Sustainable Housing in French Polynesia

End-semester Presentation

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Goals: Minimum for Spring Term

- **An integrated and locally sourced and/or manufactured materials solution set including, at very least:**
  - Proposed replacement for treated wood structure
  - Proposed replacement for wall infill panels
  - Proposed option for achieving a more insulative roof
- **Model existing MTR in Energy-10 and Virtual Environment**
  - Baseline model: input geometry and materials properties
  - Analysis of thermal comfort based on climate, materials, and two representative infiltration values: windows open + vents only
  - Ventilation CFD model (windows open, simplified surface temps, plus people) for two possible conditions: light wind + no wind
- **Same model with changes to inform proposed design**
  - Test addition of roof insulation (possible change to existing)
  - Test at least one possible ridge vent or cupola option
  - Modified materials set (all three changes noted above)

Latest Challenges

- Budget delays
- **Coup d’etat**
- More budget delays
- Different site shading
- New design
- Materials limitations
- Software learning curve
- Travel constraints

Progress

- **Reconnaissance trip**
  - New design
  - Materials research
- **Energy-10 model refined**
- **Virtual Environment (VE) refined**
  - thermal model
  - CFD model
- **Data collection plan**
- **Summer Planning**

Reconnaissance trip

MTR Version 2

MTR
Version 3

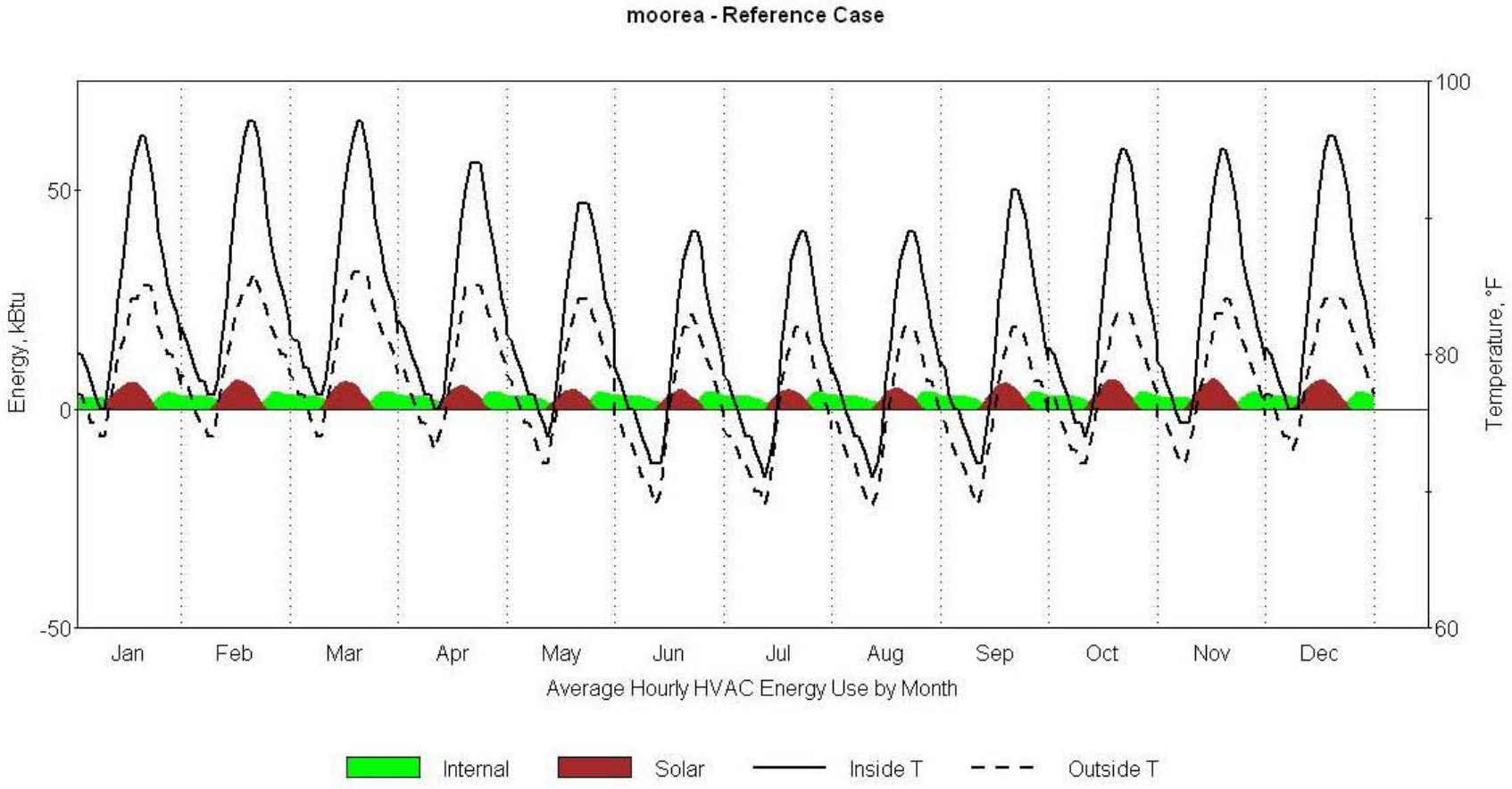
Materials Research

- **Durable**
- **Inexpensive**
- **Locally producible and sustainable**
- **Resistant**
  - Rot
  - Termites
- **Bamboo**
- **Composite materials**
  - Recycled plastic
- **High albedo metal roofing**
- **Local woods**
  - Caribbean pine
  - Coconut
  - Ironwood

