Institutional conversion to energy-efficient ultra-low freezers decreases carbon footprint and reduces energy costs: Methods and Results

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Overview

- Problem
- Pilot Project
- Campus-wide Program
- UCSF Tools for Other Institutions

UCSF's -80C fleet

Problem Statement

- UCSF operates over 1,250 -80°C freezers.
- 95% were older energy-inefficient models using triple the electricity of newer ENERGY STAR-certified freezers
- **~$2.3 million per year in excess energy costs**
  - 3,423 metric tons of CO2
  - the annual electricity use of 676 homes

Pilot Project: Is it possible?

- **Funding:** $750,000 to replace the 43 most inefficient freezers in one building at no cost to owners
- **Consolidation:** could we remove more freezers than we add?
- **Logistics:** Higher rate of large equipment movement while keeping samples cold

Step 1: Forecasting Energy Use

Institutional impact is the sum of the energy use of every freezer.

The institutional impact factors

- Freezer plug draw + HVAC electrical use
- HVAC impact is climate-dependent. For San Francisco, we added 12% to freezer energy use
- Aging. Units use more energy and emit more heat as they age

$$\text{Energy Impact} = \sum_{t=1}^{n} ((\text{Freezer Energy Use} \times \text{HVAC Impact Factor}) \times (\text{Energy Efficiency Decline}^{\text{Future Year n}}))_n$$

Current Energy Impact

Aging: Future Energy Impact

Variables

Freezer energy use: Total annual energy use for any number of freezers in kWh

HVAC impact factor: 1 + the percentage increase in HVAC electrical usage

Energy efficiency decline: 1.03 (1 + 3%) ← Based on well-maintained units; therefore conservative

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Step 2: Forecasting Energy Costs

The business case for funding

An accurate business case must account for rising electrical rates to avoid understating the project benefits

$$\text{Energy Costs}_{\text{Year n}} = (\text{Electrical Burden}_{\text{Year n}}) \times (\text{Future Electricity Rate}_{\text{Year n}})$$

$$\text{Future Electricity Rate}_{\text{Year n}} = \text{Current Electrical Rate} \times ((1 + \text{Annual Rate Increase})^{\text{Future Year n}})$$

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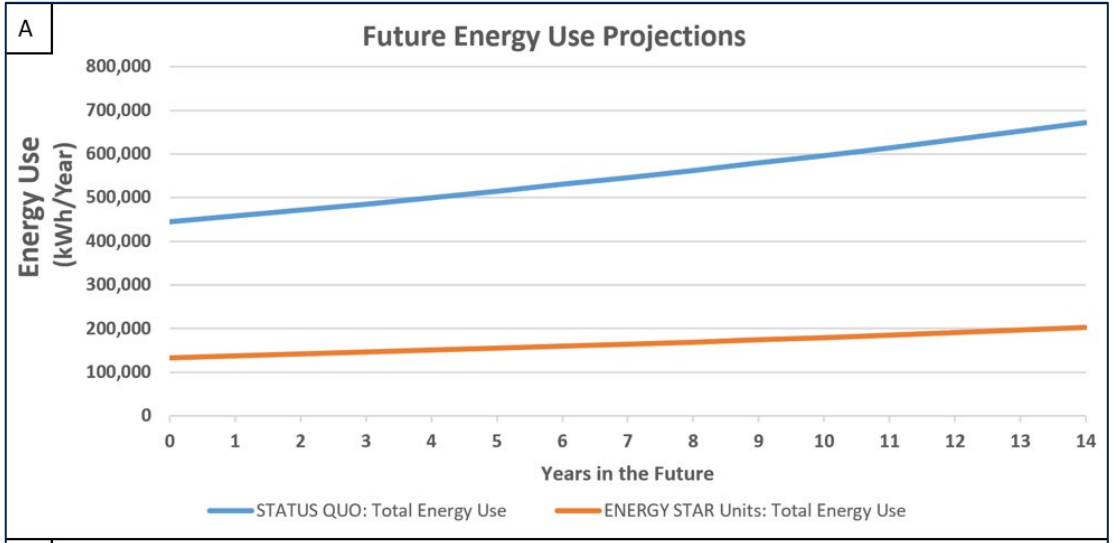
Results
Energy and Cost Forecasts

