

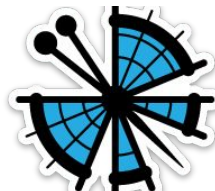


# The Tool The Toolkit

Chris Mackey + Mostapha Sadeghipour Roudsari



Design Modeling Symposium  
Sept. 19 2017

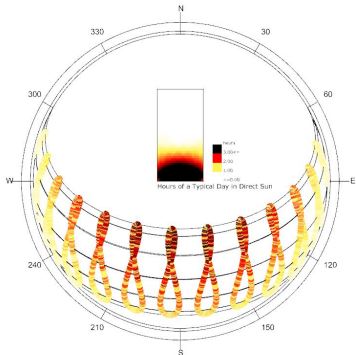


# Ladybug Tools



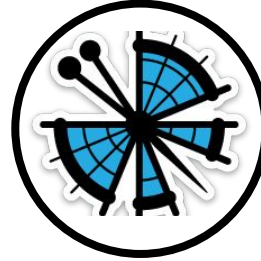
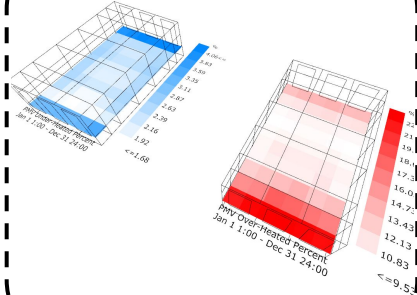
Ladybug

Climate Visualization  
+ Analysis



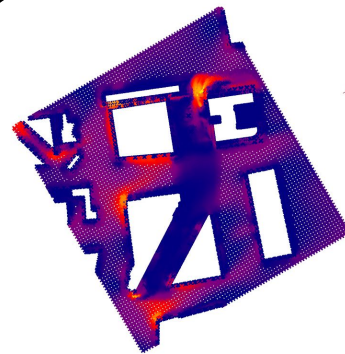
Honeybee

Building Energy, Daylight +  
Comfort Modelling



Butterfly

Airflow Modelling  
(CFD)



Dragonfly

Climate Modelling  
(heat island, climate change)

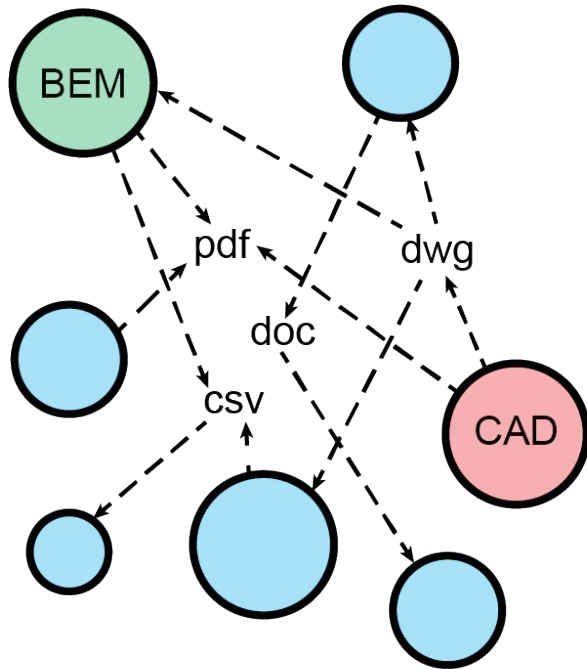


Under  
Development

# Toolkits



## Historical Context



Disconnected Tools

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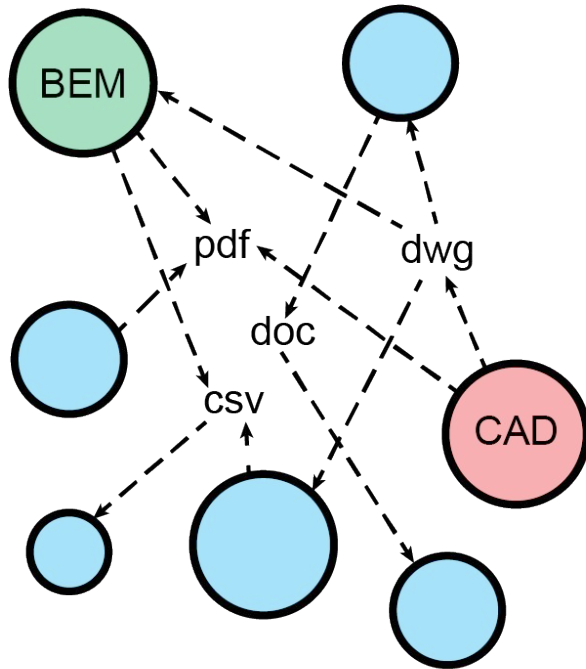
### Our Historical Software Situation

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Separate software packages that export/import to/from standard file types.



## Historical Context



Disconnected Tools

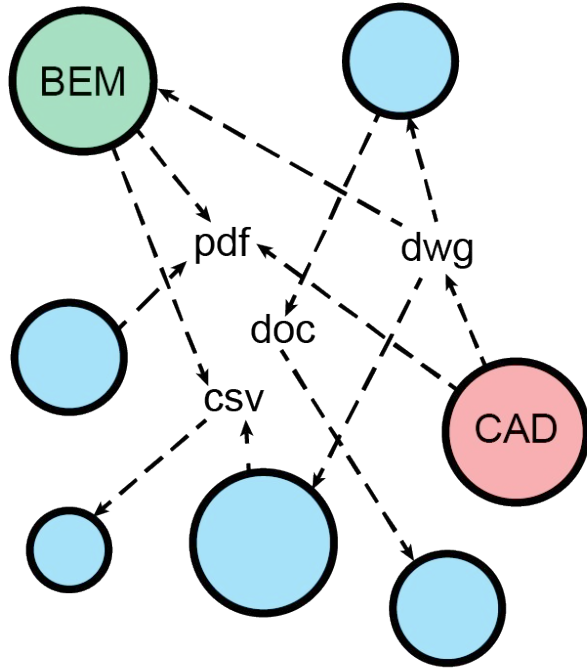
## Benefits

- Flexible / Adaptable
- Extensible
- Easy to iterate within one software package

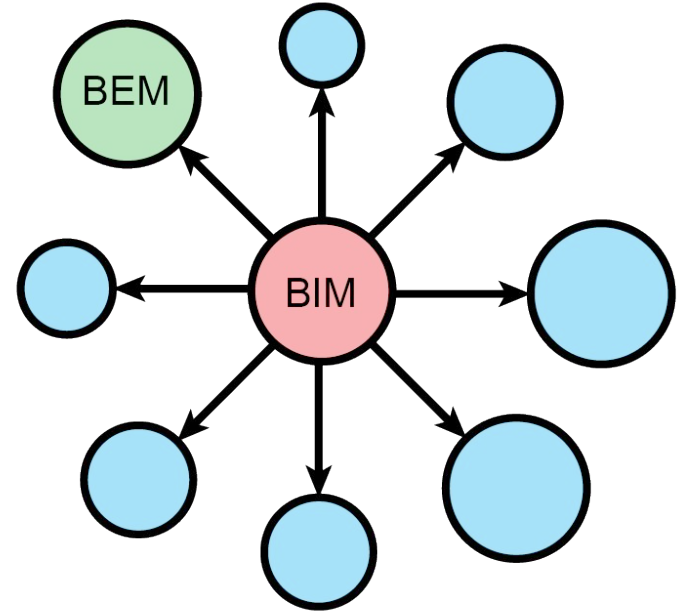
## Drawbacks

- Redundant (remake your model for each tool)
- Inefficient
- Difficult to collectively iterate
- Siloed (segregated software packages)

## Historical Context



Disconnected Tools

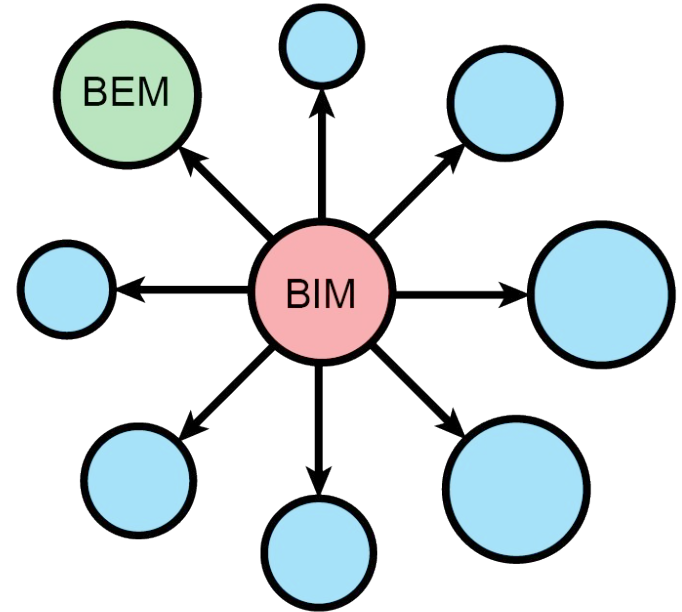


Centralized Tool

## Historical Context

### Our “Contemporary” Software Philosophy

A central model that exports basic information to other software interfaces.



Centralized Tool

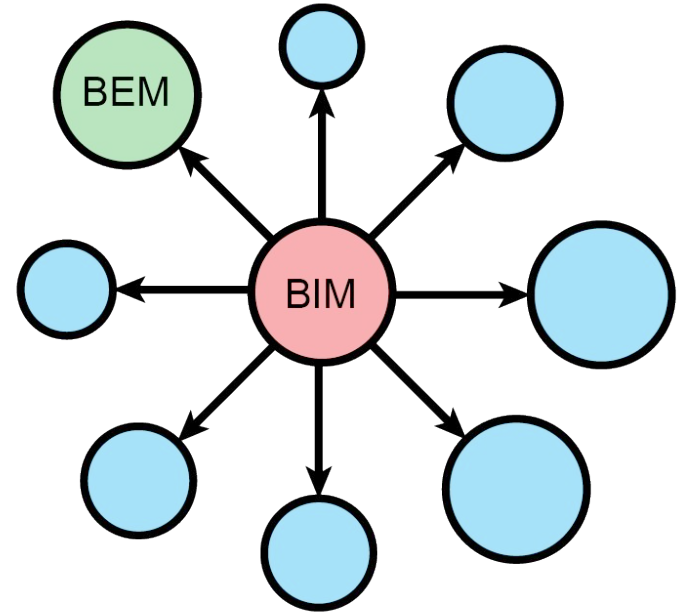
## Historical Context

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### Benefits

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- Efficient
- Connected



Centralized Tool

## Historical Context

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### Law of Inertia

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The more mass within an object, the more energy it takes to move it.

## Historical Context

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### Law of Inertia

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The more mass within an object, the more energy it takes to move it.

### Law of Design Inertia

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The more information that is in a model, the more (human) energy it takes to iterate with it.

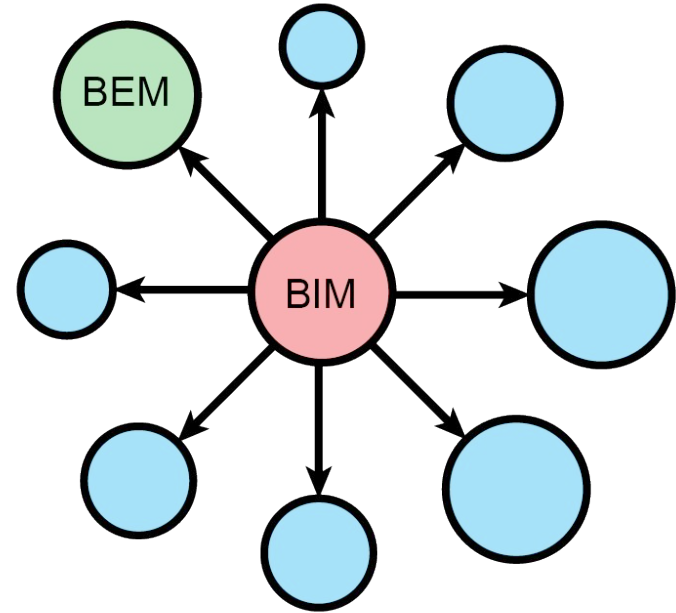
## Historical Context

### Benefits

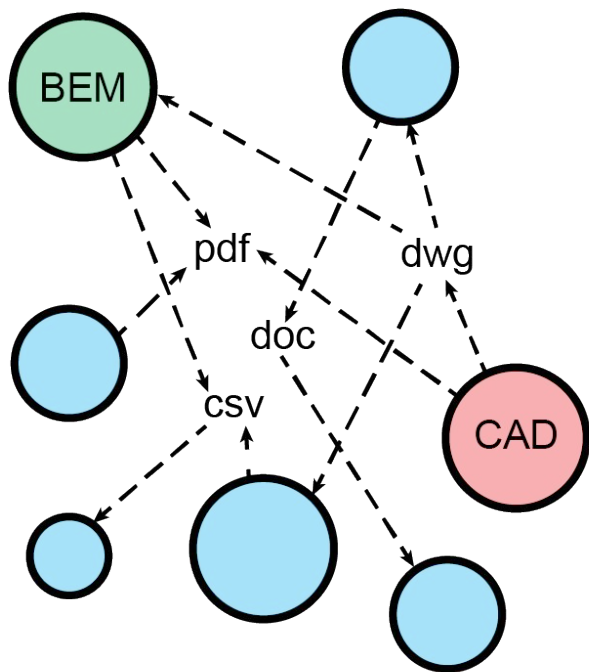
- Efficient
- Connected

### Drawbacks

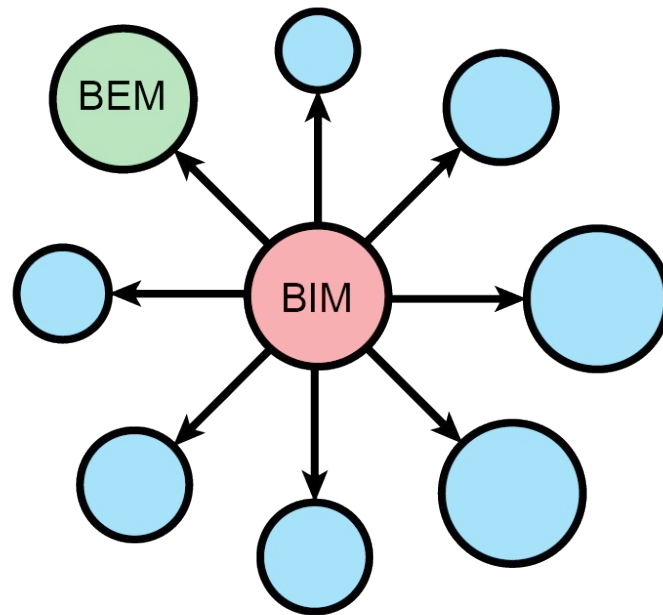
- Inflexible
- Restricted
- Unidirectional (from BIM to others)
- Not iterative



Centralized Tool



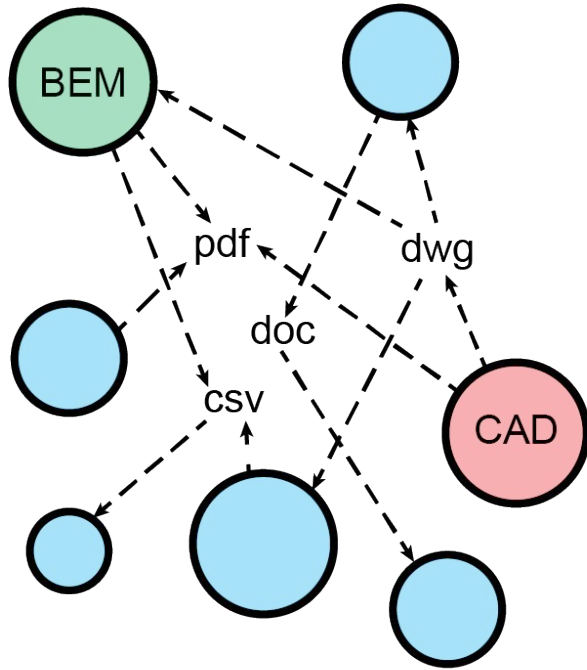
Disconnected Tools



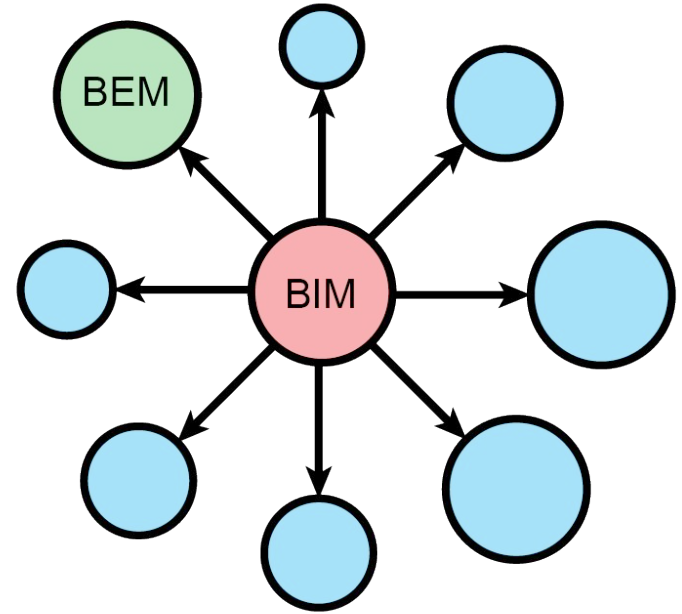
Centralized Tool



**Neither of these philosophies realizes the full potential of computational design**

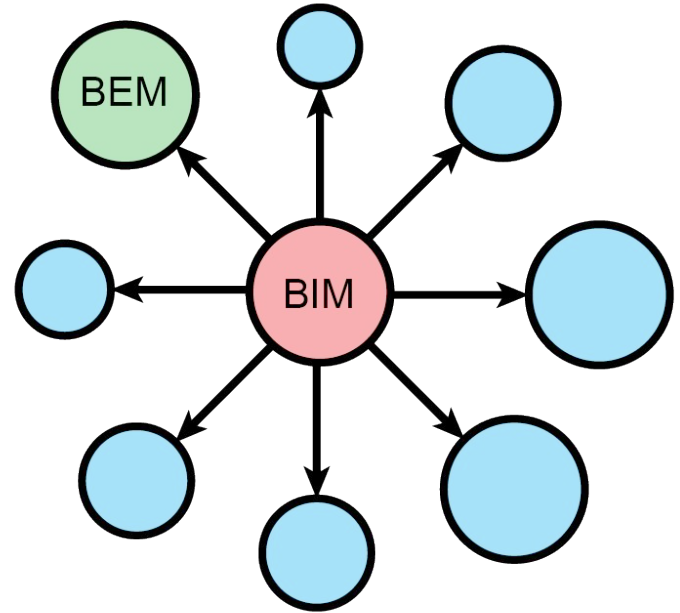
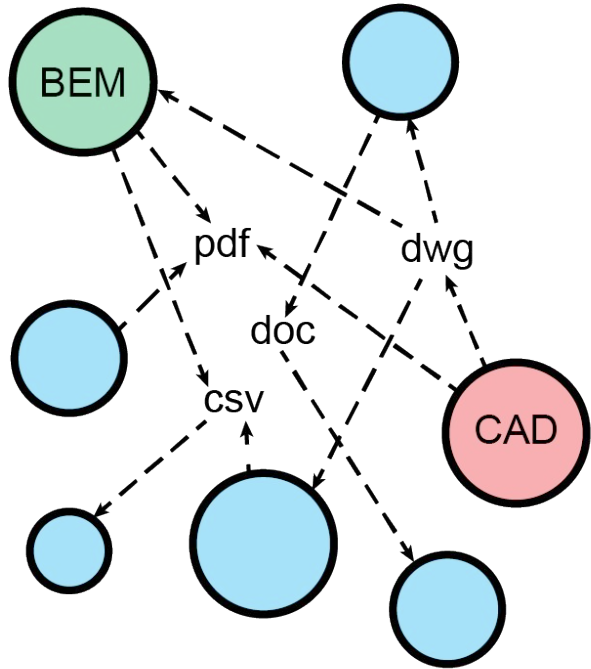


Disconnected Tools

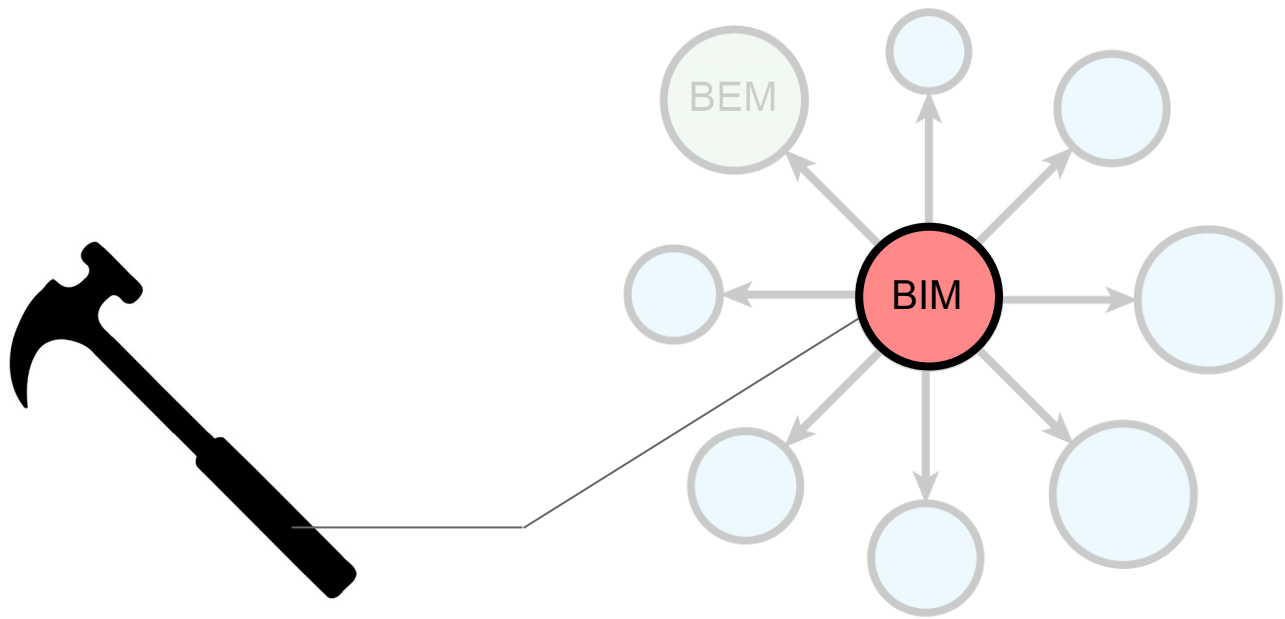


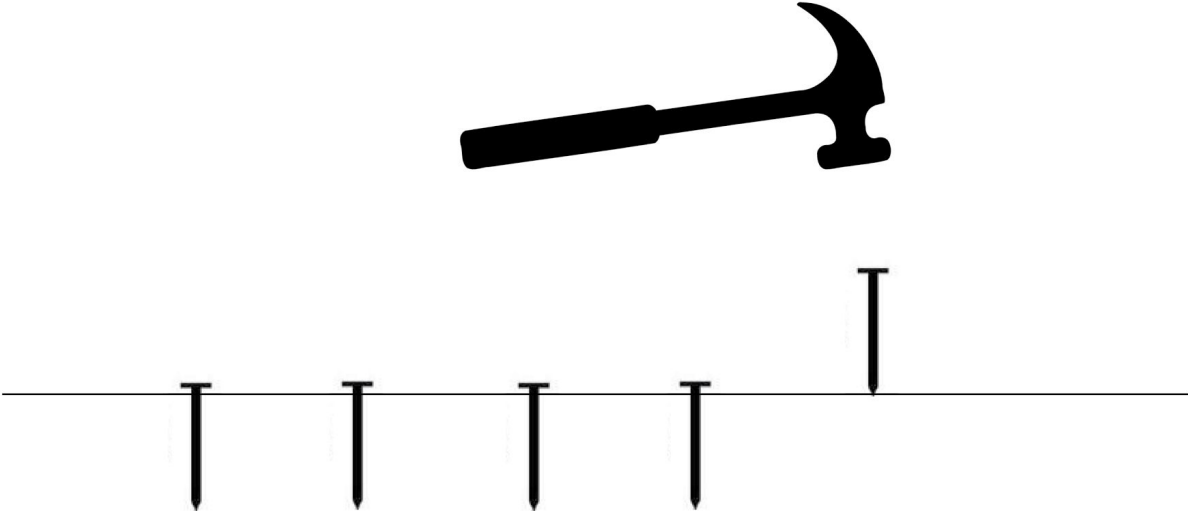
Centralized Tool

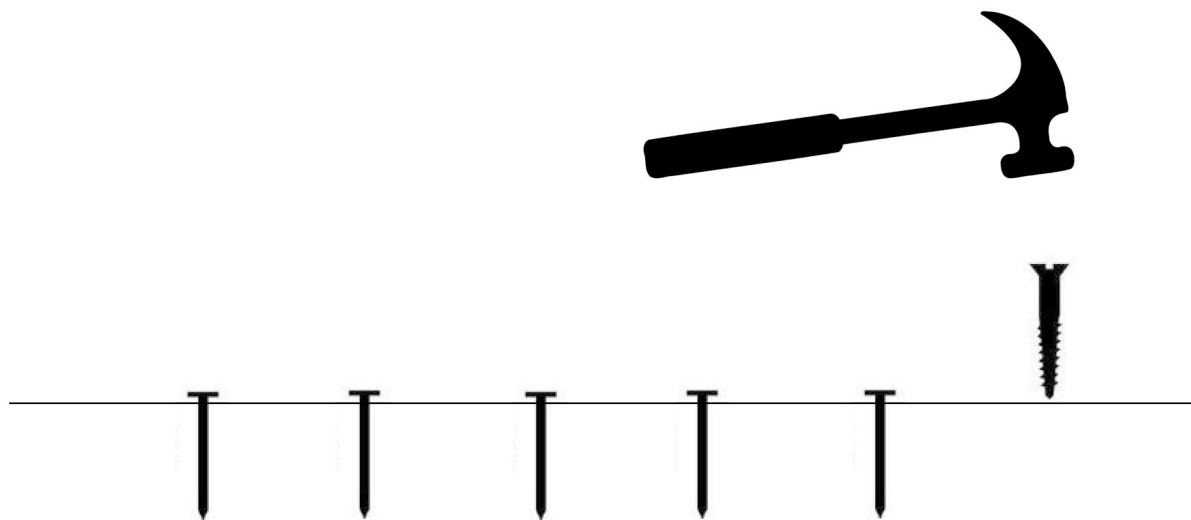
**Neither of these philosophies realizes the full potential of computational design**

