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

An Investigation into Energy Efficient Laboratory Equipments

Freezers & Autoclaves

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SUSTAINABILITY PROJECT FORMAL REPORT

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AN INVESTIGATION INTO ENERGY EFFICIENT LABRARTORY EQUIPMENTS
FREEZERS & AUTOCLAVES

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ABSTRACT

The report investigates three kinds of laboratory equipments used in UBC. The equipments consist of -20°C freezers, -80°C ultra low freezers and autoclaves. Manufacturers have been contacted to support the investigation for relevant information. All data values provided in the report is dated March 30th 2010, and values are subject to change in the future.

The main focus of the report is to determine the best models for each of the three laboratory equipments. It is important to note that the report does not focus on whether the freezers or autoclaves are useful or purposeful but instead, the report focuses on which models of the equipments are more suitable for the UBC laboratory environment.

In order to determine suitable models for the UBC laboratory environment, the triple bottom line assessment is used to evaluate the laboratory equipments by looking at their environmental, economic and social impacts to the society. By the end of the report, conclusions and recommendations will be drawn for the readers to recommend the most suitable models for the UBC laboratories.

List of Illustrations

List of Abbreviations

WEEE-	Waste Electrical and Electronic Equipment
RoHS-	Restriction of Hazardous Substances Directive
KWh -	Kilowatt Hour
ULT -	Ultra Low Temperature
NAECA-	National Appliance Energy Conservation Act

TABLE OF CONENTS

1 Introduction

In this report we conduct a triple-bottom-line comparison of two models of autoclaves and two different types of freezers. This decision making process takes into account social, environmental, and economic negative and positive impacts. Triple bottom line assessment of freezers and autoclaves addresses the energy efficiency, financial costs and the impacts these products directly or indirectly have on the users and producers. In this process the freezers and autoclaves will be selected from the Labs for the 21th Century, Laboratory Equipment Efficiency Wiki tool. First part of the assessment is about two -80°C laboratory specific freezers, Sanyo MDF-U73VC and the Revco ULT 2186-9-A35, and two -20 laboratory freezer, Frigidaire FKFH21F7HW and the Kenmore 28093. In the second section of the comparisons we assess two autoclaves of our choice which are the Tuttnauer 2540M and the Amsco SV-120. The emphasis of these assessments is on energy efficiency, which along with other factors helps us choose the most efficient available autoclave and freezers.

2 -20°C Freezers

In the following section we will take a look at two specific freezer models: the Frigidaire FKFH21F7HW and the Kenmore 28093. Both models are -20°C laboratory freezers and Energy Star rated. We will compare them with the triple bottom line assessment on their environmental, economical, and social aspects.

2.1 Environmental Analysis

According to Energy Star, around 70% of U.S. electricity is generated by coal and natural gas, and such process creates a lot of greenhouse gasses and contributes to global warming. Freezers use a huge amount of energy to operate and it needs to be constantly powered to keep the interior of the freezer below specific temperature. Therefore the most important aspect of environmental analysis will be on the energy efficiency for both freezers.

Brand	Model	Volume (ft3)	Configuration	Ice	KWH/Year	NAECA std.	% Less Energy
Frigidaire	FKFH21F7HW	20.5	Upright Freezer	No	685	767	11%
Kenmore	28093	20.5	Upright Freezer	No	685	767	11%

Figure 1: Energy Consumption, Frigidaire versus Kenmore

Both the Frigidaire and Kenmore freezers are of the same size (20.5 cubic feet) and they consume the same amount of energy (685 KWH/Year). The NAECA (National Appliance Energy Conservation Act) is the minimum standard for all appliances in the United States. Both freezers achieved greater energy efficiency than the NAECA with 11% less energy annually. That is 82 KWH a year; it is enough to power a 100-Watt light bulb for over a month. Both freezers seem to be very efficient in term of energy consumption in general, so to make a recommendation we need to look at some more detailed features.

