



# AN EXPLORATION TOWARDS FORM

A PHOTOVOLTAIC CHARGING STATION DESIGN FOR ELECTRIC SCOOTERS AT VIRGINIA TECH

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VIRGINIA TECH

By Milton A. Salcedo

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science In Architecture.

Joseph H. Wheeler, Chair *(did not approve ETD)*

Robert J. Dunay

David B. Clark

May 06, 2013

Blacksburg, Virginia

Keywords: Photovoltaic, Glass, Scooter, VT, Bus stop.

# AN EXPLORATION TOWARDS FORM

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VIRGINIA TECH

MILTON A. SALCEDO

## ABSTRACT

This project is a proposal on the versatile use of glass, its properties and technologies as well as its aesthetic qualities. A photovoltaic charging station for electric scooters is proposed for the Virginia Tech campus, combined with a bus shelter to allow mobility and integration of transportation.

# DEDICATION

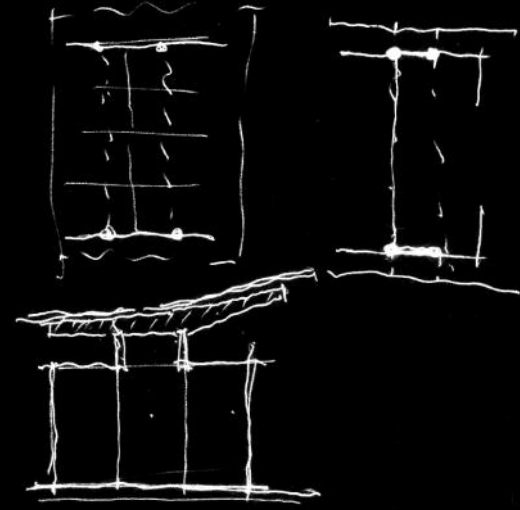
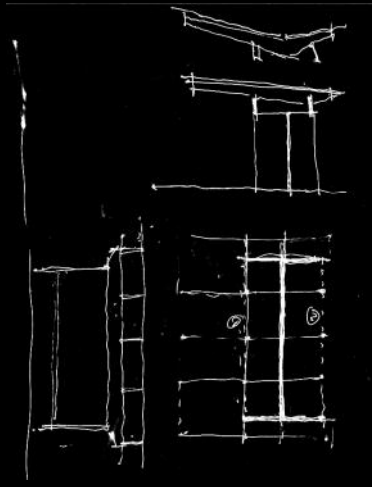
Este proyecto de grado esta dedicado a mi maravillosa familia. Mis padres que siempre me han apoyado en todo el trascurso de mi vida y enseñado a ver la vida con gran sentido. Mi hermano que siempre he querido lo mejor para él y que sé que tendra un future maravilloso. Pero este trabajo está especialmente dedicado a mi maravillosa esposa que es mi todo, mi vida, mi suspiro, mi Corazón, mi polo a tierra, mi todo. Iniciamos juntos una nueva vida llena de aventuras donde sólo somos un par de gocetas como algunos nos dicen y así será pos siempre. Te amo mi lagartija.

# ACKNOWLEDGEMENTS

I would like to thank all my committee members for their academic support and for letting me be part of the excellent Lumenhaus group and the research class. This work would not have been possible without the support of my classmates and friends, especially Chip Clark, Connor Toth, Joshua Batman, Mohammed Al-Fadil, Luisa F. Betancurt, Mauricio Sanchez, Sidney Gardner, Tommy Bett, Paulo Garcia, Steve Booth, VTLCI members and my grandparents in Blacksburg. Thank you so much for everything...

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# INTRODUCTION

This project presents an exploration of efficient alternatives to design a photovoltaic charging station for electric scooters combined with a bus stop. It is very important to integrate the bus system with the charging stations so the users can charge their vehicles and use the bus to travel to further locations.

Another objective is to reduce the use of cars to decrease the pollution in cities by encouraging the use of electric vehicles. It is common to see only one person per car generating a lot of traffic and pollution. This results in overpopulation of cars and the densification of new buildings for parking on campus.

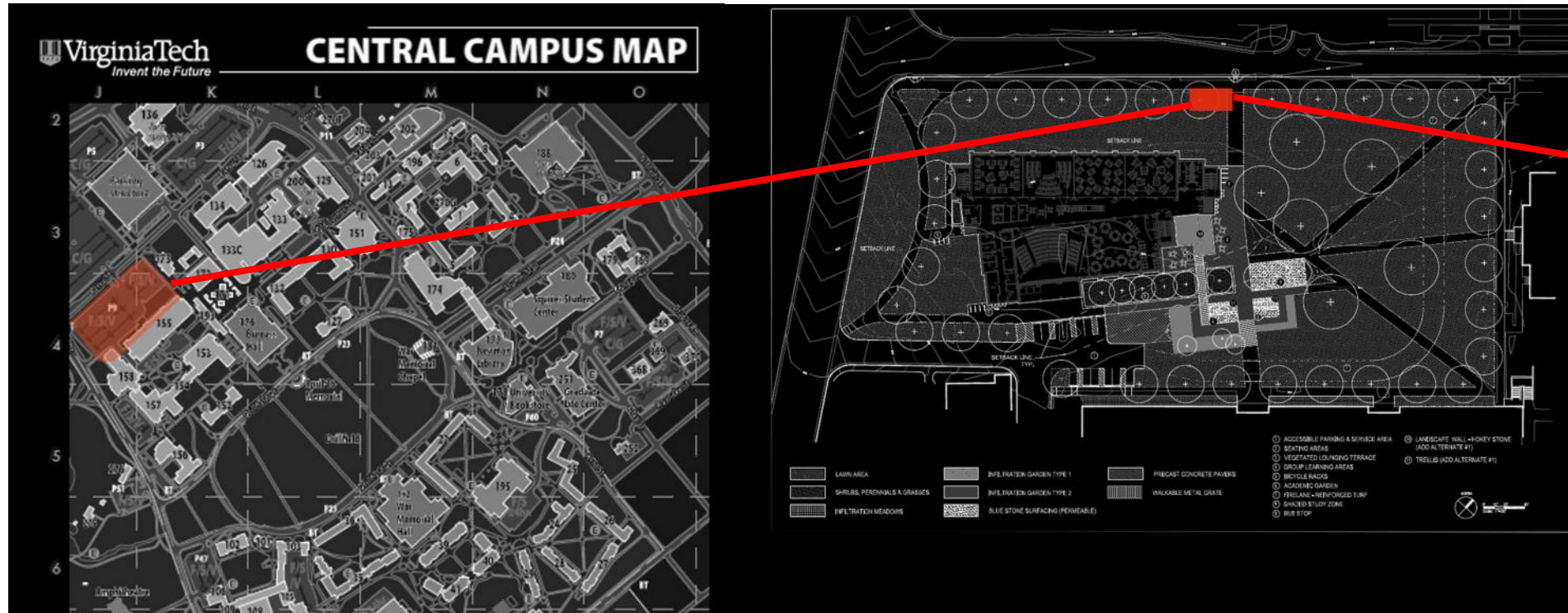
Other objectives derived from the main goal are to implement other kinds of materials, like smart glass, and new electronic systems developed by researchers at VT.

The station is made of glass because this material connects all the spaces around with its transparency and allows people to have different views from the inside without any barriers. Also, using glass allows conserving the architectural language of the buildings on campus without being intrusive, and it allows us to show the properties of glass in architectural projects.

The photovoltaic charging station (PVCS) for electric scooters at Virginia Tech promotes the use of electric scooters by the community. This project will improve the mobility of students on campus and that contributes to the environment.

The PVCS allows increasing mobility in the city, generating short routes and reducing time. The charging station will be clean, efficient, low cost and easy to use. This project aims to connect the bus shelter and the charging station into one element.

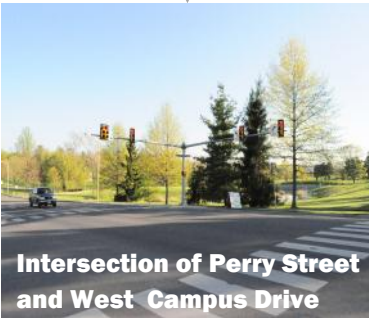
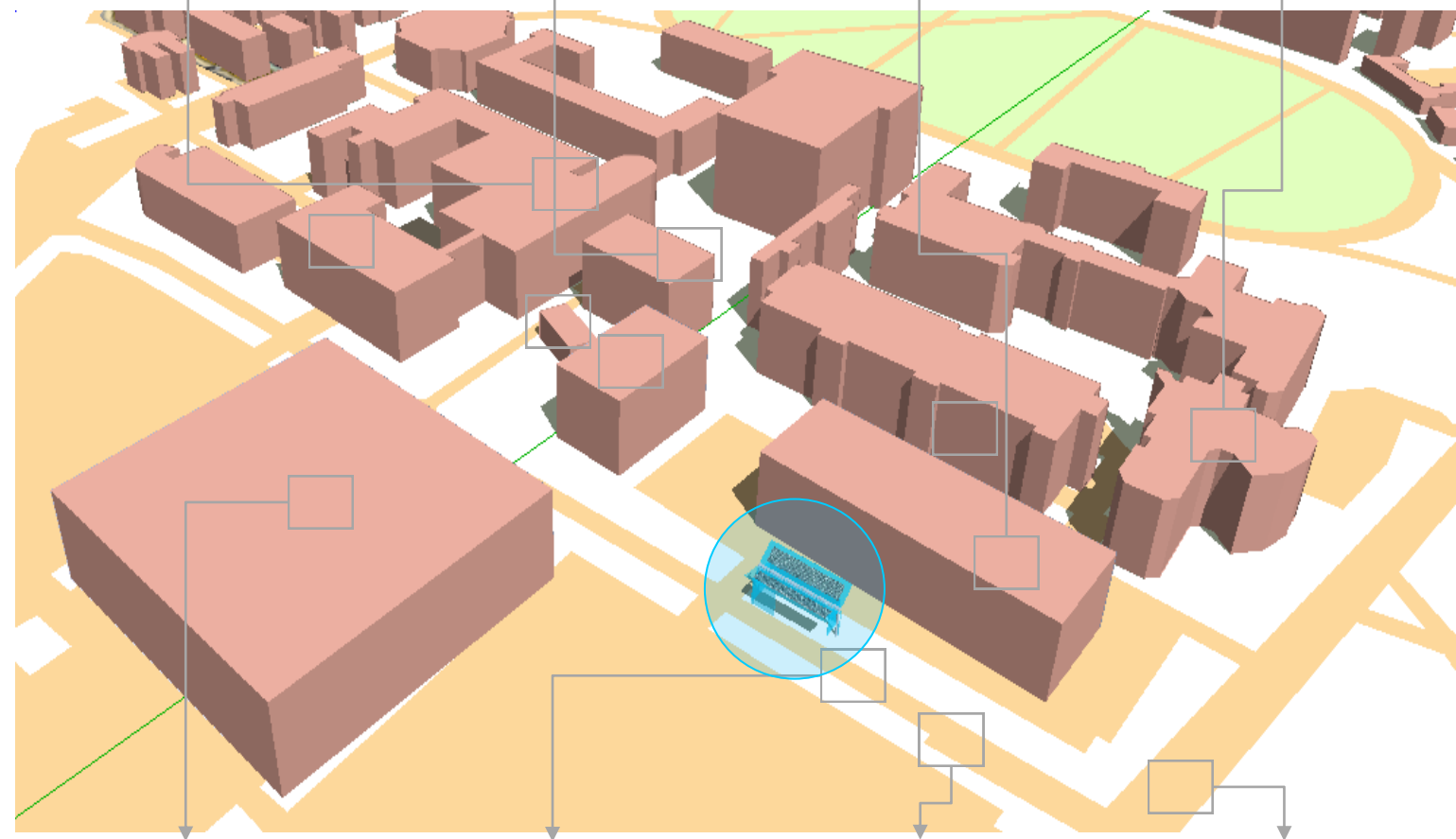
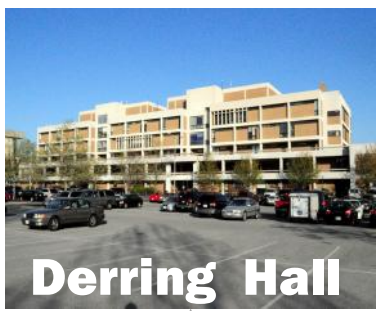
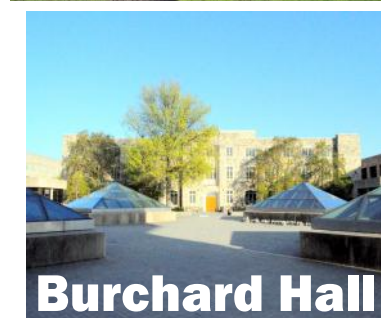
## **PART 1– SETTING THE PROJECT**



## LOCATION

The PV Charging Station location site is on the north side of Virginia Tech campus in the core of instruction activity. The chosen place is a parking lot for faculty, staff and students from the Hahn North and Derring Hall Buildings. It is in the city of Blacksburg in the State of Virginia, US. The location of this PV Charging Station is of great significance because this site will incorporate new designs consistent with the urban planning vision of the university that is planned to be developed during the next few years. The project is planned to be at the intersection of Perry Street and West Campus Drive.





COURTESY BY STEVE MOURAS  
DIRECTOR OF TRANSPORTATION PLANNING AND SUSTAINABILITY OF VIRGINIA TECH

## CONTEXT

The chosen site is located just north of campus at the intersection of Perry Street and West Campus Drive. Right now it is a parking lot for the buildings around. In the future it'll be a new classroom building with a new urbanism. The physical limits of the site are full of new buildings that try to have the same architecture language and some of them have the hokie stone in their facades that give Virginia Tech an important symbolism, history and memories.

