Innovative User-Friendly Evaluation and Design Tool for Reflective Insulations in Roof Attics

Hamed H. Saber[1] and **Saleh A. Alshehri**[2]

[1] *Chair of Research and Consultations*
Royal Commission of Jubail and Yanbu
Jubail Industrial City, Saudi Arabia

[2] *Director of the Deanship of Research and Industrial Development*
Royal Commission of Jubail and Yanbu
Jubail Industrial City, Saudi Arabia

AGENDA

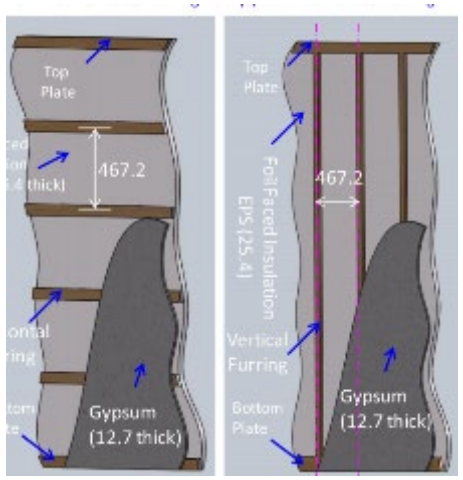
- Introduction
- Objectives
- Attic Tool Development
- Results
- Summary

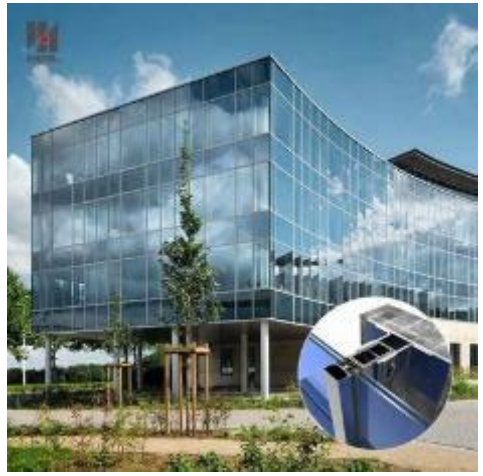
Introduction

- Airspaces with low emittance exist in many building components:
  - Windows
  - Curtain walls
  - Skylight devices
  - Reflective insulations in wall systems (e.g. furred –airspace assemblies)
  - Reflective insulations in roofing systems
  - Radiant barriers (Attic)
- Airspaces use coatings/surfaces/foils of different emittances
- R-value of radiant barriers depends on:
  - Attic dimensions
  - Attic slope
  - Temperature of all surfaces that bound the attic
  - Emittances of all surfaces that bound the attic
  - Direction of heat flow through the attic
- Determining accurately the R-value of radiant barriers results in accurate assessments for the energy performance of whole buildings

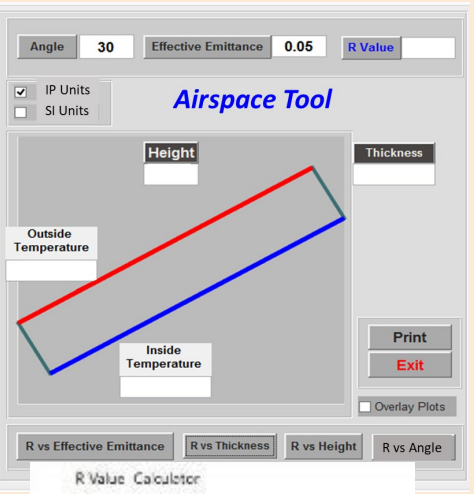
Introduction (cont.)

Examples of airspaces in building envelopes





ART recently developed



Introduction (cont.)

Examples of airspaces in attics

https://minnesotaexteriors.com/blog/how-to-cool-an-attic-and-save-on-your-energy-bill/

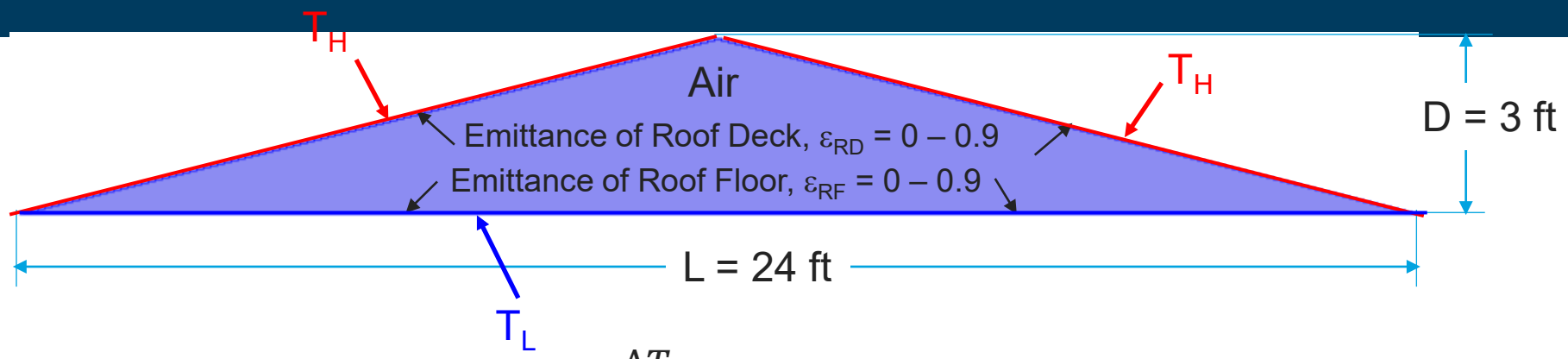
Objectives

- Use a previously developed and validated numerical model along with Artificial Intelligence (Neural Network) to develop an innovative and user-friendly evaluation and design tool, called "**Attic Tool**", for assessing the thermal performance of radiant barriers in roof attics for the following cases:
  - Heat flow down (summer conditions)
  - Heat flow up (winter conditions)
- Show comparisons between the R-values when the attic insulated with different types of mass insulations against the attic R-values having different emittance values for the attic deck and floor

R-value of Roof Attic with Different Slopes

Attic Descriptions and Parameters

Example of Roof Deck with slope : 3/12



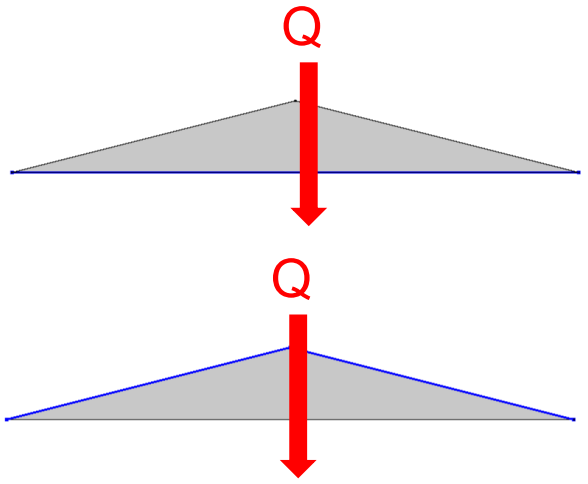
$$R - Value = \frac{\Delta T}{Q/A}$$

R-Value based on the surface area of the roof floor (A_{RF}):

$$R - Value = \frac{\Delta T}{Q/A_{RF}}$$

R-Value based on the surface area of the roof deck (A_{RD}):

$$R - Value = \frac{\Delta T}{Q/A_{RD}}$$

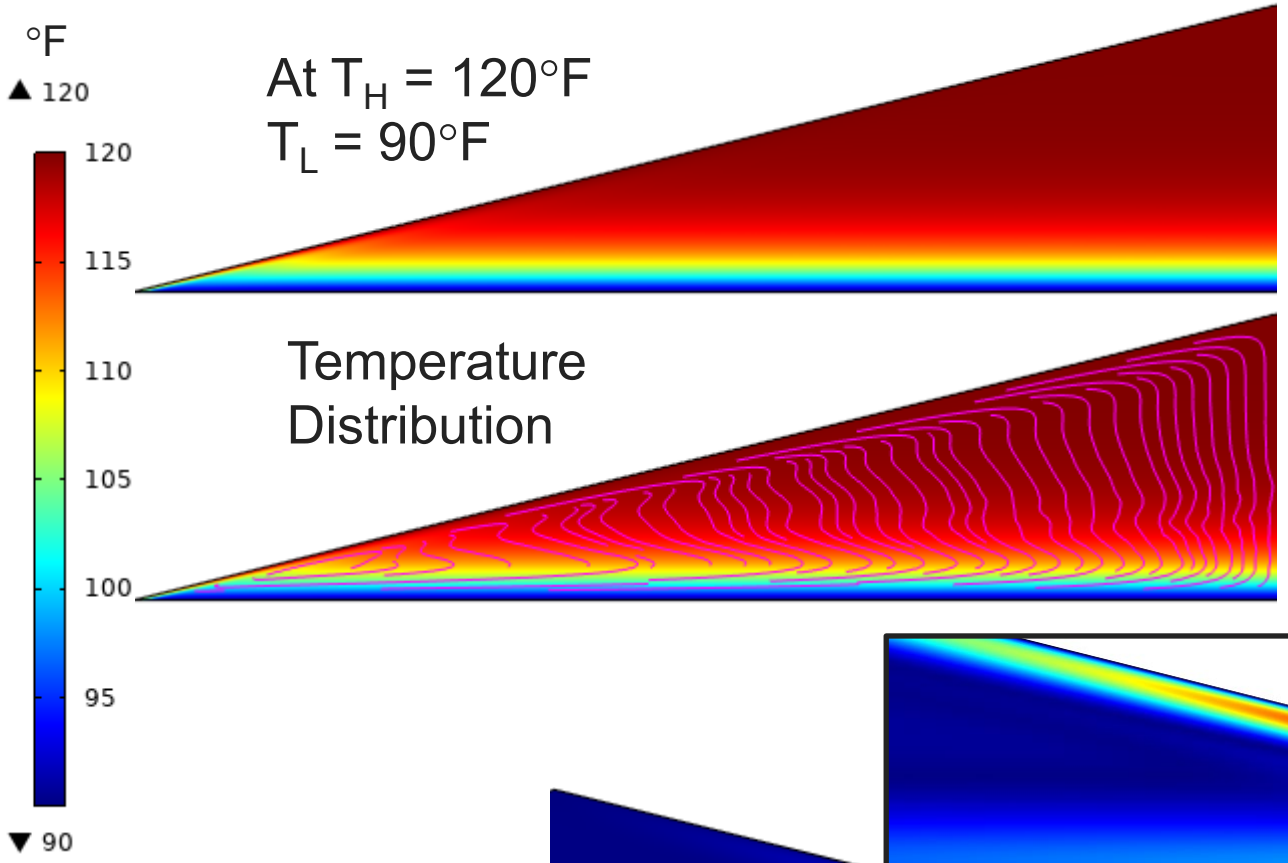


Note: Attic Tool provide the R-values are based on the surface area of the roof floor (A_{RF}) and the surface of roof deck

Attic Tool Development

- A previously developed validated numerical model was used to conduct a parametric study in order to determine the R-values of attic radiant barriers

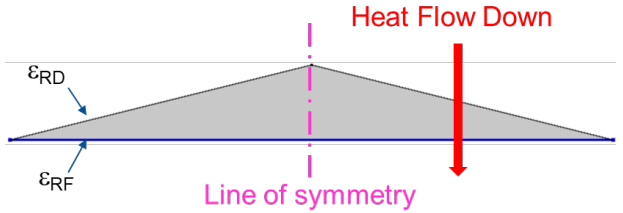
- The parametric study include a matrix of various parameters, including:
  - Range of roof floor emittance of 0 – 0.9
  - Range of roof deck emittance of 0 – 0.9
  - Range of attic slope of 1/12 – 12/12
  - Various types of thermal insulations available in the market for the case of attic insulated with mass insulations