The Frigidaire freezer has an automatic alert feature, which will warn its user if the door is left open long enough for the temperature to rises above the temperature limit. While the Kenmore freezers do have a similar feature, it only warns its user should the items inside the freezer rise above a certain temperature. Base on that feature I recommend the Frigidaire FKFH21F7HW freezer as the more environmental friendly one.

2.2 Economic Analysis

The economic aspect of choosing a freezer can be divided into two parts: first the initial cost needs to be considered, second the energy efficiency of the freezers.

Brand	Model	Volume (ft3)	Configuration	KWH/Year	cost ($)	Annual energy cost ($)
Frigidaire	FKFH21F7HW	20.5	Upright Freezer	685	799	89.43
Kenmore	28093	20.5	Upright Freezer	685	934.99	89.43

Figure 2: Cost, Frigidaire versus Kenmore

Both the Frigidaire and Kenmore freezers have the same dimension, so it is very easy to compare them in term of economical cost. The Frigidaire freezer costs 799 U.S. dollars for the initial purchase, while the Kenmore freezer costs 934.99 U.S. dollars. By choosing Kenmore the user saves 135.99 dollars, since both freezers have the same energy consumption, which will cost their user 89.43 dollars a year to operate, the Frigidaire freezer become the obvious choice in term of economic aspect.

2.3 Social Analysis

Both Frigidaire and Kenmore are owned by a parent company, so instead looking at their small domestic manufacturing operation we will take a look at their parental companies. Frigidaire is owned by Sears and later on Kmart after the merge, and Kenmore is owned by General Motors. Both Sears and General Motors have struggled with employee relations. The

main cause of these struggles is mostly from wage and commission disputes. However, GM has not dealt with them properly, and cause strikes and massive layoffs. Kmart on the other hand, has been a very contributing member of the community, it created many events and campaign such as Kmart for Kids, March of Dimes and the annual Thanks and Giving campaign at St. Jude Children's Research Hospital.

It is clearly, Frigidaire under the parental companies Kmart and Sears has a much better social impact on the community, therefore we recommend the Frigidaire freezers.

3 -80°C Freezers

In this section we will compare two -80°C laboratory specific freezers. The two freezers chosen are the Sanyo MDF-U73VC and the Revco ULT 2186-9-A35. We will use the triple bottom line assessment to compare and contrast the two freezers by analyzing the environmental, economic and social aspects of both freezers. Both freezers are energy star labeled, RoHs and WEEE compliant.

3.1 Environmental Analysis

To analyze the environmental impacts of the freezers, we will look at the environmental impacts produced during the manufacturing process and operational process. In both the Sanyo MDF-U73VC and the Revco ULT 2186-9-A35, they use the same type of materials. Generally, the freezers use three major materials, polyurethane foam insulation, hard plastic, and steel. All three major materials can be recycled and reused. The main environmental concern of the production and recycling process is that it requires large amount of energy and creates greenhouse gas emissions. Furthermore the steel required results in the damage of environment from mine sites. The petroleum required to make the plastic also damages the environment.

Comparing the operational processes, the Sanyo freezer consumes 181kWh per week and the Revco consumes 148.1kWh per week. Although the Revco consumes less energy, the CO_2 emission created from the Sanyo is 15.93 kilograms per year which is less than Revco's emission of 17.24 kilograms per year. Annually, the Sanyo uses 1715.5kWh more energy than the Revco and emits 2.9 pound less CO_2. The breakpoint for Sanyo to emit less CO_2 annually than the Revco is if the power supplier produces less than 1.69 grams of CO_2 per kilowatt hour. Depending on how clean the power is supplied, it is possible for the Sanyo to be more environmentally friendly in terms of CO_2 emission.

Last but not least, as a bonus, because the Revco emits less CO_2 from operation, it generates less heat to the surrounding environment. The last environmental factor is that the Sanyo has a noise reduction system which reduces the noise pollution created. Overall, the two freezers are extremely similar and both of them have their own merits.