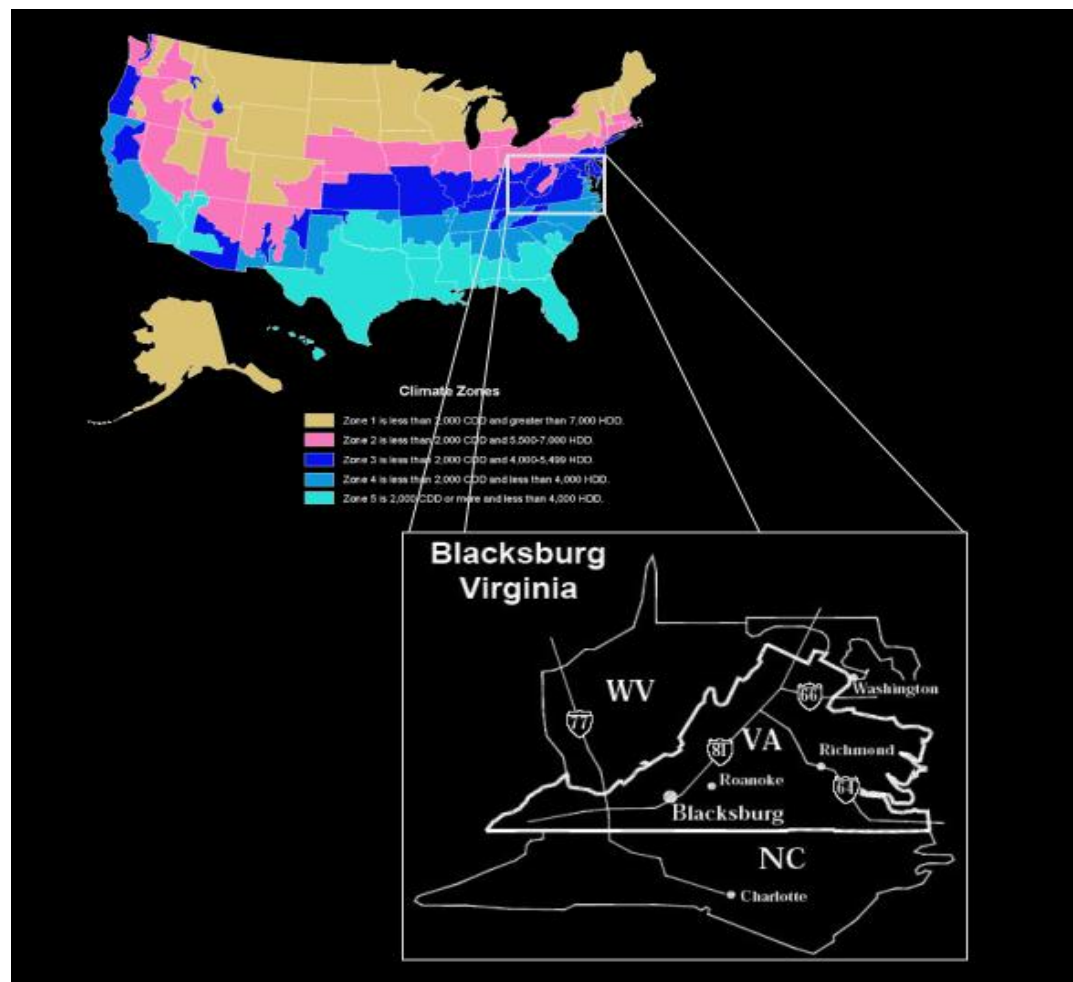
## **PART 2 – SITE ANALYSIS**

# CLIMATE ANALYSIS

Blacksburg, VA has a variety of weather conditions caused by how the different elevations of the Appalachian mountain system affect the city. This city has an average summer temperature of 70 and winter of 30.

The month when temperatures are really high is July where the average could be 82.50 degrees Fahrenheit. The coldest temperature could be 20.60 degrees Fahrenheit in January.

In Blacksburg, VA temperatures can vary between night and day causing fog early in the mornings.

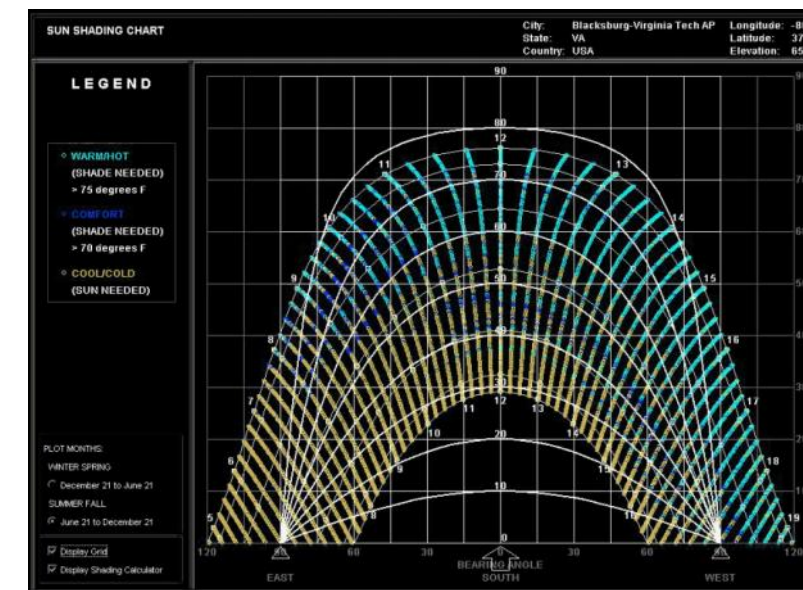
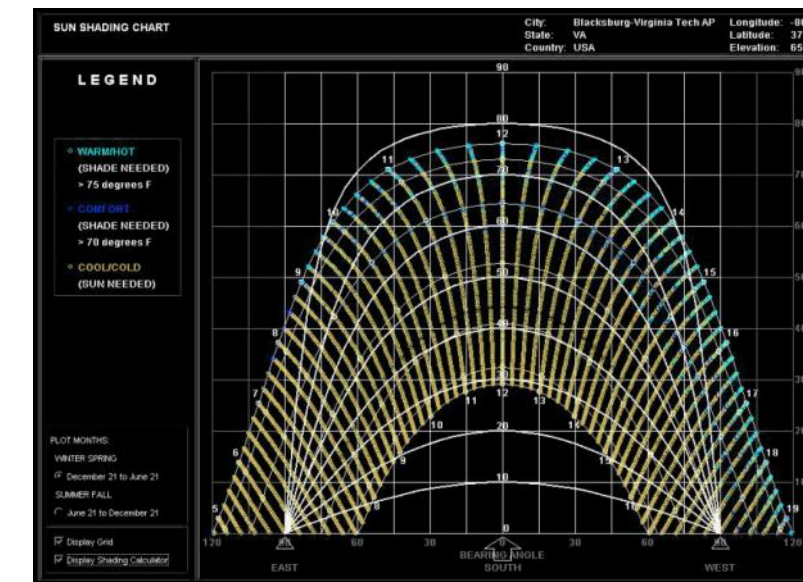


# SUN PATH

The sun path diagram for Blacksburg city shows how the sun moves in the sky during all year and for daylight hours around a center point. Horizontal sun positions are determined by azimuth angles measured between south and the circumference from the center point. Vertical sun altitude angles are indicated on the north-south center line scale.

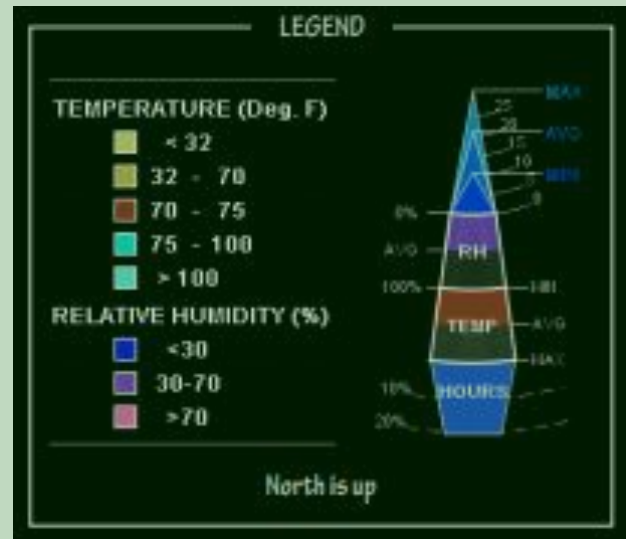
The PV in the Charging Station are facing due South directly to the sun resource with 30degree pitch. With this we can obtain 3.84 Kw to use charging the scooters.

Source:  
<http://solardat.uoregon.edu>

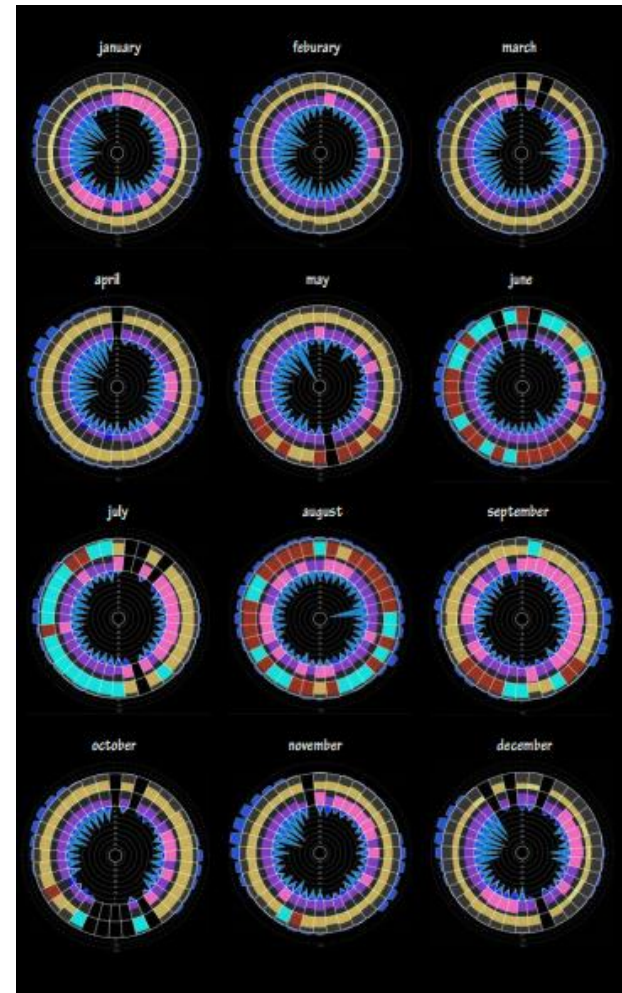


Montgomery county has variable conditions of wind. In winter and spring the more predominant cool wind is coming from the West—North West. Every Year, Blacksburg has wind velocities of 12.5 mph. The highest velocity is 15 mph and it occurs from December through April.

Record velocities have maintained 38 mph. Peak wind gusts have been measured in the high 70s.



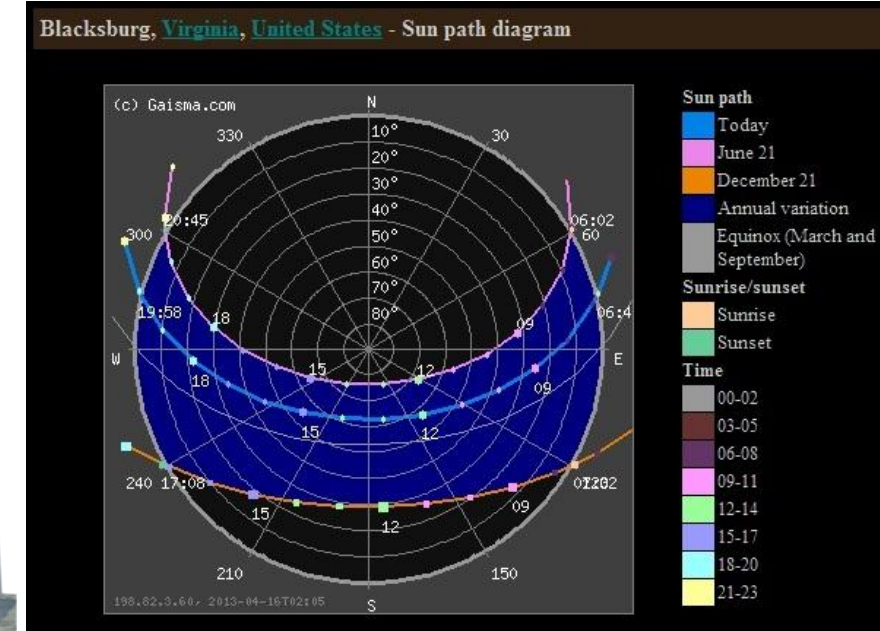
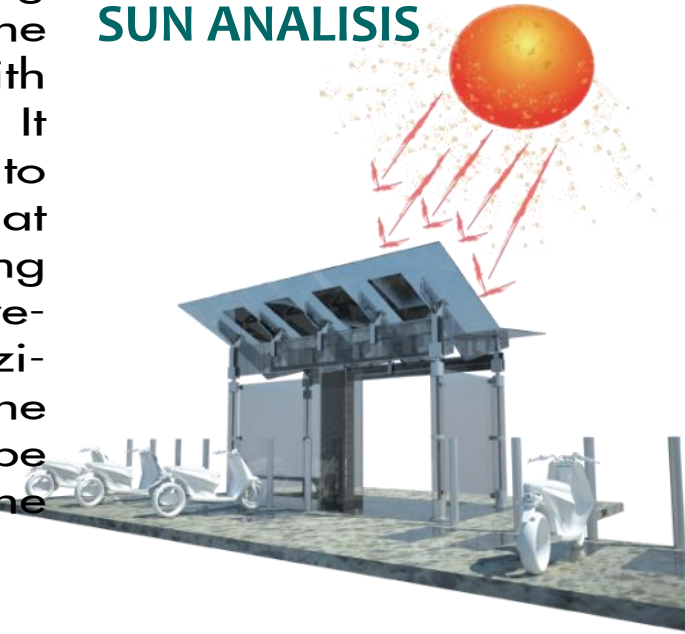
## WIND ANALYSIS



Sources:  
<http://solardat.uoregon.edu>

The sun shading charts combine sun path with thermal data. It will be helpful to understand what kind of shading strategies for related solar azimuth and the rent angles to be applied in the project.

