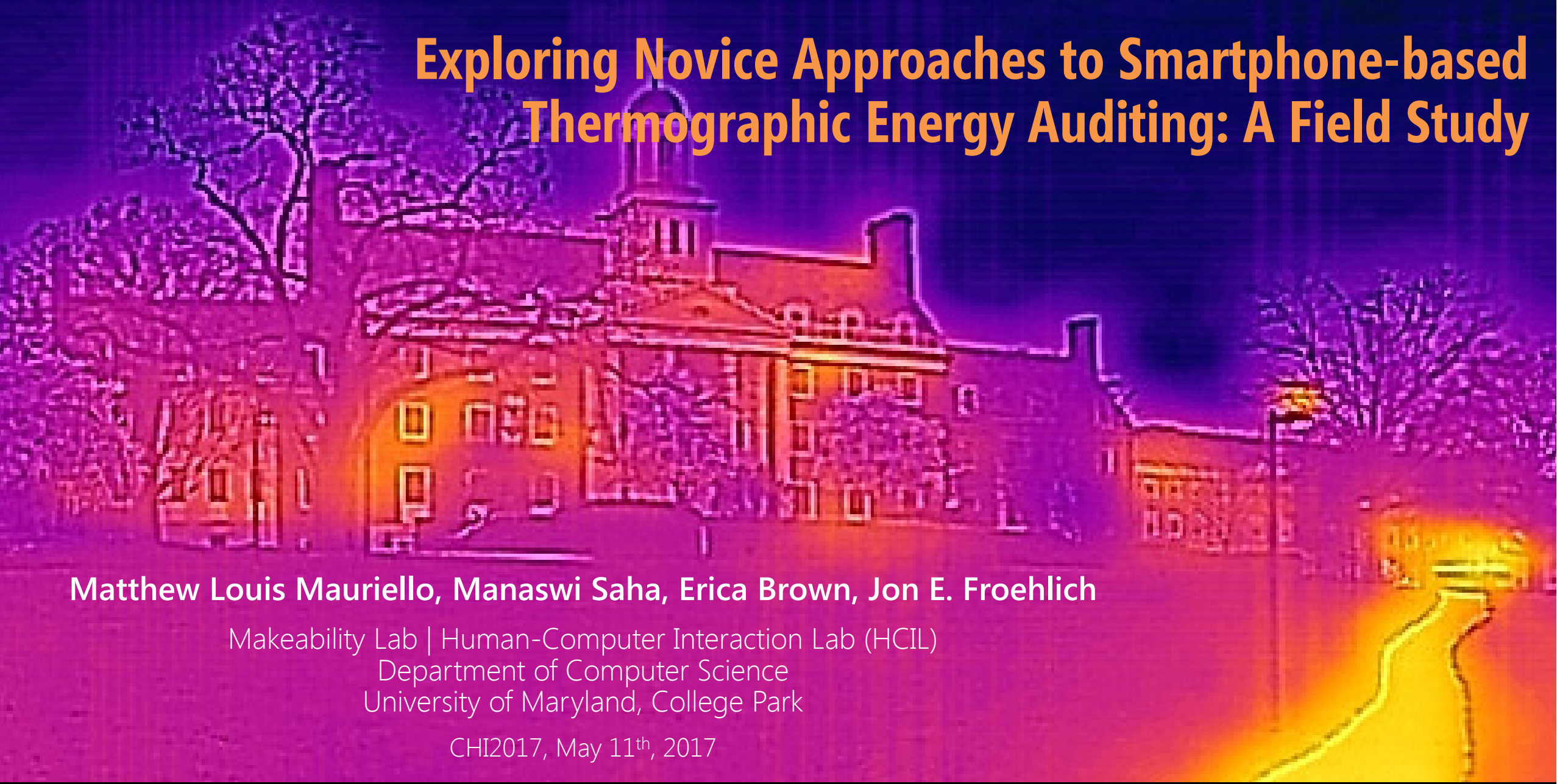
Exploring Novice Approaches to Smartphone-based Thermographic Energy Auditing: A Field Study



Matthew Louis Mauriello, Manaswi Saha, Erica Brown, Jon E. Froehlich

Makeability Lab | Human-Computer Interaction Lab (HCIL)
Department of Computer Science
University of Maryland, College Park

CHI2017, May 11th, 2017

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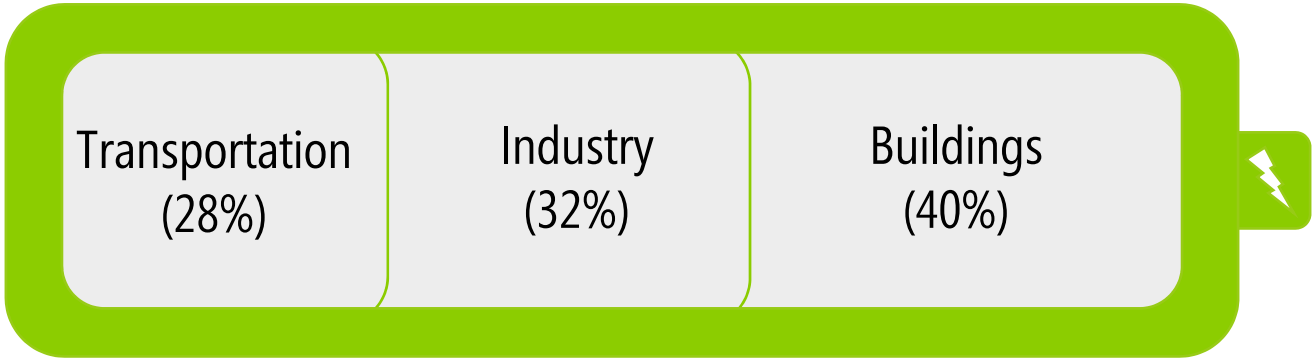
What does energy use look like in the United States. ?



Most (95%) of building in the United States are residential and approximately a quarter (25%) of their energy consumption goes toward heating or cooling.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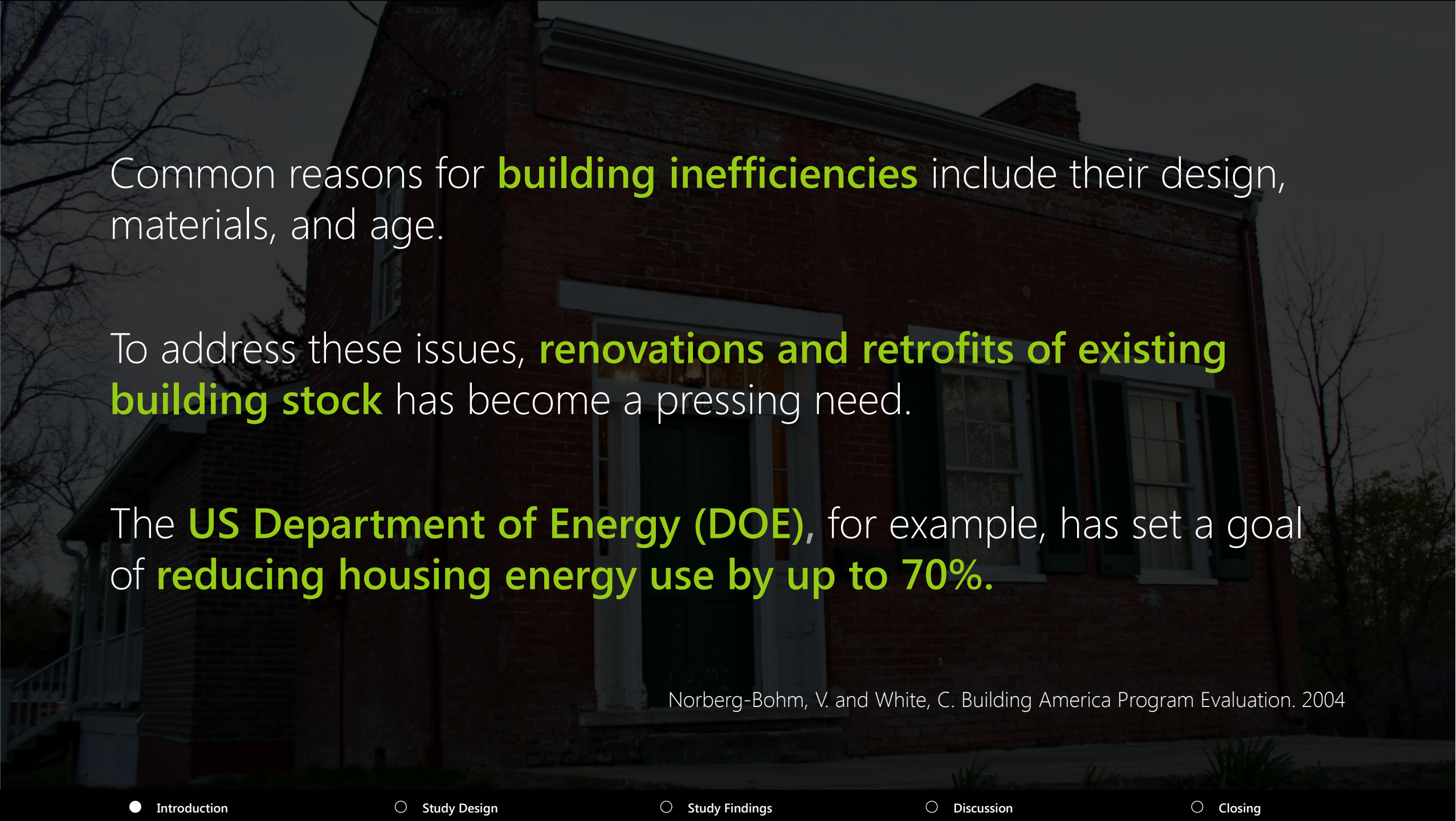


Common reasons for **building inefficiencies** include their design, materials, and age.