An accurate business case accounts for rising energy use (aging) + energy rates

- Diverging curves result from different starting values for energy use & costs which are compounded by annual aging rate and electricity rates.
- 3% aging is conservative

A



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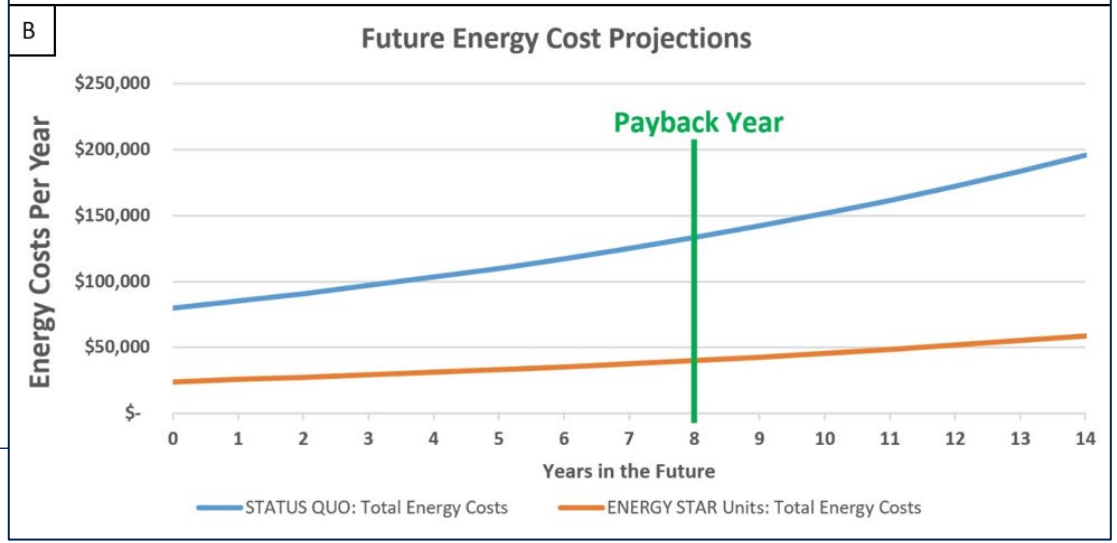

Step 3: Identify the most inefficient freezers

Model to predict energy use

- Based on energy use measurements on 34 freezers.

Benefits

- **Saves time:** Requires only storage volume and age info, versus 10 years to identify the most inefficient freezers through measuring energy use.
- **Reduces risk:** Avoids freezer failures from unplugging old units to install a meter.
- **Accuracy:** 7.5% mean absolute percentage error (MAPE) predicted vs actual energy use

Energy Use = 1.6569 – (0.4006 * Energy Star) – (0.0333 * Volume) + (0.0168 * Age)

(kWh/cubic foot/day)

Variables

ENERGY STAR: Yes = 1, No = 0

Storage Volume: in cubic feet

Age: In years

Freezers n = 34	R-sq. = 0.6862	
	Coefficient	p-value
Intercept	1.6569	0.0000
ENERGY STAR certification	-0.4006	0.0078
Storage Volume	-0.0333	0.0051
Age	0.0168	0.0230

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Pilot Results

Outcome

- 43 removed 41 installed. (2 labs consolidated)
  - 134 metric tons CO2 eliminated
  - Or the annual electricity use of 26.4 homes
- Project costs: $679,837
- 8-year payback period (conservative)

Other benefits

- Average of 7.2 cubic feet storage volume gained for the same footprint
- Average age of replaced units was 17.5 years (at 10 years, compressors working almost constantly)
- 35% of the replaced units exhibited symptoms of decline

