Rising out of the Industrial Ashes:

Reducing Energy Needs and Giving Life to Pittsburgh's Educational And Commercial Facilities Through Restoration and Retrofits

Thesis Proposal

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Introduction:

The urban environment of Pittsburgh contains numerous large structures devoted to industry, academic, or various other uses that warrant high demands on occupied space and energy consumption. The latter is a direct result of occupants' desire to control the interior climate through mechanical ventilation, heating, and cooling. Many of these structures are too old to be efficient through means of sealed modern comfort zones,[1] and yet people have lived comfortably there even before central air was invented. In the past, these large buildings were kept cool, warm, and ventilated without unsightly two ton air handlers on the roof.[2] [3] In an urban context, they were not draining the electric grid or the water system to stay cool and were not inhospitable to the occupants. However, many of the large scaled public buildings of today are using vast amounts of energy, as much as fifty percent of their energy budget to achieve the demands for lighting and air conditioning combined.[4] Surely, there were a few days when older buildings were hot but not altogether unbearable. But now, many of Pittsburgh's modern energy dependent high-rises have sealed windows that prove troublesome when there is no power for air conditioning on a

3.1 : Commercial Sector Energy Consumption

3.1.4 2010 Commercial Energy End-Use Splits, by Fuel Type (Quadrillion Btu)

	Natural Gas	Fuel Oil (1)	LPG	Other Fuel(2)	Renw. En.(3)	Site Electric	Site Total	Site Percent	Primary Electric (4)	Primary Total	Primary Percent
Lighting						1.19	1.19	13.6%	3.69	3.69	20.2%
Space Heating	1.65	0.22		0.06	0.11	0.28	2.33	26.6%	0.88	2.93	16.0%
Space Cooling	0.04					0.84	0.88	10.1%	2.60	2.64	14.5%
Ventilation						0.54	0.54	6.1%	1.66	1.66	9.1%
Refrigeration						0.39	0.39	4.5%	1.21	1.21	6.6%
Water Heating	0.44	0.03			0.03	0.09	0.58	6.7%	0.28	0.78	4.3%
Electronics						0.26	0.26	3.0%	0.81	0.81	4.4%
Computers						0.21	0.21	2.4%	0.66	0.66	3.6%
Cooking	0.18					0.02	0.20	2.3%	0.07	0.25	1.4%
Other (5)	0.30	0.01	0.14	0.05	0.01	0.69	1.20	13.7%	2.13	2.64	14.5%
Adjust to SEDS (6)	0.68	0.25				0.02	0.95	10.9%	0.06	0.99	5.4%
Total	**3.29**	**0.52**	**0.14**	**0.12**	**0.14**	**4.54**	**8.74**	100%	**14.05**	**18.26**	100%

Note(s): 1) Includes (0.43 quad) distillate fuel oil and (0.08 quad) residual fuel oil. 2) Kerosene (0.01 quad) and coal (0.06 quad) are assumed attributable to space heating. Motor gasoline (0.05 quad) assumed attributable to other end-uses. 3) Comprised of (0.11 quad) biomass, (0.03 quad) solar water heating, (less than 0.01 quad) solar PV, and (less than 0.01 quad) wind. 4) Site-to-source electricity conversion (due to generation and transmission losses) = 3.10. 5) Includes service station equipment, ATMs, telecommunications equipment, medical equipment, pumps, emergency electric generators, combined heat and power in commercial buildings, and manufacturing performed in commercial buildings. 6) Energy adjustment EIA uses to relieve discrepancies between data sources. Energy attributable to the commercial buildings sector, but not directly to specific end-uses.

Table 3.1.4 from Building Energy Data Book

[1] Such as is the case with the College of Fine Arts. The conditioned air can be perceived to drop from the upper floors down to the basement and lost to the outside. .