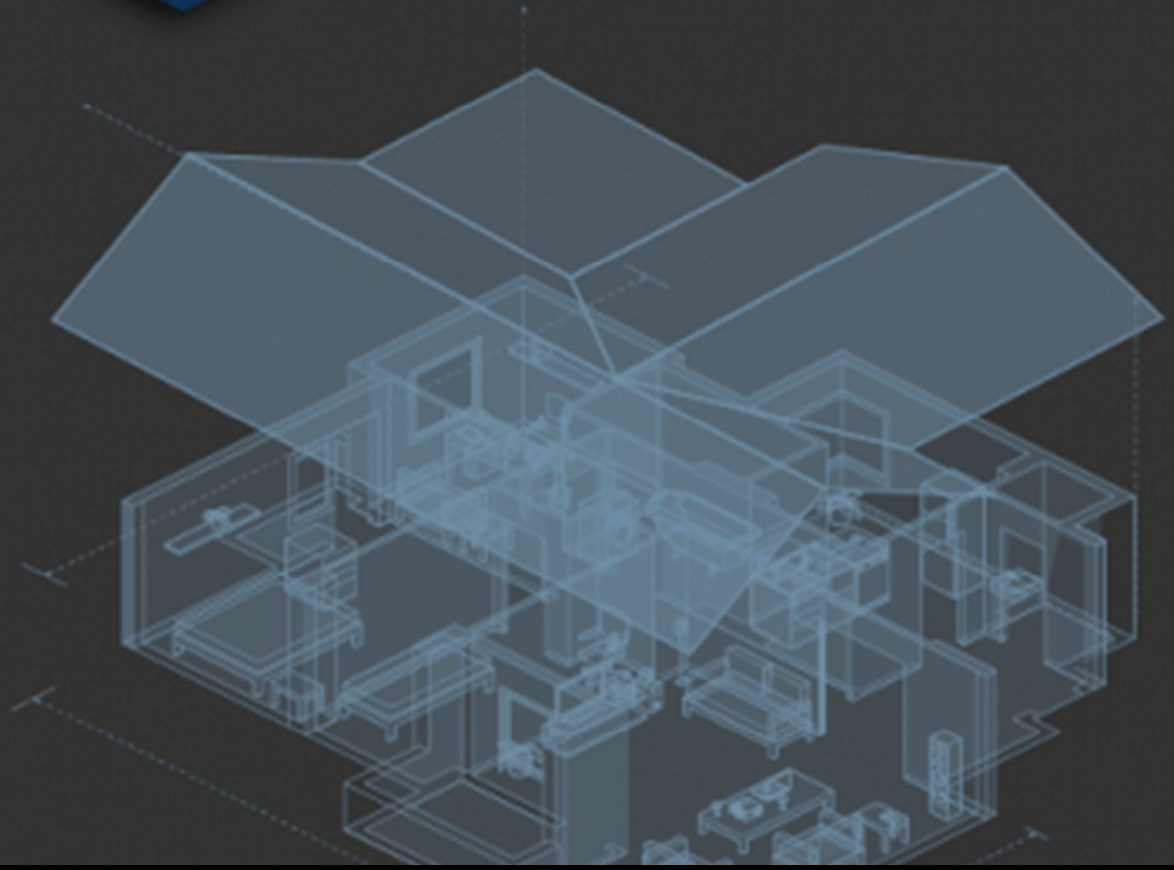
To address these issues, **renovations and retrofits of existing building stock** has become a pressing need.

The **US Department of Energy (DOE)**, for example, has set a goal of **reducing housing energy use by up to 70%.**

Norberg-Bohm, V. and White, C. Building America Program Evaluation. 2004

Energy Saver 101:
Home Energy Audits

Take the first step to improving your home's energy efficiency: get a home energy audit.



What is a home energy audit?

A home energy audit helps you pinpoint where your house is losing energy and **what you can do to save money**. A home energy auditor will also assess health and safety issues that might exist in your home.

The audit involves two parts: the **home assessment** and **analysis** using computer software.

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Home » Thermographic Inspections

Thermographic Inspections

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WHAT DOES THIS MEAN FOR ME?

Energy auditors may use thermography -- or infrared scanning -- to detect thermal defects and air leakage in building envelopes.

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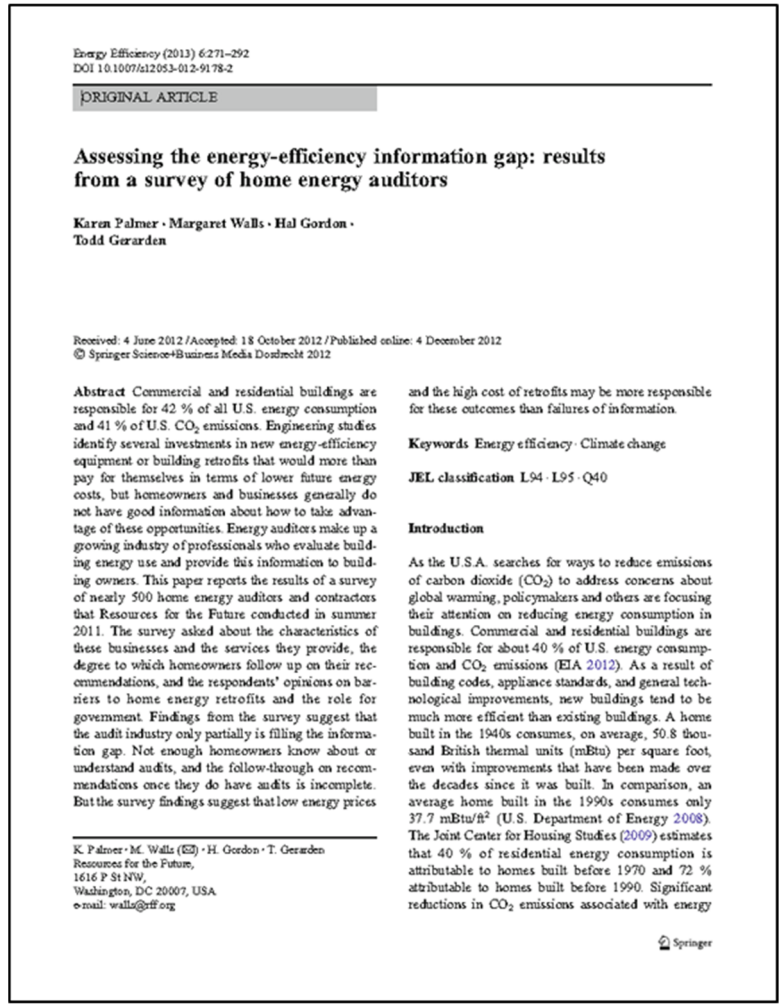
The Energy Efficiency Information Gap

Only **5%** of residential buildings have been audited.

Common recommendations for most homes include:

- Sealing air leaks
- Adding insulation
- Improving lighting
- Increasing efficiency of appliances

Including thermal imagery in reports increases the likelihood that recommendations will be implemented.



Energy Efficiency (2013) 6:271–292
DOI 10.1007/s12053-012-9178-2

ORIGINAL ARTICLE

Assessing the energy-efficiency information gap: results from a survey of home energy auditors

Karen Palmer · Margaret Walls · Hal Gordon · Todd Gerarden

Received: 4 June 2012 / Accepted: 18 October 2012 / Published online: 4 December 2012

Abstract Commercial and residential buildings are responsible for 42 % of all U.S. energy consumption and 41 % of U.S. CO_2 emissions. Engineering studies identify several investments in new energy-efficiency equipment or building retrofits that would more than pay for themselves in terms of lower future energy costs, but homeowners and businesses generally do not have good information about how to take advantage of these opportunities. Energy auditors make up a growing industry of professionals who evaluate building energy use and provide this information to building owners. This paper reports the results of a survey of nearly 500 home energy auditors and contractors that Resources for the Future conducted in summer 2011. The survey asked about the characteristics of these businesses and the services they provide, the degree to which homeowners follow up on their recommendations, and the respondents' opinions on barriers to home energy retrofits and the role for government. Findings from the survey suggest that the audit industry only partially is filling the information gap. Not enough homeowners know about or understand audits, and the follow-through on recommendations once they do have audits is incomplete. But the survey findings suggest that low energy prices and the high cost of retrofits may be more responsible for these outcomes than failures of information.

Keywords Energy efficiency · Climate change

JEL classification L94 · L95 · Q40

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Introduction

As the U.S.A. searches for ways to reduce emissions of carbon dioxide (CO_2) to address concerns about global warming, policymakers and others are focusing their attention on reducing energy consumption in buildings. Commercial and residential buildings are responsible for about 40 % of U.S. energy consumption and CO_2 emissions (EIA 2012). As a result of building codes, appliance standards, and general technological improvements, new buildings tend to be much more efficient than existing buildings. A home built in the 1940s consumes, on average, 50.8 thousand British thermal units (mBtu) per square foot, even with improvements that have been made over the decades since it was built. In comparison, an average home built in the 1990s consumes only 37.7 mBtu/ft^2 (U.S. Department of Energy 2008). The Joint Center for Housing Studies (2009) estimates that 40 % of residential energy consumption is attributable to homes built before 1970 and 72 % attributable to homes built before 1990. Significant reductions in CO_2 emissions associated with energy

Springer

Palmer *et al.* 2013

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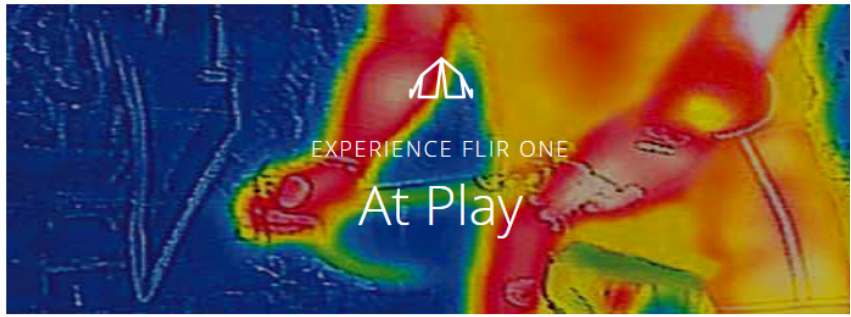
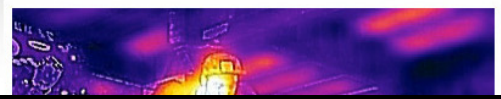
~223 Million Smartphone users in the US.

Macworld BEST OF SHOW 2014 | iPhone BEST of CES 2014 | PC PCMAG.COM EDITORS' CHOICE | POPULAR SCIENCE TOP TEN BEST FOR APRIL | Popular Mechanics House THE TOM TOP 100 BEST NEW HOME PRODUCTS



Win a second FLIR ONE.



