climatechange

AND MUSEUM COLLECTIONS

The Inaugural Event of
DIALOGUES FOR THE NEW CENTURY

Roundtable discussions on the conservation of
cultural heritage in a changing world

The International Institute for Conservation of Historic and Artistic Works

climatechange

AND MUSEUM COLLECTIONS

September 17, 2008 / 6:15 PM – 7:30 PM

The National Gallery — Sainsbury Wing Theatre

The International Institute for Conservation of Historic and Artistic Works (IIC) invites you to join the discussion on the implications of climate change and its effects upon cultural heritage, particularly that which is contained in museums and house collections.

Introductions:

Jerry Podany
President IIC

Sarah Staniforth
Historic Properties Director, The National Trust, moderator

Presentations:

Professor Christina Sabbioni
Research Director, Institute of Atmospheric Sciences and Climate, CNR (Italy) and Coordinator of EC Project Noah's Ark

Professor May Cassar
Director, Centre for Sustainable Heritage, University College London and AHRC/EPSRC Programme Director for Science and Heritage

James M. Reilly
Director, Image Permanence Institute, Rochester, New York

Michael C. Henry
Principal Engineer/Architect with Watson & Henry Associates, New Jersey

Sir Nicholas Serota
Director, Tate

The changing climate of our earth has implications that go well beyond the dramatic effects of storms and rising sea levels, shifts in migratory patterns and habitats, or the potential for increased health risks from pollutants. Weather patterns and temperature variations also affect the long term preservation of the world's cultural treasures which we enjoy and which inspire us every day.

The threats that come with climate change do not just exist in the outdoor environment. The delicate and fragile treasures within our museums are also susceptible. Museum and house collections that may not have previously required environmental control may soon require such efforts to meet their preservation responsibilities. Those collections protected by environmental systems may be at greater risk if such systems are not updated and expanded in capacity. To remain effective the maintenance plans for historic buildings, public monuments, and archaeological sites will require adaptation to our changing climate.

Such needs come at great cost unless planned well in advance, and traditional solutions may ultimately directly contribute to our global climatic problems. The development of more efficient, affordable, and environmentally sustainable systems is now more important than ever. These issues and many others are the focus of this roundtable.

This event is made possible by the generous support of the Samual Kress Foundation; Suzanne Deal Booth, Booth Heritage Foundation; Tom Pritzker and the Hyatt Regency Hotels; Julian Hills, The Ant Farm; the National Gallery in London; and the many members of the IIC world wide.

The International Institute for Conservation of Historic and Artistic Works

Dialogues for the New Century

Discussions on the conservation of cultural heritage
in a changing world

CLIMATE CHANGE AND MUSEUM COLLECTIONS

Held on 17 September 2008 at The National Gallery, London

Edited transcription

IIC photograph by Gary Black

Introductions

Jerry Podany
President, International Institute of Conservation

On behalf of the IIC Council and the speakers for this evening's dialogue, I want to thank you for coming to the Sainsbury Theater of the National Gallery of Art and to welcome you to the first event of the IIC's recent initiative ***Dialogues for the New Century***. I'm going to be very brief because what we all really want to do this evening is hear these six experts discuss and debate an extraordinarily important concept, the effects of climate change on cultural heritage. It is important however to define what the purpose of the IIC's new initiative, *Dialogues for the New Century*, is and what the intent of this evening's particular event is meant to be. *Dialogues for the New Century* was created to raise awareness and

to promote discussion focused on the issues and concerns of our time that influence, and are influenced by, heritage conservation.

This first Round Table has exactly that purpose and is focused on climate change and the effects of the changing climate on museum collections.

While this dialogue and its results will be broader than our original intent, I should perhaps explain why the title limits the topic to *museum collections* despite our awareness that climate change has an impact on all aspects of cultural heritage. The relatively small body of published work and research on the effects of climate change on cultural heritage concentrates on the built environment, sites and the natural surround. Work concerned with the relationship between climate change and museum collections is all but non existent. This roundtable is meant to fill a very specific and significant gap in our knowledge and our awareness. The IIC wishes to begin the dialogue and to hand it to the profession for further development.

I'd like you to imagine a spectrum. On one end are informed and enlightened people who know what this challenge is and who are struggling to find ways to address it. Six of them are here tonight to share their expertise. Over on the other end of this spectrum are the uninformed, the stubborn and even those who are sceptical about the very existence of climate change and its effects. Scattered along our spectrum and clustered surprisingly close to the end populated by the uninformed, are many conservation and museum professionals who, through no fault of their own, remain unaware of the challenges that museums are about to face. They believe that their collections are, after all, safely tucked within the walls of their museums, safe from any climate threat. They ask, 'What could be the problem?' And they say 'The issue of climate change is so large…what could any individual conservator really do about it?' or 'I know that climate change and natural resources conservation is an important issue, but what does it all have to do with heritage conservation and with me?'

This reminds me of the discussions a decade ago surrounding the protection of collections from damage due to earthquakes – 'Oh, it's in a museum, it's OK'. We have made great progress in the area of earthquake damage mitigation and we hope to make even more progress in this area of climate change. To do that however, we need both involvement and support.

In that cluster of the unaware and even the sceptical, exist a surprising number of funders. Pointing to their position is not meant as a criticism, but rather as a challenge. There are numerous emerging challenges which the conservation profession will face in the next decades. Efforts to resolve them may not all fit neatly into the traditional funding categories commonly used. It will require creativity and the willingness to take some risks in order to provide the needed support. It is at our peril and the peril of the heritage we claim to protect and preserve, if we greet these challenges with indifference.

It is therefore even more important that we recognise those who so generously did support this inaugural round table event:

The **Samual Kress Foundation** who recognized the value of the speakers and their topics; **Suzanne Deal Booth and the Booth Heritage Foundation**, for continuing to believe this event could be done despite significant odds to the contrary; **Thomas Pritzker and the Hyatt Regency Hotels**, I had not finished the first sentence of my description of the roundtable before Tom stopped me to acknowledge the importance of this event and offered generous assistance; **Julian Hills and The Ant Farm Design Group**, for lending their exceptionally creative touch to the program and the visualization of our topic; the **Foundation of the American Institute for Conservation (FAIC)**, for assisting the IIC in managing the financial support from the United States; and finally **Ashok Roy and the National Gallery** for generously providing this magnificent venue, the Sainsbury Theatre.

It is now time to start our dialogue; one which I am confident will expand well beyond the bounds of the program before you and well beyond the time frame of this evening. Climate change is upon us and in the spirit of collaborative strength let us seek the solutions that will benefit heritage across our world and help us meet our responsibilities as stewards of heritage collections in that changing world.

I now welcome our moderator Sarah Staniforth, well known by all of you for her tireless efforts in exactly this subject.

Sarah Staniforth
Historic Properties Director, The National Trust

Good evening, ladies and gentlemen. It's a very great pleasure to be back here, in one of my former places of work. This evening you see that I am your moderator, and you probably - those of you who have heard me on this subject - know that I am not particularly moderate on it. In fact, I'm known to be quite passionate about it. However, my role this evening is not as a protagonist but as a mistress of ceremonies, which I shall try to do, both introducing our five very distinguished speakers this evening, and also inviting you to contribute from the audience. When I ask you to contribute, because this evening is being transcribed, very capably by Susan Hughes, may I ask that you introduce yourselves with your name and the organisation, if you have one, that you are affiliated to.

But without more ado I am going to introduce all five speakers so that we can maximise the time available for discussion. And they are very well-behaved and have sat down in the order in which they are going to speak. On your left we start with Professor Cristina Sabbioni, who is Research Director from the Institute of Atmospheric Sciences and Climate in Italy, and she's been the Co-ordinator of the European Commission's Noah's Ark Project - very well-named, if I may say – not one of those incomprehensible acronyms but something that actually means something for the subject of the research. On Cristina's right is Professor May Cassar, very familiar to the IIC as a member of IIC Council, Director for the Centre for Sustainable Heritage at University College London and she's also Programme Director for the new AHRC (the Arts and Humanities Research Council) and EPSRC (the Engineering and Physical Sciences Research Council) Science and Heritage Programme.

In the middle is James Reilly, all the way from Rochester, New York. James is Director of the Image Permanence Institute. Second from the right is Michael C. Henry, Principal Engineer and Architect with Watson and Henry Associates in New Jersey, in the States, and since this programme has been printed we must congratulate Michael on his appointment as Adjunct Professor of Architecture at the School of Design in the University of Pennsylvania, based in Philadelphia. And finally on our panel of very distinguished speakers is Sir Nicholas Serota, who is Director of Tate here in London and I would say is in charge of one of the most vulnerable museums in London, if the predictions that there's going to be no ice in the Arctic in 2030, come true.

Presentations

Professor Cristina Sabbioni
Research Director, Institute of Atmospheric Sciences and Climate, CNR (Italy), and Co-ordinator of EC Project Noah's Ark

CLIMATE CHANGE AND CULTURAL HERITAGE RESEARCH

Starting this Round Table on climate change, we must all recognise that climate change is currently attracting an enormous amount of attention both at the political and research level. But this attention is focused mostly on sectors such as environment, industry,

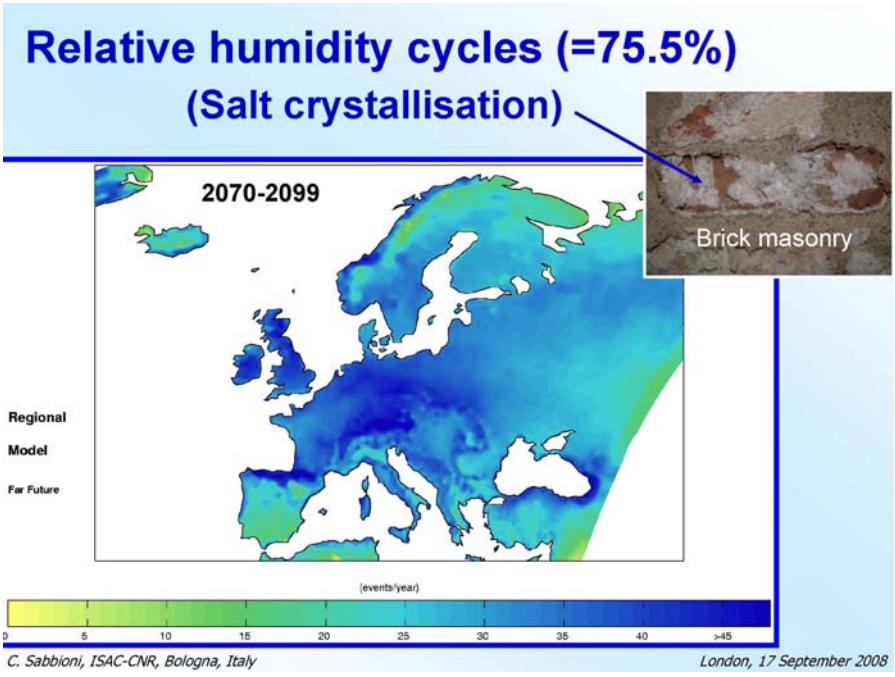
energy, transport and health. Until now it has not yet been considered as a threat to cultural heritage, a non-renewable resource which needs to be transmitted to future generations. The Noah's Ark Project created for the first time a synergy between climate change and cultural heritage scientific research.