[2] Technical Preservation Services. *National Park Service* http://www.nps.gov/tps/sustainability/energy-efficiency.htm (Accessed 5 August, 2013)

[3] "Energy Conservation for Historic Buildings" Historic Preservation Office. p. 2. http://dc.gov/DC/Planning/Historic+Preservation/Maps+and+Information/Policies+and+Procedures/Design+Guidelines/Energy+Conservation+for+Historic+Buildings (Accessed 5 August, 2013)

[4] Table: 3.1.4 : D&R International, Ltd., and Pacific Northwest National Laboratory. *Commercial Sector Energy Building Energy Data Book*. U.S. Department of Energy Consumption http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.4 (Accessed 1 September, 2013)

summer's day. And the urban islands of heat that grew with the steel and brick city now reflect that thermal energy back, even at night, spoiling nocturnal efforts to stay cool with re-emitted heat from the high walls, pavement, and spanning structures.[5] Compounding this urban problem are current laws that have designated many of these old buildings as historic landmarks and restricts them from being modified on the exterior, leaving the interior as the only possible means of improvement.[6]

Heat Island Effect is solar energy absorbed then reflected back into the city environment, increasing the temperature. Photograph by Author

Research Question:

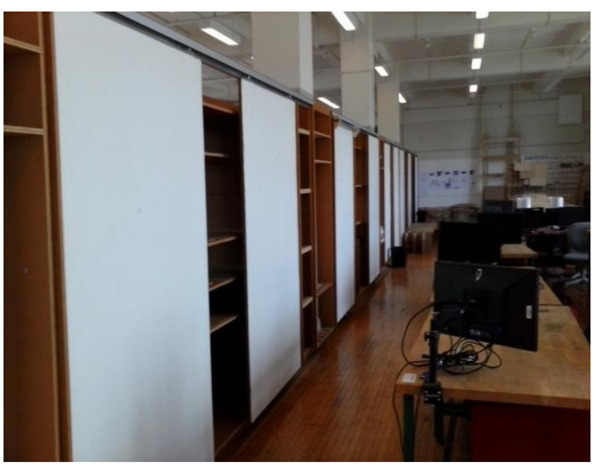
While there are numerous buildings from Pittsburgh's industrial past affected by the increase in insatiable demands for climate comfort, there exists a landmarked building on the Carnegie Mellon University campus that can serve as the typical example. The College of Fine Arts features large floor plates in plan, broad wall surfaces, and inherent climate control features in need of repair or restoration, often overlooked by newer systems that work continuously to keep the temperature and

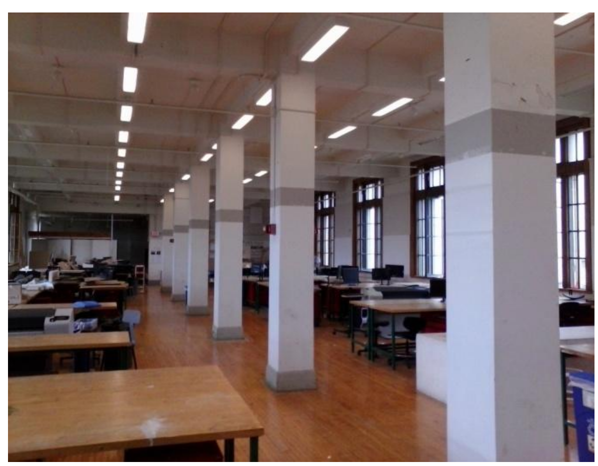
The sheer amount of direct sunlight pours into studio is amazing. Photograph by Author

[5]Heat Island Effect *Environmental Protection Agency* http://www.epa.gov/heatisland/about/index.htm (Accessed 1 September, 2013)
[6] Dian Shaw, on mention of the historic manor on Fifth Avenue, Pittsburgh PA

lighting comfortable. Not every floor has this luxury but it should not have to be the solution to every condition. Simply conditioning the air is prone to vast energy leaks and consumption that will be overburdening to the city should every office or school building take this route, as demonstrated by the C.F.A. Yet, a solution can be developed in an area where newer systems have yet to be built.

One often hears complaining by faculty, staff, and students about the extreme levels of morning and afternoon light blinding them in the CFA 200 Studio. This combined with the high temperatures and humidity that exhaust them every season except winter, gives one pause for thought. Is it possible to explore the exact conditions of that studio and propose and test a viable but efficient solution to the discomfort? Various attempts to improve the space, such as sealing the transom windows for weather-proofing appear to have lead to more uncomfortable conditions. Having dismantled the storage shelves dividing the studios, this author has personally felt the instant benefits of natural ventilation in the heat of summer, but unfortunately witnessed paperwork flying in the breeze. What is desired to be found is if there is a means to satisfy diffused light, natural ventilation, and to maintain a steady environment? Is there a synthesis possible between traditional architectural solutions and modern ones?