● Introduction ○ Study Design ○ Study Findings ○ Discussion ○ Closing

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FLIR Approved Applications

In addition to the official FLIR apps, we've built a showcase of the best of breed apps written for the FLIR ONE. When your app achieves FLIR Approved App status, it will automatically be added to the gallery.

Featured App

Boat Beacon for FLIR ONE

by PocketMariner

Boat Beacon uses AIS to show the positions of ships around you when at sea including bearing and distance and closest point of approach (CPA). It also has a Marker button (MOB) which you can use to mark a spot and track its location. Boat Beacon's Augmented Reality view shows the ship positions, a thermal view, and MOB overlaid on the live Camera View.

Available Now!

The Apps listed on this page have been reviewed and approved by FLIR and have been given the "FLIR Approved" status, which is verification that the App conforms to FLIR's corporate guidelines and policies for appropriate content and user experience. FLIR does not review the App for compliance with Intellectual Property rights, safety, or other potential factors that may result in liability to the Developer; thus FLIR disclaims any and all liability that may arise through a third party's use of the App or whether the App will meet any quality standard or level of merchantability.

FLIR ONE App

Provides a simple user interface with a variety of functions for operating your new FLIR ONE device.

Download on the App Store

FLIR Approved Apps

What does FLIR Approved app mean and what's the process for getting an app approved? Find out here ▸

FLIR Certified Developer Program

FLIR Certified Developers are trained by FLIR on thermal imaging and FLIR ONE developer tools. Want to become one of the elite certified developers? Learn more on the process ▸

iPhone Apps | iPad Apps | Android Apps

Apps for Android

Baby Monitor for FLIR ONE
by Mobile Toys & Tools

This application monitors your baby during sleep and raises alarm if he/she is out of rectangular Region of Interest defined by you.

CompassEye with FLIR
by Electric Pocket

A Professional Bearing Compass designed to help navigate at sea and used much like a pair of Compass Binoculars. When held vertically it shows the real-time camera view with a compass, bearings and artificial horizon overlaid, when flat it shows a real time map centred on where you are with the bearings and compass overlaid.

NovaVision
by NovaCoast

NovaVision utilizes the thermal image processing from the FLIR One to create thermal goggles for the user. The screen is divided in half and each half contains an image view, where the content comes directly from the FLIR One.

Remote Thermal Cam f. FLIR ONE
by Sven Killig

Remote Thermal Cam is a useful Android app that lets you use Your FLIR ONE as a Webcam for Your PC by sending an MJPEG stream to a SmartCam server via WIFI.

Thermal Camera for FLIR ONE
by Georg Friedrich

Thermal Camera uses the Flir One v2 to display a live infrared image. To achieve this task it uses its own render mechanism, that uses the 14bit raw data from the Flir SDK. Due to the nature of this implementation it can add new features, which are Flir independent.

Thermori-on
by maffydub

Thermori-on is a thermal musical instrument, inspired by the "Tenori-on", and using your FLIR thermal imaging camera.

ThermoVisual Motion Detector
by Mobile Toys & Tools

ThermoVisual Motion Detector (TVMD) is an intelligent, easy to use application that detects thermal and/or visual motion or changes automatically by using FLIR ONE infrared camera.

Thermal Paint for FLIR ONE
by Whale Tale Games

With Thermal Paint you can draw areas of the thermal image on top of the aligned visible-light image from the FLIR One. Highlight important areas of an image, or get creative and create unique works of art.

Research Questions

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1 How might novice users of commercial thermal cameras assess the built environment?

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2 What attributes of the built environment do they focus on, learn about, and what do they discover?

Research Questions

1. How might novice users of commercial thermal cameras assess the built environment?
2. What attributes of the built environment do they focus on, learn about, and what do they discover?
3. What challenges do they encounter and what benefits do they perceive?

Study Design

Study Design: Unstructured Pilot Studies

The Future Role of Thermography in Human-Building Interaction

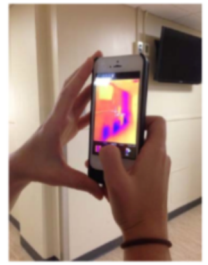

Figure 1: Thermal cameras have recently been introduced into the smartphone ecosystem and provide an opportunity for users to detect, identify, and assess thermal defects in buildings. Here, a FLIR One [21] (connected to an iPhone 5s) is used by one of our pilot study participants to assess a hallway in a building on the University of Maryland's campus.

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Part of the Future of Human-Building Interaction Workshop at CHI'16, May 7 – May 12, 2016, San Jose, California, USA.

Abstract
With recent sensor improvements and falling costs, energy auditors are increasingly using thermography—infrared (IR) cameras—to detect thermal defects and analyze building efficiency. In this workshop paper, we view thermographic energy auditing as a Human-Building Interaction (HBI). We provide an overview of emerging thermal data collection techniques in research and industry. We also reflect on our own work in this area and present our vision of citizen-science/DIY thermography (Figure 1), which has the potential to engage the public in new HBIs by expanding their ability to: perform energy audits, survey public infrastructure, and contribute to urban energy analysis.

Author Keywords
Thermography; Human-Building Interaction

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Introduction
Buildings account for 41% of primary energy consumption in the US—more than any other sector—and contribute an increasing portion of carbon dioxide emissions (33% in 1980 *vs.* 40% in 2009) [18]. One reason for these high emissions is building age.

Mauriello *et al.* 2016

Study Design: Unstructured Pilot Studies

Non-Visible Wall Degradation

Study Design: Unstructured Pilot Studies

Non-Visible Wall Degradation

Study Design: Unstructured Pilot Studies

Partially Visible Moisture Intrusion

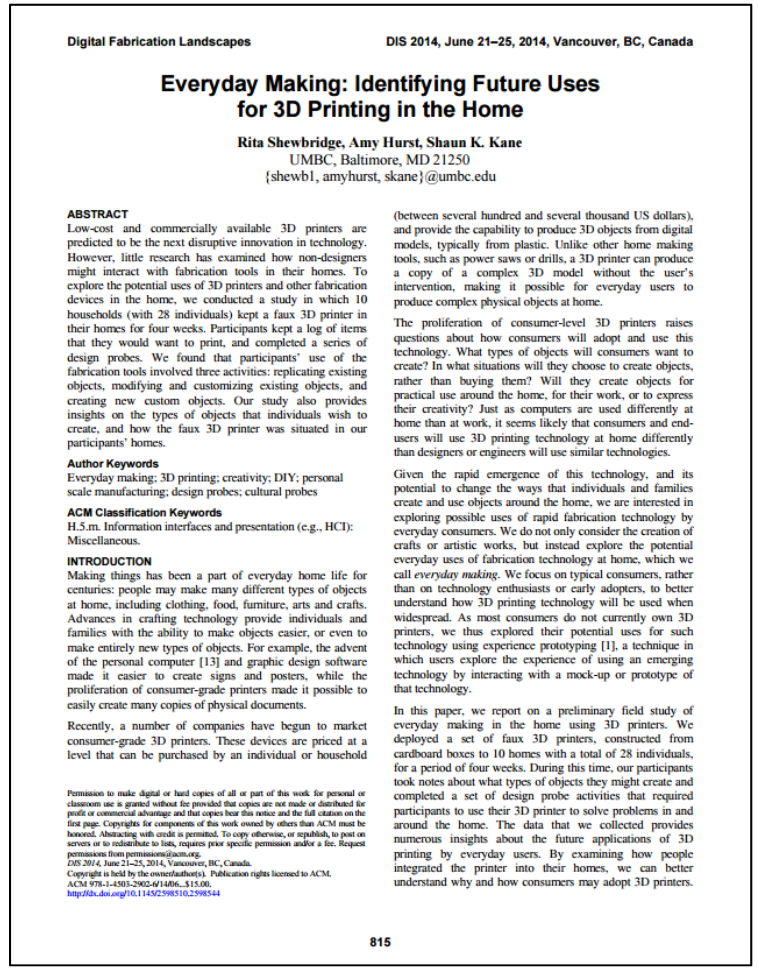
Study Design: Unstructured Pilot Studies

Partially Visible Moisture Intrusion

Study Design: Unstructured Pilot Studies

Unstructured use of thermal cameras did not provide clear goals or motivation for participants.

To address this issue, we adapted a method of providing weekly prompts from previous technology studies.



Everyday Making: Identifying Future Uses for 3D Printing in the Home

Rita Shewbridge, Amy Hurst, Shaun K. Kane
UMBC, Baltimore, MD 21250
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ABSTRACT
Low-cost and commercially available 3D printers are predicted to be the next disruptive innovation in technology. However, little research has examined how non-designers might interact with fabrication tools in their homes. To explore the potential uses of 3D printers and other fabrication devices in the home, we conducted a study in which 10 households (with 28 individuals) kept a faux 3D printer in their homes for four weeks. Participants kept a log of items that they would want to print, and completed a series of design probes. We found that participants' use of the fabrication tools involved three activities: replicating existing objects, modifying and customizing existing objects, and creating new custom objects. Our study also provides insights on the types of objects that individuals wish to create, and how the faux 3D printer was situated in our participants' homes.

Author Keywords
Everyday making; 3D printing; creativity; DIY; personal scale manufacturing; design probes; cultural probes

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Making things has been a part of everyday home life for centuries: people may make many different types of objects at home, including clothing, food, furniture, arts and crafts. Advances in crafting technology provide individuals and families with the ability to make objects easier, or even to make entirely new types of objects. For example, the advent of the personal computer [13] and graphic design software made it easier to create signs and posters, while the proliferation of consumer-grade printers made it possible to easily create many copies of physical documents.

Recently, a number of companies have begun to market consumer-grade 3D printers. These devices are priced at a level that can be purchased by an individual or household (between several hundred and several thousand US dollars), and provide the capability to produce 3D objects from digital models, typically from plastic. Unlike other home making tools, such as power saws or drills, a 3D printer can produce a copy of a complex 3D model without the user's intervention, making it possible for everyday users to produce complex physical objects at home.

The proliferation of consumer-level 3D printers raises questions about how consumers will adopt and use this technology. What types of objects will consumers want to create? In what situations will they choose to create objects, rather than buying them? Will they create objects for practical use around the home, for their work, or to express their creativity? Just as computers are used differently at home than at work, it seems likely that consumers and end-users will use 3D printing technology at home differently than designers or engineers will use similar technologies.