The Noah's Ark Project was funded within the 6th Framework Programme for Research by the European Commission. The project consortium is composed of ten partners of seven EU member states, including two universities, six public research organisations, one insurance company and one SME.

But what has been done to investigate the impact of future climate variations on outdoor cultural heritage? First of all, a database of future climate variables has been created on the basis of temperature-derived parameters including temperature range; water-derived parameters such as precipitation amount, relative humidity range, mean relative humidity; wind-driven parameters including wind speed, wind speed counts; and pollution-derived parameters such as SO_2, nitric acid, ozone, pH precipitation. The data outputs from the Hadley General Model (HadCM3) were used relating to three different periods, the recent past from 1961-1990, the near future 2010-2039 and the far future 2070-2099. For the 30-year period 2070-2099, the Regional Hadley model (HadRM3) was also adopted. The future data outputs are based on the IPCC SRES scenario A2 which is a moderately positive, optimistic one. And all data outputs are focused and limited to the European window.

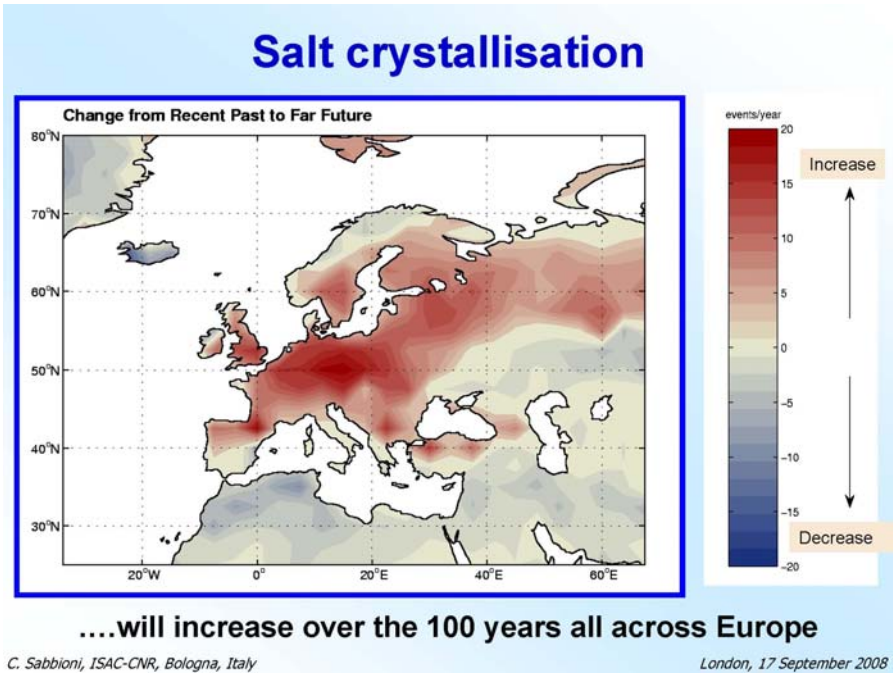
A selection of materials was performed, including natural stone, metals, wood, glass, and a number of damage functions have been used in order to quantify the damage occurring on the different materials as a consequence of the different climate factors. All these data and functions have been used in order to produce maps. And so 30-year mean maps have been produced and designed in accordance with the different types of impact, and I am going to show you some examples of the results produced by the Noah's Ark Project.

Relative humidity cycles through 75.5% have been mapped. It produces salt crystallization, precisely sodium chloride crystallization, which induces deterioration of materials, and you are all aware of the damage produced.

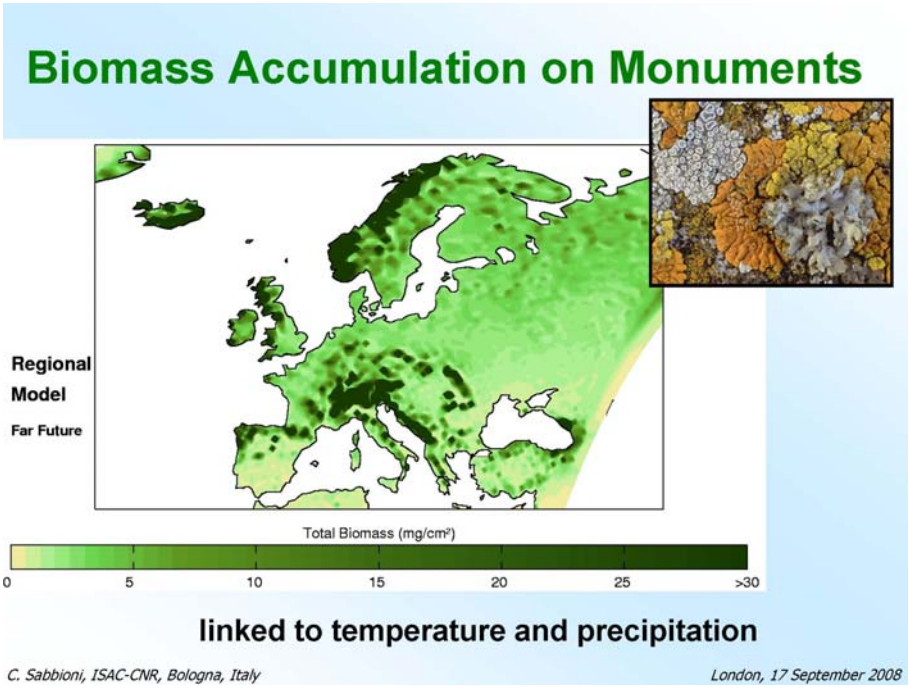


In this map you see the number of events per year that will occur in the far future period 2070-2099 and you can see the pattern of the number of events per year all over Europe predicted using the methodology I've just described.

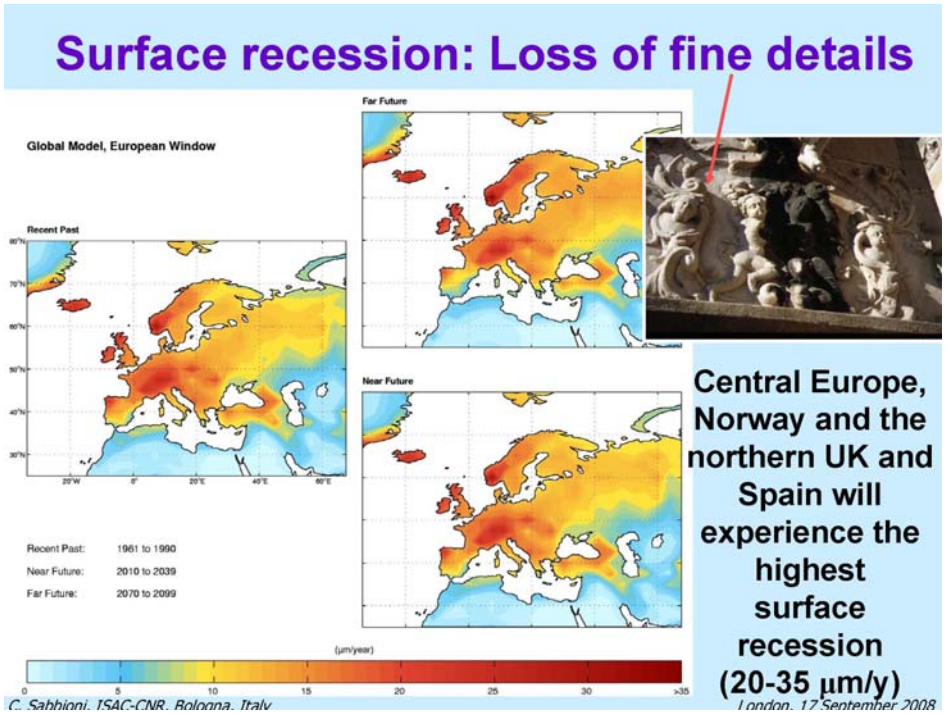
But it is not only important to know the number of events per year, but also how salt crystallization will change in the far future with respect to the 1961-1990 period taken as a reference. And in this map you can see how the change will occur. There will be a general increase in the number of cycles per year over the 100 years all across Europe.



Biomass accumulation on monuments can be modelled using some functions linked to yearly mean temperature and precipitation, and again for the far future period, and using the Regional model, the total biomass in terms of mass per square centimetre is the pattern all over Europe.

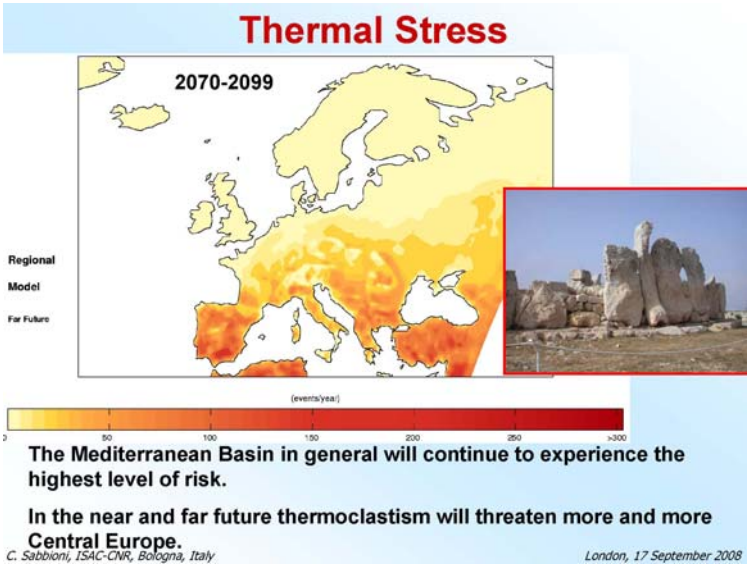


Surface damage functions based on climate parameters available from the Hadley model have also been proposed or utilised to quantify the damage occurring on building materials in future scenarios. Here you have the quantification of the surface loss of carbonate stone due to rain impact, mainly leaching on carbonate stone due to rain. So we have a loss of detail and the result is the surface recession, which can be quantified in terms of micrometres per year. So these maps show for the three different periods how the surface recession occurs on the surface and how it will develop in the three different periods. You can see that the areas which will experience the highest surface recession are central Europe, Norway, northern UK and Spain.

