Estimating A Building Envelope's Energy Performance

Residential Energy Efficiency Technical Update Meeting

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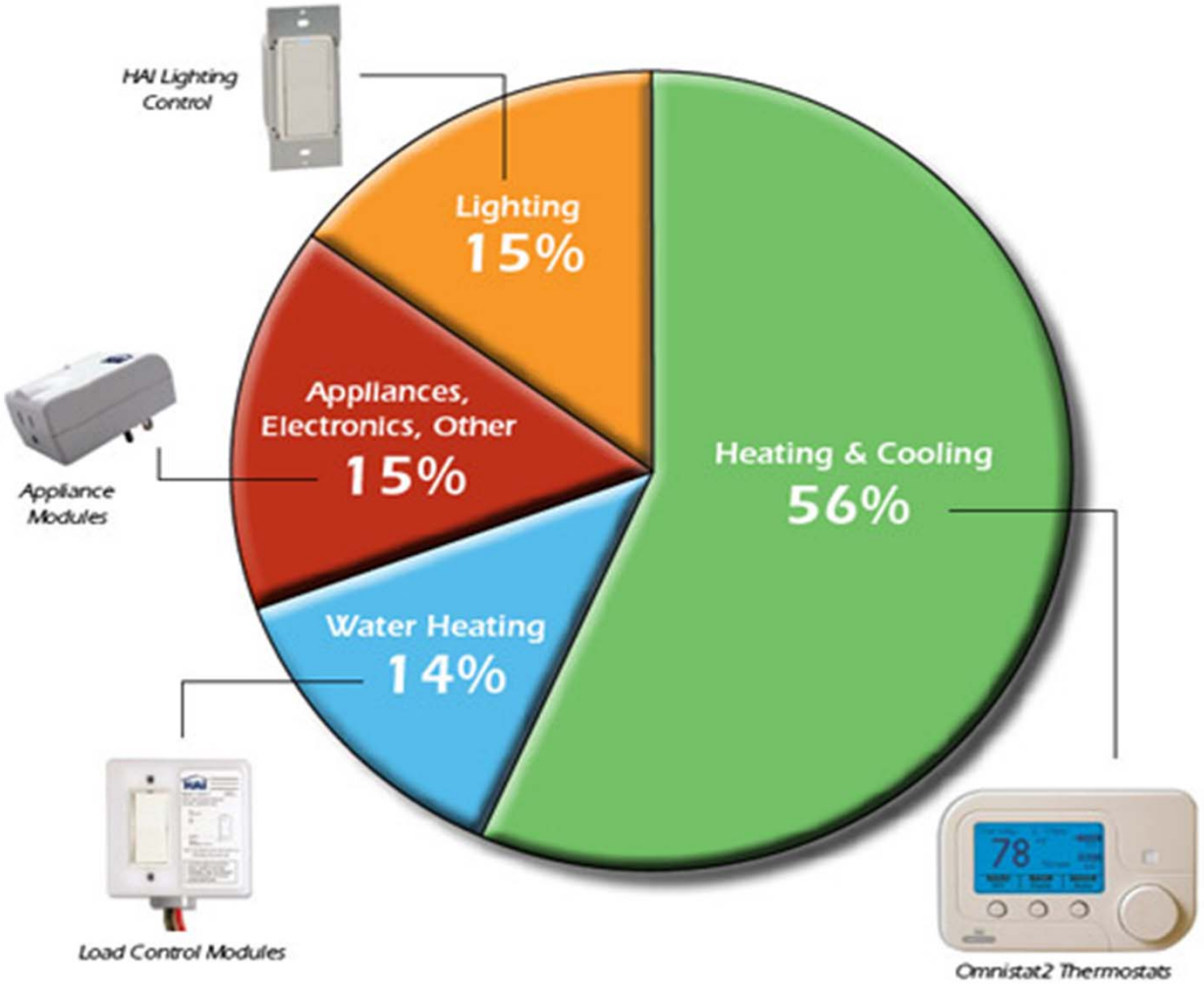
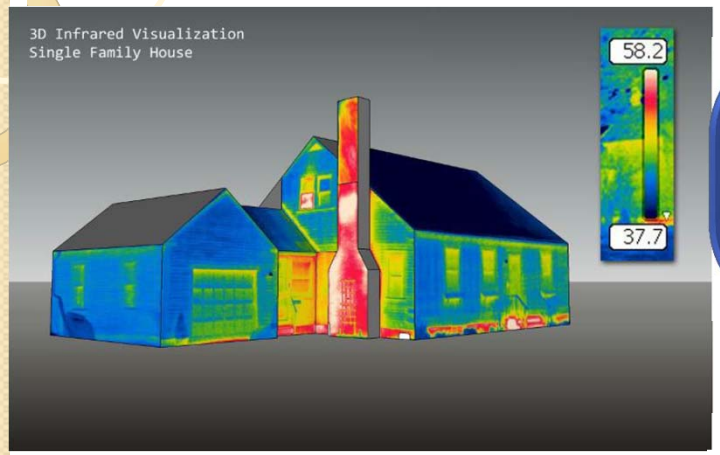
Breakdown of Household Energy Consumption



