Sustainable Energy Reduction from Relaxed Environmental Criteria in Five Canadian Cities

AIC 2015 Poster Paper

Presented at the CAC 2014 Annual Meeting
on June 8 in Quebec City

ABSTRACT:

Recent economics lead to challenges in meeting operating costs for collections-holding institutions. This has spurred interest in means to reduce annual operating costs by reducing energy use. This paper presents the potential energy savings from relaxed criteria for five Canadian cities: Montreal, Toronto, Vancouver, Winnipeg and Calgary. The savings are based on a block load analysis in a hypothetical building meeting ASHRAE Standard 90.1 for the building envelope, and ASHRAE Standard 62.1 for outside air. The variation between the five cities is due to climate, which is evaluated using a bin analysis of published weather data.

The relaxed internal building criteria considered are:

- 15-26 degC @ 40-60%RH against 20-22 degC @45-55% RH for museum collections; and
- 15-26 degC @ 30-60%RH against 15 degC @30-35% RH for archival paper collections.

Three types of collections space are analyzed for savings: a) museum gallery/collections use spaces; b) museum collections storage; and c) archival paper storage. For the archival paper storage, estimates are also made for the preservation impact from relaxed criteria, using the Image Permanence Institute's Preservation Index (PI).

Climate is the primary variable for the comparison, with a heating/cooling-humidification/dehumidification loads rationale

presented to support this comparison. Hypothetical building occupancy/use is the same between the five locations. Energy rates are the same, and are presented in a form so that the reader can easily convert to actual rates at the institution, with an example provided.

In making the comparison, in addition to energy use, each location is evaluated for its global carbon dioxide emissions for the energy used.

INTRODUCTION

The recent economic downturn has compounded the long-term rise in utility rates and drawdown of global energy resources, leading to challenges in meeting operating costs for collections-holding institutions. This has spurred interest in means to reduce annual operating costs by reducing energy use. Many different sets of alternative criteria have been proposed, including the January 2013 AIC-AAMD guidelines for loans, and discussions of similar issues on the American Institute for Conservation web site[1].

PROPOSED RELAXED CRITERIA. These proposed guidelines for relaxed criteria can be approximated and summarized as follows.

For museum collections:
15-26 degC @ 40-60%RH, against 20-22 degC @45-55%
(**60-78 degF @ 40-60%RH**, against 68-72 degF @45-55%)
For archival paper collections:
15-26 degC @ 30-60%RH, against 15 degC @30-35%
(**60-78 degF @ 30-60%RH**, against 60 degF @30-35%)

STANDARD CRITERIA. The standard museum environmental criteria for comparison are those typical for display and storage, either for typical museum collections, or required for typical loan agreements.

The standard archival storage criteria for comparison are those readily identified for practical long-term paper storage by Don Sebera's Isoperms [2], as also documented by the Image Permanence Institute [3], and as used in most of the new state archives facilities built in the US in the last 15 years (Alabama, Arizona, Delaware, Georgia, Mississippi, New York, South Carolina), and the Bermuda Archives. Isoperms and the IPI publications are collections environment management tools that allow predicting the effect of various temperature and humidity conditions on the life of collections. In the case of the US state archives, these tools were used to value the benefit of storage at cooler and drier conditions.

ESTIMATING ENERGY SAVINGS FROM RELAXED CRITERIA

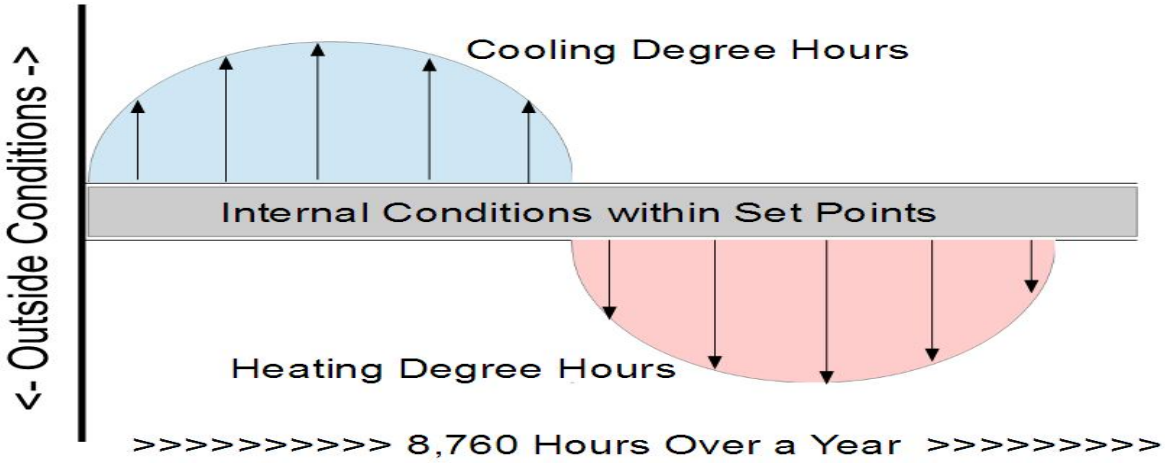
It is possible to estimate energy savings for use of the relaxed criteria through use of a block load analysis. This uses typical large loads that drive energy use, and are affected by a change in environmental set-points. The two main loads affected are the building envelope (walls, windows, roof), and the outside air drawn into the building by the heating, ventilating and air conditioning (HVAC) system.