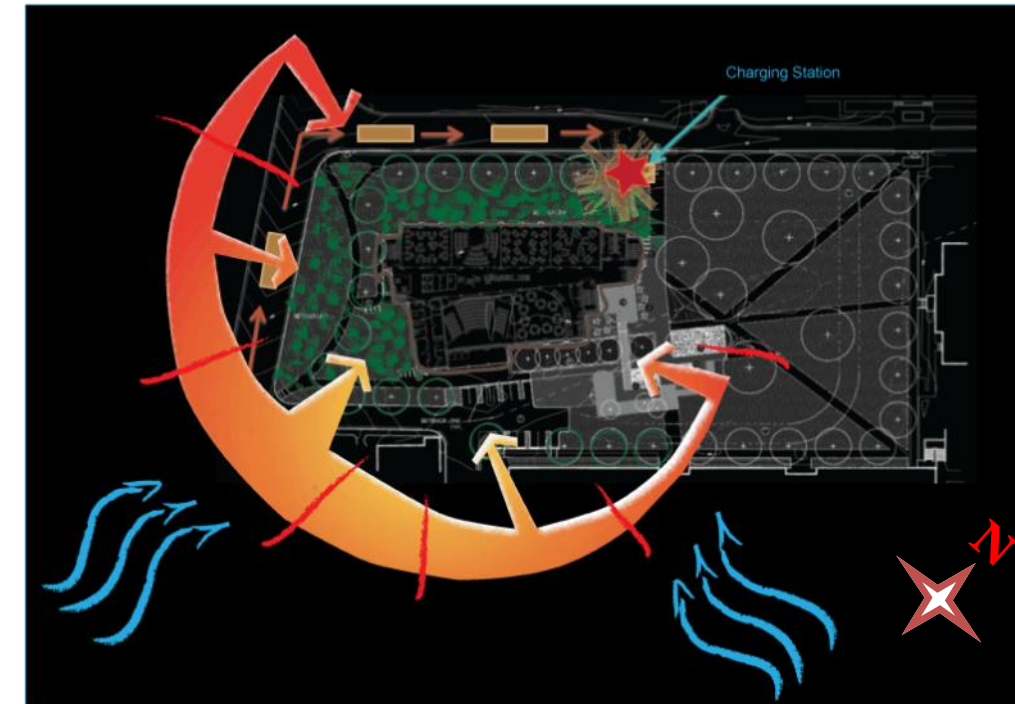
## SUN ANALYSIS



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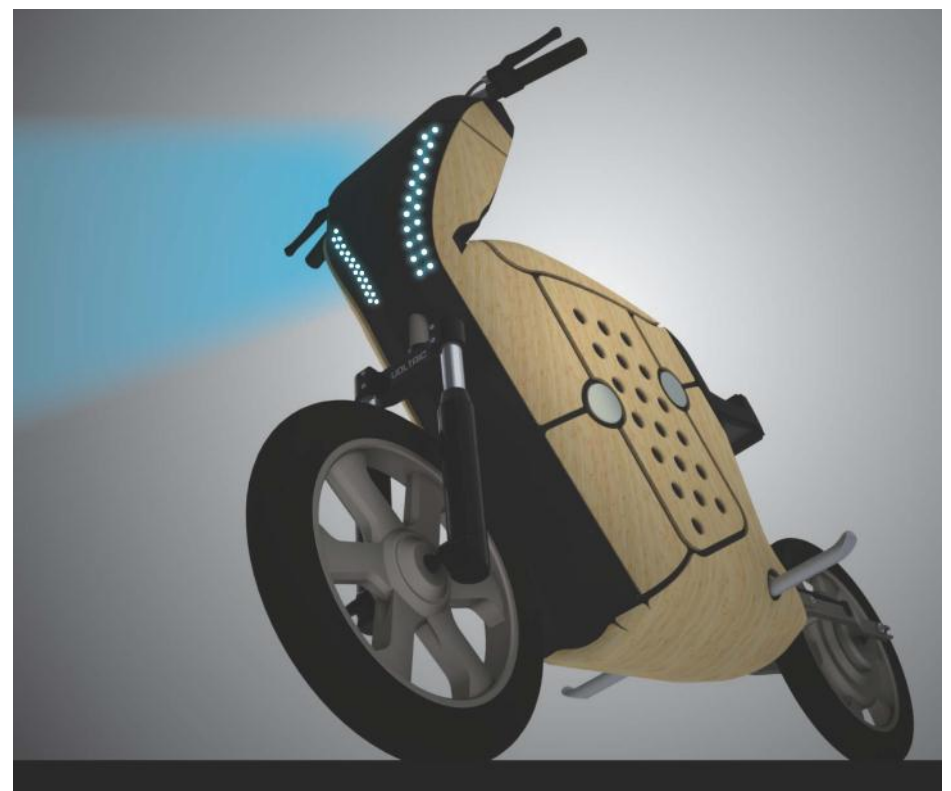
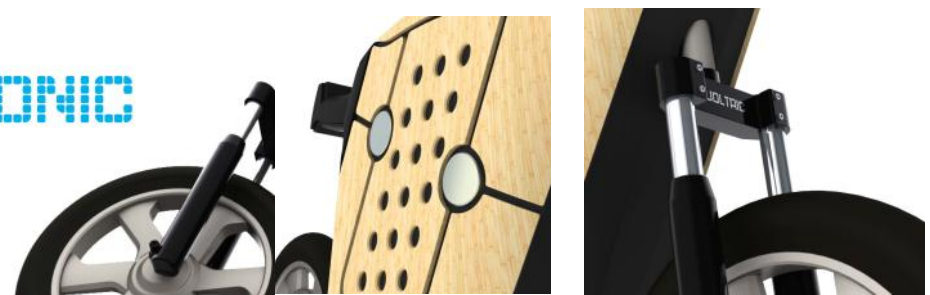
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In Blacksburg, VA temperatures can vary between night and day causing fog early in the mornings.





ICONIC



**VOLTAIC**  
 COURTESY OF Larry Fenske  
 PROFESSOR OF PRACTICE VIRGINIA TECH SCHOOL OF ARCHITECTURE + DESIGN AND INDUSTRIAL DESIGN PROGRAM

# SCOOTER

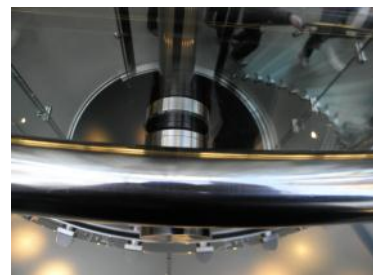
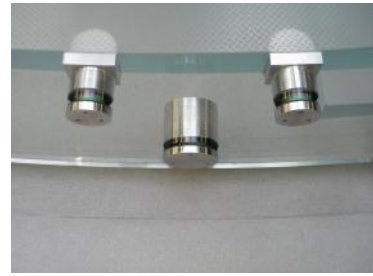
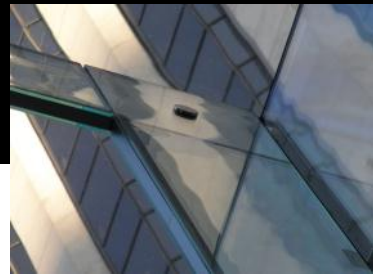
This was a collaborative project involving architecture and industrial design students. We named the scooter project VOLTAIC. The industrial design student team consisted of: Dino Tsiopoulos, Greg Mitchell and Brad Johnson.

## **PART 3– MATERIALS AND TECHNOLOGY**



## GLASS

The decision to use glass was based on the special characteristics it possesses, such as resistance, rigidity, fire resistance, deflection under load, water absorption, moisture absorption, resistance to cracking, breaking, splitting, abrasion, corrosion resistance and chemical resistance. Glass walls and roof are attached through aluminum hardware to the structure. With glass it is possible to create a cantilever of significant length. With its translucency the architectural language of the surrounding buildings to the PV charging station is respected and honored, allowing the visibility of the users to the external environment.



## PV SYSTEM

This project will use an on-Grid Photovoltaic System. It consists of solar panels, a system controller and an inverter. The PVs installed in the roof (Glass-Glass Photovoltaic Module) produces DC electricity that then goes to the converters and inverter to produce AC. The electricity produced runs into a power panel to be sent back to the grid from the utility companies, from where it can be taken when needed. With this system it is not necessary to use batteries. This system can have a long life and it is really environmentally friendly.

## MATERIALS AND TECHNOLOGY



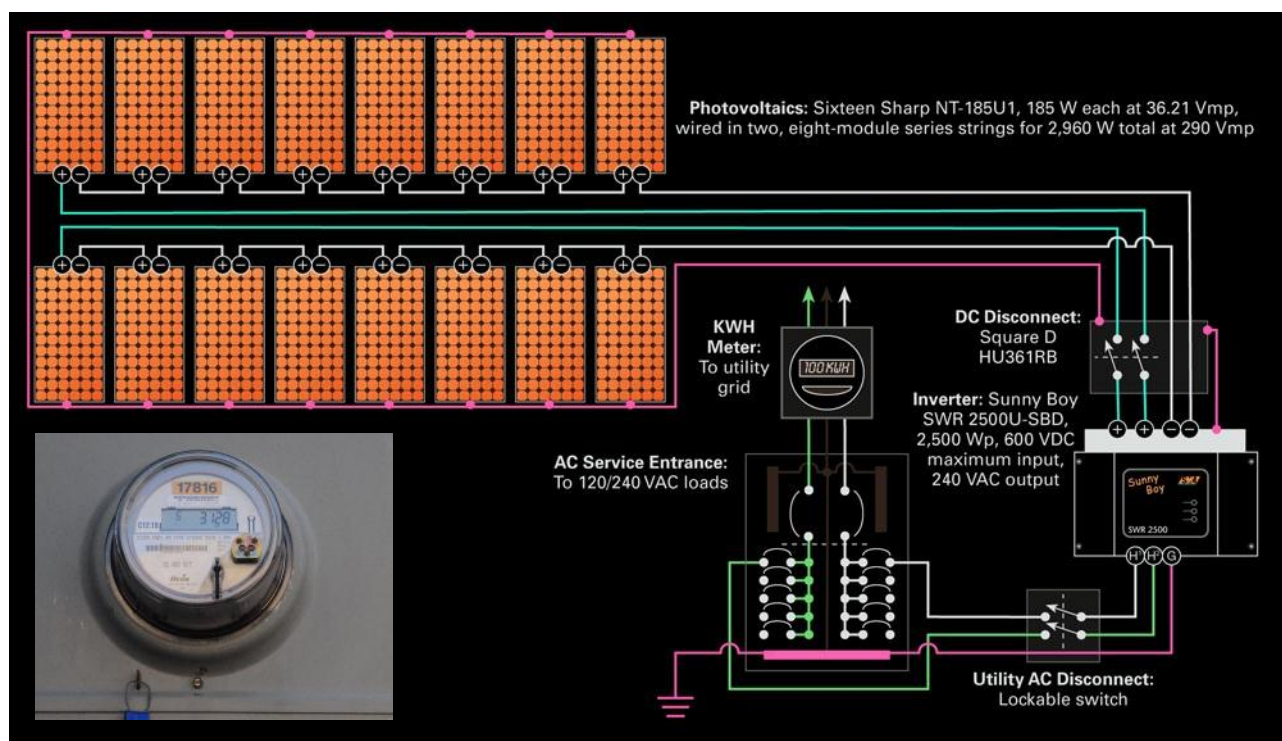
GLASS - GLASS PHOTOVOLTAIC MODULE  
 COURTESY OF : Abakus Solar AG  
 JEFF RYAN - REGIONAL SALES DIRECTOR

# ON-GRID PHOTOVOLTAIC SYSTEM



**Inverter**      **Power Panel**

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# AC Energy and Cost Savings

3.84 Kw System in Blacksburg, VA Facing due South with a 30 degree pitch.

## Station Identification

City:	Blacksburg
State:	Virginia
Latitude:	37.32° N
Longitude:	79.97° W
Elevation:	358m

## PV System Specifications

DC Rating:	3.8 KW
DC to AC Derate Factor:	0.830
AC Rating:	3.2KW
Array Type:	Fixed Tilt
Array Tilt:	30.0°
Array Azimuth:	180.0°

## Energy Specifications

Cost of Electricity:	8.0cent/Kwh
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## Results

Month	Solar Radiation kWh/m <sup>2</sup> /day	AC Energy (kWh)	Energy Value (\$)
1	3.58	362	28.96
2	4.19	375	30.00
3	4.84	460	36.80
4	5.51	499	39.92
5	5.81	523	41.84
6	5.85	503	40.24
7	5.70	500	40.00
8	5.68	503	40.24
9	5.12	444	35.52
10	4.79	440	35.20
11	3.77	351	28.08
12	3.21	317	25.36
<b>Year</b>	<b>4.84</b>	<b>5279</b>	<b>422.32</b>