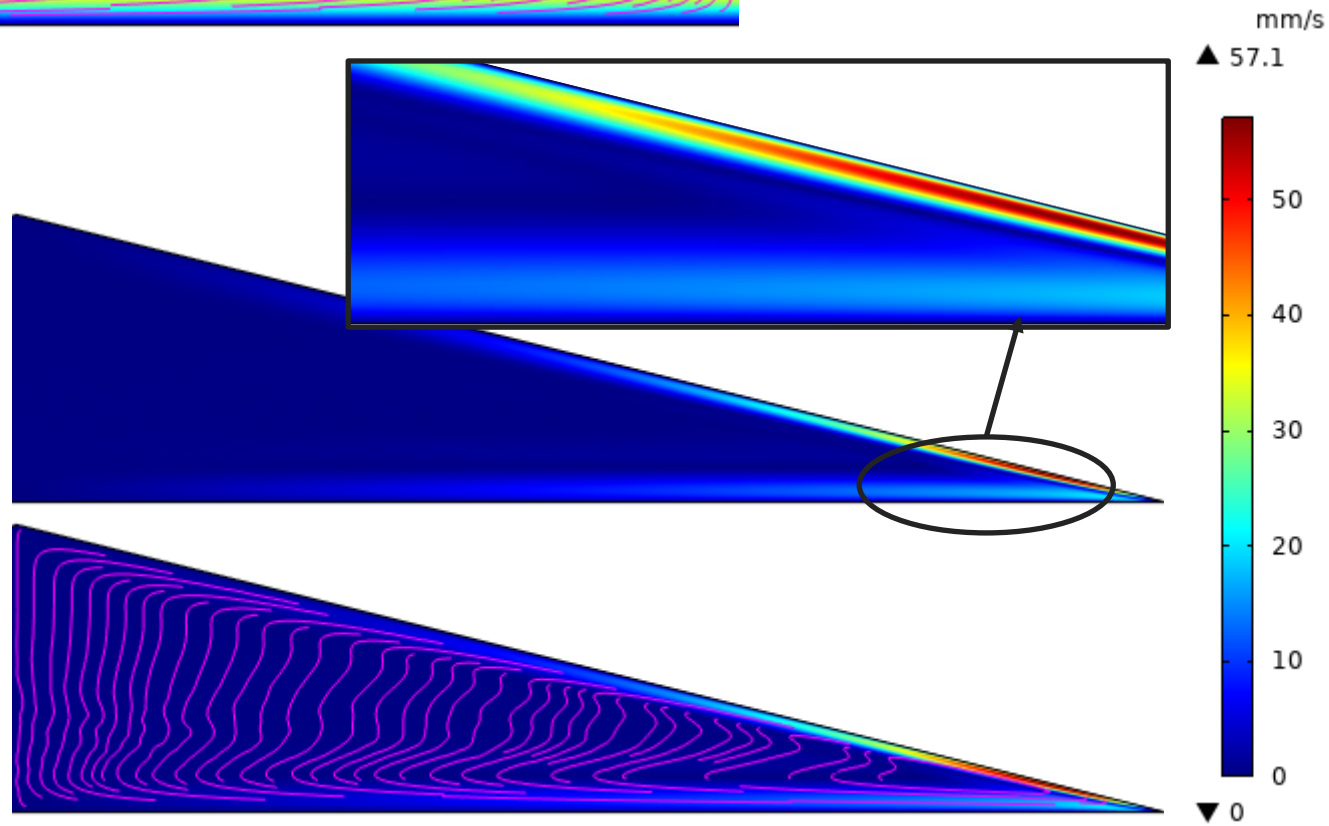


Roof Slope: 3/12

ε_{RD} = 0.05,

ε_{RF} = 0.9



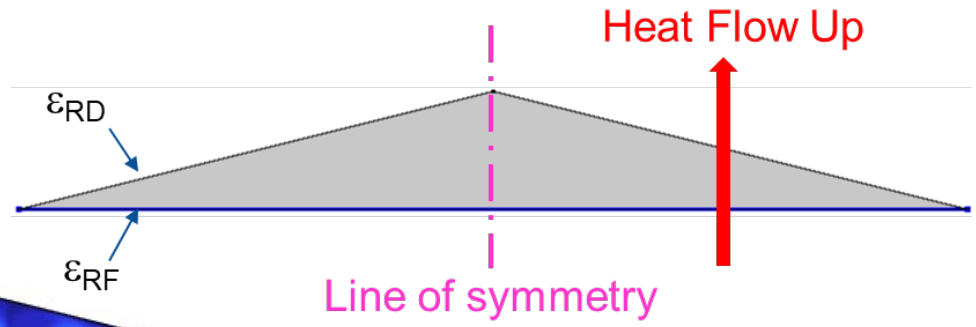


Resultant Velocity Distribution

Roof Slope: 3/12

ε_{RD} = 0.05

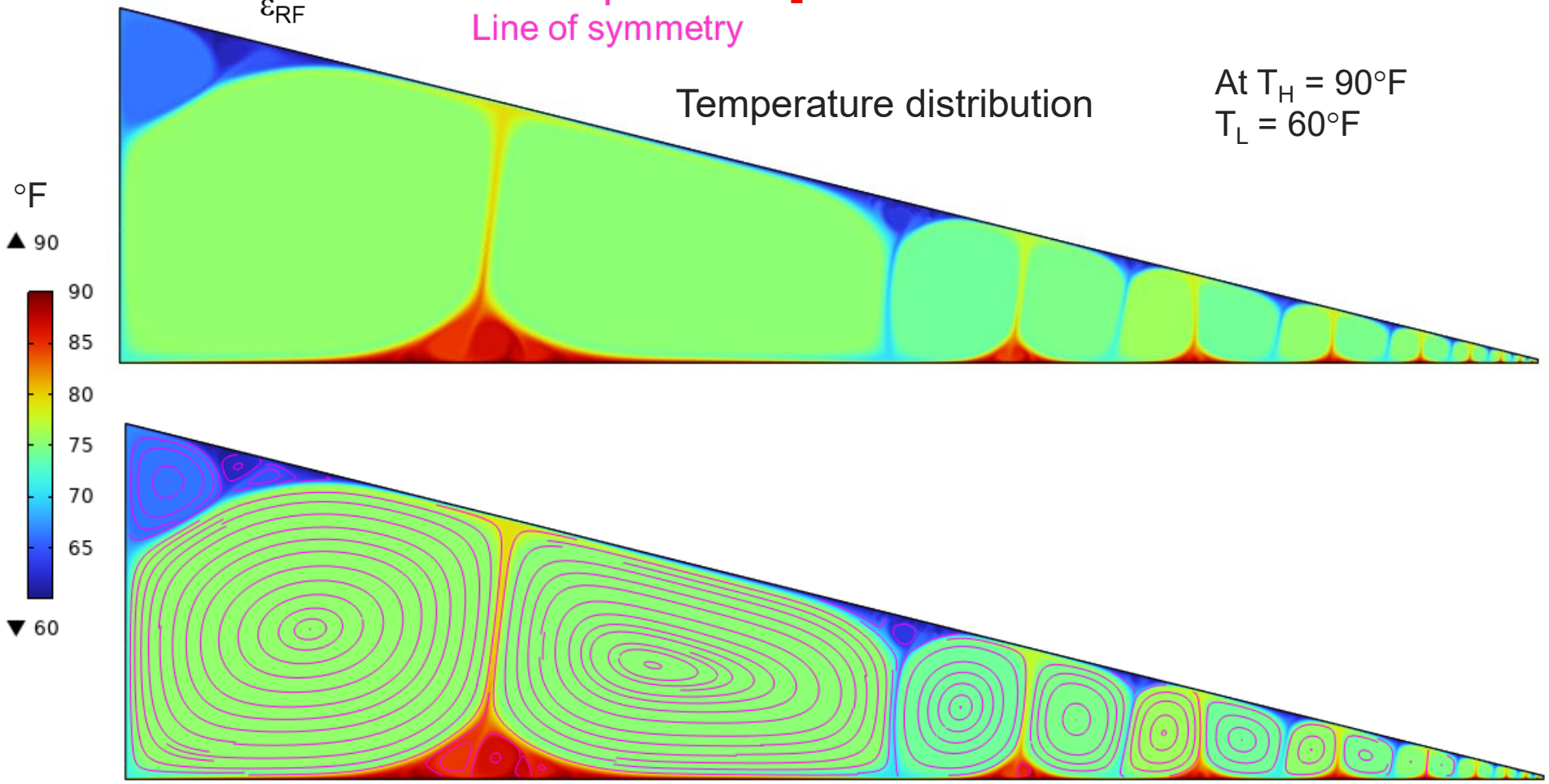
ε_{RF} = 0.9



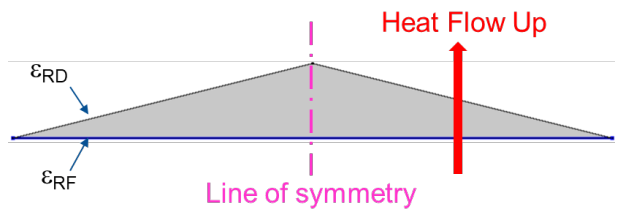
Temperature distribution

At T_H = 90°F

T_L = 60°F

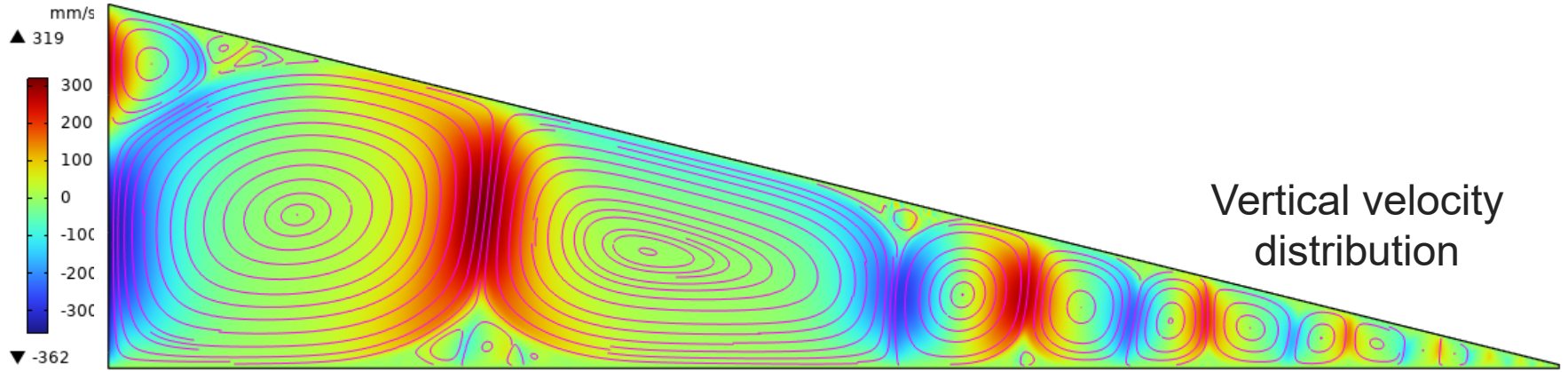


At T_H = 90°F
T_L = 60°F

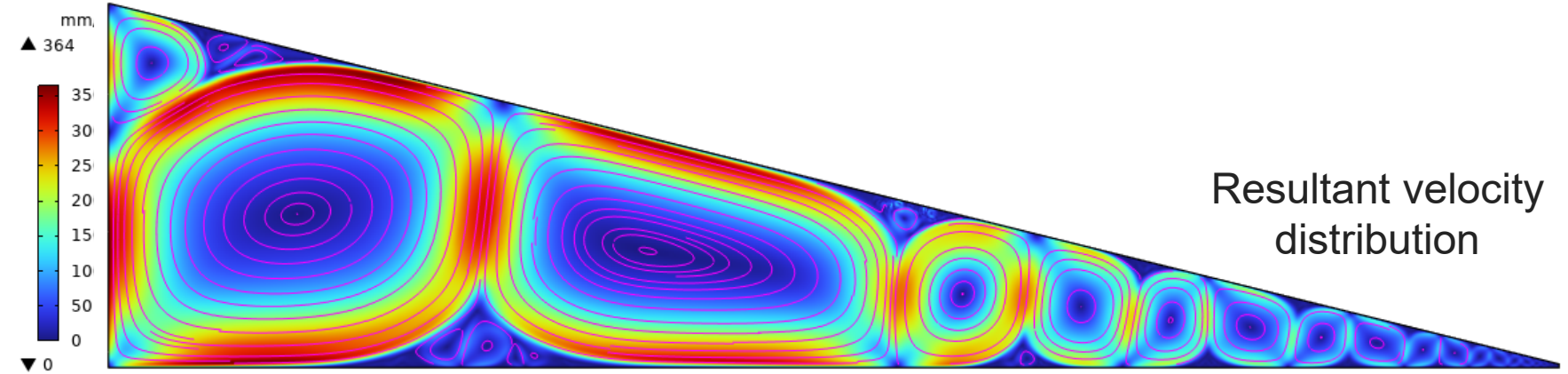


Roof Slope: 3/12
ε_{RD} = 0.05
ε_{RF} = 0.9

Horizontal velocity distribution



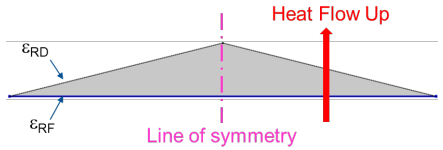
Vertical velocity distribution



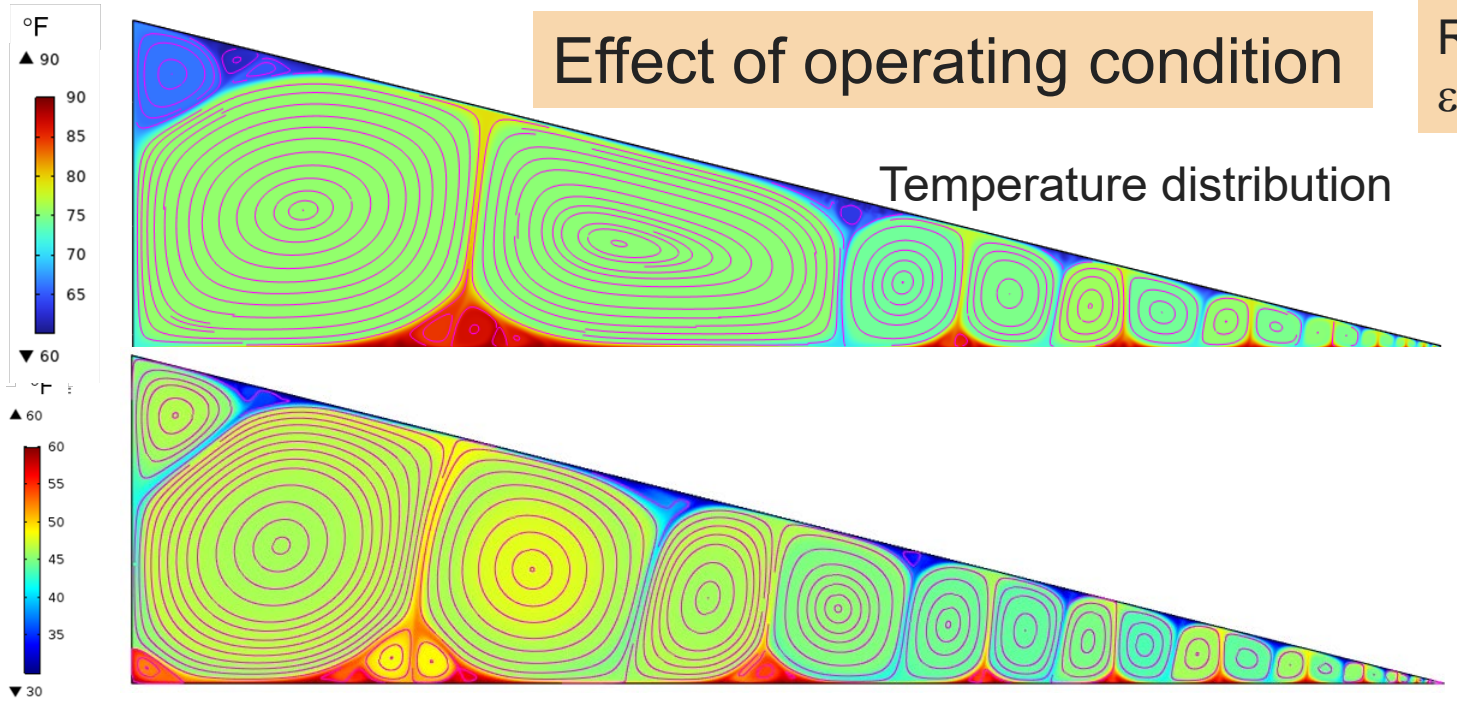
Resultant velocity distribution

Effect of operating condition

Roof Slope: 3/12
$\varepsilon_{RD} = 0.05$, $\varepsilon_{RF} = 0.9$



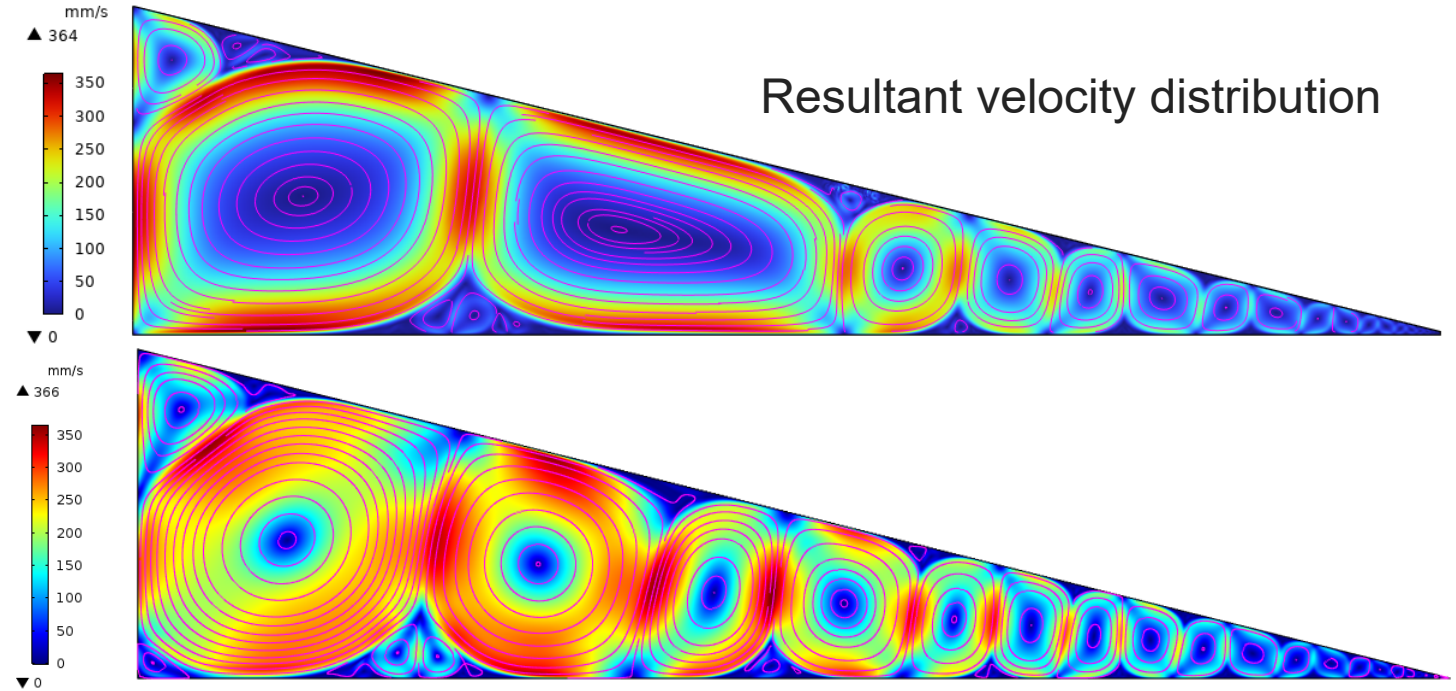
Temperature distribution



At $T_H = 90°F$
$T_L = 60°F$

At $T_H = 60°F$
$T_L = 30°F$

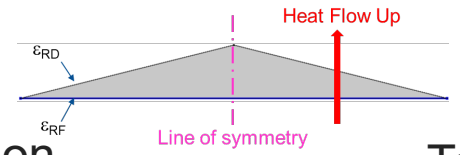
Resultant velocity distribution



At $T_H = 90°F$
$T_L = 60°F$

At $T_H = 60°F$
$T_L = 30°F$

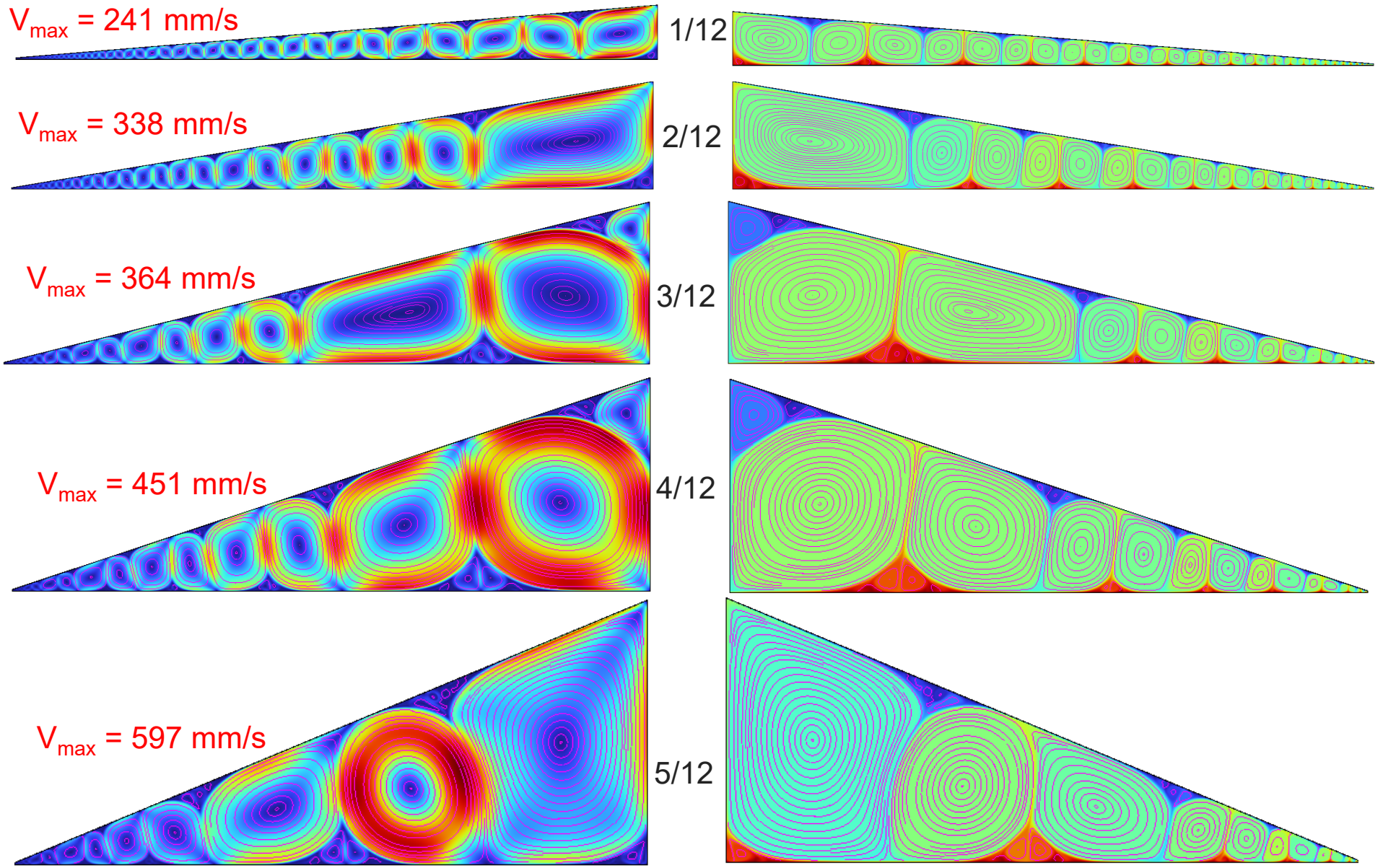
Effect of slope



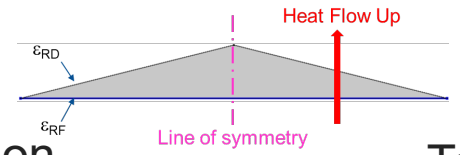
TH = 90°F & TL = 60°F
ε_{RD} = 0.05, ε_{RF} = 0.9