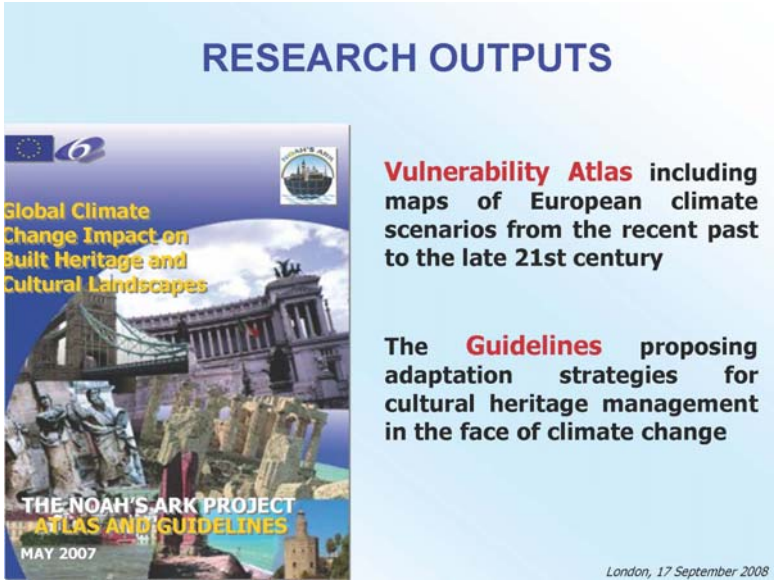


Thermal stress is another damage which can be induced on stone, particularly calcite, when temperature variation occurs. For the far future, a projection has been produced and the maps show how the Mediterranean basin in general will continue to experience the

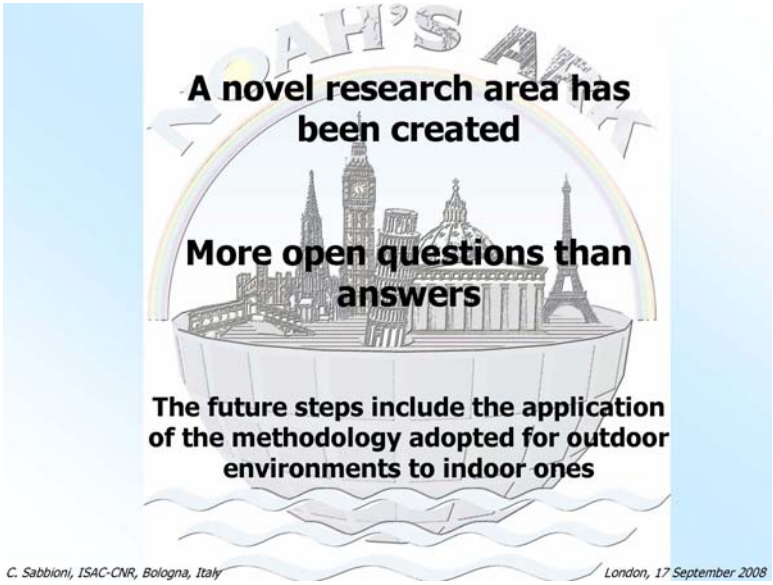
highest level of risk. But in the near and far future thermoclastism will threaten more and more Central Europe.



One of the main outputs of the Noah's Ark Project was the Vulnerability Atlas and Guidelines.



The Vulnerability Atlas includes maps of European climate scenarios from the recent past to the late 21st century and it shows the threat of climate change on the built heritage and cultural landscape. The Guidelines propose adaptation strategies for cultural heritage management in the face of climate change.



Another research area has been created, but in front of us are more open questions than answers. Future steps include the application of the methodology adopted for outdoor environments to indoor ones. It needs to be done collaboratively and above all the effort must be global. It has started in Europe but now must go global.

Professor May Cassar
Director, Centre for Sustainable Heritage, University College London, and AHRC/EPSRC Programme Director for Science and Heritage

CLIMATE CHANGE AND THE COLLECTION ENVIRONMENT

Good evening. I will touch upon damage risks to collection materials in response to indoor temperature and relative humidity changes. I would also like to comment briefly on environmental control and energy use, since this is currently a very live topic.

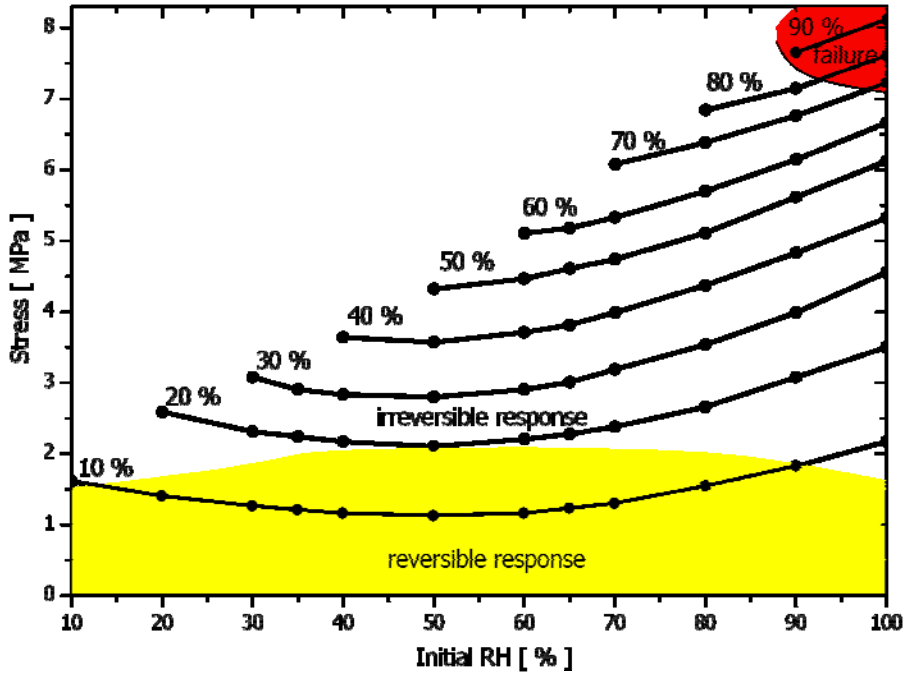
If the climate becomes more extreme or unstable, it will increase the risk of damage to collections, and we need to understand the link between damage and the environment a lot better than we do. So is the behaviour of indoor materials affected in the same way by climate change as outdoor materials, which we've just heard about? As we've heard, outdoor materials are affected by changes in the amount of precipitation, wind speed, solar radiation and biomass from which generally indoor materials are protected, while indoor materials are damaged by the rate of fluctuations and extremes of relative humidity and temperature, mould and pollutants.

An expression of damage used by geologists but used already by Cristina is the 'damage function'. Damage functions are used by scientists working on outdoor cultural heritage to express quantitatively the damage induced by climate parameters on building materials. We need an intellectual step-change in our understanding of the link between damage and environmental change so that we can base our decisions on the care of collections,

environmental specifications and energy use on good science. And good science cannot be rushed and it needs to be resourced.

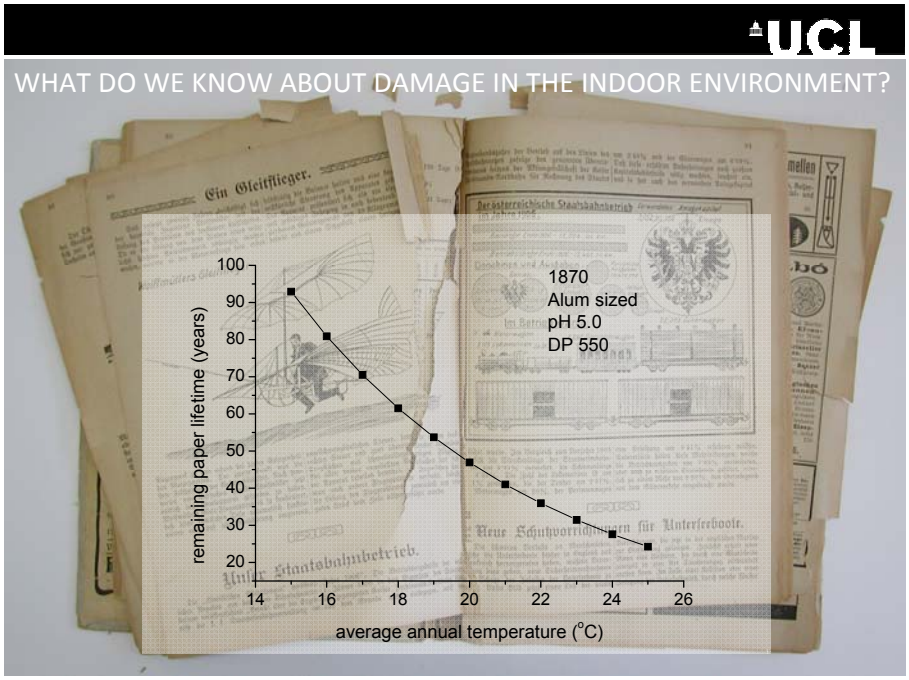
Most of the damage functions that exist for cultural heritage relate to outdoor conditions: chemical attack; heating and cooling cycles; freeze-thaw cycles for stone and masonry materials, metal, glass and wood. These would not translate meaningfully to indoor conditions.

What do we know about damage in the indoor environment? Mecklenburg in 1998 quantified the mechanical properties and swelling response of wood, and determined the allowable RH variations. Jakiela, Bratasz and Kozlowski this year have published maps of the stress levels induced by daily RH variations in limewood sculptures. They concluded that limewood could conservatively withstand fluctuations of +/- 20%. However, the band of tolerable fluctuations becomes narrower at higher initial RHs, for example when wet wood is suddenly dried, in the case of a post-flood situation for example. However, this work could usefully provide an indoor damage function for us.