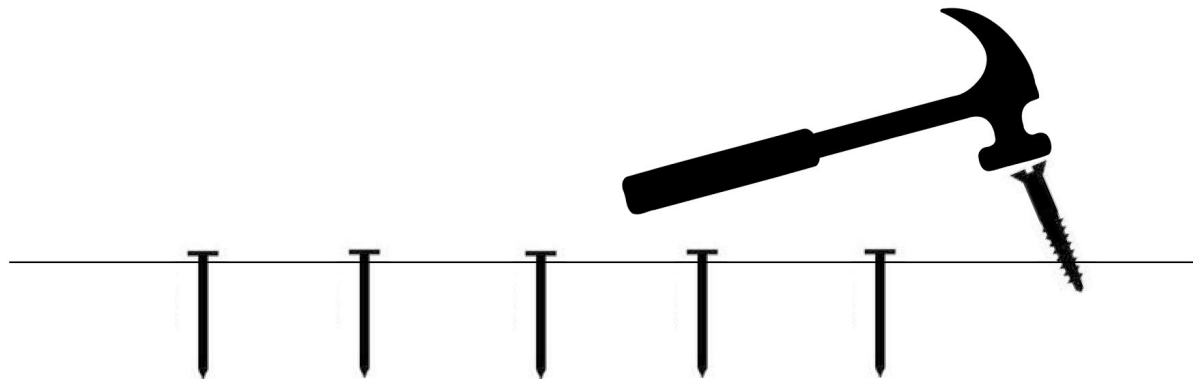


**Both focus on the tools themselves as the solution**





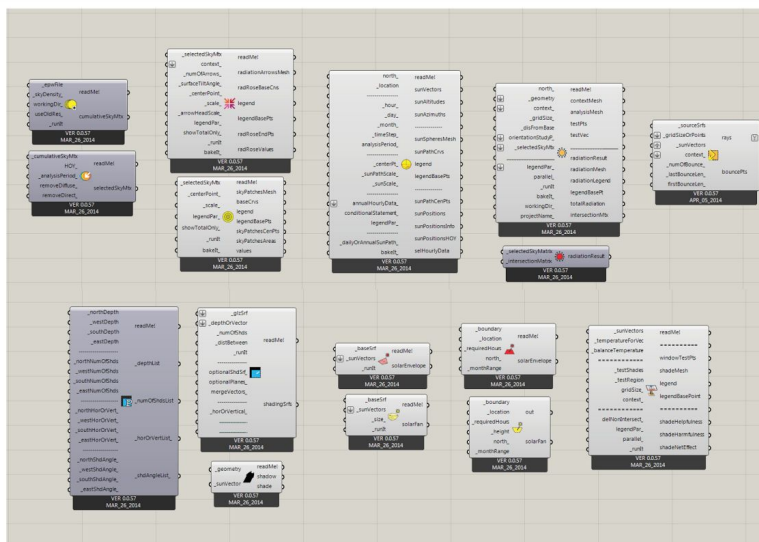
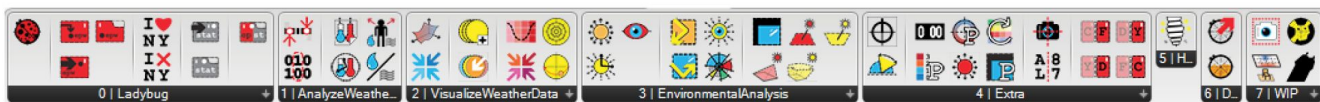




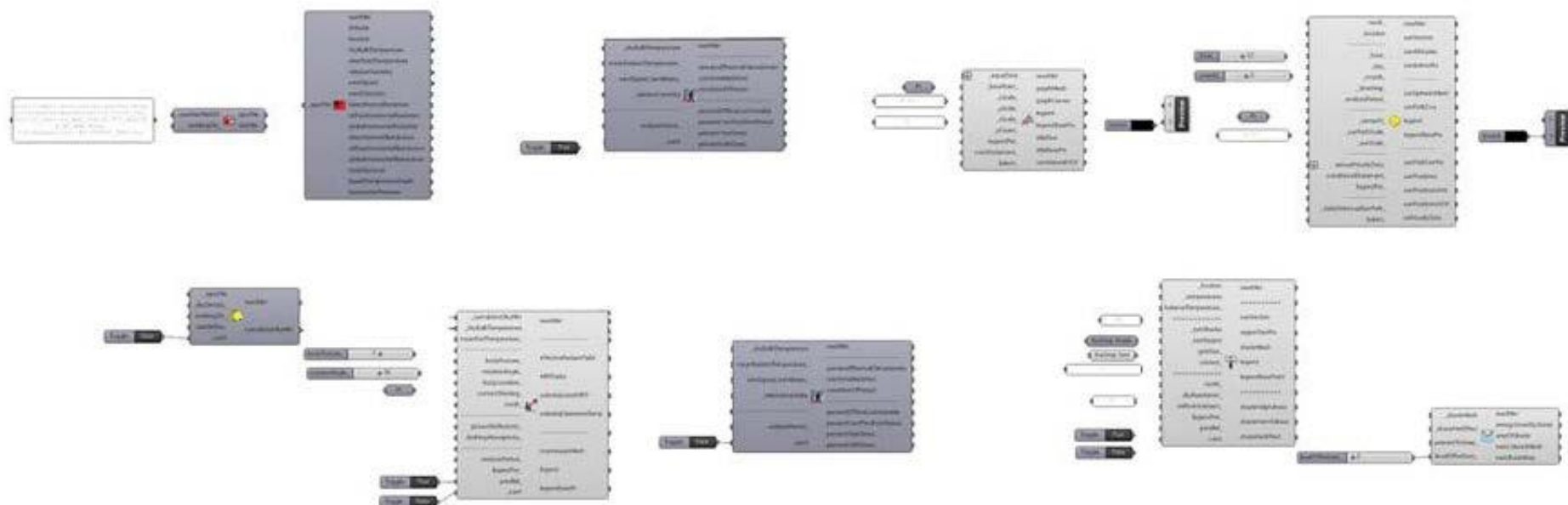


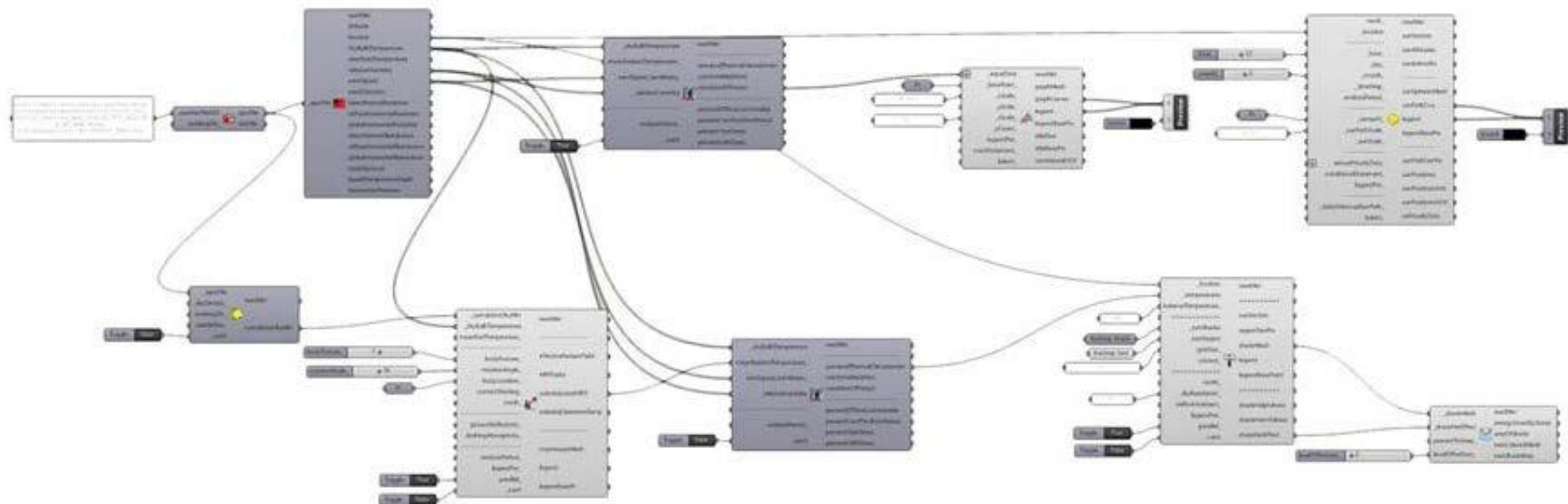
vs.



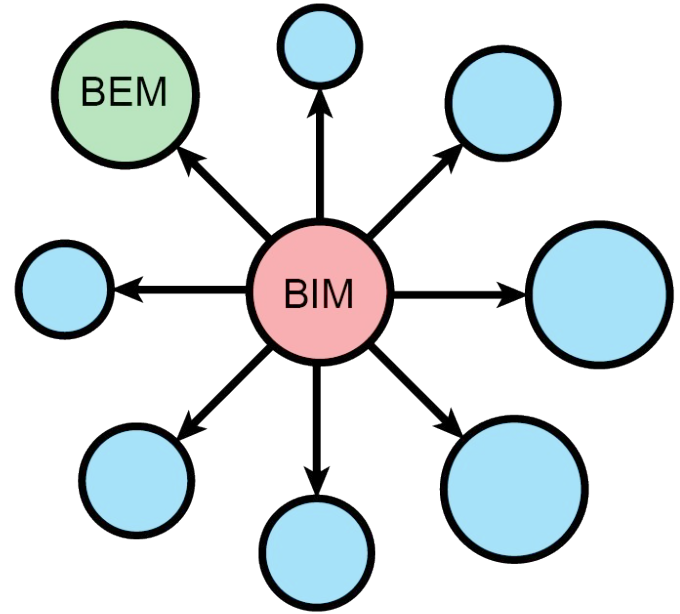
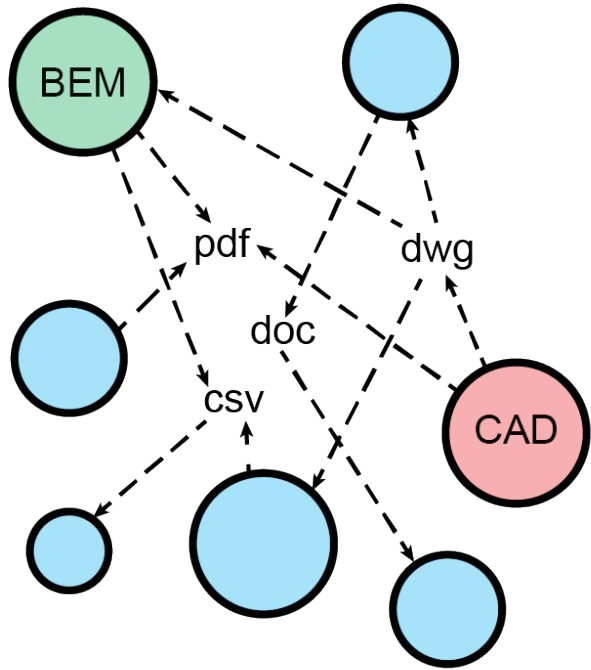




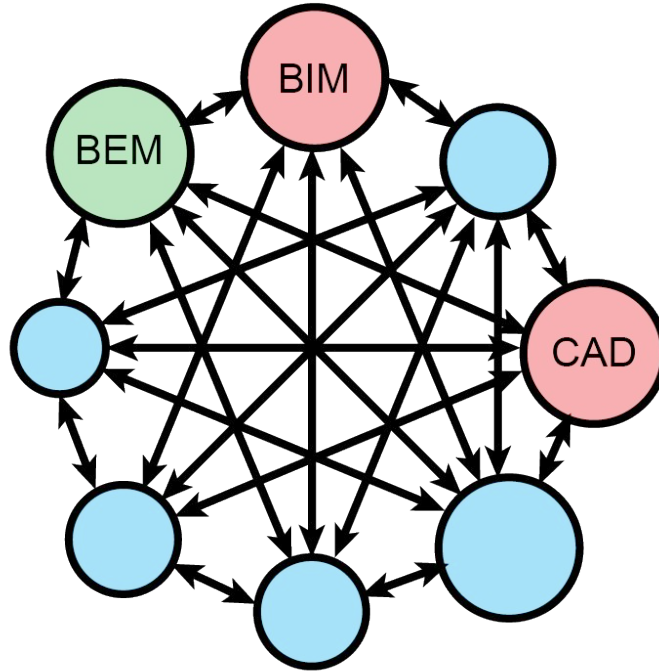




**Neither of these philosophies realizes the full potential of computational design**

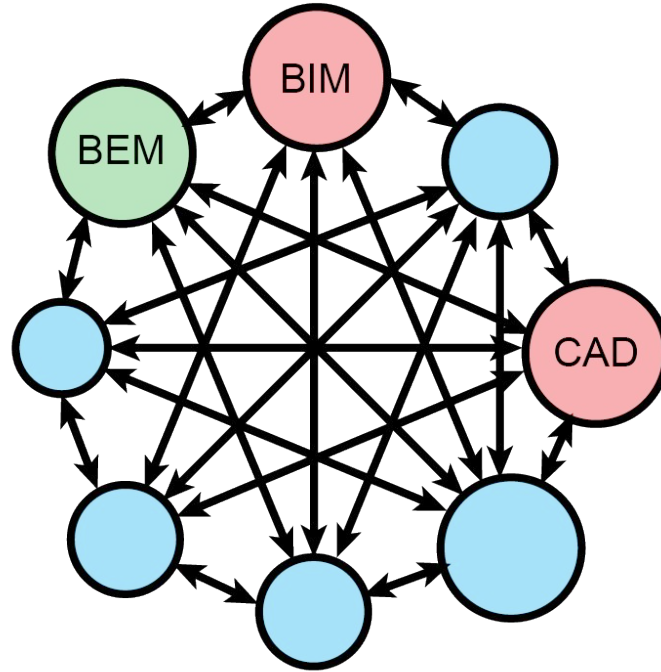


**Both focus on the tools themselves as the solution**



... rather than the **workflows** or **interconnection** between tools

# What makes software a part of a toolkit?



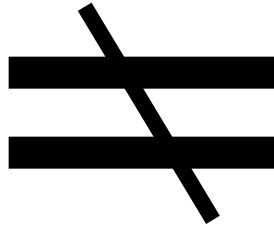
# Principles of the toolkit

1. Do One Thing and Do It Well.
2. Build Interoperability with Other Tools.
3. Use Standardized Open Formats for Data Transfer.
4. Modularize the Tool.
5. Make it Easy to Start but Impossible to Master.

**#1 Do one thing and do it well.**

## Principle 1 - Do one thing and do it well

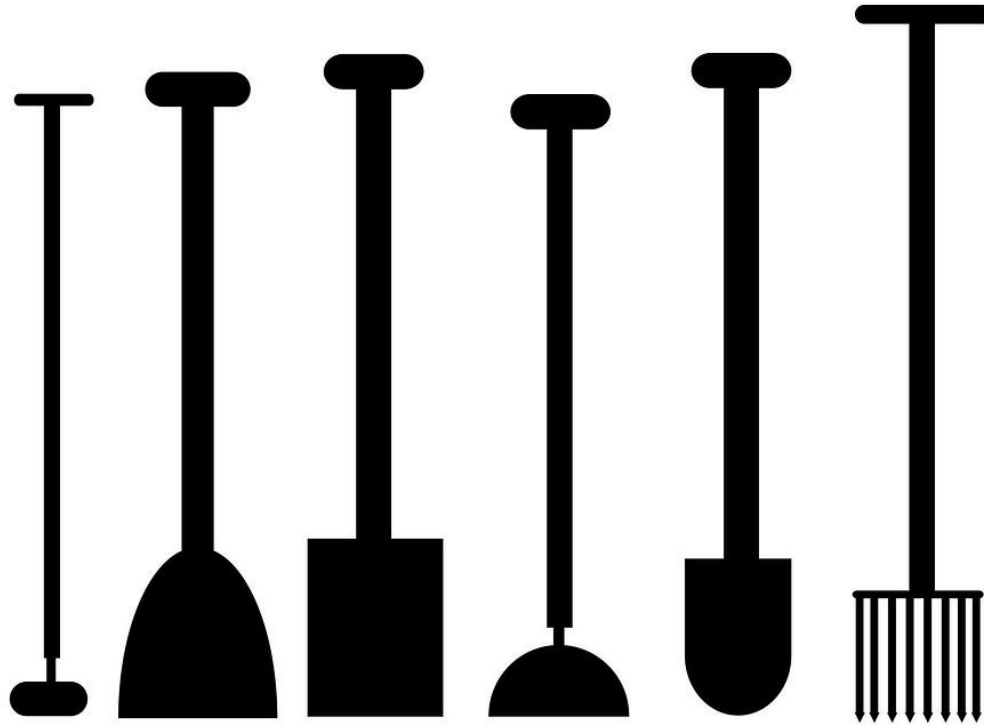
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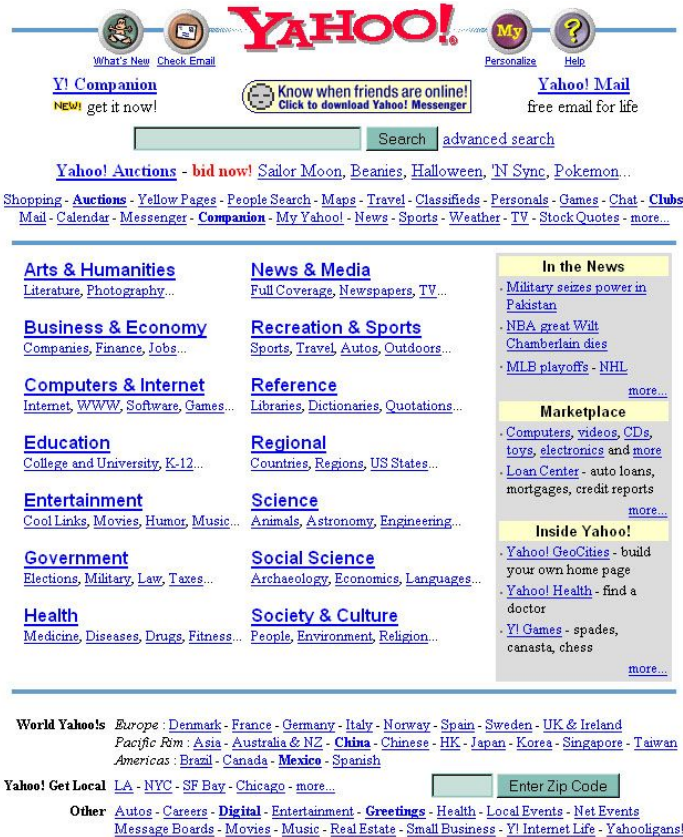


## Principle 1 - Do one thing and do it well

Specialization of tools within a toolkit



# Principle 1 - Do one thing and do it well



Yahoo (1998)

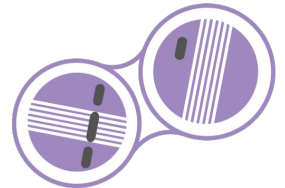


Google (1998)

## Principle 1 - Do one thing and do it well

**Welcome to the zoo!**

Specialization of plugins within the Grasshopper ecosystem



## Principle 1 - Do one thing and do it well

### Welcome to the zoo!

Specialization of plugins within the Grasshopper ecosystem



#### **Kangaroo**

Structural Form Finding



#### **Karamba**

Structural Solver



#### **gHowl**

Data formatting/  
translation



#### **VisualArq**

Plan drawings from 3D



#### **Speckle Streams**

Data broadcasting/  
sharing

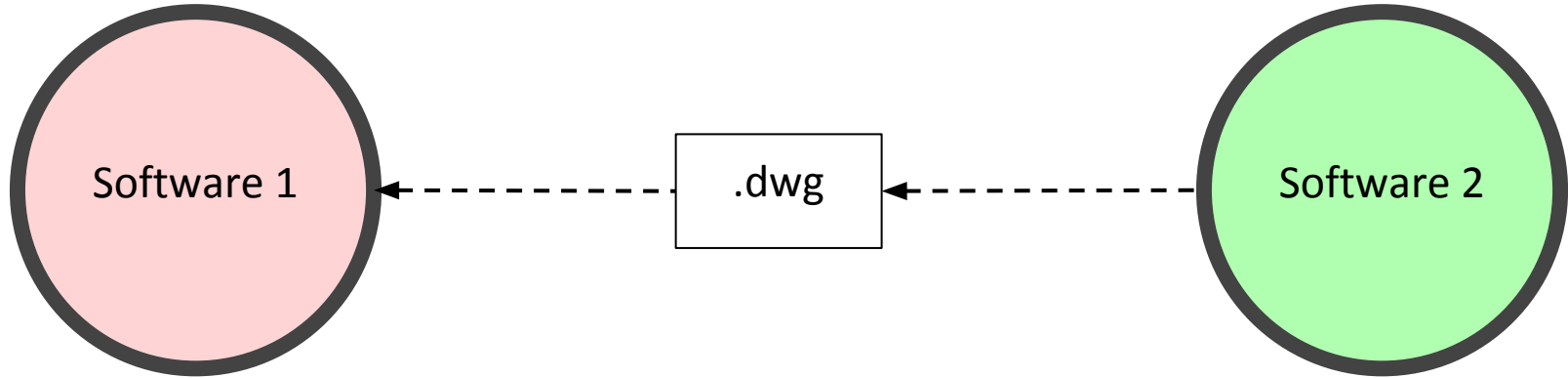


#### **Ladybug**

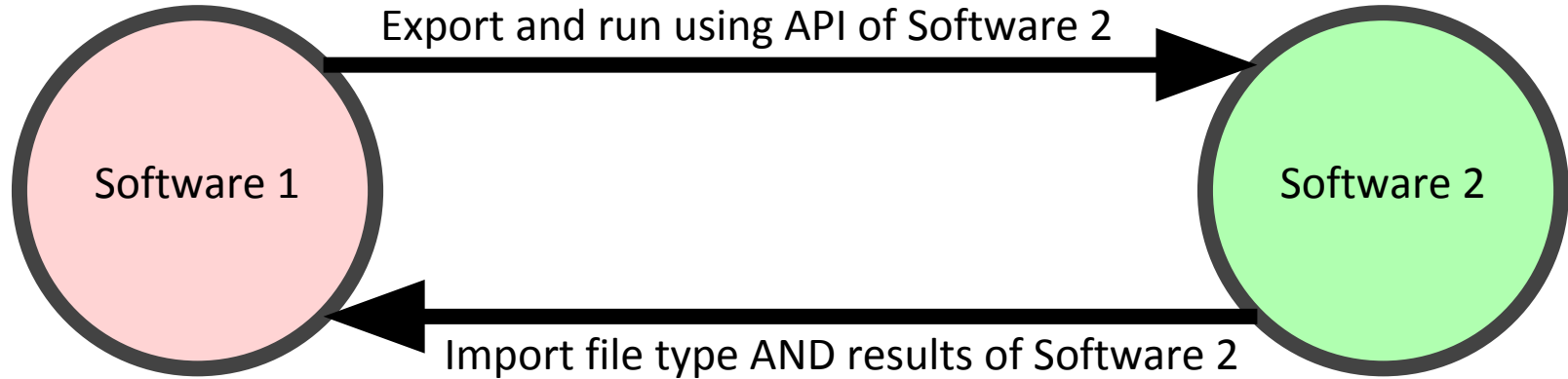
Climate Visualization/  
Analysis

## #2 Build interoperability with other tools

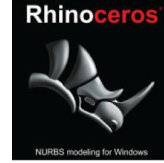
# Interoperability is **NOT**...



# Interoperability is...



# Plugin to available 3d modeling interfaces don't add a new drawing interface\*



*Rhino*



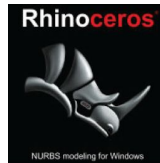
*Revit*

\* Does not apply when the “one thing you are trying to do well” is making a better interface or simulation engine.



### Plugin to available 3d modeling interfaces

don't add a new drawing interface\*



*Rhino*



*Revit*

### Connect to validated simulation engines

Don't add a new limited engine\*



*Radiance*

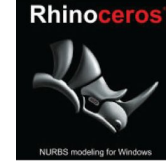


*EnergyPlus*

\* Does not apply when the “one thing you are trying to do well” is making a better interface or simulation engine.

