4.401/4.464 Environmental Technologies in Buildings – Assignment 8

Instructor:	Christoph Reinhart
Due Date:	Friday of week 11
Type:	This is a group assignment.

Objective

The objective of the game is to redesign your class project, with the lowest possible operational Source Energy Use Intensity (Source EUI, kWh/m^2) as simulated in DIVA/Archsim/EnergyPlus. Starting off with an approximate thermal model of your latest design from Assignment 6, your task is to create a version of your building with the lowest Source EUI and a purchasing budget at or under $50 MIT dollars. The team with the largest proportional EUI reduction vis-à-vis their baseline design wins. Follow all rules below. When time is up (**after 80 minutes**), your team must save all of your files and submit them along with a detailed description of your final designs and how you arrived at your best performing iteration (more details are provided under part 3).

Part 1 – Baseline design

Create an approximate thermal model of your baseline daylit building from Assignment 5. Run an energy simulation of the baseline file using no energy upgrades.

Part 2 – Model, Simulate, Evaluate

Using the Grasshopper file called *SimulationGame2018.gh* provided on the course web site, introduce upgrades to your baseline model which may be both geometric as well as based on any combination of design upgrades offered in the Grasshopper file. The design upgrades are listed on the following pages. Each upgrade has an associated cost and **you are limited to a budget of $50 MIT dollars.**

The floor to floor height of each building level **must be at least 3m**. Each level should be modeled as at least one thermal zone. While the form is completely up to you, your zones must consist of planar surfaces (no rounded, curved, or NURBS surfaces). Parametric (automated) windows by orientation (as well as automated horizontal shading) are included in the Grasshopper file. If you would like to have more control over the design of your windows and shading, you may disable automated windows and activate custom windows (instructions are in the Grasshopper file).

Each time you simulate a design in Grasshopper, your Source EUI results will be recorded in Rhino (Figure 1). Try to use previous simulation results to guide subsequent design decisions.

ENVELOPE SETTINGS

ROOF INSULATION*			
Description			**Relative Cost**
Base Building	Continuous Insulation	R-Factor: R20	**0**
	Continuous Insulation	R-Factor: R30	**$**
	Continuous Insulation	R-Factor: R40	**$$**
	Continuous Insulation	R-Factor: R60	**$$$$**

* Note: the cost of Roof Insulation is also related to the area of roof in your building.

EXTERIOR WALL INSULATION*			
Description			**Relative Cost**
Base Building	Continuous Insulation	R-Factor: R13	**0**
	Continuous Insulation	R-Factor: R19.5	**$**
	Continuous Insulation	R-Factor: R28.5	**$$$**

* Note: the cost of Wall Insulation is also related to the area of wall in your building

WINDOW GLAZING TYPE*				
Description	**U-Factor**	**SHGC**	**VLT**	**Relative Cost**
Base - Double-Pane Argon-Filled	2.55 SI (0.45)	0.50	0.70	**0**
Double-Pane Argon-Filled Low-e (High Solar Gain)	1.44 SI (0.25)	0.60	0.78	**$$$**
Double-Pane Argon-Filled Low-e (Low Solar Gain)	1.36 SI (0.24)	0.17	0.25	**$$$**

* Note: the cost of windows is also related to the area of glazing in your building.

EXTERIOR SHADING*		
Description		**Relative Cost**
Base	No shading	**0**
	Shading (depends on depth)	**$ - $$**

*Note: Shading is directly related to the amount modeled in your building. Simulations including exterior shading will take longer to complete.

SYSTEM SETTINGS

LIGHTING POWER DENSITY		
Description		**Relative Cost**
Base Building	11 W/m^2 during occupancy	**0**
	9 W/m^2 during occupancy	**$**

DAYLIGHT SENSORS		
Description		**Relative Cost**
Base Building	None	**0**

	Perimeter zones (0-4.5m from exterior wall) dim linearly down to complete shut-off (0% power) (target work plane illuminance 300 lux)	$

HEATING + COOLING SYSTEM				
Description		**Fuel Source Factor**	**Coefficient of Performance**	**Relative Cost**
Base Building	Heating: Electric Resistance Heating Cooling: Direct Expansion A/C Cooling	Elec (3.14)	COP 1.0 COP 3.1	**0**
	Heating: Boiler (hydronic heating) Cooling: Direct Expansion A/C Cooling	Gas (1.05) Elec (3.14)	COP 0.90 COP 3.1	$$
	Heating: Ground Source Heat Pump Cooling: Ground Source Heat Pump	Elec (3.14)	COP 3.1 COP 3.93	$$$$

NATURAL VENTILATION		
Description		**Relative Cost**
Base Building	None	**0**
	Automated natural ventilation tied into a building management system. - Assumes a 40% operable window area - Operates when outdoor air is between 20C and 40C - System will close windows when 22C indoor air temp is met	$

Note: Simulations including natural ventilation may take longer to complete.