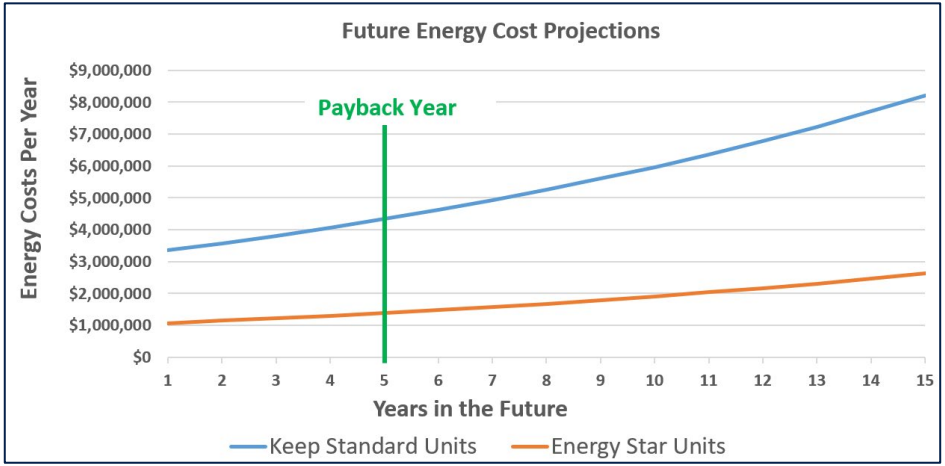
Project approved for campus-wide implementation with $3M funding

Institutional Scale Replacement

Goal: Accelerate UCSF's transition to 100% Energy Star -80C freezers

Project Goals

- **Prevent standard freezer purchases**
  - Orders for standard units sent back to departments.
- **Replace 300 most inefficient freezers**
  - $3 million in funding from UCSF
  - $10,000 Rebate per replacement
- **Split Rebate.** To incentivize consolidation
  - **$4,000 for purchasing ENERGY STAR**
  - **$6,000 for recycling standard freezer**



Results

- **204 units replaced**
- **13 units removed through consolidation**

Policy Compliance

Procurement Team Authority, References and Tools

- Buyers are vested with the authority to return requisitions for non-ENERGY STAR freezers.

Process Reference

Summary

UCSF has committed to reducing carbon emissions that contribute to climate change and their concomitant impact on global health. UCSF is stiving to achieve carbon neutrality by 2025, including a 2% annual energy usage reduction. In our effort to achieve these goals, UCSF has policy to purchase ENERGY STAR-certified products when those options are available.

Negative 80°Celcius freezers are one of the most energy-intensive equipment on our campus. Older freezers use as much energy as a 3-bedroom home; however, ENERGY STAR-certified freezers use 2/3 less electricity. The Chancellor, and cabinet, are committed to completely transitioning UCSF to ENERGY STAR negative 80°Celcius freezers.

UCSF leadership has vested SCM Buyers with the authority to convert orders for non-ENERGY STAR freezers to ENERGY STAR negative 80°Celcius freezers.

Process to Review Requisitions for ENERGY STAR Negative 80°Celcius Freezers

1. Buyer receives an order for a freezer in their que.
2. Is this an Ultra-low temperature freezer (aka –80 Celsius freezer)?
3. Is the unit certified as ENERGY STAR?
   a. Enter the unit model number in the search box on the Energy Star web site for Energy Star certified ULT freezers models. NOTE: if model is not on this site it is not officially an Energy Star certified model

   b. If Buyer is unsure if the model number is listed correctly on the requisition (e.g. it resembles a format on the Energy Star web site) please contact Dean Shehu.
4. If it the search pulls up the model: **approve the order**
5. If the search does not pull up the model: 'Return' the requisition
   a. Send an email and/or requisition note to the requestor (Can use text file: *Procurement Restrictions Email Template for SCM Buyers Use*)
   b. Attach the pdf of the signed letter UCSF Energy Star Policy Letter (signed by Vice Chancellor of Research)
6. Once the requisition is updated follow steps in step 3 to confirm the new unit is in fact ENERGY STAR certified. If yes then **approve the order**
7. If not then contact Strategic Sourcing Manager for Research (Dean Shehu) to discuss the order with the customer. Dean will discuss with lab who will update order and send to Buyer one last time.

Letter Signed by Vice Chancellor of Research

Dear Colleague,

UCSF has committed to conserve energy and reduce greenhouse gas (GHG) emissions and their concomitant impact on global health. UC policy has set targets to achieve at least a 90% reduction in total emissions by no later than 2045 and a 2% reduction in annual energy usage. In our effort to achieve these goals, UCSF has a policy to purchase Energy Star-certified products when those options are available.