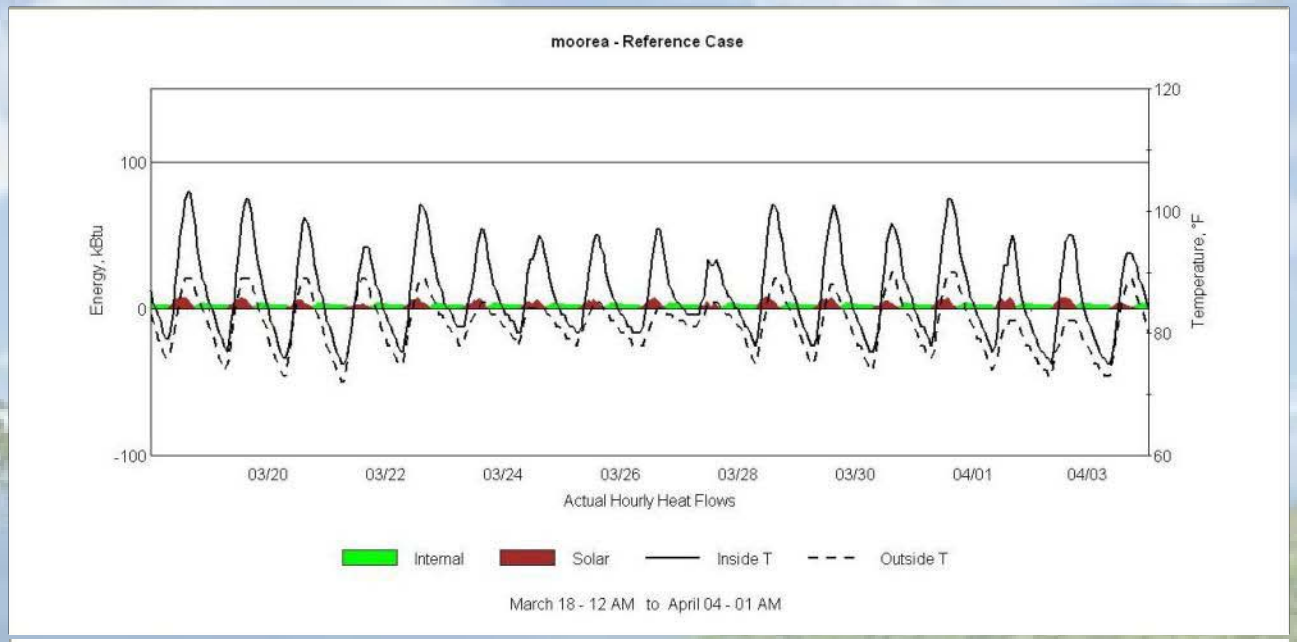
Energy-10

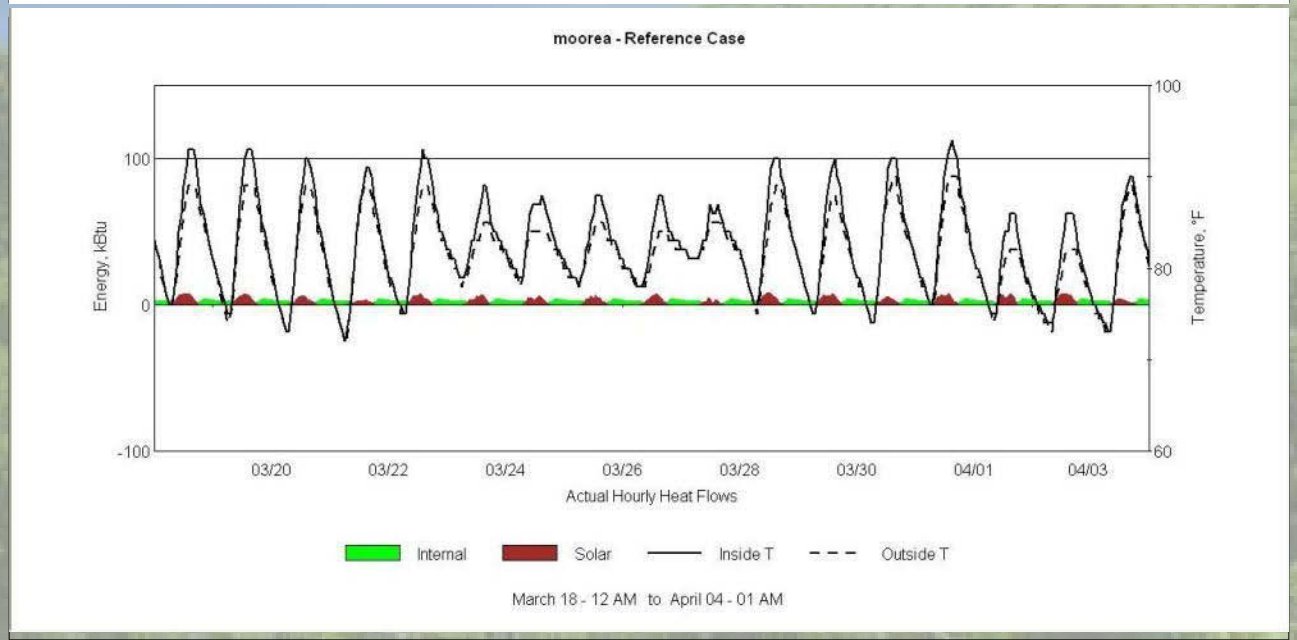
- **Problems faced:**
  - No weather file
  - Must choose an HVAC system
  - Limited natural ventilation capabilities
  - Most material constructions not in the library
- **Lessons learned from trip:**
  - Internal loads (e.g. showers, cooking)
  - Construction details (e.g. roof)

Annual Data, 3ACH



3ACH vs. 43 ACH





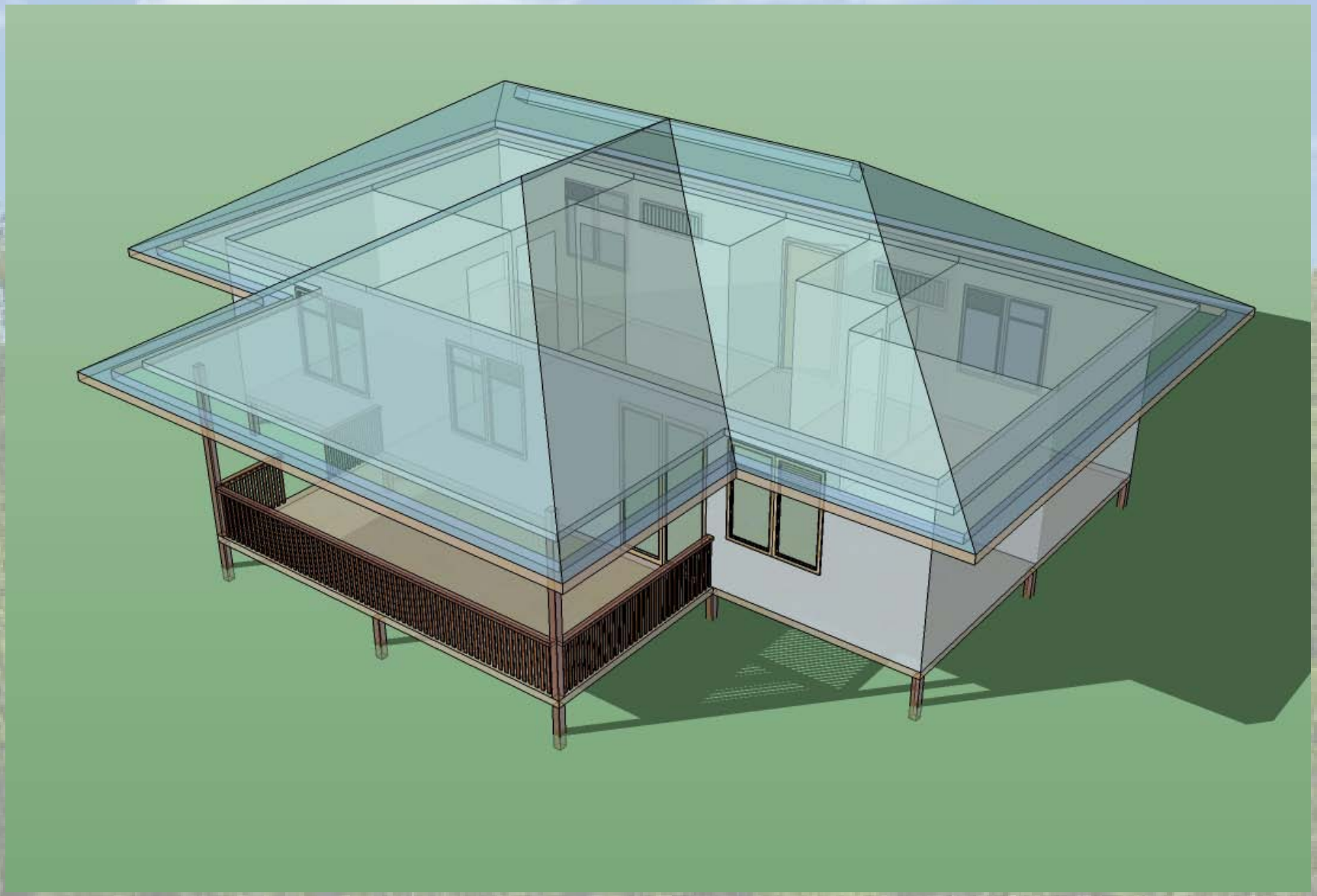
Dynamic Simulations

- **Current house modeled under various conditions**
  - Moderate cloud cover with low wind
    - <2.2 mph (<1 m/s)
  - No cloud cover with relatively high winds
    - ~11 mph (~5 m/s); ~6% of hours in typical year
- **Simple modifications simulated indicate potential for improvement**
- **Better optimized design within reach**

Modeling and Simulation Methods

- **Realistic inputs**
  - Building & site orientation* (matched to actual site)
  - Accurate material properties
  - Window and door openings according to usable area
  - Shading: large roof overhangs and covered porch
  - Open-air crawlspace
  - Soffit vents (substantial openings in roof overhang)
  - Internal loads: 4 people, small fridge, minimal lights
- **Optimization Approach**
  - No mechanical ventilation or air conditioning
  - Reduce solar gain (roof and windows)
  - Enhance natural ventilation

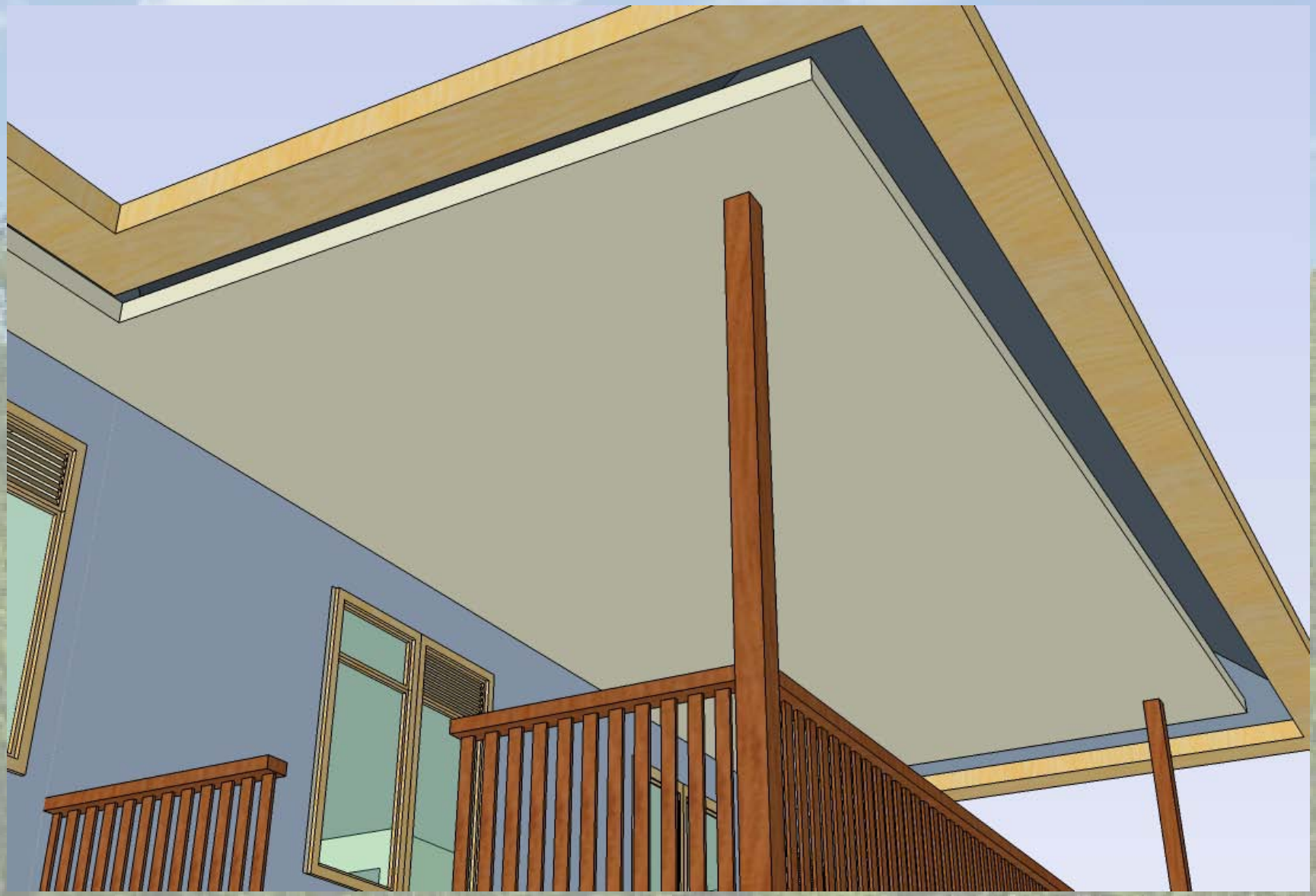
Existing MTR Design – Metal Roofed Cottage