Proposal:

In theory, one should be able to reduce the thermal loads of the C.F.A. studio by means of a system utilizing specialized wooden blinds or slats and window restorations that would allow the building to stay well-ventilated and cooler. As it stands, opening the main windows causes papers and projects to fly in the breeze. Operating the transom windows would allow ventilation of the hot air out of the environment. Operable wooden blinds would match the historic architecture, be movable to promote unfiltered views when wanted, but feature a profile to adequately block summer sun and let in the winter sun, as explained in a concept by Professors Loftness and Harptkoff in their lectures.[7] [8] Using the C.F.A. Studio as the example, it is this thesis project's proposal to offer interior solutions to many large studio and office spaces in historic buildings that

There should be a way to use the daylight to reach into all of C.F.A. 200 and keep the room well-ventilated, saving energy. Photographs by Author.

[7] Hartkopf, Volker. 48-415 Advanced Building Systems Lecture Notes from Carnegie Mellon University, Pittsburgh PA, Spring 2013

[8] Loftness, Vivian 48-315 Enviro I Climate and Engineering Lecture Notes from Carnegie Mellon University, Pittsburgh PA, Fall 2011

restrict alterations to the inside surfaces. Using research into restoring existing architecture such as transom windows and by designing integrated systems to diffuse light while retaining window operability and visibility as needed, this project could assist future development in Pittsburgh. This city is in need of careful solutions for many historic buildings to remain operable and not heavily dependent on the urban power grid.

Method:

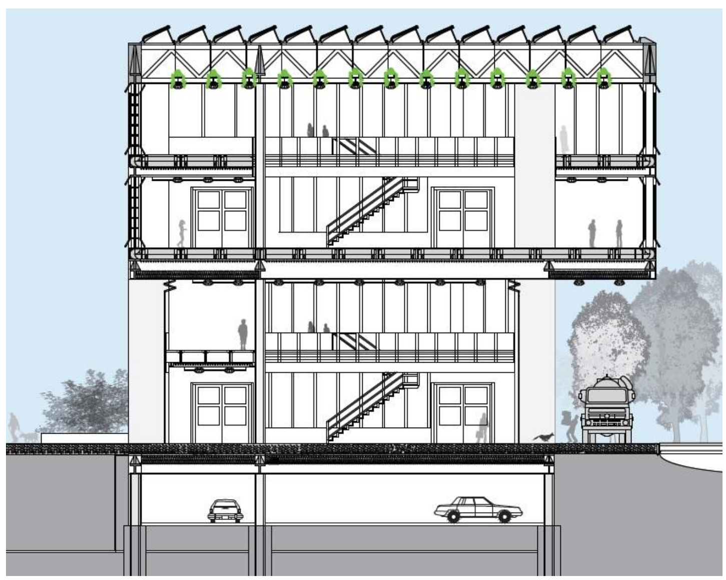
The thesis project is divided into several phases for the duration of the academic year. Beginning in the autumn of A.D. 2013, C.F.A. 200 will be thoroughly measured and analyzed. Detailed plans and sections will be produced, with exceptional attention to be given to the window details. Circulation studies and use diagrams will be drawn in accordance to actual observation. Paper surveys will be handed out to students and faculty to assess what seems to work and fail in that environment, at particular times. (Studio environments vary on the weekends and into the nights.) Respondents will also rank the deficiencies of studio as well as strengths of the space, including natural or artificial light and acoustics. The room will be measured by means of light and thermal sensors and even photography to capture the precise moments and conditions of discomfort.

Once the physical dimensions of the studio are attained, it is then intended to recreate the studio in a large-scaled wooden model, at one inch equals a foot or thereabouts. While data is still being collected on the light and thermal and survey factors, the model would be built in detail to the actual environment so that conditions can be replicated in physical experiments.

Materials already in possession would allow the model to truthfully replicate the physical qualities of the space with real materials instead of digitally simulating them.

After the model is built and the data collection is obtained, the information will be used to replicate the solar conditions with incandescent and fluorescent lighting experiments to test key days of the year. It is hoped that the same sensors used to measure studio will fit within the model. With use of a fan, streamers, and possibly canned smoke, the ventilation patterns will be demonstrated. A spatial model of the former storage spaces may also be built to demonstrate the crucial effectiveness of open circulation.

