

## ArchSim Simulation Game Instructions

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This document describes a simulation game that may be played as a 90 minute in-class exercise to teach architectural students three interrelated skills:

- To conduct a basic thermal simulation,
- To understand the results and
- To adapt a building design according to what they have learnt from a simulation

### Preparations

The simulation game is based on a plug-in called ArchSim for the parametric scripting environment Grasshopper for Rhinoceros 3D. ArchSim generates and executes whole building energy model out of Rhino. It uses the US Department of Energy's EnergyPlus program as the simulation engine. To play the game you need to do the following:

- Download and install Rhinoceros3d (<http://www.rhino3d.com/>; free 90 day trial versions are available)
- Download and install Grasshopper (<http://www.grasshopper3d.com/>; free program)
- Download and Install ArchSim (<http://www.grasshopper3d.com/>; free program; pay attention to the installation instructions)
- Download the Simulation Game File from <http://web.mit.edu/sustainabledesignlab/projects/SimulationGameRevisited/index.html>. If you are playing the game as part of a class, your instructor might provide you with a custom file for your particular project and climate.
- You will need a recent version of EnergyPlus on your computer. The Simulation Game file from the MIT web site assumes the following path for EnergyPlus C:\EnergyPlusV8-2-0. This can be changed.
- If you are a student you should watch the first video tutorial to play the game at <https://www.youtube.com/watch?v=GOIS-gZQSc&feature=youtu.be>. Instructors are encouraged to also go through the two advanced game tutorials.

### Game Objective

The objective of the game is to design a **XXXXm<sup>2</sup>** office building located in **site**, with the lowest possible Greenhouse Gas (GHG) emissions [kgCO<sub>2</sub>e/m<sup>2</sup>] due to operational energy use according to ArchSim/EnergyPlus. The team with the lowest GHG emissions and a purchasing budget (see below) under 50 MIT\$ /m<sup>2</sup> at the end wins and each team member will receive 10 bonus points for the semester. Follow all rules below. This is a timed exercise. When time is up (**after 90 minutes**), your team must submit a Rhino file with at least **three** different documented *Variant Descriptions*, and accompanying GHG emissions results including your entry variant (the model with the lowest emissions). Next week in class each group will be asked to present (8

minutes) the logic that lead you from variant to variant as well as to comment on some questions provide below. Remember, final designs will be judged on simulated GHG emissions **only**.

## Setting up a Simulation

Using the Grasshopper file called *SimulationGame.GH* provided on the game web site, model a roughly **xxxxm<sup>2</sup>** building in **site** (actual size may vary between from the target value by around 10%) and add any of combination of design upgrades offered in the Grasshopper file. These design upgrades are listed below. **The floor to ceiling height of each level should be at least 3m (no exceptions)**. In order to save time, you may model each floor as a single thermal zone and use the automatically generated windows. Different levels have to be modeled as separate zones in ArchSim/EnergyPlus.

Once a simulation is run, the game will automatically bake your geometry into an “iteration” layer as well as automatically visualize results. For at least three iterations, document the design variant by providing a brief description under the simulation results in Rhino as shown in Fig 1.

**Remember that valid designs have a purchasing budget for design upgrades below 50 MIT\$<sup>1</sup> or less.**

Run as many different simulations as you can and use previous simulation results to guide your decisions.

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<sup>1</sup> All \$ amounts in this document are in MIT\$. Care has been taken to make sure that the relative cost differences between the different design upgrades are somewhat realistic. An upgrade using all possible options would cost about 100 \$MIT/m<sup>2</sup>.