Existing Building Envelope Testing Methods

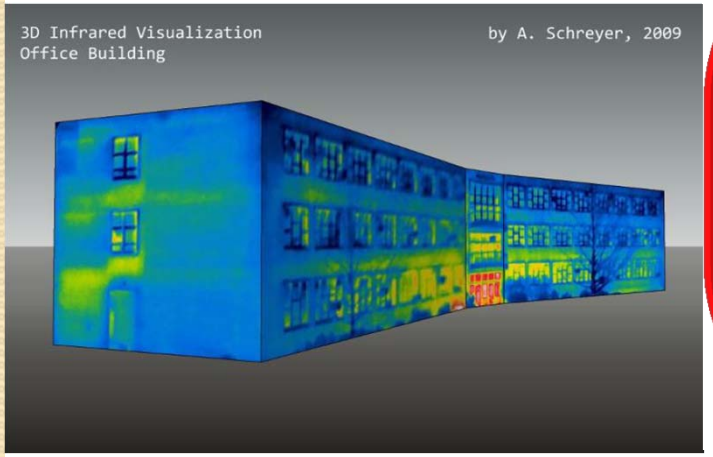
- Blower Door Test
- PFT Air Infiltration Measurement
- Thermographic Scanning

Infrared Images



Highlight:

Infrared image + 3D model built in Google SketchUp

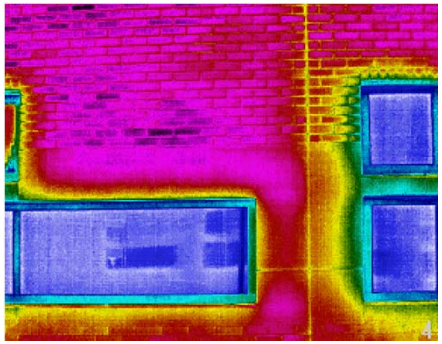


Limits:

- **Post-registration process**
- **Hard to read accurate temperature**
- **Inevitable image distortion**
- **Need a 3D model built before mapping the image (difficult to use for existing old houses)**