Existing MTR Design – Divided Interior

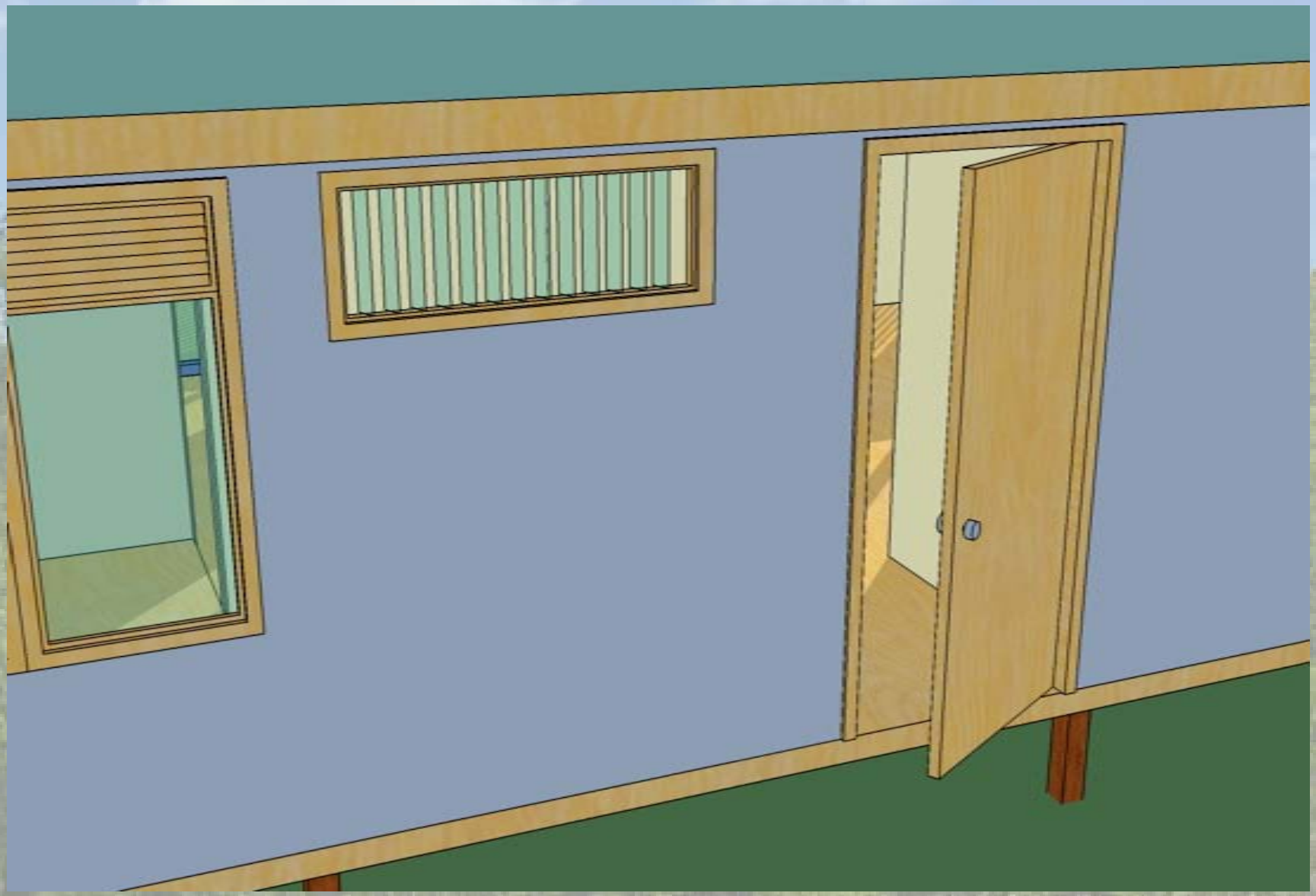
Existing MTR Design – Overhang & Airflow

