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Citation for published version:

Moffitt, L 2020, 'Victor and Aladar Olgay's thermoheliodon: Controlling climate to reduce climate control', *arq: Architectural Research Quarterly*, vol. 23, no. 3, pp. 255-266.
<https://doi.org/10.1017/S1359135519000319>

Digital Object Identifier (DOI):

[10.1017/S1359135519000319](https://doi.org/10.1017/S1359135519000319)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

arq: Architectural Research Quarterly

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arq: Architectural Research Quarterly



CAMBRIDGE
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Victor and Aladar Olgyay's Thermoheliodon: Controlling Climate to Reduce Climate Control

Journal:	<i>arq: Architectural Research Quarterly</i>
Manuscript ID	ARQ-Paper-2018-0052.R1
Manuscript Type:	Full Paper
Keywords:	Environmental Design, Environmental Model, Thermoheliodon, Victor and Aladar Olgyay

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14 May 2019

Introduction: Environmental Models and their Targets

Architectural models are reductive representations. Traits included or excluded from a model reflect designer intent as well as larger values held at the time of their construction. As such, models are reflective, acting as cultural mirrors of both conscious and unconscious priorities at the time of their construction. Models are also projective, offering new conceptions and interpretations about the subjects of their representations. Calvino's character Mr. Palomar reflects on the dialogic relationship between a model and reality: 'A delicate job of adjustment was then required, making gradual corrections in the model, so it would approach a possible reality, and in reality to make it approach the model...even the most rigid model can show some unexpected elasticity. In other words, if the model does not succeed in transforming reality, reality must succeed in transforming the model'.² The world shapes construction of the model and the model, in turn, shapes construction of the world.

In Philosophy of Science, those full-scale attributes in the world that a model represents are referred to as a model's *target system*.¹ The target of a conventional architectural model is the future building that the model represents. Similarly, the target of a conventional environmental apparatus such as a wind tunnel or heliodon, when understood as a scale model of an environmental system, is the climatic phenomena at full scale that the model simulates—a space of wind flow from a given direction or of solar trajectories for a set latitude. Environmental models therefore appear to have at least two model/target systems: an architectural proposition and an environmental phenomenon, creating direct dialogues between the two. Thus architectural models that simulate environmental conditions offer rich insights about possible or real models of environmental design.

This paper explores the dialogic relationship between environmental models and their target systems using [an environmental simulation device](#) featured in the appendix of the canonical environmental design book by Victor Olgyay, *Design with Climate: A Bioclimatic Approach to Architecture* (1963): the thermoheliodon. Olgyay's *Design with Climate* outlines an environmental design methodology that can be tailored to each of the four major climate zones in the US, including both regional-specific applications of this methodology as well as corresponding climate data. The thermoheliodon was an advancement of the heliodon, simulating solar trajectories, wind and thermal conditions on physical models; [absolute humidity was, however, disregarded](#). It was intended to test thermal performance of buildings designed using Olgyay's method. While *Design*

with Climate is far-reaching and its legacy extensive, the thermoheliodon has received less attention likely because funding was not renewed and it remained an incomplete project.³ It is worthy of closer attention as it acts as a distillation of many of Olgyay's ambitions outlined in *Design with Climate*; it thus sheds light on some of the origins of contemporary environmental design. Moreover as a complex work-in-progress, the thermoheliodon acts as a rich speculative device, opening up new dialogues between model and world. This article provides one close reading of the models and targets in the thermoheliodon, presenting two conceptions of environment—variable exterior and controlled interior—as well as two conceptions of architecture that mediates these environments—one predicated on variability and adaptation and the other on stasis and control. While these models of architectural mediation reflect particular post-war concerns about building climate control, their broader legacies remain relevant in sustainable discourse today.

The Climate Control Project, Design with Climate, and the Thermoheliodon

Victor and Aladár Olgyay were accomplished practitioners in Budapest, Hungary before emigrating to the United States in 1947. When the Olgyays arrived in the United States, suburban housing design generally, and building climate control specifically, was the locus of many inter-related environmental concerns. Environmental performance of hastily constructed suburban stick-framed homes was compromised by decreased lot sizes, increased paving, decreased shade trees, and poor insulation. Summer overheating, in particular, was a concern.⁴ Thermal comfort expectations were becoming more stringent, and while air conditioning was widely available, it was still considered a luxury. Creating an interior environment of climate control entailed developing design methods for reconciling exterior and interior climatic demands. Lack of accurate and consistent regional climate data as well as techniques for codifying and applying the data to architectural design methods proved professional obstacles to this agenda.⁵

Within this broader context, the Olgyays' professional focus shifted from establishing a practice to pursuing academic careers, taking academic appointments at University of Notre Dame, then MIT, and finally at Princeton University. Their early research was a direct outgrowth of the agenda to develop precise environmental design techniques that could be adapted to a range of climate zones. One of their earliest attempts at refining a known rule of thumb solar design strategy appears in Aronin's *Climate and Architecture* (1953) [1]. The sketch reconciles asymmetry of thermal gain on west versus east side of rectilinear buildings in temperate climate zones; the diagram, now widely understood, indicates that an orientation shift of the east side slightly north would reduce west/southwest overheating. This diagram advances the work of Augustin Rey, J. Pidoux, and C.