3.2 Economic Analysis

In this section we will compare the initial and operational cost of the two freezers. To compare the initial cost, we are only looking at the purchasing price and disregards potential tax and shipping cost differences. For the operational cost, we evaluated both freezers with the same hours of operation at 168 hours per week and the same electricity cost at 0.0186 Canadian dollars per kWh as suggested by BC Hydro. It is also important to note that the Revco ULT 2186-9-A35 has a capacity of 0.572 cubic metres while the Sanyo MDF-U73VC is slightly larger with a capacity of 0.736 cubic metres.

The initial purchasing price of the Sanyo MDF-U73VC is approximately $11469.92 US dollars. It uses 230V and draws a power of 2074W. The total energy consumed by the freezer is 181kWh/week. This gives an approximate weekly cost of $3.37 or an annual cost of $1228.81. The Revco ULT 2186-9-A35 has a purchasing price of $12398.32 US dollars. It uses 115V and draws a power of 1134. The total energy consumed by the freezer is 148.1kWh/week. This gives an approximate weekly cost of $2.75 or an annual cost of $1005.45. Below is a table of energy efficiency of each freezer.

Freezers	Sanyo MDF-U73VC	Revco ULT 2186-9-A35
Voltage	230V	115V
Power Draw	2075W	1134W
Energy Consumption	181kWh/week	148.1kWh/week
Annual Operation Cost	$1228.81	$1005.45
Initial Purchasing Price	$11469.92	$12398.32

Figure 3: Energy Consumption, Sanyo MDF-U73VC versus Revco ULT 2186-9-A35

As one can see, the Revco has a higher initial purchasing cost than the Sanyo even though the Revco has a lower operational cost. In order for the Revco to break even with the Sanyo, it will take four years and two months. After this period, the Revco is better economically and furthermore these ultra low freezers are expected to last decades. However, as noted before, the Sanyo has a larger capacity. Therefore its higher energy consumption is to be expected and proportionally, the Sanyo is 29% bigger but only consumes 22% more energy.

Based solely on the economic analysis, we recommend purchasing the Revco ULT 2186-9-A35 if only a small freezer is required as it has a lower annual cost. However, the Sanyo MDF-U73VC is still the better economic choice if a large freezer is needed.

3.3 Social Analysis

The -80°C freezers are used to preserve samples in a variety of applications. The technology has brought many new possibilities to the world. In research laboratories, the freezers are used to keep cell cultures in an inactive state. The preservation of samples in this case is crucial as it saves both time and money for researchers. Another important application is the freezing of the sperm in sperm banks. Although the application has created many controversies, it provided new possibilities to birth giving.

The production of these freezers may lead to poor labour conditions from the raw material side such as mining and oil extraction. However, the assembly process of the freezers mostly takes place the United States or domestically in Canada. Overall, the ultra low -80°C freezers bring social benefits to the society without directly creating controversies in the society.

4 Autoclaves

An autoclave is one of the devices for steam sterilization of research tools and consumables. An autoclave heats sterilizing solutions above their boiling point to sterilize medical or laboratory instruments. An autoclave is a one-touch device, i.e. the technician loads the machine and presses one button and the machine does the rest.

Process

The first step in the autoclave process is totally removing all of the air in the autoclave chamber. The chamber is sealed, and all of the air is removed through a vacuum pump, steam pumping or steam pulsing. The air may also be forced out through downward displacement, using steam to force it downwards. Once the air has been totally removed from the unit, the tools or instruments are sterilized by exposure to heat. The sterilization cycle typically runs anywhere from 3 to 18 minutes, and the heat level is usually set between 121 and 134 degrees Celsius. The intense heat kills bacteria, viruses and other organisms. The autoclave works best when the items are place inside in an arrangement that allows the heat to circulate completely [1].
The exact process of autoclaves depends on their models. Our report addresses environmental, economic, and social impacts of two models of autoclaves of our choice which are the Tuttnauer 2540M and the Amsco SV-120.

4.1 Environmental Analysis

Autoclaves are generally environmental friendly devices since the main substance used in these devices is water. No chemical is essentially needed for this device to function properly. Therefore, the only issue which should be addressed in this part of the analysis is the energy efficiency of two models.