Existing MTR Design – Large Soffit Vents

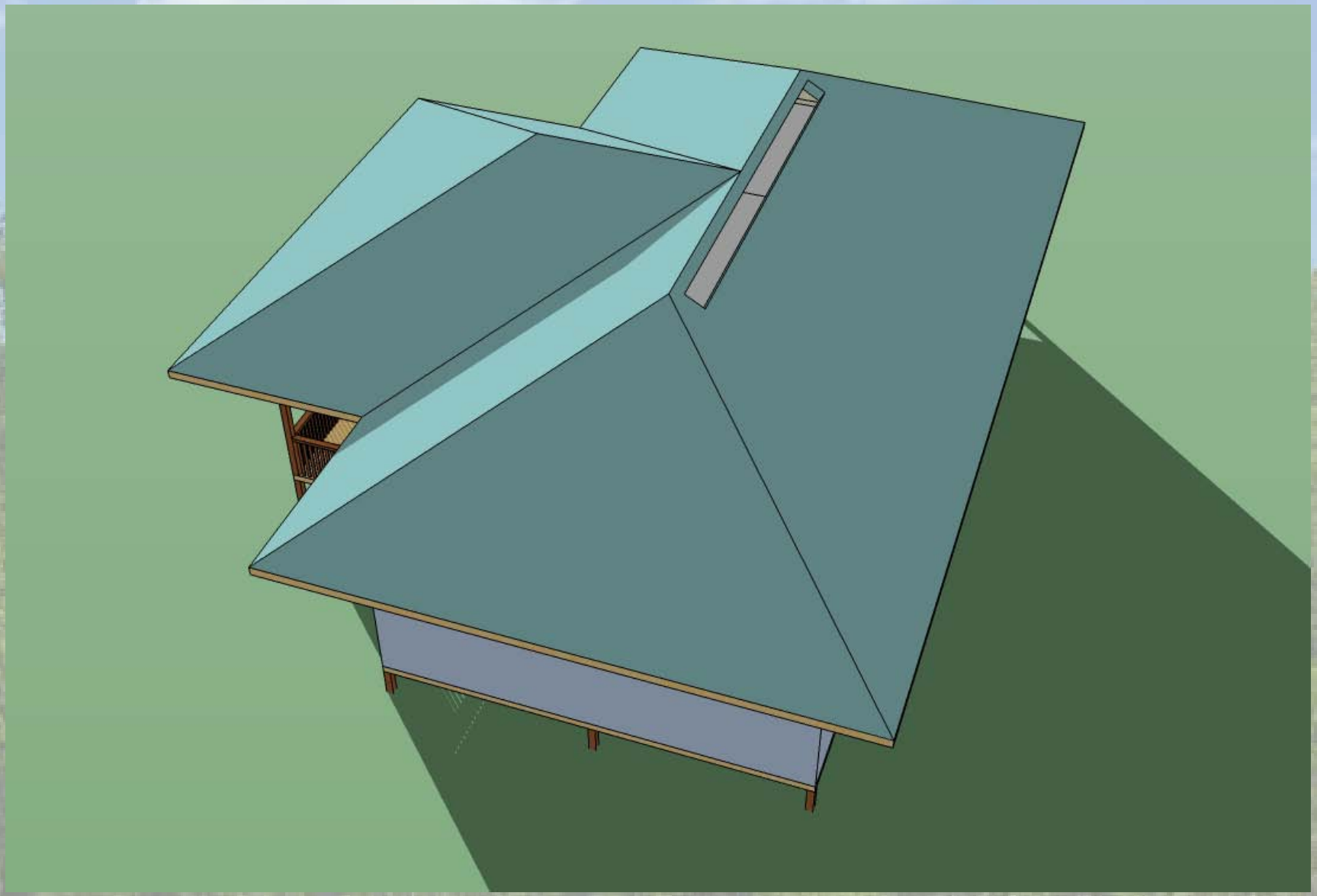


Existing MTR Design – Sliders & Louvers

Existing MTR Design – Back Door & Jalousie

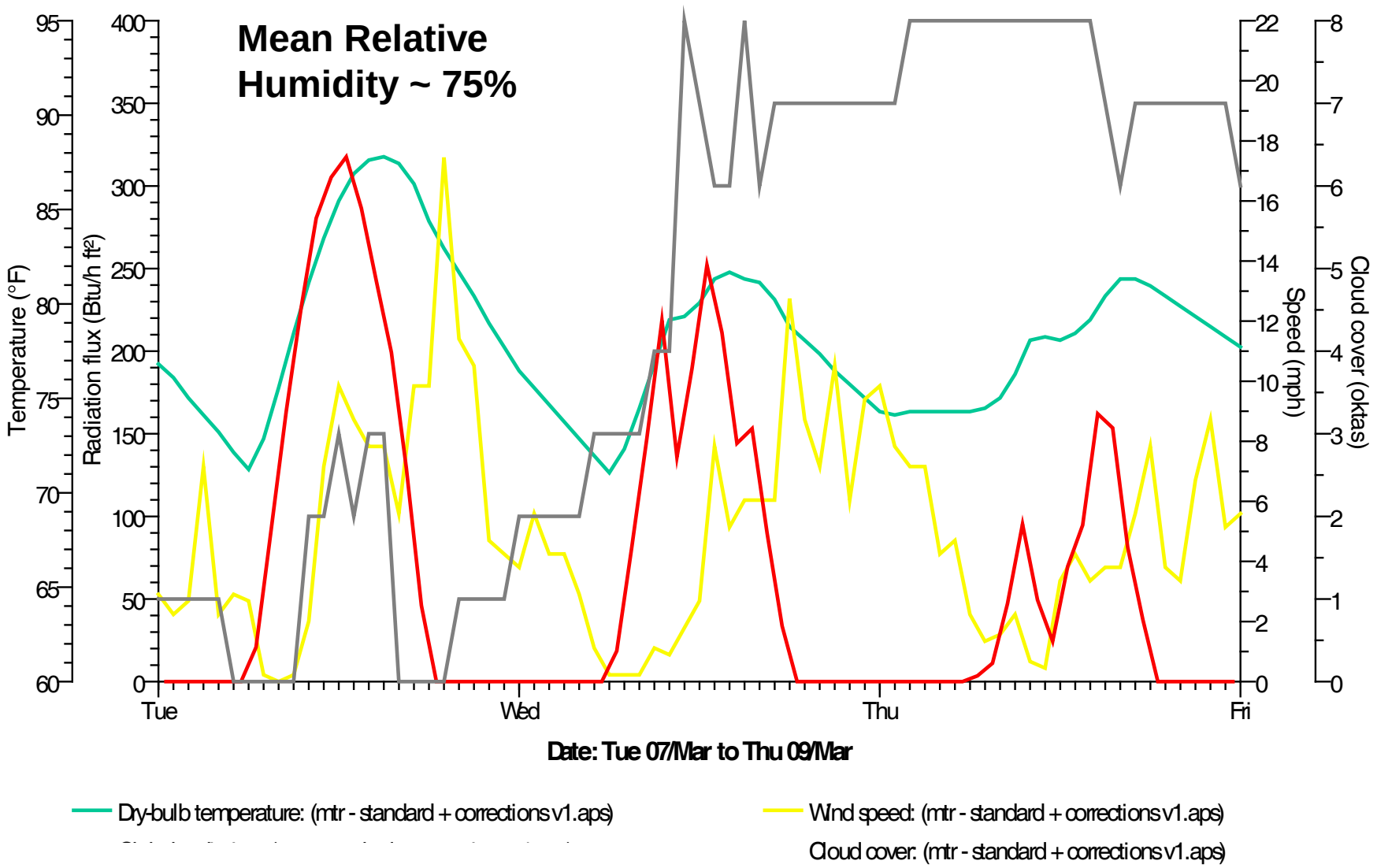


Existing MTR Design – Ridge Vent Tested



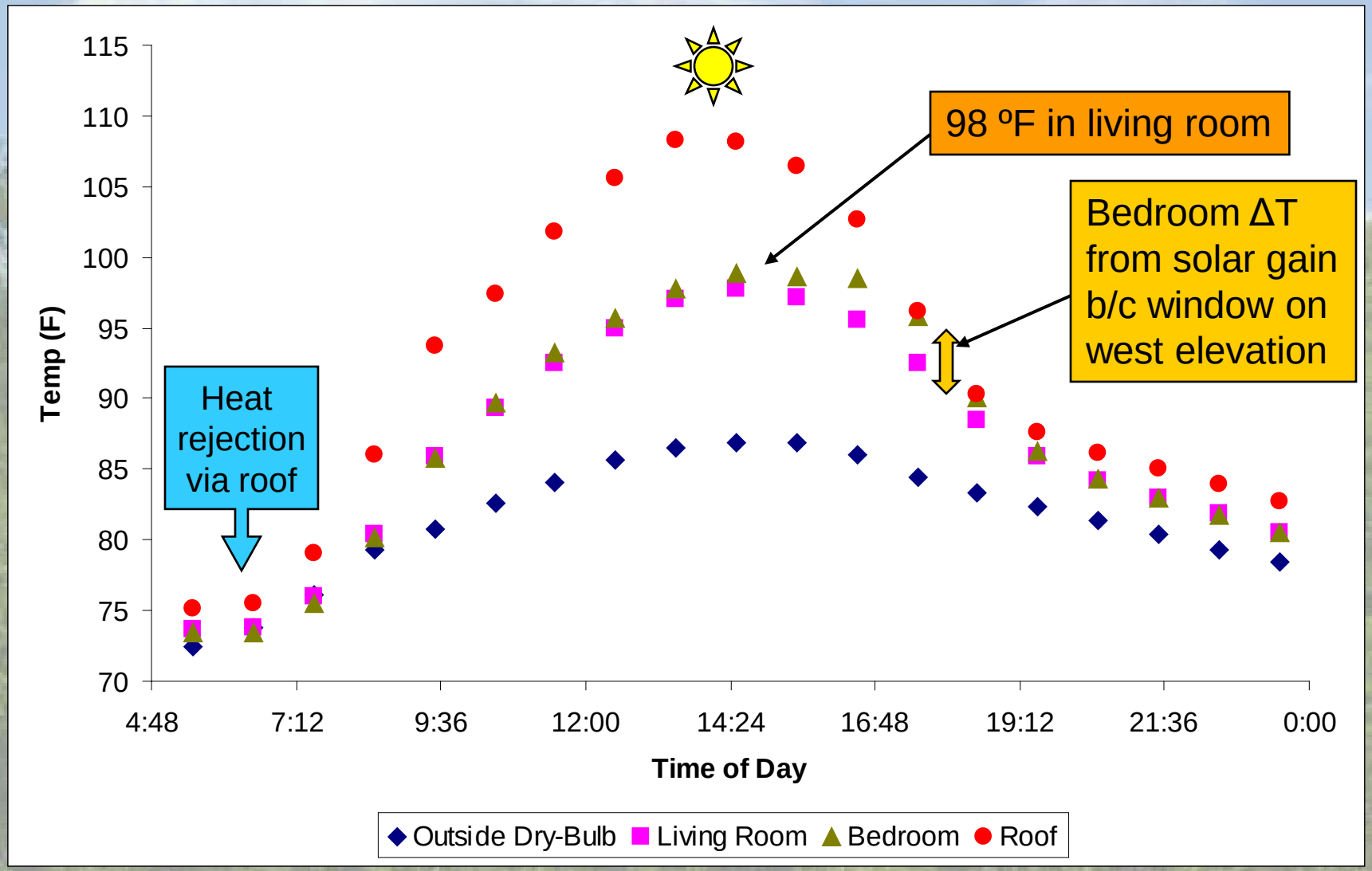