BUILDING ENVELOPE. For the building envelope, the overall conductivity, or U-value, is usually set by ASHRAE Standard 90.1 [4], commonly used in energy codes as a minimum requirement. When the interior set-point for temperature is changed, it will effect the amount of heat lost and gained through the building

envelope over a year, depending on the annual range of ambient temperature for a given location.

OUTSIDE AIR. For the outside air, the amount required in a building is usually set by ASHRAE Standard 60.1, similarly used as a code-required minimum amount for occupied spaces. When the interior set-point for temperature is changed, it will effect the amount of heating and cooling required to condition that air over a year, depending on the annual range of ambient temperature for a given location. In addition, the interior humidity set-point will effect the amount of humidification and dehumidification required to condition that air over a year, depending on the annual range of ambient humidity for a given location.

CLIMATE DATA. The annual temperature and humidity conditions for a given location can be determined using various references and climate analysis tools.



These are used to derive sets of climate data “bins,” sets of conditions that occur and the number of hours each occurs. These bins can then be simplified to time-weighted conditions for any selected interior set-point. These time-weighted conditions (Degree-Hours for temperature, Humidity-Ratio-Hours for humidification, and Ethalpy-Hours for cooling and

dehumidification of air) can be analyzed for their block load, using the difference between the conditions at standard and relaxed criteria.

Envelope Load

Winter Heating: **BTU/Year =**
(Degree Hours @ 68 degF – Degree Hours @ 60 degF) x U-value

Summer Cooling: **BTU/Year =**
(Degree Hours @ 72 degF – Degree Hours @ 78 degF) x U-value

Outside Air Load

Winter Heating: **BTU/Year =**
(Degree Hours @ 68 degF – Degree Hours @ 60 degF) x CFM x 1.08

Winter Humidification: **BTU/Year =**
(HR Hours@68 degF/50% RH – HR Hours@60 degF/40% RH) x CFM x 0.643

Summer Cooling & Dehumidification: **BTU/Year =**
(Enthalpy Hrs @ 72 degF/50% RH – Enthalpy Hrs @ 78 degF/60% RH) x CFM x 31.342

Dehumidification Reheat: **BTU/Year =**
Latent Enthalpy Hrs Difference – Occupied Hours Internal Gain

These loads can be converted to an estimated energy utility use by these equations and typical system efficiencies:

For heating:

$$\text{BTU/Year (Source)} = \frac{\text{BTU/Year(Load)}}{\text{Boiler Efficiency(\%)}}$$

For cooling:

$$\text{KWH} = \frac{\text{Load (BTU)}}{\text{12,000 BTU/Ton-Hour}} \times \text{KW/Ton for cooling}$$

Utility energy rates can then be applied to arrive at savings in annual energy use from the difference in the annual block loads in dollars.

$$\text{Annual \$ Heating} = \frac{\text{BTU/Year(Source)}}{\text{100,000 BTU/Therm}} \times \text{\$/Therm}$$

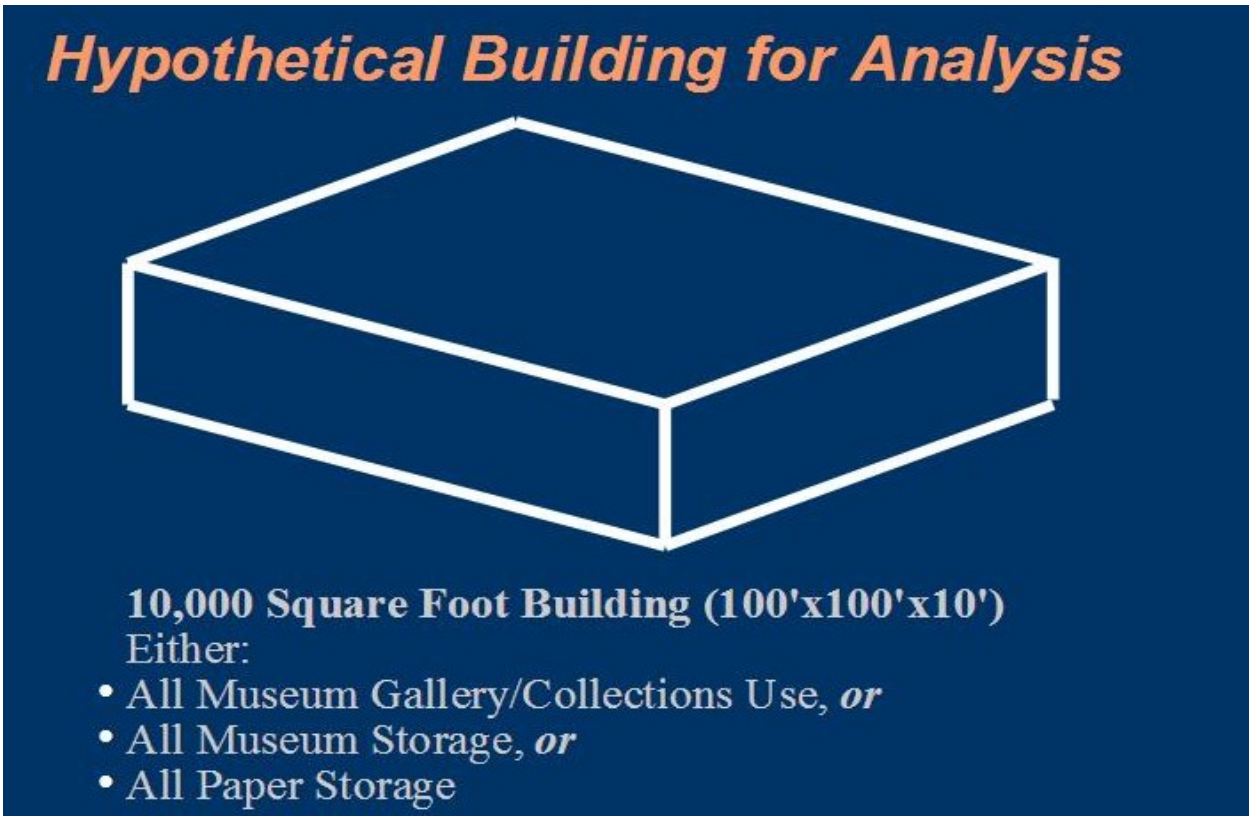
$$\text{Annual \$ Cooling} = \text{KWH} \times \text{\$/KWH}$$