### Plugin to available 3d modeling interfaces

don't add a new drawing interface\*



*Rhino*



*Revit*

### Connect to validated simulation engines

Don't add a new limited engine\*



*Radiance*



*EnergyPlus*

### Use existing Graphical User Interfaces (GUIs)

Don't build your own GUI\*



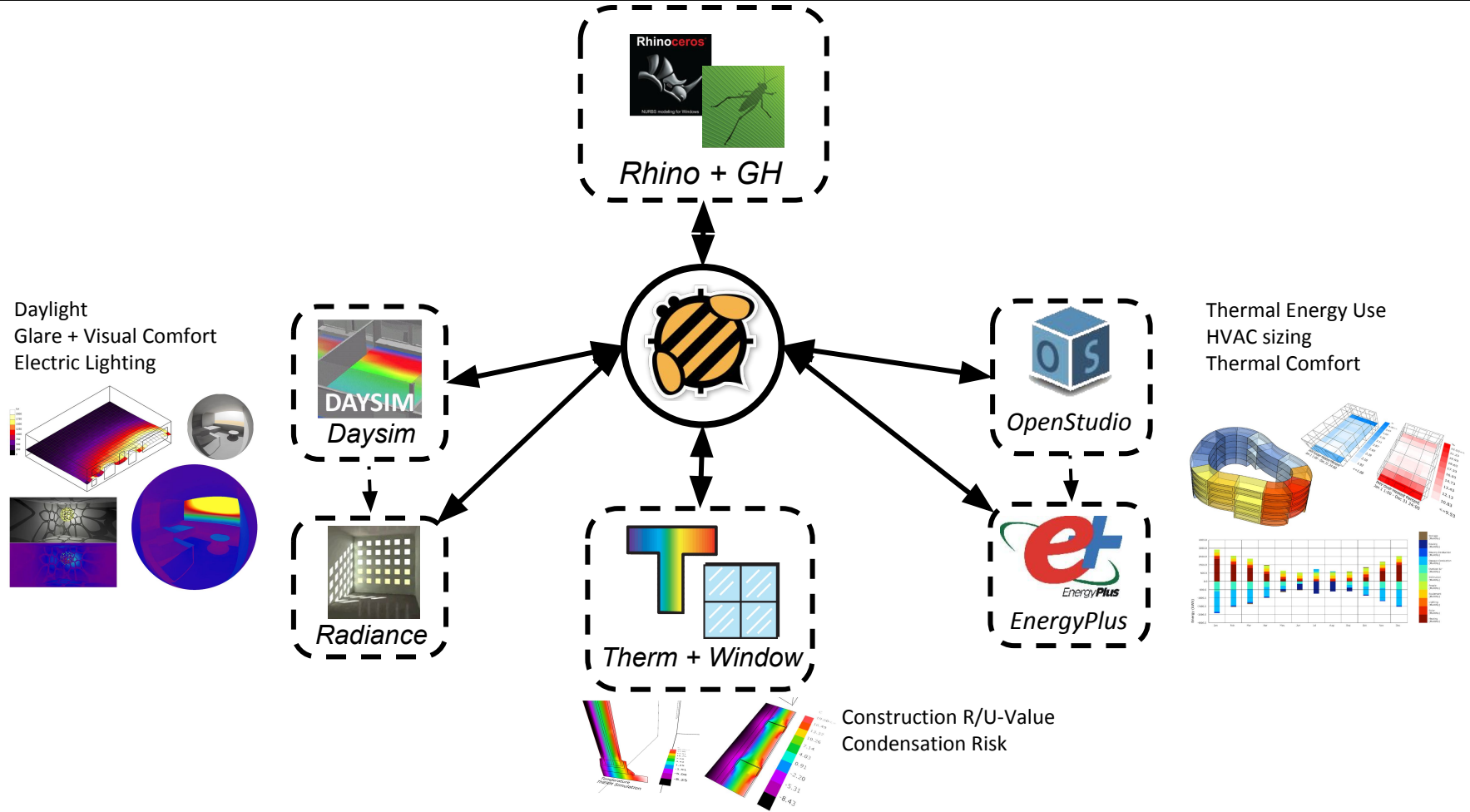
*Grasshopper*



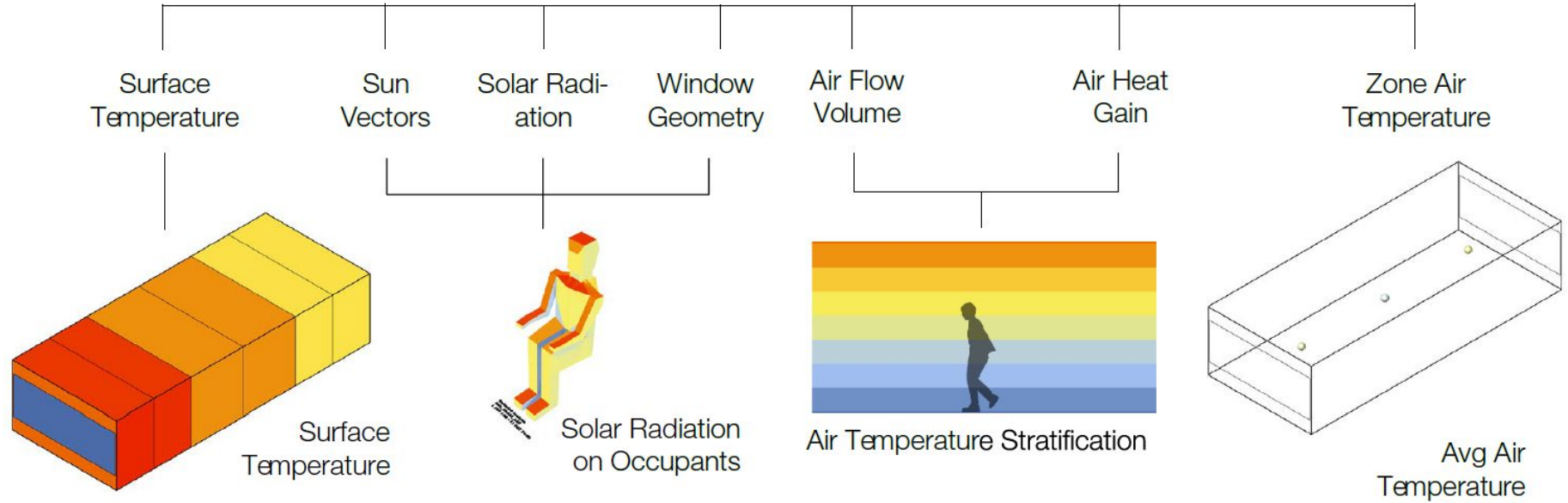
*Dynamo*

\* Does not apply when the “one thing you are trying to do well” is making a better interface or simulation engine.

## Principle 2 - Build Interoperability with Other Tools

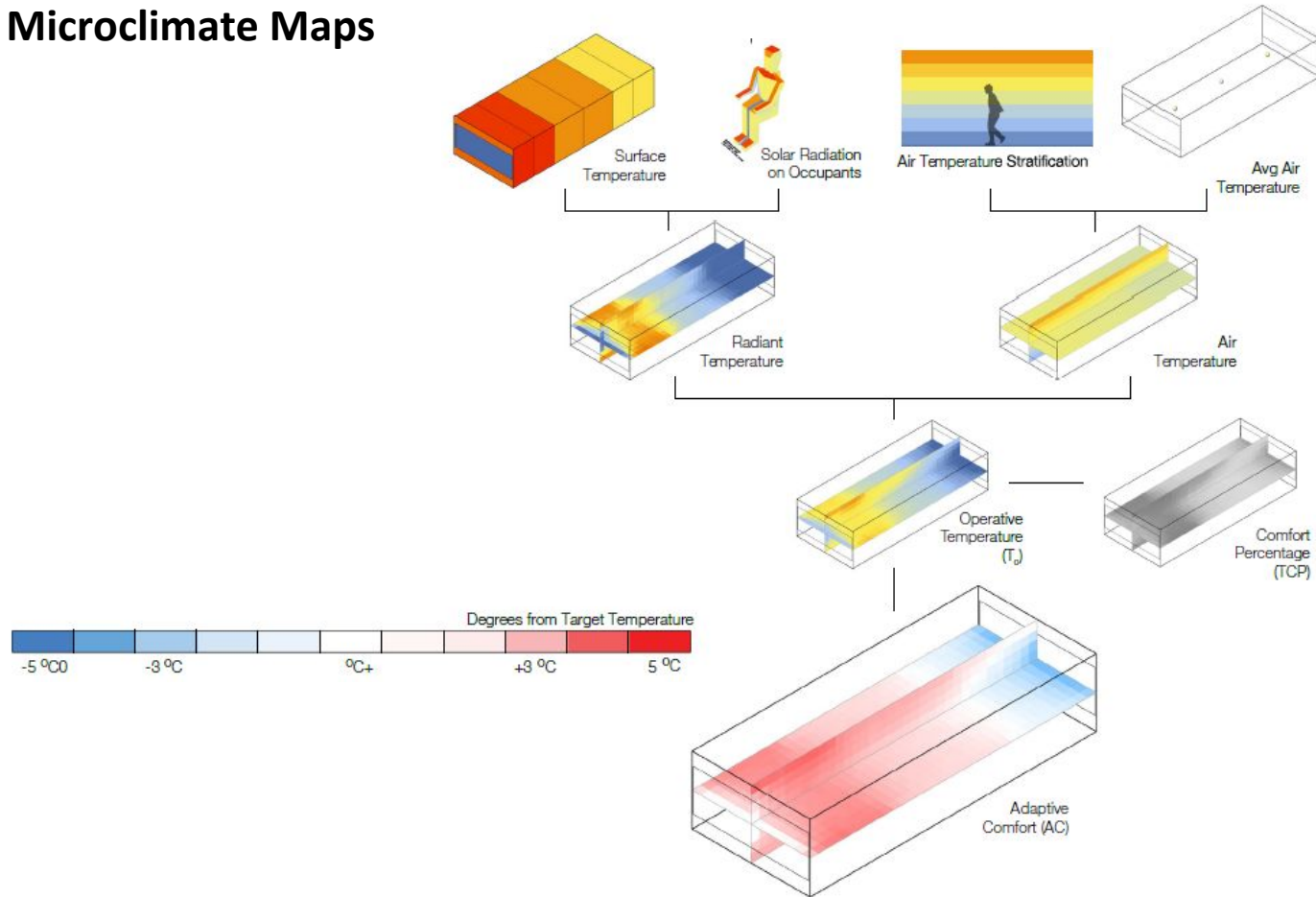


## Principle 2 - Build Interoperability with Other Tools



## Principle 2 - Build Interoperability with Other Tools

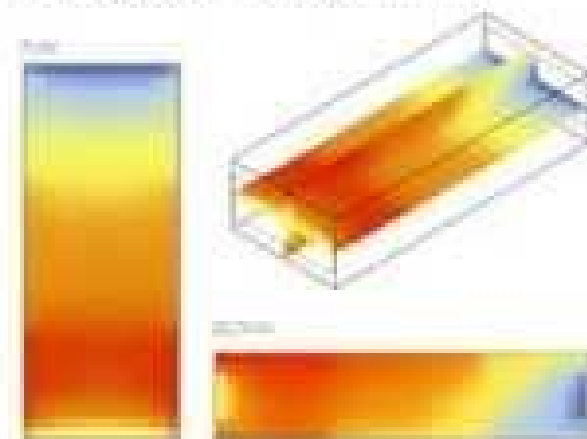
### Microclimate Maps



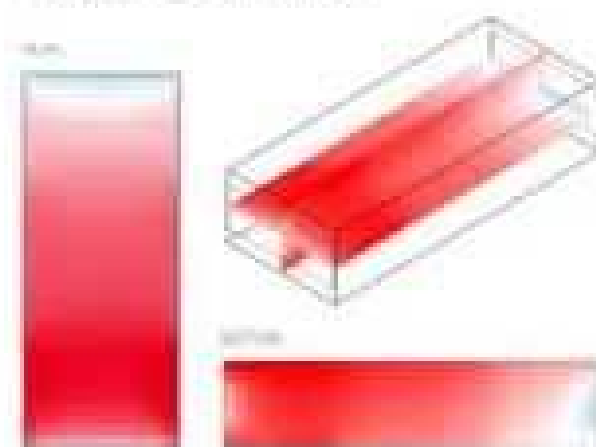
## Radiant Temperature



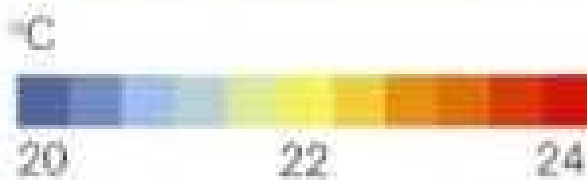
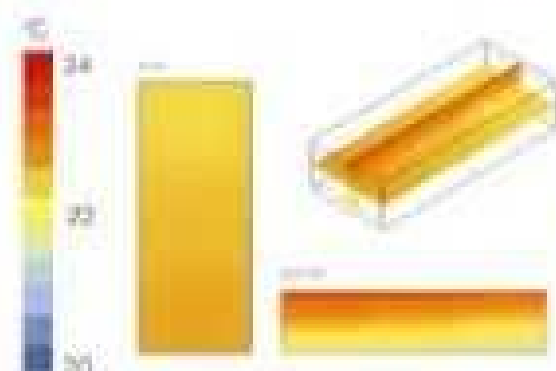
## Operative Temperature



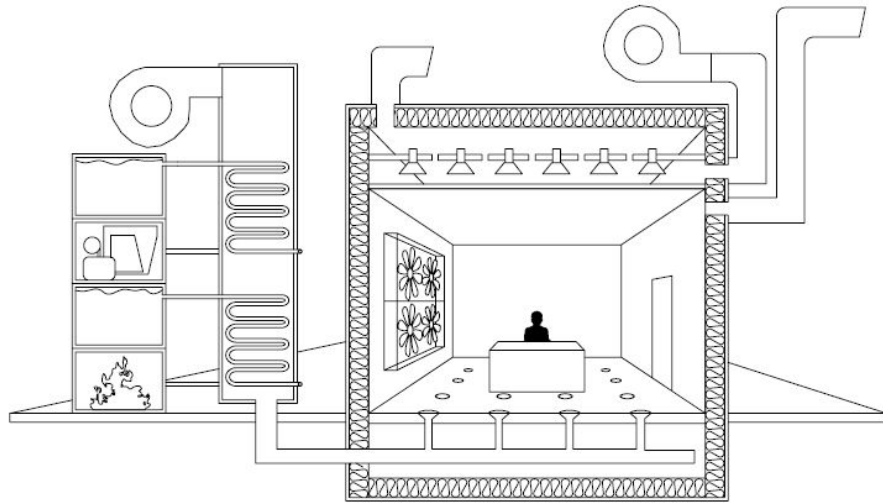
## Adaptive Comfort



## Air Temperature

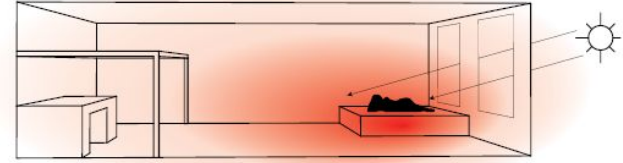


## Principle 2 - Build Interoperability with Other Tools

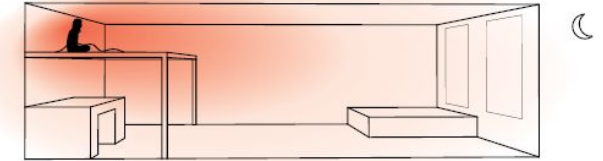


VS.

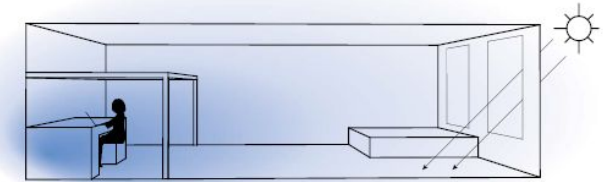
Winter Day



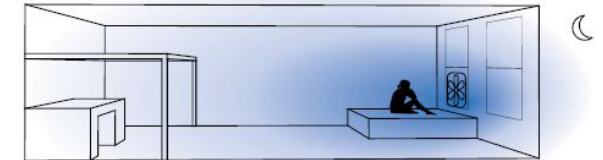
Winter Night



Summer Day



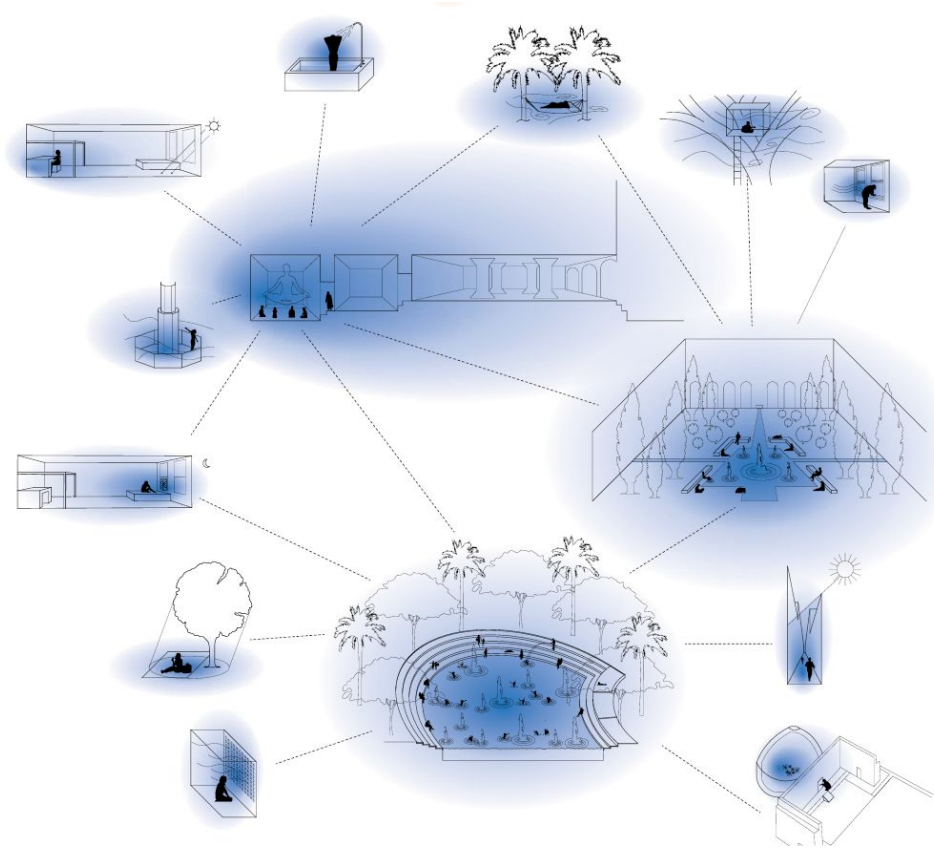
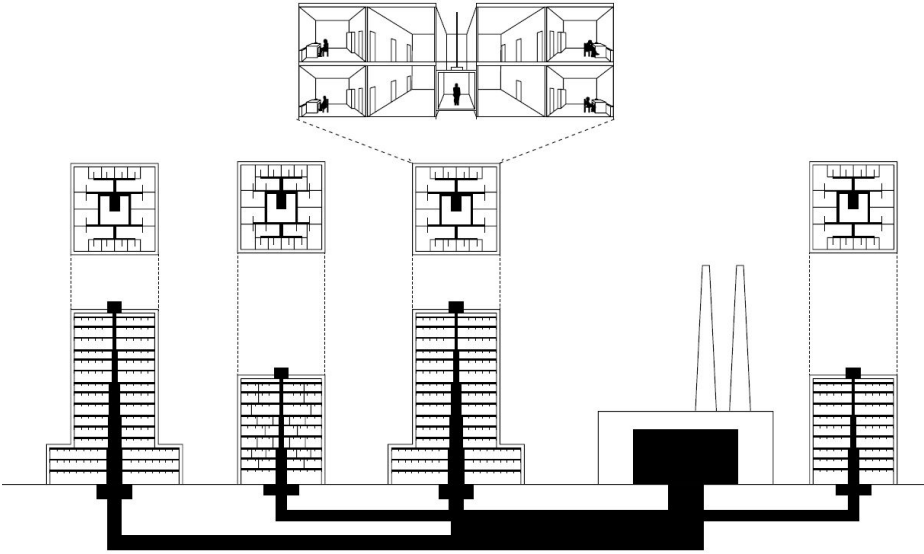
Summer Night



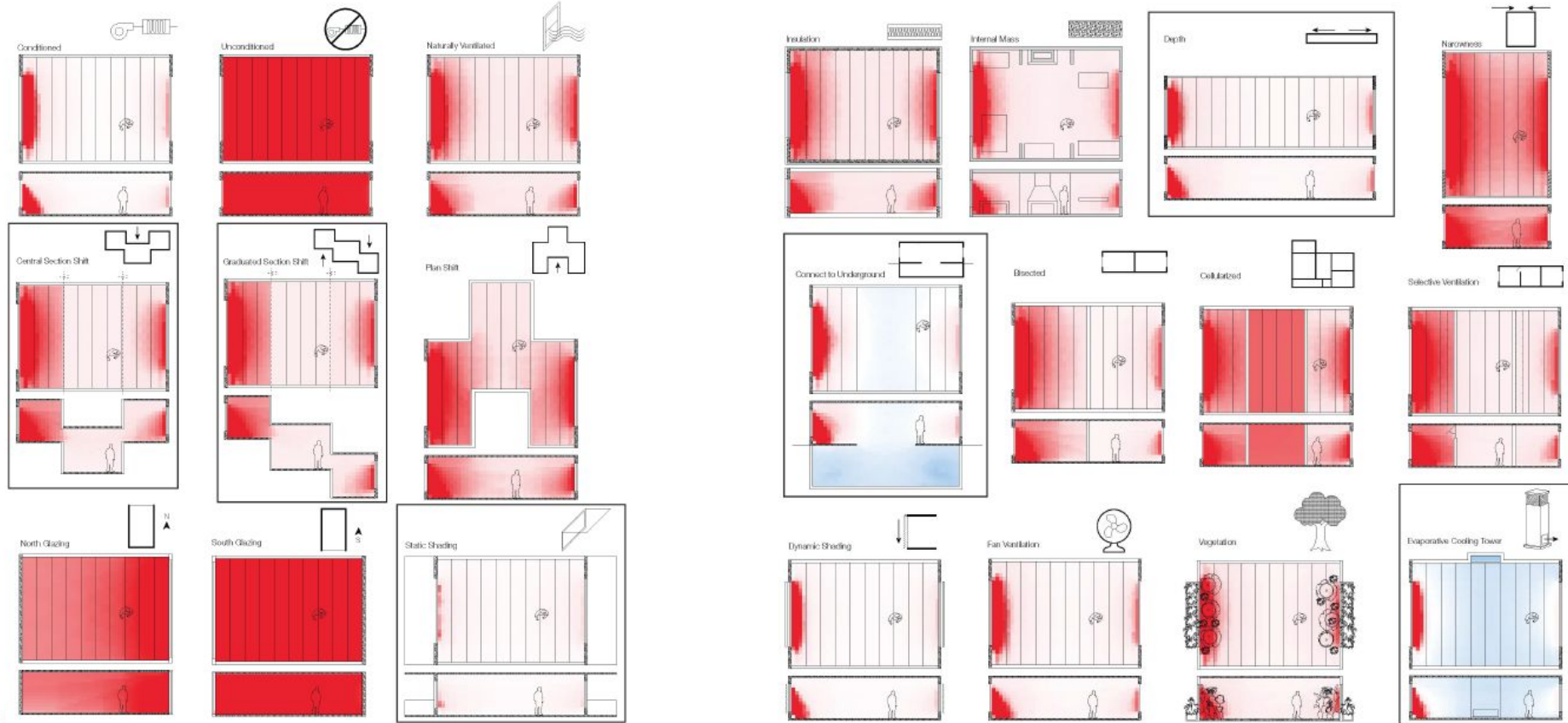




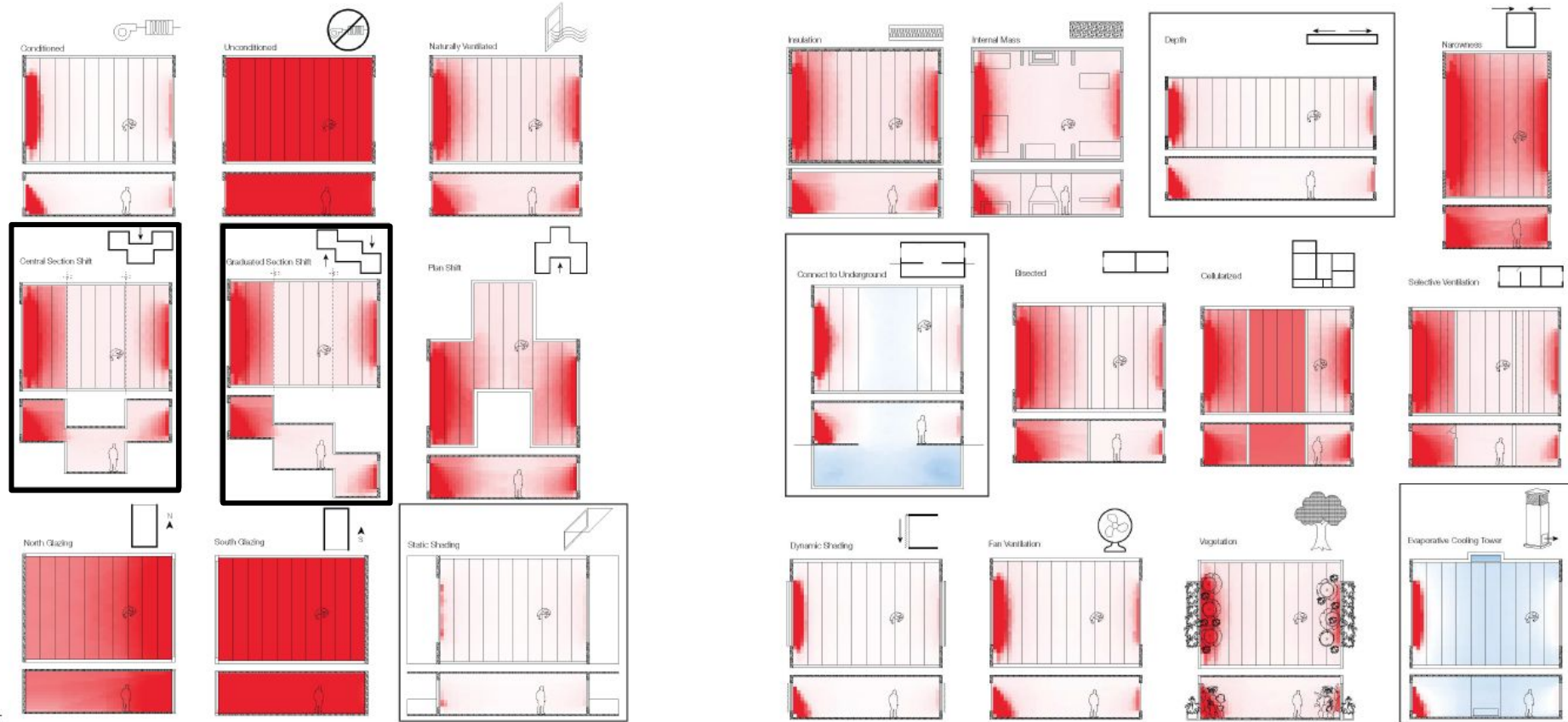
## Principle 2 - Build Interoperability with Other Tools



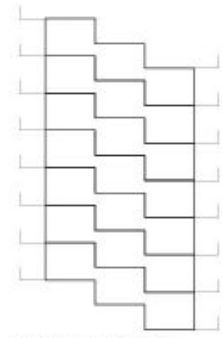
## Principle 2 - Build Interoperability with Other Tools



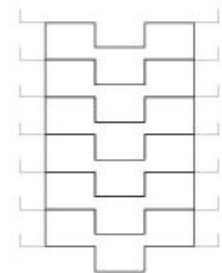
## Principle 2 - Build Interoperability with Other Tools



## Principle 2 - Build Interoperability with Other Tools

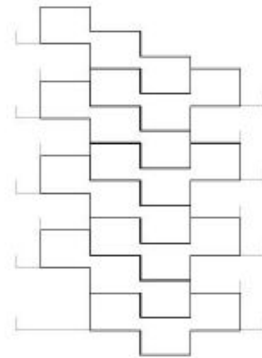


Central Topo Shift



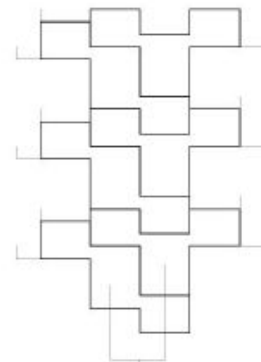
Graduated Topo Shift

Hybrid Topo Shift



This helps self-shade, increasing the effect of static shading. It also increases building depth while still allowing similar air ventilation.