Existing MTR Design – Solar Shading

Typical Weather According to Data Set



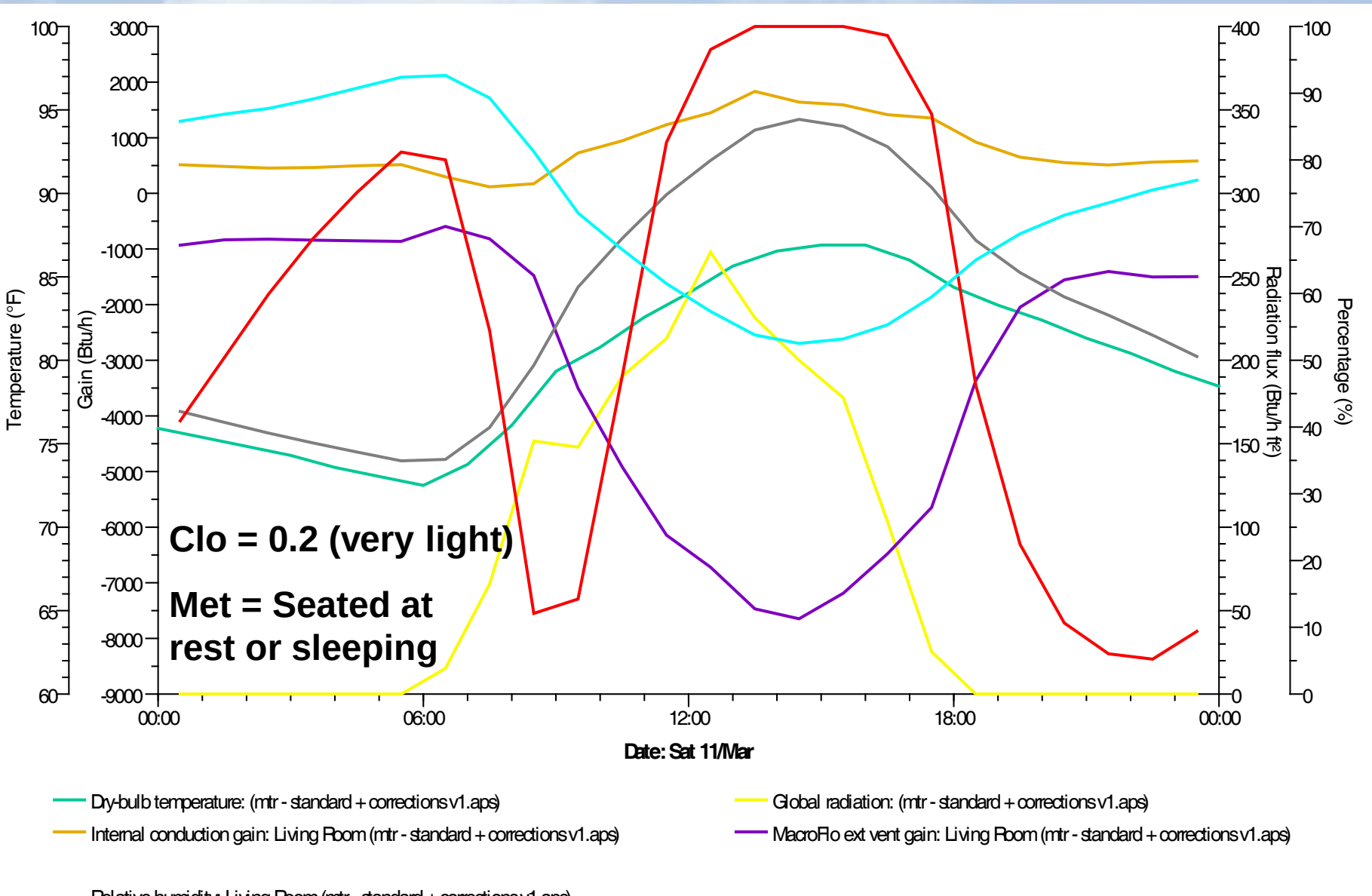
MTR Behavior

– Late Summer Day with Low Wind and Moderate Cloud Cover



Thermal Comfort

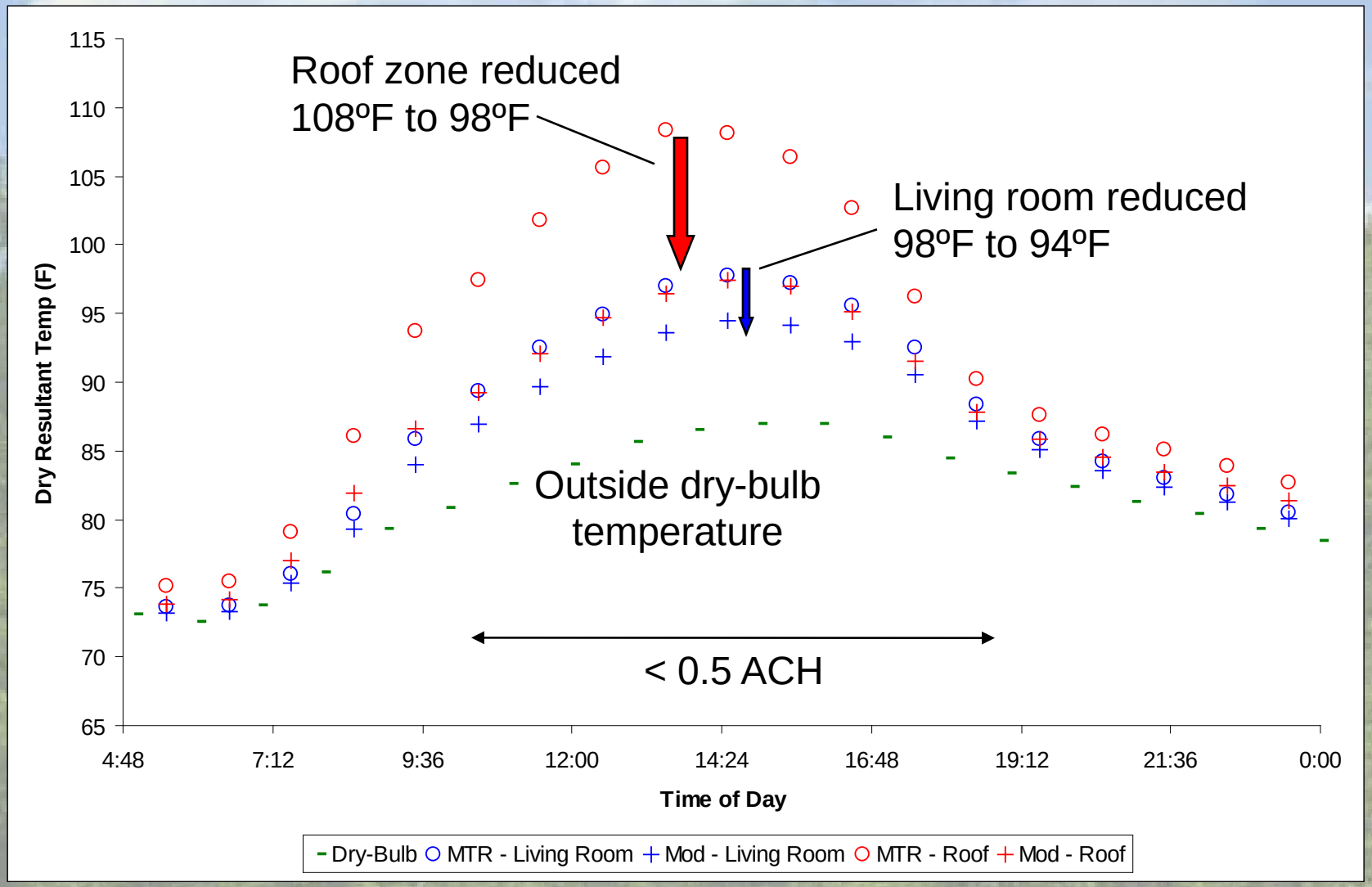
– Late Summer Day with Low Wind and Moderate Cloud Cover



MTR with Changes:

Larger Window, Roof Vent, Reflective Roof, Open Ceiling

– Low Wind and Moderate Cloud Cover



Simulation Results for MTR Modifications

– Low Wind and Moderate Cloud Cover

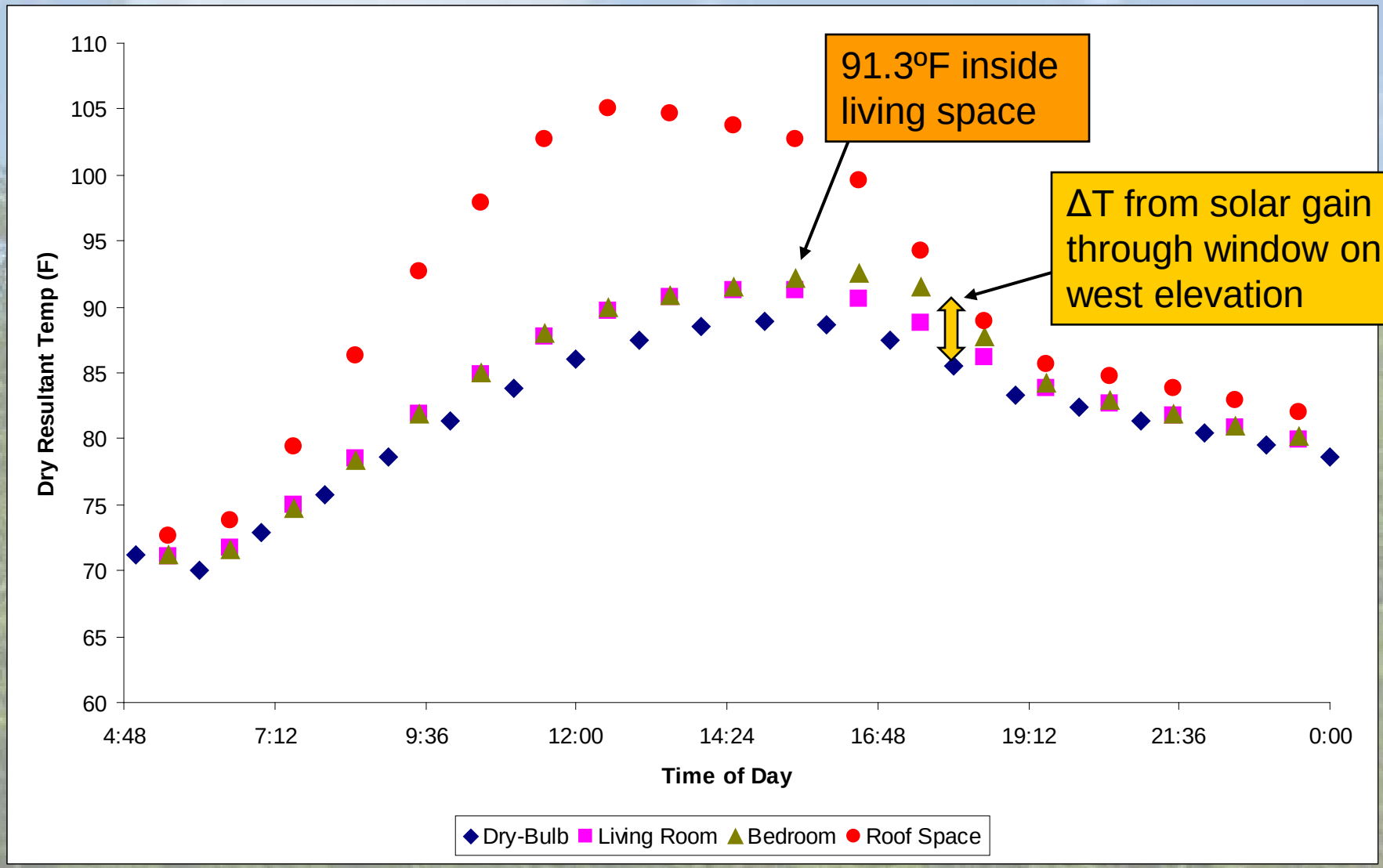
Outside Dry-Bulb Temperature: 86.7ºF

Change to Model	1	2	3	4	5	6	7	8	9
MTR currently	**X**								
Larger Window Openings		**X**			**X**	**X**	**X**		**X**
Reflective Roof Coating			**X**			**X**	**X**		**X**
Roof Vent				**X**	**X**	**X**	**X**		**X**
Vents btw occupied rooms and roof space								**X**	**X**
No Internal Partitions							**X**		
Resulting Max Temp.	**97.7**	**96.9**	**96.7**	**95.6**	**96.0**	**94.4**	**94**	**93.4**	**93.2**
% Lowered*		7.27	9.09	19.1	15.5	29.1	33.6	39.1	40.9

*normalized to outside dry-bulb temperature (*i.e.*, % inside-to-outside ΔT)

MTR Behavior:

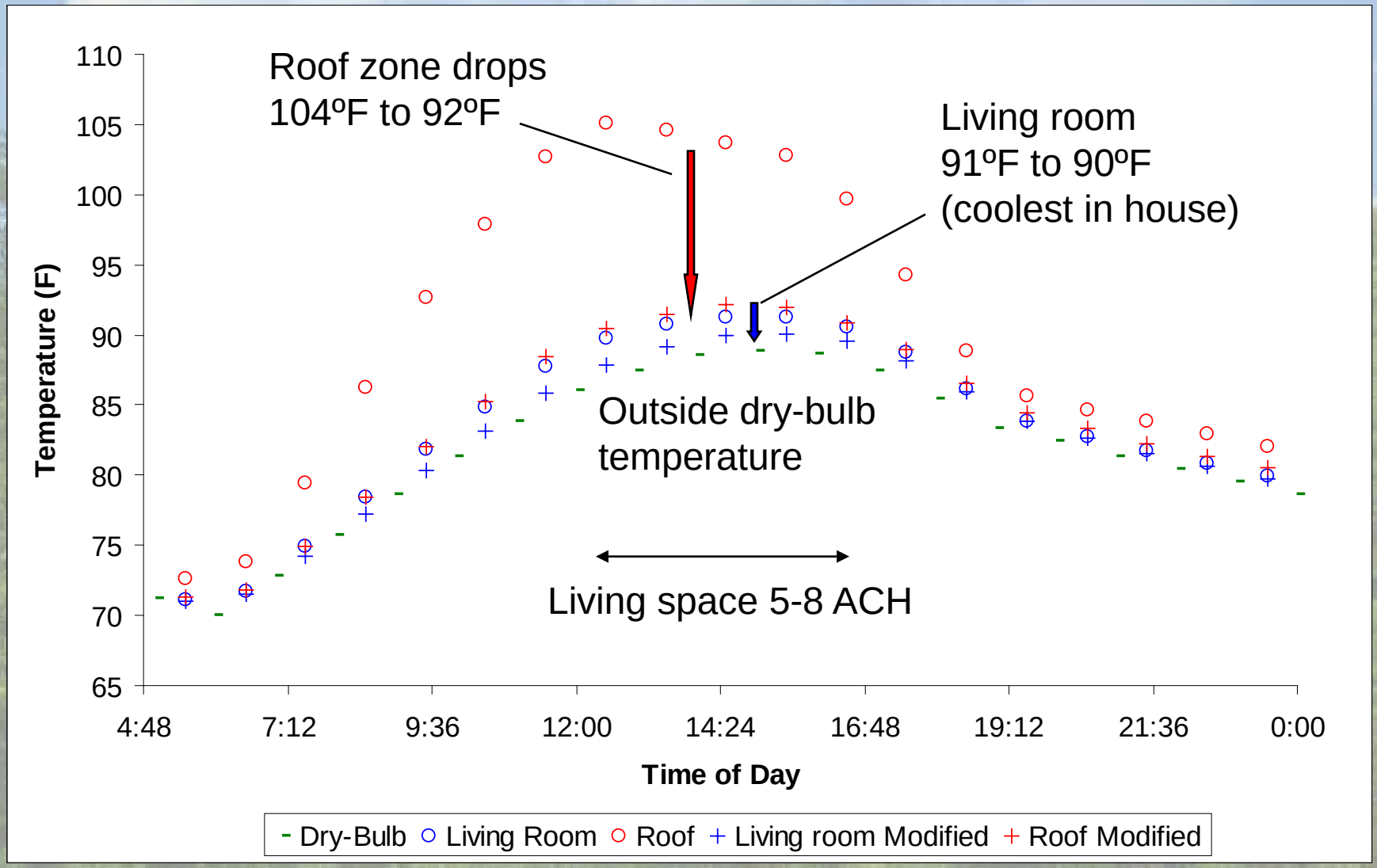
– Relatively High Winds and Very Little Cloud Cover



MTR with Changes:

Larger Window, Roof Vent, Reflective Roof, Open Ceiling

– Relatively High Winds and Very Little Cloud Cover



Simulation Results for MTR Modifications

– Relatively High Winds and Very Little Cloud Cover

Outside Dry-Bulb Temperature: 88.9ºF

Change to Model	1	2	3	4	5	6	7	8	9
MTR currently	**X**								
Larger Window Openings		**X**			**X**	**X**			**X**
Reflective Roof Coating			**X**			**X**	**X**	**X**	**X**
Roof Vent				**X**	**X**	**X**	**X**	**X**	**X**
Vents btw occupied rooms and roof space								**X**	**X**
Wall openings btw rooms							**X**		
Resulting Max Temp.	**91.3***	**91.1**	**91.0**	**91.0**	**90.9**	**90.8**	**91.0**	**90.2**	**90.1**
% Lowered**		8.3	12.5	12.5	16.7	20.8	12.5	45.8	50.0