Amsco SV-120 (size: 20” x 20” x 38”) processes at temperatures from 100^{o} C to 141^{o} C. This high temperature is for decontamination of supplies after laboratory procedures and for sterilizing moisture-stable goods. The energy efficiency information of this autoclave is listed below:

Power mode	Definition	Power Draw	Hours Per Week
Lower power mode 1	bring up boiler to temp	3.29 kWh	(10 min per cycle)
Lower power mode 2	liquid sterilization protocol	4.74 kWh	(25 min at sterilization temp)
Stand-by level	Power draw when turned off but connected to power	2500 W	

Figure 4: Energy Efficiency Information for Amsco SV-120

Tuttnauer 2540M (size: 20” x 20” x 15”) is a professional grade sterilizer and is perfect for all General Medical, Dental, laboratory and Cosmetic applications. The energy efficiency information of this autoclave is listed below:

Power mode	Definition	Power Draw	Hours Per Week	kWh per week
Rated Capacity	Nameplate power rating	1400 W		
Lower power mode 1	bring up boiler to temp	0.3 kWh	0-25 cycles per week (~30 min/cycle)	0 - 7.5 kWh
Lower power mode 2	liquid sterilization protocol	0.25 kWh	0-25 cycles per week (~20 min/cycle)	0 - 6.25 kWh
Stand-by level	Power draw when turned off but connected to power	0		

Figure 5: Energy Efficiency Information for Tuttnauer 2540M

We previously talked about the energy efficiency of our choices in the economic analysis section. By referring to tables 1 and 2, and the economic analysis we concluded that for the same amount of workload, the Amsco SV-120 autoclave uses twice the electricity consumed by the Tuttnauer 2540M model. Tuttnauer 2540M is facilitated with heat insulation which prevents increasing of the room temperature.

Comparing data in table1 and table2 we understand that if Tuttnauer 2540M is turned off no power is drawn even if it is not disconnected from power, but Amsco SV-120 consumes 2500 W power if it is left connected to power even after it is turned off. Moreover, Tuttnauer 2540M has the option of automatic shut off at the end of both the sterilization and dry cycles. These

observations prove that Tuttnauer 2540M autoclave is more energy efficient compared to Amsco SV-120.

Autoclaves operate by vaporizing during each use cycle a small amount of purified water to well above boiling temperature. Non-toxic distilled or de-ionized water has traditionally been used in sterilizing autoclaves. In section 1.3.1 we mentioned that the same amount of distilled water is consumed for the same workload in both autoclaves and this amount is very small during each cycle, typically less than 100 millilitres, so the consumption of distilled water is not a concern in this part of analysis.

4.2 Economic Analysis

To the start the economic analysis for both types of autoclaves, the first factor must be determined is the potential resources consumed by the equipment. Similar to other types of laboratory equipment, the electricity consumption is of the most significance. Although it is tabulated on the *Labs for 21st Century* website for both autoclaves, the efficiency cannot be judged or compared directly through the electricity consumed in each sterilization cycle since each of the autoclaves has its unique operating modes and the sterilization capacities. Thus, a generalized criterion must be determined for further analysis.

The criteria employed here is to set up a lumped-sum weekly task for both autoclaves. In general, no matter how many cycles are conducted separately by each model, the same task must be completed by both autoclaves, respectively. Moreover, the initial purchase price of the autoclaves must be taken into consideration in order to generate a complete cost-saving analysis.

4.2.1 Tuttnauer 2540M

The typical operating cycles for the Tuttnauer 2540M autoclave is provided on the *Labs for 21st Century* as follows:

Mode	Cycle Type	Cycles per Week
Lower power mode 1	Hot-start cycle	25
Lower power mode 2	Cold-start cycle	25

Figure 6: Tuttnauer 2540M Operating Mode

Thus, we shall take the suggested weekly operation load as our standard task for efficiency analysis. The website also tabulates the electricity consumed for respective cycle. Thus, the energy consumed can be calculated on a weekly basis, mainly as follows.