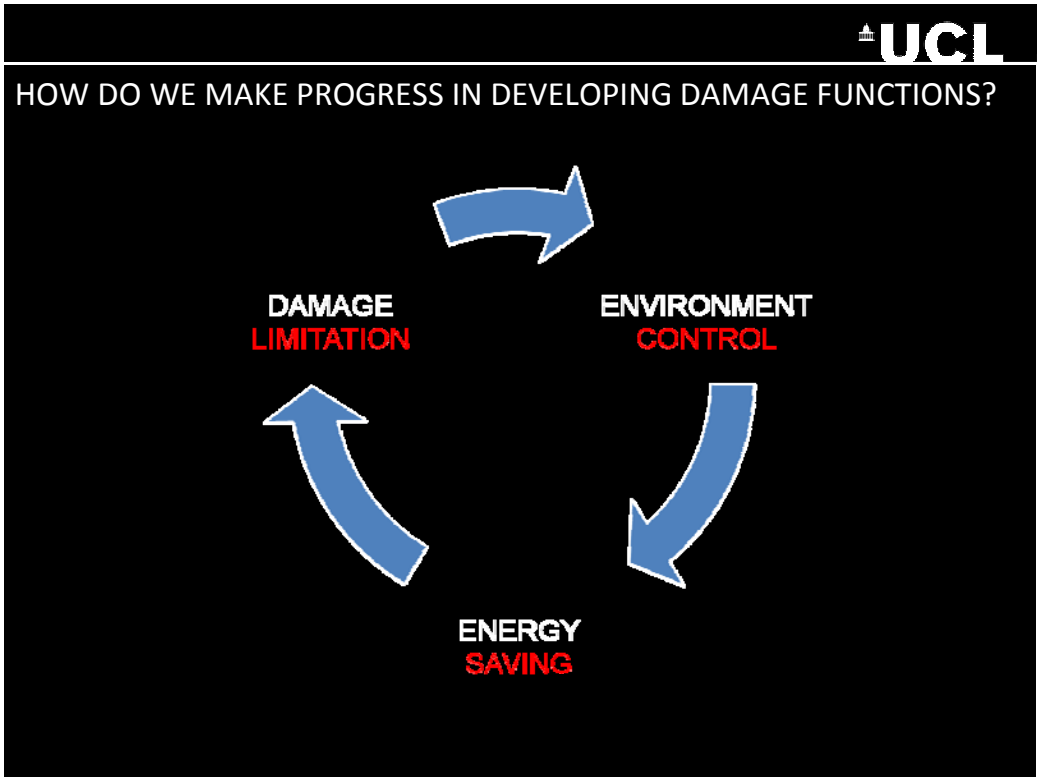
Ref: Jakiela, Bratasz, Kozlowski, *Wood Science and Technology,* **42**, 21-37 (2008).

Presently, we only know the dependence of the rate of the degradation of paper on temperature (at and around room temperature), but not on relative humidity. Strlič and Kolar in 2005 have shown that a 4ºC increase in storage temperature may be reflected in a 40%-50% reduction of lifetime. Since we currently do not have data that enables us to predict the damage effect of RH at room temperature, it is not possible to model climate change impact on paper with increased indoor relative humidity.



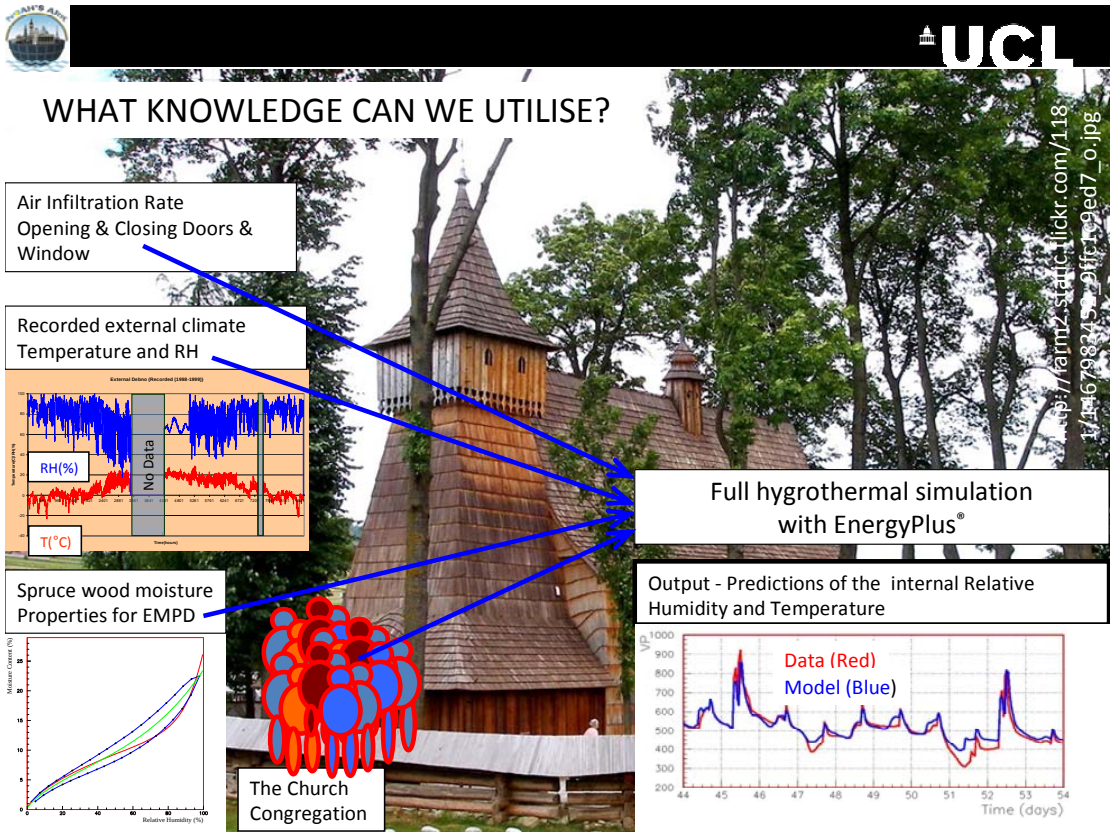
Ref. Strlic and Kolar (2005)

So how do we make progress in developing damage functions for museum materials, so that we can then go on to look at what the likely future impacts of climate change might be on these materials? Conservators have the best knowledge of the physical state of collections and which materials best represent a collection, using data from condition surveys, to work out the risk of damage. This is a good starting-point for developing damage functions for museum materials. Conservators and scientists, together with curators, need to work together to develop damage functions for a range of collection materials. Once we have these, we can model the links between damage and the environment, and then the environment and energy.



Are we monitoring the right parameters and is the data of the right quality? Data older than a decade may be difficult to source and their quality may also be difficult to assess. More recent temperature and relative humidity data may be available but it will be managed in a variable way. Light data may be available but it may not be cumulative data. Pollution data is more complex because of the catalytic effect of pollutants - there are many methods of collecting pollutant data but unless these are standardised measurement techniques, it is not possible to produce reliable comparative results. No-one is yet monitoring mould growth indoors systematically.

What knowledge is out there that we can utilise, for example from the built environment research? We all use a range of 'models' to understand what's going on, from 'simple common sense' through the 'back of an envelope' to simple spreadsheets and finally sophisticated computer building simulation tools for predicting indoor temperature, relative humidity and energy use. Material properties and other data about the building are used to calibrate the model, then the model can be validated by comparing its predictions with real data.



Ref: Nigel Blades, May Cassar and Phillip Biddulph, *Optimizing Drying Strategies to Reduce Down Times for Actively-Used Flood Damaged Historic Buildings*, Contributions to the London Congress CONSERVATION AND ACCESS, Edited by David Saunders, Joyce H. Townsend and Sally Woodcock, 15–19 September 2008

Once there is a validated model, other scenarios can be examined, for example: what effect will the changing weather have on the indoor environment? What will happen to environmental control and energy use if we alter the settings of the HVAC system? Modelling can also be used to simulate changing moisture content of large wooden objects indoors, and also for massed archival materials such as paper. But models are simply analogues and not a replacement for real data. Building simulation software is a single part of a wide set of tools needed to understand what is happening.

So what can we offer the debate on environmental standards at this time of climate change? As conservation professionals, we are challenged to be responsible for our use of energy. With our current knowledge, we can negotiate environmental standards for some wood- and paper-based collections, and we can apply modelling of the built environment and energy to different scenarios, for example present and future indoor environments and energy consumption.

We can reduce our use of fossil fuels now without altering our current environmental specifications. We can look around other activities with which we are engaged and look at their sustainability, for example we could consider having fewer blockbuster exhibitions transporting collections around the globe. We can switch to alternative forms of energy, but we may have to accept some changes in the appearance of cultural heritage, as solar panels and other forms of wind generation might appear. We can also relax environmental specifications. But with our present state of knowledge, we also have to understand better the implications for a possible increase in conservation treatments.

And we can work with scientists to develop damage functions for a wider range of collection materials. While energy is the current external driver of change to environmental specifications, as we strive to become more responsible stewards, not only for our museum collections, but for the global environment, damage to collections is the internal driver. I believe we cannot deal with one without the other.

James M. Reilly
Director, Image Permanence Institute, Rochester, New York

CLIMATE CHANGE AND THE CARE OF MUSEUM COLLECTIONS

Let's begin at the beginning, shall we? I would like to express my thanks at the beginning here to Jerry and to the IIC for asking me to be a part of this very interesting event tonight. It is clear from what we've heard today that the care of museum collections will indeed be affected by global climate change. In my remarks, I would like to present some thoughts on how we might respond to the challenge of effectively managing museum environments.

During the last twenty years, the advancement of preservation research has fundamentally altered the basic approach to analysing temperature and humidity conditions for cultural heritage collections. In the past, the paradigms for environmental control were based on the work of Harold Plenderleith and Gary Thompson, whose provisional suggestions of steady room temperature and near 50% RH, have taken on the force of established doctrine for many museums.

In the present day, with the advancements of research in chemical kinetics, biology and material science, we have a more nuanced understanding of how the environment influences collection materials. The scientific facts of collection deterioration do not support the simple notion of "one-size-fits-all environments". Every environment is a compromise in which various threats operate to greater or lesser degrees, depending on the nature of the object and the prevailing conditions. However, our ability to understand and model the effects of temperature and humidity has progressed to the point where we can manage the environment differently than in the past.