Given the rapid emergence of this technology, and its potential to change the ways that individuals and families create and use objects around the home, we are interested in exploring possible uses of rapid fabrication technology by everyday consumers. We do not only consider the creation of crafts or artistic works, but instead explore the potential everyday uses of fabrication technology at home, which we call *everyday making*. We focus on typical consumers, rather than on technology enthusiasts or early adopters, to better understand how 3D printing technology will be used when widespread. As most consumers do not currently own 3D printers, we thus explored their potential uses for such technology using experience prototyping [1], a technique in which users explore the experience of using an emerging technology by interacting with a mock-up or prototype of that technology.

In this paper, we report on a preliminary field study of everyday making in the home using 3D printers. We deployed a set of faux 3D printers, constructed from cardboard boxes to 10 homes with a total of 28 individuals, for a period of four weeks. During this time, our participants took notes about what types of objects they might create and completed a set of design probe activities that required participants to use their 3D printer to solve problems in and around the home. The data that we collected provides numerous insights about the future applications of 3D printing by everyday users. By examining how people integrated the printer into their homes, we can better understand why and how consumers may adopt 3D printers.

DIS 2014, June 21–25, 2014, Vancouver, BC, Canada.

ACM 978-1-4503-2902-6/14/06...$15.00.
http://dx.doi.org/10.1145/2598510.2598544

Shewbridge *et al.* 2014

Study Design: Recruitment

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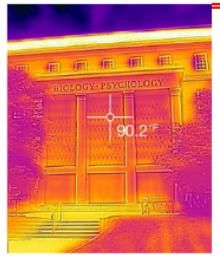

Participants Needed for Four Week Study on Emerging Smartphone-based Environmental Technology

Are you interested in environmental sustainability? Do you have an iPhone? Come help University of Maryland researchers explore the future of smartphone-based technology used to document and explore sustainability issues in urban environments!

As a participant in our study, we will provide you with a thermal camera attachment for your iPhone mobile device. You will be asked to take thermal pictures throughout the four-week study (as you go about your daily life). Once or twice a week, we will also prompt you to take pictures around a particular theme (e.g., energy usage in the home), to record brief notes about these pictures, and to complete a short survey about your weekly activities. The expected time commitment is approximately 1-2 hours per week.

At the end of the fourth week, we will schedule a 1-hour interview about your experience. We will discuss your activities, notes, the images you collected, and you will return the thermal camera attachment. Participants will receive $100 for the successful completion of the field study and exit interview.

Qualifications
Any person above 18 years old can participate; however, you must have and use an iPhone device, version 5 or greater, as your primary phone and should live within the DC metropolitan area (including Virginia and Maryland suburbs). Apart from these requirements, we encourage people of all genders and ethnicities to participate.

Contact Information
If you have any questions or would like to participate in this study, please email Matthew Mauriello (mattm@cs.umd.edu). Feel free to take a look at our research lab's website to find out more about our research program: http://www.cs.umd.edu/hcil/. Please also feel free to redistribute this posting.

Sincerely,

~Matthew Mauriello, MS
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--
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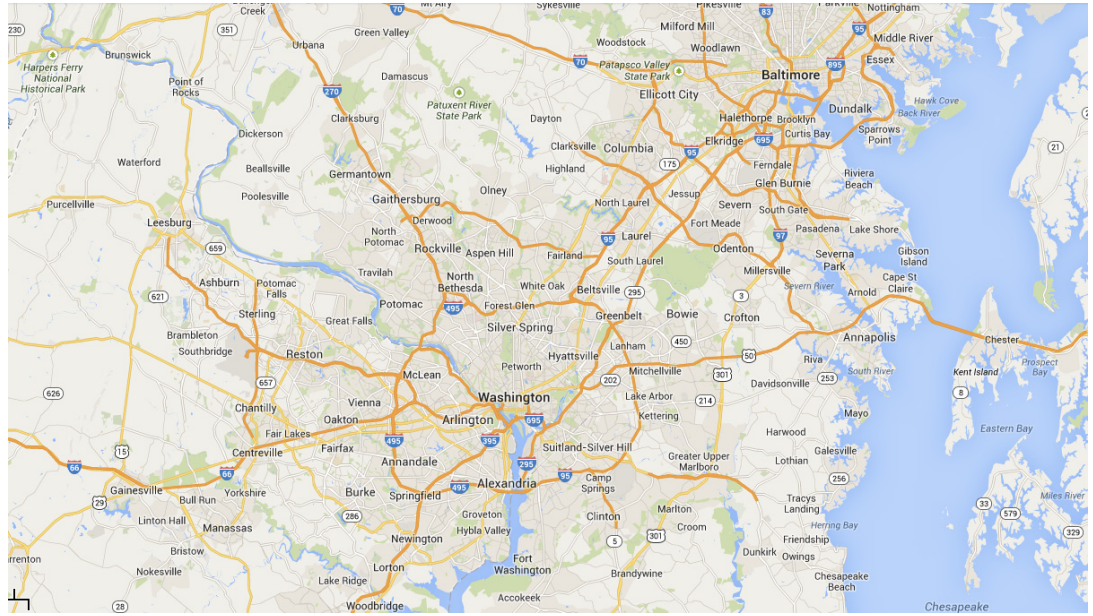


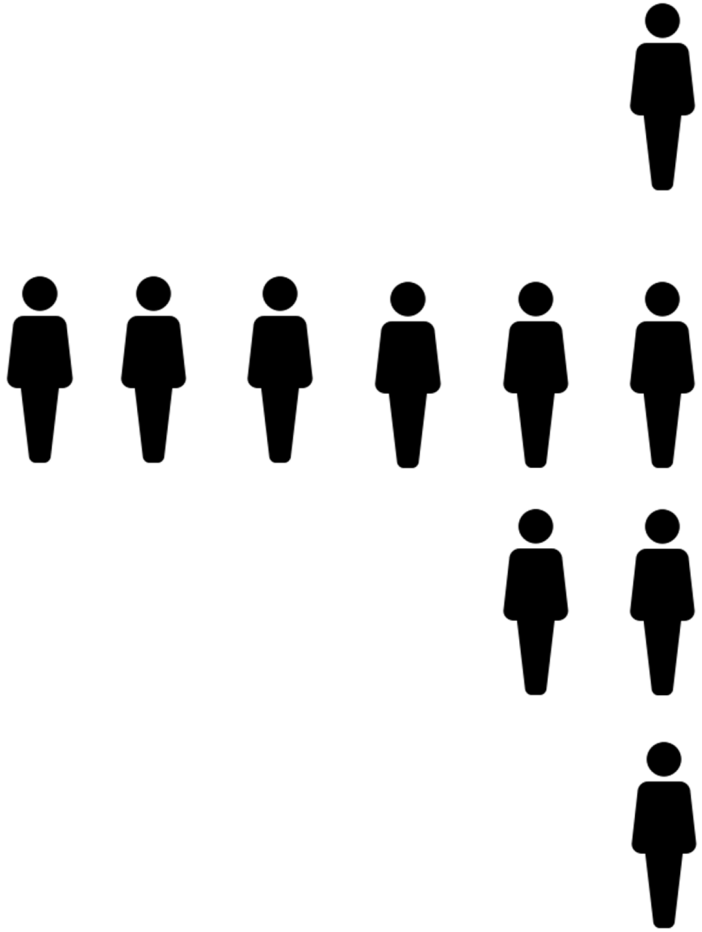
We recruited local participants using listserv, community message boards, and word-of-mouth.

Study Design: Participants

10 Participants (5 Female)

Avg. Age:	37.7 Years
Avg. Green:	6.7 (7pt Likert)

Study Design: Participants



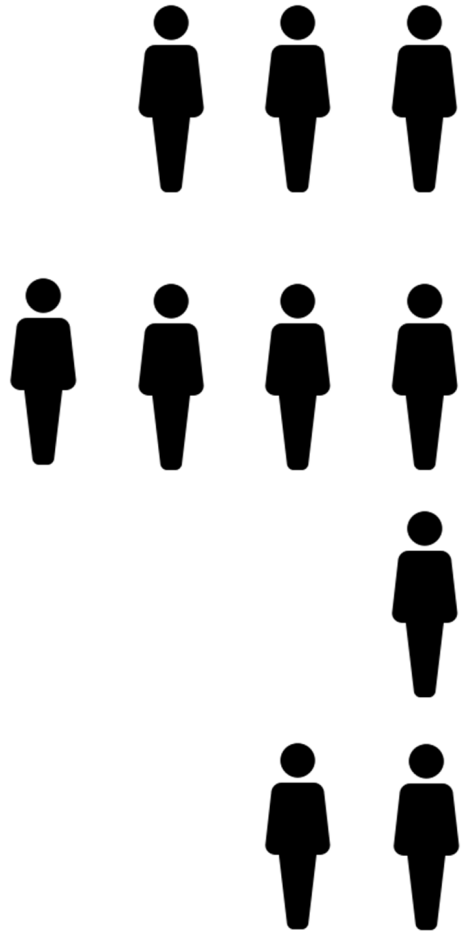
Doctoral Degree (1)

Master's Degree (6)

Bachelor's Degree (2)

High School Degree (1)

Study Design: Participants



Scientist/Engineers (3)

Other Professionals (4)

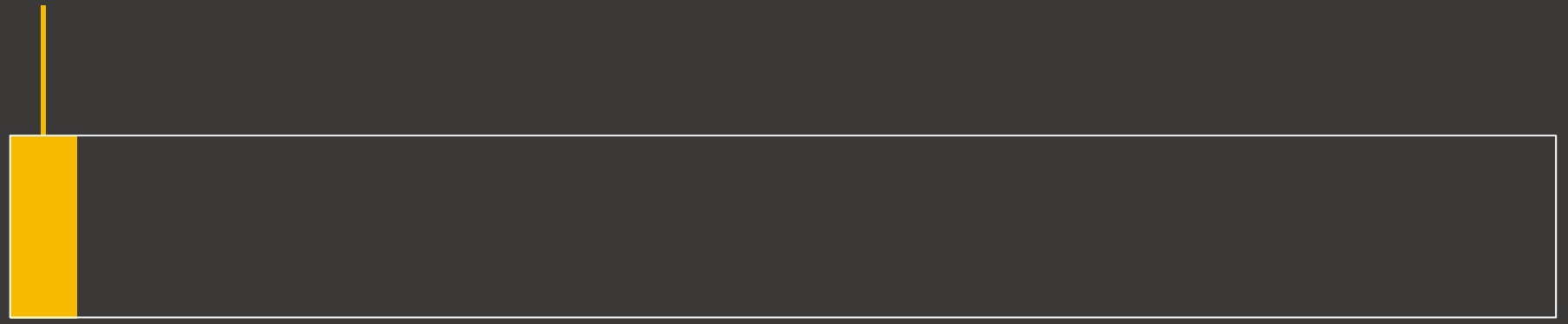
UX Designer (1)