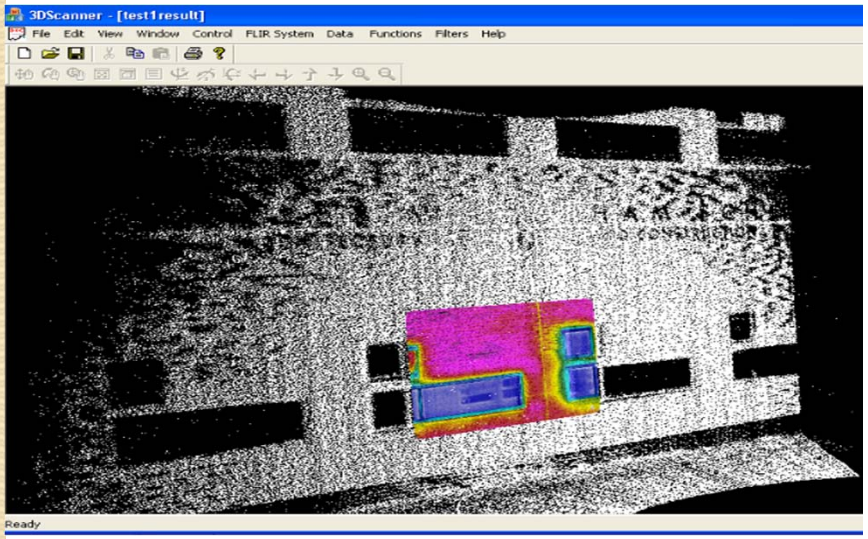
Schreyer, A. C., and Hoque, S. (2009). "Interactive Three-Dimensional Visualization of Building Envelope Systems Using Infrared Thermography and SketchUp." *Proc. of InfraMation 2009*, Las Vegas, NV.

Infrared Images + 3D Point Cloud



Highlight:

Infrared image + 3D point cloud



Limits:

- **Temperature information is lost.**
- **The same object can be differently colored**

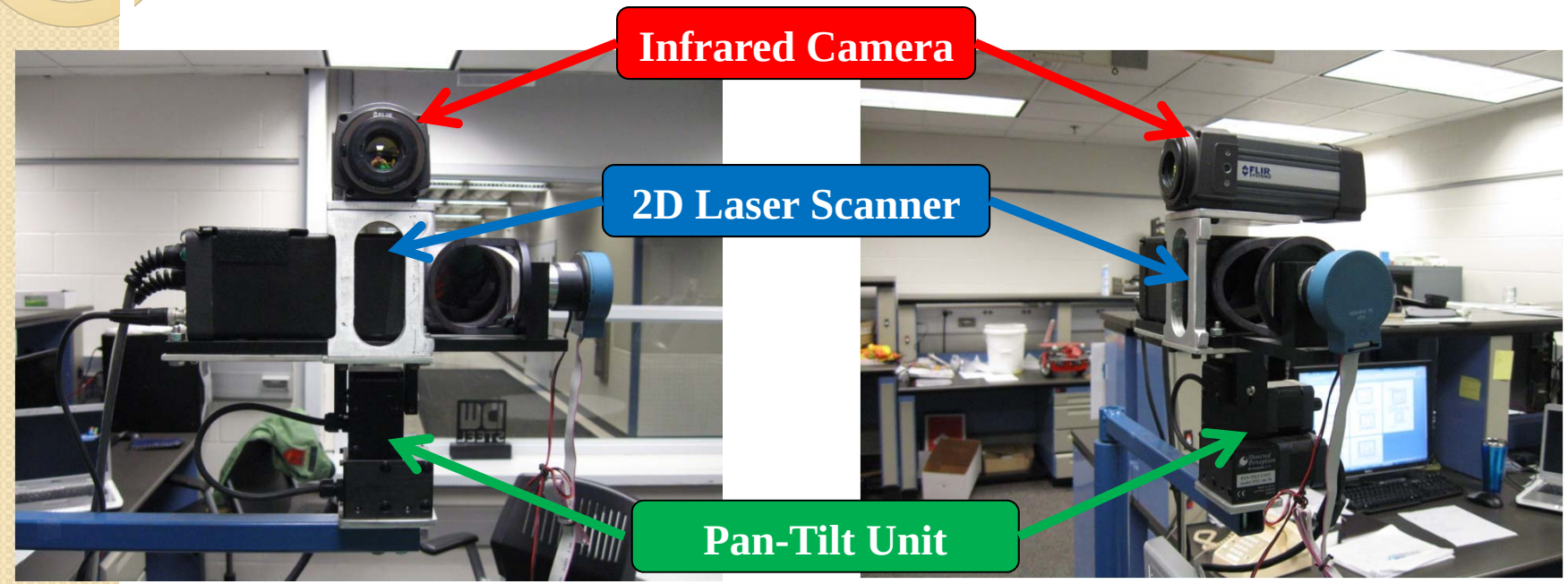
3D Thermal Modeling Using a Hybrid LIDAR System