For this analysis, the following hypothetical energy rates are used for all locations to allow cross-comparisons:

$0.10/KWH
$1.00/Therm

Using these equations, and the local climate data for Montreal, Toronto, Vancouver, Winnipeg, and Calgary, the effect of relaxed interior conditions - changed interior set-points - can be estimated. Climate is the operative variable for the comparison, with other factors (building construction, systems, utility rates) held constant.

HYPOTHETICAL BUILDING. To consider the effects of relaxed criteria, a hypothetical building must be considered to have the area and air volume factors to use in the equations. For this analysis, a building 100 feet by 100 feet and 10 feet tall, 10,000 gross square feet in area (30.5m x 30.5m x 3m, 929 gross square meters) is considered. Further, this building might be any one of three types: a) museum gallery/collections use spaces; b) museum collections storage; and c) archival paper storage. Hypothetical building occupancy/use is the same between the five cities for this analysis.



Such a building then has these conditions and requirements:

- 10,000 CFM of Supply Air Fan @ 3 inches total pressure
- Building Envelope to ASHRAE Standard 90.1
- 100' x 100' x 10' space = 4,000sf walls, 10,000 sf roof,
- ASHRAE 90.1-2007 U-values: 0.09 walls, 0.048 roof
  Combined U-value for Envelope = 0.060
- Outside Air to ASHRAE Standard 62.1

Gallery/Collections Use spaces:
  - 0.060 CFM/sf, 7.5 CFM/person, 40 sf/person = 2,475 CFM

Storage spaces:
  - 0.060 CFM/sf, 7.5 CFM/person, 2 people = 1,215 CFM

- Occupied Internal Gain (Lights + Equipment)
  Gallery/Collections Use spaces: 3 watts/sf
  Storage spaces: 1 watt/sf
- No System Effects/Loads Only (i.e., maximum savings for changes)
- Occupied 10 hours/day (2 hours in storage), 7 days/week, 51 weeks/year
  (3,570 hours/year), *but 24 hour/365 days control*

ENERGY COST SAVINGS FROM RELAXED CRITERIA

The following three tables, one for each building type, summarize the annual energy cost savings estimates for the five cities cited in the hypothetical building:

Table 1.1 - Energy Cost Savings From Relaxed Criteria in Gallery/Collections Use Space

Annual Savings from Relaxed Criteria (60-78@40-60% vs 68-72@45-55%) in Gallery Building	**MTL**	**TO**	**CGY**	**WPG**	**VAN**
KBTU Heating/SF	46	44	52	47	40
KWH Cooling/SF	0.52	0.67	0.07	0.43	0.12
Cost Savings/SF	$0.56	$0.58	$0.61	$0.59	$0.49