The –80C lab freezer you have selected to purchase is not Energy Star-certified. The U.S. Department of Energy's web site shows all current models of Energy Star –80C freezers. Please select a ULT freezer from this list.

UCSF has a goal to decrease the number of older –80C ULT freezers which use as much energy as a 3-bedroom home. Energy Star-certified ULT freezers use a third of the electricity compared to older non-Energy Star ULT freezers.

We appreciate your understanding and support in making an environmentally conscious purchase decision to help protect our planet. **UCSF has a ULT Freezer Rebate Program which is designed to mitigate the typical cost difference between Energy Star-certified and non-certified -80C freezers.** The Program offers a rebate when buying a new ULT freezer. For more information, go to UCSF ULT Freezer Rebate Program.

For questions regarding Energy Star -80C freezer rebates, please contact UCSF Sustainability: *sustainability@ucsf.edu*. If an Energy Star model does not meet your laboratory's specific requirements, please speak with Sustainability about next steps.

Respectfully,

Harold R. Collard
Vice Chancellor for Research

Email Language

Procurement Restrictions Email Template

Dear [Requisition Requestor Name],

The –80C lab freezer you have selected to purchase is not Energy Star-certified. To be in compliance with UCSF's Energy Conservation policy (please refer to attached letter from UCSF's Vice Chancellor of Research).

Please refer to the U.S. Department of Energy's web site to select from one of many models of Energy Star –80C freezers.

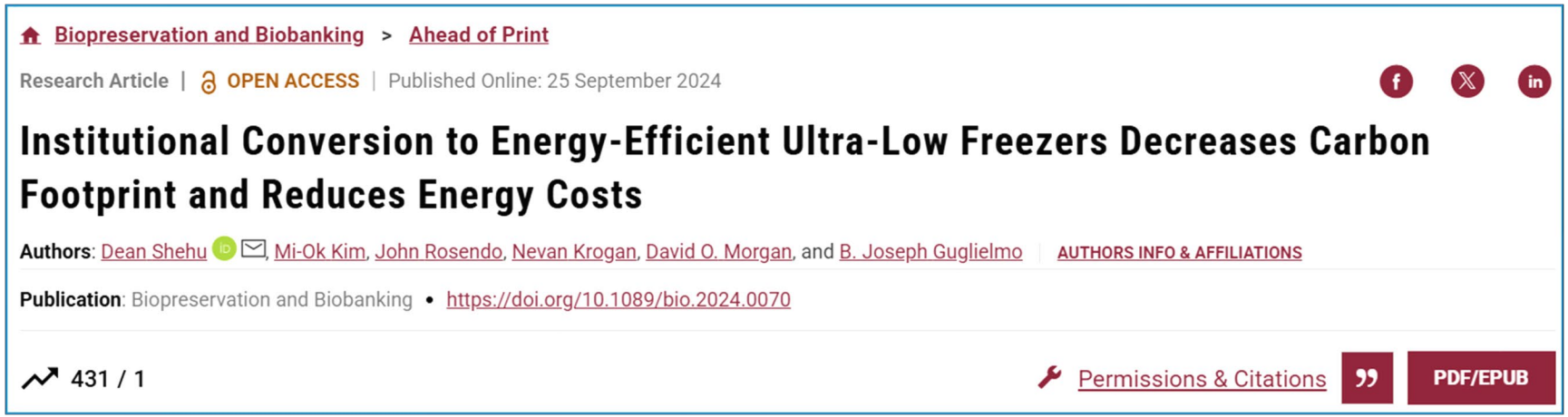
Best regards,

UCSF Buyer Name

Paper is available online as open access

Read the supplemental also

- Examples demonstrating calculations
- Raw data
- Background on model development and factors impacting energy use prediction



Biopreservation and Biobanking > Ahead of Print

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Business Case Tool – Available Soon

Spreadsheet model programmed with equations in our paper

- Will be downloadable from our open access paper
- Energy use prediction for individual freezers
- Energy use forecast: status quo vs replacement with energy-efficient freezers
- Automatic payback period and net present value (NPV) calculations
- Automatic chart