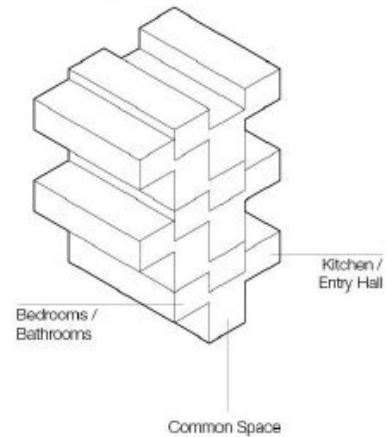
Double-Height Common Space



Common Spaces

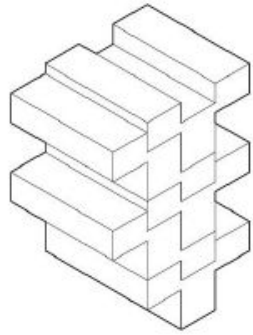
This not only reinforces a notion of apartment community by emphasizing the common space but also strengthens the spaces thermal benefit.

Extruded Profile

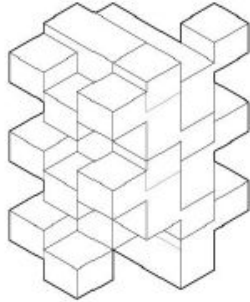


PRIVATE ← PUBLIC  
S N  
WARMTH DESIRED (especially in morning) COOL DESIRED

## Principle 2 - Build Interoperability with Other Tools

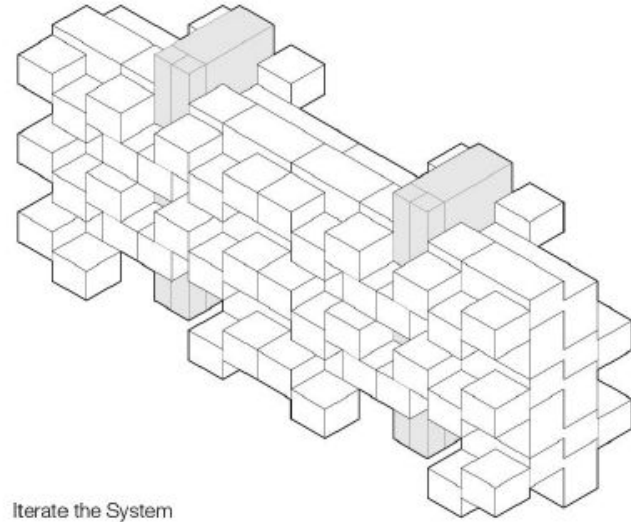
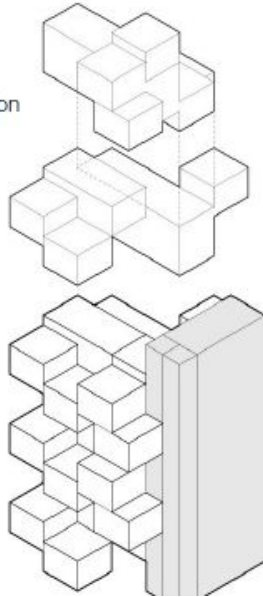


Extruded Profile



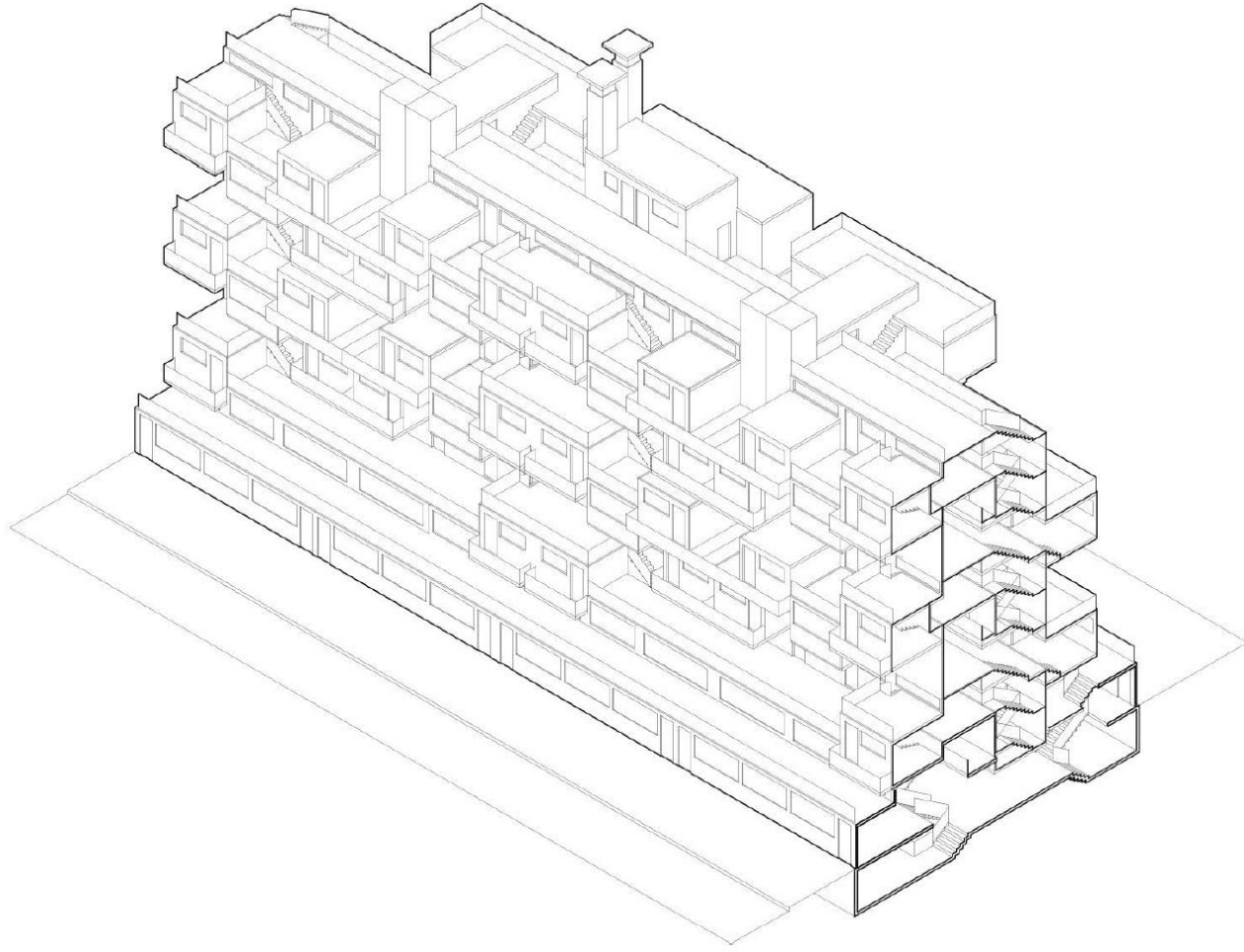
Subtract/Add + Sectional Shift  
to Add Privacy

Wrap Around  
Vertical Circulation



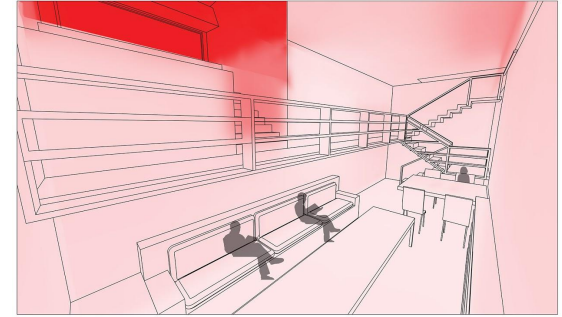
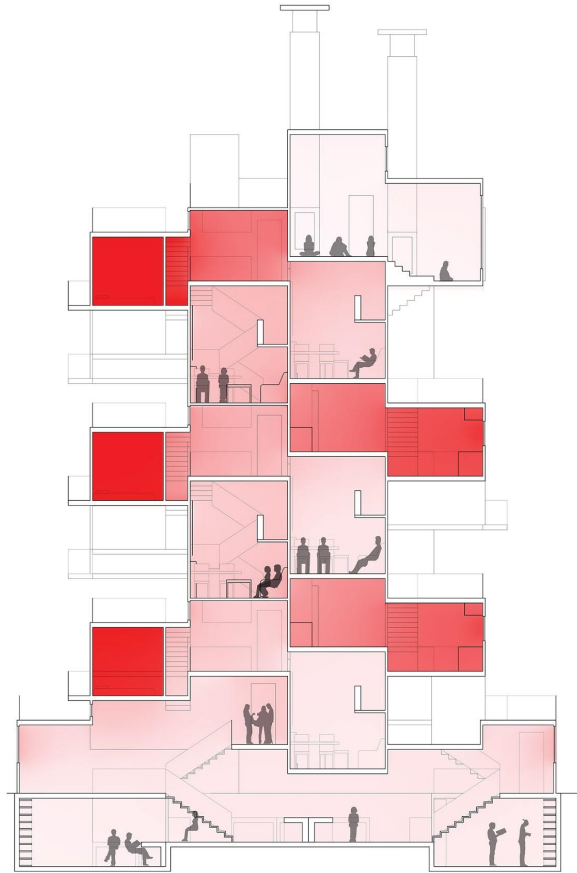
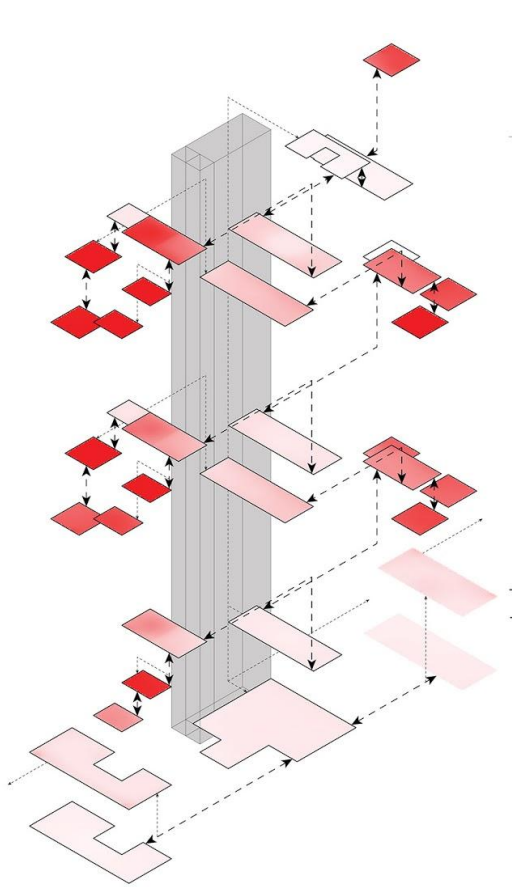
Iterate the System

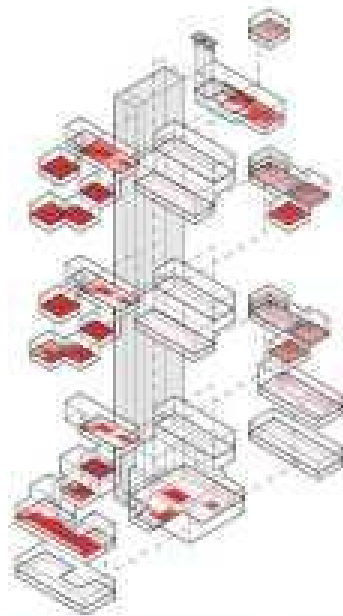
## Principle 2 - Build Interoperability with Other Tools



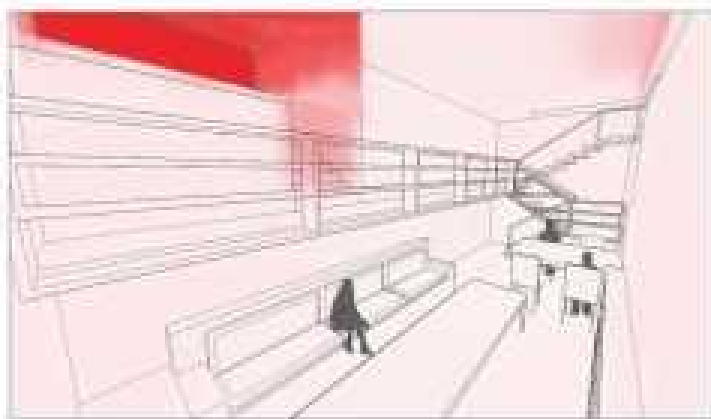
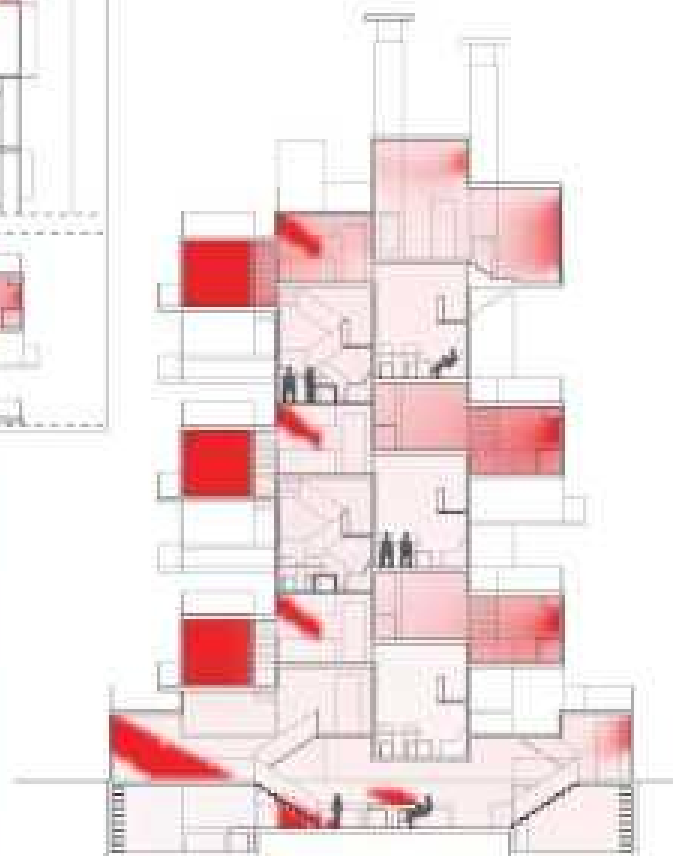


## Principle 2 - Build Interoperability with Other Tools





3 PM

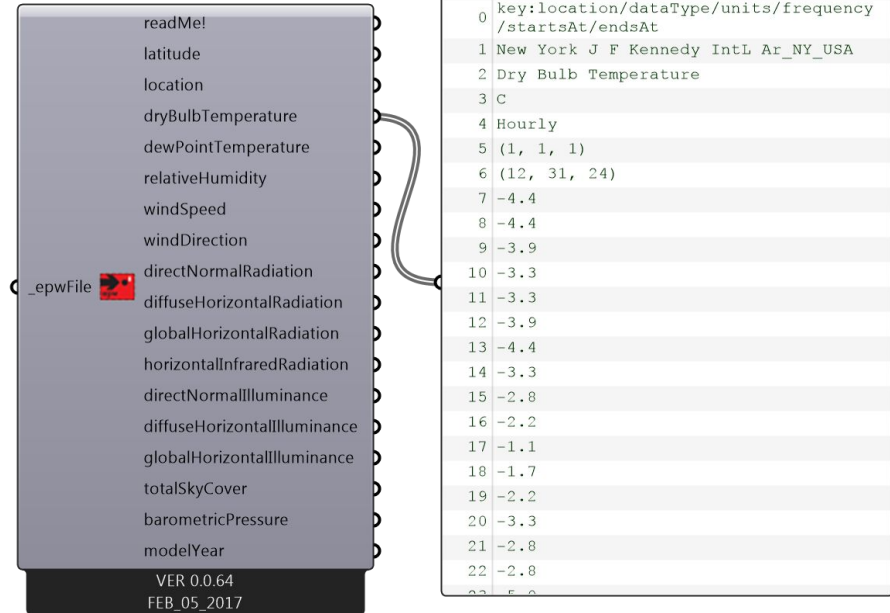




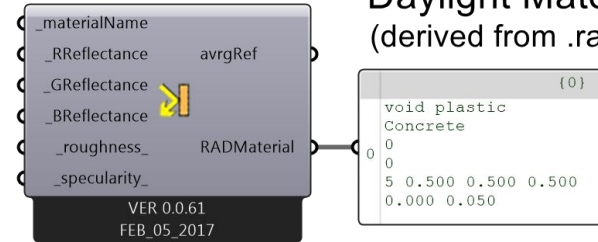
## **#3 Use Standard Formats for Data Transfer**

# Principle 3 - Use Standardized Open Formats for Data Transfer

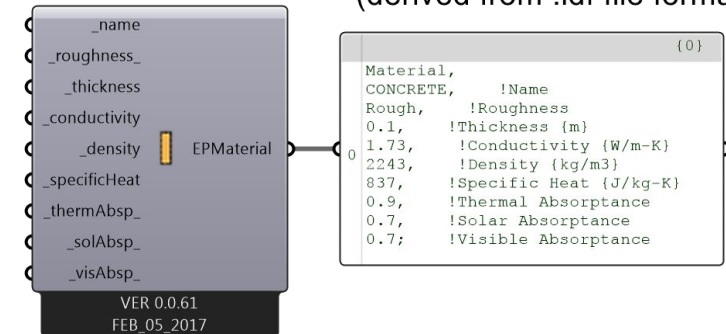
## Annual Hourly Data Format (derived from .epw file format)



## Daylight Material Format (derived from .rad file format)



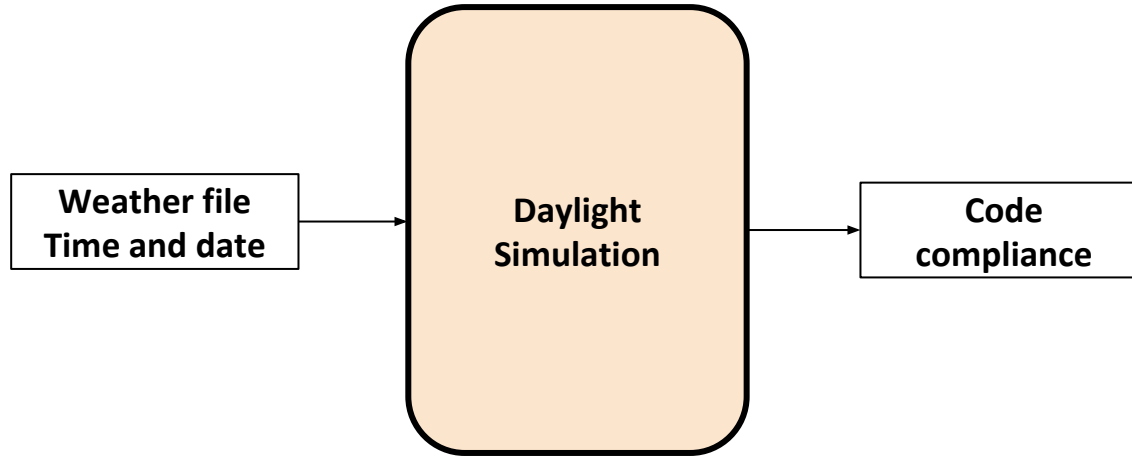
## Energy Material Format (derived from .idf file format)