Bardet's "heliothermic" theories for urban building orientation in 1912 Paris, which went on to influence Le Corbusier's heliothermic axis in Villa Radieuse.⁶ The Olgyays' 1957 book *Solar Control and Shading Devices* builds further on this research, outlining methods for designing appropriate solar shading placement, configuration and orientation based on understanding of solar trajectories, over and underheating periods, and shading criteria of different architectural shading devices.

While Aladár continued research focusing on solar mitigation, Victor Olgyay shifted focus to codifying and synthesizing a more comprehensive range of climatic variables. An unconventional partnership between the popular magazine, *House Beautiful* and the American Institute of Architects (AIA) laid the groundwork for the Olgyay's next project, the incorporation of additional climatic parameters into a systematic bioclimatic design methodology. In 1949, *House Beautiful* magazine and the AIA initiated the *Climate Control Project*, simultaneously popularising the solar house design concept while also codifying and disseminating regional climate data to architects. Climate Control case study houses were predicated on utter site specificity, claiming: 'the very reason it's a remarkably good house would make it a bad house if it were ever repeated on another lot. For the very core of its perfection is that it is perfect for its site'.⁶ One of the defining features of the series was the publication of a series of regional climate control charts developed by *House Beautiful's* climate consultant, military geographer Paul Siple. The first article of the series, published in the AIA Bulletin, included a twenty-one page spread of climatic and corresponding design data for Columbus, Ohio.⁷ Similar data was published for other cities in the publications, which ran until 1952 [2]. Victor Olgyay included a modified version of the *AIA Regional and Climate Analysis* chart for the New Jersey-New York region in *Design with Climate*.

While general principles associated with bioclimatic design were understood before *Design with Climate* was published, the book provided a comprehensive methodology for calibrating these techniques to the climatic particularities of a given site. Olgyay's bioclimatic methodology is based on four seemingly simple steps: 1 climate data analysis; 2 thermal comfort evaluation; 3 developing technical responses to site selection, building orientation, shading requirements, building form, ventilation, and balancing indoor temperature; and 4 honing an architectural response synthesising the above three findings.⁸ In a condensed form, Olgyay's technique involved analysing climate data to determine building over and underheating periods, examining this criteria in relation to desired interior thermal comfort conditions, developing architectural responses to mitigate between these existing exterior conditions and a desired interior condition, and then refining the design accordingly. Application of this methodology is described in its most distilled form as 'climate → biology → technology → architecture,' reflecting the range of disciplinary concerns required for

bioclimatic design.⁹

In 1955, the Olgyays', with mechanical engineer A.E. Sorenson, received a two-year, \$19,000 US National Science Foundation grant to study 'thermal behavior of buildings by means of study of models'.¹⁰ This funding supported development of the thermoheliodon, an elaborate apparatus with a dizzying array of environmental simulation devices including a wind tunnel, heliotrope with motored 5000-watt bulb *sun*, temperature sensors, air conditioning units, and heating coils. Intended as an improvement on the heliodon, which simulates solar trajectories on architecture models, the thermoheliodon also tested thermal performance of scaled architectural models [3,4]. The device was still a work in progress when described in the appendix of *Design with Climate*. At that time, six years after the grant had expired, the team was still investigating problems related to thermal scaling criteria to ensure that the 'model systems ...are geometrically, dynamically and thermally similar to their prototypes'.¹¹

The central failure of the thermoheliodon was related to difficulties accurately monitoring interior climatic conditions due to problems with scaling thermal capacity of building materials. Barber notes, 'The buildings the Olgyays inserted into the device were tested for shape and orientation, but the internal climatic conditions could not be adequately monitored because of the difficulty of scaling up the thermal capacity of materials—a small brick operates very differently, in thermal terms, than a large brick. The modeling of the radiation of stored heat was also difficult to model at scale'.¹² When the Olgyay's applied for a grant to test full-scale thermal requirements of building materials to hone similarity criteria for the thermoheliodon models, the grant was denied.¹³ A closer look at the thermoheliodon as a scale model reveals some of the competing conceptions of both environment and architecture emerging at the time; these conceptions continue to resonate today.