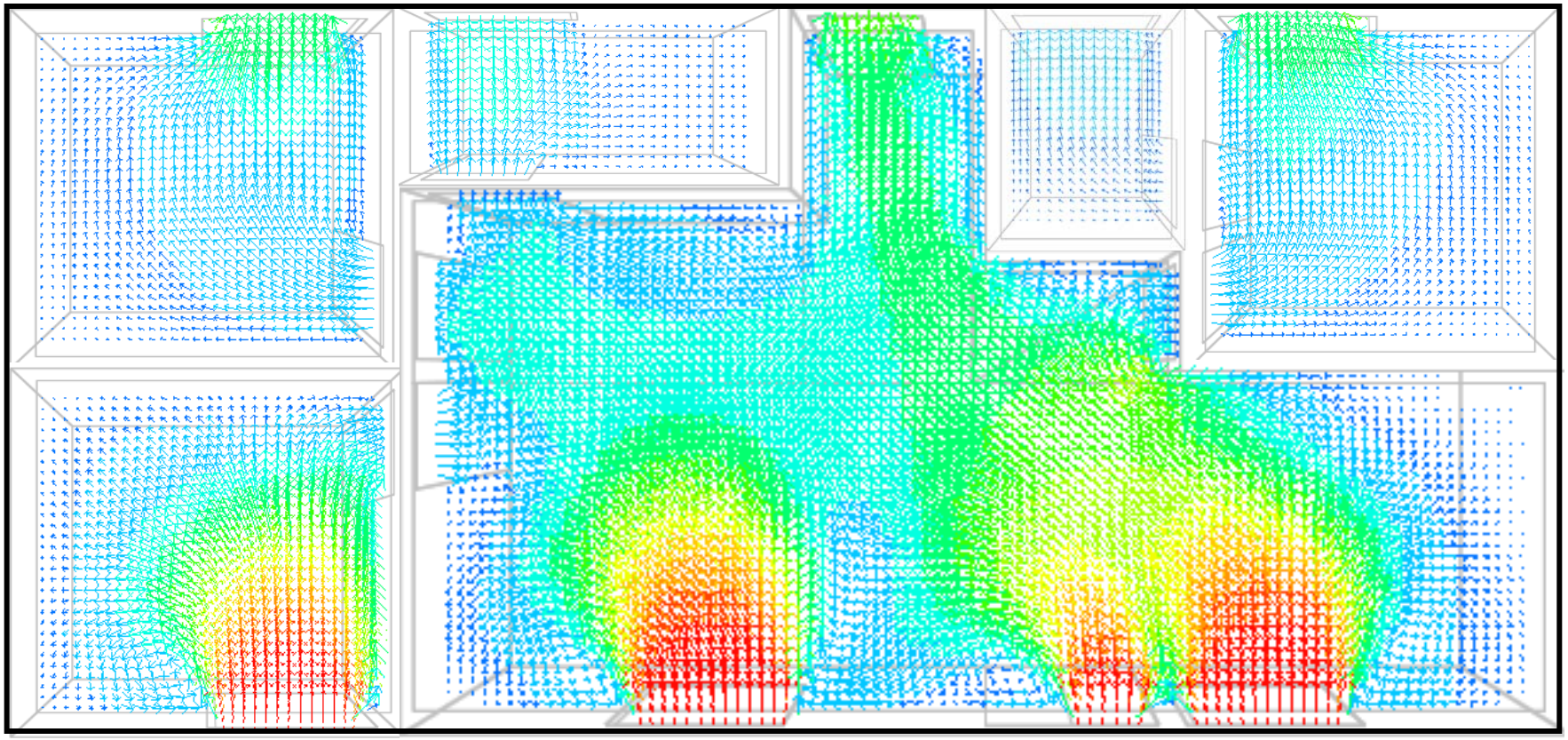
* Temperature in living room, the highest flow room in floor plan (CFD results)

**normalized to outside dry-bulb temperature (*i.e.*, % inside-to-outside ΔT)

MTR with Changes:

Larger Window, Roof Vent, Reflective Roof, Open Ceiling – Higher Winds and Very Little Cloud Cover Case

- **Many stagnant air spaces exists even under high flow conditions**
- Slice at 5’ height



Next Steps…

Spring semester

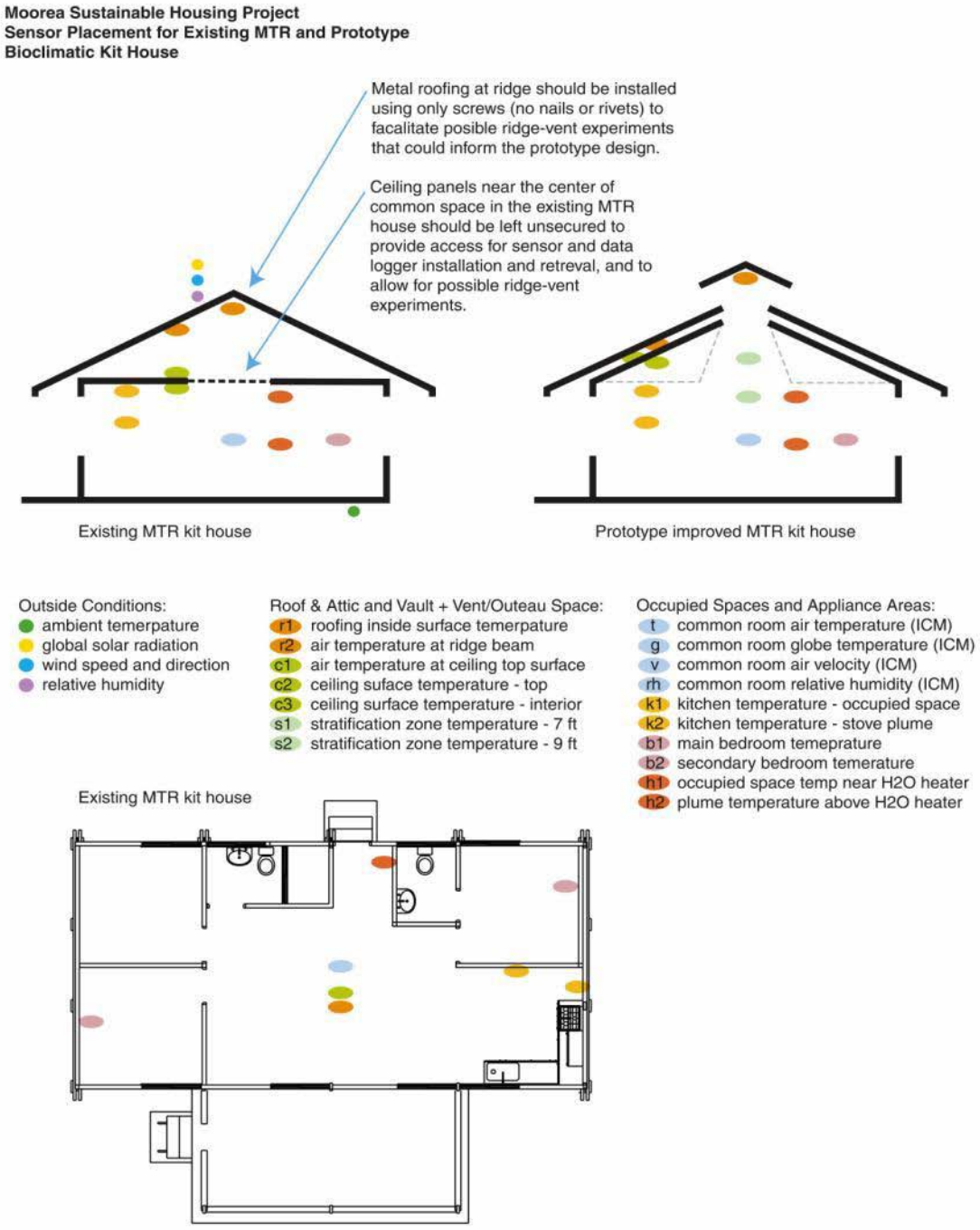
- Thoroughly analyze simulation results
- Compile modification recommendations for current MTR owners based on their microclimate
- Write report

Summer

- Calibrate model with built prototype
- Test design approaches
- Design new house to fit climate and cultural lifestyle
  - Modular to fit to lot shape, minimize solar gain, and utilize wind

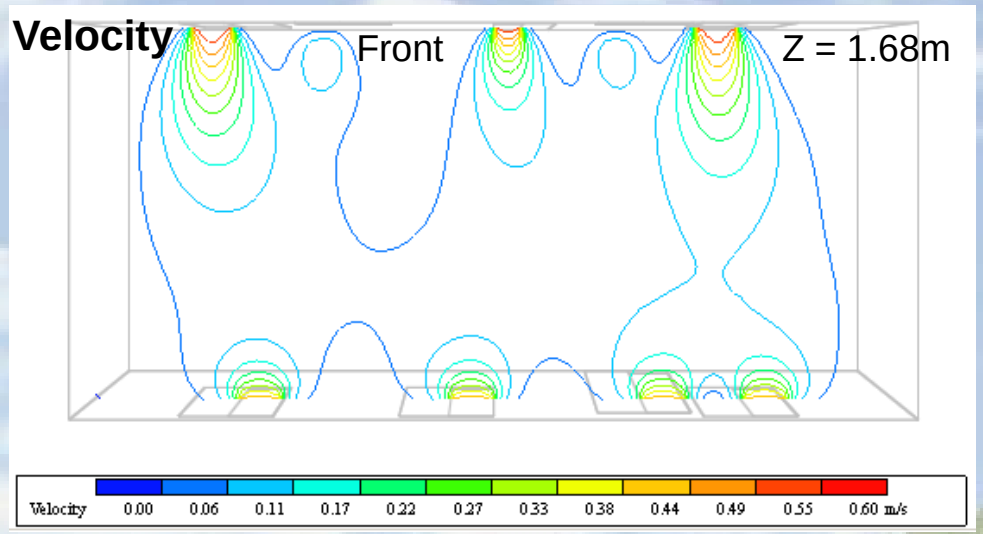
Testing

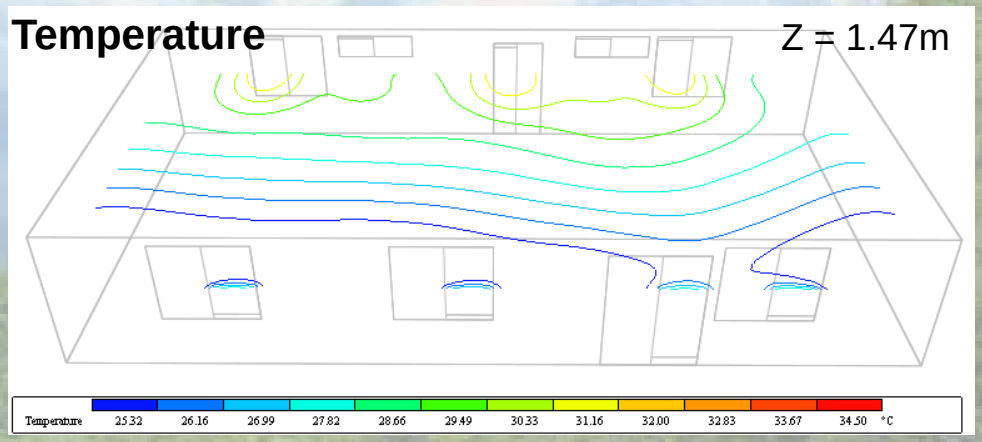
- **Sensors and data loggers**
- **Calibrate model**
- **Test changes to existing MTR**
  - Actual
  - Virtual
- **Test strategies for new design**