Graduate Students (2)

Study Design: Field Study Procedure

Study Design: Field Study Procedure

Pre-Study Questionnaire



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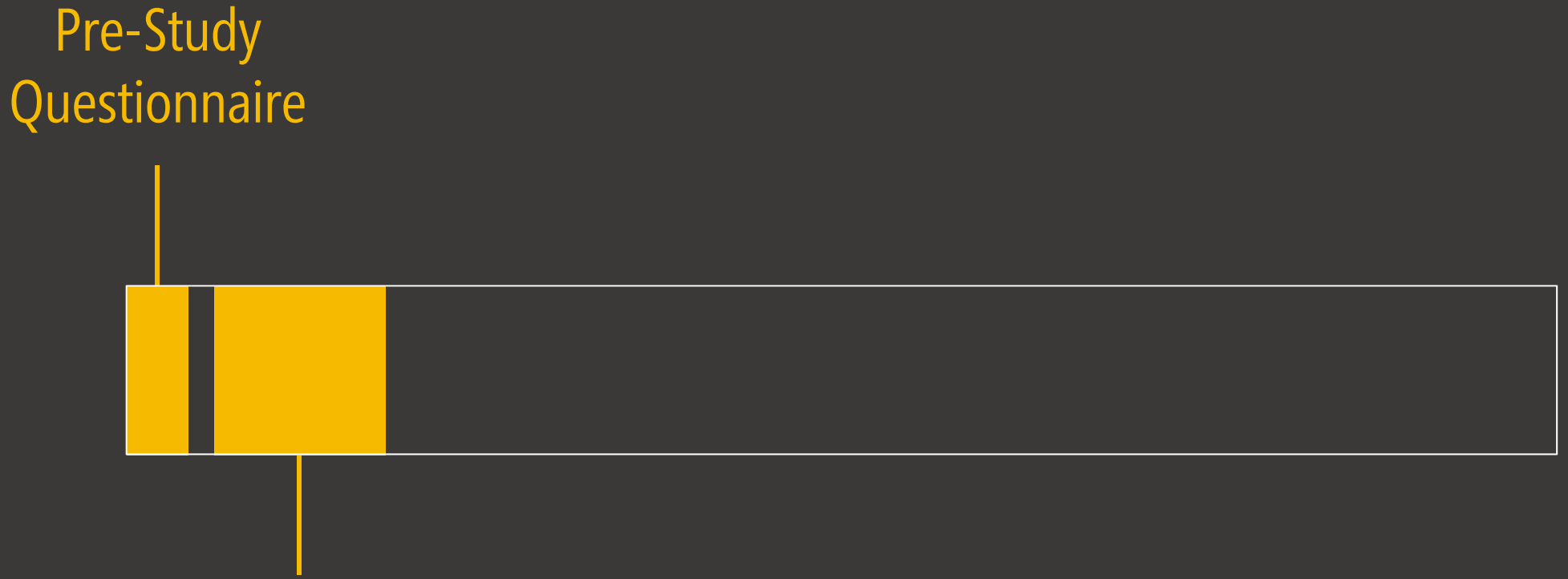


FLIR


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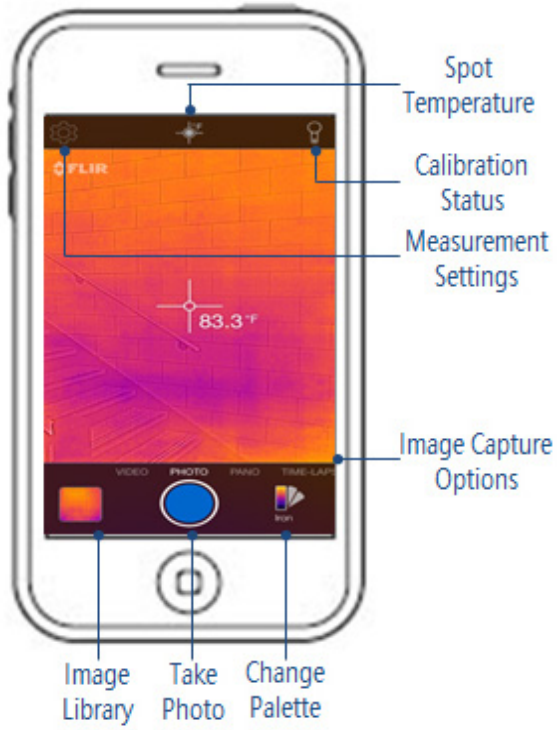
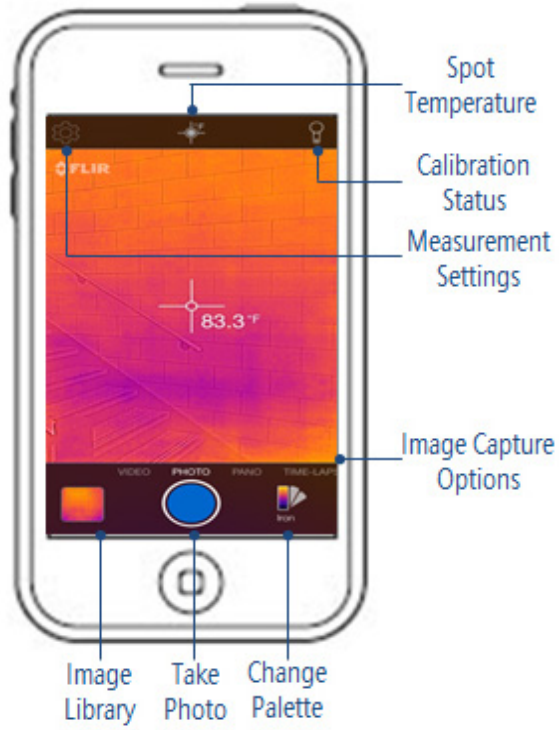
Study Design: Training

Study Design: Training

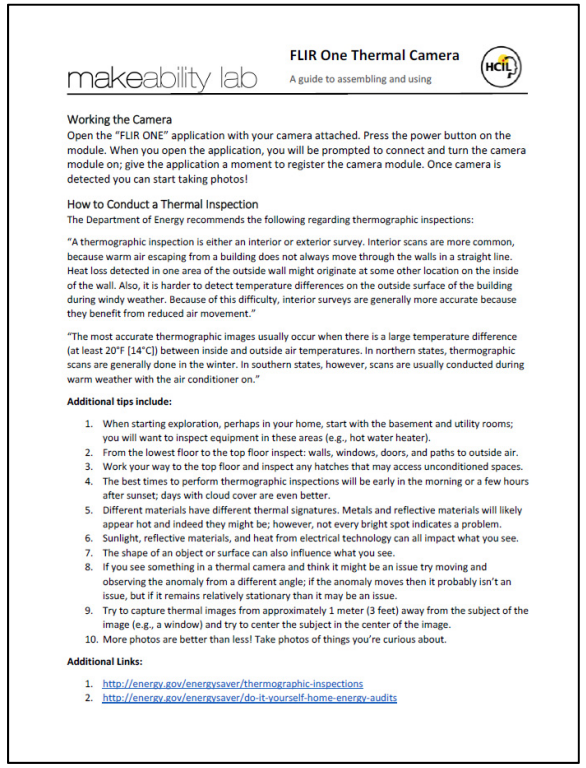


Hardware/Software Overview

Study Design: Training



Hardware/Software Overview



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FLIR One Thermal Camera

A guide to assembling and using

Working the Camera

Open the "FLIR ONE" application with your camera attached. Press the power button on the module. When you open the application, you will be prompted to connect and turn the camera module on; give the application a moment to register the camera module. Once camera is detected you can start taking photos!

How to Conduct a Thermal Inspection

The Department of Energy recommends the following regarding thermographic inspections:

"A thermographic inspection is either an interior or exterior survey. Interior scans are more common, because warm air escaping from a building does not always move through the walls in a straight line. Heat loss detected in one area of the outside wall might originate at some other location on the inside of the wall. Also, it is harder to detect temperature differences on the outside surface of the building during windy weather. Because of this difficulty, interior surveys are generally more accurate because they benefit from reduced air movement."

"The most accurate thermographic images usually occur when there is a large temperature difference (at least 20°F [14°C]) between inside and outside air temperatures. In northern states, thermographic scans are generally done in the winter. In southern states, however, scans are usually conducted during warm weather with the air conditioner on."