Table: Simulation Game Upgrades

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

EXTERIOR WALL INSULATION					
Description				SI units (IP units)	Relative Cost
	Base Building	Continuous Insulation	R-Factor: R13	\$	
		Continuous Insulation	R-Factor: R19.5	\$\$	
		Continuous Insulation	R-Factor: R28.5	\$\$\$	

WINDOW-TO-WALL-RATIO (WWR)				
Description				Relative Cost
		Storefront or punched opening construction	20%	\$
	Base Building	Storefront or punched opening construction	40%	\$\$
		Storefront or punched opening construction	60%	\$\$\$
		Curtainwall construction	80%	\$\$\$\$

WINDOW GLASS TYPE					
Description		SI units (IP units)			Relative Cost
Double-Pane Argon-Filled		U-Factor = 0.45 (2.5)	SHGC= 0.41	VLT = 0.65	\$
Double-Pane, Argon-Filled, Low-e coating on outside pane (#2 surface)		U-Factor = 0.23 (1.3)	SHGC= 0.25	VLT = 0.51	\$\$\$
Double-Pane, Argon-Filled, Low-e coating on inside pane (#3 surface)		U-Factor = 0.23 (1.3)	SHGC= 0.38	VLT = 0.51	\$\$\$
Double-Pane, Argon-Filled, Higher performing Low-e coating on outside pane (#2 surface)		U-Factor = 0.23 (1.3)	SHGC= 0.22	VLT = 0.37	\$\$\$\$

EXTERIOR SHADING*				
Description			Relative Cost	
	Base Building	None	0	
	0.5m (1.64 ft) deep horizontal overhang		All facades	\$
	1m (3.3 ft) deep horizontal overhang		All facades	\$\$
	1.5m (4.9 ft) deep horizontal overhang		All facades	\$\$\$

\*Note: Simulations including exterior shading will take longer to complete.

LIGHTING POWER DENSITY				
Description				Relative Cost
	Base Building	11 W/m <sup>2</sup> during occupancy	5% LPD during non-business hours	0
		9 W/m <sup>2</sup> during occupancy	5% LPD during non-business hours	\$

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)	\$

OCCUPANT SENSORS			
Description			Relative Cost
	Base Building	None	0
		Reduces Lighting Power Density by 10% during occupancy.	\$

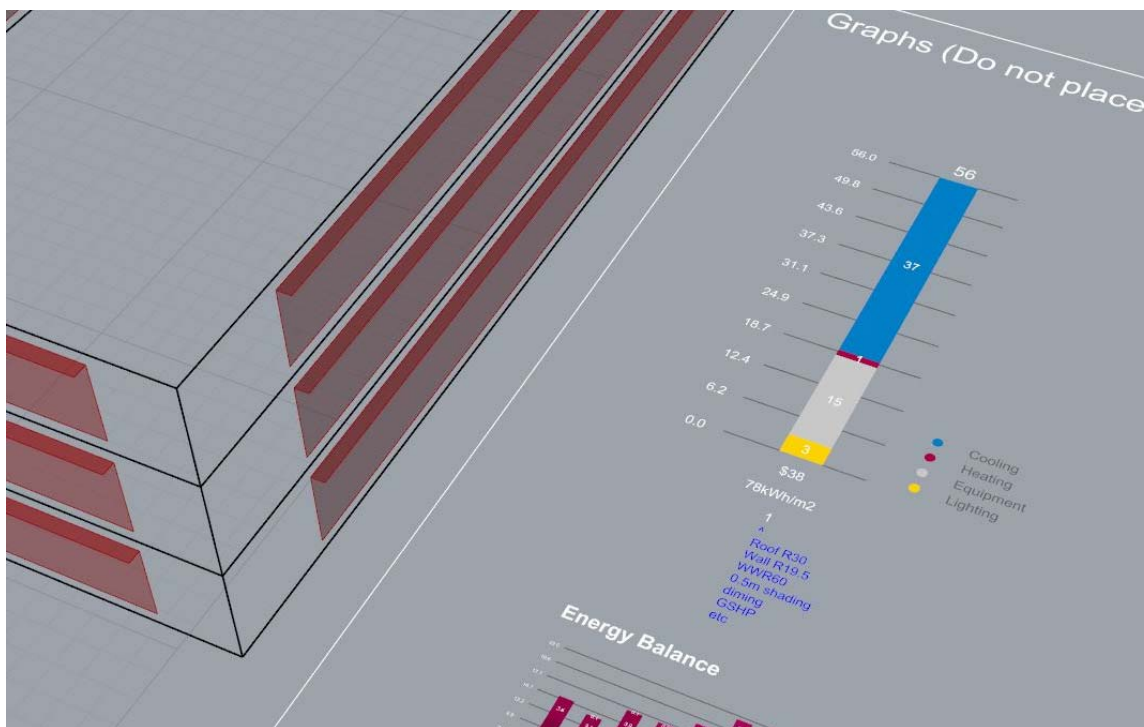


Fig 1 Screenshot of documented simulation results (in blue) and building geometry in Rhino