Energy and Costs Forecasting Model	Energy Use Variables		Freezer Energy Use Inputs	
	Electricity Costs ($/kWh) >	$0.24	Target Freezers	
	Annual Electrical Rate Increase >	3.5%	TOTAL Annual Energy Use of Freezers Removed (kWh/Year) >	500,000
Project Cost	Energy Efficiency Decline >	3.0%	Energy Star Freezers	
$700,000	Added HVAC Burden >	12%	TOTAL Annual Energy Use of Installed Freezers (kWh/Year) >	150,000

Energy Use (kWh/Year)

Years after replacement >	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTALS
STATUS QUO: Plug Draw	500,000	515,000	530,450	546,364	562,754	579,637	597,026	614,937	633,385	652,387	671,958	692,117	712,880	734,267	756,295	778,984	**10,078,441**
STATUS QUO: HVAC Electrical Use	60,000	61,800	63,654	65,564	67,531	69,556	71,643	73,792	76,006	78,286	80,635	83,054	85,546	88,112	90,755	93,479	**1,209,413**
STATUS QUO: Total Energy Use	**560,000**	**576,800**	**594,104**	**611,927**	**630,285**	**649,193**	**668,669**	**688,729**	**709,391**	**730,673**	**752,593**	**775,171**	**798,426**	**822,379**	**847,050**	**872,462**	**11,287,854**
ENERGY STAR Units: Plug Draw	150,000	154,500	159,135	163,909	168,826	173,891	179,108	184,481	190,016	195,716	201,587	207,635	213,864	220,280	226,888	233,695	**3,023,532**
ENERGY STAR Units: HVAC Electrical	18,000	18,540	19,096	19,669	20,259	20,867	21,493	22,138	22,802	23,486	24,190	24,916	25,664	26,434	27,227	28,043	**362,824**
ENERGY STAR Units: Total Energy Use	**168,000**	**173,040**	**178,231**	**183,578**	**189,085**	**194,758**	**200,601**	**206,619**	**212,817**	**219,202**	**225,778**	**232,551**	**239,528**	**246,714**	**254,115**	**261,739**	**3,386,356**
Total Annual Savings (Plug Draw	**392,000**	**403,760**	**415,873**	**428,349**	**441,199**	**454,435**	**468,069**	**482,111**	**496,574**	**511,471**	**526,815**	**542,620**	**558,898**	**575,665**	**592,935**	**610,723**	**$7,901,457**

Energy Costs ($/Year)