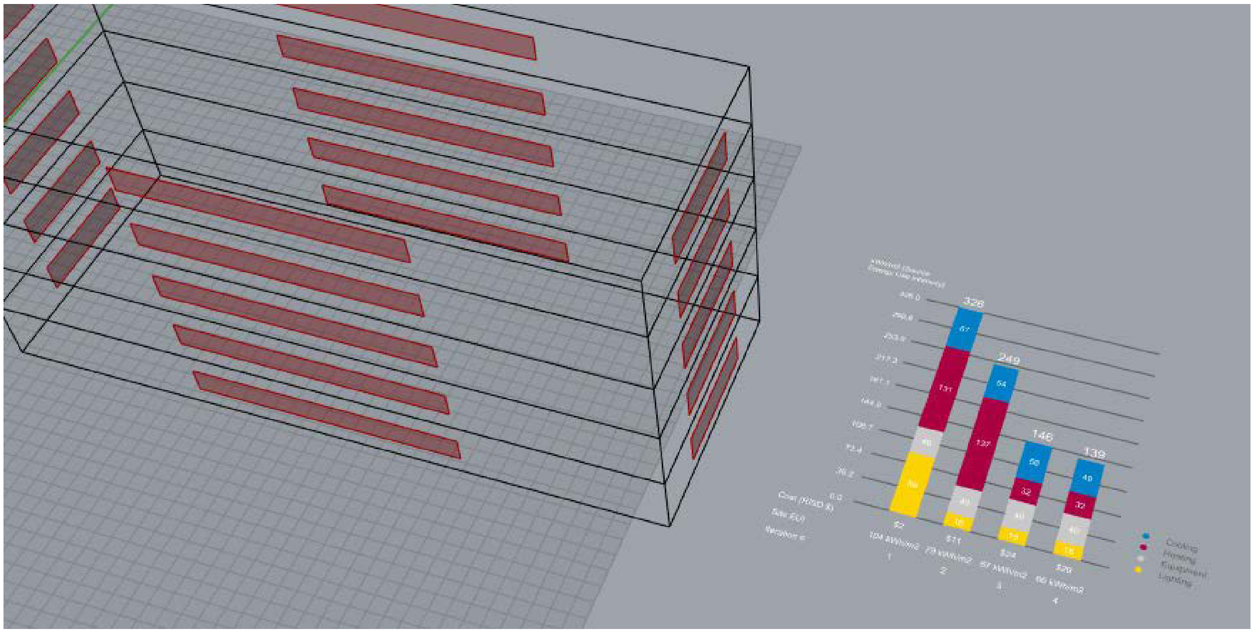

Fig 1 Screenshot of iterative simulation results and building geometry in Rhino.

End of Game

Note that each time you ran a simulation, a unique layer is created in Rhino that documents your geometry. See Figure 2.

When the game is complete, you must bake your simulation results into your Rhino file so that you have a graphic record of your simulation results in addition to your geometry.

1. In the grasshopper file, "bake" the simulation results in the Rhino file by "middle-clicking" the twelve components on the right side of the Student Dashboard (labeled "bake results at end of game"). See Figure 3.
2. Save this Rhino file in a safe place for your record.

Lastly the grasshopper file creates a C:₩SimulationGame folder, and a series of subfolders for each simulation you ran. These subfolders are where all the "behind the scenes" input/output simulation files are located. The only file you need to be aware of is the

"SettingsX.txt" text file which contains a written documentation of the settings you chose for each iteration.