Resultant velocity distribution

Temperature distribution



Effect of slope

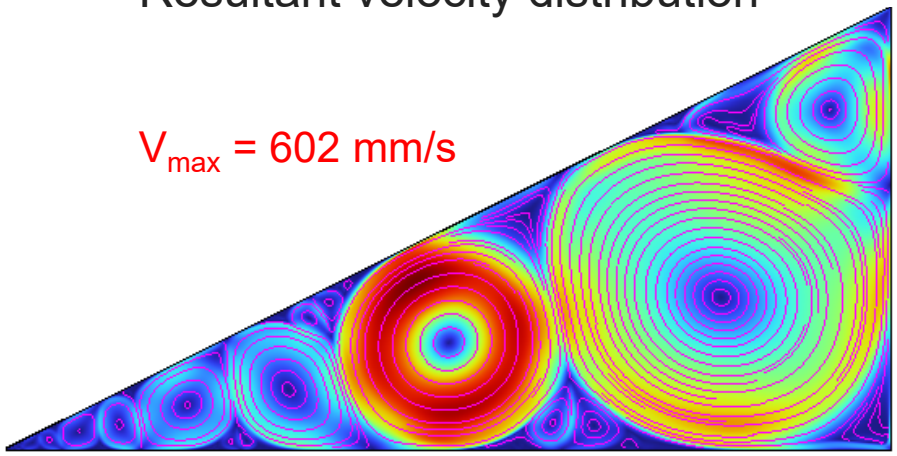


TH = 90°F & TL = 60°F
ε_{RD} = 0.05, ε_{RF} = 0.9

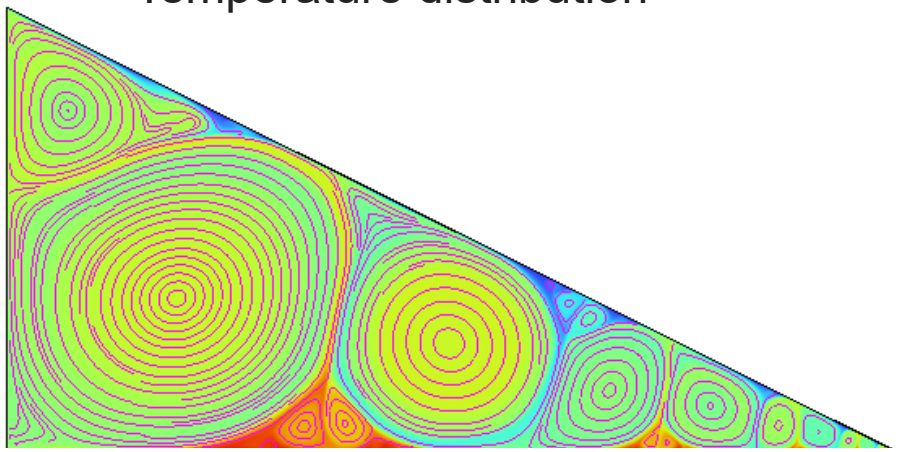
Resultant velocity distribution

Temperature distribution

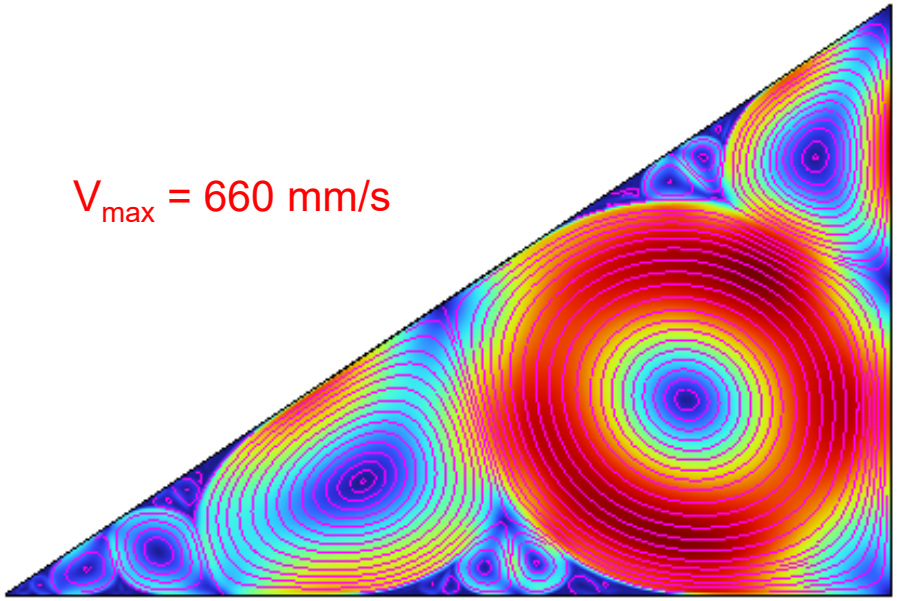
V_{max} = 602 mm/s



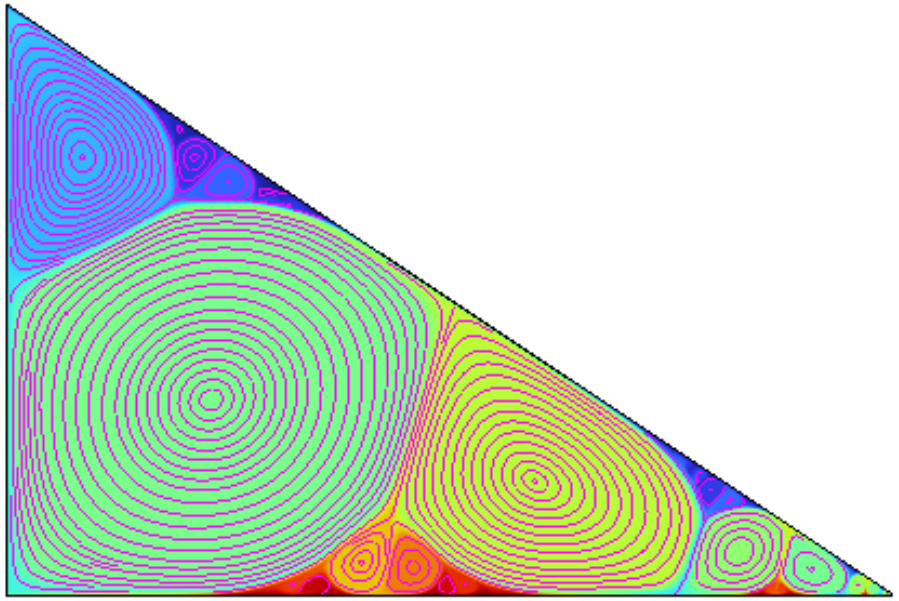
6/12



V_{max} = 660 mm/s



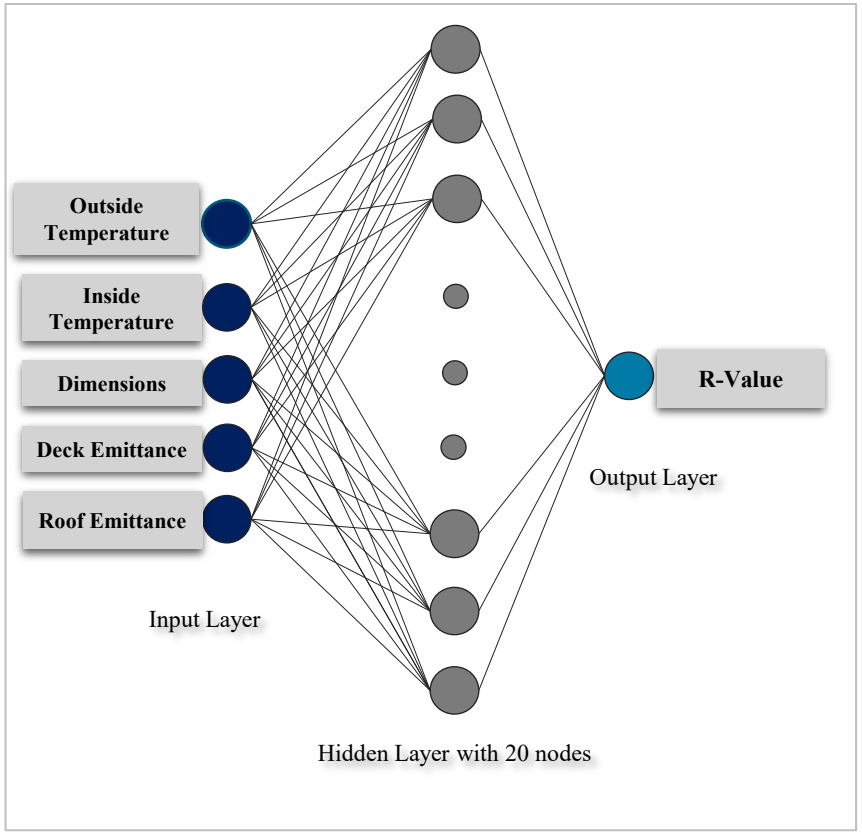
8/12



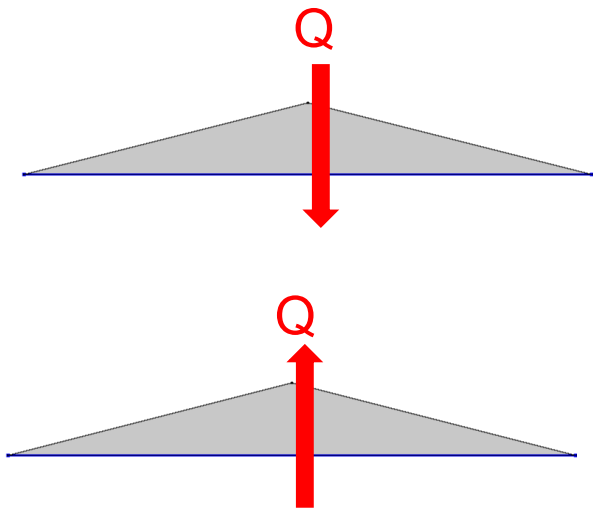
Attic Tool Development (cont.)

- Development of Neural Network (NN) model that uses the R-values of radiant barriers obtained from the parametric study from the validated model

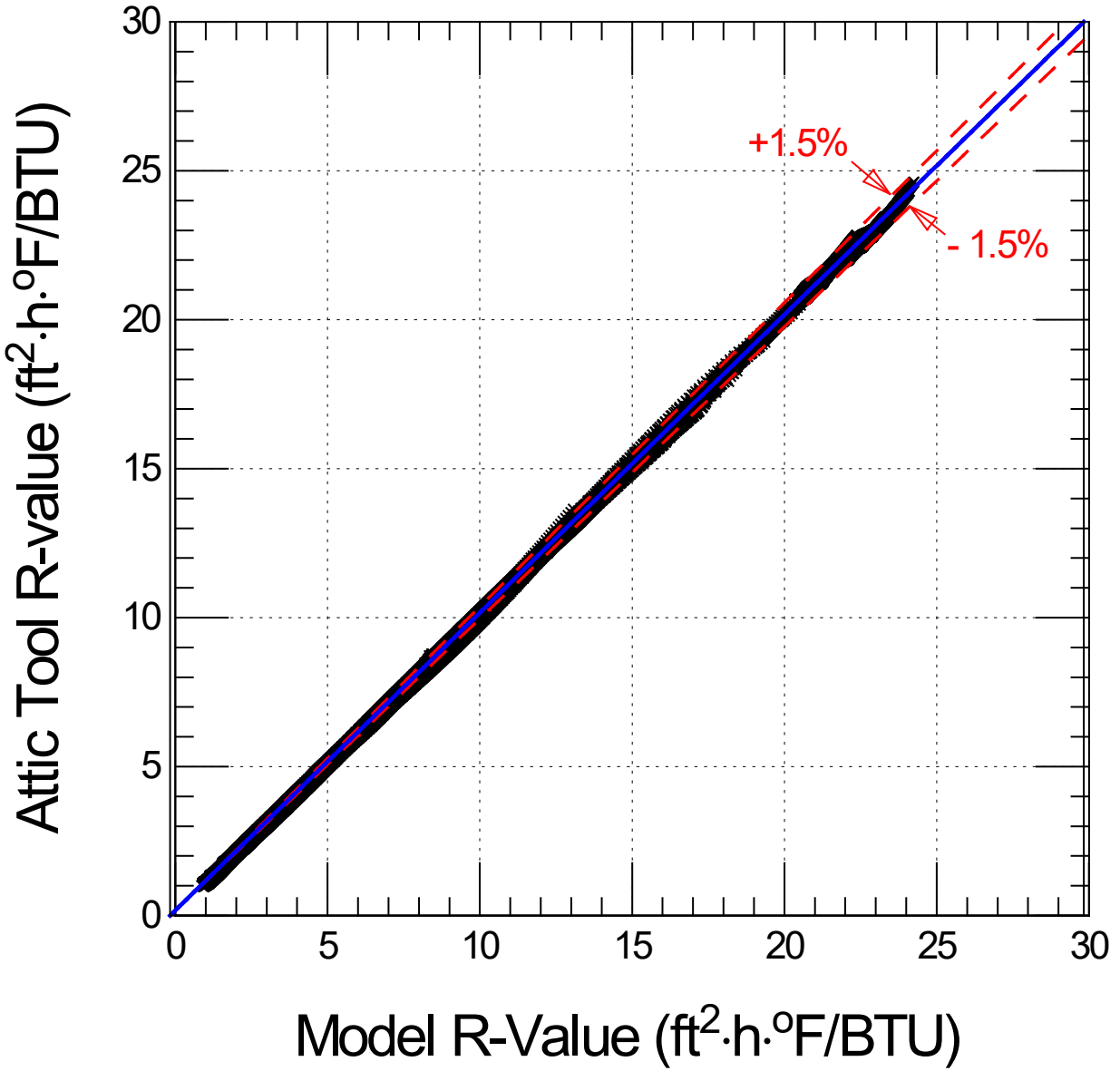
- ✓ NN was developed with 5 nodes in the input layer and a hidden layer having 20 nodes
- ✓ Based on the values of outside and inside temperatures, the direction of heat flow is identified according



Attic Tool Development (cont.)