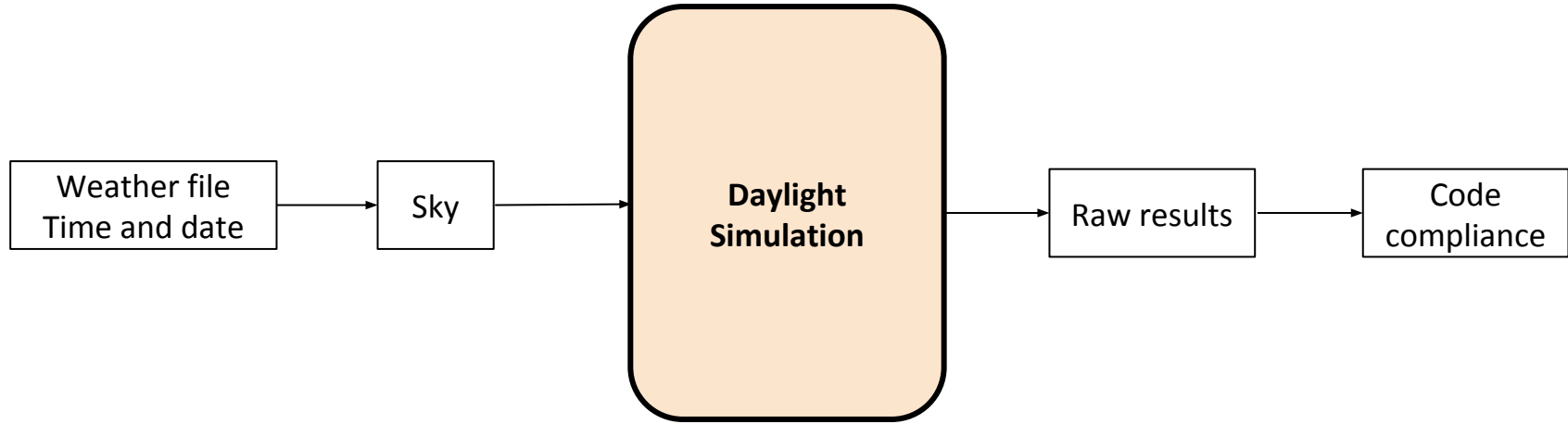
**#4**

**Modularize the Tool**

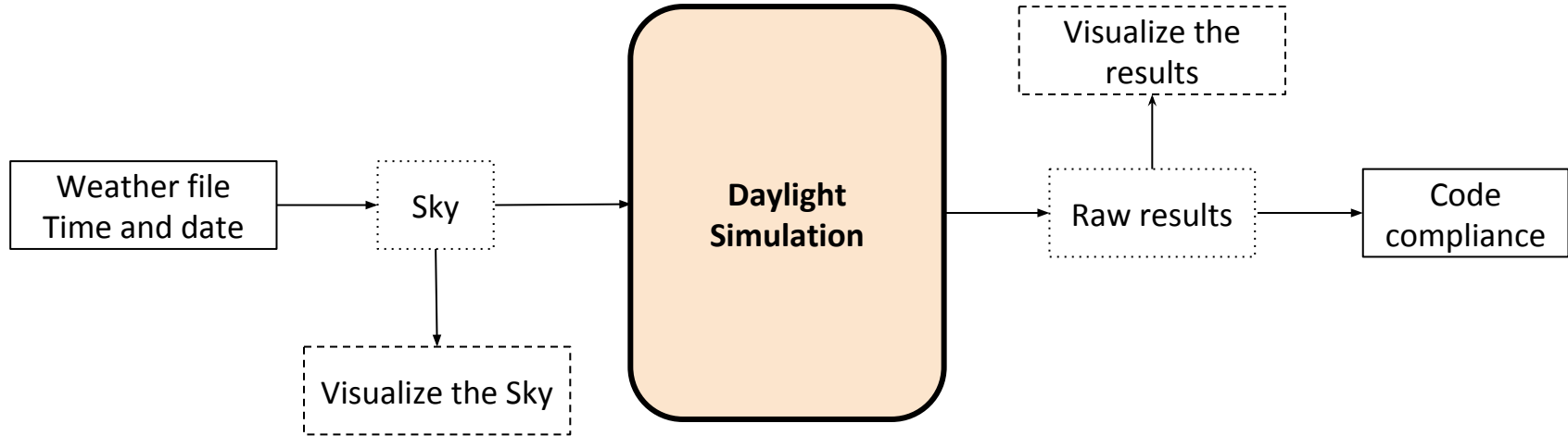
## Principle 4 - Modularize the Tool



## Principle 4 - Modularize the Tool

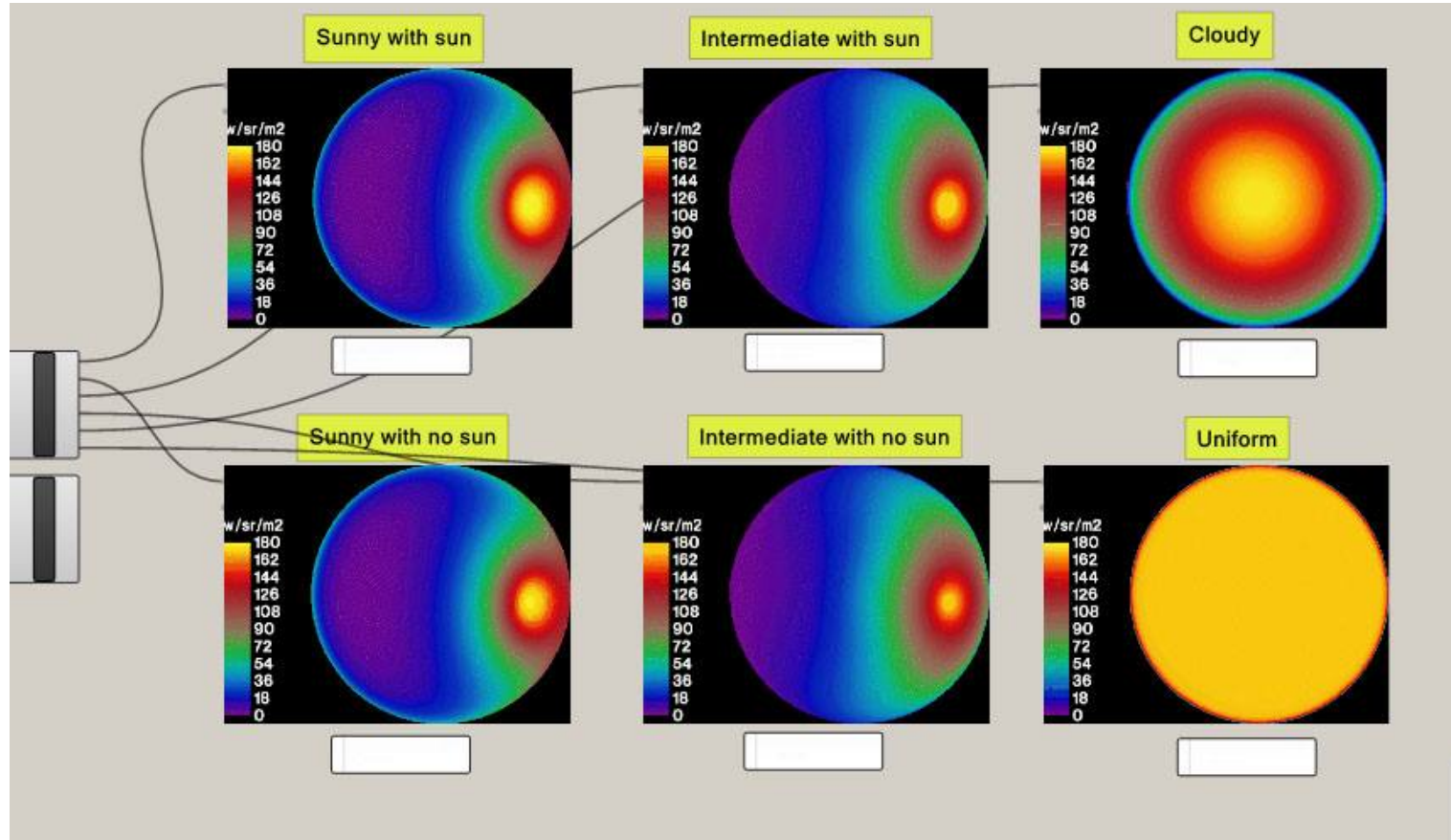


## Principle 4 - Modularize the Tool

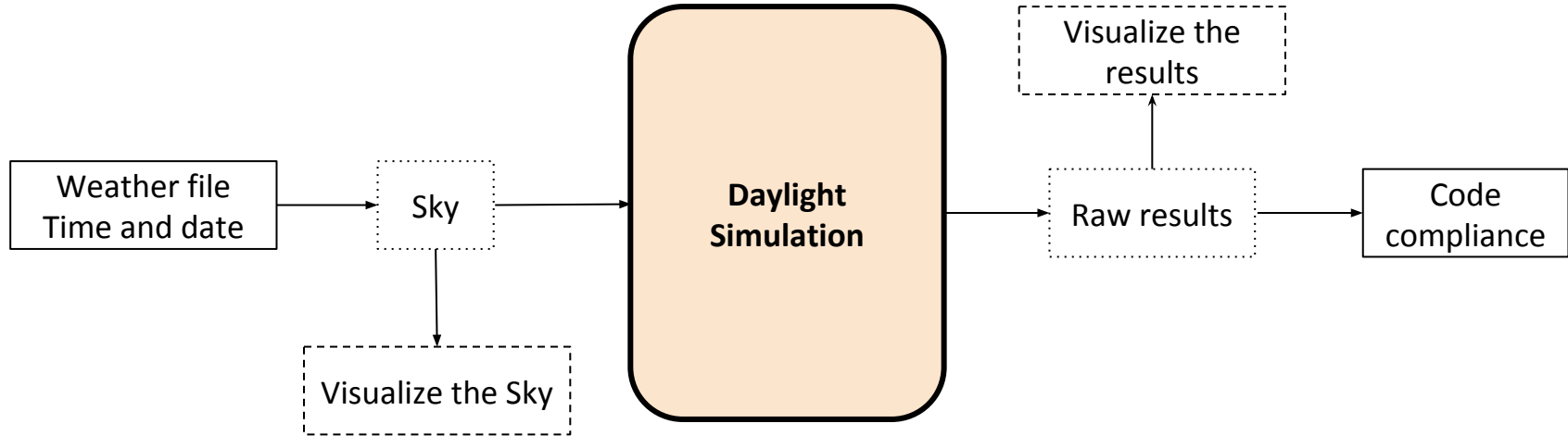


## Principle 4 - Modularize the Tool

### Visualize the sky



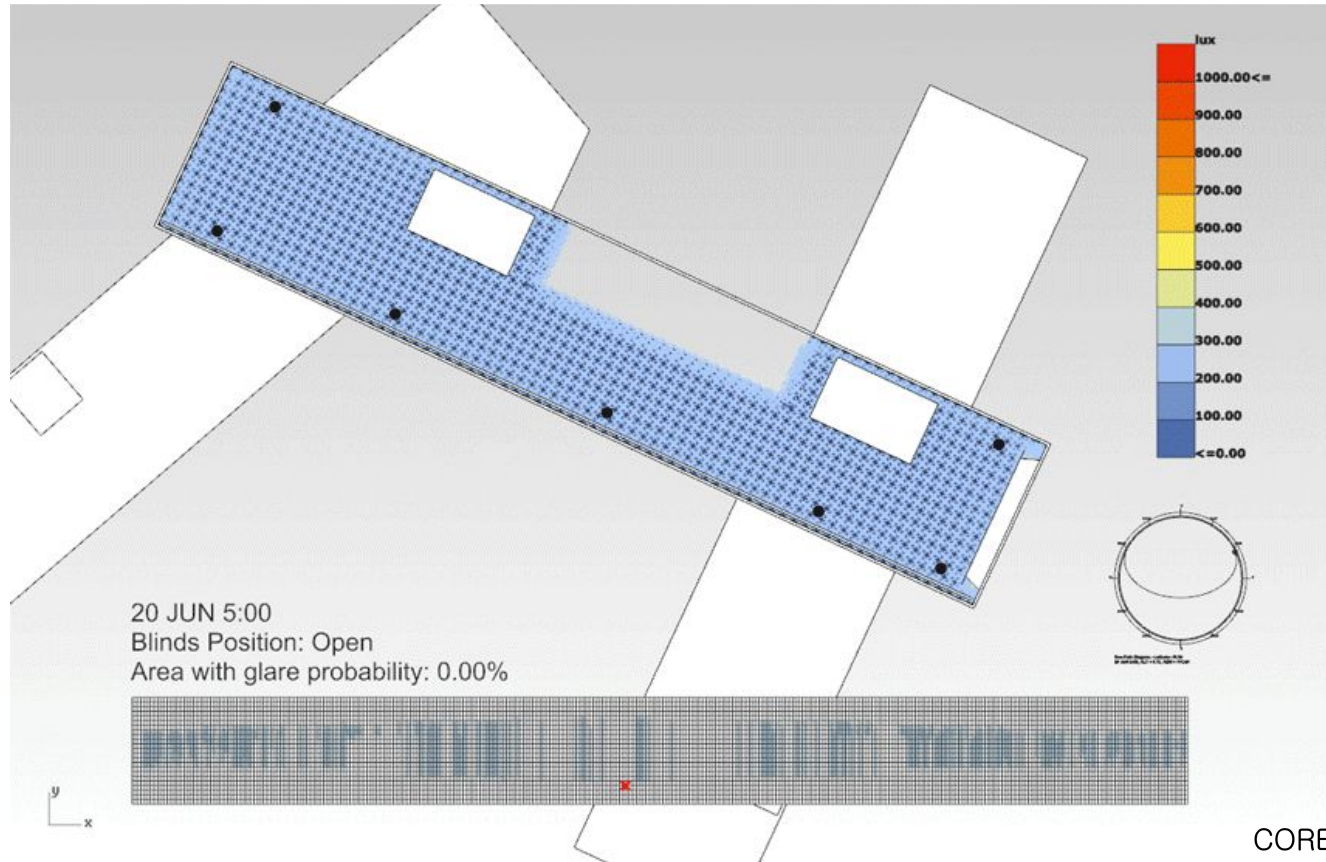
## Principle 4 - Modularize the Tool



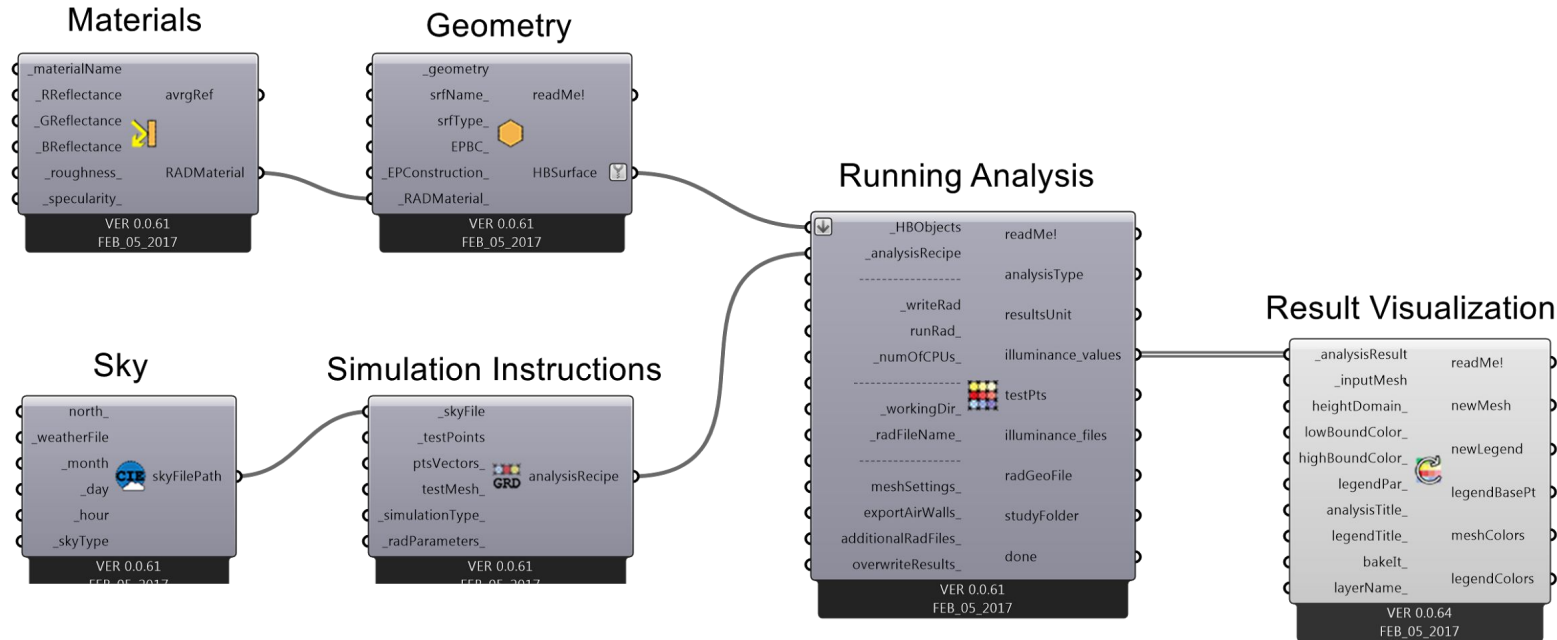


## Principle 4 - Modularize the Tool

### Visualize the hourly results



# Principle 4 - Modularize the Tool



## Principle 4 - Modularize the Tool

With **2** lego bricks there are **24** different combinations.

With **3** lego bricks there are **1060** different combinations.

With **6** lego bricks there are different combinations.



## Principle 4 - Modularize the Tool

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With **2** lego bricks there are **24** different combinations.

With **3** lego bricks there are **1060** different combinations.

With **6** lego bricks there are **915,103,765** different combinations.



## Principle 4 - Modularize the Tool

With **6** lego bricks there are **915,103,765** different combinations.

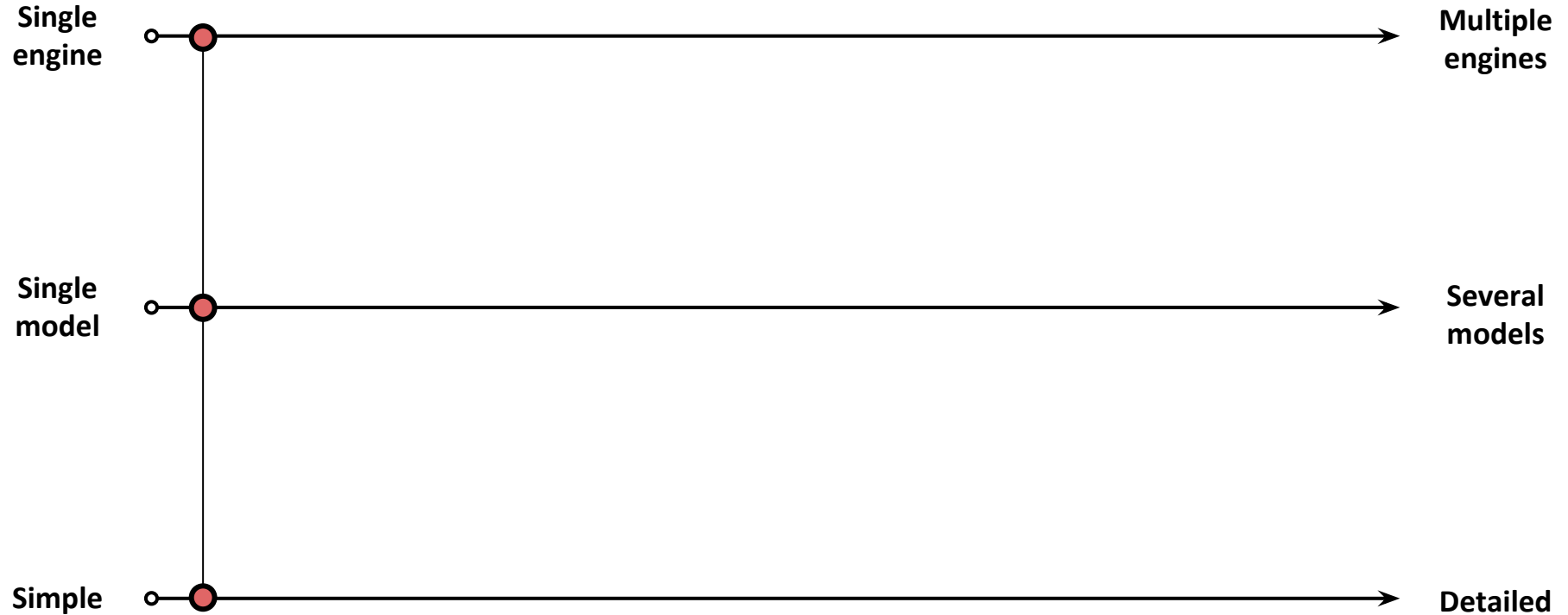
How many different combinations can you make with **370** components?



**A craft to how modular components are arranged to address different problems**

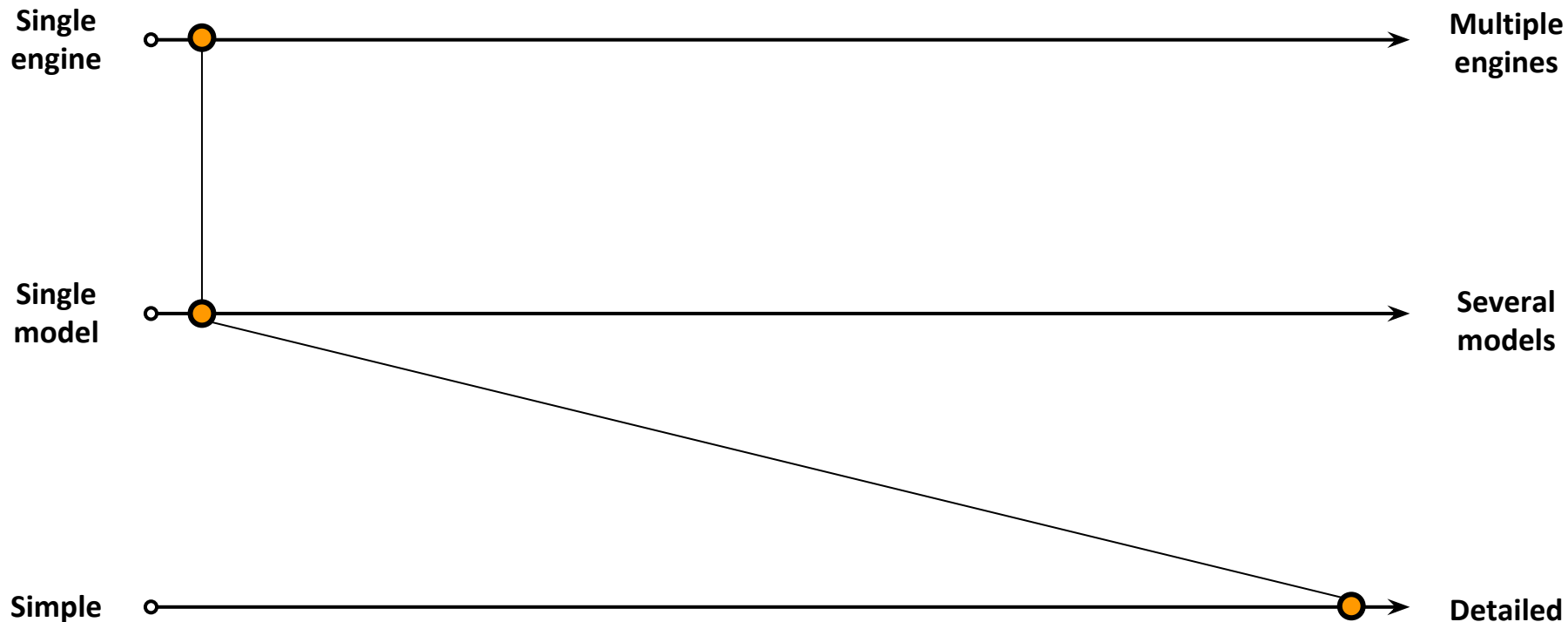
## Principle 4 - Modularize the Tool

### Conventional Simulation Tools for Conceptual Design



## Principle 4 - Modularize the Tool

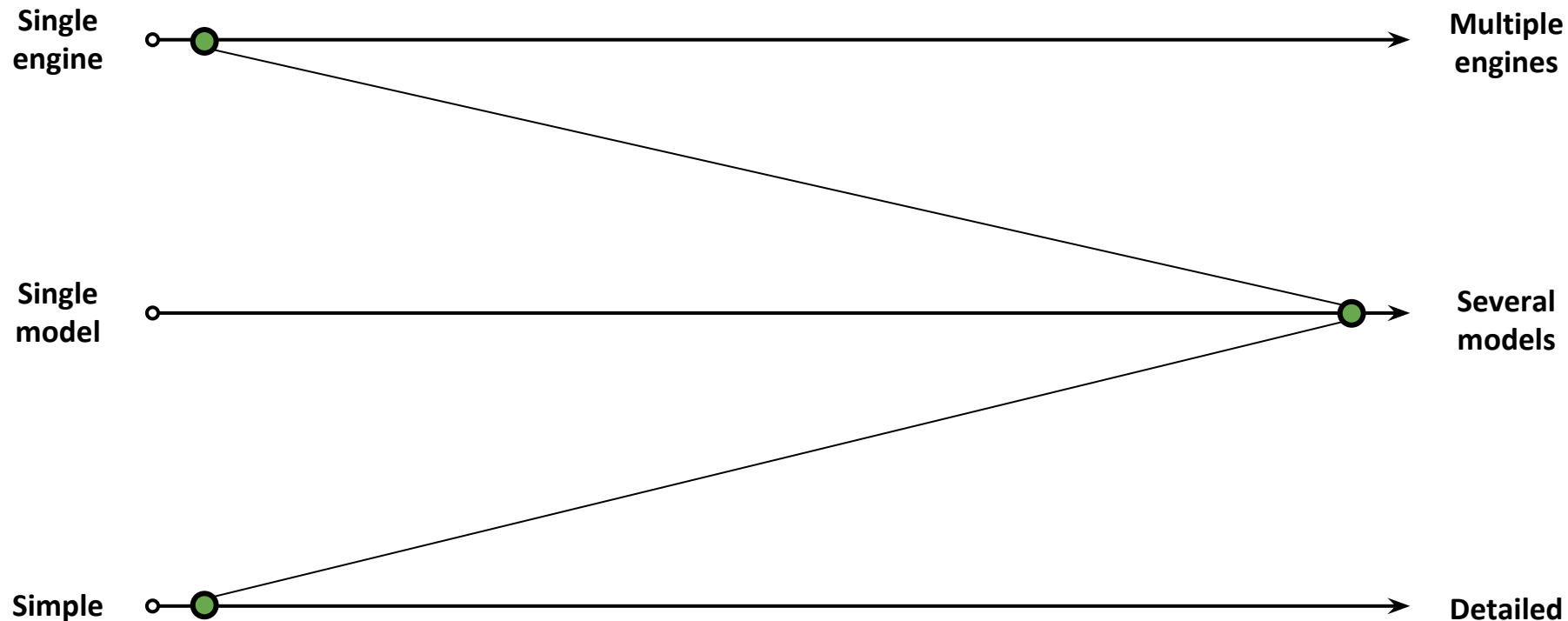
### Conventional Simulation Tools for Conceptual Design





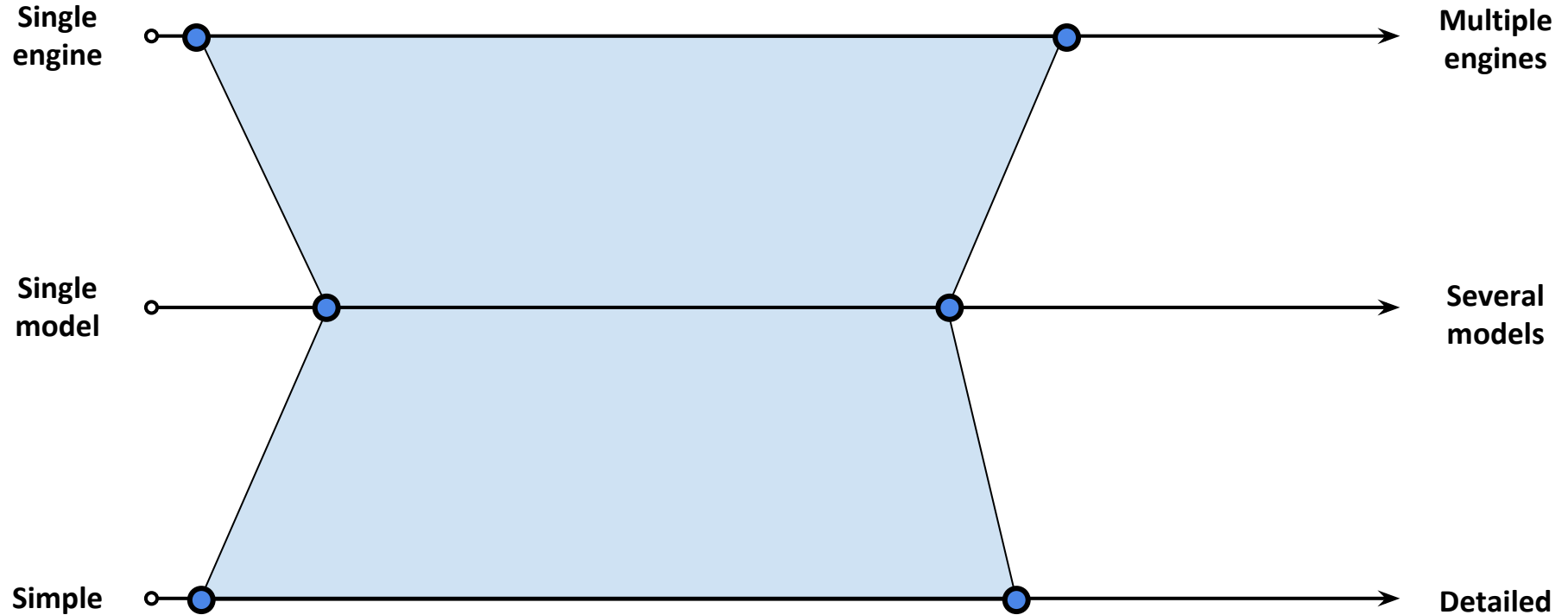
## Principle 4 - Modularize the Tool

### [New] Simulation Tools for Conceptual Design



## Principle 4 - Modularize the Tool

### Day to Day Practice



# Principle 4 - Modularize the Tool

## Case Study 1

Design Explorer

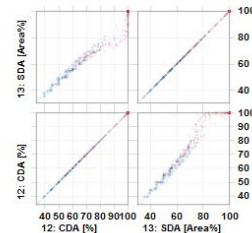
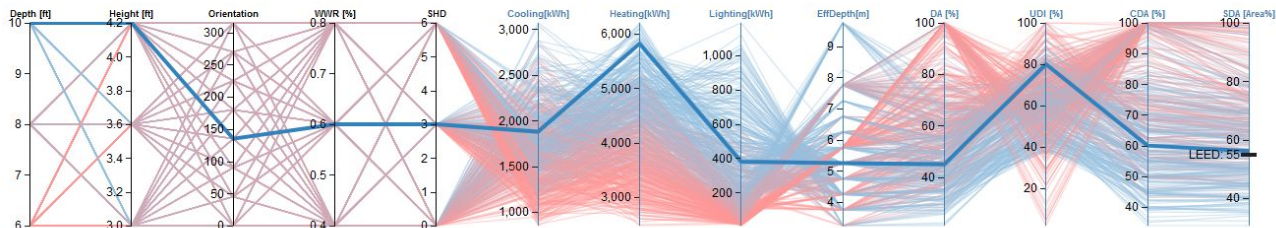
Get Data