Additional tips include:

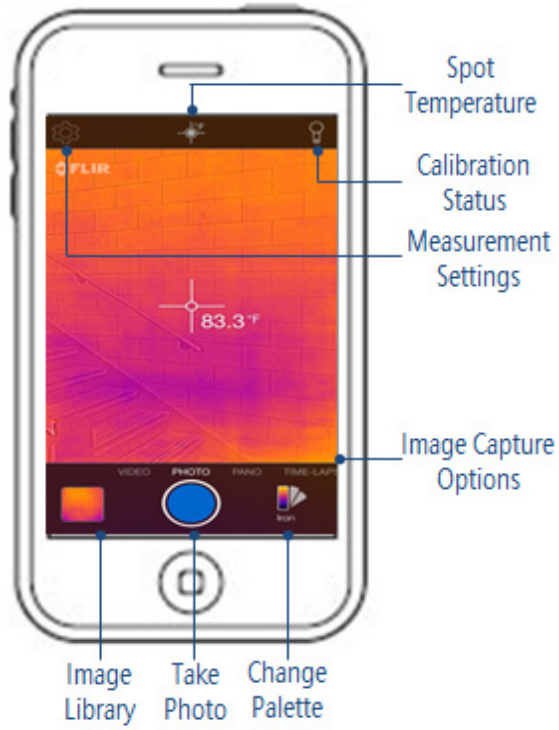
1. When starting exploration, perhaps in your home, start with the basement and utility rooms; you will want to inspect equipment in these areas (e.g., hot water heater).
2. From the lowest floor to the top floor inspect: walls, windows, doors, and paths to outside air.
3. Work your way to the top floor and inspect any hatches that may access unconditioned spaces.
4. The best times to perform thermographic inspections will be early in the morning or a few hours after sunset; days with cloud cover are even better.
5. Different materials have different thermal signatures. Metals and reflective materials will likely appear hot and indeed they might be; however, not every bright spot indicates a problem.
6. Sunlight, reflective materials, and heat from electrical technology can all impact what you see.
7. The shape of an object or surface can also influence what you see.
8. If you see something in a thermal camera and think it might be an issue try moving and observing the anomaly from a different angle; if the anomaly moves then it probably isn't an issue, but if it remains relatively stationary than it may be an issue.
9. Try to capture thermal images from approximately 1 meter (3 feet) away from the subject of the image (e.g., a window) and try to center the subject in the center of the image.
10. More photos are better than less! Take photos of things you're curious about.

Additional Links:

1. http://energy.gov/energysaver/thermographic-inspections
2. http://energy.gov/energysaver/do-it-yourself-home-energy-audits

4-Page Thermographic Inspection Guide

Study Design: Training



Hardware/Software Overview

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FLIR One Thermal Camera

A guide to assembling and using

Common Uses

Missing Insulation: In these two photos you can see a typical example of missing insulation in a wall cavity. What this picture likely demonstrates is that the insulation has "settled" over time (*i.e.*, gravity has pulled the insulation down the wall) leaving the upper cavity empty, which the camera sees as dark patches on the wall.

Internal Structure: In these photos we can see a new well insulated wall, but because the studs conduct heat differently than the insulation they show up slightly darker; however, this is normal.

Leaking Windows (and Doors): In this photo we can see the heating pattern that results from hot air leaking out around a window; we are seeing the results of a weakened window seal on the exterior wall. On the interior we would likely see cold air leaking in around the window on the interior wall.

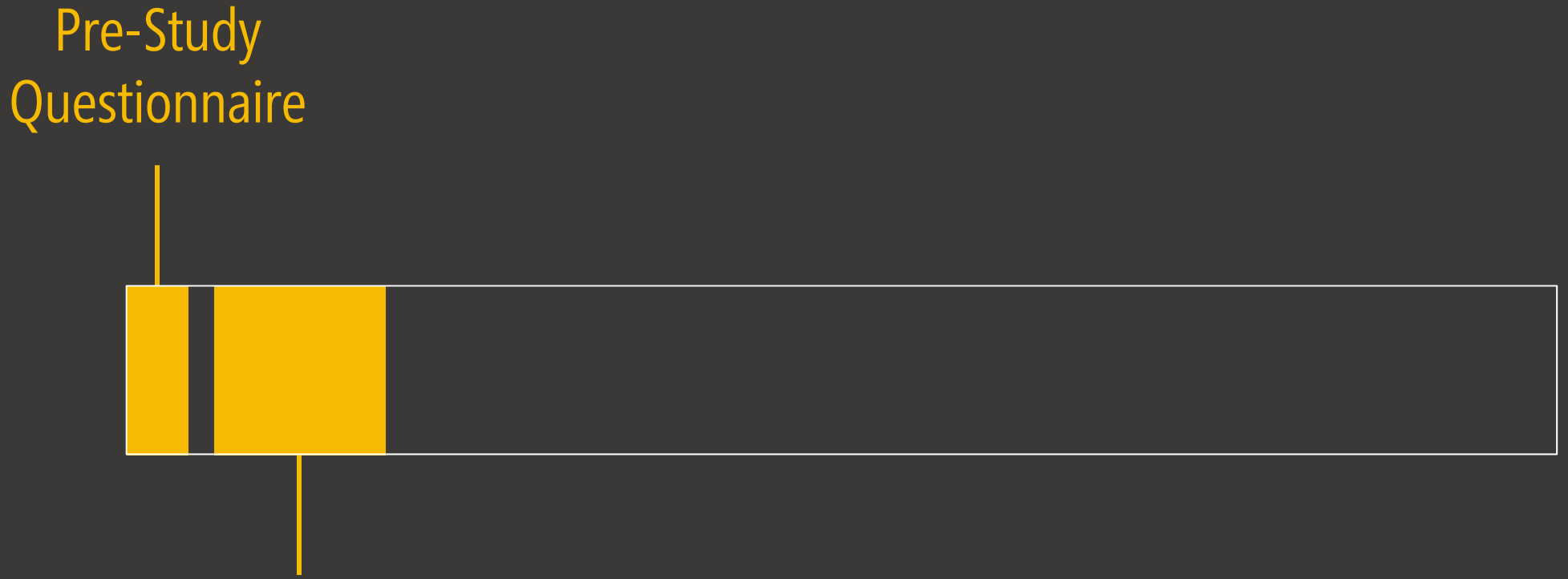
Moisture Damage: Leaking pipes in between walls and the resulting damage from moisture build up is shown as dark splotches on warm walls and can indicate a problem long before there is visual signs of a problem. Note the inconsistent patterns on the ceiling and walls, which should look different from a case of missing wall insulation.

Electrical Inspection: Another common use of thermal cameras is to inspect electrical equipment. In this image we can see that one of the connections to the power transformers is potentially damaged or degraded.

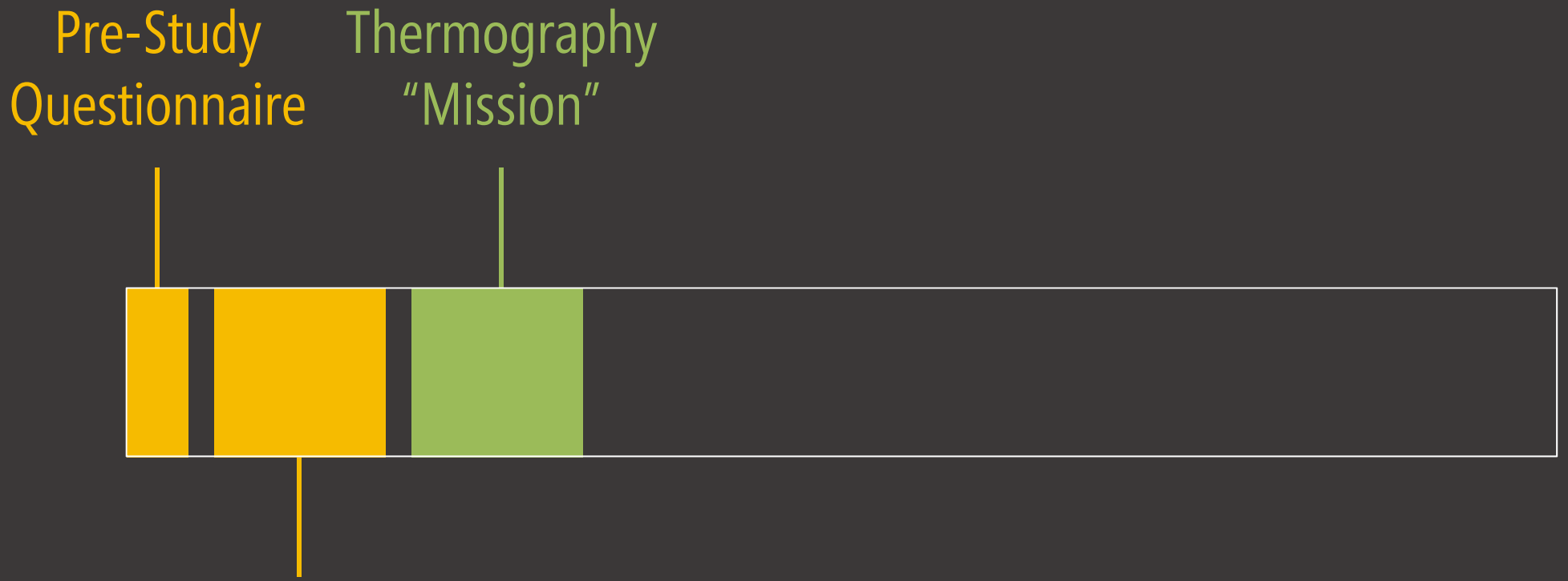
While this is a list of some of the common uses of thermal cameras, you should feel free to explore other potential applications (e.g., cooking food) that might exist using your FLIR ONE camera.