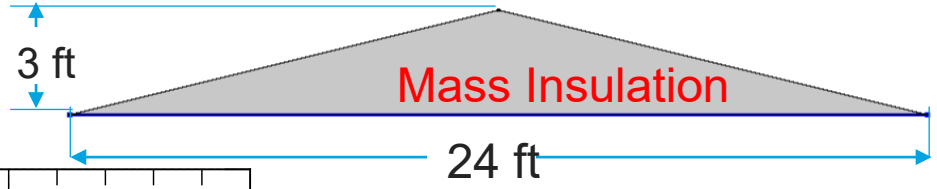


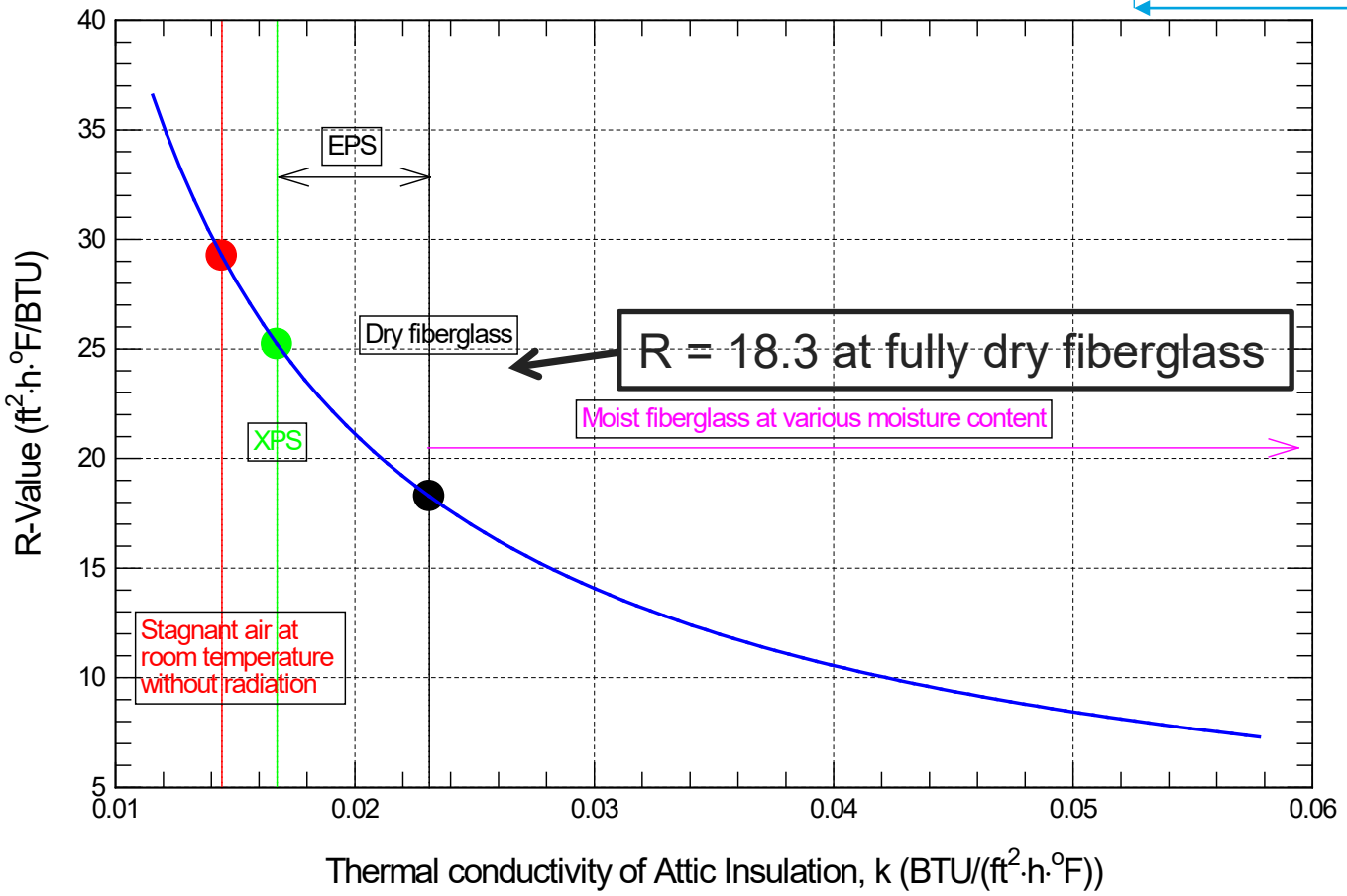
Comparisons between Attic Tool and Model R-values at variety of conditions



Results

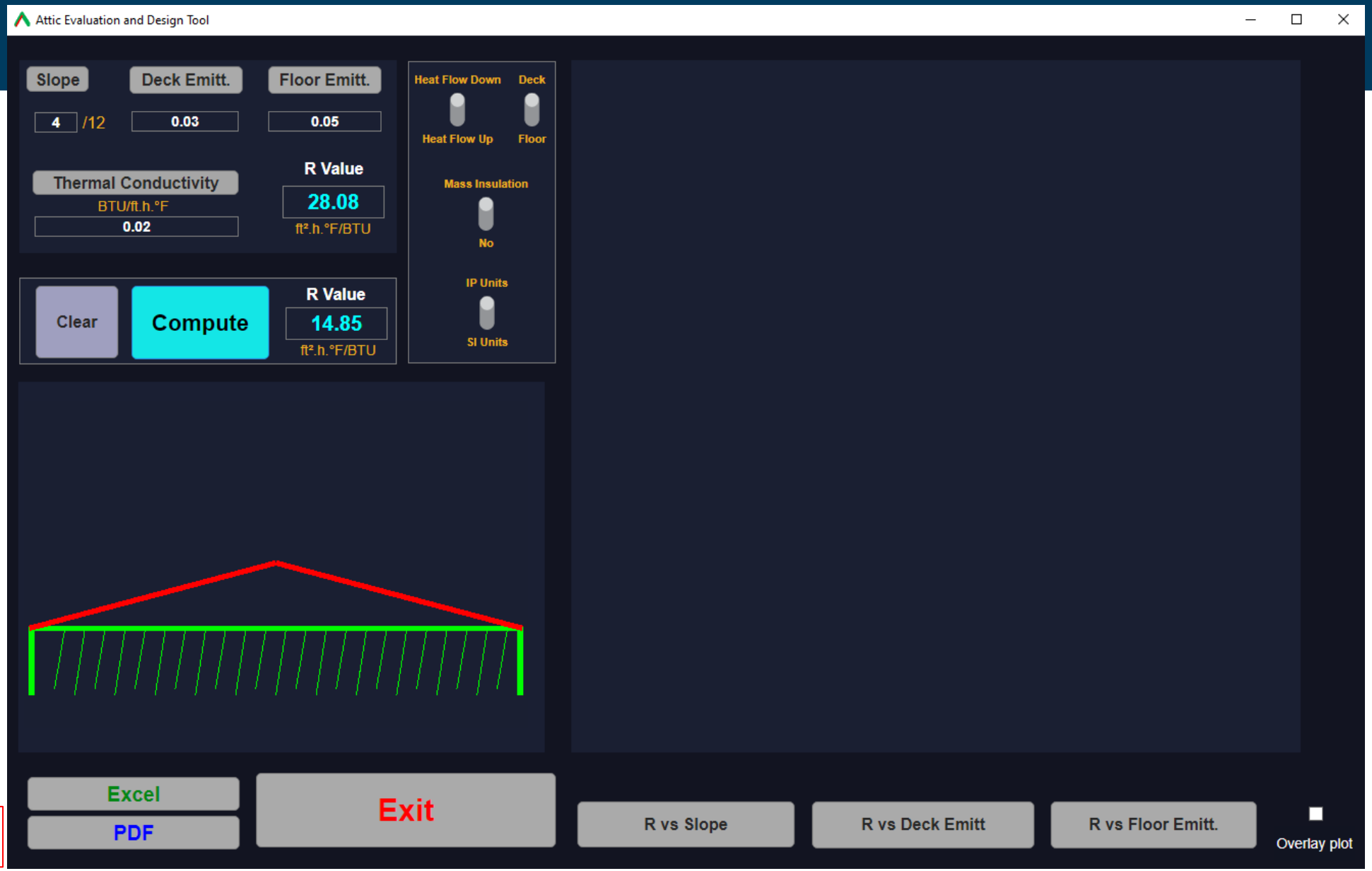
Slope of Roof Deck: 3/12



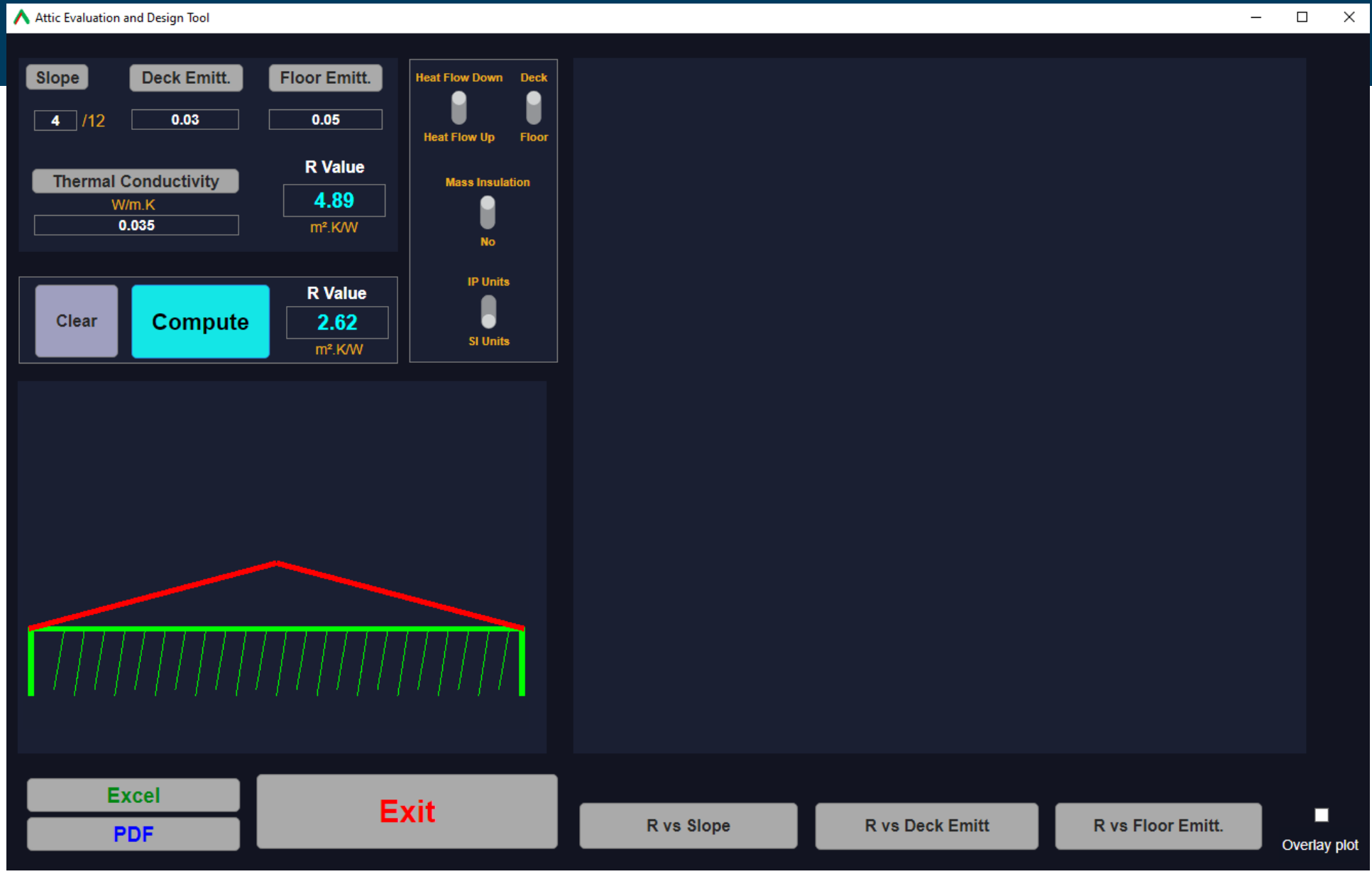


$$1\ \frac{BTU}{ft \cdot h \cdot {}^{\circ}\mathrm{F}} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot {}^{\circ}\mathrm{F}}$$