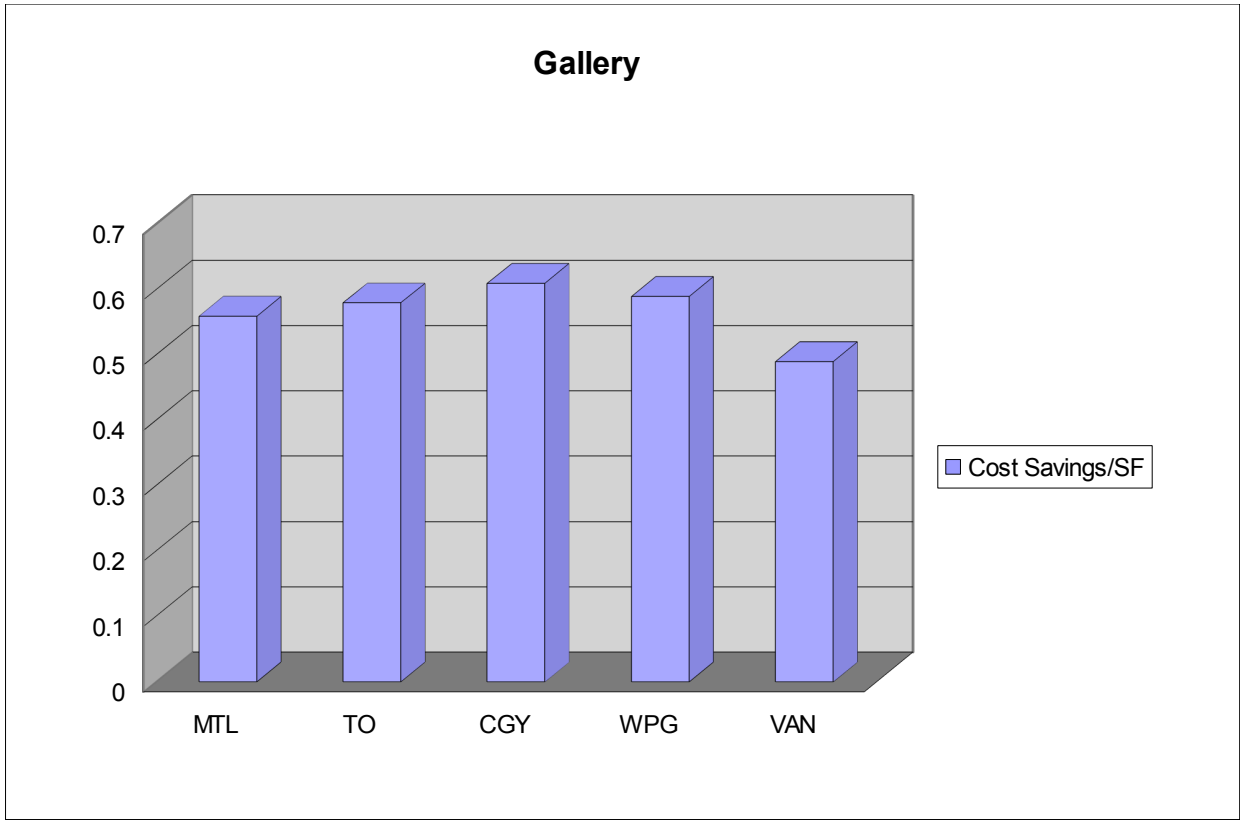


Table 1.2 - Energy Cost Savings From Relaxed Criteria in Museum Storage Space

Annual Savings from Relaxed Criteria (60-78@40-60% vs 68-72@45-55%) in Storage Building	**MTL**	**TO**	**CGY**	**WPG**	**VAN**
KBTU Heating/SF	**26**	**25**	**28**	**27**	**23**
KWH Cooling/SF	**0.26**	**0.34**	**0.03**	**0.22**	**0.06**
Cost Savings/SF	**$0.33**	**$0.33**	**$0.34**	**$0.33**	**$0.28**