Mode	Cycles per Week	Power Draw per Cycle	Weekly Consumption
Lower power mode 1	25	0.3 kWh	7.5 kWh
Lower power mode 2	25	0.25 kWh	6.25 kWh
		Total	13.75 kWh

Figure 7: Energy Consumption Information for Tuttnauer 2540M

It is preferred to convert the kWh consumption basis to be actual dollar based. However, as the size of the laboratory varies, the demand for the electricity changes significantly. Thus, the analysis must be conducted based on the assumption that the autoclaves are purchased and operating in ideally the same laboratories. As suggested by BC Hydro, the rate charged for a medium sized laboratory (under 35 kW demand of electricity) is 0.0816 dollars per kWh. If we apply this rate to the 2540M model autoclave, the weekly charge for electricity is 1.12 dollars.

The purchasing price varies among retailers. After consulting one of the local retailers, we obtain the quoted price for the Tuttnauer 2540M model as 3981 dollars.

4.2.2 Amsco SV-120

As mentioned before, the weekly workload must be standardized to be equivalent for both autoclaves. The difficulty encountered is how to convert a certain number of Tuttnauer 2540M model's operating cycles to be expressed in terms of the specification of the Amsco SV-120 model. In another word, a universal standard must be found to express the workload. The standard must be suitable for both models. The approach employed by us is to express the workload in terms of the total sterilization capacity. It is conducted as follows:

1) The main assumption here is that, for each model of the autoclaves, the sterilization capacity per cycle is proportional to the product of area of trays and the number of trays.

2) In our case, the 2540M autoclave contains 4 trays, each of which has a usable dimension of $16.3'' \times$

$6.7''$ (obtained through the specification provided by the Tuttnauer website). So the sterilization capacity per cycle for 2540M model is $16.3'' \times 6.7'' \times 4 = 436.84\ \text{in}^2$. As we set the weekly workload as 25 cycles for both modes respectively, the total weekly capacity can be expressed as $436.84\ \text{in}^2 \times 25 = 10921\ \text{in}^2$ for both hot and cold start modes.

3) The Amsco SV-120 model, on the other hand, also has 4 trays. However, the datasheet provided by the manufacturer does not specify the usable area of the trays. Fortunately, the chamber dimension of the autoclave is provided on the *Labs for 21st Century* website. It is reasonable for us to conduct the approximation and assume the usable area of the trays is equivalent to the chamber area, which is given as $20'' \times 38'' = 760\ \text{in}^2$. With 4 trays in total, the weekly workload for the SV-120 model consists of $10921\ \text{in}^2 / 760\ \text{in}^2$ = 3.6 cycles for both modes, respectively.

As the equivalent weekly workload for the SV-120 autoclave is obtained, we shall follow the same analysis done with the Tuttnuaer 2540M model. The *Labs for 21st Century* website has tabulated the energy consumption for both modes of operation for the SV-120 autoclave. The weekly energy consumption can be calculated as follows.

Mode	Cycles per Week	Power Draw per Cycle	Weekly Consumption
Lower power mode 1	3.6	3.29 kWh	11.84 kWh
Lower power mode 2	3.6	4.74 kWh	17.06 kWh
		Total	28.90 kWh

Figure 8: Energy Efficiency Information for Amsco SV-120

With the electricity rate suggested by BC Hydro, 0.0816 dollars per kWh, the weekly cost is estimated to 2.36 dollars. However, due to lack of sources, it is difficult to find the purchasing price of the Amsco SV-120 autoclave. After searching for the prices quoted by various online retailers, we found that the price ranges from 14000 to 18500 dollars, depending on the condition of the equipment.

4.2.3 Comparison

From the economic analysis conducted above, it is apparent that for the same amount of workload, the Amsco SV-120 autoclave uses twice the electricity consumed by the Tuttnauer

2540M model. Moreover, the purchasing price of the Amsco-SV120 model is also much higher than Tuttnauer 2540M. In conclusion, the 2540M autoclave is economically much more efficient than the SV-120 model.