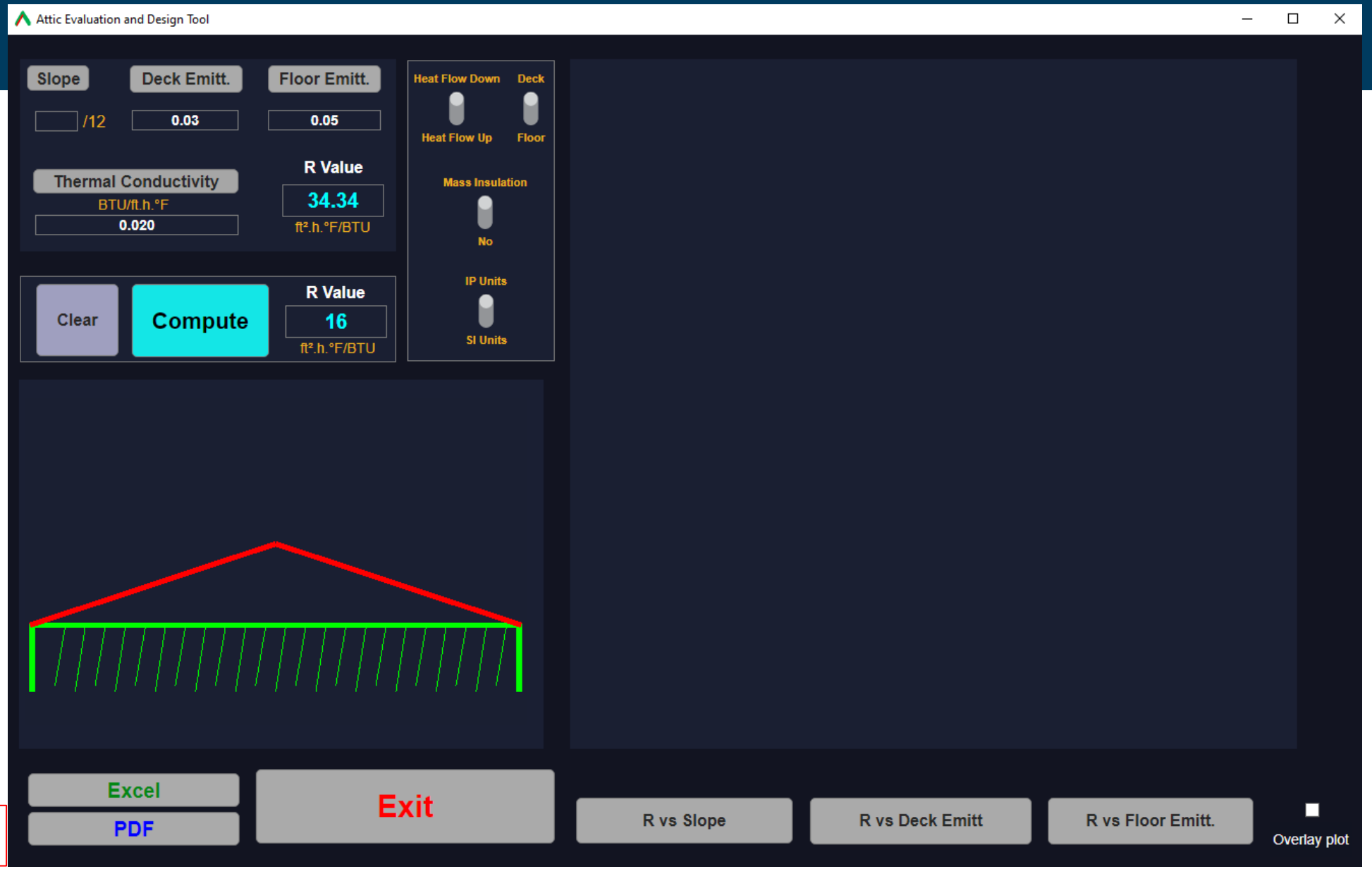
Evaluation Mode



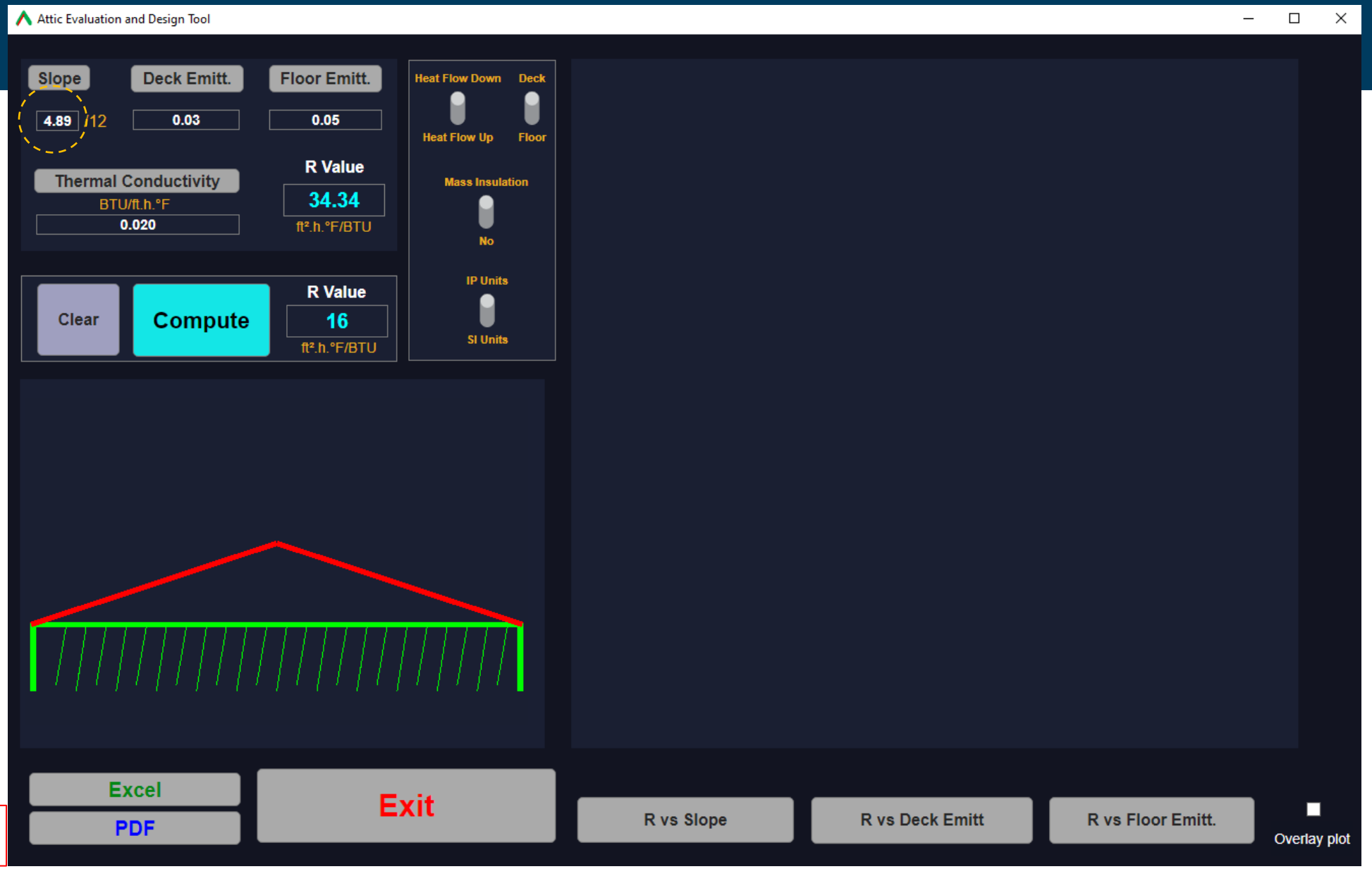
$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$


Attic Evaluation and Design Tool
Slope
Deck Emitt.
Floor Emitt.
4
/12
0.03
0.05
Thermal Conductivity
W/m.K
0.035
R Value
4.89
m².K/W
Clear
Compute
R Value
2.62
m².K/W
Heat Flow Down
Deck
Heat Flow Up
Floor
Mass Insulation
No
IP Units
SI Units
Excel
PDF
Exit
R vs Slope
R vs Deck Emitt
R vs Floor Emitt.
Overlay plot

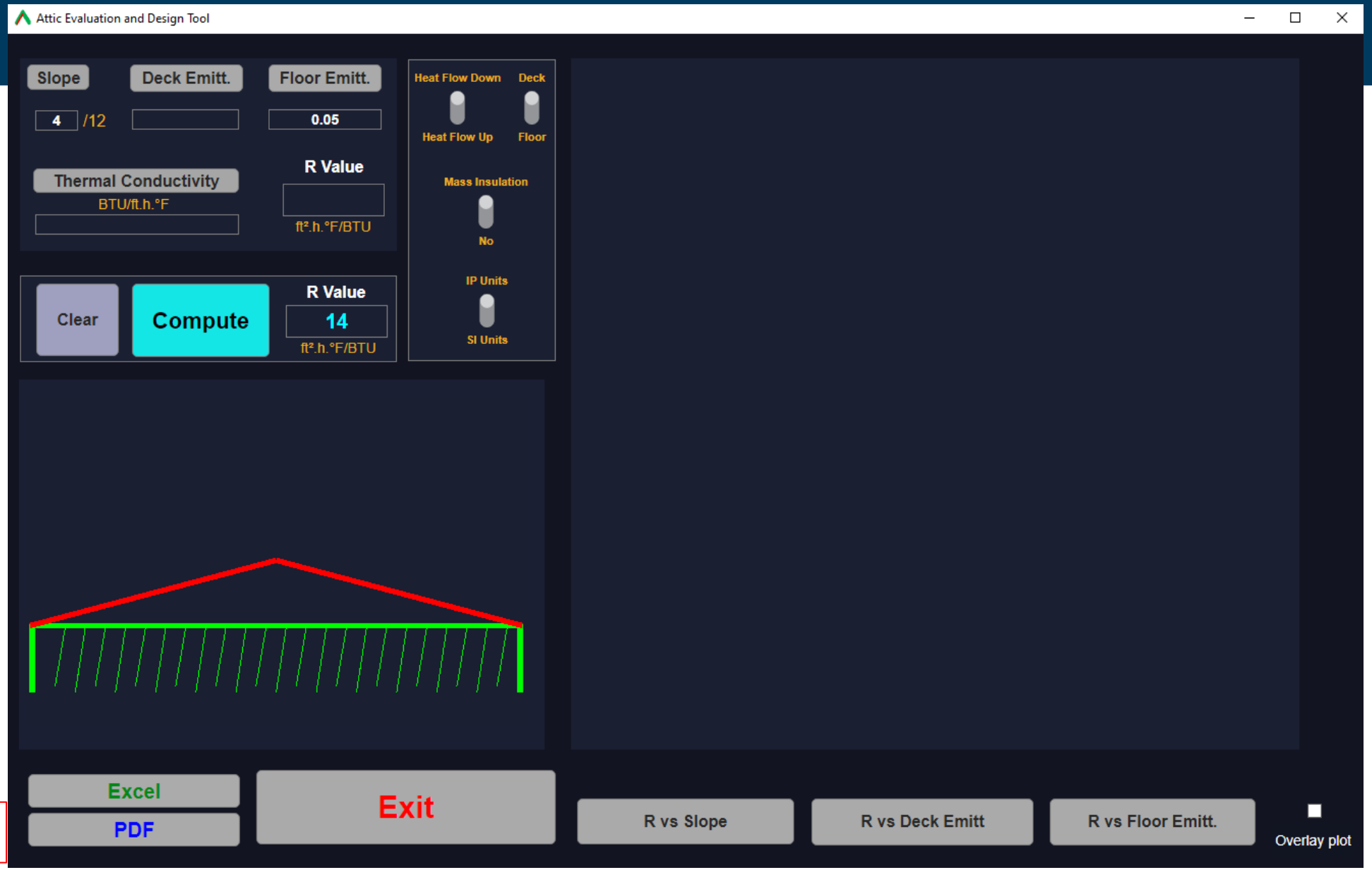
Desing Mode



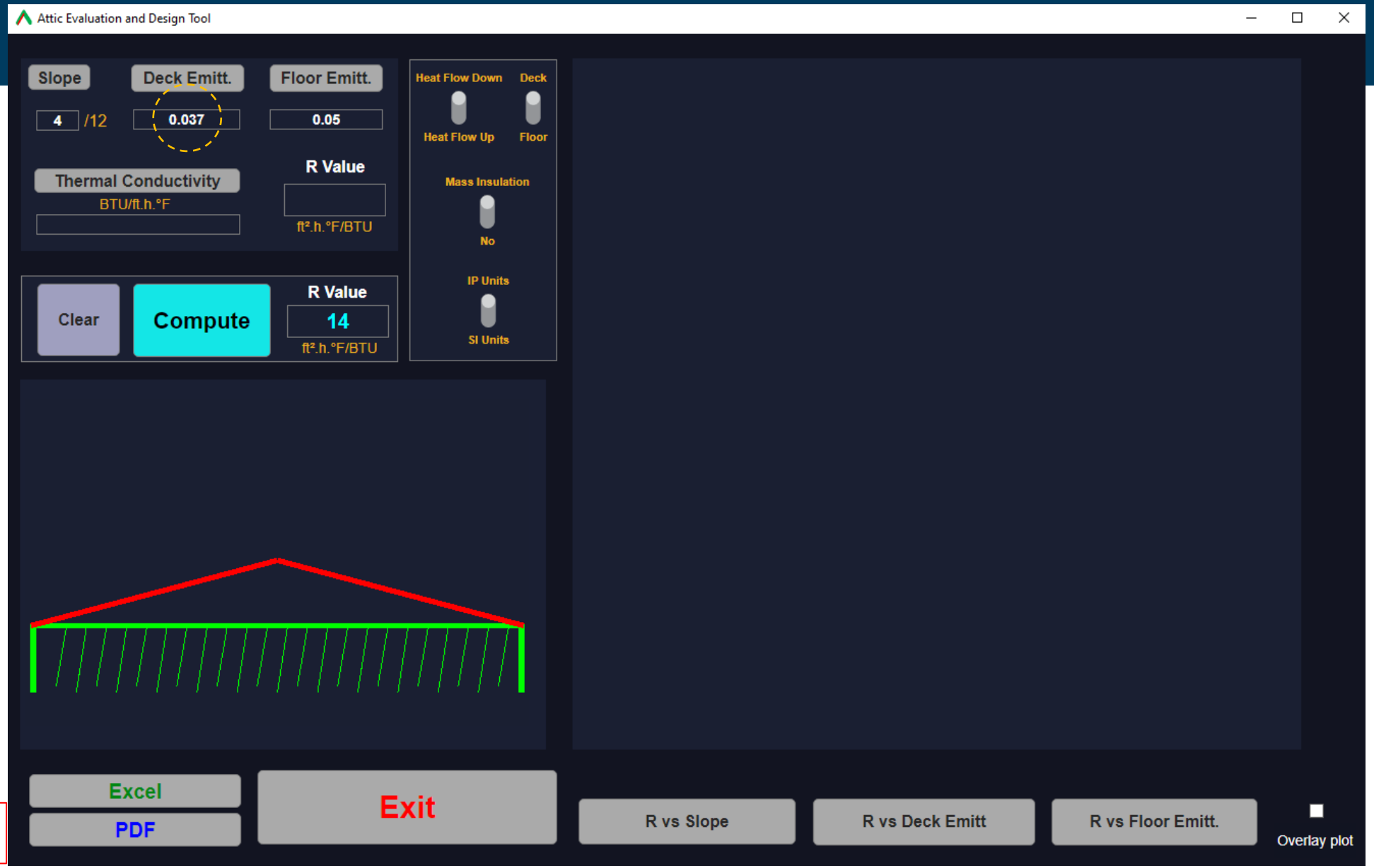
$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$



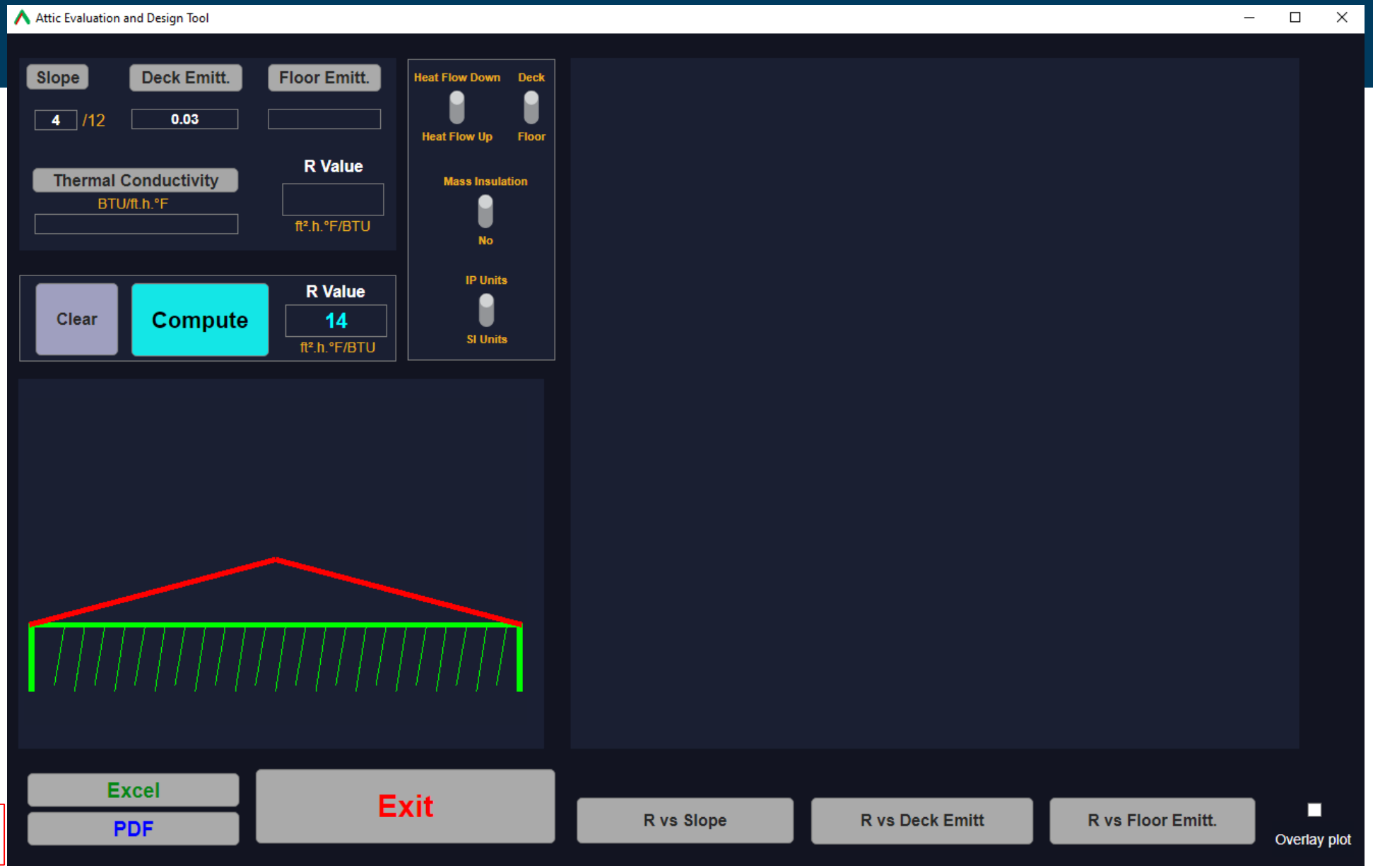
$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$



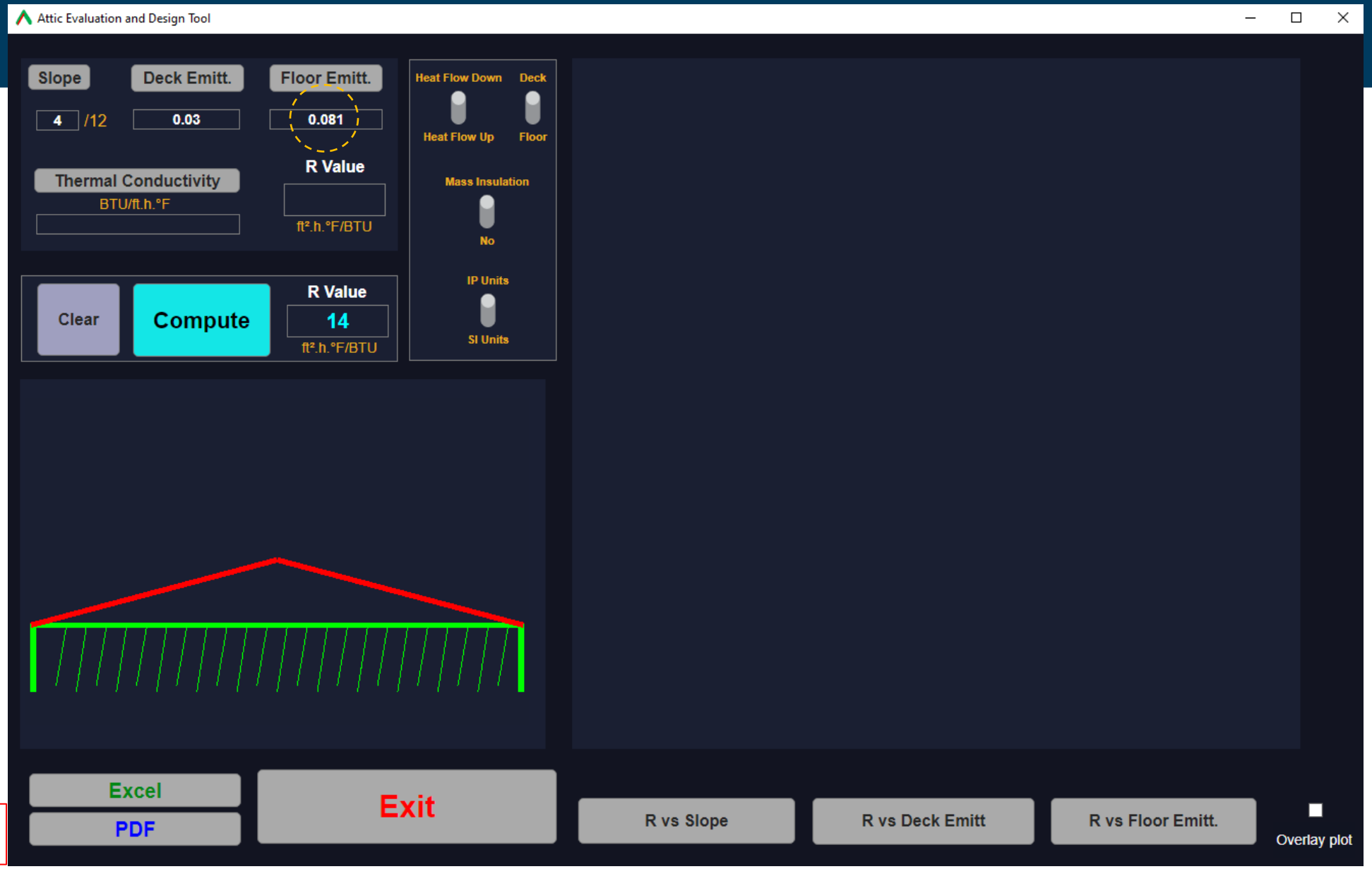
$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$