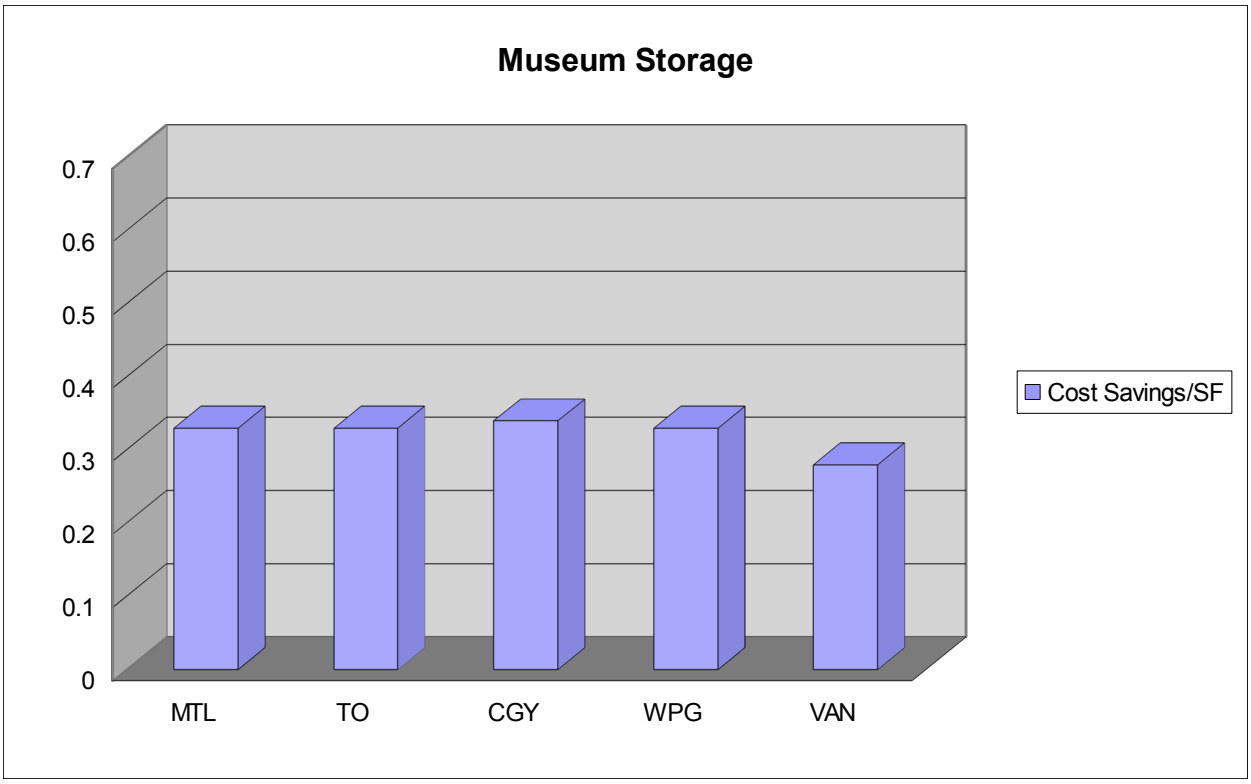
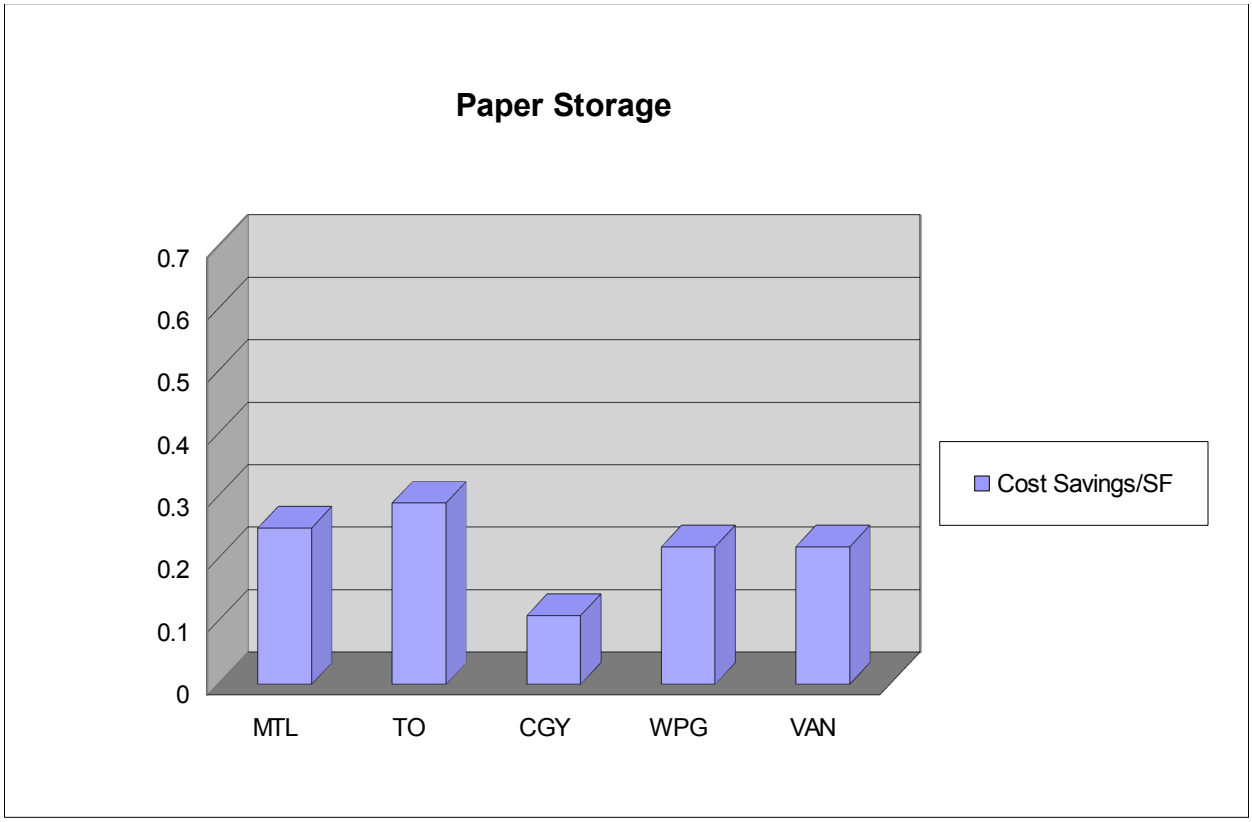


Table 1.3 - Energy Cost Savings From Relaxed Criteria in Archival Paper Storage Space

Annual Savings from Relaxed Criteria (60-78@40-60% vs 60@35%) in Paper Storage	**MTL**	**TO**	**CGY**	**WPG**	**VAN**
KBTU Heating/SF	**11**	**12**	**5**	**9**	**10**
KWH Cooling/SF	**1.39**	**1.66**	**0.63**	**1.25**	**1.18**
Cost Savings/SF	**$0.25**	**$0.29**	**$0.11**	**$0.22**	**$0.22**



PERMANENCE IMPACT OF RELAXED CRITERIA. For archival paper storage, the preservation impact from relaxed criteria can be made using the Image Permanence Institute's Preservation Index (PI).

60 degF/35% RH = **110 PI**
60-78 degF/35-60% RH = (16 to 110 PI range) **63 PI**
Changed permanence ratio (63/110) is **57%**

If collections were going to last 500 years, changed conditions reduce life to 286 years, or *an additional loss of 0.15% per year.*

Consider the value at risk in typical archival storage of books on compact shelving:

Compact Stacks @ 30 volumes/square foot
Presume cost to reformat is $130/volume
= $3,900 per square foot at risk

This leads to an additional loss of:

0.15% x $3,900 per year = **$5.82/SF/year**

Compare this to total energy savings per square foot/year. The institution should decide if the energy savings are a good idea.

CONVERTING COSTS TO LOCAL ENERGY RATES. Energy use rates vary not only by location but by utility schedules for customer types. To allow a direct comparison, the previous cost comparisons all use the same rates: $0.10/KWH, and $1/Therm. The actual rates an institution will pay will vary from these, and the savings can be adjusted for actual rates.