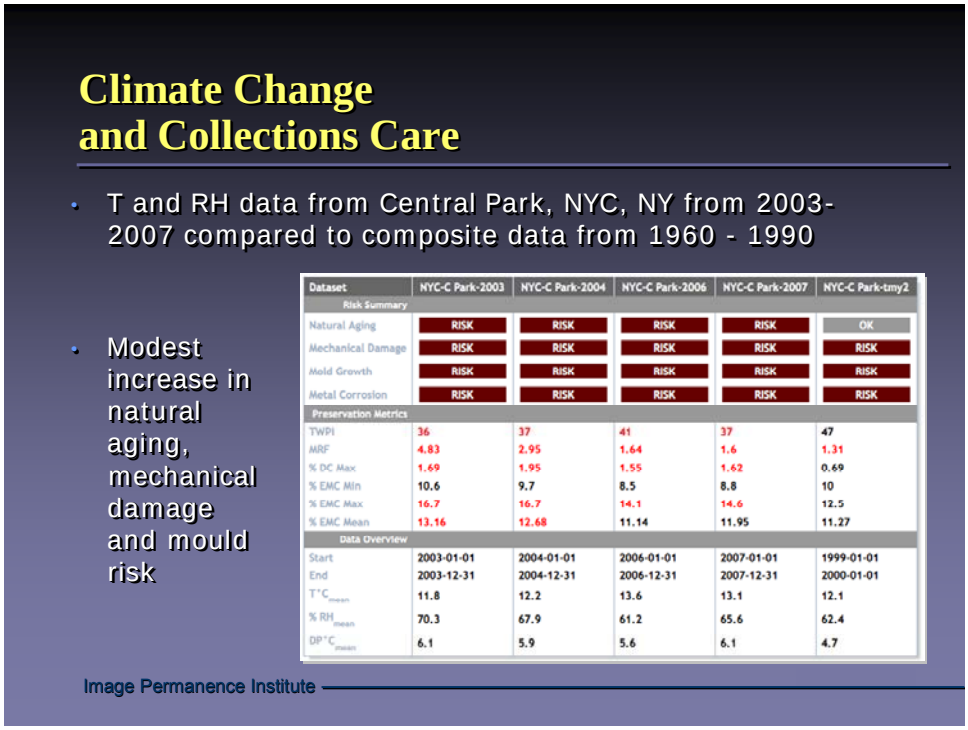
Modern tools for environmental management allow us to measure temperature and RH conveniently and accurately. Computers allow us to perform complex calculations on the data that yield quantitative estimates of the benefits or risks that may arise from any pattern of environmental conditions, be they steady or fluctuating. IPI (and that is the Image Permanence Institute that Sarah mentioned. We are in fact a full service provider of preservation technology. We began with photographs but are big into the environment right now.) has developed a number of such algorithms, calling them "Preservation

Metrics". They are useful because they directly address how much damage may be occurring to the collection objects. Because the Preservation Metrics integrate the effects of dynamic environmental changes over time, they can therefore yield some insight into what it means, for example, for a collection to experience more frequent and intense periods of heat and humidity than it has been accustomed to.

This approach of measuring the environment a priori, of examining the environment's influence on chemical, mechanical or biological processes of decay, represents a new way to manage the museum environment. It enables the optimisation of environments by incremental steps to respond to local climatic realities and by seeking out efficiencies in the operation of mechanical systems.

This management approach also lends itself well to meeting the challenges of global climate change and expensive energy. The impact of climate change will of course vary depending upon locality, but we can expect that collection objects will experience new environmental stresses on a regular, repeated basis. We expect the average temperatures to increase nearly everywhere; but another common consequence will be an increased frequency of extremes of temperature and RH. Higher average temperatures mean faster rates of chemical decay; more dramatic extremes of heat, humidity and dryness increase the risks of physical change and biological attack, in the form of mechanical damage or mould growth.

In addition to global climate change, local climate changes will occur as well. Major museums are located in major cities, many of which are becoming 'heat islands' as their own mass of concrete absorbs radiation and concentrates heat. New York City is an example. To the extent that control of the indoor environment contributes to the underlying causes of global climate change, ie. through the carbon footprint, as well as contributing to the financial burdens on the institution, it is both the interest and the responsibility of museums to monitor, understand and manage their environments in as precise and efficient manner as possible.



Dataset	NYC-C Park-2003	NYC-C Park-2004	NYC-C Park-2006	NYC-C Park-2007	NYC-C Park-tmy2
Risk Summary					
Natural Aging	RISK	RISK	RISK	RISK	OK
Mechanical Damage	RISK	RISK	RISK	RISK	RISK
Mold Growth	RISK	RISK	RISK	RISK	RISK
Metal Corrosion	RISK	RISK	RISK	RISK	RISK
Preservation Metrics					
TWPI	36	37	41	37	47
MRF	4.83	2.95	1.64	1.6	1.31
% DC Max	1.69	1.95	1.55	1.62	0.69
% EMC Min	10.6	9.7	8.5	8.8	10
% EMC Max	16.7	16.7	14.1	14.6	12.5
% EMC Mean	13.16	12.68	11.14	11.95	11.27
Data Overview					
Start	2003-01-01	2004-01-01	2006-01-01	2007-01-01	1999-01-01
End	2003-12-31	2004-12-31	2006-12-31	2007-12-31	2000-01-01
$T°C_{mean}$	11.8	12.2	13.6	13.1	12.1
$\%RH_{mean}$	70.3	67.9	61.2	65.6	62.4
$DP°C_{mean}$	6.1	5.9	5.6	6.1	4.7

How large will the effects of global climate change be on museum collections? One way we thought to explore this question was to analyse outdoor data from five large American cities with the Preservation Metrics that I alluded to. Data from 2003-2007 was compared to a composite of typical years from 1960 to 1990. The more recent data did contain

evidence of periods of higher temperature, higher dew point and higher RH than were found in earlier years.

The Preservation Metrics are indicated in red for various forms of decay: mechanical, mould and chemical change. One can clearly see that there's more red in more recent times, and that's because, precisely, that there are higher temperatures, periods of higher temperature and humidity.

And so it's both long-term averages but especially these excursions to unusually high or low values of RH and high values of temperature that are driving what we think is some evidence at least of faster change. The Metrics indicated a modest but significant increase in the estimates of decay rate for both natural ageing and mechanical damage. One should not make too much of this data, but it does help confirm that global climate change will not be good news for either collection health or energy bills from mechanical systems.

If I may be permitted to speculate about the future, the challenges that global climate change will bring to the care of museum collections – and this is quite apart from disasters such as cyclones and hurricanes, which may well become more frequent and more severe – these will be real and significant. They will come in the form of worse heat, worse humidity, and fluctuations between extremes. These will be noticeable in the form of higher energy bills and faster rates of collection decay. A greater premium than ever will be placed on managing museum environments to obtain the longest life for collections at the lowest cost in staff time, energy consumption, and capital equipment. Management approaches that are based on quantifying the effects of environmental conditions will predominate and museums will seek to compromise gracefully with outdoor climatic conditions and not neutralise them.

If you want to see more about Metrics and our approaches, go to that website http://www.pemdata.com, and you can have a look at them and try them for yourself.

Michael C. Henry PE AIA
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CLIMATE CHANGE: BALANCING ENVIRONMENTAL NEEDS OF SOCIETY AND COLLECTIONS

I'd like to consider this dilemma, if you will, of how do we resolve being good stewards for collections and still reduce the impact of climate management within our museums and archives, the impact with respect to fossil-based fuel and energy consumption. If we look back at traditional buildings, the building envelope was used in active management of interior conditions. As contemporary building systems for interior environmental control became widespread, use and knowledge of the active functions of the building envelope were lost. Actively operated building envelopes can provide light control, natural ventilation and moisture management, negating the need to operate systems when exterior conditions are acceptable. Obviously the emphasis is on 'when exterior conditions are acceptable'.

We can also consider passive stability and cascading gradients. Building materials with high thermal inertia and moisture-buffering capacity can stabilise fluctuations in temperature and relative humidity. In many climates, passive stability can reduce the size and capacity necessary for building systems and smaller capacity means that such systems can operate closer to their efficiency point. In some climates, passive features can eliminate the need for systems altogether. Large differences between exterior and interior conditions can be cascaded across multiple spaces and enclosures, reducing the gradients that drive thermal energy and moisture exchange through the building envelope.

The effectiveness of this approach can be seen on a smaller scale, as implemented when objects are nested within packing materials, housings and storage enclosures or packing crates, as we saw earlier this week in the paper on the icons from St Catherine's Monastery in Sinai. So all we are asking to do is extend this further into the building itself and look at placement within the building of our objects, especially where we have extremes between exterior and interior conditions.

In the twentieth century, as May has mentioned and also Jim, criteria for collections environments progressively tightened with low-cost energy and the availability of building systems for control. There was a general sense that 'If we can get it, we need it and it's available'. But Marion Mecklenberg at the Smithsonian reported strong correlation between stringent temperature and relative humidity control and increased energy costs. And this was about eleven years ago, 1997 I believe. Recently, David Artigas at the University of Pennsylvania, confirmed this correlation of energy consumption and control for a sampling of historic house museums. The graph below comes from his thesis: *A comparison of the efficacy and costs of different approaches to climate management in historic buildings and museums*.

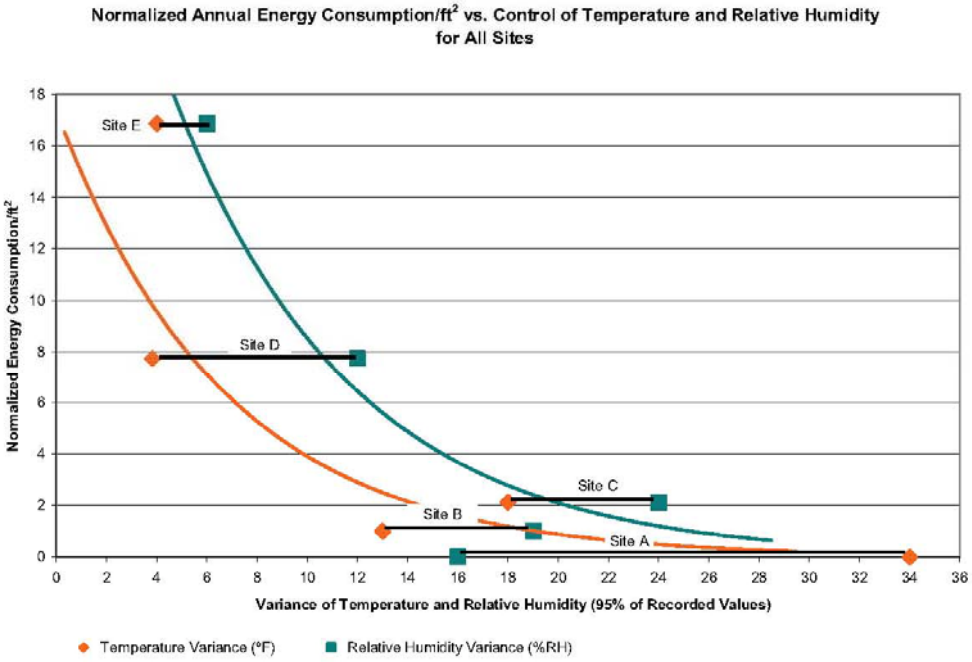

Figure 33: Normalized Annual Energy Consumption per Square Foot vs. Control of Temperature and Relative Humidity for All Sites.

Source: D. Artigas, 2007. Anne and Jerome Fisher Fine Arts Library, University of Pennsylvania Libraries

Certainly not a statistically significant sample, but what we see here is the emergence of the curve of diminishing returns. This should be no surprise to any of us, the curve of diminishing returns being applied to environmental control and energy costs, so perhaps what we need to do is restate the question as: what interior conditions are necessary, reasonably achievable and cost-effective for collections' longevity?