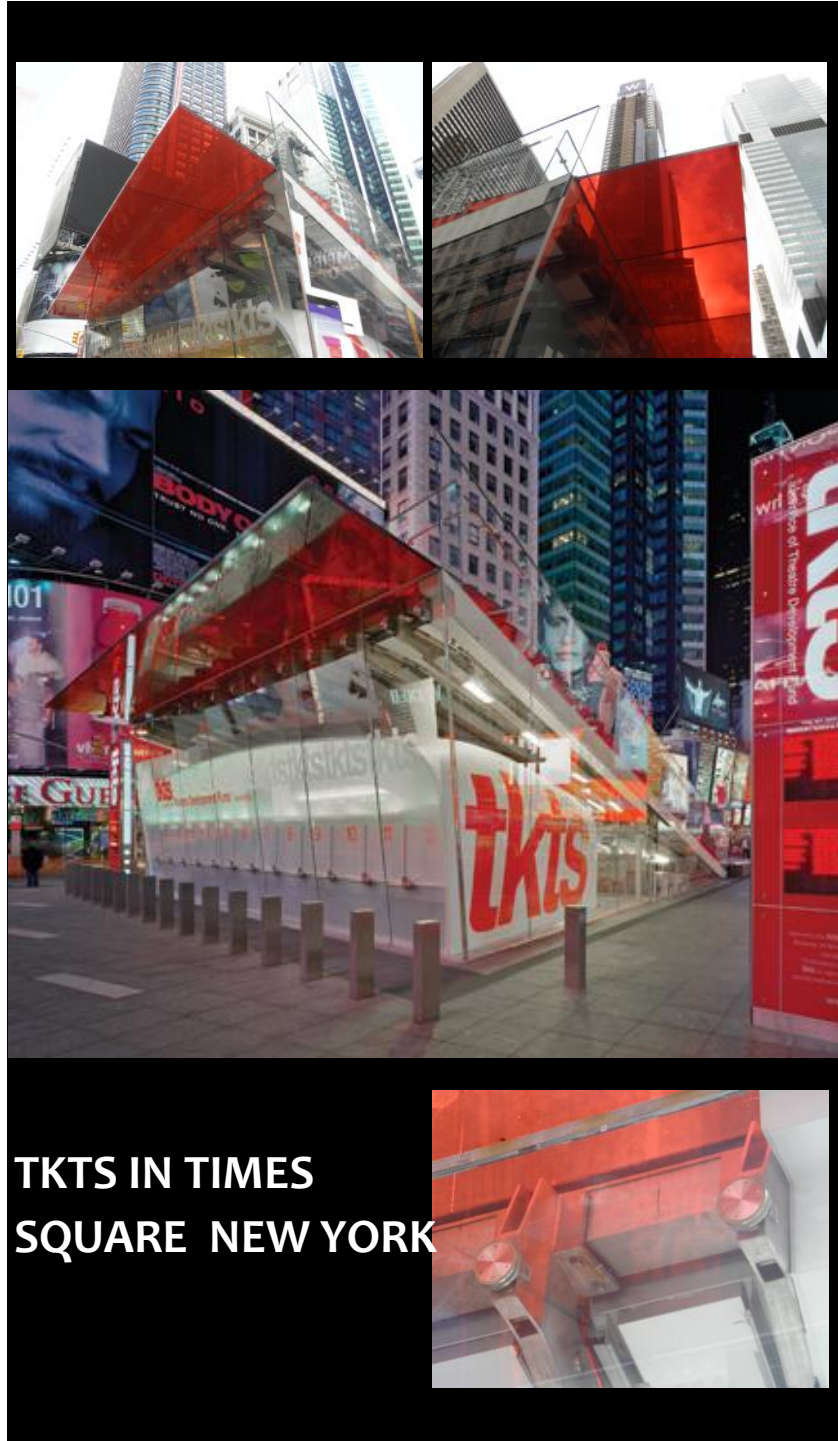
# SMART GLASS



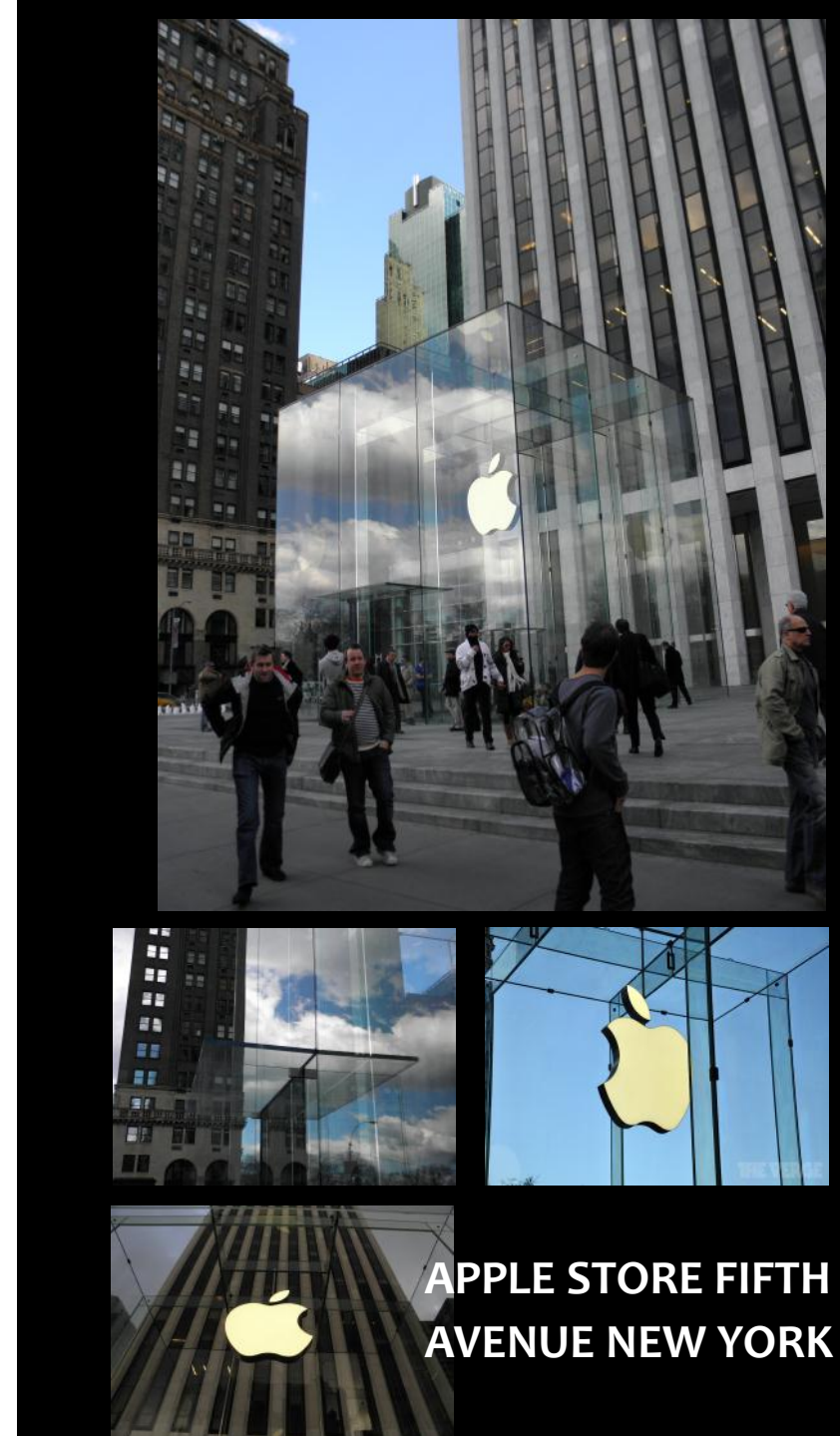
This new technology offers integration of information directly into the structure. Glass components can take on a duality of functions, reducing visual and spatial clutter while enhancing interaction.



## **PART 4— GLASS TECHNOLOGY IN PRACTICE**



**TKTS IN TIMES  
SQUARE NEW YORK**



**APPLE STORE FIFTH  
AVENUE NEW YORK**

## GLASS TECHNOLOGY

This project reveals all the magnificence of the glass. TKTS shows the vital connection between the structural components and the properties of glass. The project combines all glass technology into a really unconventional design that generates an icon for the city in the form of a glowing jewel. It is really interesting to see all the details that conform the structure. This project demonstrates the versatility and durability of glass in the public realm; the glass amphitheater stairs offer visitors a place to watch a performance of the city.

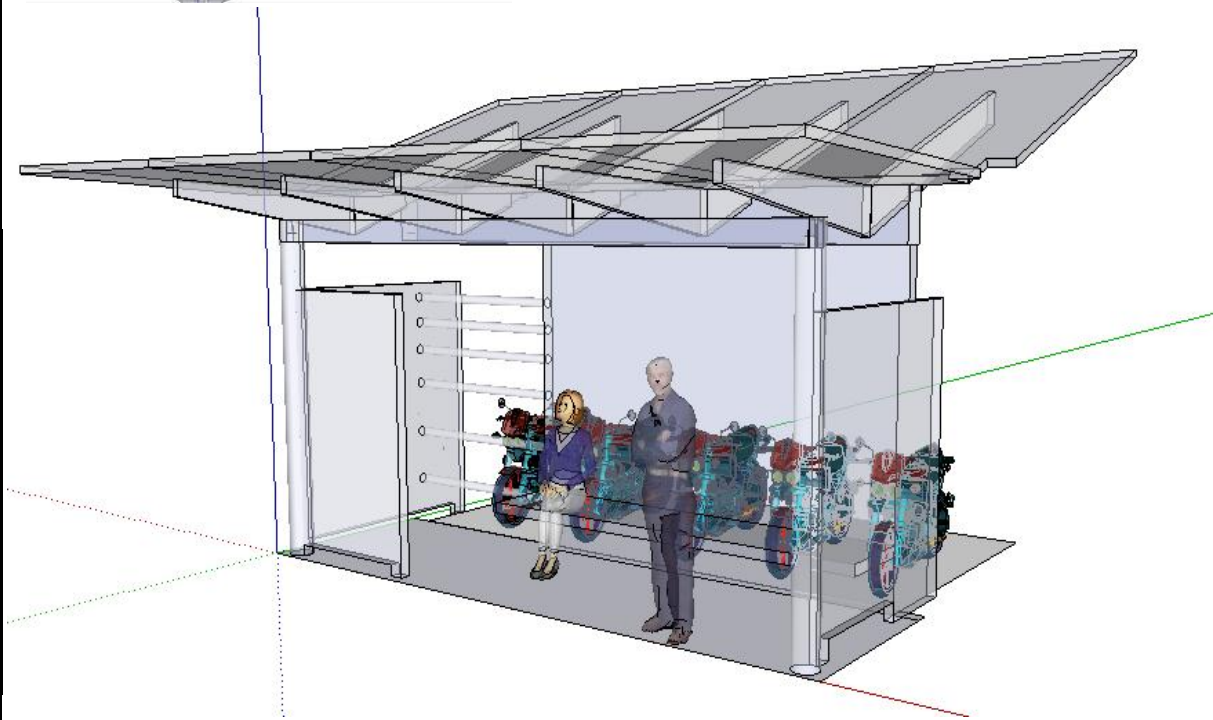
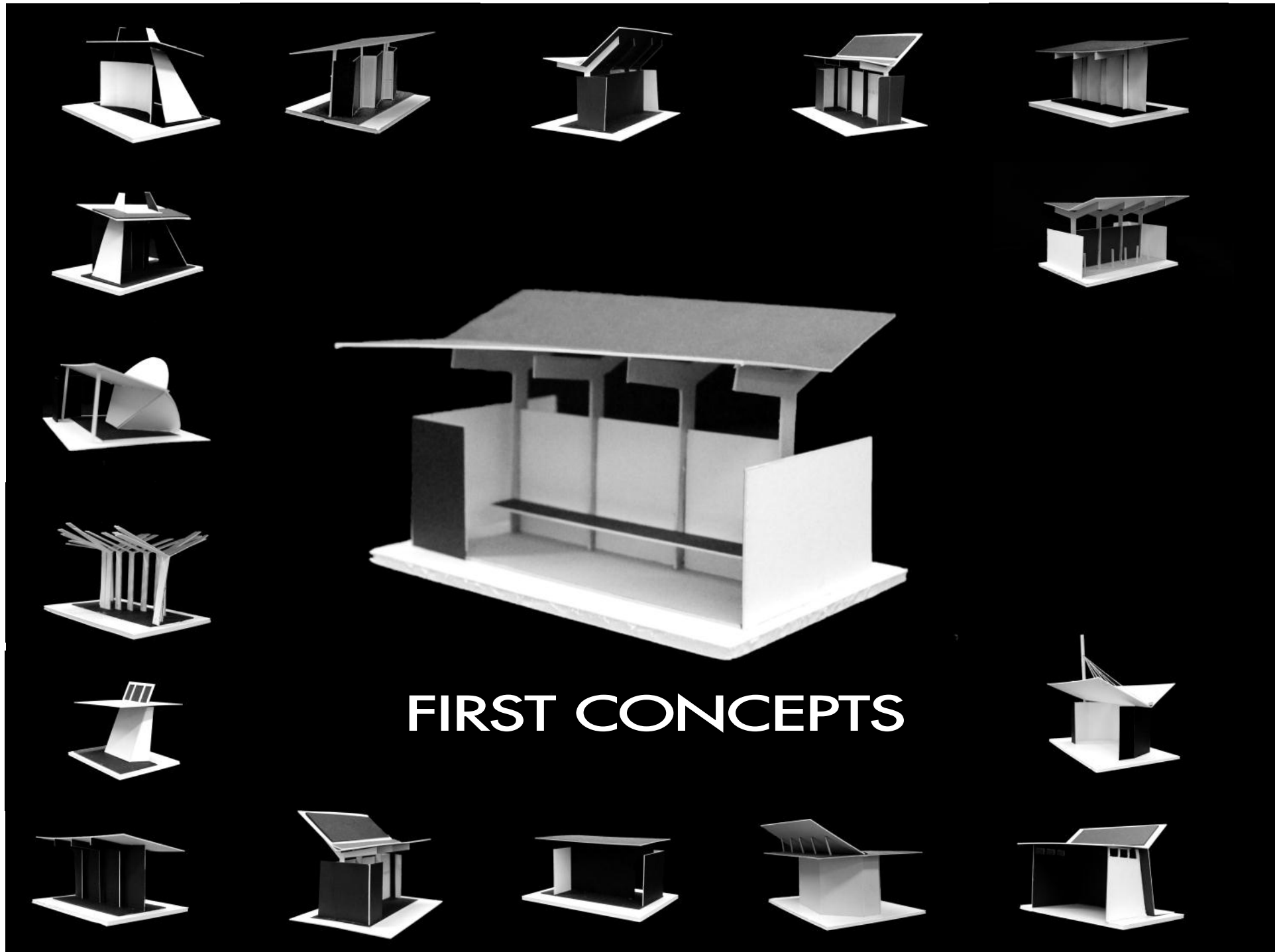
The Apple Store is an extreme scaled application of its mobile device technologies. The minimal and essential presence of building components stands as a reflection of their business model and their product design beliefs.



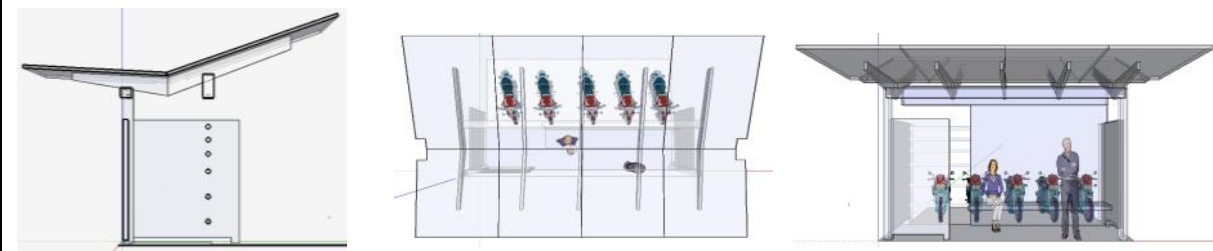
**BUS STOP  
ARLINGTON, VA**

This Bus Stop is located in Arlington, VA. This project is recently built and it has received many critics from the users. They say that the shelter doesn't satisfy the necessities such as protection from the bad weather conditions. When it is raining it is impossible to be inside because there is not enough wall protection there. Also, it is planned to have a heat system in the floor that doesn't work properly. The people said that the construction of this project was about two years and the price was around one million dollars.