Reset Selection Exclude Selection Zoom to Selection Save Selection to File My Static Link Tutorial Info

Setting L M S

Building Performance Study - Demo

© 2017 Thornton Tomasetti

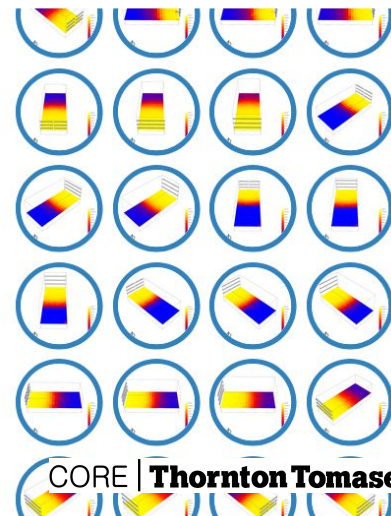
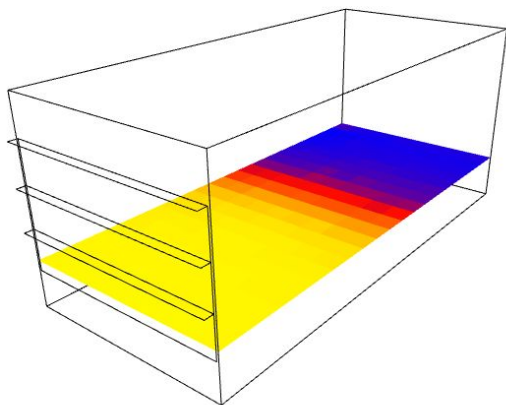


2D 3D X  
★ ★ ★ ★ ★

Sort by: Depth [ft]

### Attributes

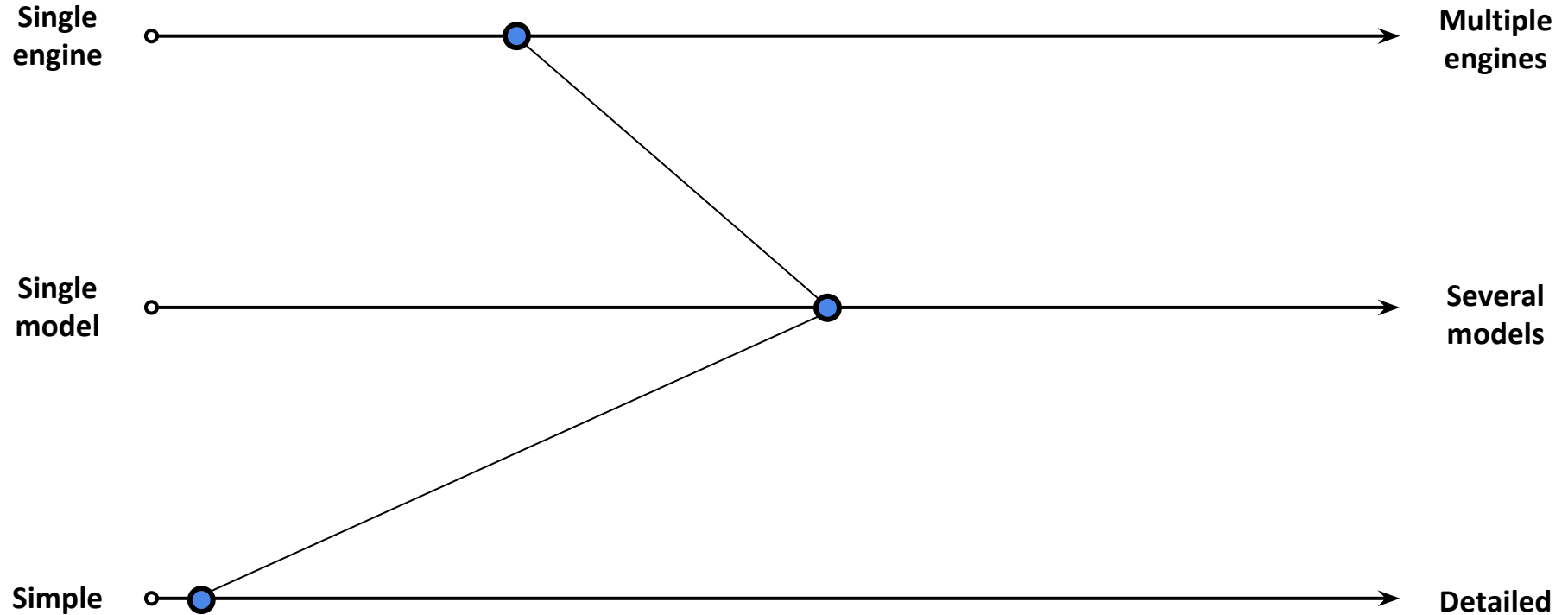
Depth [ft] : 10  
Height [ft] : 4.2  
Orientation : 135  
WWR [%] : 0.6  
SHD : 3  
Cooling[kWh] : 1878.690778  
Heating[kWh] : 5820.018758  
Lighting[kWh] : 380.404003  
EffDepth[m] : 5.25  
DA [%] : 45  
UDI [%] : 80  
CDA [%] : 60

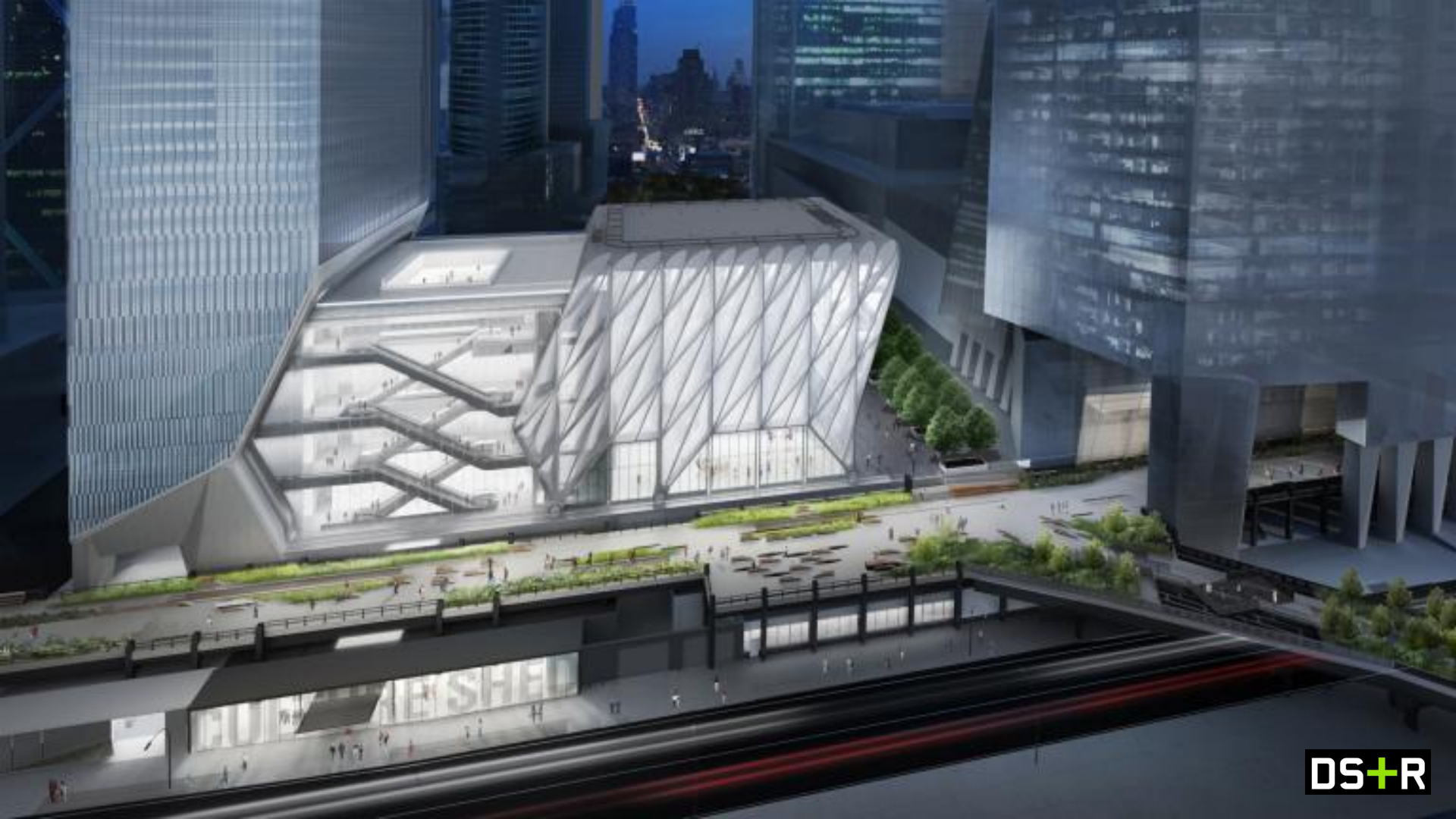


CORE | Thornton Tomasetti

## Principle 4 - Modularize the Tool

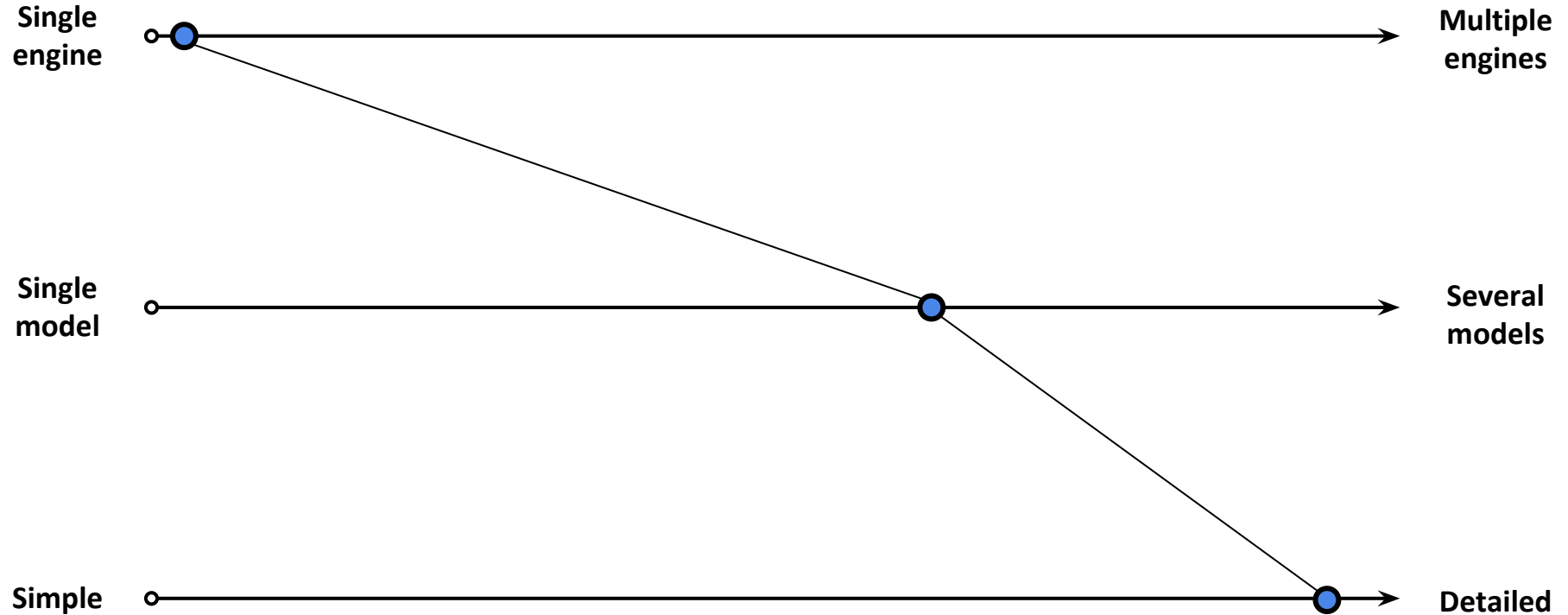
### Case Study 1



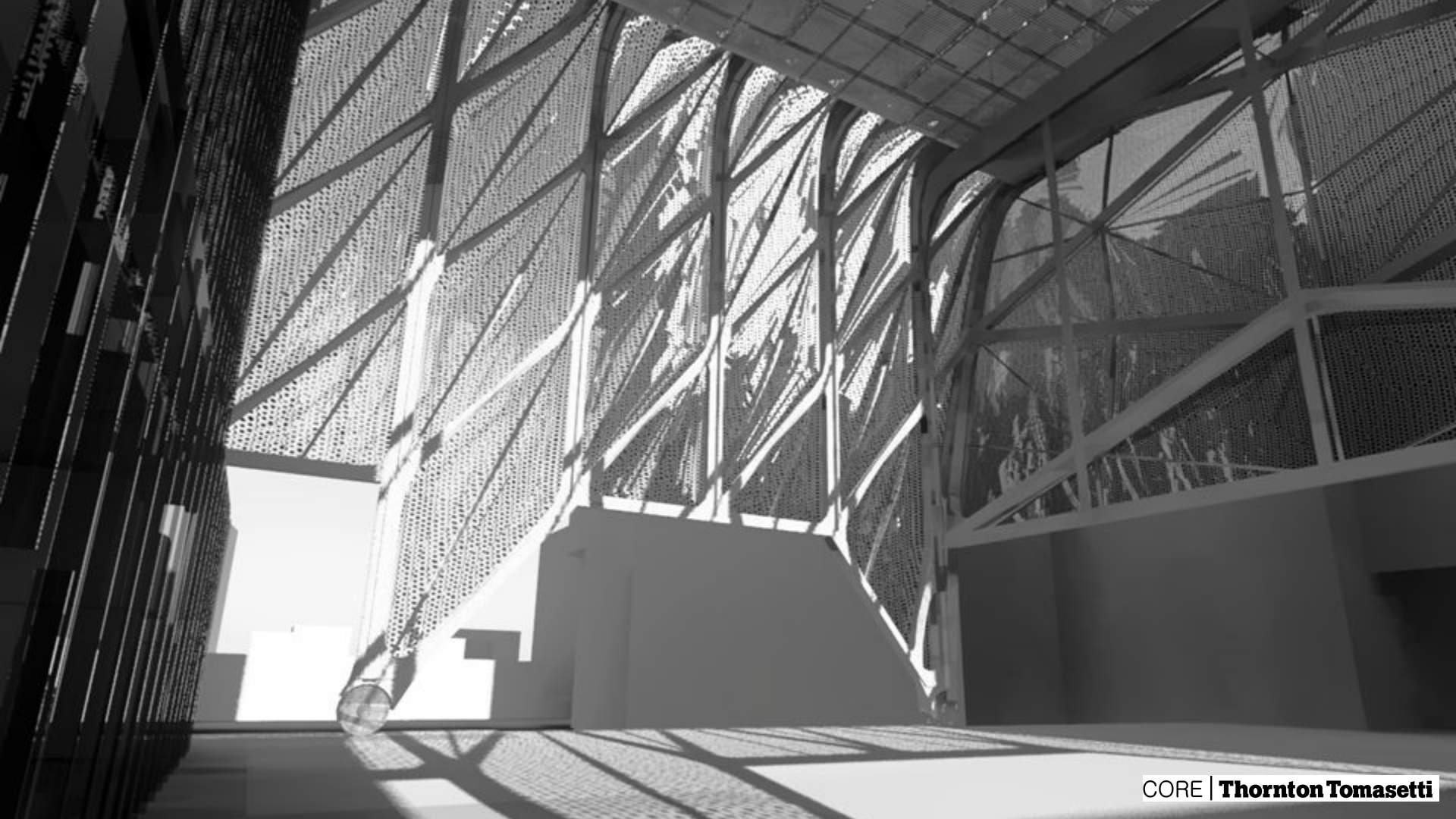


## Principle 4 - Modularize the Tool

### Case Study 2

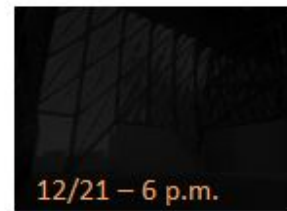
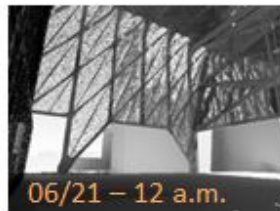
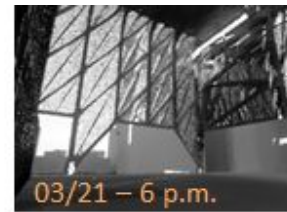
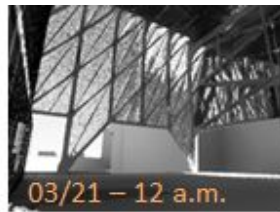
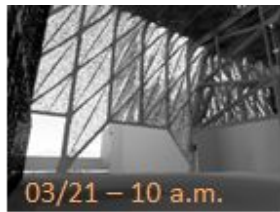






## Principle 4 - Modularize the Tool

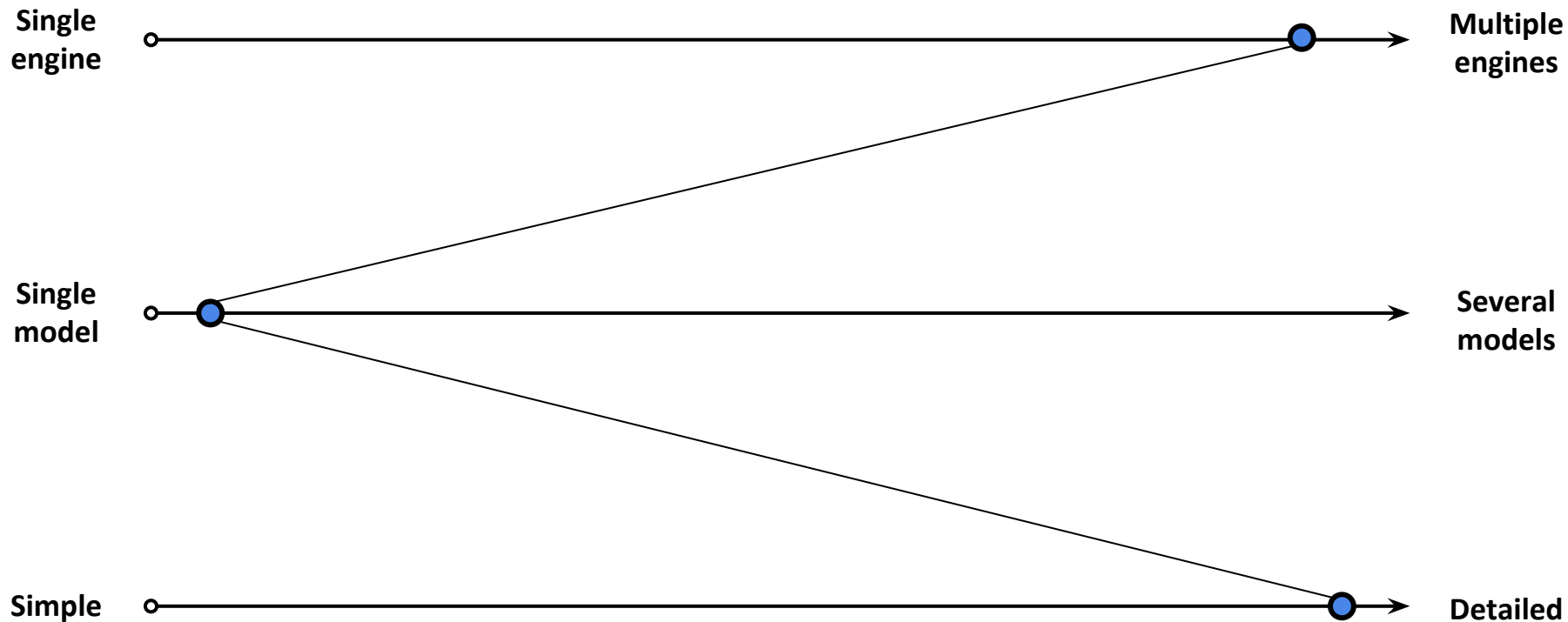
### Case Study 2





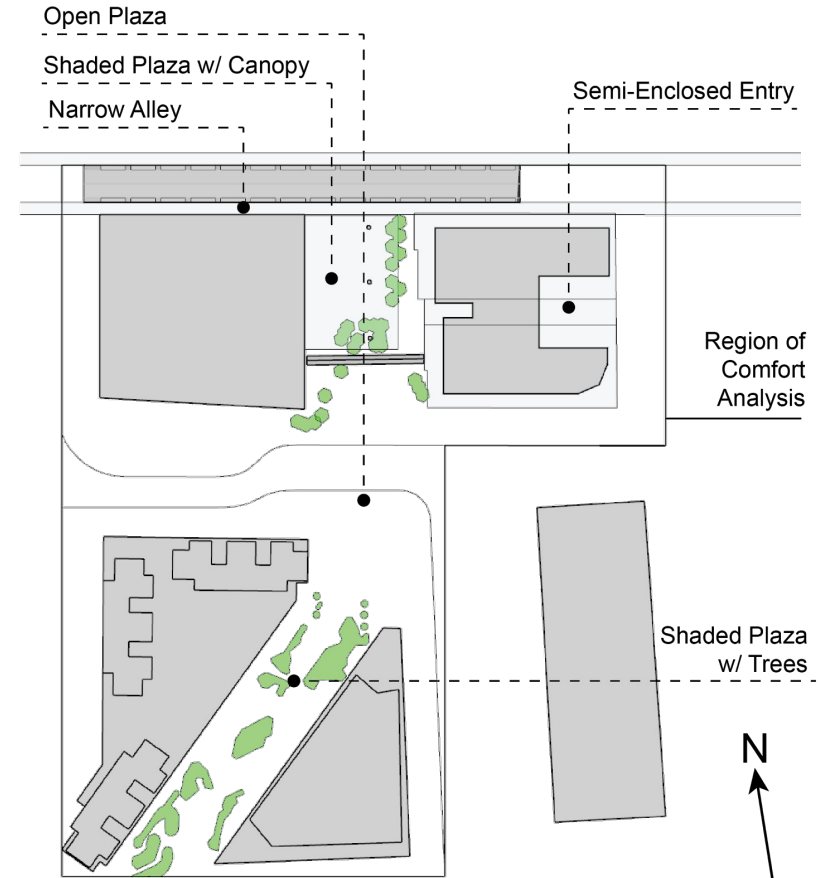
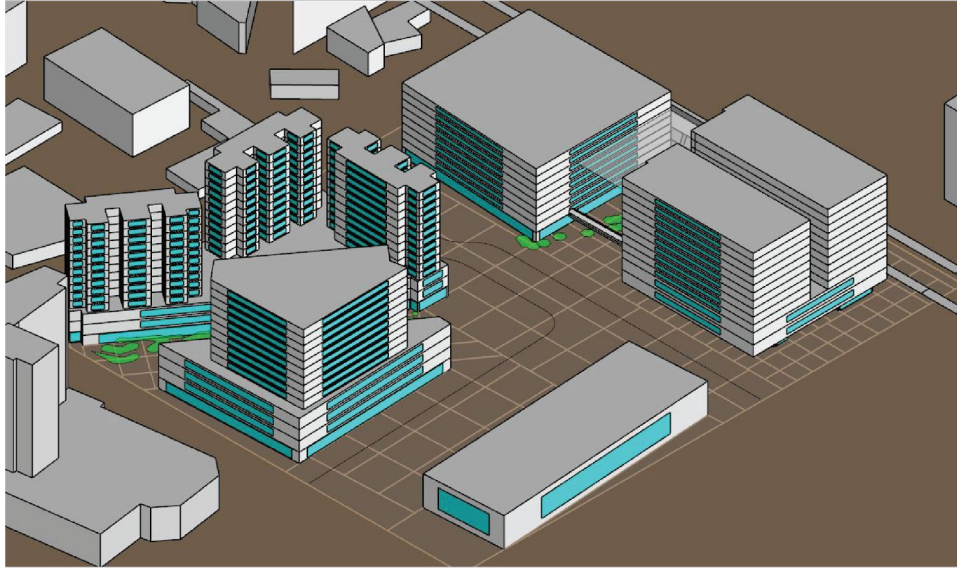
## Principle 4 - Modularize the Tool