- This research was supported by a grant from **the U.S. DOE** (Contract #: DE-EE0001690).

- Yong Cho, Chao Wang, University of Nebraska - Lincoln

Hybrid 3D LIDAR System

System Preparation



$$ {}^{0}_{Laser+Thermal}T = {}^{0}_{pan}T\,{}^{pan}_{tilt}T $$

$$ {}^{tilt}_{mirror}T\,{}^{mirror}_{laser}T $$

$$ {}^{tilt}_{thermal}T $$

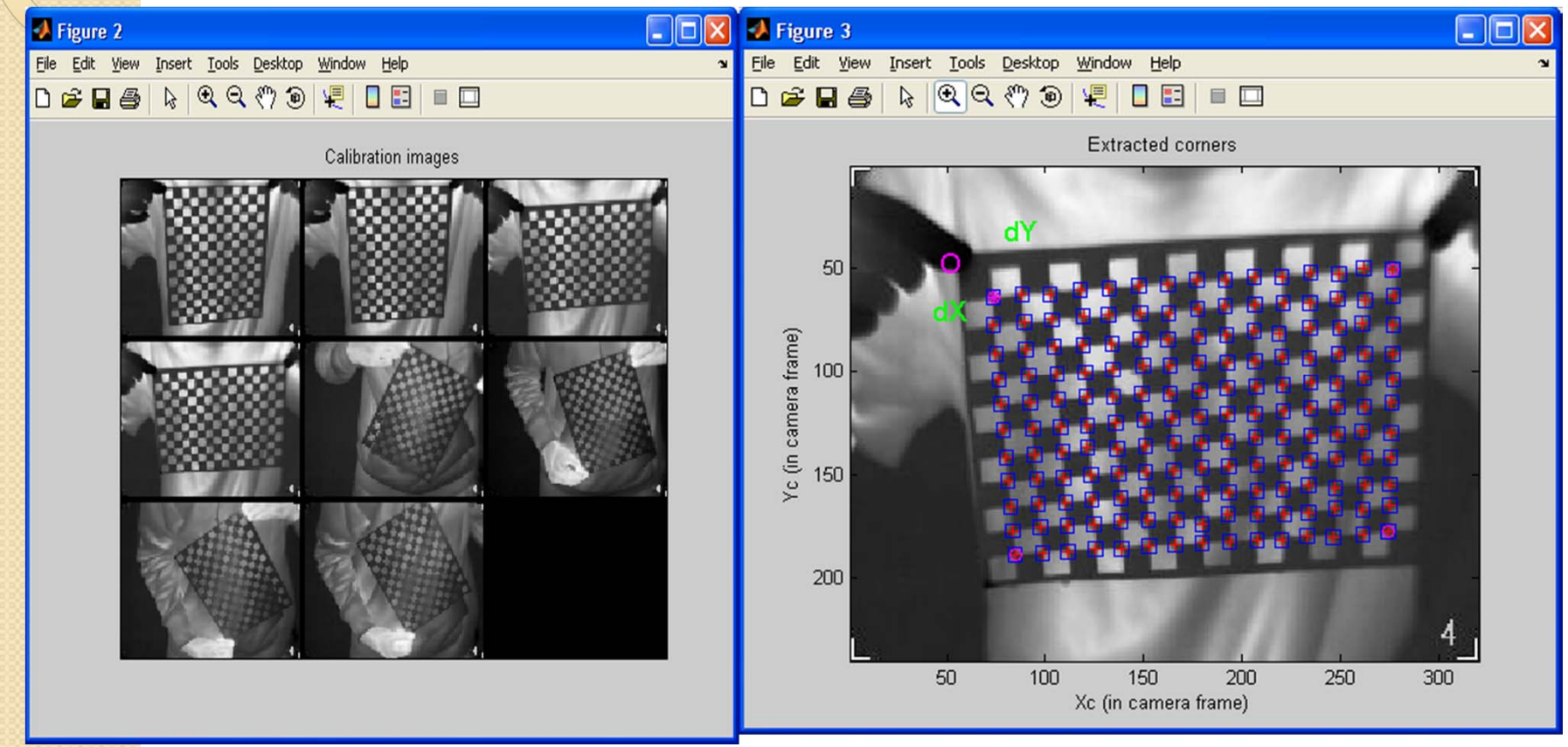
Point Clouds

Temp. on Pixels

Data Fusion

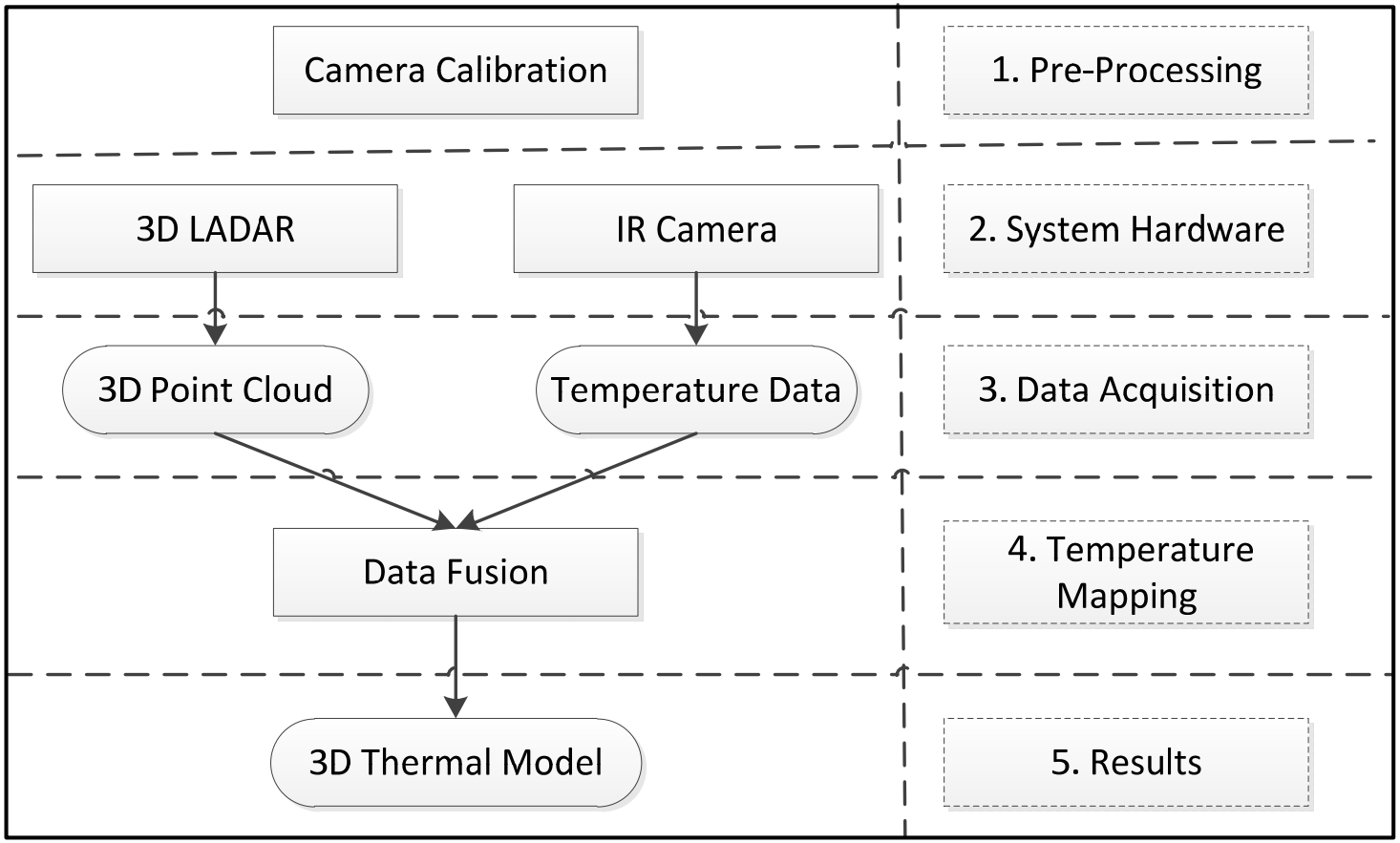
Hybrid 3D LIDAR System

Camera Calibration



Hybrid 3D LIDAR System

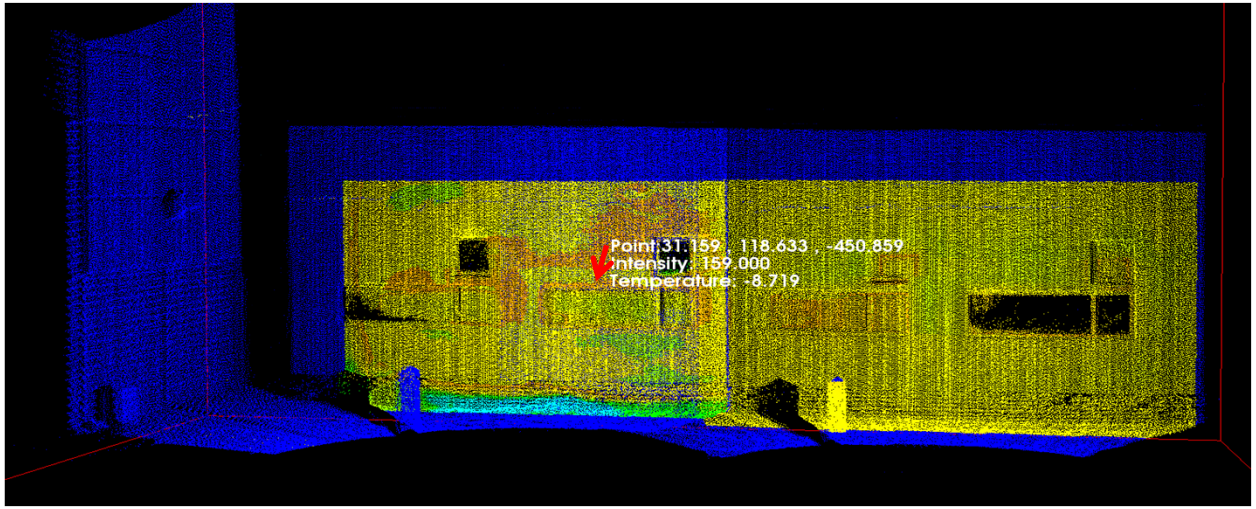
Data Acquisition and Fusion



Field Test Results

Building

Test Date: Dec, 2010