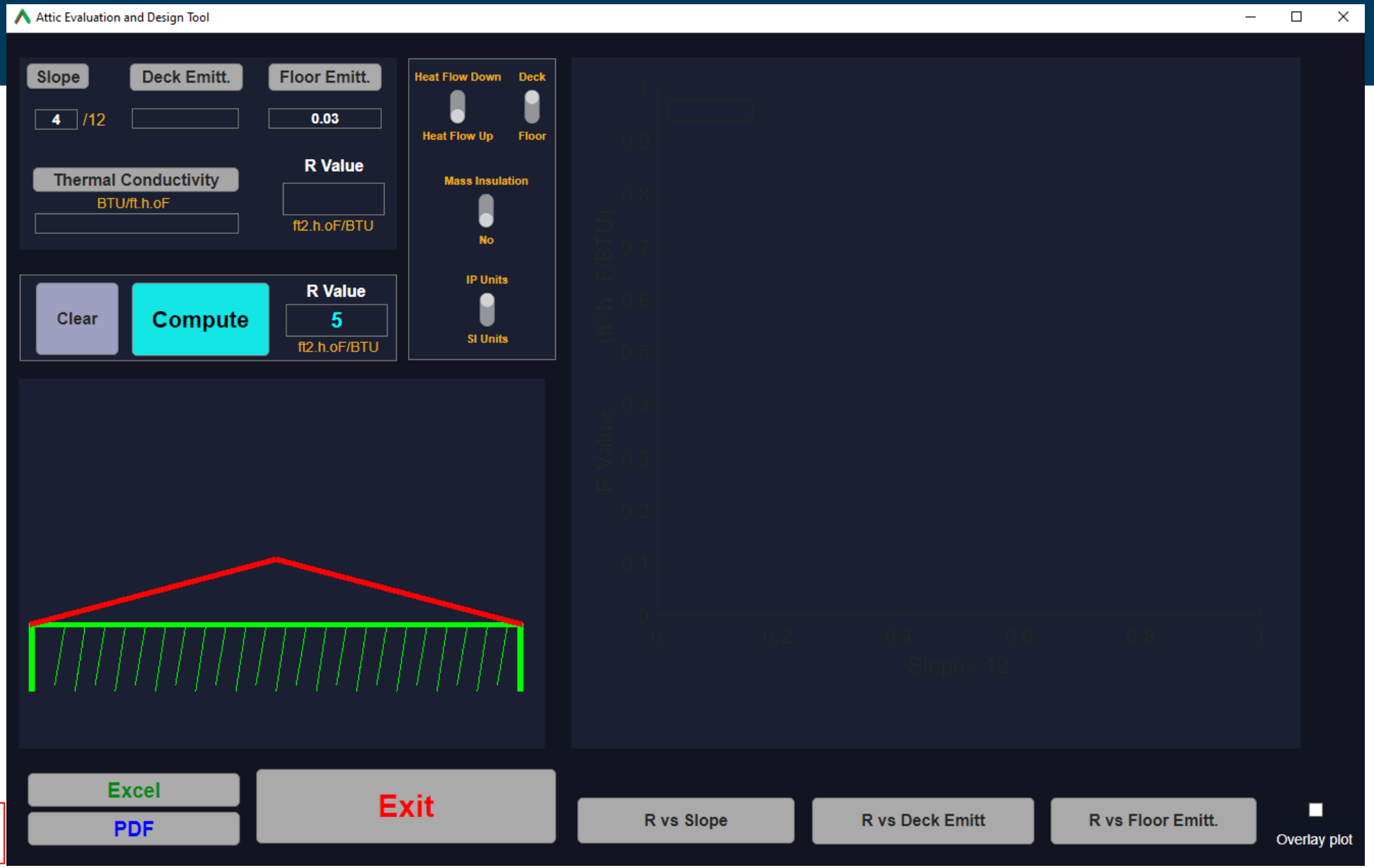
$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$



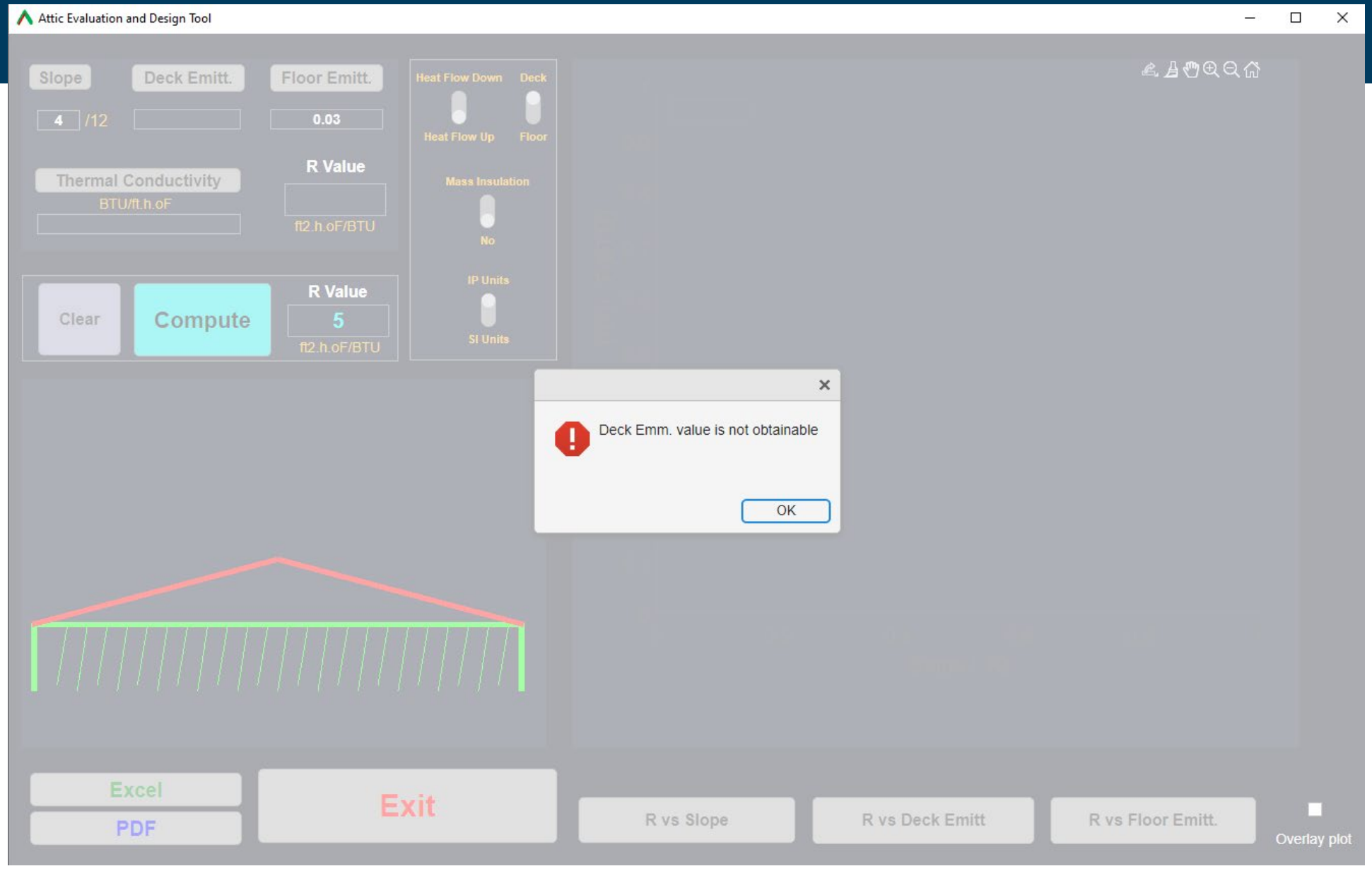
$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$