### Case Study 3



## Principle 4 - Modularize the Tool

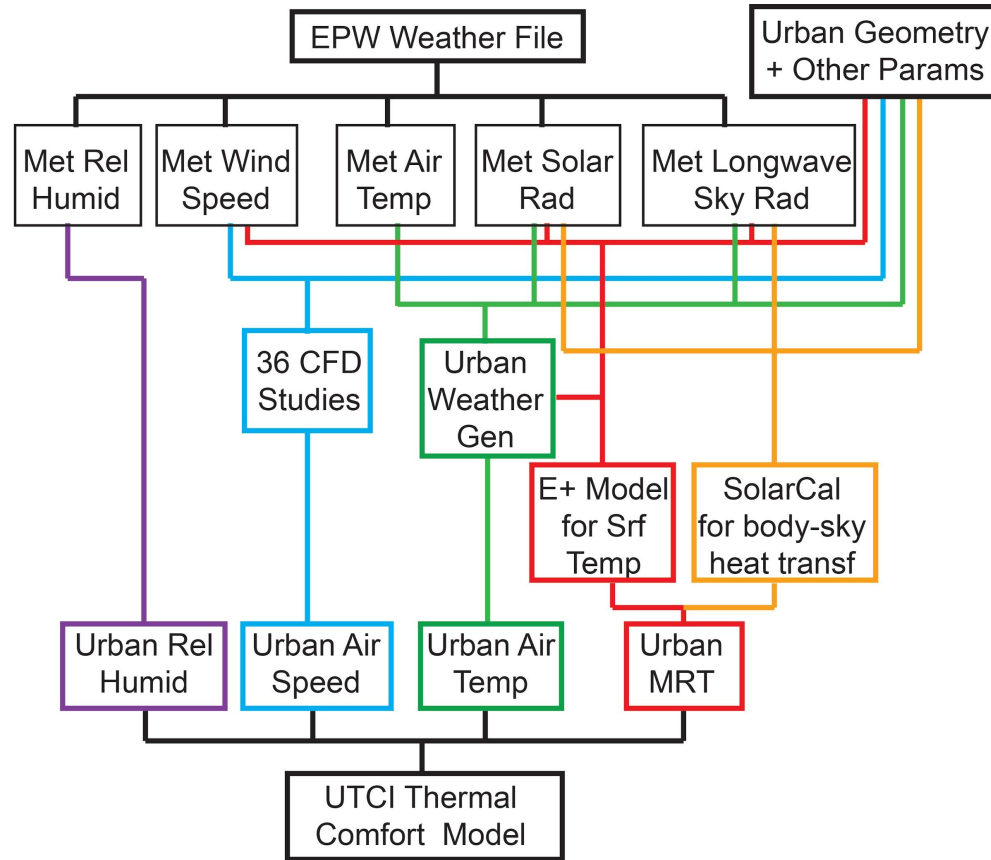
### Case Study 3



Mackey, Galanos, Norford, Roudsari. (2017) Wind, Sun, Surface Temperature, and Heat Island: Critical Variables for High-Resolution Outdoor Thermal Comfort. Proceedings from the International Building Simulation Conference. <https://drive.google.com/open?id=0Bz2PwDvkjovJQ25IZmtadXczakU>

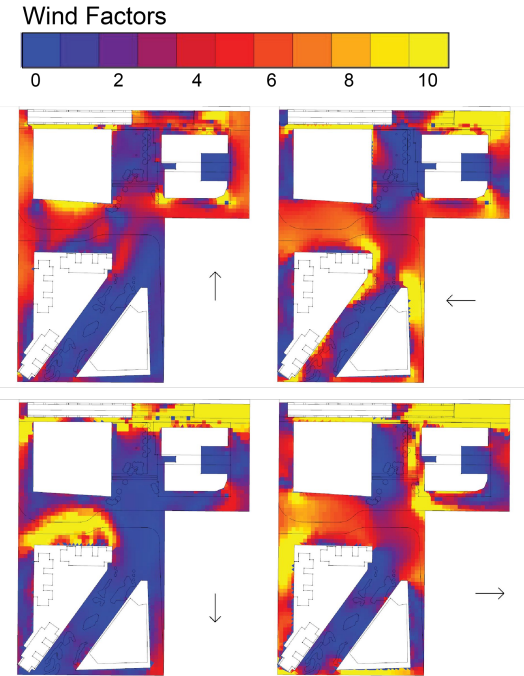
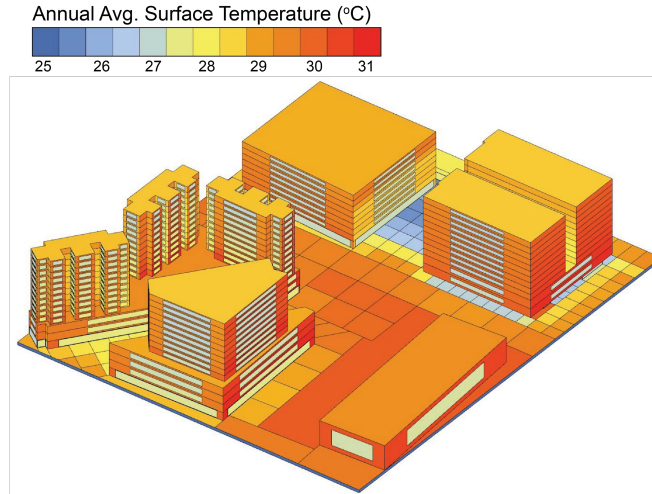
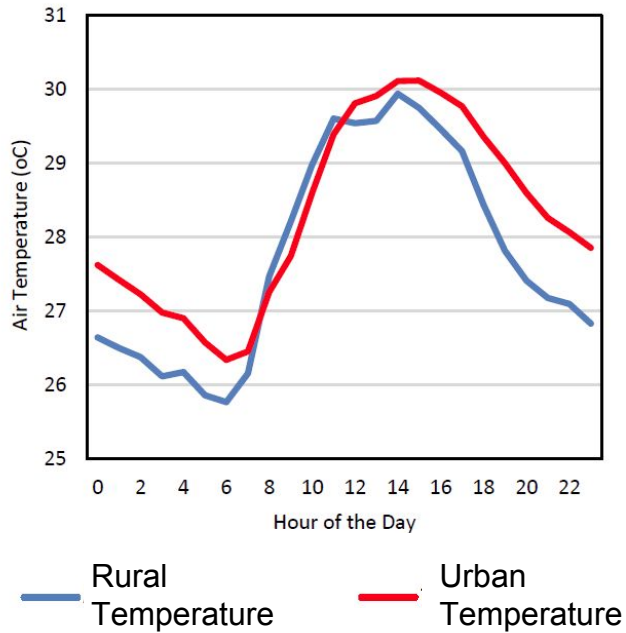
## Principle 4 - Modularize the Tool

### Case Study 3



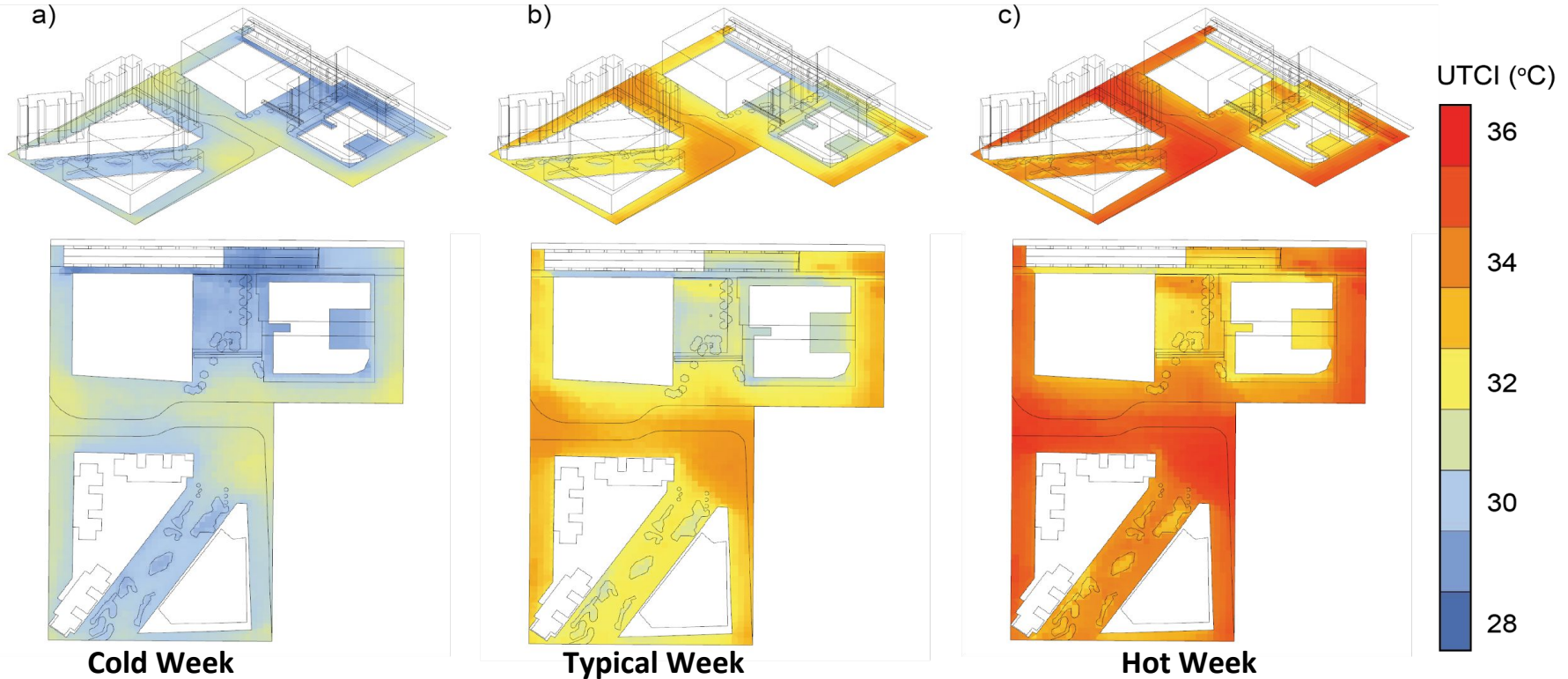
# Principle 4 - Modularize the Tool

## Case Study 3



# Principle 4 - Modularize the Tool

## Case Study 3



# #5 Bushnell's Law

## Principle 5 - Make it Easy to Start but Impossible to Master

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“The games that were **most successful** were those that were **simple to learn** but **impossible to master.**”

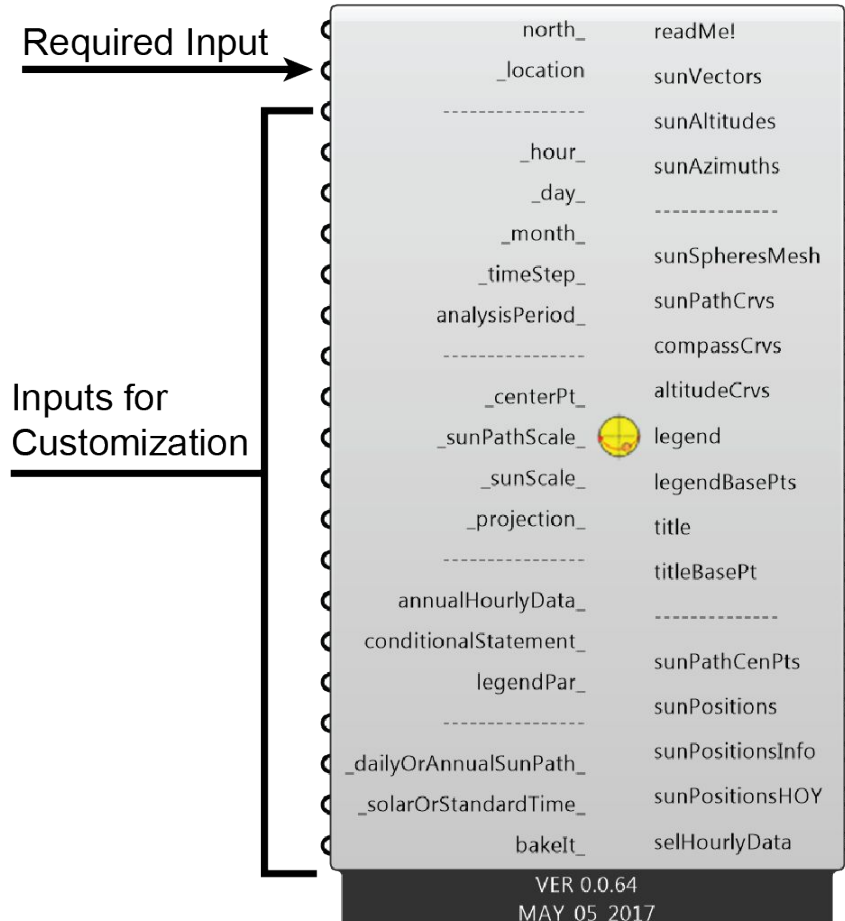
- Nolan Bushnell  
ATARI co-founder

# IKEA Effect

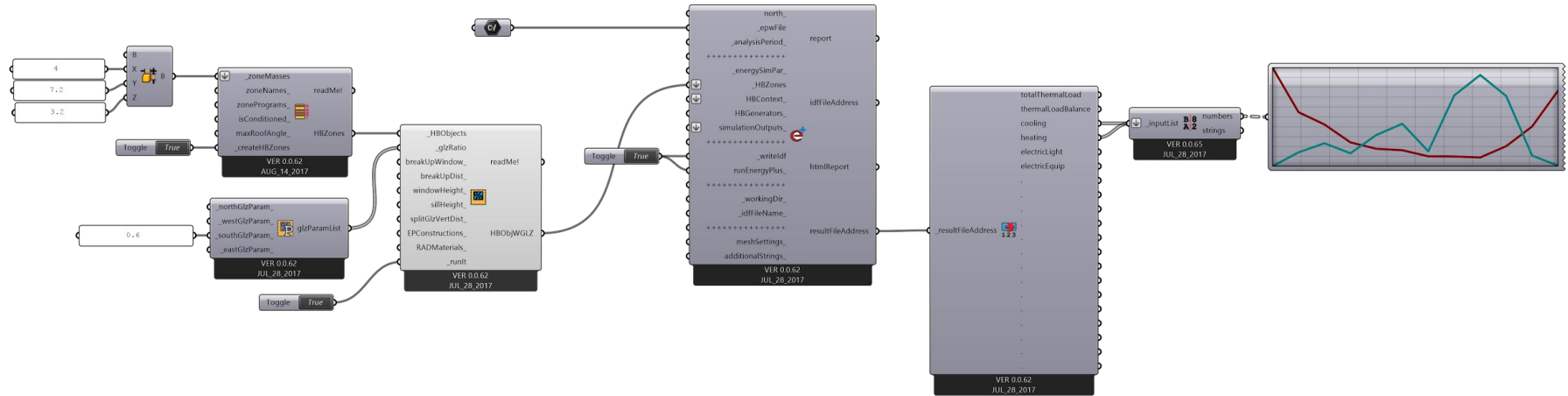
A feeling of ownership after one has spent time working on something and customizing it.



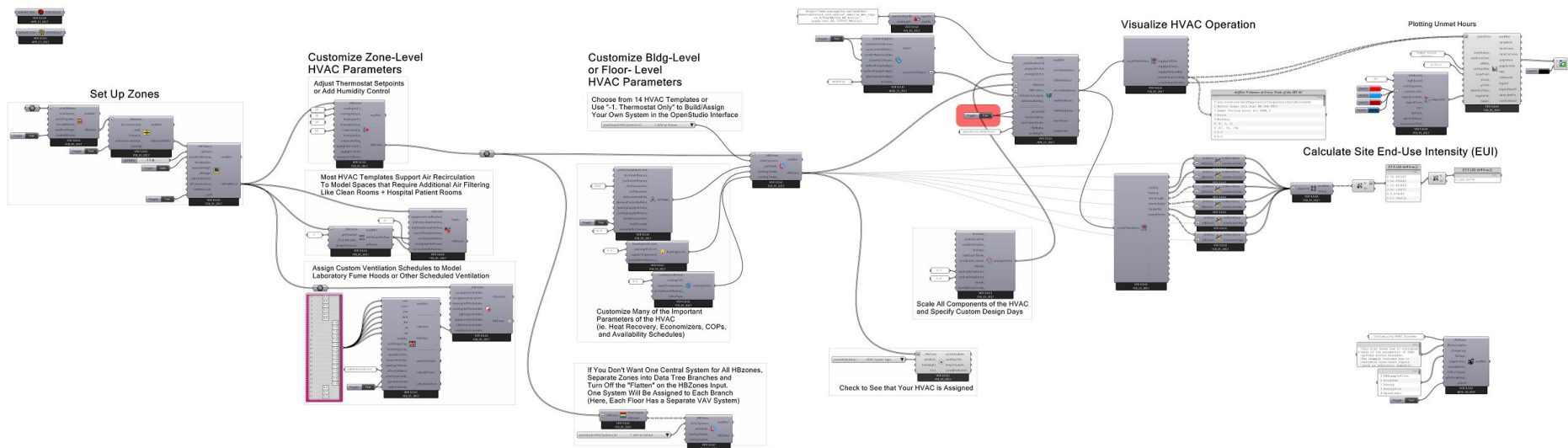
## Principle 5 - Make it Easy to Start but Impossible to Master



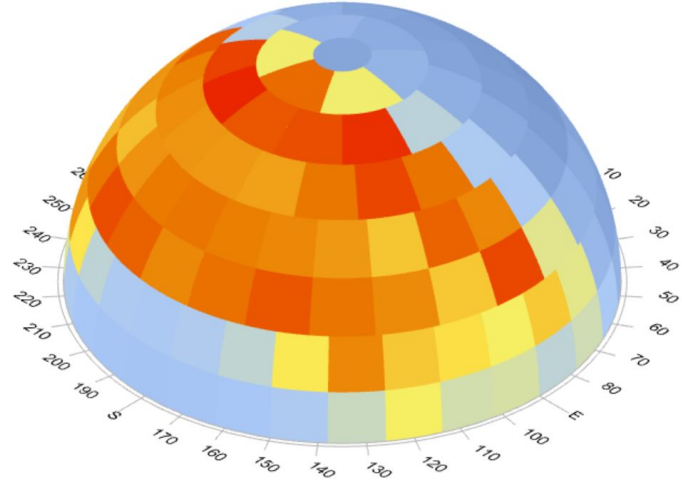
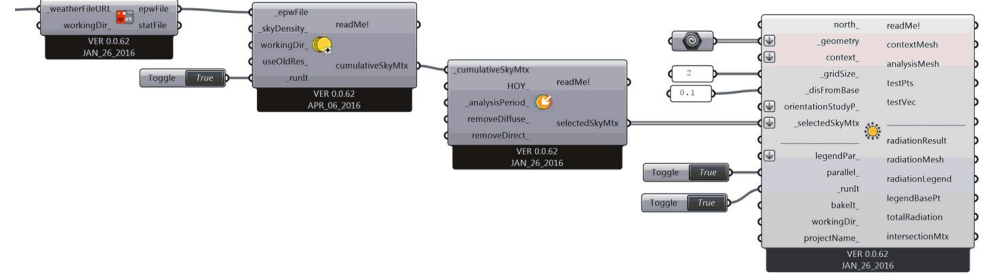
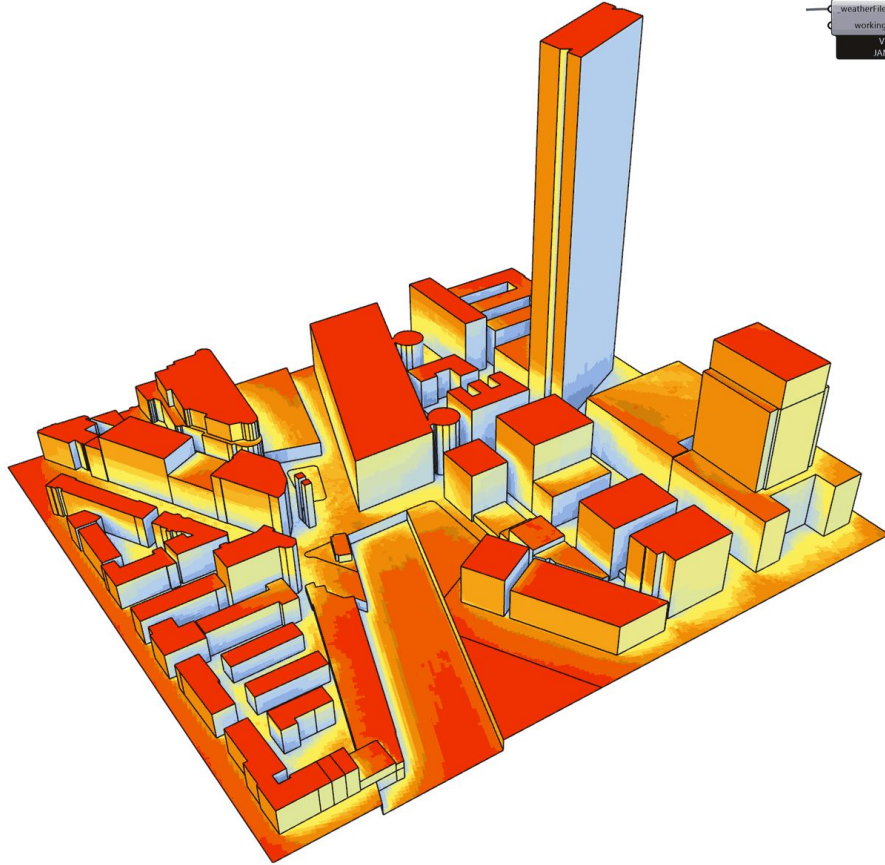
# Principle 5 - Make it Easy to Start but Impossible to Master



# Principle 5 - Make it Easy to Start but Impossible to Master

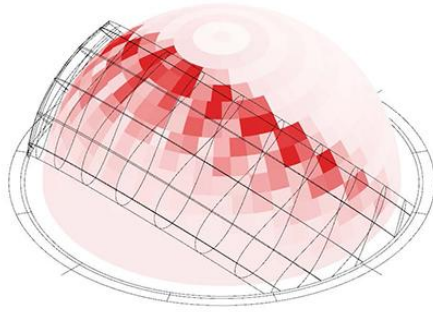


# Principle 5 - Make it Easy to Start but Impossible to Master

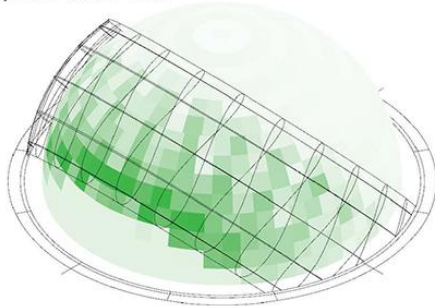


## Principle 5 - Make it Easy to Start but Impossible to Master

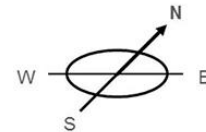
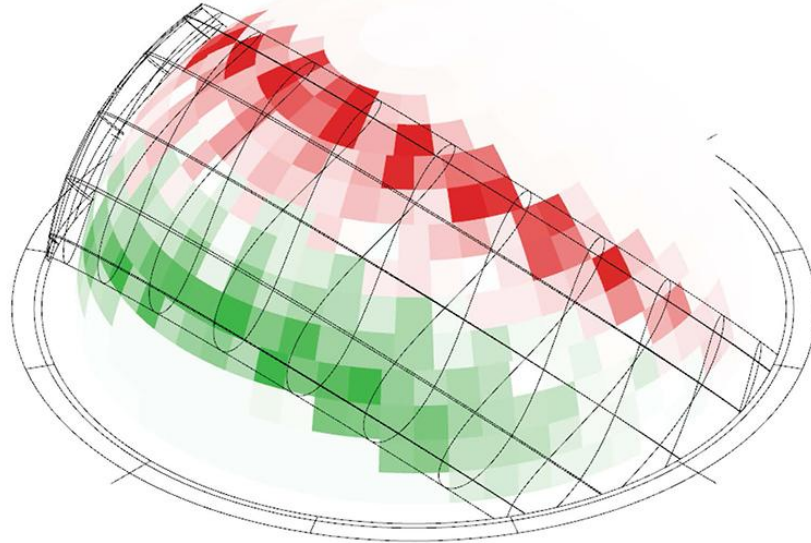
Harmful Summer Sun



Helpful Winter Sun



Solar Radiation Benefit / Harm  
(kBTU / ft<sup>2</sup> of Facade)