Two Environmental Model/Target Systems

Neither static nor unidirectional, the relationship between a model and its target system(s) is complex and dynamic. The thermoheliodon, like the methodologies outlined in *Design with Climate*, was intended to "investigate the application of thermal balance principles to building design and construction."¹⁴ The thermoheliodon was understood by the Olgyays as an advancement of their heliothermic planning principles. Both attempted to correlate multiple environmental variables and to assess them in relation to designed buildings in an effort to achieve interior comfort. However, whereas the heliothermic planning method relied on cumbersome calculations that yielded "abstract

measures of heating which, unlike temperatures, are not easily relatable to human physical sensations,” the thermoheliodon relied on “actual measurements of the temperatures obtained in diverse structures under varying climatic conditions.”¹⁵ Because the thermoheliodon is a device for testing designs developed using the bioclimatic methodology outlined *Design with Climate*, an appropriate source for defining models and the target systems of the nested environments of the thermoheliodon is *Design with Climate*’s methodological mantra: climate → biology → technology → architecture. This sequence suggests two environmental model/target systems are at work in the thermoheliodon. The first is the meteorological world—the externalized environment simulated around the scale architectural model. The second starts in the biological world—the interiorized environment of thermal comfort contained within the envelope of the scale architectural model. How were these environments characterised at the time?

The exterior climate of a given site is the starting point for all of Olgyay’s work. For Olgyay, climate is at its most basic level raw data, a series of inputs to be used as a means towards the end of creating interior of *climate-balance*. The first stage of Olgyay’s bioclimatic method is as follows: ‘Climate data of a specific region should be analyzed with the yearly characteristics of their constituent elements, such as temperature, relative humidity, radiation, and wind effects. The data, if necessary, should be adapted to the living level. And the modified effects of the microclimate conditions should be considered’.¹⁶ The AIA/House Beautiful project established the data groundwork by codifying the ‘mass of Weather Bureau records’ for use as a design aid.¹⁷ Olgyay made these meteorological datasets available to architects, graphically translating them into regional climate analyses charts, regional timetables of over and underheating periods, radiation charts for specific latitudes, and building material time lag tables. The thermoheliodon was designed to process this data, inputting existing climate data at one end and then outputting results in the form of numeric data about interior environmental performance at the other end.

The thermoheliodon was referred to in the ‘Daily Princetonian’ as *The Weather Maker* because it simulated ambient exterior ‘weather’ and related impacts on interior ‘weather’ contained within the scale architecture model.¹⁸ It was a dynamic analogue device that processed meteorological data in an era of emerging computation. The thermoheliodon reflects a particular spatial conception of meteorological space, one of a hemispheric data matrix, honed by developments in the meteorological sciences at the time. Edwards’ *A Vast Machine Computer Models, Climate Data, and the Politics of Global Warming* (2010) recounts a shift that took place mid-20th century from ground-level to sky-level meteorological data acquisition. Weather balloons, airplanes and other aerial craft facilitated this shift from horizontal data acquisition to vertical data acquisition. A corresponding representational shift took place in the meteorological sciences from presenting weather as a

flattened two-dimensional plane indicated via isobars to a complex projection of three-dimensional space subdivided into a matrix of cells. Edwards notes, ‘In the period 1950-1960...two dimensional models gave way to three-dimensional ones, and model grids expanded to include the entire northern hemisphere’.¹⁹ Simultaneously, as analog methods of visualization gave way to digital methods of visualization, ‘the regularly spaced, abstract grids of computer models...shifted forecasting from a fundamentally qualitative, analog principle (isolines) to a fundamentally quantitative, digital one (precise number of gridpoints)’.²⁰ The atmospheric world was increasingly understood as a dense dome mesh of meteorological data collection points [5].

What were some of the characteristics of this data-driven notion of weather and climate? In the meteorological sciences, weather was understood as dynamic, quantifiable, controllable, stable, predictable, and within the full grasp of human comprehension. Meteorologists at the time had a ‘widespread believe that global atmospheric flows might display predictable symmetry, stability, and /or periodicity. Research aimed at finding such predictable features remained active throughout the 1950s’.²¹ While drawings and models present the thermoheliodon as a static artifact, in fact, its machining would have been dynamic, yet highly regulated; it would have balanced dynamic flux with predictable periodicity. The electrical sun was designed to move along its arcing rail and the model base was designed to rotate to simulate air-flow directionality. It was even designed to accelerate time; a ‘day,’ marked by the passage of the electronic sun, arced across the model in just under an hour.²²

Olgyay’s valuation of this climatic data varied from invigorating to adversarial. In ‘The Temperate House’ (1951), he states: ‘The climate is the architects’ true adversary’.²³ In *Design with Climate*, he describes the central problem of house design as ‘securing a small controlled environment within a large-scale natural setting—too often beset by adverse forces of cold, heat, wind, water, and sun’.²⁴ In *Solar Control and Shading*, sun exposure ‘attacks the building’ and is described as ‘punishing’.²⁵ Elsewhere, however, climate is described as ‘invigorating’ or ‘stimulating’.²⁶ The range of characterisations, from hostile to inviting, is entirely consistent with Olgyay’s methodology. Ultimately, Olgyay’s characterization of climate varied according to its distance from desired thermal comfort standards. The further away the exterior climate from desired interior conditions, the more antagonistic the relationship. The key aim of a building designed using Olgyay’s method was to create a ‘climate-balanced’ building which resisted adversarial environmental factors while amplifying advantageous factors, in an attempt to ‘flatten the curves’ of climatic variability in the building interior.