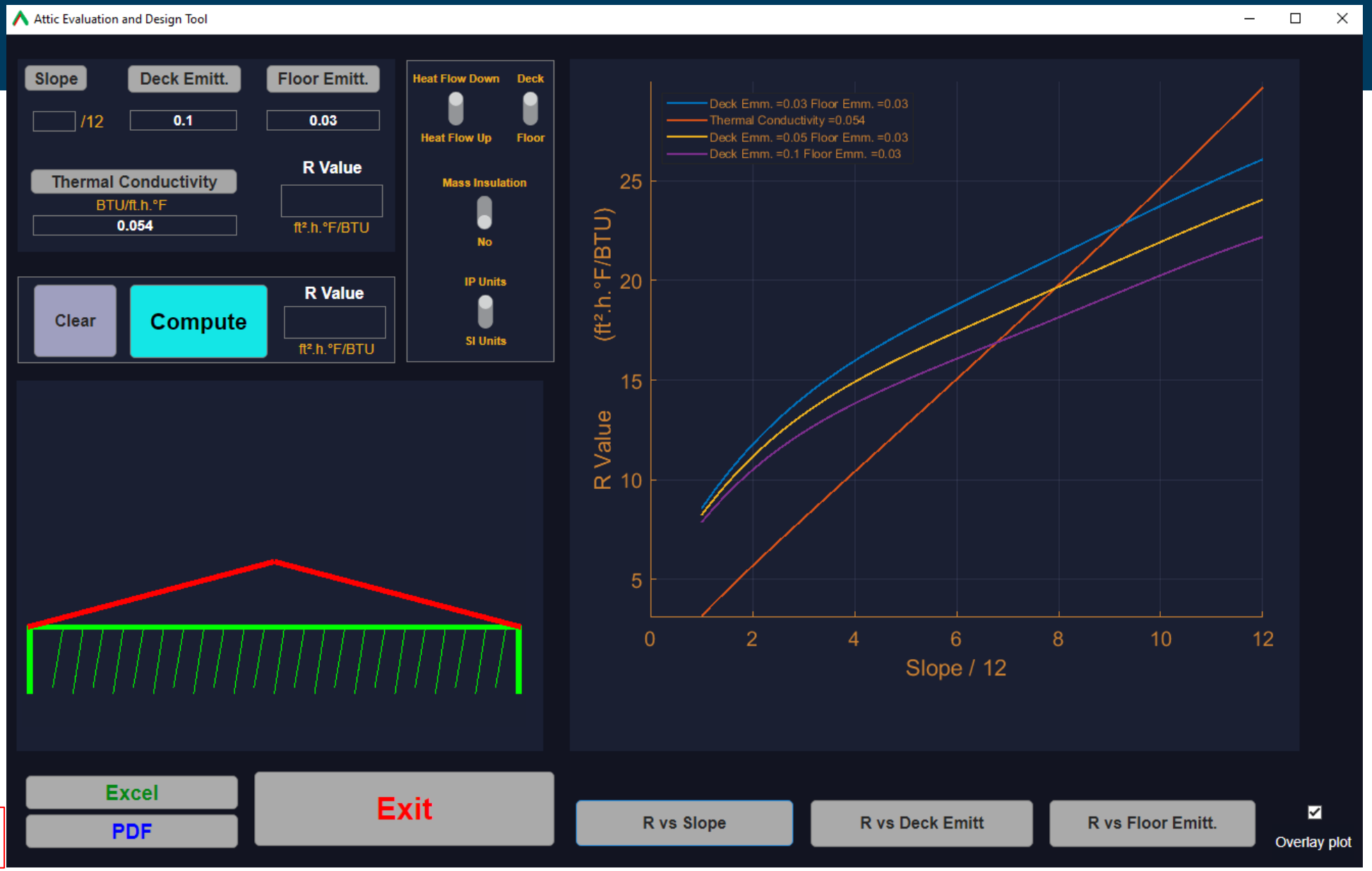


$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$

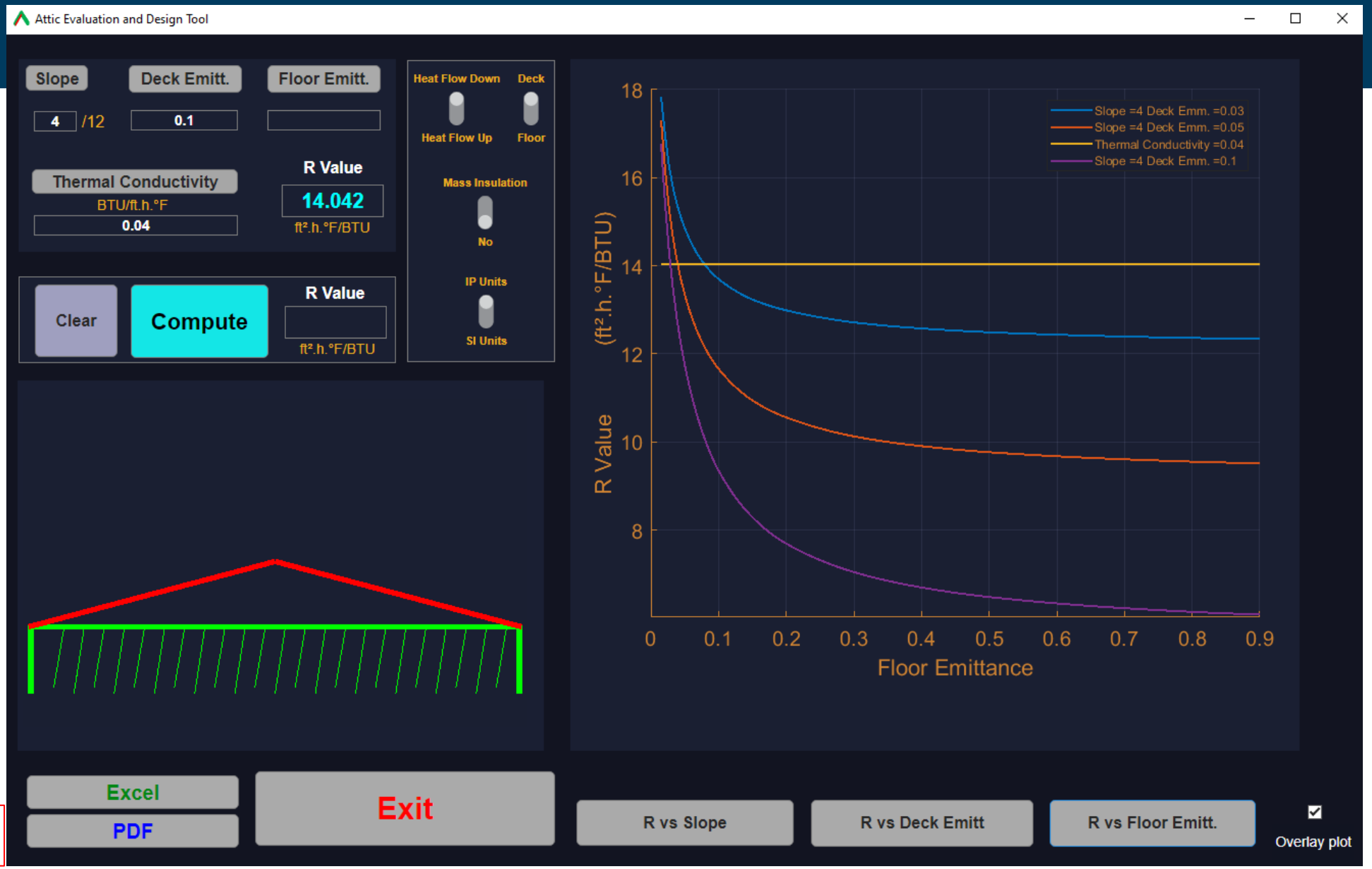


$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$

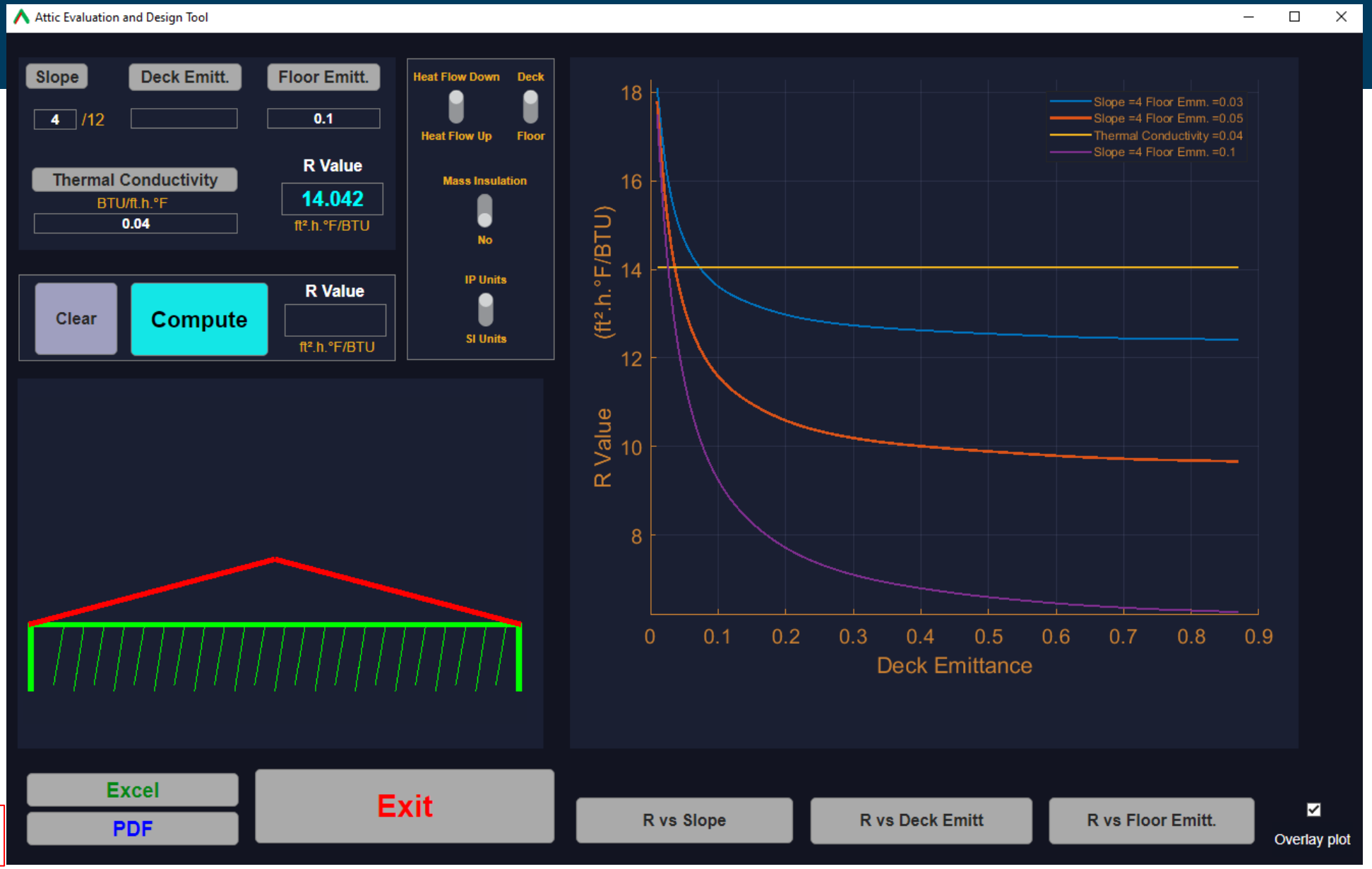

Attic Evaluation and Design Tool
Slope
Deck Emitt.
Floor Emitt.
4
/12
0.03
Heat Flow Down
Deck
Heat Flow Up
Floor
Thermal Conductivity
BTU/ft.h.oF
R Value
ft2.h.oF/BTU
Mass Insulation
No
IP Units
SI Units
Clear
Compute
R Value
5
ft2.h.oF/BTU
Deck Emm. value is not obtainable
OK
Excel
PDF
Exit
R vs Slope
R vs Deck Emitt
R vs Floor Emitt.
Overlay plot



$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$

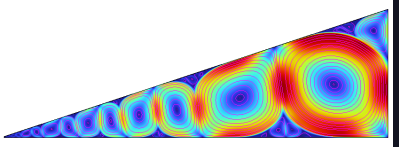


$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$



$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$

$$1\ \frac{BTU}{ft \cdot h \cdot {}^{\circ}\mathrm{F}} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot {}^{\circ}\mathrm{F}}$$



$$1\ \frac{BTU}{ft \cdot h \cdot {}^{\circ}\mathrm{F}} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot {}^{\circ}\mathrm{F}}$$

Attic Evaluation and Design Tool

Slope | Deck Emitt. | Floor Emitt.

4 /12 | 0.9

Thermal Conductivity
BTU/ft.h.°F

R Value
ft².h.°F/BTU

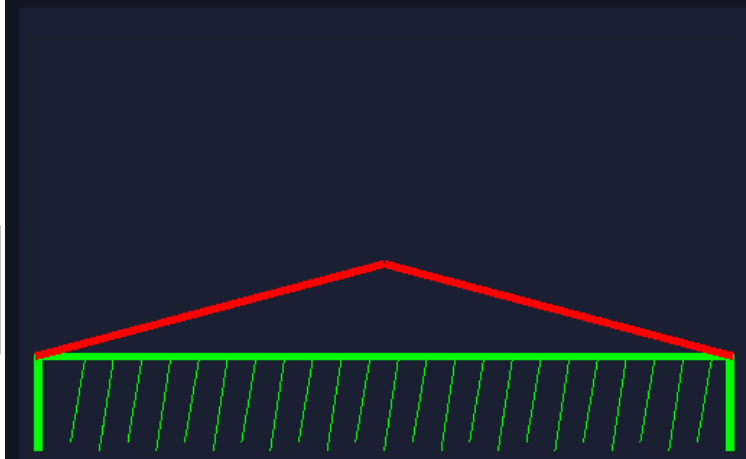
Clear | Compute

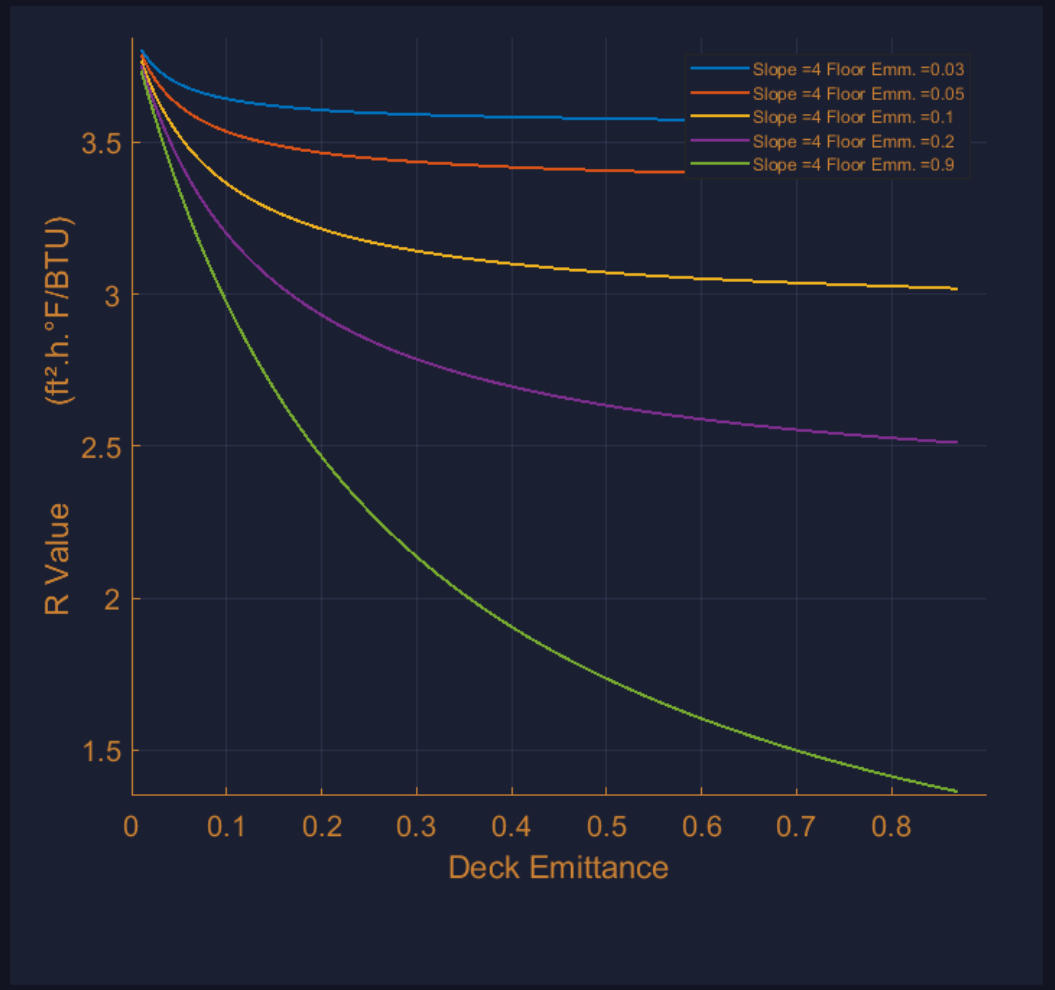
R Value
ft².h.°F/BTU

Heat Flow Down | Deck
Heat Flow Up | Floor

Mass Insulation
No

IP Units
SI Units

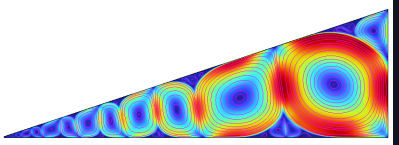




Excel | PDF | Exit

R vs Slope | R vs Deck Emitt | R vs Floor Emitt.

Overlay plot



$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$

Attic Evaluation and Design Tool

Slope | Deck Emitt. | Floor Emitt.

4 /12 | 0.9

Thermal Conductivity
BTU/ft.h.°F

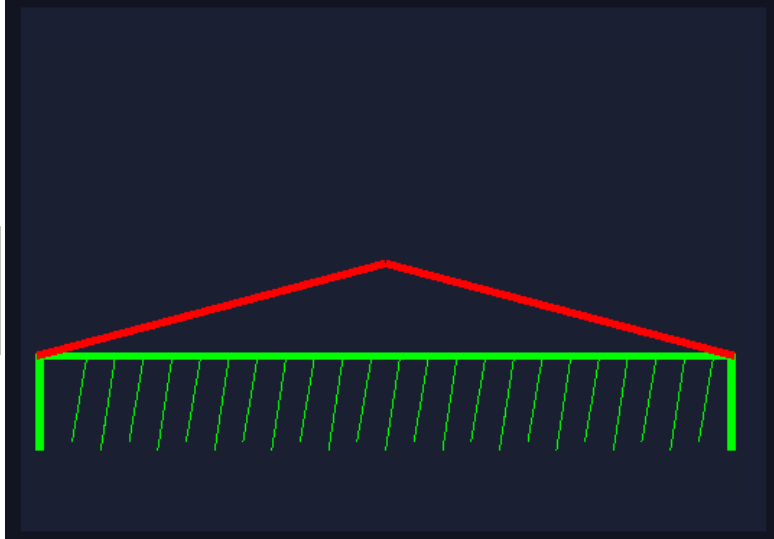
R Value
ft².h.°F/BTU

Clear | Compute | R Value
ft².h.°F/BTU

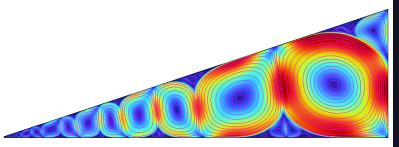
Heat Flow Down | Deck
Heat Flow Up | Floor

Mass Insulation
No

IP Units
SI Units



Excel | PDF | Exit | R vs Slope | R vs Deck Emitt | R vs Floor Emitt. | Overlay plot



$$1\ \frac{BTU}{ft \cdot h \cdot {}^{\circ}\mathrm{F}} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot {}^{\circ}\mathrm{F}}$$

Attic Evaluation and Design Tool

Slope
4 /12

Deck Emitt.
0.9

Floor Emitt.

Thermal Conductivity
BTU/ft.h.°F

R Value
ft².h.°F/BTU

Clear

Compute

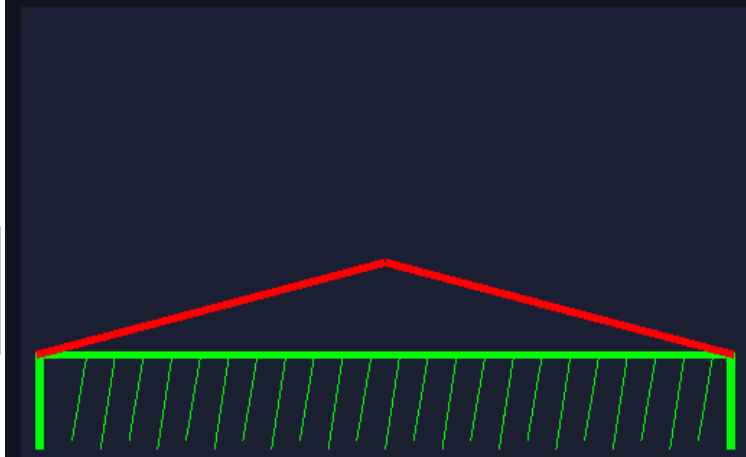
R Value
ft².h.°F/BTU

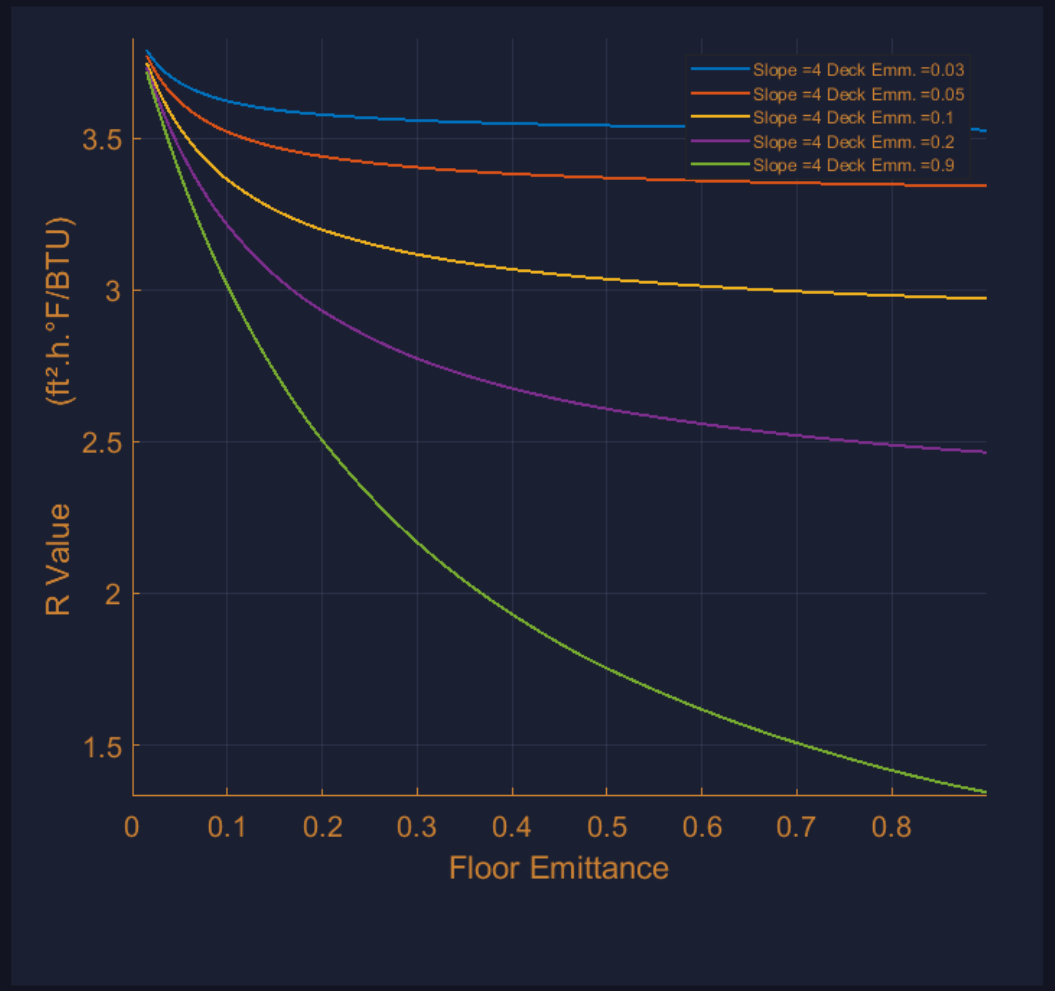
Heat Flow Down
Heat Flow Up

Deck
Floor

Mass Insulation
No

IP Units
SI Units





Excel

PDF

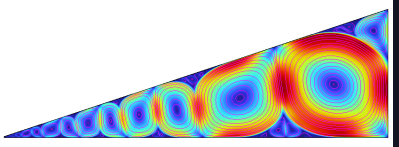
Exit

R vs Slope

R vs Deck Emitt

R vs Floor Emitt.