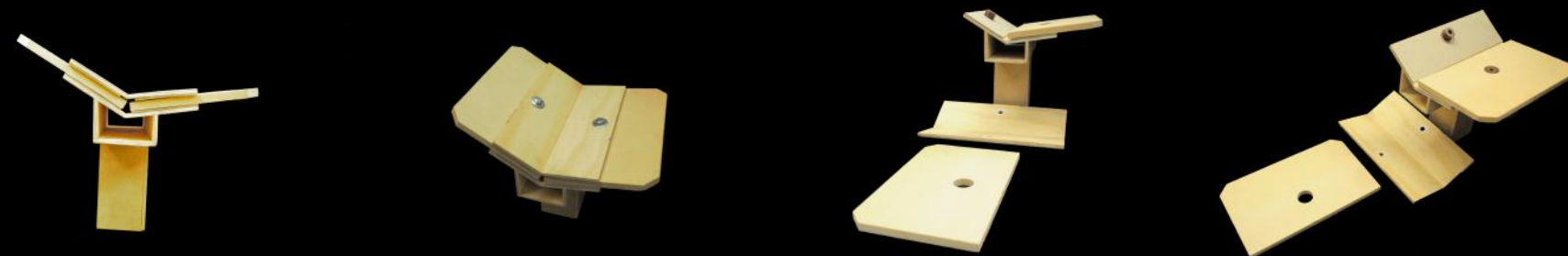
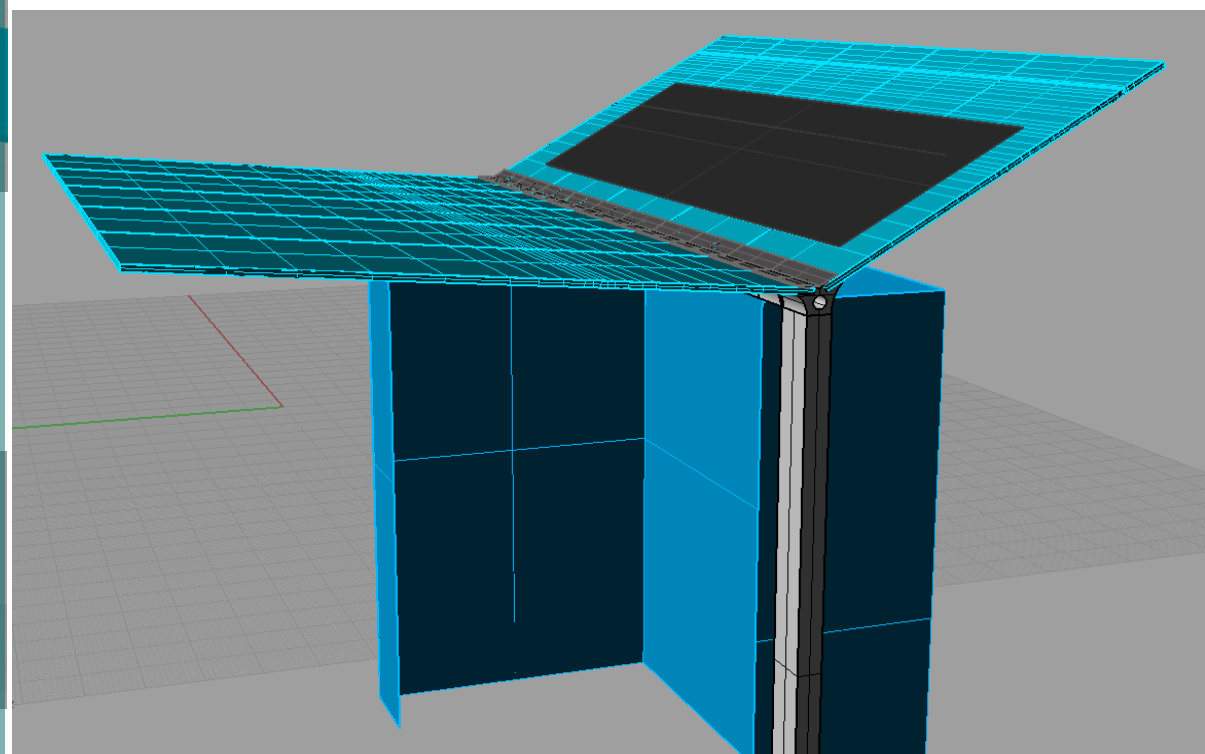
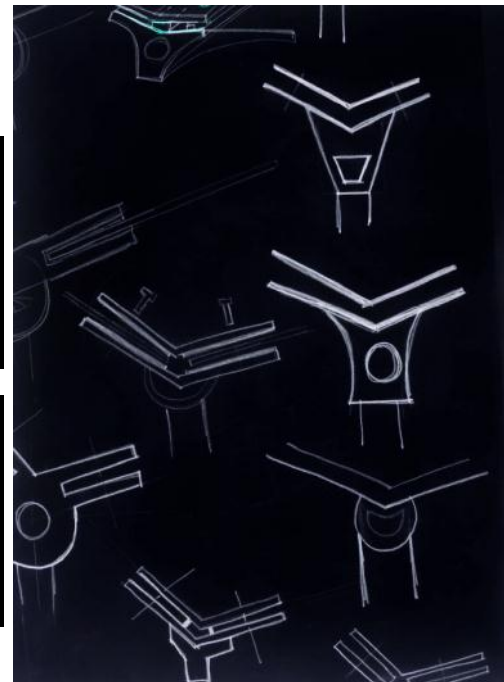
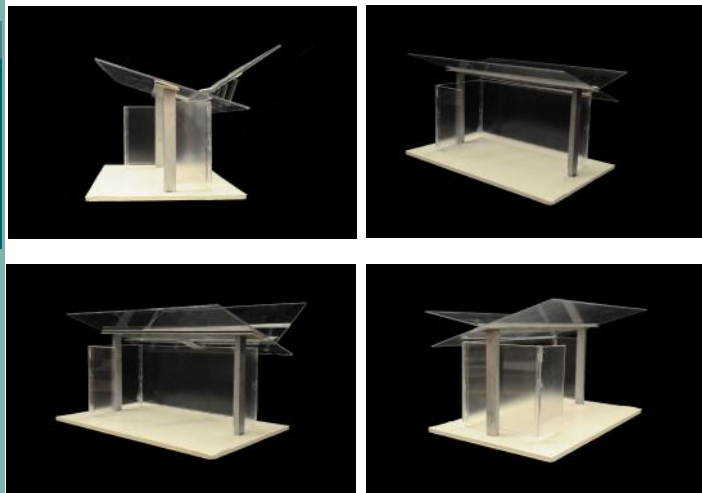
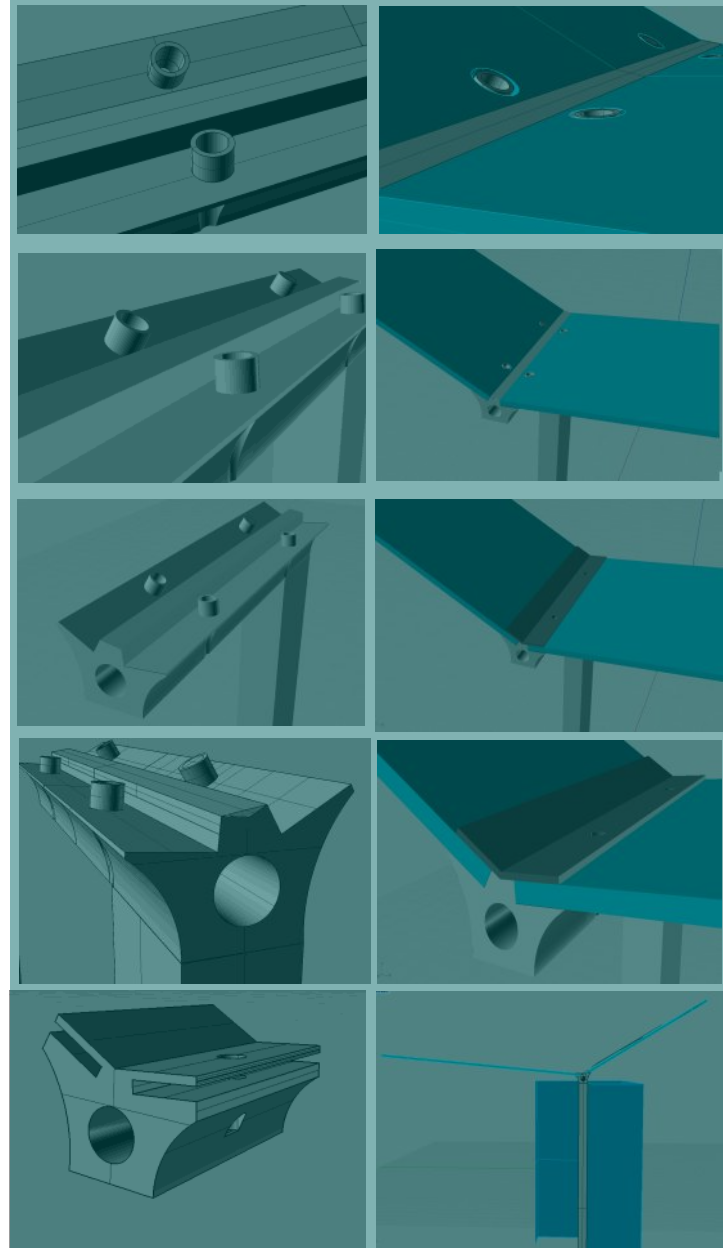
## **PART 5– WORK**