For your reference: GHG emissions typically vary between 35 kgCO<sub>2</sub>e/m<sup>2</sup> to a median of 116 kgCO<sub>2</sub>e/m<sup>2</sup>.

## End of Game and Entry Submission

FOLLOW THESE INSTRUCTIONS CAREFULLY:

When you run out of time or are satisfied with your best design (and you're sure that it costs equal to or below 50 "MIT dollars"):

1. Re-run your winning design so that the last simulation shown in the Rhino results panel is your best entry.
2. BAKE the simulation results into the Rhino file and save.
3. Save your Grasshopper file with your final (best) settings
4. Create a ZIP file of the entire C:\SimulationGame folder.
5. Submit the Rhino file, Grasshopper file, and ZIP file to the course instructor.

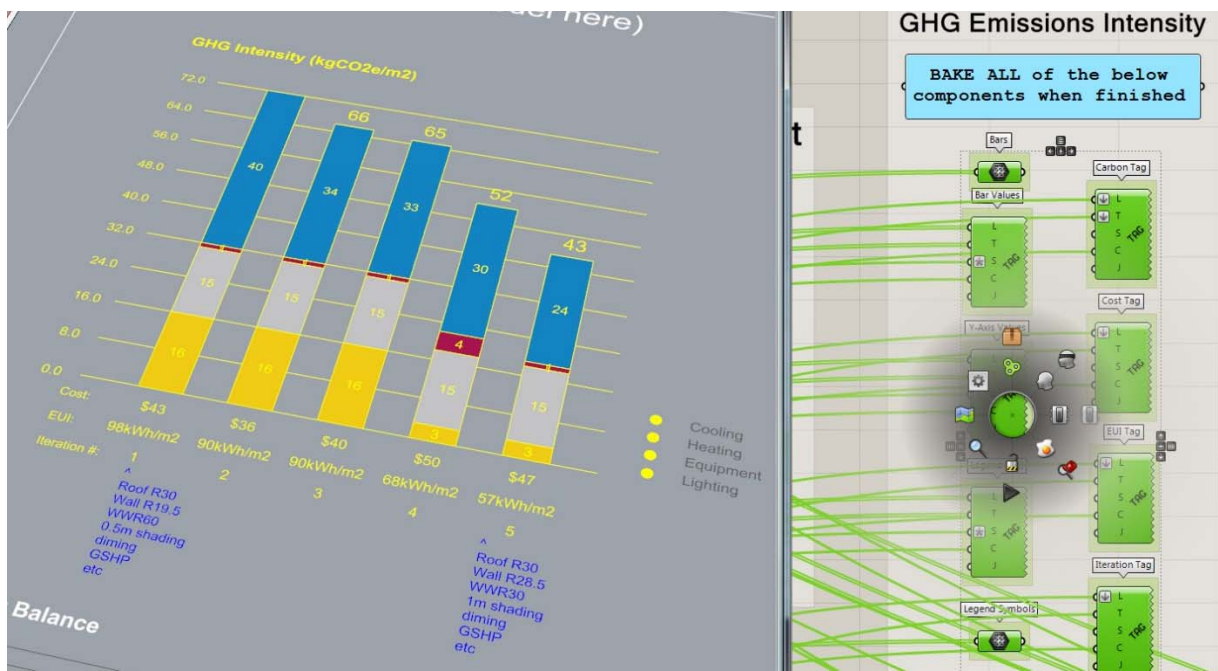


Fig 2 Screenshot of baked results and documented entries in Rhino

Most important, have fun!