For example, if the actual rate an institution in Montreal pays is $0.09/KWH and $0.60/Therm, their hypothetical gallery building energy savings from Table 1.1 would be calculated as follows:

Given:

in Gallery Building	**MTL**
KBTU Heating/SF	**46**
KWH Cooling/SF	**0.52**
Cost Savings/SF	**$0.56**

Heating/SF by natural is $0.60/Therm:

46,000 BTU divided by 100,000 BTU/Therm = 0.46 Therm

0.46 Therm X $0.60/Therm = **$0.28/SF**

Cooling/SF by electric power is $0.90/KWH:

0.52 KWH X $0.09/KWH = **$0.05/SF**

Cost Savings/SF is then: $0.28 + $0.05 = **$0.33/SF**

GLOBAL CLIMATE SUSTAINABILITY FOR CARBON DIOXIDE EMISSIONS

The following three tables, one for each building type, show the carbon dioxide emission savings associated with the energy cost savings from the same relaxed criteria.

Table 2.1 - Carbon Dioxide Savings From Relaxed Criteria in Gallery/Collections Use Space

Annual Savings from Relaxed Criteria (60-78@40-60% vs 68-72@45-55%) in Gallery Building	**MTL**	**TO**	**CGY**	**WPG**	**VAN**
KBTU Heating/SF	**46**	**44**	**52**	**47**	**40**
KWH Cooling/SF	**0.52**	**0.67**	**0.07**	**0.43**	**0.12**
Pounds CO2 Savings/SF	**5.43**	**5.26**	**6.12**	**5.62**	**4.72**
CO2 based on:					
KWH: http://carma.org/region					
Pounds CO2 Per MWH	85	169	527	277	370
Pounds CO2 Per 100,000 BTU	3	5	15	8	11
Natural Gas: http://www.epa.gov/cleanenergy/energy-resources/calculator.html					
Pounds CO2 Per 100,000 BTU	12	12	12	12	12

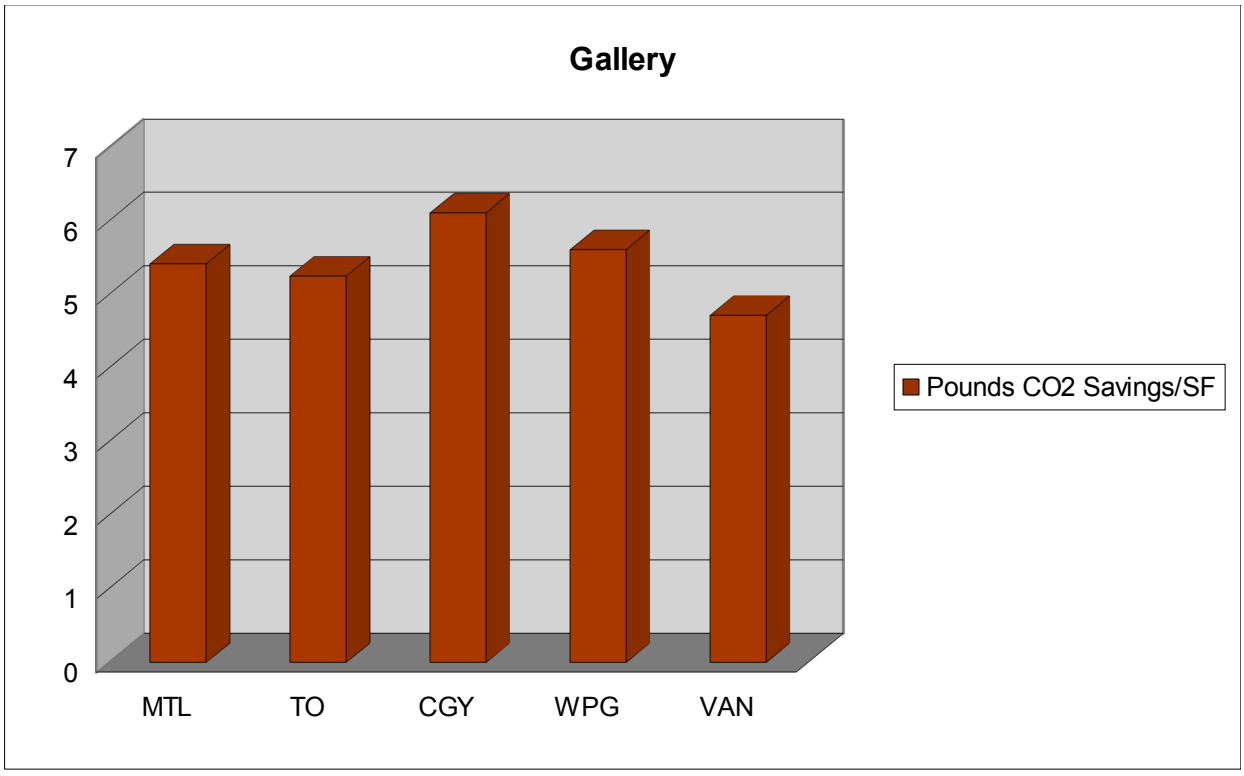


Table 2.2 - Carbon Dioxide Savings From Relaxed Criteria in Museum Storage Space

Annual Savings from Relaxed Criteria (60-78@40-60% vs 68-72@45-55%) in Storage Building	**MTL**	**TO**	**CGY**	**WPG**	**VAN**
KBTU Heating/SF	**26**	**25**	**28**	**27**	**23**
KWH Cooling/SF	**0.26**	**0.34**	**0.03**	**0.22**	**0.06**
Pounds CO2 Savings/SF	**3.06**	**2.98**	**3.29**	**3.22**	**2.71**
CO2 based on:					
KWH: http://carma.org/region					
Pounds CO2 Per MWH	85	169	527	277	370
BTU Gas: http://www.epa.gov/cleanenergy/energy-resources/calculator.html					
Pounds CO2 Per 100,000 BTU	12	12	12	12	12