We also should take a look at how we specify conformance with environmental criteria. It's basically a measurement problem, and yet real-world measurements involve instrument accuracy, precision and statistics. Yet measurement error and statistics are rarely addressed in statements of interior environmental criteria. A reasonable approach to stating criteria for collections environments would include standard deviations, allowable seasonal or daily fluctuations, excluded singularities - those one-time excursions - as well as the necessary precision with which the results will be checked.

Data are essential – Jim has already discussed this, as has May – but what I'd like to add is that with reliable, accurate, accessible data specific to a building or site, it's indispensable for us then to analyse that data, determine what the building response is and identify specific, targeted strategies for improving environmental management. And this is really key. We don't need wholesale solutions that go for twelve months. We need merely to analyse the data and say, 'When do we have a problem? What is that problem?' It may be a seasonal problem, it may be a problem that happens over the course of a week or it may be a problem that happens just in the diurnal cycle. But looking at the data then closely and analysing it gives us the opportunity to say, 'When do we have situations for which soft, low-tech solutions that might be available?

The American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE for short) has published guidance in Chapter 21 Museums, Libraries and Archives of it's Application Handbook. It's an interesting form of guidance because it looks at the building first and asks what kind of interior climate and what kind of system can we accommodate within the building

Building typology may limit interior environmental "control"

Table 4 Classification of Climate Control Potential in Buildings

Category of Control	Building Class	Typical Building Construction	Typical Type of Building	Typical Building Use	System Used	Practical Limit of Climate Control	Class of Control Possible
Uncontrolled	I	Open structure	Privy, stocks, bridge, sawmill, well	No occupancy, open to viewers all year.	No system.	None	D (if benign climate)
	II	Sheathed post and beam	Cabins, barns, sheds, silos, icehouse	No occupancy. Special event access.	Exhaust fans, open windows, supply fans, attic venting. No heat.	Ventilation	C (if benign climate) D (unless damp climate)
Partial control	III	Uninsulated masonry, framed and sided walls, single-glazed windows	Boat, train, lighthouse, rough frame house, forge	Summer tour use. Closed to public in winter. No occupancy.	Low-level heat, summer exhaust ventilation, humidistatic heating for winter control.	Heating, ventilating	C (if benign climate) D (unless hot, damp climate)
	IV	Heavy masonry or composite walls with plaster. Tight construction; storm windows	Finished house, church, meeting house, store, inn, some office buildings	Staff in isolated rooms, gift shop. Walk-through visitors only. Limited occupancy. No winter use.	Ducted low-level heat. Summer cooling, on/off control, DX cooling, some humidification. Reheat capability.	Basic HVAC	B (if benign climate) C (if mild winter) D
Climate controlled	V	Insulated structures, double glazing, vapor retardant, double doors	Purpose-built museums, research libraries, galleries, exhibits, storage rooms	Education groups. Good open public facility. Unlimited occupancy.	Ducted heat, cooling, reheat, and humidification with control dead band.	Climate control, often with seasonal drift	AA (if mild winters) A B
	VI	Metal wall construction, interior rooms with sealed walls and controlled occupancy	Vaults, storage rooms, cases	No occupancy. Access by appointment.	Special heating, cooling, and humidity control with precision constant stability control.	Special constant environments	AA A Cool Cold Dry

ASHRAE Handbook-Applications, Chapter 21, 2007. (c) American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org<http://www.ashrae.org.

Then it goes on to look at what's a reasonable degree of control or what's an achievable degree of control within the building.

Table 3 Temperature and Relative Humidity Specifications for Collections

Type	Set Point or Annual Average	Maximum Fluctuations and Gradients in Controlled Spaces: Class of Control	Short Fluctuations plus Space Gradients	Seasonal Adjustments in System Set Point	Collection Risks and Benefits
General Museums, Art Galleries, Libraries, and Archives All reading and retrieval rooms, rooms for storing chemically stable collections, especially if mechanically medium to high vulnerability.	50% rh (or historic annual average for permanent collections) Temperature set between 15 and 25°C *Note*: Rooms intended for loan exhibitions must handle set point specified in loan agreement, typically 50% rh, 21°C, but sometimes 55% or 60% rh.	**AA** Precision control, no seasonal changes	±5% rh, ±2 K	Relative humidity no change Up 5 K; down 5 K	No risk of mechanical damage to most artifacts and paintings. Some metals and minerals may degrade if 50% rh exceeds a critical relative humidity. Chemically unstable objects unusable within decades.
		A Precision control, some gradients or seasonal changes, not both	±5% rh, ±2 K	Up 10% rh, down 10% rh Up 5 K; down 10 K	Small risk of mechanical damage to high-vulnerability artifacts; no mechanical risk to most artifacts, paintings, photographs, and books. Chemically unstable objects unusable within decades.
			±10% rh, ±2 K	RH no change Up 5 K; down 10 K	
		B Precision control, some gradients plus winter temperature setback	±10% rh, ±5 K	Up 10%, down 10% rh Up 10 K, but not above 30°C	Moderate risk of mechanical damage to high-vulnerability artifacts; tiny risk to most paintings, most photographs, some artifacts, some books; no risk to many artifacts and most books. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods double life.
		C Prevent all high-risk extremes	Within 25 to 75% rh year-round Temperature rarely over 30°C, usually below 25°C		High risk of mechanical damage to high-vulnerability artifacts; moderate risk to most paintings, most photographs, some artifacts, some books; tiny risk to many artifacts and most books. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods double life.

ASHRAE Handbook-Applications, Chapter 21, 2007. (c) American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org<http://www.ashrae.org.

Admittedly, this is based on North American building typologies right now and our four-season climate, and even within the United States it's geared pretty much for our eastern and north-eastern climates. Bart Ankersmit at ICN has told me this week that in the Netherlands they are adapting it to their climate and looking at how to extrapolate this as a means of judging what can be done with buildings and interior environmental control.

Downside risk: one of the things that's going to come as the result of climate change is increased risk of loss of infrastructure. There have been several studies in this regard. We see it in extreme events throughout the world, but as energy demand increases we are going to see increasing strains on infrastructure. So we have to ask ourselves 'What are the effects of climate change on infrastructure, and when that infrastructure fails, what are the implications for our buildings and our collections, and if we are using systems or relying on those systems, how do the systems operate under those circumstances?'

So that might lead us to start thinking about more simple, robust systems, systems that can withstand interruptions in off-site power, robust buildings that can provide for passive measures during those interruptions. Certainly I think many of us would rather have that kind of approach during interruptions of service than to have to do the sort of temporary installations that we see here in the building at the left.

Long-range thinking: building systems – that is a bit of looking out into the clouds – are major investments with 20-30 year service lives. The capital investment is known at the beginning, operating and energy costs will increase with time, and successive institutional administrations will bear the financial burden of the environmental criteria that we set today. Design of buildings and building improvements and systems should be adaptable in order to avoid climatic- or financially-driven obsolescence. Any of us can think of institutions who don't operate their systems on spec because they can't afford to. I can think of several. David Watkinson's presentation this week during the IIC's conference on *Conservation and Access* regarding the *ss Great Britain* is a great example of this adaptability, where he indicated that as energy costs increase, they have the ability to change their approach to climate management.

Technological innovation, climate change and the need for energy efficiency are already driving innovation in products. The problem for us, or the challenge for us, is that these

technological advances are typically created for large markets and their integration into museums and archives will be derivative rather than direct. We need to be alert and open to the opportunities that these innovations afford and be ready to try them and see if they are effective, with of course the proper research.

And lastly, whatever we do, we have to do it in a collaborative environment across all disciplines and responsibilities. All institutional departments – facilities (in the United States), conservation, curatorial, education, interpretation and finance - as well as design consultants, specialists and construction contractors, should have active and engaged representation throughout the planning, design, commissioning and post-occupancy evaluation of any approach that we take from a building standpoint for providing our collections environments.

Photo Michael C. Henry

Photo Wendy C. Jessup

Photo Michael C. Henry

And I'd just like to mention that this is a Cuban-American team which resulted from great diplomatic efforts to work on Hemingway's Finca Vigia in Cuba and as of this afternoon we haven't heard from the Cuban team since Hurricane Ike. We are reasonably assured that the Cuban team – half of this team - has survived, but their infrastructure has not, and we're not getting any news out as to how they are or how the resource is.

Sir Nicholas Serota
Director, Tate

Good evening. My role on the panel this evening is perhaps to try and broaden the issues slightly. Evidently I'm not a specialist in the area, but, along with many colleagues, I do care for one of the great collections in this country and, as Sarah has reminded us, in many ways it is at risk. Climate change, as we were advised in the leaflet that drew you to this session, and as speakers have already mentioned ahead of me, is seen very much as a threat, but I think we have to see it as a challenge. I think we also have to see it as an opportunity, and an opportunity to begin to run the institutions in which many of us work in a rather different way.

If I can try and set that into a broader context, it is I think because public museums exist by virtue of having established a public trust. Without that public trust, we cannot maintain our

position in the society, and we achieve that public trust by the way we care for the objects, the depth of our scholarship, the range of it, our imaginative acquisitions, the way in which we deploy the collections and the way in which we look after the funds that are given to us from the public exchequer to care for such collections. But it is also a public trust engendered by the general way in which we run our institutions and it is essential I think that we reflect, respond to and in some instances, lead public opinion.

At a time of climate change and recognition that there are finite resources in our world, we have to run our organisations in a way that responds to that contemporary concern, especially amongst young people. We have to act responsibly and create organisations which are in every sense sustainable. If we don't do so, we will forfeit public trust and ultimately the public investment and public funding that helps us pursue our activities. That is one of the reasons why I'm so pleased that the Museums Association has been leading in this country on issues to do with sustainability in museums.

What does this mean for museums in practical terms? First of all, we are quite simply institutions that consume and we therefore need to put our own houses in order. We need to be sure that we understand what the carbon footprint of our institutions is, we need to understand how we can run ourselves more effectively in terms of the use of our resources, in terms of establishing sustainable supply chains in all the materials that we use. And in order to do that we need to collect data. As several members of this panel have already said, a great deal of additional research needs to be done in this area if we are to become as effective as we might.

Secondly, I think as a museum sector we need to play our part, again as other speakers have suggested, in beginning to rethink the environmental conditions within our museums – what those standards should be and the way in which we go about achieving them. We need to look at some of the current conventions and again, we need further research to understand, as May was suggesting, exactly what the limitations could be rather than simply applying very narrow criteria, as has often been the case in the past.

In the UK, there has been an initiative recently, led by the National Museum Directors, to begin to examine these questions and in May I presented a short paper put together with colleagues including Stephen Hackney at the Tate, which was considered by directors of all the major European museums, a group which meets twice a year. As you might expect it is a group that has a fairly significant number of large egos sitting round the table [laughter], and what was rather remarkable about the reception of the paper was that there was not just universal recognition that something needed to be done, but also enthusiasm and a determination to take a new look at the way in which we consider these matters across the whole sector.