**Design 1: All glass construction with open back wall**



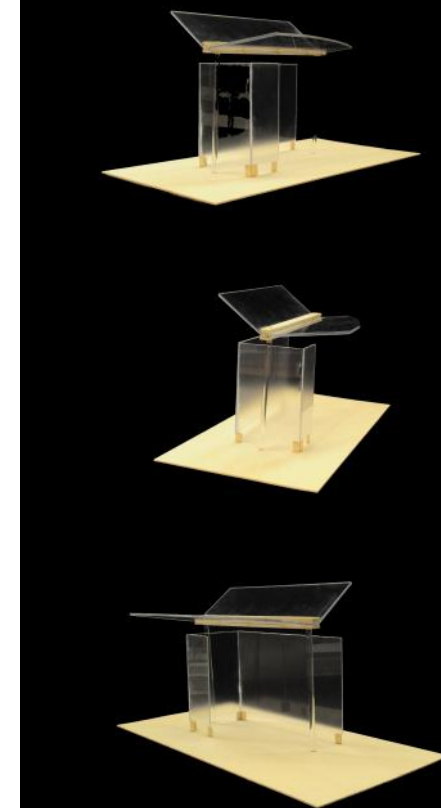
## BEGINNING

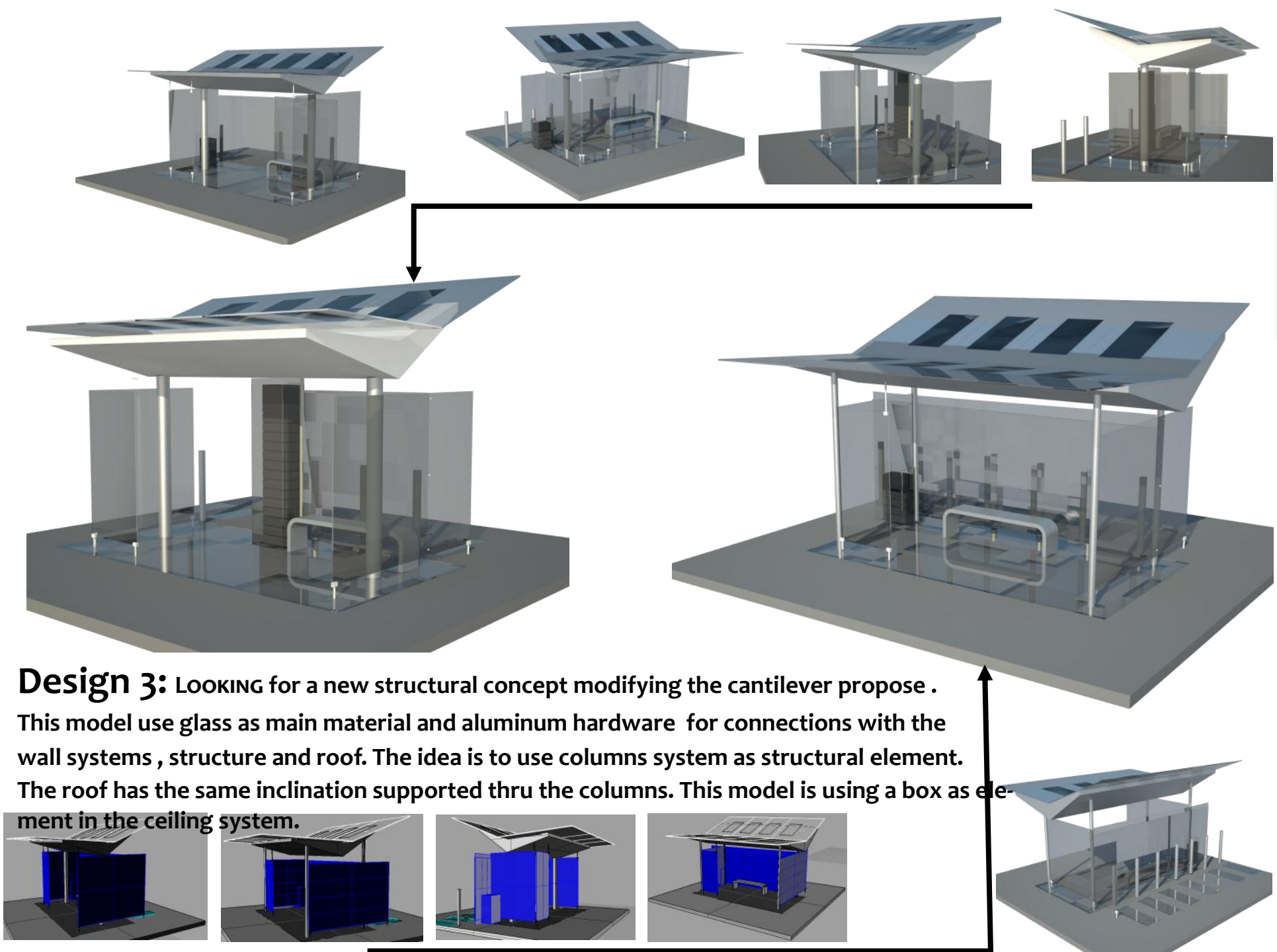
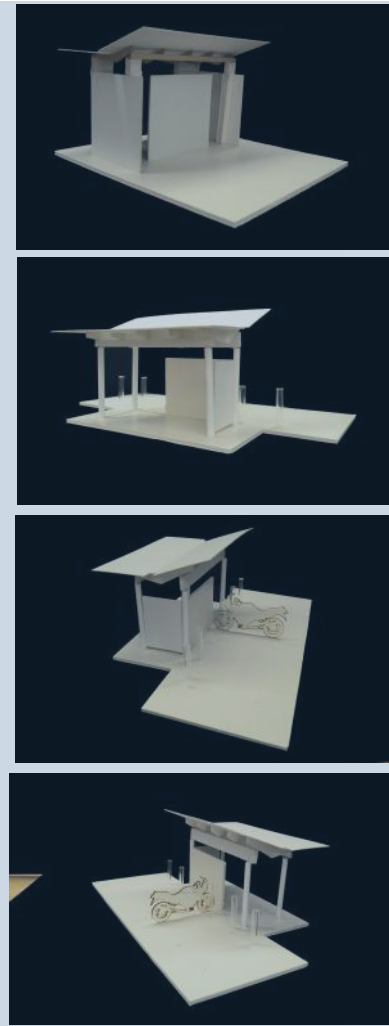
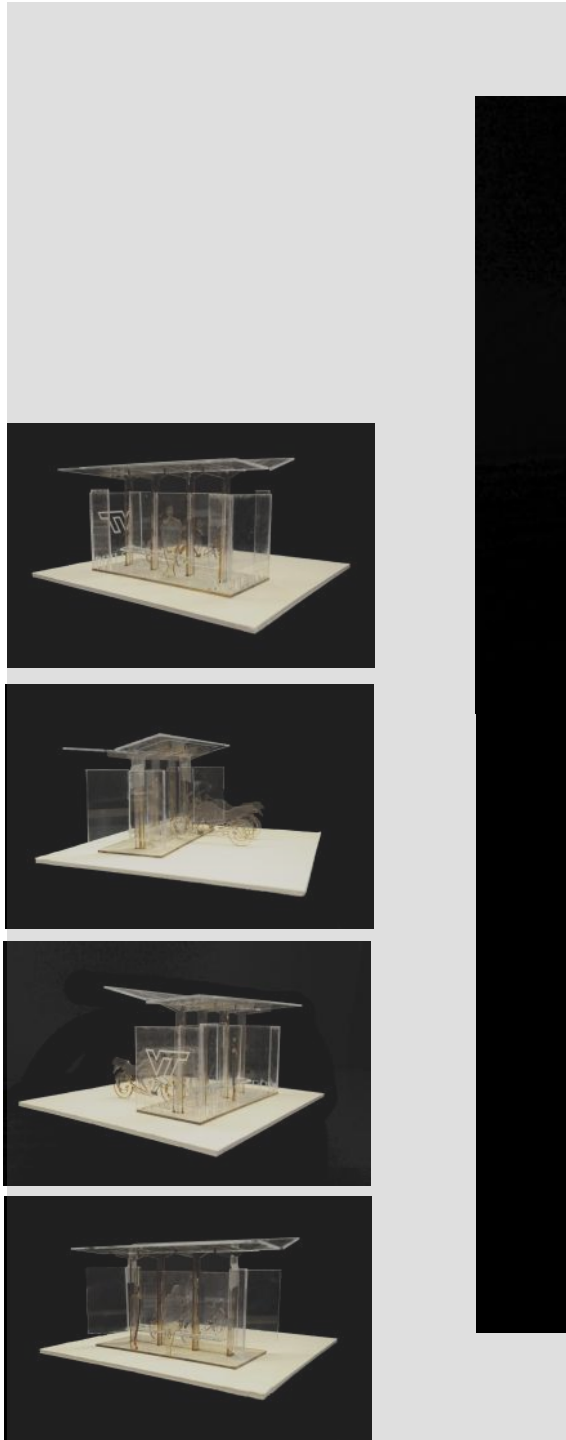


WOOD MODEL SHOWING THE BEAM SYSTEM STRUCTURE

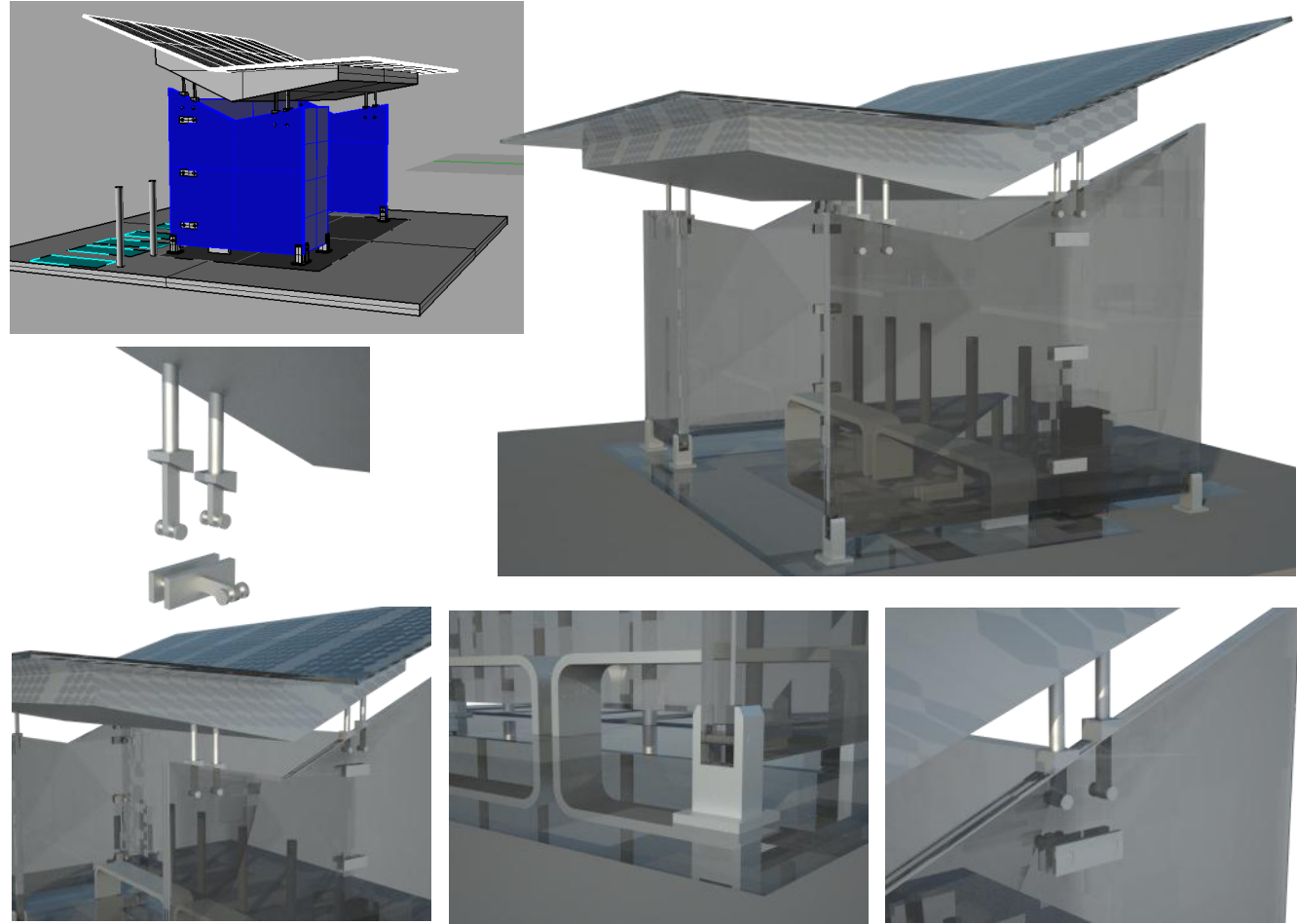
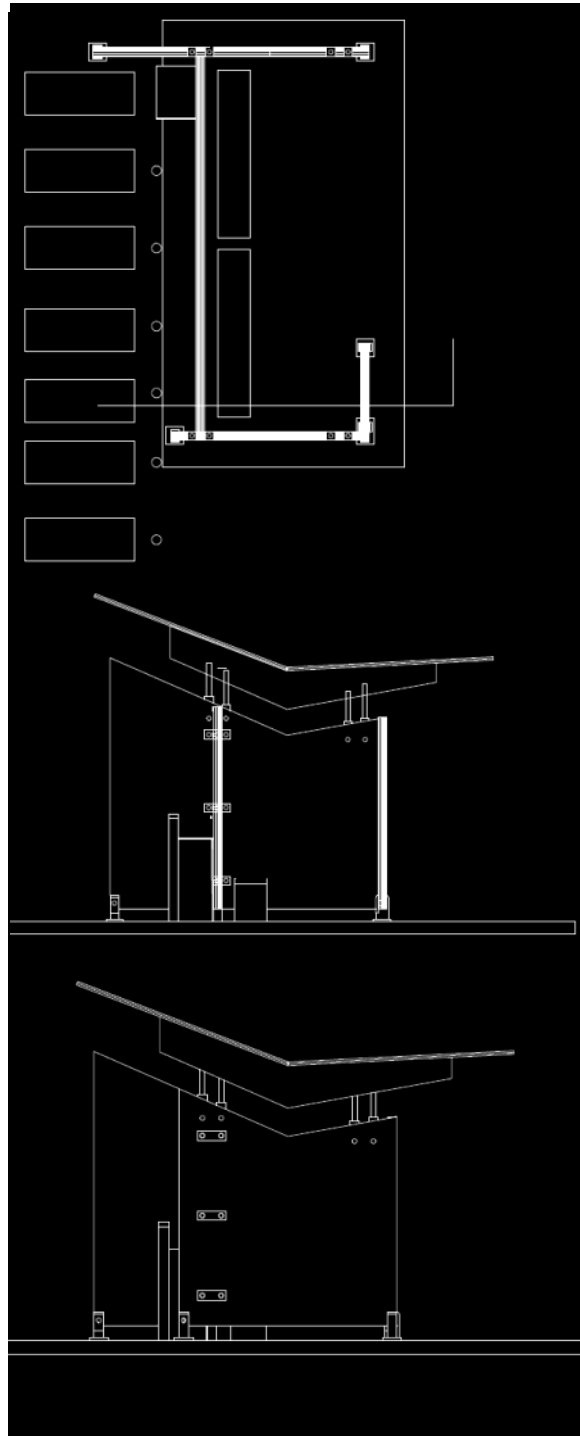
## DESIGN 2: THE CANTILEVER

My initial model studies were looking to demonstrate how the glass technology and properties allow developing an element that can generate a cantilever with glass. The result of this study was to create a beam system that supports all the tension that the glass generates from the movement for different conditions such as wind, rain etc. This element is composed of a steel plate connected to the columns from end to end, supporting the glass panes that make the roof. Over the glass panes there is another steel plate that holds it with screws that penetrate the three elements and are held by bolts at the opposite side finishing the sandwich.

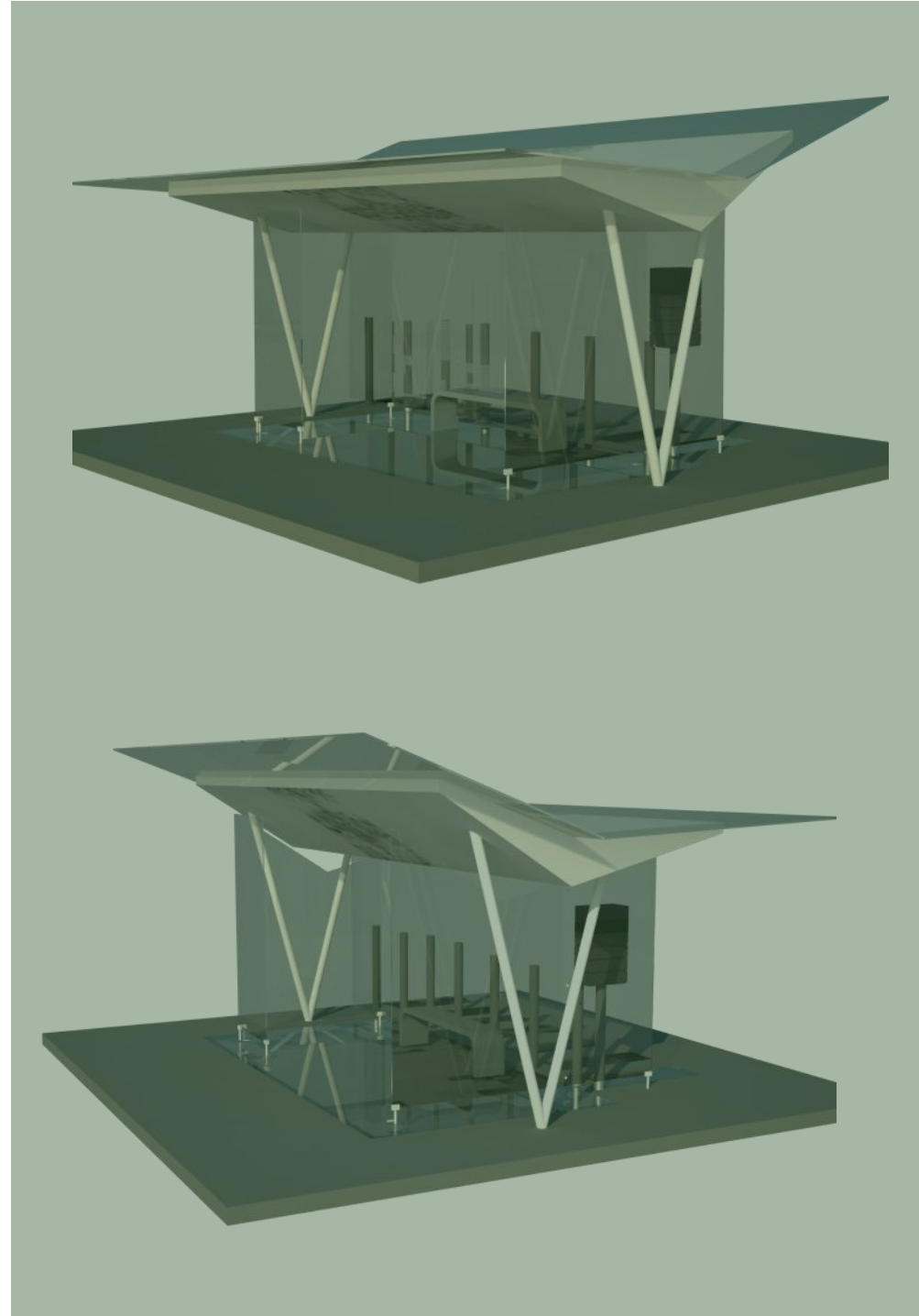




**Design 3:** LOOKING for a new structural concept modifying the cantilever propose . This model use glass as main material and aluminum hardware for connections with the wall systems , structure and roof. The idea is to use columns system as structural element. The roof has the same inclination supported thru the columns. This model is using a box as element in the ceiling system.