Large scaled models and drawings will aid the proposal, driven by the findings in research to physically test ideas. (Photograph and drawing by Author)



Large scaled models and drawings of proposed solutions for the interior sides of C.F.A. 200 will be built after the above has been demonstrated. “Smaller” models will be made by hand to fit inside the studio replica so that their effects may be observed with experiments. At this point, three dimensional modeling software and printers may be implemented to produce some of the more complicated mathematically based test models to fit the scaled C.F.A. 200 replica. However such works will then have to be build out of like materials to match the context, should it prove to be a functionally desirable design. With focus on the functionality of the windows, the design will be challenged to keep the manner of operating the windows and enabling views as an irrevocable requirement of the design.

If one of the designs can be demonstrated in the studio model to successfully diffuse the light, retain visibility, improve ventilation, reflect the traditional architecture, and be feasible and approved by faculty for testing, then full scale prototyping may begin on several adjacent windows in the actual studio, using wood and materials appropriate to the wall architecture. If that proves to achieve the same requirements and results as the modeled design, then remaining windows will have the same design installed.

Another round of data collection will commence after full installation, to analyze the changes in natural illumination, use of artificial illumination, retention of desired visibility, ventilation, and functionality. Post occupancy surveys will be distributed to evaluate student and staff's response to the installations.

A final presentation of findings and a conclusion to the thesis project will be given at the end of the spring A.D. 2014 semester. It will be challenging to complete all the above in an academic year, given the size of scope and space and even the size of a single window. But there exists a potential to fix problems that have plagued C.F.A. 200 for decades, problems that many large public spaces share, which are too expensive or restricted to treat with sealed air conditioning. The key is understanding the existing traditional architectural solutions to climate concerns, restoring them and integrating solutions to augment rather than replace them. If that could be done, then historical urban contexts like that of Pittsburgh can be updated to meet new demands for comfort.

Schedule:

Month	Date	Items Completed by Date
Sept.	3	Second Draft
Sept.	9	Bibliography Review
Sept.	16	Revision
Sept.	23	Final Draft
Sept.	30	Initial light and space mesurements
Sept.	31	Occupant survey
Oct.	10	Detailed C.F.A. 200 Model 1" = 1'
Oct.	14	All light measurements on site done. Transom studies and restoration recommendations complete.
Oct.	21	First round of small models and mesurements in CFA model
Oct.	23	Thesis Mid. Sem. Review
Nov.	4	Second round of models with light studies
Nov.	11	Large iterations of second models
Nov.	18	Third round of models.
Nov.	25	Large iterations of third models with light studies
Dec.	1	Testing large or full scale iteration with light studies
Dec.	8	Final Review, Winter
Dec.	13	Book delivered
Jan.	13	Resume
Jan.	20	Fourth round of models with light studies
Jan.	27	Large scale of fourth model
Feb.	10	Final (?) round of models with light studies
Feb.	17	Large scale prototype. Transoms restored.
Mar.	10	Installation on several windows and data collection
Mar.	14	Mid semester review
Mar.	31	Installation complete
April	7	Light, ventilation, and temperature studies
April	14	Occupant surveys
April	21	Usage studies
April	28	Longetivity and wearing studies
May	5	Final Presentation
May	12	Book published
May	18	Graduation

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Annotated Bibliography

As Precedent:

Dank, Richard, and Christian Freissling "The Framed Pavillion" Robotic Fabrication in Architectrue, Art and Design (New York: Springer Wein, 2013) 238-247

This particular article proved insightful in demonstrating the capabilities of robotic multi-axial fabrication for actual full-scale wooden structures. In this case, the wooden 2x4's required custom ends to be self-supporting without any adhesives or metal insertions on the compound joints. For this thesis project, the article provides a viewpoint on the usefulness of automated machinery to produce repeating elements as well as the methodology to effectively use such tools in a timely manner.

Meek, Christopher M., and Kevin G. Van Den Wymelenberg. Daylight Design in the Pacific Northwest. (Seattle: University of Washington Press, 2012)

In conditions eerily similar to Pittsburgh, these designs tackle natural lighting in constantly overcast skies as well as undesirable weather. Despite the cloud cover, the light diffusing shelves and other solutions do a wonderful job of creating natural but even lighting. Apparently a single light shelf can be as effective as a complete set of blinds.