Overlay plot



Attic Evaluation and Design Tool

Slope | Deck Emitt. | Floor Emitt.

4 /12 | 0.9 |

Thermal Conductivity
BTU/ft.h.oF
0.057

R Value
9.855
ft2.h.oF/BTU

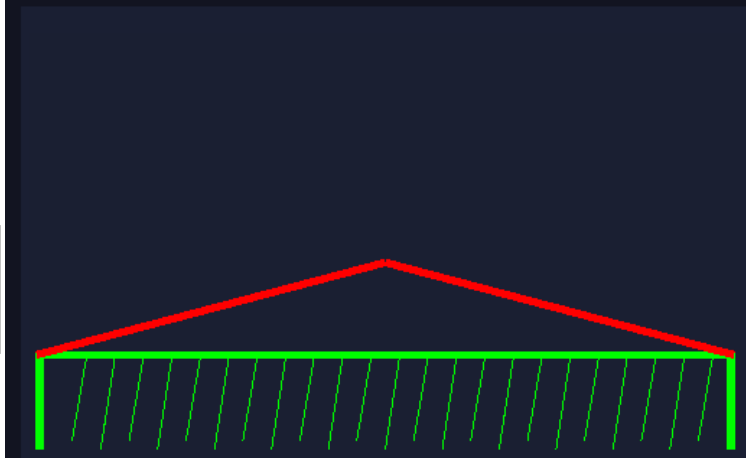
Clear | Compute

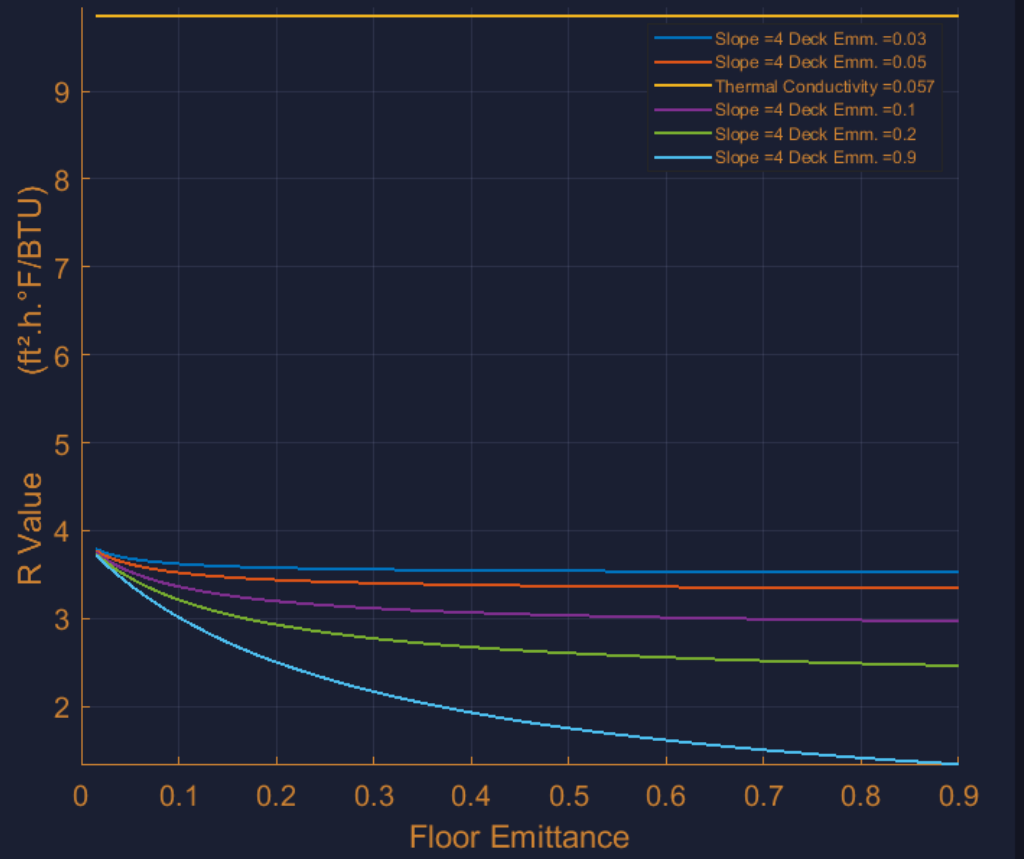
R Value
ft2.h.oF/BTU

Heat Flow Down | Deck
Heat Flow Up | Floor

Mass Insulation
No

IP Units
SI Units



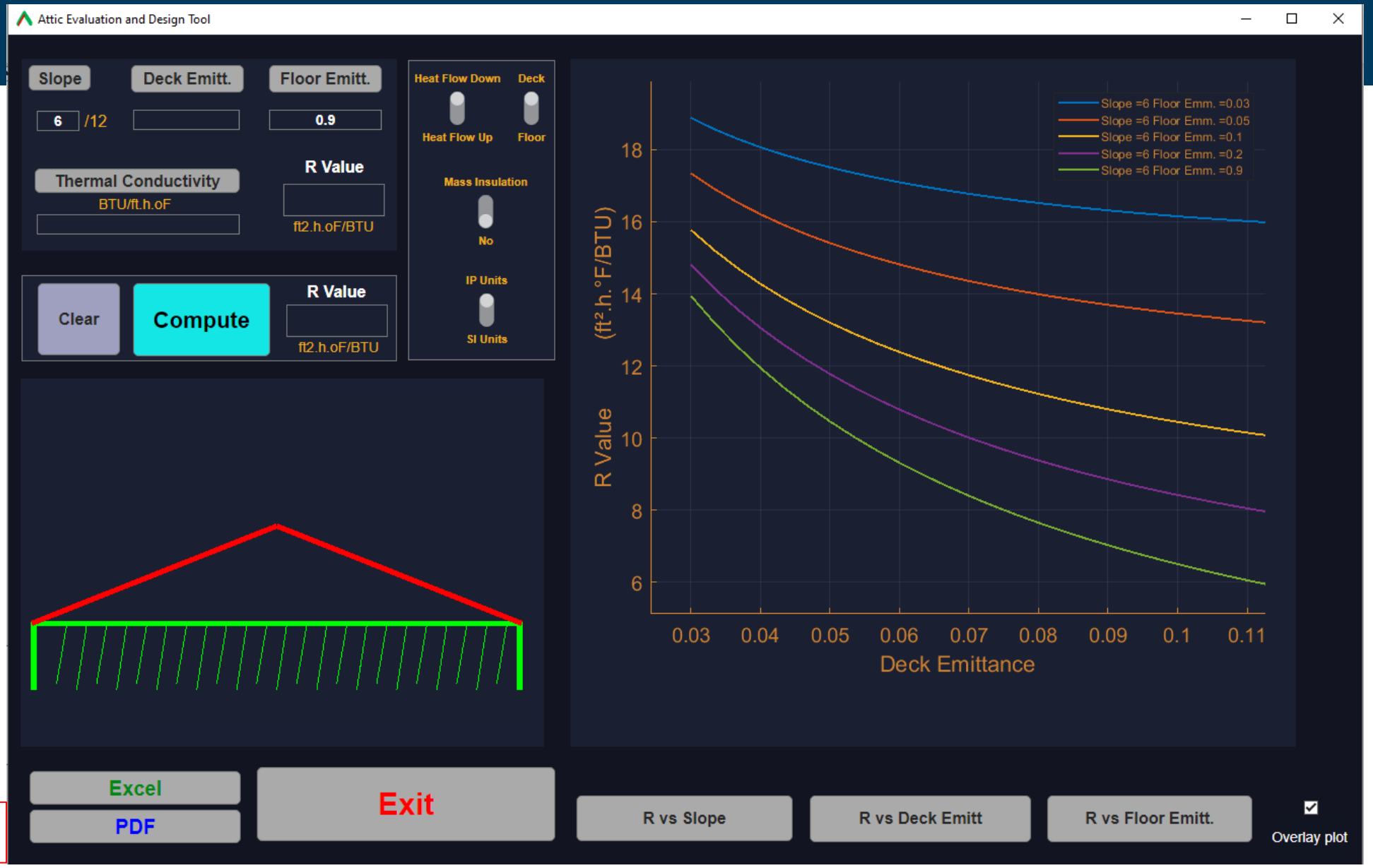


Excel | PDF | Exit

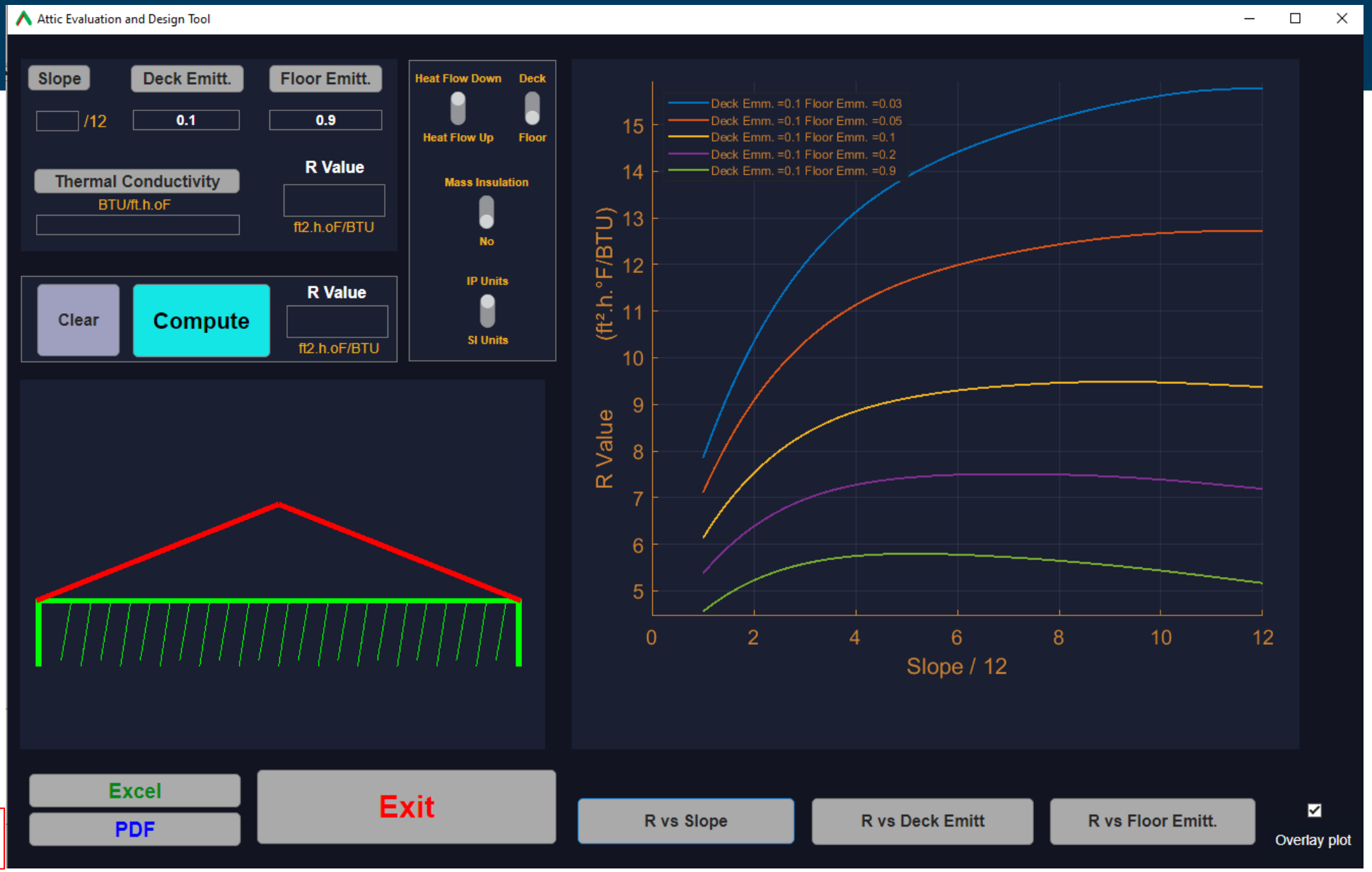
R vs Slope | R vs Deck Emitt | R vs Floor Emitt.

Overlay plot

$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$



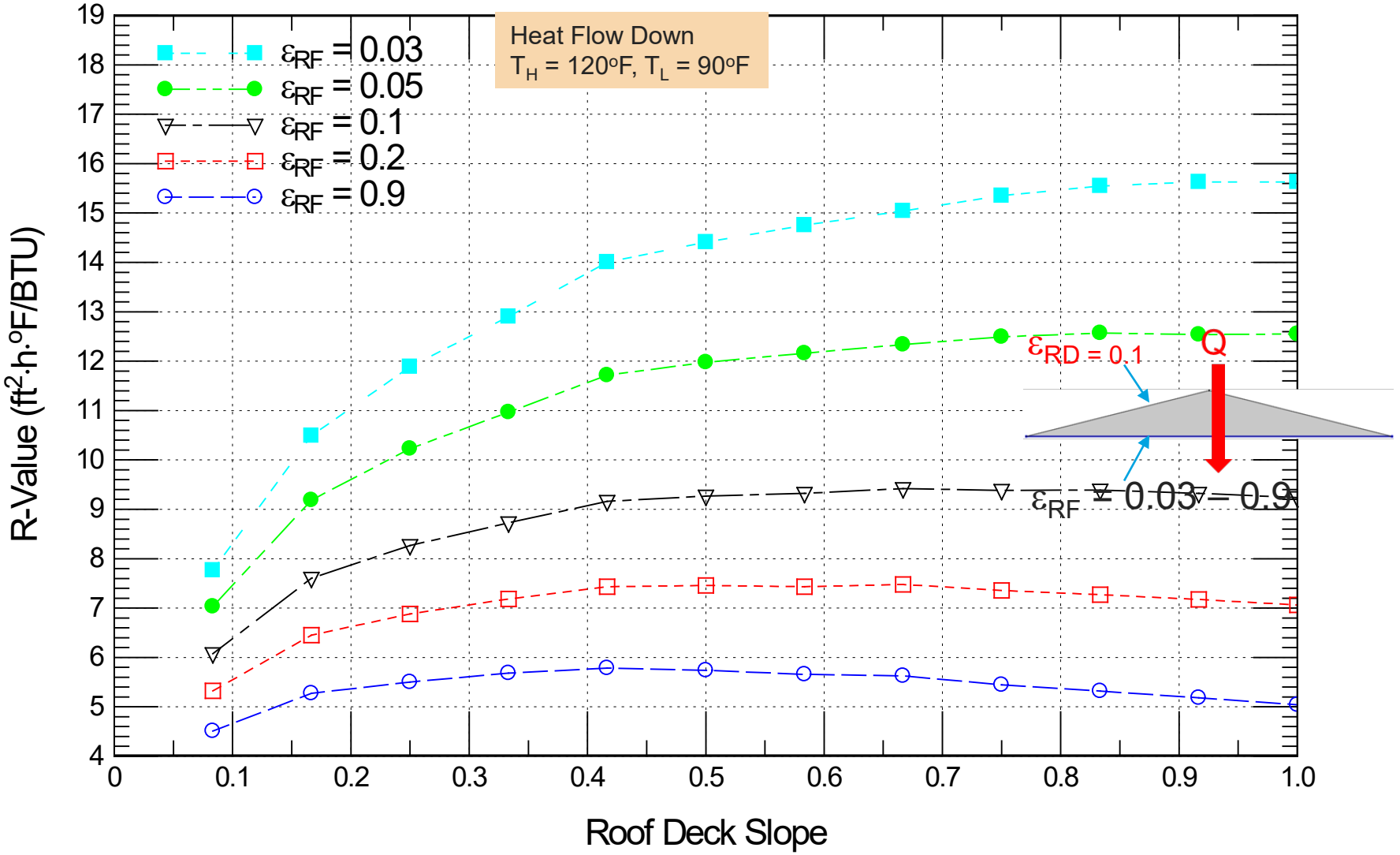
$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$



$$1\ \frac{BTU}{ft \cdot h \cdot °F} = 12\ \frac{BTU \cdot in}{ft^2 \cdot h \cdot °F}$$

Results (cont.)

Roof Deck Emittance, ε_{RD} = 0.1



SUMMARY

- Validated numerical model was used to conduct an extensive parametric study in order to determine the R-values of radiant barriers for a variety of conditions.
- Neural Network (NN) model was developed to use the results from the parametric study to develop an innovative and user-friendly evaluation and design tool, called "**Attic Tool**"
- The predicted R-values from Attic Tool and those from the parametric study by the numerical model are in good agreement within ±1.5%
- Attic Tool can be used in evaluation mode
- Attic Tool can be used in design and optimization mode

Thank You

H.H. Saber and S.A. Alshehri

Get in touch

National institute of Building Sciences
1090 Vermont Avenue NW, Suite 700
Washington, DC 20005
(202) 289-7800
nibs@nibs.org