4-Page Thermographic Inspection Guide

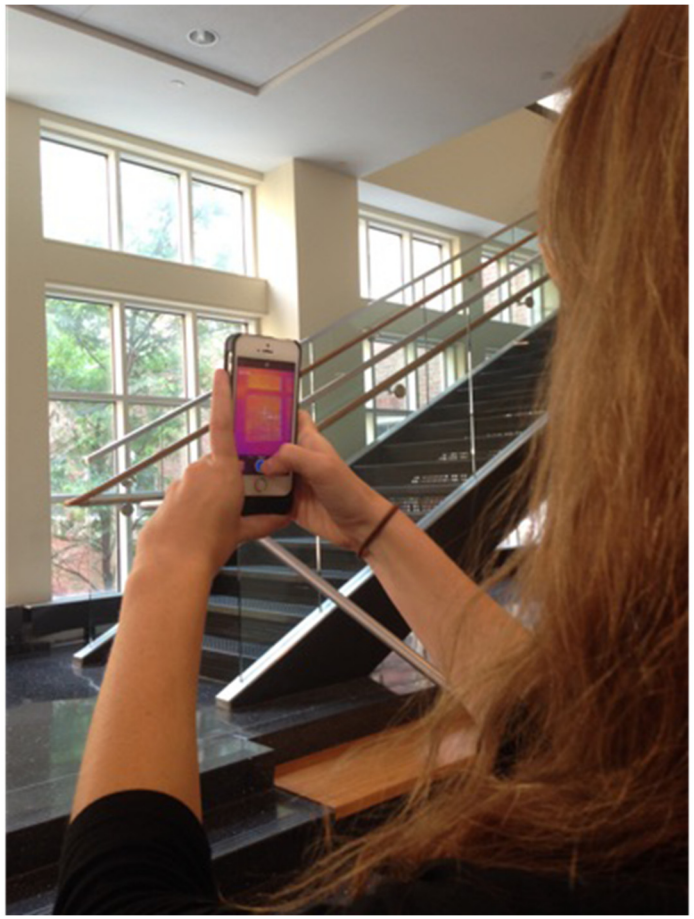
Study Design: Field Study Procedure



Study Design: Field Study Procedure

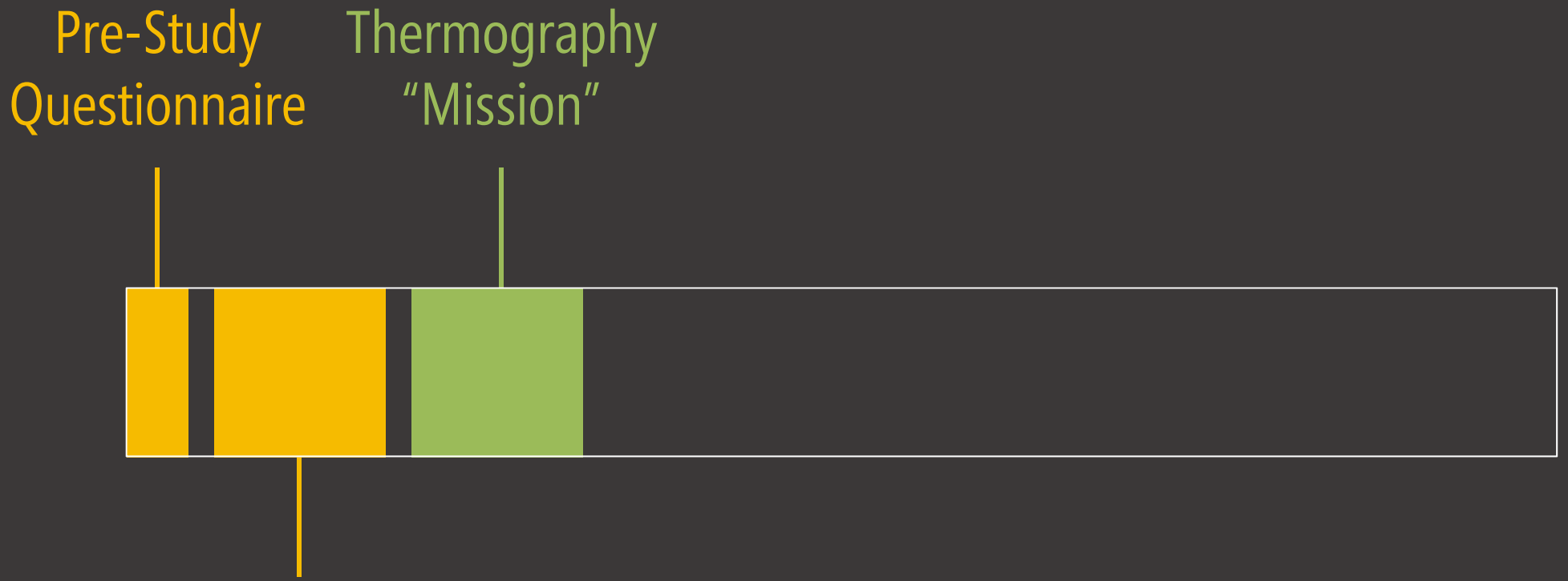


Study Design: Missions



"Investigate your home with your thermal camera for signs of energy inefficiencies; collect at least 25 photos that highlight aspects of your investigation."

Study Design: Field Study Procedure



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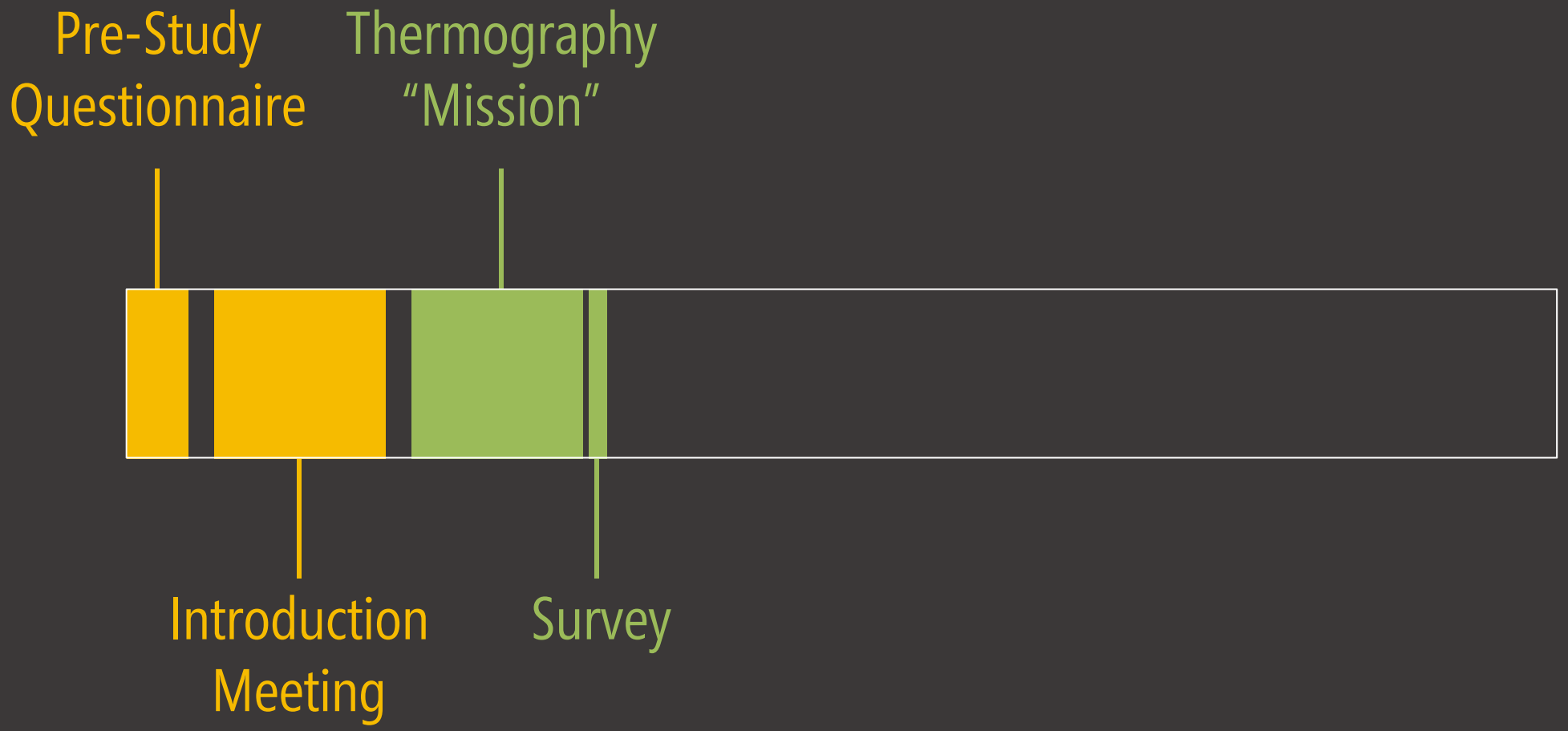


Study Design: Survey

Thermography Field Study: Weekly Questionnaire

Location

Please describe, to the best of your knowledge, the building(s) you explored during your mission.

6. What type of building(s) did you explore during your mission? *

- ○ House (i.e., a building completely separated from any others)
- ○ Apartment / Condo (i.e., a residence in a building with many others)
- ○ Townhouse / Row House (i.e., many homes sharing a wall with each other)
- ○ Warehouse
- ○ Office Building
- ○ Commercial Building
- ○ Manufacturing Building
- ○ Other - Write In (Required) *

7. To the best of your knowledge, what materials were used in the construction of the building(s)? *

Photograph Descriptions

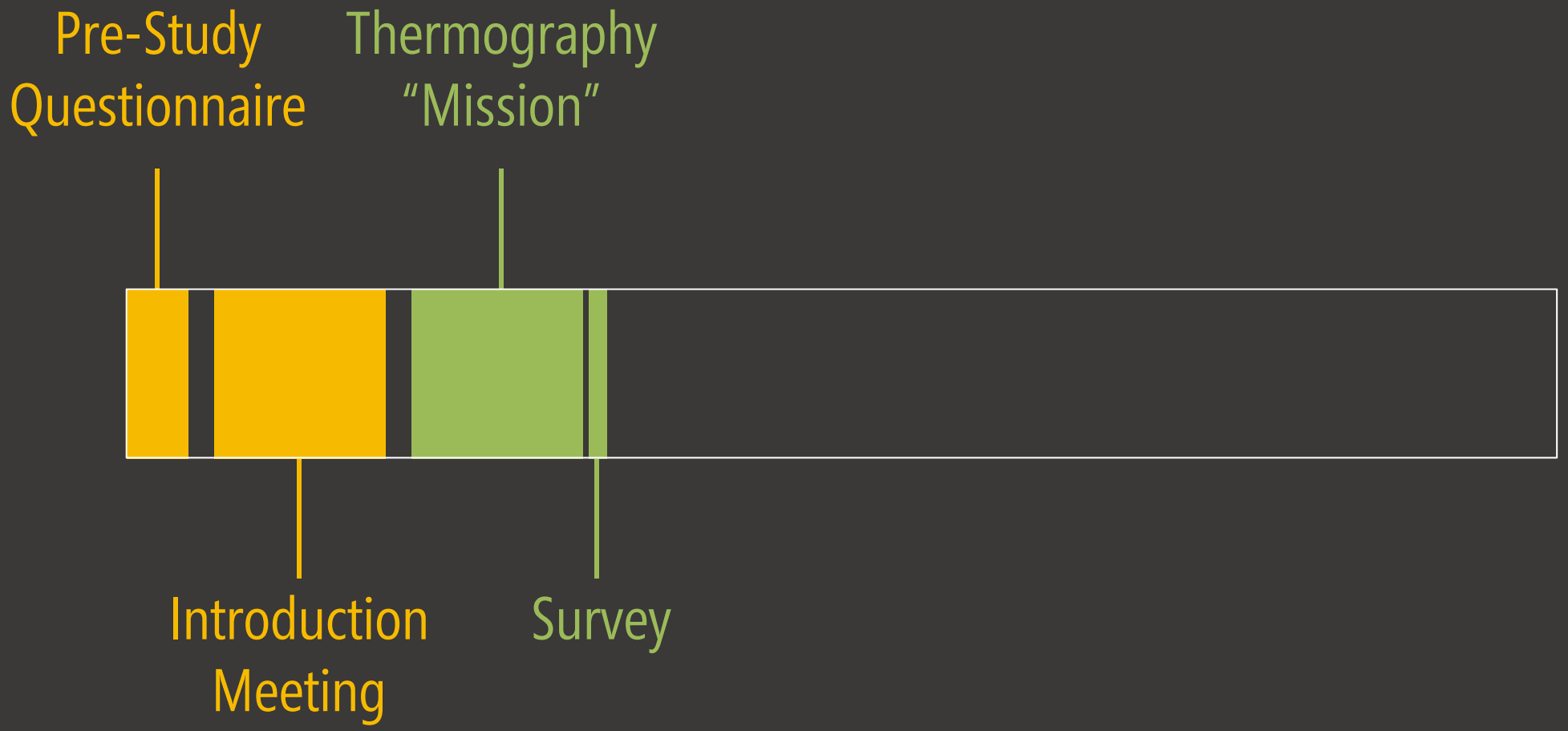
Please provide a brief summary of the images that you submitted