The perimeter of the models tested within the thermoheliodon were lined with temperature

sensors to measure exterior as well as interior temperatures. As such, the second environmental model/target system of the thermoheliodon was based on biology, or on creating a climate-balanced building interior of thermal comfort. The second stage of Olgyay's [bioclimatic](#) methodology describes how to do so: 'Biological Evaluation should be based on human sensations. Plotting the climate data on the bioclimatic chart at regular intervals will show a "diagnosis" of the region with the relative importance of the various climatic elements. The result of the above process can be tabulated on a yearly timetable, from which measures needed to resort comfort conditions can be obtained for any date'.²⁷ Establishing climate-balance entailed numerically codifying thermal comfort needs. As with exterior climate, interior climate was treated as data; this data was compiled and visually registered in the form of bioclimatic charts with carefully constructed thermal comfort zones. This data too tremored and shifted over the course of the day, month, and year, rendering itself as a cloud of thermal possibilities when mapped on his bioclimatic chart [6].

While both exterior and interior climate were understood as 'a system of data inputs and predictive outputs',²⁸ the interior environment, constructed and controlled, took precedence over the exterior environment. The exterior environment was a given condition to work around, to use selectively. The interior environment was, however, a construction, an artifact altered by the designer through careful design modification. The prioritization of interior climate reflected increasing thermal comfort expectations perpetuated at the time on two competing fronts. On the one hand, air conditioning manufacturers focused on codifying thermal comfort using psychrometric charts in the pursuit of creating mechanically operated *ventilation-free* homes. On the other hand, popular magazines such as *House Beautiful* promoted climate-responsive house design that was utterly attuned climatically to the particularities of a given site. Both factions were focused on the issue of controlling interior climatic conditions in service of thermal comfort, but the mechanisms for achieving this goal and their resultant architectural manifestations couldn't have been more different.

Air conditioning pioneer Willis Carrier was one of the first to develop the now ubiquitous psychrometric chart around 1904, [advancements of Glashier's 1847 Hygroscopic tables and Marvin's 1900 psychrometric tables developed for the US Weather Bureau](#).²⁹ Carrier advocated for a model of total mechanical environmental control that promised what would now be considered an unpleasant, internalized interior devoid of meaningful contact with the outside world. Moe notes that 'Amidst the sprawling, post-war housing fervor, in 1952 the Carrier Corporation sponsored a house that featured a Carrier air-conditioning system'.³⁰ Carrier described this mechanically-determined house as starting a 'revolution' because it, 'need not depend on natural ventilation. Ells

and wings wouldn't be necessary. Only a few windows need have a movable sash. The bathrooms needn't require a window. Windows, doors, and even the rooms themselves could be placed to suit the convenience of the owner, not to catch a breeze'.³¹ Carrier's revolutionary model of architecture offered an image of a controlled and buffered suburban life.

House Beautiful's 'Climate Control' case study projects promoted a counter model of climate-responsive design to that of Carrier—one utterly attuned to the particularities of temperature, solar and wind exposure, and humidity levels on a particular site in an effort to reduce mechanical heating and cooling demands and their associated energy costs. This model of living was promoted as easy and care-free; the editor of *House Beautiful* presented Climate Control project as a 'research project, the aim of which was to make your life easier, by showing you how to improve your comfort'.³²

While the mechanisms for achieving climate-control varied and their architectural manifestations couldn't have been more different, both factions appealed to similar sensibilities about thermal comfort. Willis Carrier would have likely agreed with *House Beautiful* magazine editor, E. Gordon's sensitive characterisation of human physiology: 'feeling just a little too cool, a little too hot, really raises the dickens with body and soul'.³³ Thermal discomfort was understood not only as affecting work performance, it had the capacity to change one's personality ('did you know your personality changes when you are either too hot or too cold?').³⁴

For Olgyay, there would have been much at stake in achieving this model of thermal comfort. In its most ideal form, the interior environment was relatively static, 'balanced', and 'flattened', achieving a narrow bandwidth of comfort required to keep its sensitive occupants content and productive. Technological progress was marked by thermo-stability. Olgyay's bioclimatic conception was predicated on the idea that 'man' was the central measure of progress and that creating an optimized interior would contribute to the construction of an optimized life, one in which its human occupants would both physically and emotionally flourish. While this model of thermal comfort was relatively easy to achieve within a sealed, mechanically controlled environment, creating this ideal within a bioclimatic design placed a great deal of responsibility on creating a highly attuned building envelope, one that could respond to the range of meteorological 'inputs' impacting it.³⁵

Two Architectural Model/Target Systems

The architectural model featured in photographs of thermoheliodon, tasked with mediating

these two model environments, is described elsewhere in *Design with Climate* as the Phoenix 'Balanced' House, a prototypical bioclimatic design based on climatic data for Phoenix, Arizona [7]. The perimeter of the model is lined with sensors, 'thermistors for interior heat measurements and thermocouples to measure exterior temperatures'.³⁶ The interface of exterior environment and interior environment is the building envelope. The envelope was tasked with the weighty responsibility of not only accepting desirable exterior conditions while limiting undesirable conditions, but with doing so for multiple environmental variables over multiple timescales simultaneously. The point of failure for the thermoheliodon was the interface where these two conceptions of environment meet which failed to resolve thermal scaling properties.