That has now led to a working party being established in this country, led by the National Museum Directors working with conservators from all the institutions including some of the non-national museums, and they will present a paper to an international - not just a European - group of museum directors in October. The aim is to ensure that the directors are fully behind this kind of re-examination, fully behind putting resources into research and fully supporting initiatives that have already been instigated, as I know very well from seeing certain faces in the audience, by many of you.

Those initiatives apply to environmental standards, but they also apply to making exhibitions in a more sustainable way. Any one of us who witnesses the extraordinary lengths to which curators go to create a new environment for every exhibition and then throw it away at the end of the exhibition, will know that we have to reform the way in which we work. What are the methods of construction we use? Can we find reusable materials and so on? And should we perhaps, as I think has already been suggested this evening, run our exhibitions to fewer venues, for longer? Again, research is required, looking into the carbon footprint and indeed the simple costs of moving exhibitions around, just as, ten, fifteen, twenty years ago, a great deal of research was done into the whole

question of how we move works of art around the world in a safe manner. We really need to think again about the way in which we structure the whole exhibition business. And we need to be looking at more sustainable ways of moving works of art across the globe. Should we indeed send quite as many couriers as we do on every occasion whenever there appears to be a need or a wish?

Thirdly, beyond looking at environmental standards and the way in which we run ourselves, there is a real need to do what one might describe as 'push the limits'. As we've already heard, there are many ways of creating a greater buffer between the exterior and the interior of our institutions. We can use cases, we can use lime-plaster, we can put backing boards on paintings, all of this is work that is easily undertaken, but it needs to be co-ordinated and it needs to be brought together in a coherent and holistic way.

We can of course, as has again already been mentioned, look at new heating and lighting sources. If you go into European museums you see most of the museums lit by fluorescent light and if you go to America, where energy costs are much lower, you see everything lit by incandescent light, a method that cannot be a sustainable position in the long term. We need to look at ways of using the energy resources that are available to us free. When we build the second phase of Tate Modern, for instance, we will be using the waste energy created by EDF Energy in the neighbouring switch station where they bring the National Grid electricity down from the National Grid voltage to a domestic voltage.

I do think, coming back to the place of museums in society as a whole, we have a responsibility to lead. We need to lead architects and engineers and not wait for them to tell us what to do. We need to lead the funding bodies so that they do not impose on us standards that we no longer regard as relevant or indeed responsible. And we need to train our audiences to recognise that there may be times when they go into a museum and it is not as warm as they would wish in the winter, and not as cool in the summer. Only then will we be responding to the current expectations of society as a whole.

Question and Answer Session

Sarah Staniforth: Panel members, thank you very much indeed. I am going to very quickly show you a few slides that illustrate some of the extreme weather events we have experienced in the UK in the last few years. These are the equivalent, on a much smaller scale, of the hurricanes: Ike and Katrina, that have had such a severe impact in the United States in the last couple of years. Although disasters have only been referred to obliquely today, they are events that I'm sure some of you have been involved with, particularly those of you from North America.

Photograph property of The National Trust of England, Wales and Northern Ireland

Blickling has flooded in 2001, 2004, 2007 and 2007. There have been many similar floods in National Trust properties since the year 2000. Water coming into the houses, from overflowing gutters, flash floods that go in through the doors, fill up the ground floors, and the basement as in this case, creating damp conditions within the houses.

Photograph property of The National Trust of England, Wales and Northern Ireland

It is curious that the most serious floods have happened on Fridays, so that we can spend the weekend mopping up after them. I'd like a bit of research to be done on what it is about the climate that creates heavy rainfall on Fridays. I think that's worth an EC grant!

We now get early warning from the Metreological Office whenever severe weather is on the way. Last week we had a warning three days in advance, that we were going to get heavy rain, up to 50mm (2" in Imperial measurements), in the north-east and the north-west.

Photograph property of The National Trust of England, Wales and Northern Ireland

At Cragside, Lord Armstrong, the industrialist's property north of Newcastle, where there are designed cascades through the garden, which could be turned on and off at will when a large valve was opened, cascades created themselves, sweeping away the scaffolding that we'd just put up at huge expense to repair the iron bridge, flooding the Pump House and the Power House where he generated hydroelectricity to fuel the first incandescent lamps used in a country house in England, and into the Billiard Room, down the chimney, because the gutters overflowed and the water on the roof found its way through the soot-holes into the chimney, flooding the floor with water.

Photograph property of The National Trust of England, Wales and Northern Ireland

This is the slide I particularly wanted to show you, because 'Rome-burning-fiddling' is what I think when I see this slide. This shows the conservation heating system, which controls the relative humidity in the room, standing in a pool of water. I thought 'What are we bothering about, controlling the environmental conditions, when our houses repeatedly fill up with water as a result of climate change?' So just a little bit of perspective and prioritisation about the risks that we are facing I think is something that all conservators can do something about in their own institutions. We are going to need to review emergency plans to take into account the new scenarios that may result from the impacts of climate change.

I'd like to invite comments and questions from the floor. But first a review of the presentations by our five speakers. First, Cristina Sabbioni introduced us to the impacts of the predicted scenarios on outdoor cultural heritage, including freeze and thaw cycles, salt crystallization, and surface recession.

May Cassar then brought those scenarios indoors and thought about the impacts on collections. She ended up offering wise advice, things that we can do straightaway in reducing our use of fossil fuels, therefore mitigating further climate change, switching to renewables where possible, and she used the word 'relaxing' environmental conditions. I think our last speaker, Sir Nicholas Serota, talked about 'rethinking' environmental conditions. We may want to debate that.

James Reilly then went on to talk about the use of Preservation Metrics as a way of measuring damage functions and that wonderful Holy Grail of managing the museum environment to obtain the longest life of collections at the lowest cost in staff-time, energy, consumption and capital equipment.

Michael Henry observed – and I think that we all now understand this - that the environmental specifications that we've been using have been driven by what is possible rather than what is needed. And I think those were very wise words. He also flagged up the loss of infrastructure that will sometimes surround climate events, or catastrophic climate events, and the need for planning for that.

And then finally, Sir Nicholas Serota talked about the museum's role in leading public opinion and reflecting contemporary concerns because of the need to have public support; looking at our carbon footprint; and that clarion call about rethinking our environmental conditions; and talking about the National Museum Directors' Conference initiative, in which some of the Heads of Conservation in the UK national museums are looking again at environmental specifications, particularly with reference to loans.

I now open the floor for questions.

Jane Henderson, Cardiff University: I very much agree with all the discussion about relaxing environmental standards, but I really just wanted to make a point, perhaps on behalf of smaller and medium-sized museums, where the issue hasn't been about enforcing environmental specifications all the time, the issue has often been about trying to raise the standards of environmental control up to a minimum to preserve the collections, by taking action such as improving the building fabric, rainwater goods and so forth. So that we should remember that we should be coming at the problem from both sides, we can improve the condition of the collections out there in some of the smaller museums, not by more HVAC and so forth, but by improving the infrastructure. We should be levelling the environmental standards perhaps, rather than just dropping them from one side.

James Reilly: I would just like to make a comment on that. Whether you're coming up from no standards, or you are coming down from very high standards, and trying to figure out where you can hit that sweet spot, the real necessity is to be able to understand what your collections are feeling from whatever cause and whatever circumstance. I think that's the theory we've pursued in our research and that's what I think we should concentrate on in terms of finding a better management strategy. I completely agree with the spirit of what you are asking, and understand you very well.

Mimi Leveque, Peabody Essex Museum, Salem, Massachusetts: Sarah, this is actually for you. My husband is the director of the Clark Labs IDRISI Project and I know he has data on why at weekends it rains, and it has a lot to do with our own use of transportation. But my question is about what's going to happen with museums that are

now engaging in building new wings and museums that have recently opened new wings, built by very famous architects, but none of which have taken into account any kind of environmental change issues.

Sir Nicholas Serota: I think I should remind you perhaps first, that those museums were not only built by very famous architects, but they were often built by very famous engineers, very famous directors and very famous Museum Boards of Trustees! And. So I think architects can't take total responsibility. But I think that there is gradually a recognition that a different course needs to be taken. In order to achieve that, I think we are going to have to undertake further research. We're going to have to prove the case, we're going to have to find new methods, both of heating and cooling and dealing with energy issues, but also the way in which we administer our institutions as Sarah was suggesting and as the National Trust has done so successfully.

May Cassar: Every architect has a client – I think that's the point that has already been made – and I think there is a leadership role here for museums to actually work with leading architects to create iconic buildings, that are not only iconic for the way they look but also iconic for the way they perform and how sustainable they are. So there is a real challenge and a real opportunity. I also think that at the end of the day, it is not only for collections that we provide good environments within our buildings, it is for our staff and our visitors, and I think that that is part of the tension, so to speak, as to when we actually hear about environmental specifications. Are they really about what is required by collections or is it about human comfort? And what will the future mean for human comfort? Certainly in cities, with the heat island effect, we are actually experiencing greater cooling within our cities and that is much more expensive in terms of energy than heating. So it's what we do to raise awareness among our publics about their perception of how our buildings feel, as well as how they look.

Paul Schwartzbaum, Solomon R Guggenheim Foundation: I think all the speakers made extremely good points and looking at them all, it's very obvious how complicated things are. It's one thing to talk about reducing standards of climate control, which all of us can do, from a scientific or a responsibility point of view for our own collections, but international loan agreements for borrowing works of art have the most stringent climate control specifications in them, and whenever one builds a museum, one is terrified of deviating from them, because maybe people won't lend things to us. Then we get requests during very important exhibitions for very important objects, for specifications that exceed these already extremely conservative and usually unnecessary conditions by individual lenders, who make us absolutely jump through hoops, to the point that we are sometimes asked to exhibit works on paper in the dark, where it makes no sense whatsoever.

In terms of working with architects, the Guggenheim has a reputation for working with very great architects. Our first project was a fabulous one: to build a museum in Salzburg, which from the point of view of thermal inertia was wonderful because it was carved out of a mountain. What could you ask for more? Perfect for sustainability, perfect for reducing mechanical systems to a minimum – needless to say, the project never got built. Working with another great architect, he designed most of the main floor of the museum to be underwater, which was very, very interesting. Thank God that was never built! We're about to embark on building a museum half again as big as Bilbao in Abu Dhabi. Now, in that project I can promise you that there is an enormous emphasis on sustainability, for obvious reasons. The point is, it's very complicated. We built another museum in Spain, and one thing that we ran into was that all public spaces are considered by the European norm to be the same, and we needed the same amount of air changes in our museum as a gym, a workout gym or somewhere that people would go and exercise – which makes no sense whatsoever and certainly doesn't help you reduce the size of your air-conditioning system.