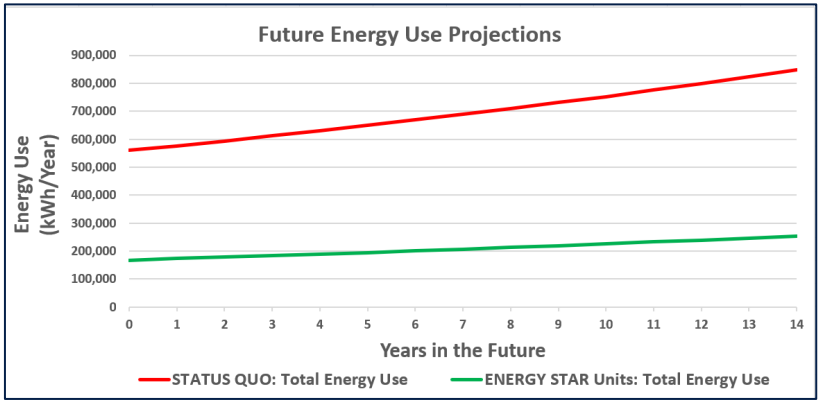
Years after replacement >	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTALS
STATUS QUO: Plug Draw	$ 120,000	$ 127,926	$ 136,376	$ 145,383	$ 154,986	$ 165,222	$ 176,135	$ 187,769	$ 200,171	$ 213,393	$ 227,487	$ 242,513	$ 258,531	$ 275,607	$ 293,810	$ 313,217	**$ 3,238,526**
STATUS QUO: HVAC Electrical Use: HV	$ 14,400	$ 15,351	$ 16,365	$ 17,446	$ 18,598	$ 19,827	$ 21,136	$ 22,532	$ 24,021	$ 25,607	$ 27,298	$ 29,102	$ 31,024	$ 33,073	$ 35,257	$ 37,586	**388,623**
STATUS QUO: Total Energy Costs	**$ 134,400**	**$ 143,277**	**$ ######**	**$ 162,829**	**$ 173,584**	**$ ######**	**$ 197,272**	**$ 210,301**	**$ 224,192**	**$ 239,000**	**$ 254,786**	**$ 271,614**	**$ 289,554**	**$ 308,679**	**$ 329,068**	**$ 350,803**	**$ 3,627,149**
ENERGY STAR Units: Plug Draw	$ 36,000	$ 38,378	$ 40,913	$ 43,615	$ 46,496	$ 49,567	$ 52,841	$ 56,331	$ 60,051	$ 64,018	$ 68,246	$ 72,754	$ 77,559	$ 82,682	$ 88,143	$ 93,965	**971,558**
ENERGY STAR Units: HVAC Electrical	$ 4,320	$ 4,605	$ 4,910	$ 5,234	$ 5,579	$ 5,948	$ 6,341	$ 6,760	$ 7,206	$ 7,682	$ 8,190	$ 8,730	$ 9,307	$ 9,922	$ 10,577	$ 11,276	**116,587**
ENERGY STAR Units: Total Energy Cos	**$ 40,320**	**$ 42,983**	**$ 45,822**	**$ 48,849**	**$ 52,075**	**$ 55,515**	**$ 59,182**	**$ 63,090**	**$ 67,258**	**$ 71,700**	**$ 76,436**	**$ 81,484**	**$ 86,866**	**$ 92,604**	**$ 98,720**	**$ 105,241**	**$ 1,088,145**
Total Annual Savings (Plug Draw	**$94,080**	**$100,294**	**$106,918**	**$113,980**	**$121,509**	**$129,534**	**$138,090**	**$147,211**	**$156,934**	**$167,300**	**$178,350**	**$190,130**	**$202,688**	**$216,076**	**$230,347**	**$245,562**	**$ 1,088,145**

Project Payback Period

Years after replacement >	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTALS
Cumulative Annual Savings	$ 94,080	$ 194,374	$ 301,292	$ 415,273	$ 536,782	$ 666,316	$ 804,406	$ 951,617	$ 1,108,551	$ 1,275,851	$ 1,454,201	$ 1,644,331	$ 1,847,019	$ 2,063,095	$ 2,293,442	$ 2,539,004	**$18,989,636**
Cumulative Net savings (Savings - Pr	$ (605,920)	$ (505,626)	$ (398,708)	$ (284,727)	$ (163,218)	$ (33,684)	$ 104,406	$ 251,617	$ 408,551	$ 575,851	$ 754,201	$ 944,331	$ 1,147,019	$ 1,363,095	$ 1,593,442	$ 1,839,004	**$6,989,636**

The period when the project yields savings net of costs is automatically highlighted in green above in row 39. The earliest year (start of green highlight) is the payback year for financial reporting purposes.

Discount Rate	3.0%																
Net Present Value																	
Years after replacement >	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTALS
Cumulative Annual Savings	$ 94,080	$ 194,374	$ 301,292	$ 415,273	$ 536,782	$ 666,316	$ 804,406	$ 951,617	$ 1,108,551	$ 1,275,851	$ 1,454,201	$ 1,644,331	$ 1,847,019	$ 2,063,095	$ 2,293,442	$ 2,539,004	**$18,989,636**
Discounted Cash Flows	$ 94,080	$ 188,713	$ 283,997	$ 380,033	$ 476,923	$ 574,770	$ 673,677	$ 773,752	$ 875,101	$ 977,834	$ 1,082,062	$ 1,187,900	$ 1,295,462	$ 1,404,867	$ 1,516,236	$ 1,629,690	**$13,415,097**
Sum of Discounted Cash Flows	$13,415,097																
Project Cost	$700,000																
Net Present Value	**$12,715,097**																



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Thank you!

UCSF's ULT Freezer Replacement Resources