Just as the Phoenix Balanced House model proves the point of technical failure in the device, it also reflects some tensions in Olgyay's work and the *Climate Control Project*. Despite Olgyay's interest in utter climatic specificity and corresponding architectural fine-tuning, the architectural model is marked by its generic features. This tension between generic and specific, between global and local, was mirrored by conflicts in the stylistic intention of his work—to develop regional modifications to a style, the International style, whose foundations were based on establishing thermal continuity through total mechanical control. There are similar tensions evident in his bioclimatic methodology. While Olgyay's method required nuanced modification of climate data to reflect specificities of microclimate conditions, he provides little advice on how to make these increasingly fine site-specific adjustments: 'Since the AIA cover general climatic conditions—or macroclimate—or a region, any specific application should be modified to some extent by the surroundings of the building in question—the microclimate'.³⁷ The vacillation between general and specific application of climate control strategies is evident in the *House Beautiful* 'Climate Control' case study projects as well. Langewiesche, for example, suggests 'lets try not for perfection. Let's be content to do nothing very wrong and to do the main things approximately right'.³⁸

Despite the fine-grained nature of Olgyay's analytic methods, his architectural proposals rely on repetitive use of orthogonal forms and features. In other words, while Olgyay's method relied on increasingly fine-grained understanding of environmental specificity, the architectural designs featured in *Design with Climate* seem to lack this same specificity. This may be a function of the fact that as increasing number of variables are taken into consideration, they cancel each other out in an effort to 'flatten the curve'; this, in turn, has an effect of 'flattening' the architectural response. Perhaps for Olgyay, the architectural model is more of a mental ideal rather than an actual design proposal; 'the ideal structure in the ideal location might be able to keep physical sensations wholly within the comfort range'.³⁹ Attuning this ideal to every possible climatic combinatorial possibility, however, would have required a seemingly impossible array of architectural modifications.

Models are reductive distillations; it is as much the readings as the misreadings of a model that reveal new understandings of both models and/or their targets. Historian of Science D. Graham Burnett describes those productive moments in which a dialogue emerges between a model and its target system. He suggests that it is the oscillations between a physical model and the target system that it represents that allow the model to become a ‘thinking’ tool, opening up new conceptions of the model and the world that it represents.⁴⁰ With that in mind, there is another model of architecture suggested by the thermoheliodon: that suggested by the domed enclosure and associated simulation componentry [8]. This architectural model represents an alternative environmental design strategy popularised at the time in particular by Buckminster Fuller’s domed projects. Fuller and Sadao’s 1960 ‘Dome over Manhattan’ makes visual parallels evident [9]. The three-kilometer radius dome was intended as a structurally-economical shelter that selectively filtered undesirable exterior environmental conditions, particularly snow, while simultaneously mechanically generating an ideal interior environment.

While Fuller and the Olgyay’s agendas were very different in scope and intent, they share some intentions worthy of reflection. Both pioneered working methods that conceived of environmental conditions numerically as data; just as the architectural model in the thermoheliodon was literally a sensed interface between interior and exterior climatic conditions, some of Fuller’s early projects were designed with literal data matrices embedded into the enclosure. His Geoscopes, for example, displace the sensed interface of Olgyay’s architectural model to the dome enclosure, creating the kind of three-dimensional hemispheric data matrix used in meteorological modeling at the time.⁴¹ Just as Olgyay conceived of the meteorological world as dynamic, shifting and data-rich, Fuller ‘conceived of the universe itself as an energetic-informational continuum, something dynamic, and always transforming’.⁴² The world was at least partially conceived by both Olgyay and Fuller as a dense data matrix (of meteorological data in Olgyay’s case and of a wider range of resource data in Fullers). Fuller’s architectural approach, while rigid in shape, was conceptually more flexible, locatable, and adaptable. This flexibility was enabled by associating energy efficiency with material efficiency. Thus the thermohelidon’s domed enclosure, understood as a model of architecture, offers a countervailing view about the relationship between energy minimization and human progress. This view starts to address some of the curious inversions—between interior and exterior, between the domestic and global scales, between infinite specificity and utter consistency—raised by the Phoenix Balanced House model.

Olgyay and Fuller’s architectural projects were of course very different in form and intent. Olgyay’s architecture relied on calibration of form, orientation, and environmental accessories (shades, overhangs, screens, etc) to negotiate the interface between exterior and interior climates.