Andreas Burmester, Doerner Institut: I am Andreas Burmester, Doerner Institut in Munich, which is part of the Pinakotheken, which will be opened in springtime, where we put a lot of energy in building, a nice building which is sustainable and which is saving energy, and we hope to use from 30to 50% less of energy to drive that building. Now, what I'm a bit nervous about, coming back to Sir [Nicholas] Serota's comments, is that we are now asked to think about the museum conditions, climate conditions, but we do not talk about the wrong architecture which has been built in the past, where we compensate wrong architecture by huge machinery, and to stay in the standards, we waste a lot of energy. We endanger our mission. I think, because – I think it's everywhere the same – but at least in Munich all the money goes to the façade of the museum, a lot of the money is eaten up by the energy costs and there is not very much left for the background work of the museum. So that's a real, major concern and I follow you fully: we have to come together and to talk about this and to find a solution very soon.

James Reilly: Well, in reference to your point, I think you make it very clear that a lot of conservators are in museums with elaborate mechanical systems and essentially getting very large energy bills. And if the point hasn't been made before, it's incumbent on the conservation profession to understand the basics of temperature, humidity and dew point, to understand how mechanical systems work and really to begin that dialogue in a better and different way with the building operators. You emphasised the circumstance where 'Hey, we're already in this building, it already has very large air-handlers, it already gets very large energy bills.' This is something we've worked on for the past ten years with the Library of Congress in Washington DC. They have extensive mechanical systems, and we are working together to realize efficiencies wherever possible and are convinced that 10 to 30% savings are possible in most instances.

And I think there's even greater opportunity – we were looking for things like, essentially circumstances of 'one foot on the gas, one foot on the brake', where air is heated and then it's immediately cooled, de-humidified and heated back up again, when the dew point doesn't require it to be subcooled and you could just pass that air through. If you look for those kind of things, you can save as I said 10 to 30%. There's another frontier, which is: do these systems have to be on 24 hours a day? And the air-volume question that was mentioned – collections don't need to breathe, they don't need the same amount of fresh outside air. But I think in general the comment I would make is that conservators have to be much more comfortable, instead of articulating what it should be, to understand what it could or might be, and to really talk the language of the what you call here in the UK the estates manager and what we call the facilities manager or the building operator. And that's definitely a frontier as well and the conservation profession would be the better for it, is what I've concluded.

Michael Henry: We have to be careful though, as we're trying to improve the performance of existing systems. First of all, the most important part, if you take the systems approach, the most important part of the project from an environmental criteria standpoint is the commissioning phase. And the commissioning phase occurs when the construction is done and you put the system in operation, and very often what happens is that the commissioning phase gets squeezed between the opening and the ribbon-cutting, and the contractors' overrun on schedule. And the commissioning phase does not happen overnight. These building systems are not like our automobiles: we don't put a key in them and start them. They are custom-built with custom equipment for every building and every one of them is different, and it takes time to sort them out. And once they're sorted out, they start a period of attritional loss of performance. It's a given. And so they have to be re-commissioned periodically.

But we also have to be careful, in today's world especially with energy costs as they are, that we implement changes that are going to still continue to give us what we need for collections. I left a museum last week where variable speed drives had been put into the air-handlers as an energy-conserving measure. It cut down the air-flow in the galleries, it didn't allow for enough de-humidification on the cooling coils and they have a mould

outbreak in the rare books section. And all was because there was an energy efficiency improvement that was made without understanding how the system fully worked. It was seeking the energy improvement and not understanding the other requirements of the system. So we have to tread very carefully when we go there.

May Cassar: In response to what Andreas has said, I believe that conservation is an intellectually mature profession. I take for granted that conservators are involved on projects, on building projects, I take that for granted, I would expect to see that at this particular point in time: that our input is actually there from the design stage right through to implementation and commissioning. However, we also talk among ourselves about display strategies and we have done a lot of work on microclimates and we put the obvious things inside display cases, but we haven't tackled the thorny issue. What about those pictures that have never been glazed in their life, that could actually be conserved behind glass? These are the kind of things that actually at the end of the day will help reduce our energy costs, but do change the appearance of the works of art that we are there to care for and for which we are open for the public. And these are the things that we have to tackle.

Sarah Staniforth: I'm then going to ask Maurice Davies and Charlie Costain to do the next two questions.

Maurice Davies, Museums Association: Nicholas Serrota kindly mentioned the work we've been doing this year to talk with museums in the UK about sustainability, and we've been spending the summer talking with people in all sorts of museums, large and small, throughout the UK. Inspired by Sarah's work at the National Trust, we've taken a very broad view of sustainability, looking at social and economic sustainability as well as environmental, and one of the things that's become very clear to us is that museums are absolutely at the heart of the sustainability business. The mission of museums, the purpose of museums, to serve past, present and future by communicating and caring for collections is absolutely part of the sustainability of the world, so it should be very natural for museums to care deeply about sustainability at the level of their purpose and mission.

In order for museums to work as well as possible with the sustainability of the planet, there will need to be changes to the way they work, and we've heard about some of the technical challenges and the research challenges, but I think we have to think much more broadly about the overall impact of museums and why we have museums. Collection care standards in particular, which has been the theme here, was raised spontaneously by about half of the participants in our workshops this summer. Interestingly, many more, about twice that number, about 80%, raised lighting as a way of saving energy so actually for a quick win, to save energy in museums in the UK at least, I think lighting would be pushing at a more open door than collection care standards.

But collection care standards do need to be addressed and our current view at the Museums Association, based on the talking and thinking we've been doing, and some specific research with major lending museums in the UK about their attitudes to lending, is that environmental standards, especially for temperature and relative humidity, need to be reviewed – is my word rather than rethought or relaxed – they need to be reviewed so the energy used in managing the museum environment is fully justified and that we're not being over-cautious in our attitude to risk to collections in the way we run our museums. History shows that many collections are extremely robust, they've survived all sorts of things, they've been lugged across the Alps by Napoleon and so on. And so the amount of damage we are willing to accept may simply be too low at the moment, and in any case, perhaps we should accept higher levels of damage as part of the broader picture of the purpose of museums.

So simply to say that, in endeavouring to preserve collections almost perfectly for future generations, we must not contribute inadvertently to making the planet more uninhabitable for those same future generations. And we absolutely have to see the broadest view in the

purpose of our museums. And for more of what we're doing, including discussion papers and details of a workshop next week at Tate Britain, there's a section of our website, which is museumsassociation.org/sustainability.

Charles Costain, Canadian Conservation Institute: Michael Henry did talk about the ASHRAE chapter and that was about ten years ago. That was prompted by a number of things, energy costs certainly in Canada and the northern States, building repair being a big part of it because that's causing problems. We came to the conclusion that much as the conservators may be at the table, there was a real problem with communicating the issue to the engineers, which is why we went that route, and there was a lot of interesting discussions, because there were engineers there who had made their livelihoods making very high-end systems, and what came out of that was at least a first attempt to rationalise the decisions, so different classes of control based on the vulnerability of different types of collections.

I agree with May we need more research, we can always get better data, but to some extent I think we need to go with what we have, sooner rather than later. I realise the ASHRAE chapter is not that accessible, and that's certainly a challenge we've had, communicating that. We have a version that's now just ready to go to translation of a kind of simplification of the classes of control and the vulnerabilities that we're looking at. Actually, we've got a version of that running on our computer at the booth, if people are interested in looking, but that should be out before Christmas. It is an attempt to try and broadcast that approach and disseminate it, a little more broadly.

May Cassar: Yes, we have to go with what we've got, but I think we also need to expand our knowledge. We simply don't know enough about materials indoors and I think we have to really know more about damage, because whether we lose it or whether we keep it, we have to make it as a conscious decision. I think we need the information in order to be able to make that conscious decision. And I'm all for reviewing the environmental standards, but let energy be the external driver and let damage be the internal driver.

Nancy Bell, The National Archives: I thought it was timely to say something on other initiatives that are moving forward and I'm pleased to hear the panel and participants mention the words 'complexity' and 'research' because this is a hugely complex subject and we do need research. We saw through all those presentations there's a lot of questions we don't know the answers to. Thanks to the AHRC/EPSRC Science and Heritage Programme, there has just been recently a call for research clusters, and I'm pleased to say that The National Archives, along with Tate and the Centre for Sustainable Heritage, have submitted an application to look at current environmental standards and the implications for buildings, people and collections, so hopefully, if this application is successful, we'll start to be able to identify the research questions necessary to answer some of the broader themes that emerged today.

Sarah Staniforth: I'm now going to draw the questions and comments from the floor to a close, and I'm just going to ask each member of the panel if they were to give the audience one piece of advice about what they can personally do in leaving this conference, what that would be.

Sir Nicholas Serota: I think that you should argue with your museum directors and trustees and bring forth the evidence, because I think they're ready to listen.

Michael Henry: I think I would ask us all to consider our responsibilities for stewardship in the broadest possible context. It was said very well: what are we leaving behind for future generations? It's not just about the 'stuff', if you'll excuse me for calling it that.

James Reilly: Well, my final thoughts would be it's really important to understand what your environments are and what they are doing to the collections. Actually I would suggest

to you: work with our Preservation Metrics – they've proven to be ultimately practical by the institutions that we've applied them with, for example the National Museum of Denmark. One of the nice things are that they are able to answer a variety of questions for you, not only where can we save energy, but also which ones are good, which ones are bad, which ones should we abandon, how much more like this should we build and things like that – it's a very practical starting-point. And there's no substitute for data, as one of my teachers once said and I say: let's start down that road.

May Cassar: I would like us to work collectively with our respective professional organisations to influence international policy in this area. Cultural heritage appears nowhere in terms of climate change. It is active among a few researchers but at a policy level you have human habitats mentioned, you have settlements, you have society, you have industry and cultural heritage appears nowhere. So how can we ensure that resources are directed into this area, which is going to be an opportunity but a growing threat, if there is invisibility?

Cristina Sabbioni: Thank you. Well, I fully support that there is an urgent need for the inclusion of cultural heritage into the IPCC Report, that is the report produced by the Intergovernmental Panel on Climate Change. The Fourth IPCC Report has been presented at the beginning of this year – the skiing industry is included but cultural heritage is excluded. And I think this is unacceptable. Through your professional organisation I think that as conservators you need to raise the point and this Round Table is a unique opportunity to raise awareness.

Sarah Staniforth: Thank you very much indeed. So a clear role I think from members of the panel for IIC and indeed for the other international conservation organisations. I'm sure that today what we have done is to open up the debate. This is definitely work in progress, and I'd like to thank very much our five absolutely extraordinarily excellent panel members for both their very clear presentations, and also for their responses to the audiences thoughtful contributions.

The IIC wishes to thank Susan Hughes for her transcription of this event. The transcription has been edited for publication on this web site. Use of this material is restricted.