**Design 4: Structural Glass Wall System**



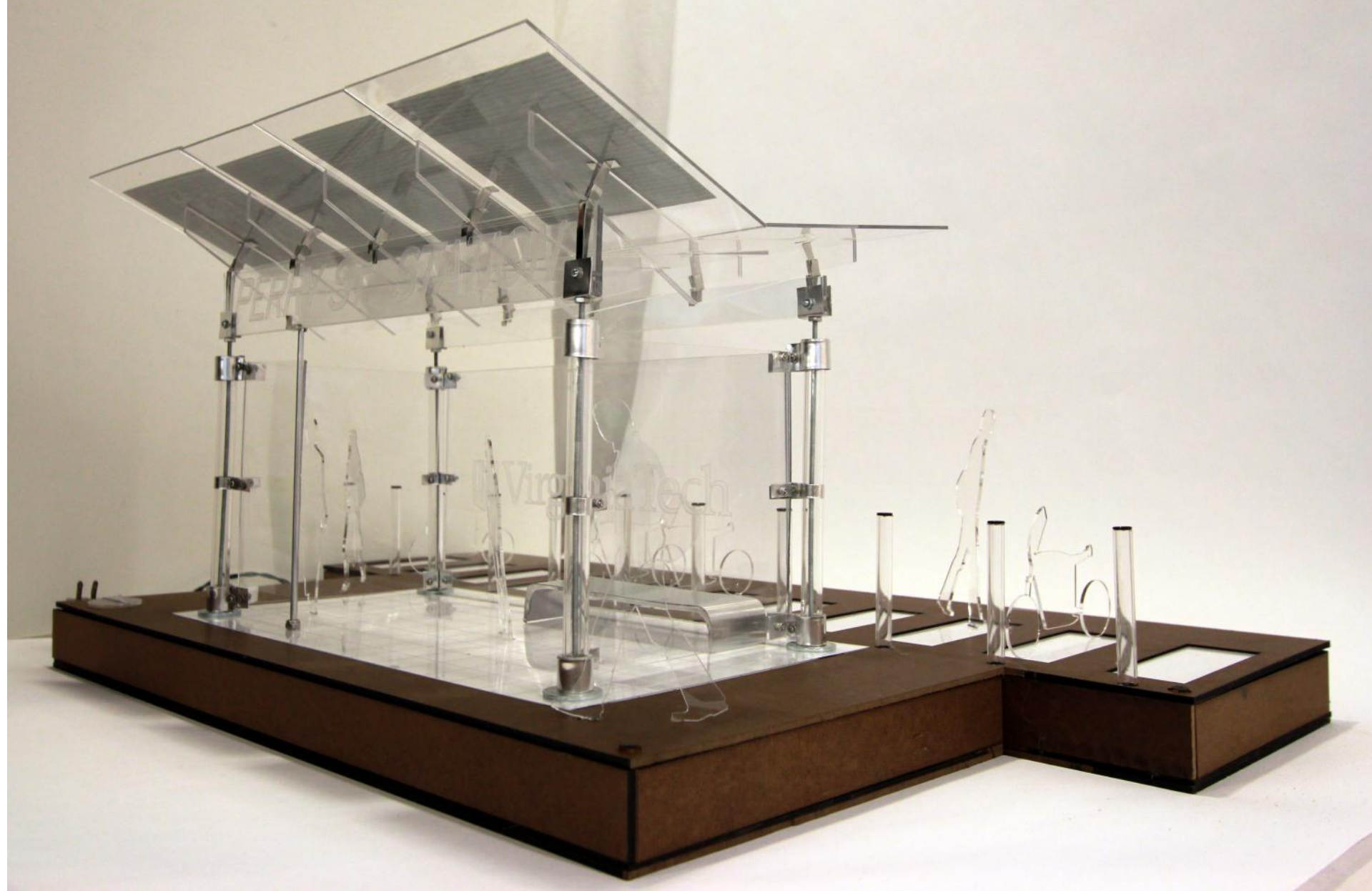
**Box Ceiling combined with aluminum Structure**



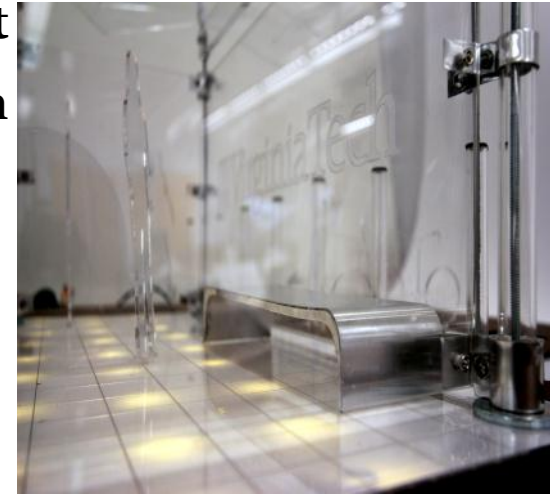




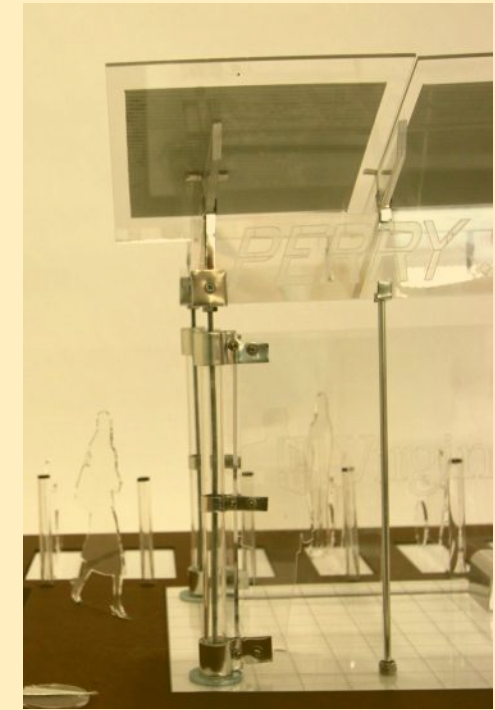
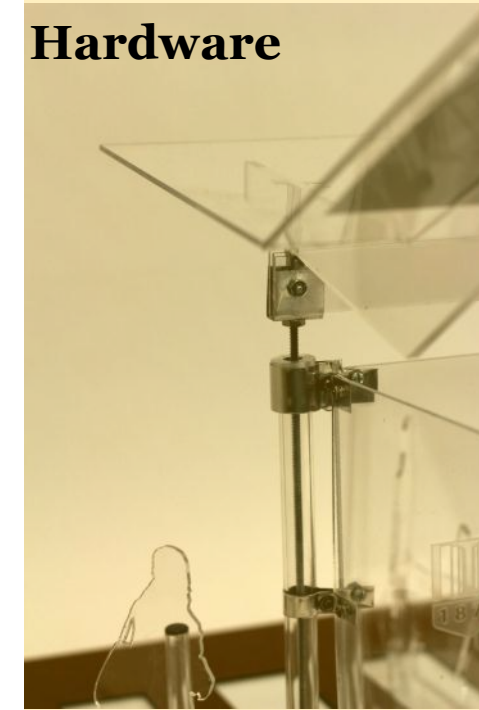
**Night View**