Fuller's domes bypassed architectural complexity for structural and environmental efficiency, following a structural template and environmental response that was replicable across a range of scales and climates. Whereas Fuller understood his domed enclosures as environmental filters, he relied on mechanical means to create interior thermal comfort. The building envelope was both a climatic filter as well as a climatic generator. When describing the *Dome over Manhattan*, Fuller notes, 'From the inside there will be uninterrupted contact with the exterior world. The sun and moon will shine in the landscape, and the sky will be completely visible, but the unpleasant effect of climate, heat, dust, bugs, glare, etc. will be modulated by the skin to provide a Garden of Eden interior'.⁴³

In Fuller's work, the domed interior environment is, as is the dome of the thermoheliodon, an entirely climate-controlled space—a hermetically sealed environment that generates its own programmed thermal and air-flow requirements, creating an interior climate of thermostability. It is an entirely closed loop system in which environmental inputs are internally controlled. Fuller's domes offer a different vantage point from which to consider the relationship between the general and the specific, the local and the global that contrasts that of Olgyay's bioclimatic architectural designs. Fuller's project operate from the outside, the global perspective, to the inside rather than the opposite. One of the first design thinkers to understand that material and energy resourcing was fraught with global-scale inequities, Fuller developed a comprehensive planetary logic for his work that allowed him to bypass questions of regional identity and to design in a way that was both universally applicable (without modification) while also being environmentally responsive.

The Olgyay's bioclimatic design methodology, as tested within the thermoheliodon, focused on designing environmentally calibrated, regional architecture that balanced out climatic extremes. Fuller's domes, on the other hand, are conceived of as being infinitely locatable, operating anywhere on Earth, bypassing the question of contextual specificity. Fuller's encapsulations offered comfort in the most adversarial climates—deserts, the arctic, rain forests. Conceiving of the thermoheliodon's domed enclosure as an architectural model shifts focus back to what appears to be Olgyay's key priority in thermoheliodon: the development and calibration of the elaborate apparatuses, controls, and devices that simulate an exterior environmental condition within the domed enclosure. When conceived of in this way, the total environmental control required to simulate exterior environment can be understood in relation to these more radical views of climate control and the corresponding global vantage points they suggested emerging at the time.

Conclusion: Legacies

Good models act **both reflectively and projectively**. At the time, the thermoheliodon revealed, through its workings and methodological intentions, prevailing views about both its interior and exterior climatic target systems. The perimeter of the architectural model contained on the testing bed struggled to reconcile these two climatic constructs. Viewing the domed enclosure as an architectural model **offers a counter model of environmental management, one predicated on total climate control**. The thermoheliodon reflected two models of environmental design and their associated working methods and embedded value systems that have broader legacies that continue to shape environmental **architecture today**.

While environmental agendas in architecture have greatly intensified in the past half-century, the legacy of Olgyay's work is expansive. His bioclimatic design strategies are still referenced in canonical technical textbooks such as Szokolay's *Introduction to Environmental Science: The Basis of Sustainable Design*, Lechner's *Heating Cooling and Lighting: Sustainable Design Methods for Architects*, and DeKay's *Sun, Wind, and Light: Architectural Design Strategies*. In the fifty years since the publication of *Design with Climate*, some of the gaps in Olgyay's methodology have been filled. New models of thermal comfort reconcile passive design strategies with need for a broader bandwidth of thermal comfort expectations. For example, adaptive models of thermal comfort, necessary for passive design in anything but the most ideal climatic contexts, expand Olgyay's ideal of interior of 'thermo-stability' and 'climate-balance'. The adaptive model of thermal comfort challenges the prevailing view in the 1950s that climatic fluctuations were disruptive, suggesting instead that variability to point is desirable and at time even pleasurable. Moreover, mixed-mode models of environmental control establish a middle ground between entirely passive and entirely active modes of climate control.

The legacy of the two models of environmental building response suggested by the Phoenix Balanced House and the thermoheliodon dome *as architectural model* persist. The former model, informed by vernacular adaptation, relies on building configuration, orientation, window locations and associated architectural componentry for largely passive environmental control. Hawkes refers to this strategy as the 'selective mode' of environmental control, contrasting this with the 'exclusive mode,' marked by compact building form, total environmental control, and lack of specificity with regards to building orientation.⁴⁴ The thermoheliodon dome reflects this countervailing 'exclusive' model of environmental design, one that relies on the building envelope to act as a total climatic buffer in service creating a stable, highly controlled interior environment. **There are very direct legacies of Fuller's domes in more recent projects such as Grimshaw and Partner's Eden Project**. However, the broader legacy of relevance is that of Fuller's dome as both agent of energy efficiency and of sealed environmental control. In this regard, there are contemporary sustainable

architectural models that rely on heavy climate control in an effort to minimise energy consumption. The most direct comparison is PassivHaus standard, which entails creating a tightly sealed building envelope that operates as a climatic buffer, containing an interior of homogenous thermal environment. While the form and articulation of PassivHaus project bear no resemblance to Fuller's domes, they do share the trait of relative formal continuity and strict environmental management techniques.