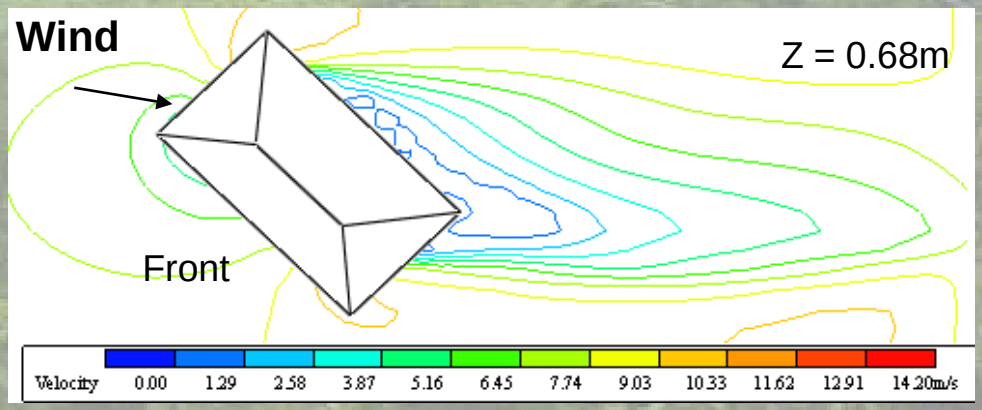


VE CFD Model

- **Uncover opportunities**
- **Assess proposed designs**
- **Inform possible options for modularity**
- **Inform kit instructions for best sites and orientation per microclimate**

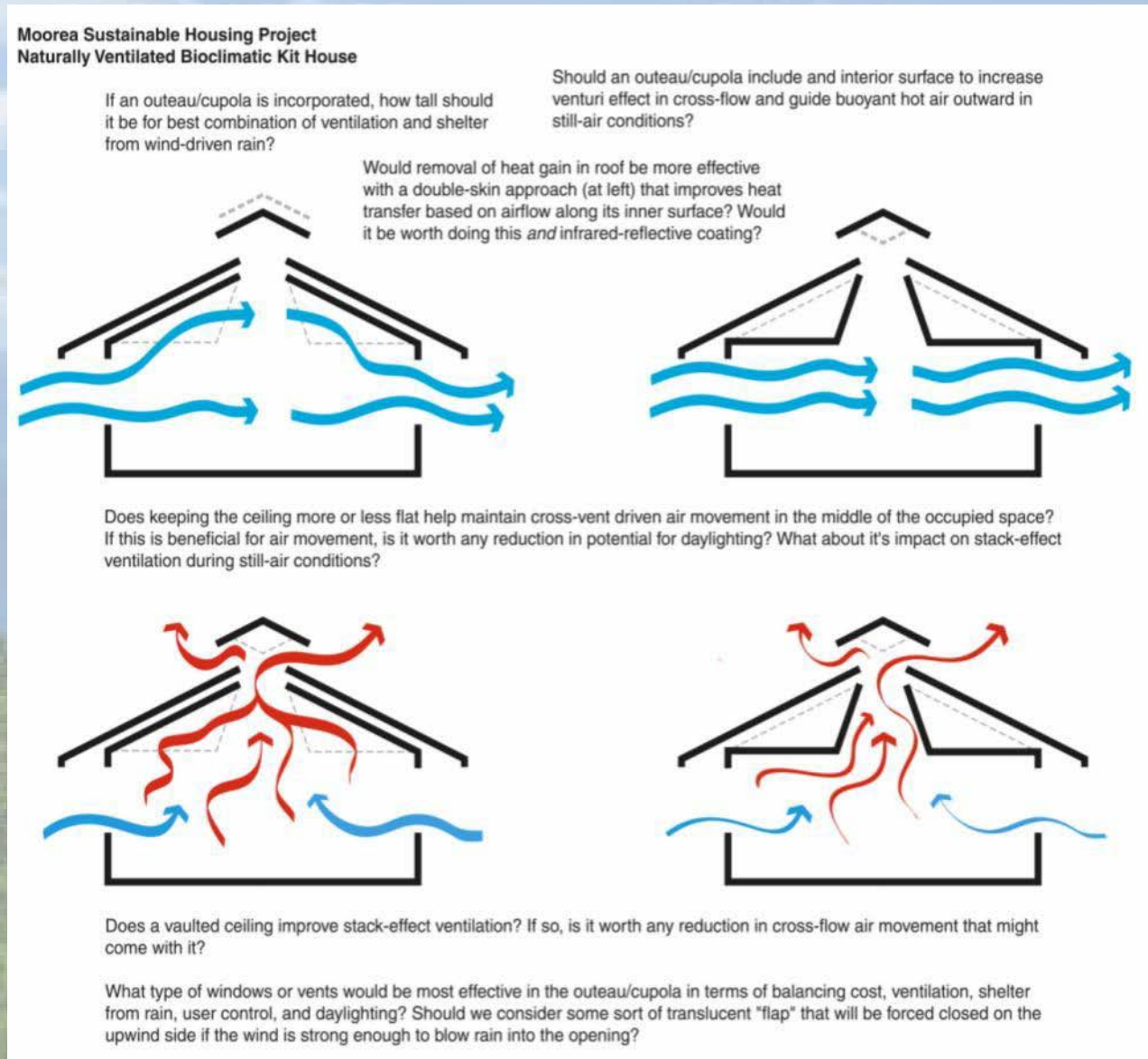






Design Strategy Development

- **Re-design for better natural ventilation**
- **Vent waste heat from refrigerator**
- **Closer look at high-albedo & “double-skin” roof options**
- **Evaluate nighttime pre-cooling with thermal mass**



Main Project Objectives*

- **Learn from monitoring of current MTR kit house**
- **Design a new bioclimatic MTR house**
  - More local resources
  - More affordable
  - Energy efficient
  - Improved comfort
- **Construction and monitoring of the new prototype**
- **Economic and ecological comparison**

***Objectives for <u>overall</u> project, not just UC Berkeley team**

Summer Planning

ACTION	trimestre A			trimestre B			trimestre C			
	april	may	june	july	august	september	october	november	december	january
construction of mtr on Te Pu Atitia site										
computor simulation of existing mtr model	UCB									
installation of probes and data analysis		UCB								
development of questionnaire/questionning period										
progress report										
materials research (meetings with entire team TBD)			UCB		UCB?					
prototype design										
analysis of hypotheses and sucessive simulations		UCB	UCB	UCB						
discussions/critiques				UCB						
progress report										
construction documents										
construction of bioclimatic prototype					UCB?					
installation of probes and data analysis of prototype							UCB??			
data analysis (wet season) for existing mtr and protoype									UCB	
progress report										
preparation of final document: comparison & conclusions									UCB	
submission of ecological assessment/final document										
demounting of existing mtr										
landscaping and further analysis of prototype possible										

Acknowledgements

French Polynesia

- **Bruno and William: FP Ministry Equipment**
- **Hinano Murphy: Association Te Pu Atita - cultural consultants**
- **Madelaine Fava: Tropical Architecture - architectural plans, project management**
- **Neil Davies: UCB Gump Station - administrative coordinator and scientific consultant**

UC Berkeley

- **Ashley Murray and Kate Huck: Teaching Assistants**
- **Ashok Gadgil: UCB Professor**
- **Ed Arens: UCB Professor - our advisor**
- **Design for Sustainable Communities class**


Questions?

Goals: Optimal for Spring Term

In addition to minimal goals…

- **Baseline survey of owner experience of the existing MTR**
  - Administered by locals incorporating input on questions from us
- **Materials**
  - Confirmation that proposed materials are sufficiently available
  - Confirmation that proposed materials/structural systems are locally producible or manufacturability
  - Confidence the new materials/systems are structurally appropriate
  - Approximate first attempt at LCA
- **Modeling**
  - Additional geometry or design strategies tested for comparison
  - LCC analysis (req. utility rates + assumptions re: use of fan or AC)
- **Quantification of economic impact**
  - Approximate change in costs as seen by a typical family