**Radiant Bench**



**Hardware**



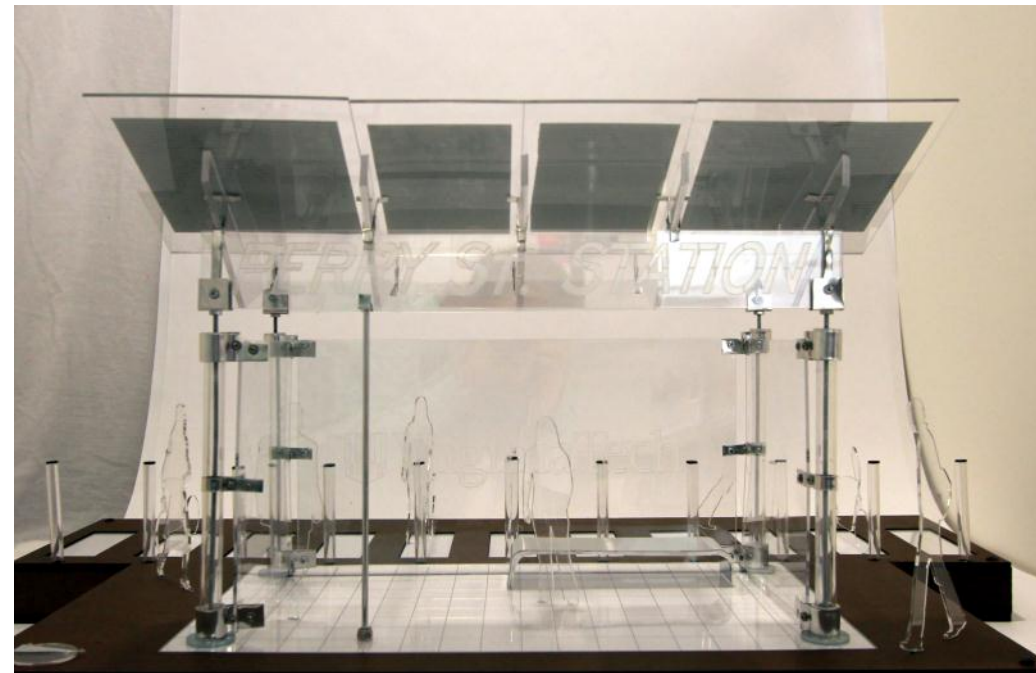
**Scooter Charging**



**South Facing PV Panels**



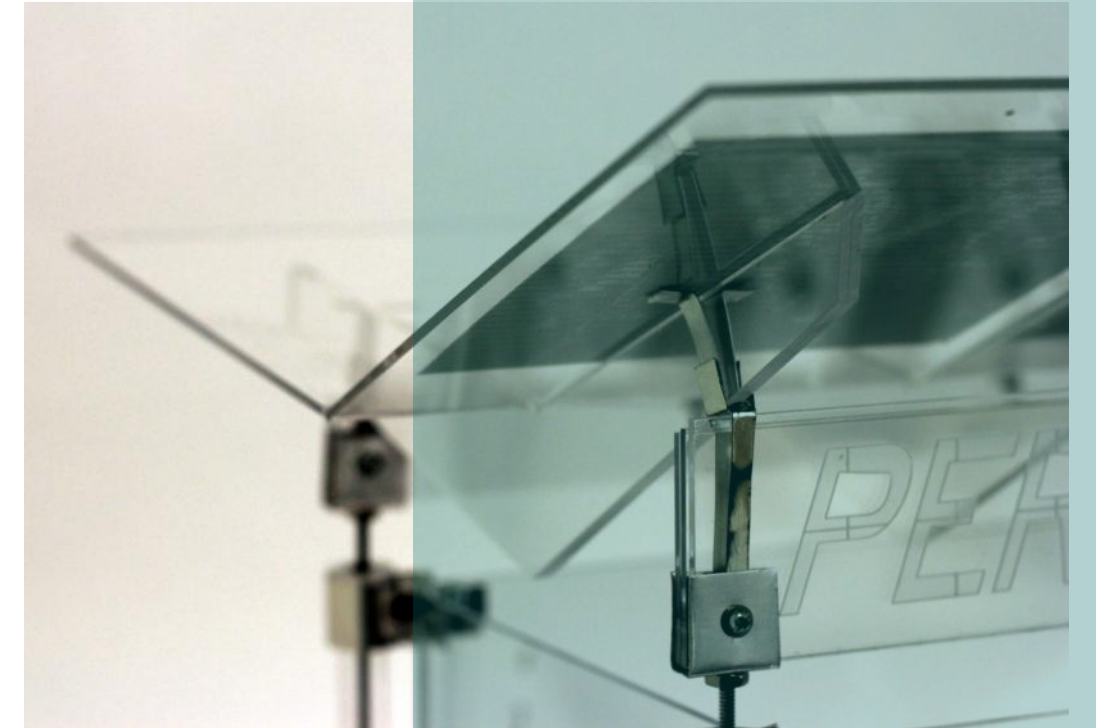
**Front View**



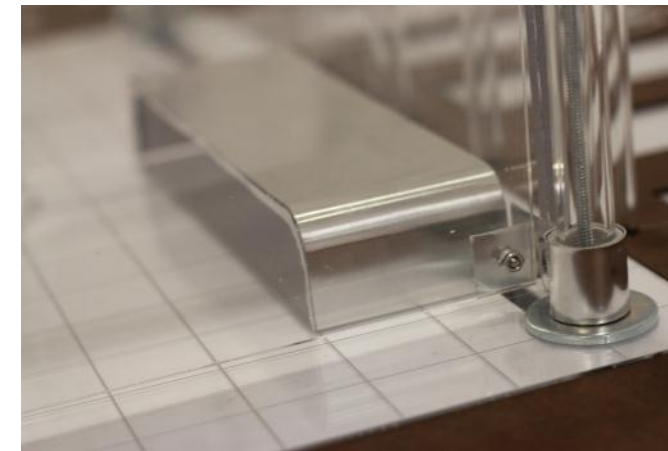
**Side View**

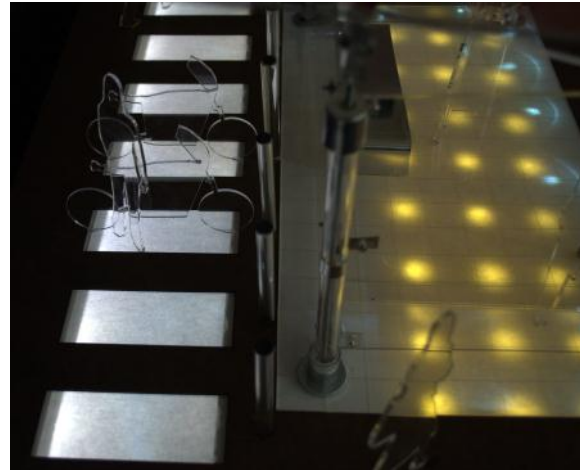


**Roof Detail**



**Bench**





Right Side View



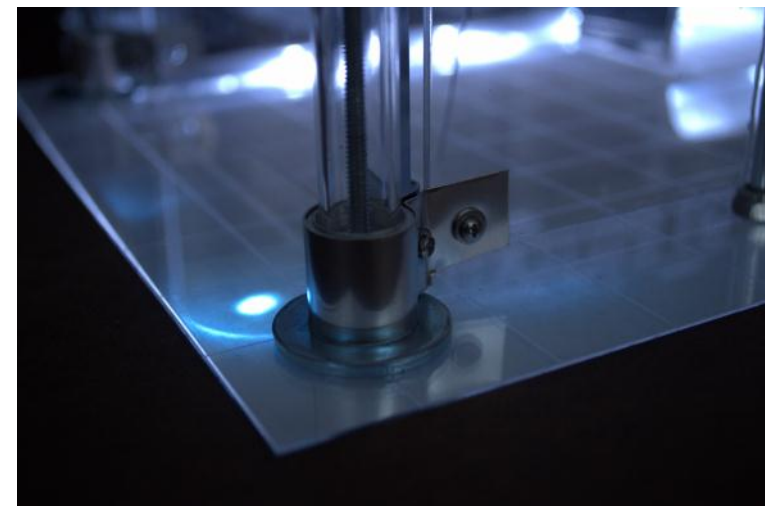
Entrance View



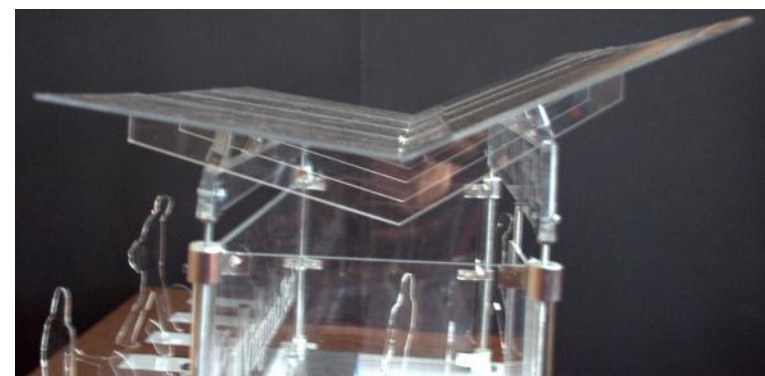
Radiant Floor



Front View



Column Base



Roof Beams

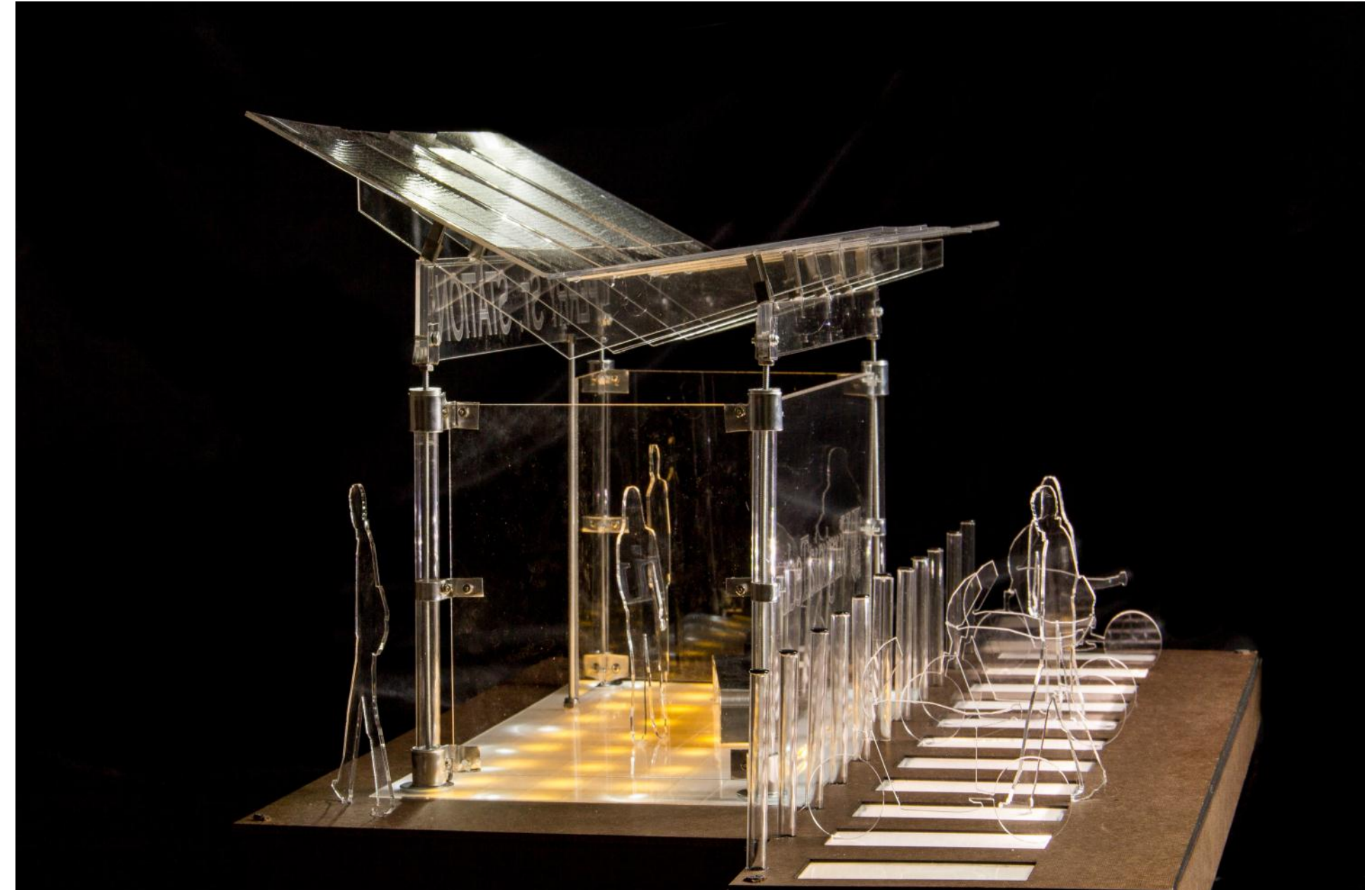
## CONCLUSION

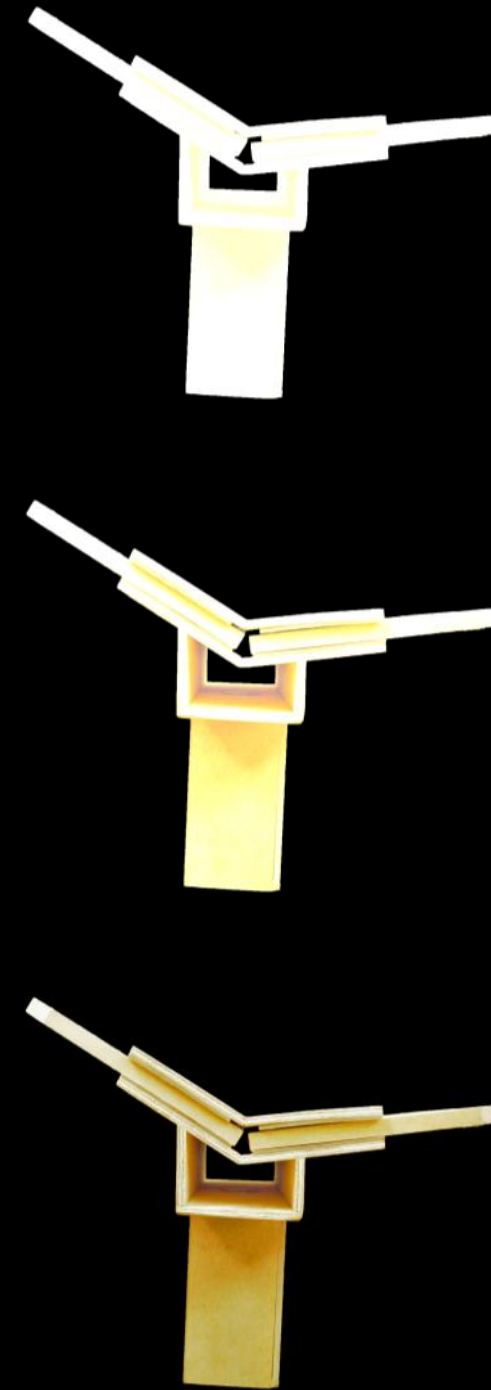
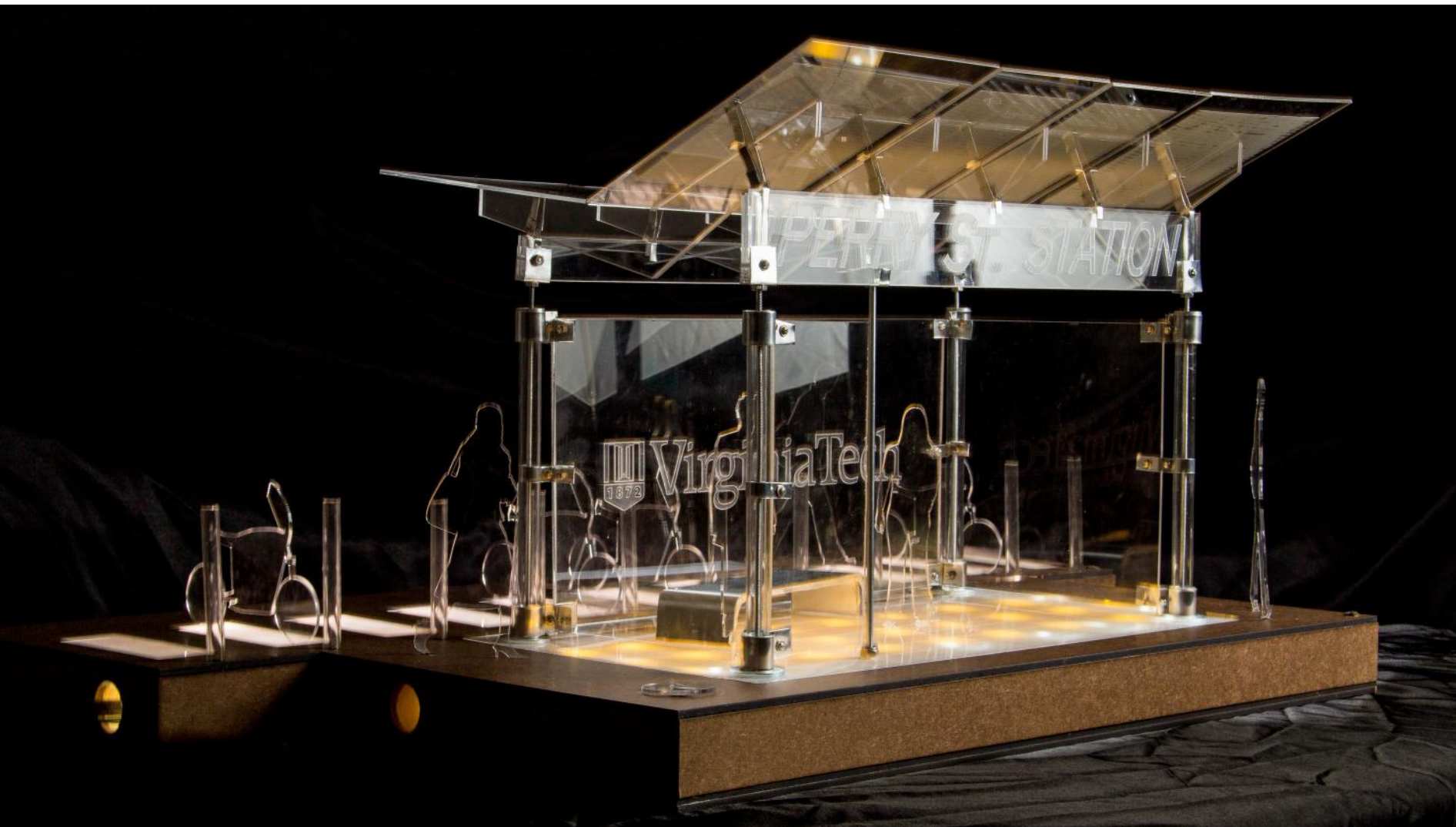
This work was intended to explore how a material can be used in different projects showing its qualities and properties as main material in the project.

This thesis started with the goal of using glass as the main material in the project. The challenge was to create different bus shelter designs that allowed an exploration of several forms and structures that can be implemented at an electric charging station.

The photovoltaic charging station for electric scooters at Virginia tech is a project that will allow all of the students and the community to improve the mobility system in Blacksburg that at the moment is a real problem. This station will provide the user easy to use elements to enjoy their stay at the station. All of these elements are possible to use, as the smart glass to navigate the web and get information about weather conditions, news, bus routes, navigation maps and other kinds of entertainment. Another element is the radiant floor for extreme weather conditions providing a comfortable warm space for the users. The radiant bench is another element that it's activated with the weigh when a user sits down on it.

With this work I have had the opportunity to explore new technics and systems that allow me to identify and design new concepts for the application of high technology, and the research for new applications continues.





## REFERENCES AND CREDITS

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*Page 10: New Classroom Building project*

*Courtesy by Steve Mouras*

*Director of Transportation Planning and Sustainability of Virginia Tech*

*Pages 17 and 18: VOLTAIC*

*Courtesy by Larry Fenske*

*Professor of Practice Virginia Tech School of Architecture + Design and Industrial Design Program*

*Page 22: Glass - glass photovoltaic module*

*Courtesy by : Abakus Solar AG*

*Jeff Ryan - Regional Sales Director*

*Image in page 39 by Connor Toth*

*Images in pages 41, 42, 50 and 51 by Erwin Kristobal Felipe Gudenschwager Basso*

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*Images in pages 47 and 48 by Ricardo Jaramillo*