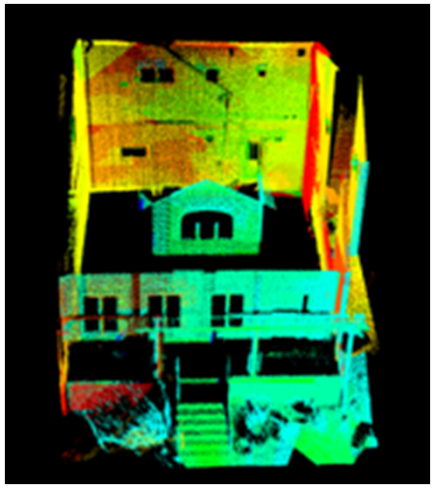


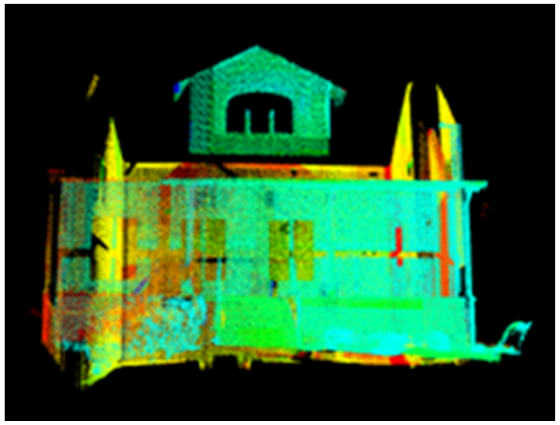
Field Test Results

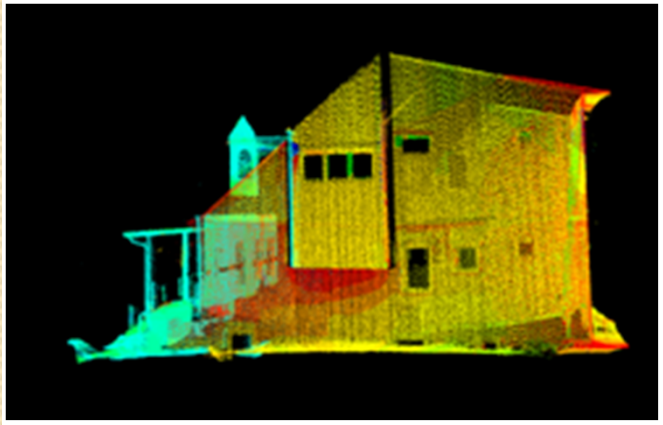
ZNETH House

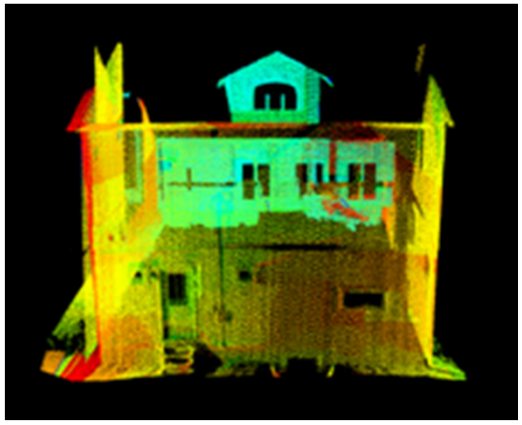
Test Date: Jun, 2011

Field Test Results





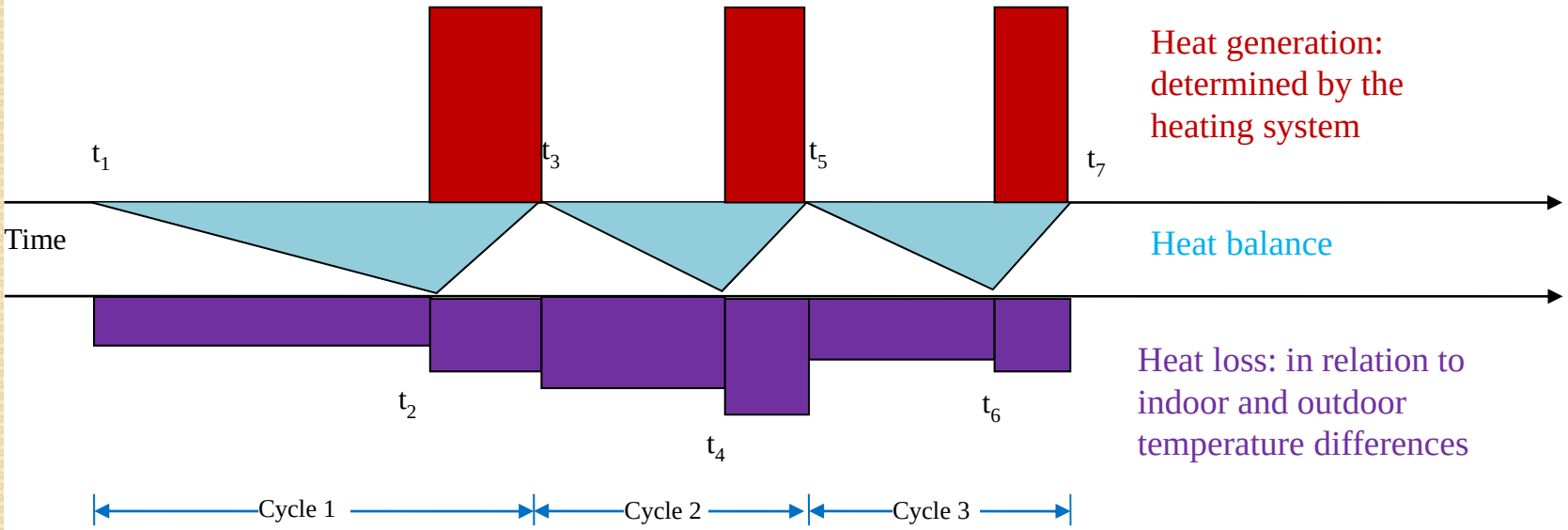




An Inverse Modeling Approach

- To estimate a building envelope's heat conductance (U) and air infiltration (CFM) values based on the monitored and logged operation patterns of the HVAC system in relation to outdoor weather conditions.

Heat Loss, Generation and Balance Process in a Building



Heat Balance Equations

$$\dot{G} - \dot{L} = mC\frac{dT_i}{dt} \qquad (1)$$

Where:

$\dot{G}$ = rate of total space heat gain

$\dot{L}$ = rate of total space heat loss

m = total space air mass

C = specific heat of air

T_i = space temperature , or indoor temperature

t = time

Heat Transmission

$$\dot{L}_T = U * A * TD \qquad (1)$$

where:

U = equivalent conductance value of the building envelope

A = total area of building envelope subject to transmission heat loss

TD = temperature difference between indoor and outdoor air

Heat Loss Due to Infiltration

$$\dot{L}_I = 1.08 * CFM * TD \qquad (1)$$

where CFM is the quantity of outdoor air brought into a building by infiltration.

Linear Regression

$$\hat{U} = a + b * TD$$

$$\hat{CFM} = c + d * TD + e * V \quad (1)$$

where:

$\hat{U}$ = estimated building envelope conductance

$\hat{CFM}$ = estimated infiltration rate

TD = indoor and outdoor temperature difference

V = wind speed

a, b, c, d, e = regression constants.

HVAC System Operation Cycles

- Each operation cycle generates one set of data points that include U_i, CFM_i, and TD_i.
- If "n" cycles are monitored, "n" sets of data points will become available.
- Using this "n" sets of data, the linear regression constants a, b, c, and d can be determined.
- A 90% or 95% of confidence level will be used to determine the required number of data sets.

Next Step

- Data collection
  - A house in Omaha has been identified and its electricity consumption was monitored from Jan.-May 2011.
  - Weather data was downloaded.
  - Data analysis is underway
- Regression analysis
  - To start soon

Conclusions

- An envelope has a significant impact on the building's energy consumption.
- A lack of knowledge and low cost tools to assist auditors/users in quantifying an envelope's energy performance.
- An inverse modeling based on field data provides a potential revolutionary solution.
- An accurate estimation of transmission and infiltration in a building can lead to better selection of effective energy retrofit measures for the given building.