/Ozone/history.html>

National Measurement Office. *What is RoHS?* Retrieved April 5, 2010 from <http://www.rohs.gov.uk/Docs/8878%20NMO%20ROHS%20Leaflet%20in%20blue%20and%20updated%20FINAL.pdf>

Natural Resources Canada. *Energy Star Product Labelling*. Retrieved April 5, 2010 from <http://oee.nrcan.gc.ca/residential/business/energystar/faq.cfm?attr=12>

Priority Worldwide Services. (2009, October 16). *ISPM 15 Solid Wood Packaging Update*. Retrieved April 5, 2010 from <http://www.priorityworldwide.com/packaging/specialty.asp>

ScienTemp Corporation. (2007, September 06). *About Scientemp*. Retrieved April 2, 2010 from <http://www.scientemp.com/about-us.htm>

ScienTemp Corporation. (2010, January 15) *Ultra cold, super-cold, moderate-cold freezers*. Retrieved April 5, 2010 from <http://www.scientemp.com/freezers.htm>

Standards Council of Canada. *Home*. Retrieved April 5, 2010 from <http://www.scc.ca/en/web/scc-ccn>

Underwriter Laboratories Inc. *Underwriter Laboratories Inc.* Retrieved April 5, 2010 from <http://www.ul.com/global/eng/pages/>

Woolliams, J., Lloyd, M., & Spengler, J.D. (2005). The Case for sustainable laboratories: first steps at harvard university. *International Journal of Sustainability in Higher Education*, 6(4), 363-382.