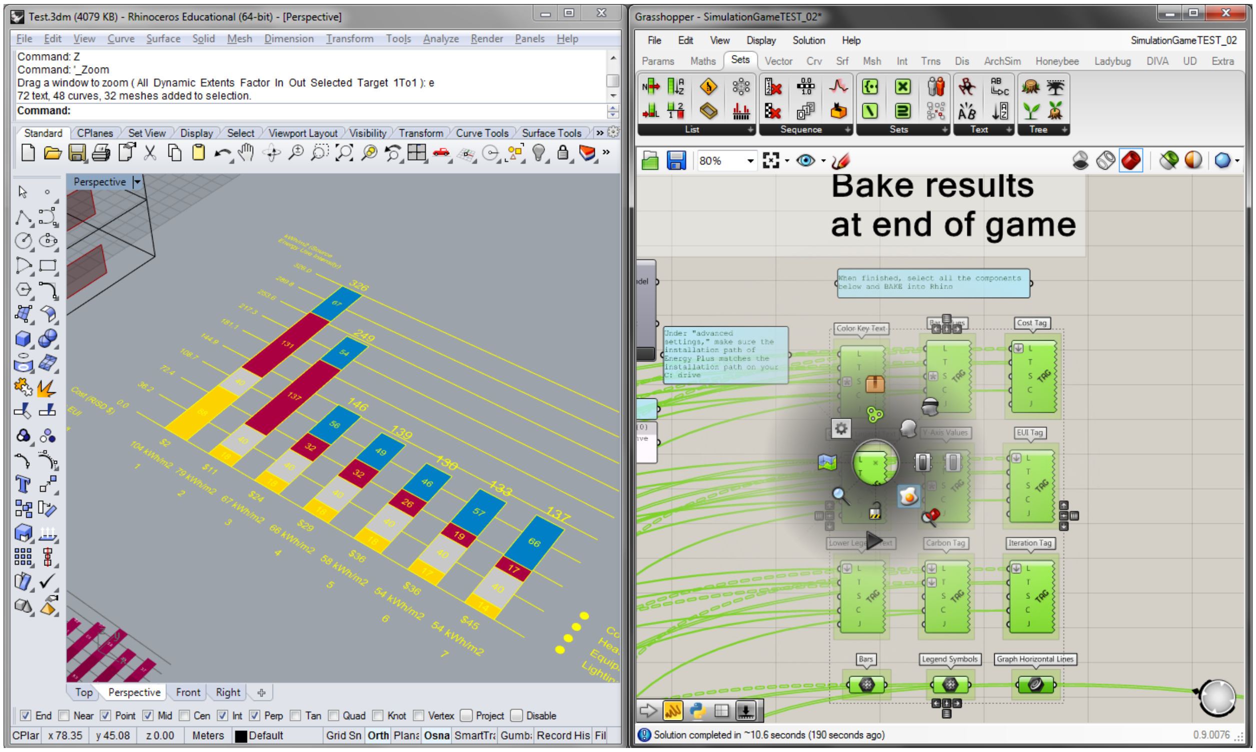

Fig 2 Screenshot of baked results and documented entry in Rhino.

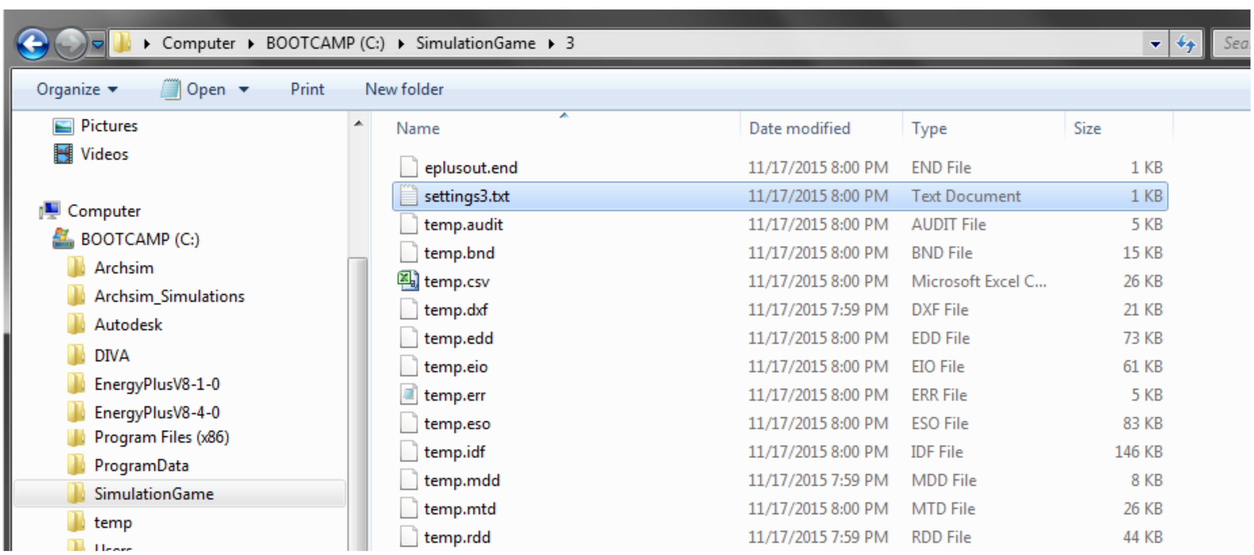

Fig 3. Location of your "settingsX.txt" file in the numbered subfolders within the C:₩SimulationGame directory.

Part 3 – Design description

Along with Rhino and Grasshopper files prepare a description of your simulation game experience. You description should include:

1. Graphic representation of your baseline design and at least four of your most important iterations (in perspective or axonometric) from Part 2 – they could include your starting point, decisive moments in the middle where you decided to make a big change, and/or your best performing scheme. **Include the settings you used** (reference the text file from Figure 3).
2. Source EUI results of each scheme you present. These can be taken straight from Rhino or you can create a new graph that shows how your performance evolved.
3. Comment on the following:
   - What strategy or upgrade worked the best in reducing Source EUI? What was least effective?
   - Do you feel that the simulations helped you to improve the energy concept of your building over your baseline design?
   - Do you trust your results as far as a comparative analysis is concerned? Would you feel comfortable using your simulation skills in studio or during a design internship in an architectural office?
   - How will what you learnt during the simulation game impact for your final project?

Good luck and have fun!