The thermoheliodon a pre-computational device that processed raw data, foreshadowing complexities of the acquisition, processing and valuation of this data. Another significant legacy of the Olgyay's methodologies resides in that of contemporary building environmental simulation. The thermoheliodon was a complex, dynamic machine that processed data in an emerging era of computation. Some of the earliest digital building simulations were being developed roughly in parallel with the development of the thermoheliodon.⁴⁵ While the thermoheliodon was never completed, it was an advancement of other environmental simulation devices such as heliodons and wind tunnels which have largely since been eclipsed by digital simulation tools. Many of the methods outlined in *Design with Climate* went on to inform the development of contemporary thermal modelling software such as the recently discontinued Autodesk software Ecotect.⁴⁶ Just as the thermoheliodon as a project was one that remained a work in progress due to challenges associated with thermal scaling of building materials, computational strategies for reconciling scale effects continue to stymie software development. As workflows associated with developing an intuitive system for designing high performance building in the digital environment become increasingly complex, the thermoheliodon is a reminder of the value of working with objects in the physical world.⁴⁷ The thermoheliodon offers the designer a view of a totality in a way not possible in the black box of the digital environment.

In documentation of the thermoheliodon, it is striking how seemingly inconsequential and diminutive the architectural model appears; it recedes from view, overshadowed by the supporting componentry required to simulate its surrounding environment. This may reflect a shift in focus of the Olgyays' work, from that of the design of buildings to the design of methodologies. It also likely reflects broader turns in the development of environmental models, particularly of sundials and heliodons at the time as the site of operation of these models shifted from outside using the 'real' sun to inside using an 'electrical' sun. A comparison between 'sun-dials' and 'sun-machines' presented in the Olgyays' *Solar Control and Shading* makes evident that the machining of the electrical sun increasingly takes visual precedence over its effects on the architectural model [10].

Rather than view this diminution as a loss, what was gained by this change in status of the

architectural model? Fundamentally, what was gained were the questions raised and the concerns these questions foreshadowed. First, the thermoheliodon was a single fixed totality, placing buildings within a physical meteorological context that is difficult to conceptualise within the infinitely scalable digital environment. The act of attempting to construct the thermoheliodon raised complex questions about the construction of environments in general and of the building's role as a mediator of these constructions. Second, by conflating scales, the thermoheliodon reflects two emerging local versus global worldviews, described by Anker and Anker as the 'view from within' vs the 'view from without'.⁴⁸ These worldviews are evident when comparing the regionally-scaled work of the Olgyays with the globally-scaled work of Fuller. Finally, as a codification of a complex multi-valent sustainable design methodology, the thermoheliodon acts as a prescient reminder that as the variables of environmental consideration expand, there is risk that the architectural response dampens under the weight of reconciling these often competing demands. The thermoheliodon is presented as an incomplete experiment in *Design with Climate*, but what makes it remarkable is that it is simultaneously a totality and a distillation, offering multi-scalar readings and interpretations of the relationship between buildings and their environmental surroundings. The thermoheliodon acts as a reminder of architecture's increasingly necessary, yet potentially productive, diminution in relation to the complex climatological forces at play upon it.

Notes

- 1 R. Frigg and S. Hartmann, 'Scientific Models', in *The Philosophy of Science: An Encyclopedia*, ed. by S. Sarkar and J. Pfeifer (New York: Routledge, 2006), pp. 740-749.
- 2 I. Calvino, *Mr. Palomar*, (Vintage Classics, 1994), p.98.
- 3 D. Barber, 'Climate and Region, The Post-War American Architecture of Victor and Aladár Olgyay', in *Manifest*, vol. 1: Looking Inward, Fall 2013, 63-75.
- 4 A. Rose, *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism*. (Cambridge: Cambridge University Press, 2010).
- 5 Passive solar house design principles were understood at the time, but they required refinement. In the 1930s, George Fred Keck and his brother William had pioneered passive solar house design principles of glazing a south building wall to encourage winter solar gain while minimizing openings on the east, west and north walls to minimize heat loss. See J. Reynolds, 'The Roots of Bioclimatic Design,' in *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, new and expanded ed., by V. Olgyay (Princeton University Press, 2015). However, it was known that these designs were prone to summer overheating, and design was predicated on only general principles of orientation. See D. Barber, 'Climate and Region'..
- 6 Victor Olgyay includes a section in *Design with Climate* crediting related theories of sol-air building orientation, including that by Rey, Pidoux and Bardet; Ludwig Hilberseimer; and Henry Wright among others. See also I. Giovagnorio and G. Chiri, 'The Environmental Dimension of Urban Design: A Point of View', in *Sustainable Urbanization*, ed. by M. Ergen, (InTech Open, 2016).
- 7 M. Colean, 'How to Look at a Pacesetter House' in *House Beautiful*, 91 (Nov 1949), pp. 200-201.
- 8 J. Reynolds, The Roots of Bioclimatic Design.
- 9 V. Olgyay, *Design with Climate Bioclimatic Approach to Architectural Regionalism*, new and expanded ed., (Princeton University Press, 2015).
- 10 Ibid., p. 11
- 11 Anon., 'News and Notes: Grants and Fellowships Awarded in Science', in *Science*, vol. 121:3139 (25 February 1955), p. 289.
- 12 V. Olgyay, *Design with Climate*, p. 183. Extracts from previous two paragraphs are taken from a previous publication by the author (2012).
- 13 D. Barber, 'The Thermoheliodon' in *Applied Research Practices in Architecture Journal*, 01 [online], Available at: <http://www.arpajournal.net/thermoheliodon/> [accessed 21.4.17], p. 4.
- 14 Ibid.
- 15 V. Olgyay, *Design with Climate*, p.180.
- 16 Ibid, p. 152.
- 17 Anon., Climate Control Project House Beautiful October, 1949 to July, 1951. In *Weatherwise*, 2:6, December, p.139.
- 18 R. Bolgard, 'Architects Build Thermoheliodon to Try Houses for Climate Fitness: Olgyay Twins