4.2.4 Distilled Water

Water used by autoclaves must be distilled to reduce the impurity contained since the impurity will accumulate in the pipe and result in more frequent maintenance. However, the approach of acquiring distilled water varies among laboratories. Also, the standard of chemicals dissolved in distilled water also various among different models of autoclaves. Unfortunately, these standards and amount of distilled water required for the two models in our analysis are not listed in the specifications provided by the manufacturers.

The approximation we make to fix this issue is to assume for the same workload assigned, the amount of utensils requiring sterilization are the same for both models of autoclaves. Thus we can assume that the same amount distilled water is consumed for the same workload so that the consumption of distilled water can be neglected from the analysis based on the cost-saving approach.

4.2.5 Stand-by Power Consumption

It is recommended that the autoclaves should be turned off and disconnected from power after the sterilization operation is completed. Though no warm-up period is required, leaving the equipment turned on can cause a considerable amount of energy consumption. As suggested by the *Labs for 21st Century* website, 2500 Watt power is consumed by the Amsco SV-120 autoclave by leaving the autoclave connected to power even when it is turned off. On the other hand, the feature of automatic shut-off enhances the overall efficiency of the Tuttnauer 2540M model as no power consumption is needed after sterilization is completed. This feature further shows that the Tuttnauer 2540M is economically more efficient.

4.3 Social Analysis

Autoclaves have a very important and special purpose in the labs. Generally speaking, autoclaves keeps laboratory apparatus sanitized, bacteria-free, before and after use. Without autoclaves, it is difficult to keep laboratory equipment clean and safe. Furthermore, chemicals and cell cultures used in laboratories can be potentially life threatening if not treated properly. With the new technology, laboratories become a safer working place and it also reduces the risk of dangerous lab samples getting outside the lab. Both the autoclaves and freezers aid researchers in their job and similar to freezers, it is safe to say that autoclaves do not bring any negative social impacts to the world but only benefits.

5 Conclusion

Though we endeavored to gather more information regarding to the selected models of freezers and autoclaves in our research, the origin of the resources is still confined within the feedbacks from retailers and end-users. We deeply believe that the research can be conducted more convincingly if actual testing is available. However, via the research on the available resources, we obtained certain key features of the chosen laboratory equipment, which indicates the energy efficiency based on the triple-bottom-line criteria. According to these features, the following preliminary recommendation can be drawn.

First, for the -20°C freezers, we recommend the Frigidaire FKFH21F7HW model as it consumes less energy than the Kenmore 20893 model. Further, though both models have an equivalent annual operating cost, the initial cost of the Frigidaire model, as quoted by the retailers, is lower. Thus, it is more environmentally friendly and performs better in an economic view. Moreover, the owner of Frigidaire, Kmart, is enrolled in a mutually beneficial relation with the community, involving both the public and its employees. Thus, for the -20°C freezers, Frigidaire FKFH21F7HW model shall be recommended.

For the -80°C freezers, though the Revco ULT 21869-A35 model consumes less energy than the Sanyo MDF-U73VC model, it emits more CO_2 gas and creates more noise during operation. Further, the energy saved by the Revco freezer is not adequate to compensate its smaller capacity. In an economic view, though the Revco model requires a lower annual operating cost, it has a higher initial purchasing price, which requires more than four years to breakeven with the Sanyo freezer. As both models are manufactured without major social impact, the Sanyo MDF-U73VC model shall be recommended due to its better performance.

For the autoclaves, the Tuttnauer 2540M model performs better in all aspects. It consumes less energy, incurs a lower annual operating cost and also has a much lower purchasing price than the Amsco SV-120 autoclave. Moreover, its automatic shut-off feature shows it is more environmentally friendly. According to our research, no major social impact can be incurred during the manufacturing and operation of both autoclaves. Thus, the Tuttnauer 2540M model should be our recommendation.

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