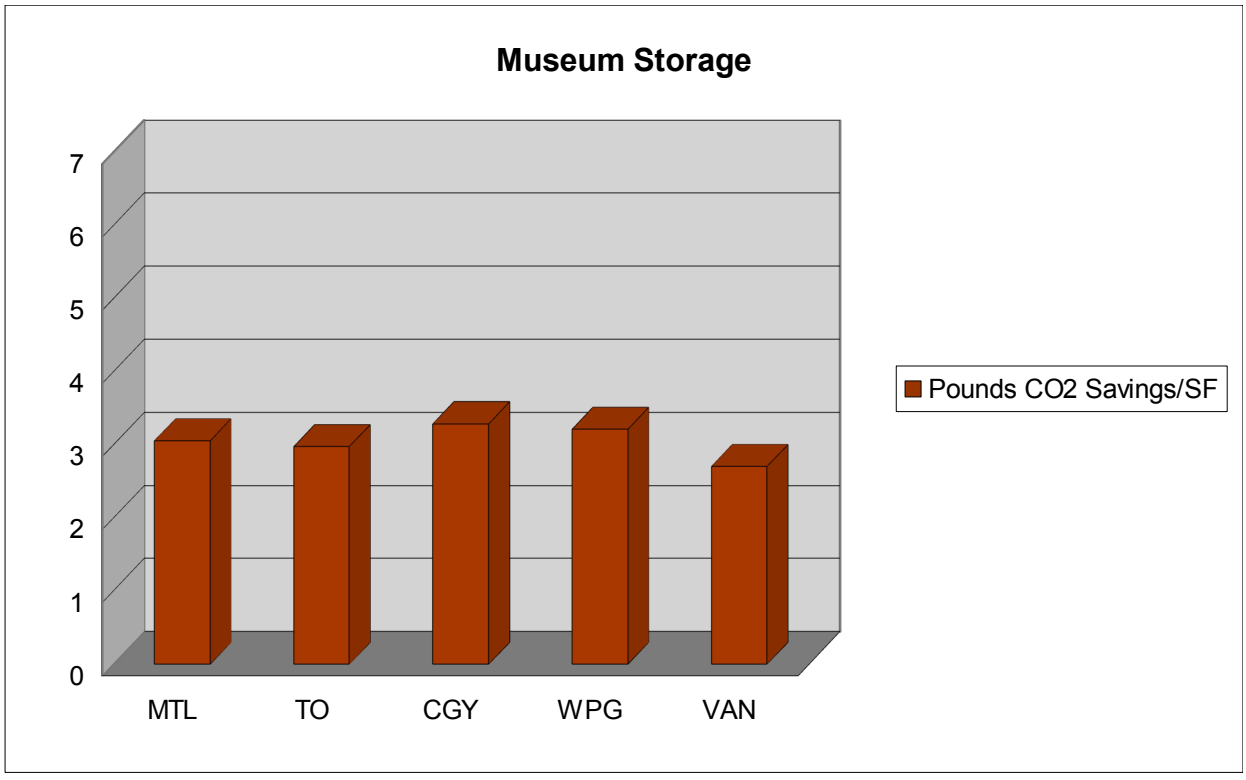
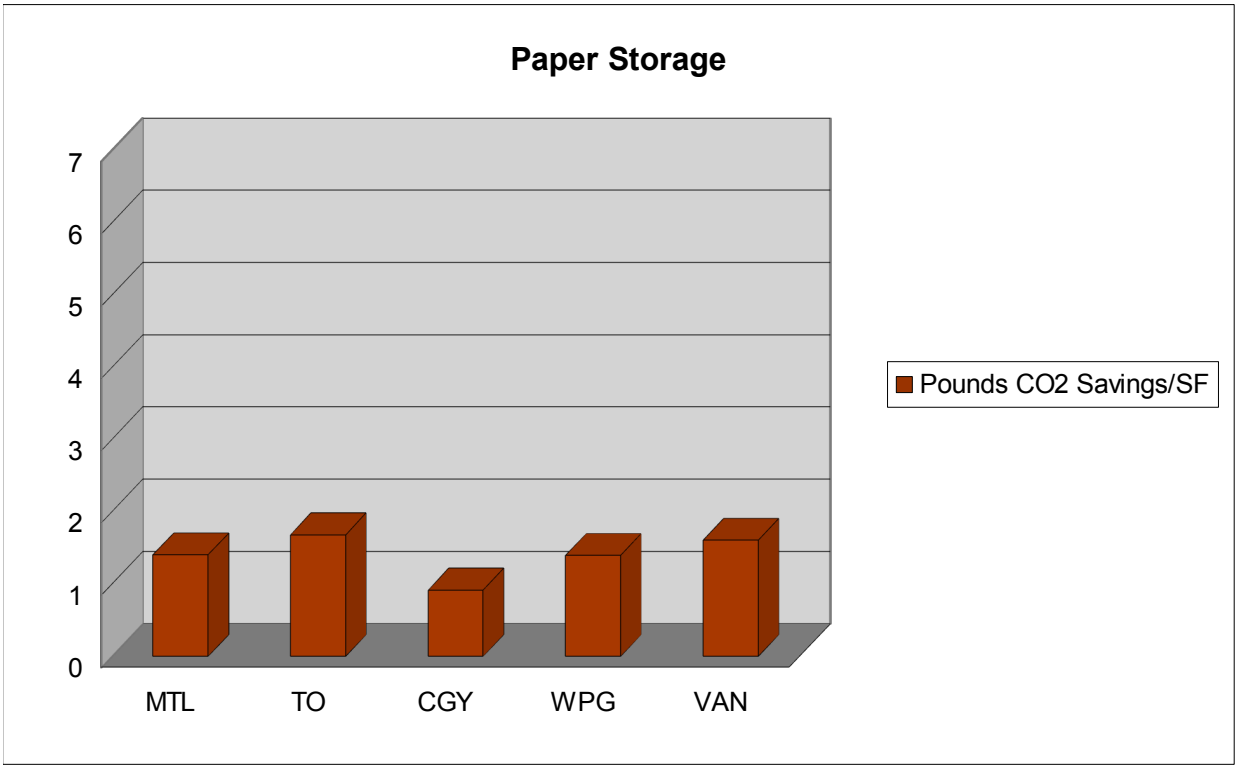