## ALL GLASS - ONE STORY RENOVATION

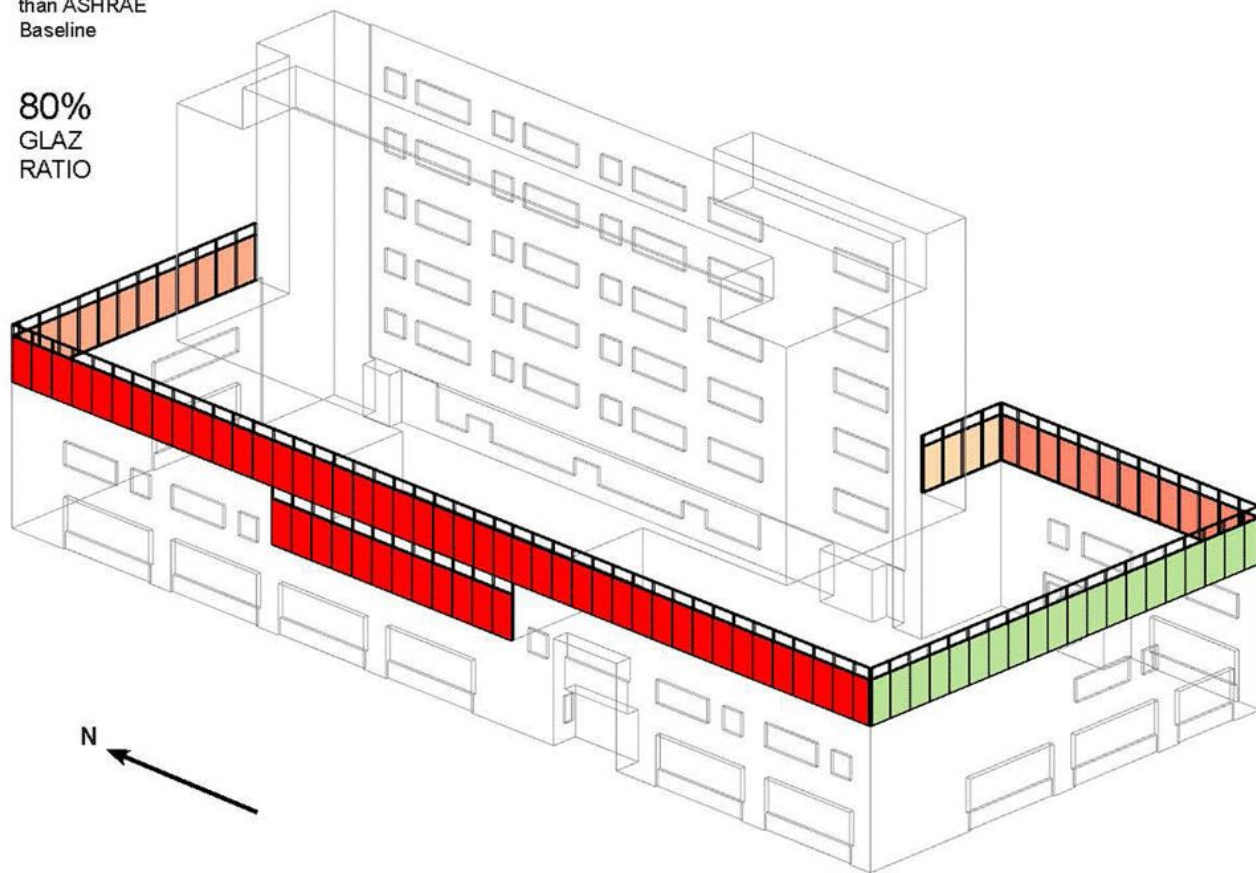
14.6

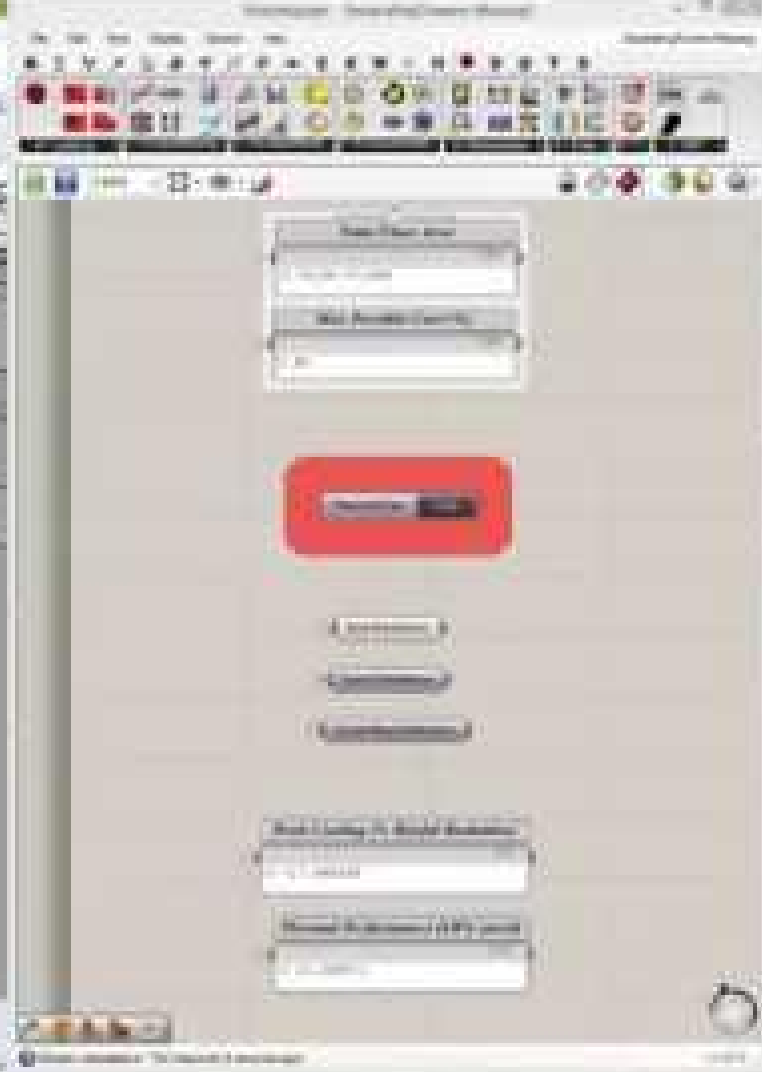
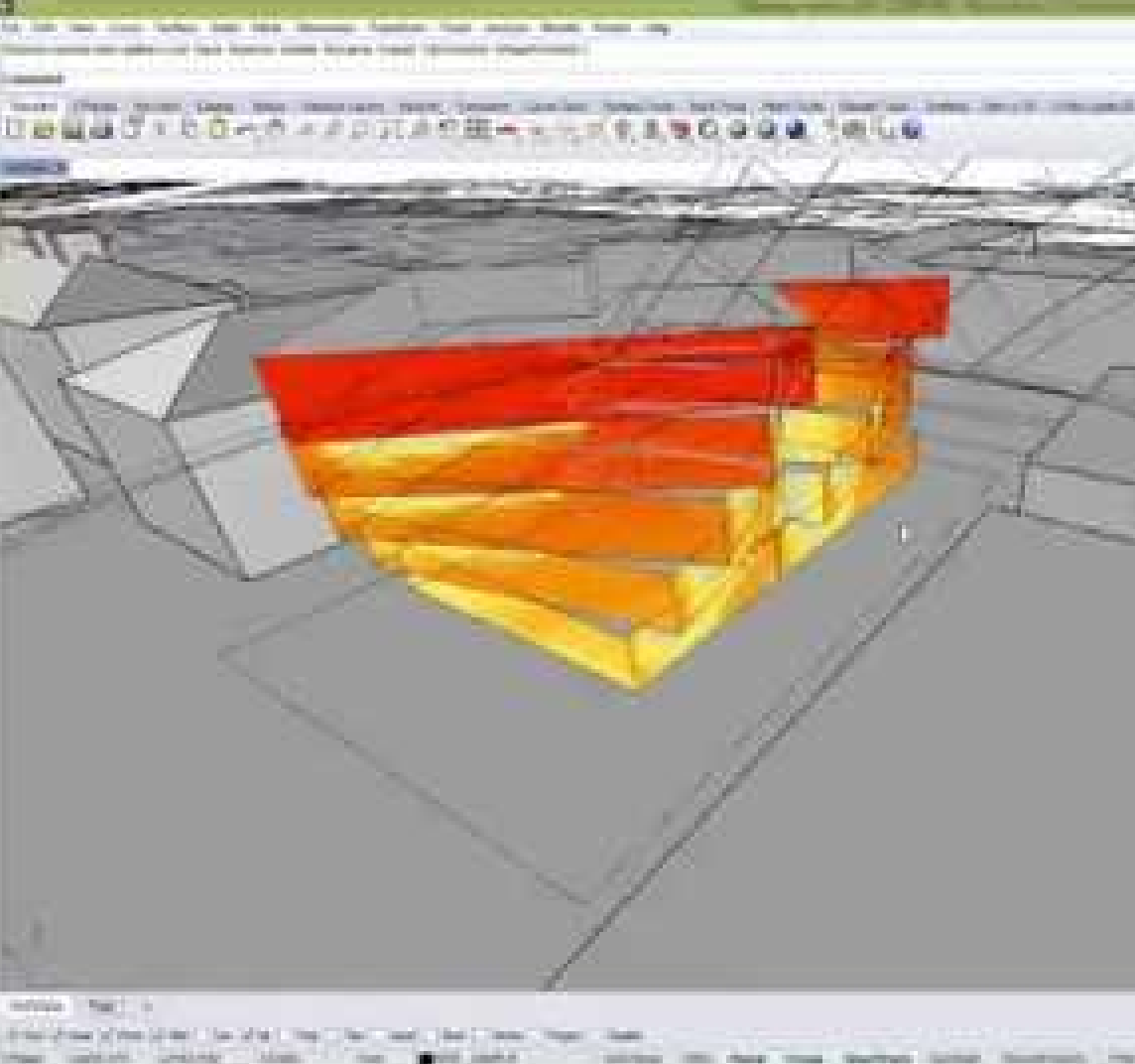
kBTU / ft<sup>2</sup>

WORSE  
than ASHRAE  
Baseline

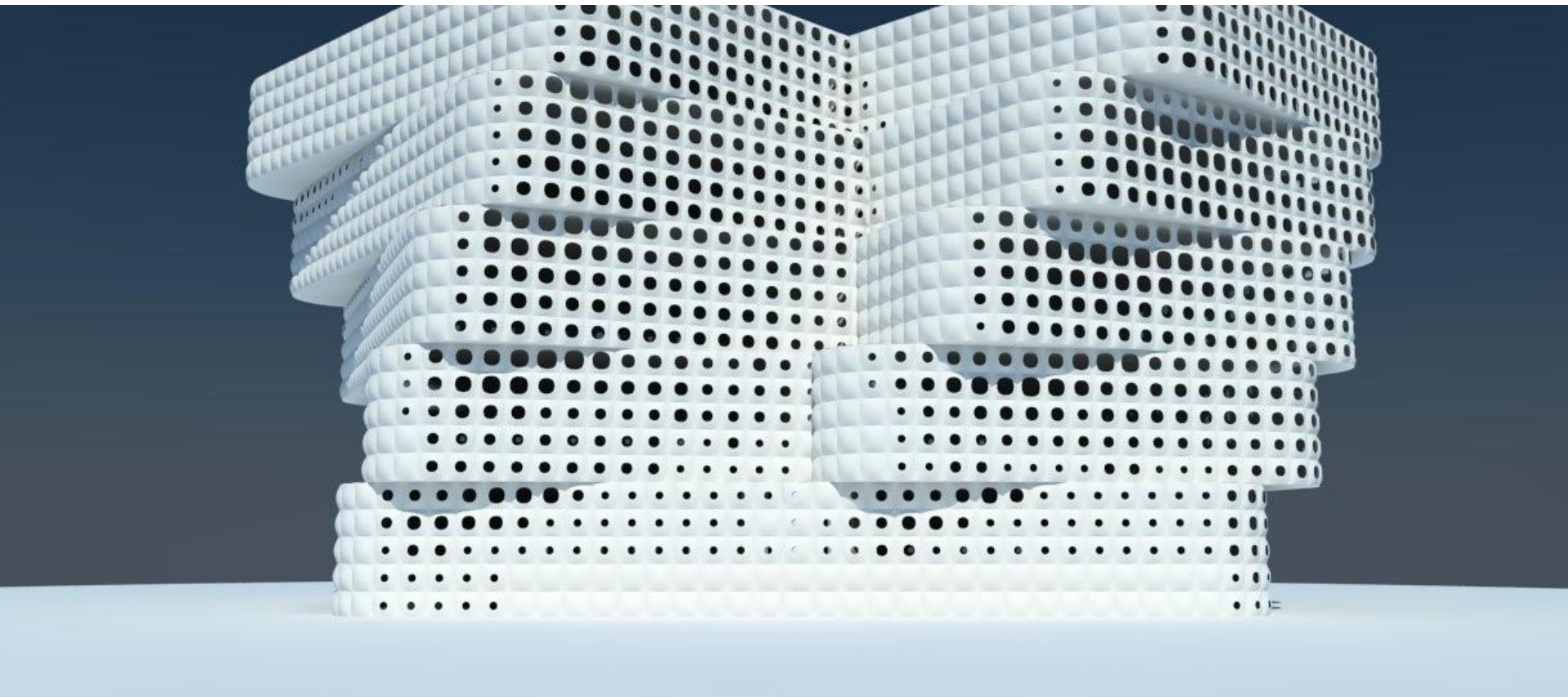
80%  
GLAZ  
RATIO

Solar Radiation Benefit / Harm  
(kBTU / ft<sup>2</sup> of Facade)

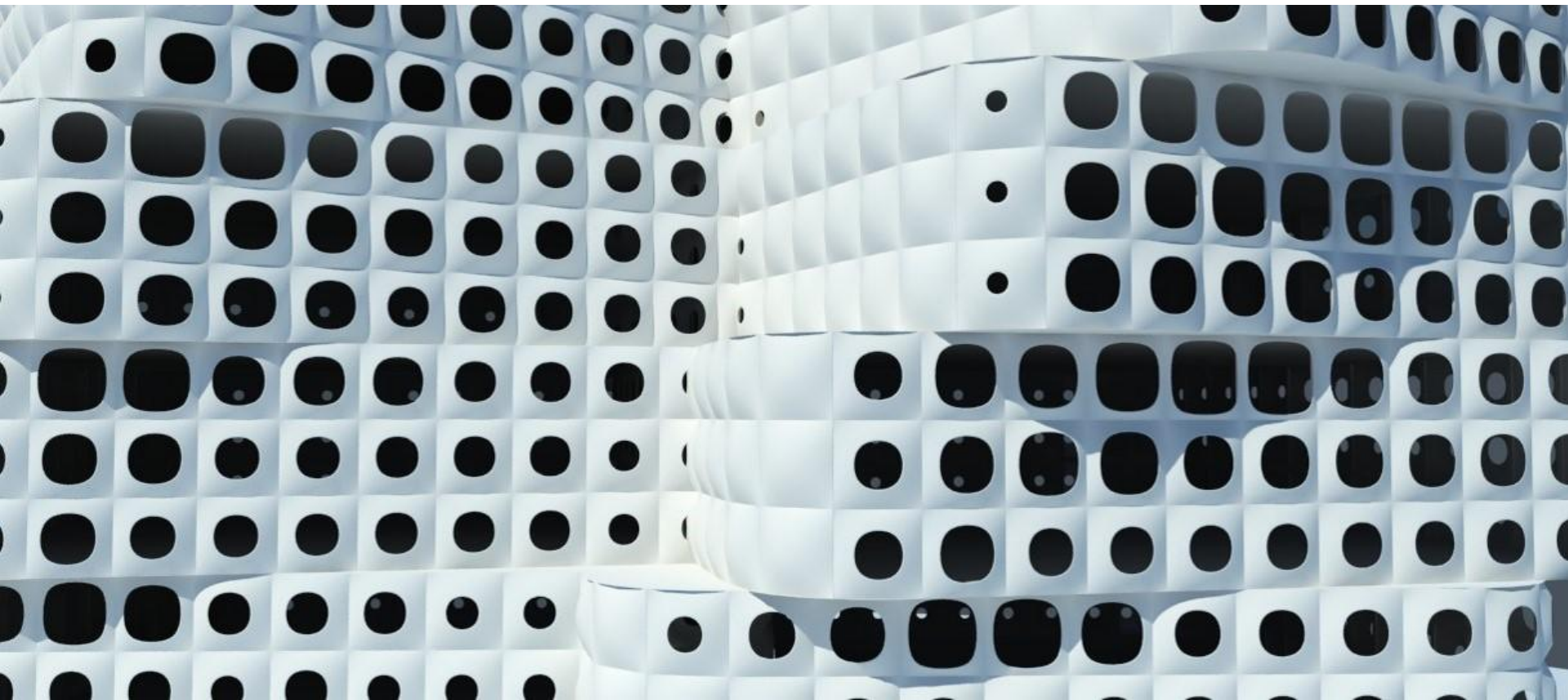


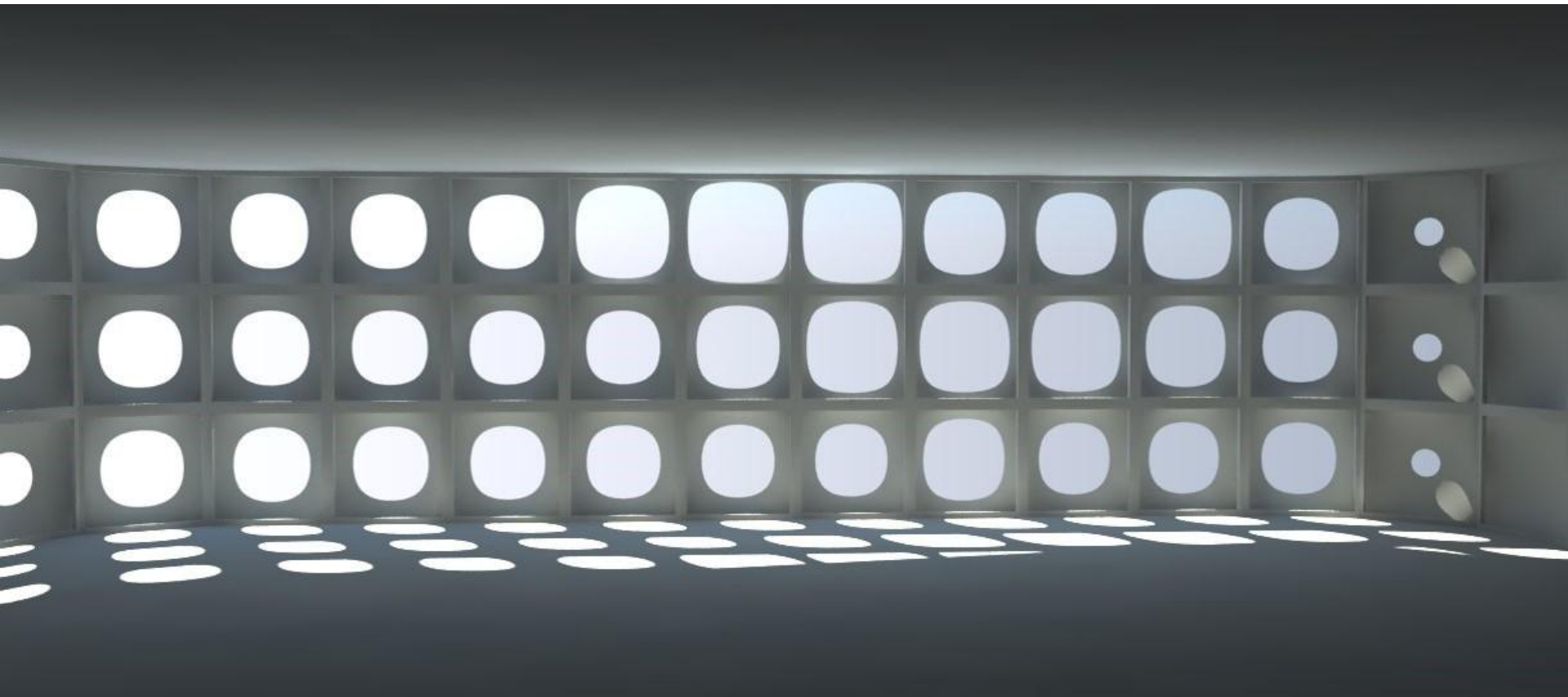




















## Principle 5 - Make it Easy to Start but Impossible to Master

cool - I'm happy that you are getting heavily involved in environmental modeling



Sep 16

anyway, thanks a TON. you are a life saver

not just tonight - your tools have totally changed my life :D

they are making me smarter

Sep 16

# Principle 5 - Make it Easy to Start but Impossible to Master



## [discussion] Sky View Factor

old forum



Grasshope

Feb '16

Dear bee and bugs,

I'd like to share and discuss with you my understanding of Sky View Factor, considering that it is an important concept frequently misunderstood.

Sky View Factor is first and foremost defined from the discussion of **radiation exchange between urban surfaces and the sky** in urban heat island research (See Oke's literature list below). It will be affected by the proportion of sky visible from a given calculation point on a surface (vertical or horizontal) as a result of the obstruction of urban geometry, but it is not entirely associated with the solid angle subtended by the visible sky patch/patches.

So, I think using "geometry way" to approximate Sky View Factor is not correct. Sky View Factor calculation shall be based on the first principle defining the concept: radiation exchange between urban surface and sky hemisphere:

We may now define the *sky view-factor* ( $\psi_s$ ) for the surface element  $\Delta A$  as the fraction of radiant flux leaving  $\Delta A$  which is intercepted by the sky. Then

$$\psi_s = \frac{1}{\pi R^2} \int_{S_v} \cos \phi dS. \quad (8)$$

It may be helpful to note that  $\psi_s$  is equal to the ratio of the radiant flux received by  $\Delta A$  from the visible sky, to that which would be received by  $\Delta A$  from an unobscured sky. This is shown by replacing  $F_e$  by  $F_s$  in (6) and integrating over  $S_v$ .



Feb 2016

1 / 15

Feb 2016

Feb 2016



2,047  
discussions

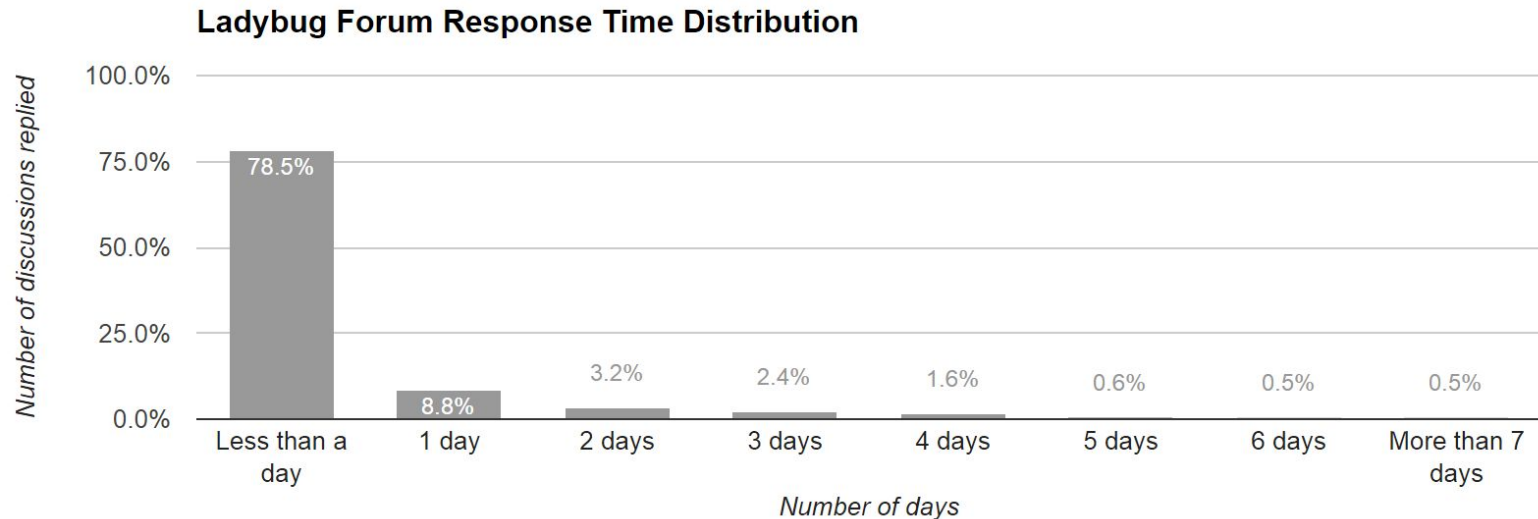
11,175  
replies

498  
comments

by 903  
people

## Principle 5 - Make it Easy to Start but Impossible to Master

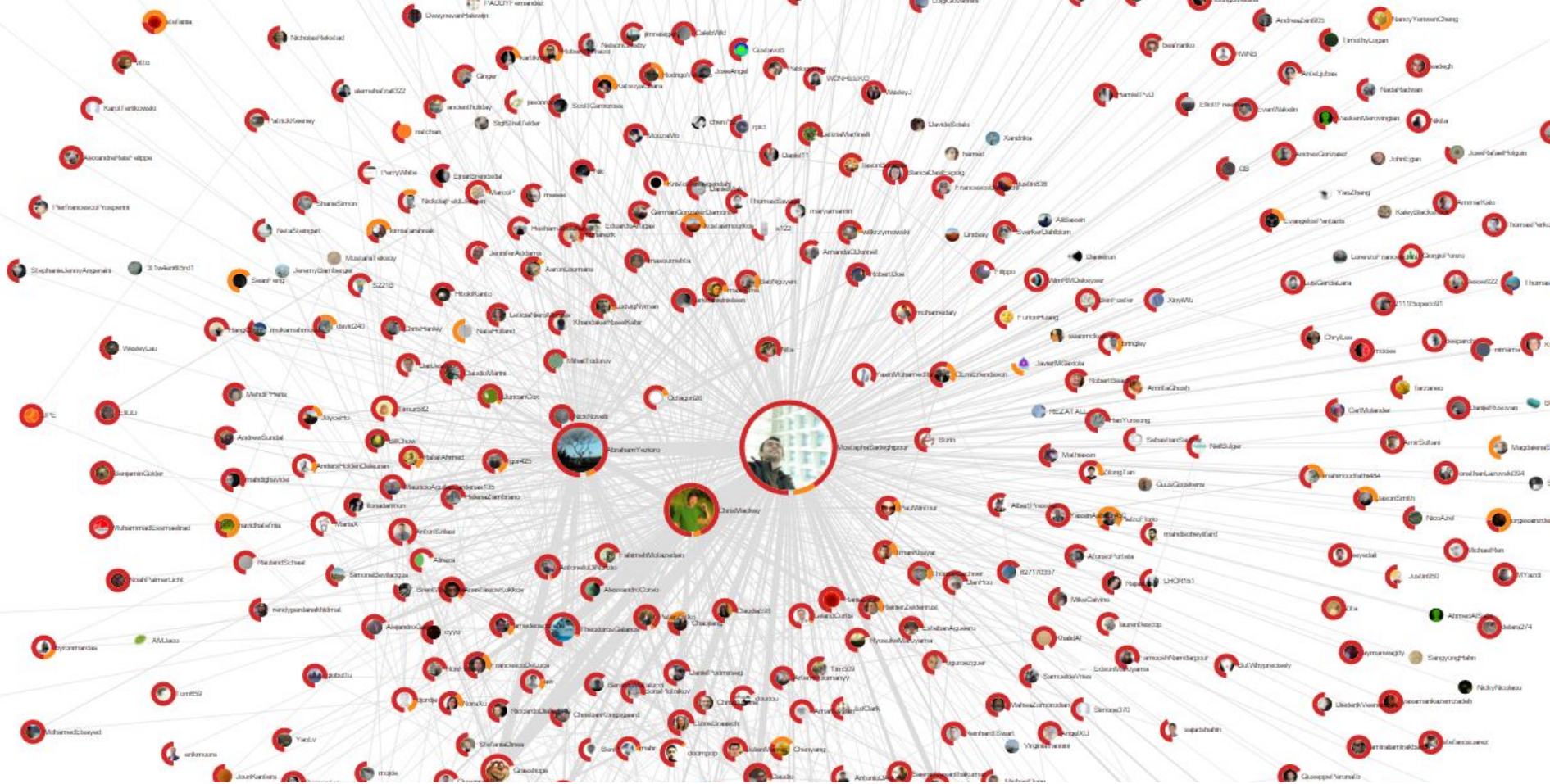
**78.5%** of the discussions get the first reply **in less than a day**.  
**95.0%** of them will get the first reply **in less than 3 days**.





# Principle 5 - Make it Easy to Start but Impossible to Master





**It's not about tools. It's about people.**





**It's not about tools. It's about people.**