- Seek Ideal Home Types' in *The Daily Princetonian*, 79:96 (6 October 1955), p. 3.
- 19 P. Edwards, *A Vast Machine Computer Models, Climate Data, and the Politics of Global Warming*, (Cambridge: The MIT Press, 2013). p. 126.
- 20 Ibid., p. 125.
- 21 Ibid., p. 141.
- 22 The thermohelidon operated according to its own accelerated temporality. It 'can divorce itself from the natural time cycle and accelerate the test "day," increasing the rate of experimentation'. V. Olgyay, *Design with Climate*, p. 181.
- 23 V. Olgyay, V. 'The Temperate House' in *Architectural Form*, 94 (March 1951), pp. 179-194.
- 24 V. Olgyay, *Design with Climate*, preface.
- 25 V. Olgyay, and A. Olgyay, *Solar Control and Shading Devices*. (Princeton University Press, 1957) p. 7.
- 26 Ibid., p. 14.
- 27 Olgyay. *Design with Climate*, p. 11.
- 28 D. Barber, D. 'The Thermoheliodon'.
- 29 Gatley, D. 'Psychrometric Chart Celebrates 100th Anniversary' in *ASHRAE Journal* (Nov 2004).
- 30 K. Moe, *Thermally Active Surfaces in Architecture*, (Princeton Architectural Press, 2010), p. 49.
- 31 W. Carrier cited in Moe, *Thermally Active Surfaces in Architecture*, p. 49.
- 32 E. Gordon, 'Report on the Climate Control Project' in *House Beautiful* 92 (Oct 1950), pp. 173-178.
- 33 Ibid., p. 174.
- 34 Ibid., p. 178.
- 35 Neither Olgyay nor the Climate Control agenda proposed eliminating mechanical systems altogether for supplemental heating and cooling. For Olgyay, using mechanical supplements were the final stage of his bioclimatic methodology. Similarly, the climate control project guidance prioritizing passive means of heating and cooling, but advised supplementing as needed with mechanical heating and cooling.
- 36 V. Olgyay, *Design with Climate*, p. 181.
- 37 Ibid., p. 26.
- 38 W. Langewiesche, 'A Quickie Course in Climate Control' in *House Beautiful* 92, (Nov 1950), p. 216.
- 39 V. Olgyay, *Design with Climate*, p. 31.
- 40 D. Burnett, and D. Solomon, 'Masters of the Universe', in *306090 Models*, ed. by D. Solomon (Princeton Architectural Press, 2008), pp. 44-51.

41 Hays notes, 'Fuller designed a globe, 200 feet in diameter... furnished with 10 million tiny computer-controlled pixels of light—a spherical computer display monitor for viewing Earth in the universe from inside out, like an enfolded Google Earth except with more cosmic ambitions'. K. M. Hays, *Buckminster Fuller: Starting with the Universe*. (Yale University Press, 2008). As the geoscopes gained sophistication, their relationship to computation and data management became increasingly sophisticated.

42 B. Fuller cited in Hays, *Buckminster Fuller: Starting with the Universe*, p. 169.

43 K.M. Hays, *Buckminster Fuller: Starting with the Universe*, p.3.

44 D. Hawkes, 'The Selective Environment: Environmental Design and Cultural Identity,' in *Tropical Sustainable Architecture: Social and Environmental Dimensions*. J Bay and B Ong eds. (Elsevier, 2006), pp. 29-54.

45 T. Kasuda, 'Building environment simulation before desk top computers in the USA through a personal memory' in *Energy and Buildings* 33 (2001) pp.291-302. Kasuda notes that the first ASHRAE paper featuring a computational technique was published in 1959. His pioneering work digitally simulating interior thermal environments of bomb shelters for the US National Bureau of Standards was published in 1964, a year after *Design with Climate* was published.

46 D. Leatherbarrow, and R. Wesley, 'Performance and Style in the work of Olgyay and Olgyay', in *arq* 18.2, (2014), pp. 167-176.

47 T. Gado, and M. Mohamed, 'More accurate computer simulation for intelligent buildings: Exporting 3D building models to Detailed Thermal Simulation Software,' in *Intelligent Buildings International* (n.d.).

48 N.Anker and P.Anker, 'Viewing the Earth from Without or from Within,' in *New Geographies 4: Scales of the Earth*, ed. by El Hadi Jazairy (Harvard University Press, 2011), pp. 89-93.