Table 2.3 - Carbon Dioxide Savings From Relaxed Criteria in Archival Paper Storage Space

Annual Savings from Relaxed Criteria (60-78@40-60% vs 60@35%) in Paper Storage	**MTL**	**TO**	**CGY**	**WPG**	**VAN**
KBTU Heating/SF	11	12	5	9	10
KWH Cooling/SF	1.39	1.66	0.63	1.25	1.18
Pounds CO2 Savings/SF	1.41	1.68	0.92	1.40	1.61
CO2 based on:					
KWH: http://carma.org/region					
Pounds CO2 Per MWH	85	169	527	277	370
BTU Gas: http://www.epa.gov/cleanenergy/energy-resources/calculator.html					
Pounds CO2 Per 100,000 BTU	12	12	12	12	12



CONCLUSION

Relaxed criteria clearly provide energy and operating cost savings, as well as reduced carbon dioxide emissions. The institution must decide if collections are put at risk from the relaxed criteria. For archival paper storage, this may not be a good economic choice depending on the collections stored and the cost to reformat to recover from environmental deterioration over time.

Endnotes:

(1) **http://www.conservation-wiki.com/wiki/Environmental_Guidelines**

(2) http://www.clir.org/pubs/reports/isoperm/isoperm.html Sebera, Donald K.; Isoperms: An Environmental Management Tool, Commission on Preservation and Access, June 1994; (based on "A Graphical Representation of the Relationship of Environmental Conditions to the Permanence of Hygroscopic Materials and Composites," Proceedings of Conservation in Archives, International Symposium (Ottawa, May 10-12, 1988), Paris: International Council on Archives (1989), p. 51-75). (The Commission on Preservation and Access has merged into the Council on Library and Information Resources, 1755 Massachusetts Avenue, NW, Suite 500, Washington, DC 20036, 202-939-4750. They are now the source for the old Commission publications, including Sebera's Isoperms.

(3) **http://dpcalc.org/**

(4) **http://ashrae.org/**; ASHRAE, 1791 Tullie Circle, N.E. Atlanta, GA 30329; (404) 636-8400

Key Words and Terms: Energy, Climate, Criteria, Load, Temperature, Humidity, Archival, Preservation, Utility, Relaxed, Heating, Cooling, Humidification, Dehumidification

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Mr. Lull is a graduate of the Building Technology program at MIT, a principal and senior conservation environment consultant at Garrison/Lull Inc., and Adjunct Associate Professor of Building Technology at New York University. He has formerly worked as a designer and project manager for architects, engineers and government agencies.

Mr. Lull has been an invited lecturer for many university, professional and state-sponsored training programs. He has made presentations at AIC, IES, ASHRAE and AIA, and has consulted to the Department of Energy. Active in on several ASHRAE technical and research management committees, he has written several articles and papers on conservation environment issues in building construction, and regularly contributes to the ASHRAE Handbook. He is certified by ASHRAE as a Building Energy Analysis Professional.

In the last 30 years, he has consulted on new or renovated environments on over 200 museums, libraries and archives, including: the Museum of Modern Art, the Nelson-Atkins Museum, Monticello, the new Mount Vernon Museum, the Harvard Depository, Widener Library; the new or renovated state archives in Alabama, Arizona, Delaware, Georgia, Mississippi, New York, Oregon, South Carolina, Utah; and the Bermuda Archives.

Prior to his conservation environment work, Mr. Lull was involved in energy management, including positions as:

- Manager of the Energy Management Division at Dubin-Bloome Associates where he was Project Manager for the 1981 Conceptual Design of the Solar Energy Research Institute (SERI), now the National Renewable Energy Laboratory (NREL).
- Project designer in the Solar and Energy Conservation Group, Architectural Design Branch (ADB), Division of Engineering Design (EnDes), at the Tennessee Valley Authority (TVA); and
- Assistant Chief of Design at Syska & Hennessy Engineers.

In recent years, he has consulted to the Department of Energy to evaluate grants on energy conservation in buildings. In November 2010, Mr. Lull was a formal reviewer for the US Department of Energy for over 30 grant proposals under FOA115.