Moloney, Jules. *Designing Kinetics for Architectural Facades State Change*. (New York: Routledge, 2011)

With an adaptive or adjustable interior treatment proposed for this thesis project, this book provides much needed information on the manner of kinetic façade treatment that may prove useful on the inside for light diffusing. It treats kinetic systems as an art, encouraging beauty along with utility. The ability to adjust the facades will be better understood and accounted for, because of this book.

"Natural lighting benefits new building" *American School & University* 71.10 (Jun 1999): 66H

Although skylights are different than traditional window treatments, the positive effects of natural light is mentioned as a benefit to the school that utilized it.

Rasmussen, Steen Eiler. "Chapter VIII Daylight in Architecture" *Experiencing Architecture.* (Cambridge: MIT Press, 2001) 186-214

Various examples of effects achieved with natural lighting is shown in historical efforts to illuminate interior spaces. The article shows the unique Dutch window placement, among others. Overall, the past examples are laden with the common goal of diffusing then distributing light to provide a bright but even level of illumination. The materiality or colors come to play with making the reflected light seem warm or cool, in relation to the nature of the rooms.

Steane, Mary Ann. *The Architecture of Light Recent Approaches to Designing with Natural Light*. (London: Routledge, 2011)

The author presents the case for using natural light to evoke "potential" in spaces that can not be had with static lighting. In other words, rooms must be dynamically lit because people change throughout the day and a great space is one that reflects this. The modern examples from the last eighty years, starting with Modernism and ending at the turn of the Millennium, show how the moving sun can be utilized, not just during strategic periods of time.

For Preservation and Restorations:

"Energy Conservation for Historic Buildings" Historic Preservation Office. http://dc.gov/DC/Planning/Historic+Preservation/Maps+and+Information/Policies+and+Procedures/Design+Guidelines/Energy+Conservation+for+Historic+Buildings (Accessed 5 August, 2013)

This government pamphlet covers energy restoration needs typical to a Washington, D.C. historical building. It outlines examples of how to improve while still retaining façade appearances as well as how to restore the already inherent climatic features.

Plummer, Henry. *Masters of Light First Volume: Twentieth-Century Pioneers*. (Tokyo: a+u Publishing Co. Ltd., 2003)

The author demonstrates the changing perception of light in the last century from artistic expression to a more scientific, therapeutic approach by showing the growing transparency of structures coinciding with new scientific theories on the principles of light. Technology in architecture enabled them to build according to those theories, he stipulates, even as far back as Medieval times, when innovations in glass and stone work enabled the beautiful Gothic architecture to splash light across the spectrum.

Technical Preservation Services. *National Park Service*

http://www.nps.gov/tps/sustainability/energy-efficiency.htm (Accessed 5 August, 2013)

A government website that is written to help homeowners to identify systems already built in their historic homes that can be restored to save energy. It also links to alternative means that can improve a building without negatively impacting the historic nature of the structure.

For Calculations and Quantified Information:

D&R International, Ltd., and Pacific Northwest National Laboratory. *Commercial Sector Energy Building Energy Data Book.* U.S. Department of Energy Consumption http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.4 (Accessed 1 September, 2013)

An exhaustive proof of energy demands and defined usage, this book provides the strongest case for energy reduction in buildings by outlining every major fuel type and the end use of such fuels by building typology and function in two hundred and eighty-six pages. It features projected use into the future as well as information on the past research so that the rate of change is fully understood. By demonstrating how much energy goes to lighting, ventilation, and cooling, the resource validates efforts to reduce that energy need in this thesis project.

Edwards, L. and P. Torcellini. “Daylighting in Schools” *Report: A Literature Review of the Effects of Natural Lights on Building Occupants*. (Golden: National Renewable Energy Laboratory, 2002) 17-22 Accessed 4, August 2008 http://www.parans.com/swe/lightacademy/pdf/

The authors make use of a reference-rich report prepared for the federal government to demonstrate proof of the effects of daylight and the lack of it in schools. They cite studies on the effects of vitamin d, growth, test scores and other factors that would be useful in demonstrating need for natural lighting in the C.F.A. studio, if only diffused to avoid the negative aspects of direct lighting.

Hartkopf, Volker. 48-415 Advanced Building Systems Lecture Notes from Carnegie Mellon University, Pittsburgh PA, Spring 2013

Professor Hartkopf's class provided an invaluable source of information on systems that addressed occupant's needs with minimal need for the typical HVAC systems. Real world examples serve as inspirations for this project.

Heat Island Effect *Environmental Protection Agency* http://www.epa.gov/heatisland/about/index.htm (Accessed 1 September, 2013)

This government website features a basic understanding of the urban heat island issue by outlining the relationship between a built environment, the solar heat gain and delayed release of heat, the increased temperature of night air and even runoff water, loss of aquatic animals, and the drain on urban energy resources that ironically cast more heat into the environment. From these factors, it would seem that buildings would have their windows and other glazed surfaces barraged by the reflected heat, increasing the interior temperature. Thus, the proposed study for C.F.A. would then have to address this issue by reflecting the heat back to the outside.

Hopkinson, R.G., and J. B. Collins. *The Ergonomics of Lighting*. (London: Macdonald Technical and Scientific, 1970)

Featuring studies on lighting such as hospitals as well as biological explanations of human perception of light, this work is another good source of information on the science and need for natural light. It goes into detail about undesirable effects of lighting such as glare or flickering light sources and the reason for discomfort.

Hopkinson, R.G., P. Petherbridge, and J. Longmore. *Daylighting*. (London: Heinemann, 1966)

With beautiful slides and pictures of real world conditions and figures, these three professors make a case for natural daylight and the mathematics needed to go beyond minimum lighting standards. The book covers a wide variety of scenarios with daylight, both from the sun itself and from the diffused sky as well, so that different and variable factors can be handled simultaneously.

Loftness, Vivian 48-315 Enviro I Climate and Engineering Lecture Notes from Carnegie Mellon University, Pittsburgh PA, Fall 2011

This class provided the foundation for calculating loads by using a real domicile for problem solving. It served as an example of research projects. This same manner of examining a building down to the details and proposing a solution will be performed for this thesis project, if permitted.

Lynes, Judith A, Lecturer of Architecture from University of Manchester. *Principles of Natural Lighting*. (Amsterdam: Elsevier Publishing Company LTD, 1968)

The author lays out the basics of natural daylight and the mathematics involved in identifying existing conditions as well as the procedure to produce a solution from that data. Despite the age of the book, the beauty and utility of the mathematics remain valid for modern design.

Measuring Heat Island. *Environmental Protection Agency* http://www.epa.gov/heatisland/about/measuring.htm (Accessed 1 September, 2013)

This government agency webpage provides insight into how heat island effects are recorded and how they, in turn, affect the environment, even altering weather station readings miles away! Methods listed include satellite imagery and traditional weather station readings. With this background information in place, one could logically suppose that the Heat Island Effect could infiltrate buildings through infrared radiation, whether directly from the sun or reflected from buildings into occupied spaces. Thus, devices on the window could reflect the unwanted light but still provide a source of visible and diffused light.

Mattern, Jerry 48-412 Enviro II Building Systems Lecture Notes from Carnegie Mellon University, Pittsburgh PA, Fall 2012

This class provided an opportunity to calculate system performance from loads figured out originally from Enviro I. As a precursor to Advanced Building Systems, the course was open to new designs to solve building concerns but at a scale appropriate for C.F.A. 200. The large square footage floor plates used in the class's calculations are relatable to the ones expected for C.F.A. 200.

Wong, Eva. "Reducing Urban Heat Islands: Compendium of Strategies Urban Heat Island Basics" ed. Kathleen Hogan, Julie Rosenberg, and Andrea Denny. *Climate Protection Partnership Division, U.S. Environmental Protection Agency's Office of Atmospheric Programs.* http://www.epa.gov/heatisland/resources/pdf/BasicsCompendium.pdf (Accessed 1 September 2013)

This government publication is the result of much research into Heat Island Effect and supplements it with usual solutions, such as green roofs, cool colors, and more trees. But it also demonstrates the novelty of this thesis project because of the displayed general interest in greenery, paving, and building materials instead of solutions for the large window surfaces that let the heat into the interior of a building.

Verges, Mireria. *Light in Architecture*. (Antwerp: Tectum Publishers, 2007)

This book divides light into categories by conditions, from louvers to perforations to artificial and natural conditions with numerous examples and insight. It will prove useful in the synthesis of natural and fluorescent lighting in studio by demonstrating the different needs of each situation.