18. What types of issues did you look for during your mission? *

19. Did you find any evidence of issues (e.g., missing insulation)? *

20. Did you find anything else that interested you during your mission? *

Study Design: Field Study Procedure



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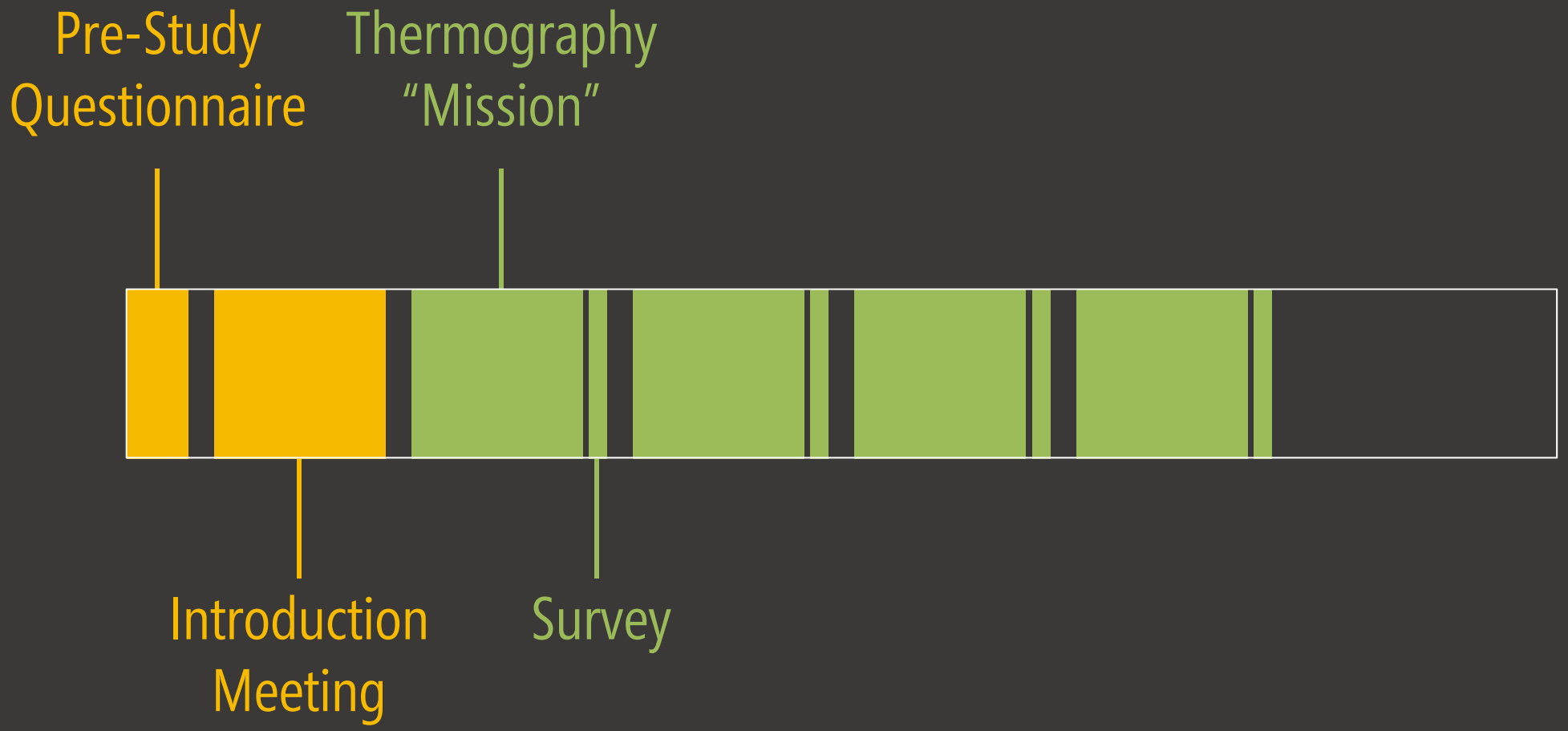

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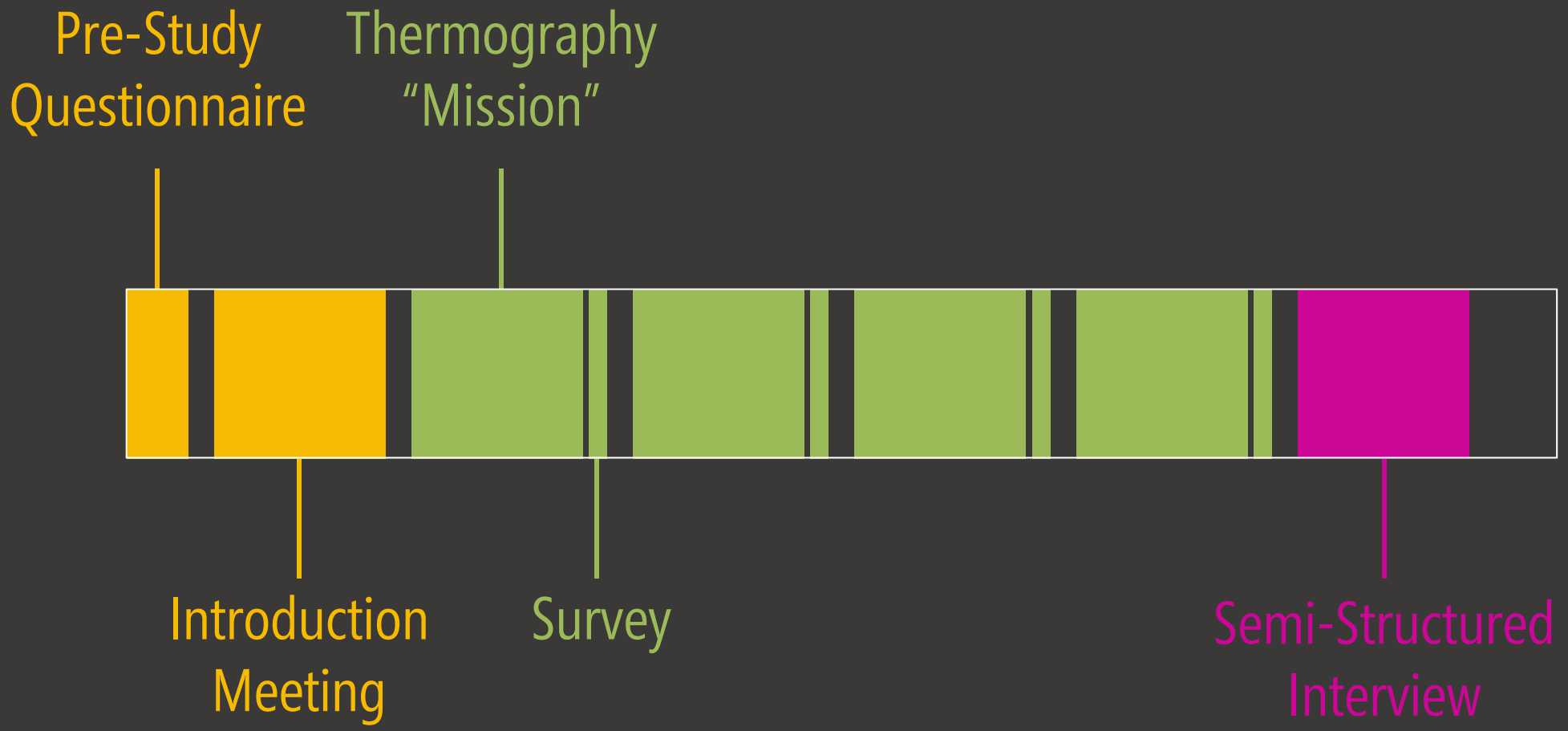
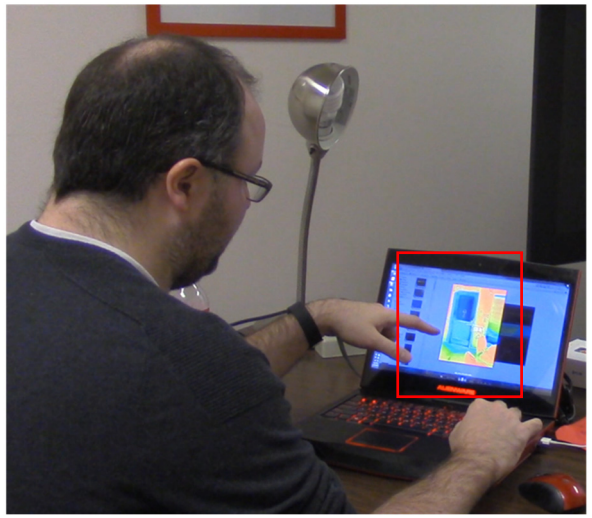
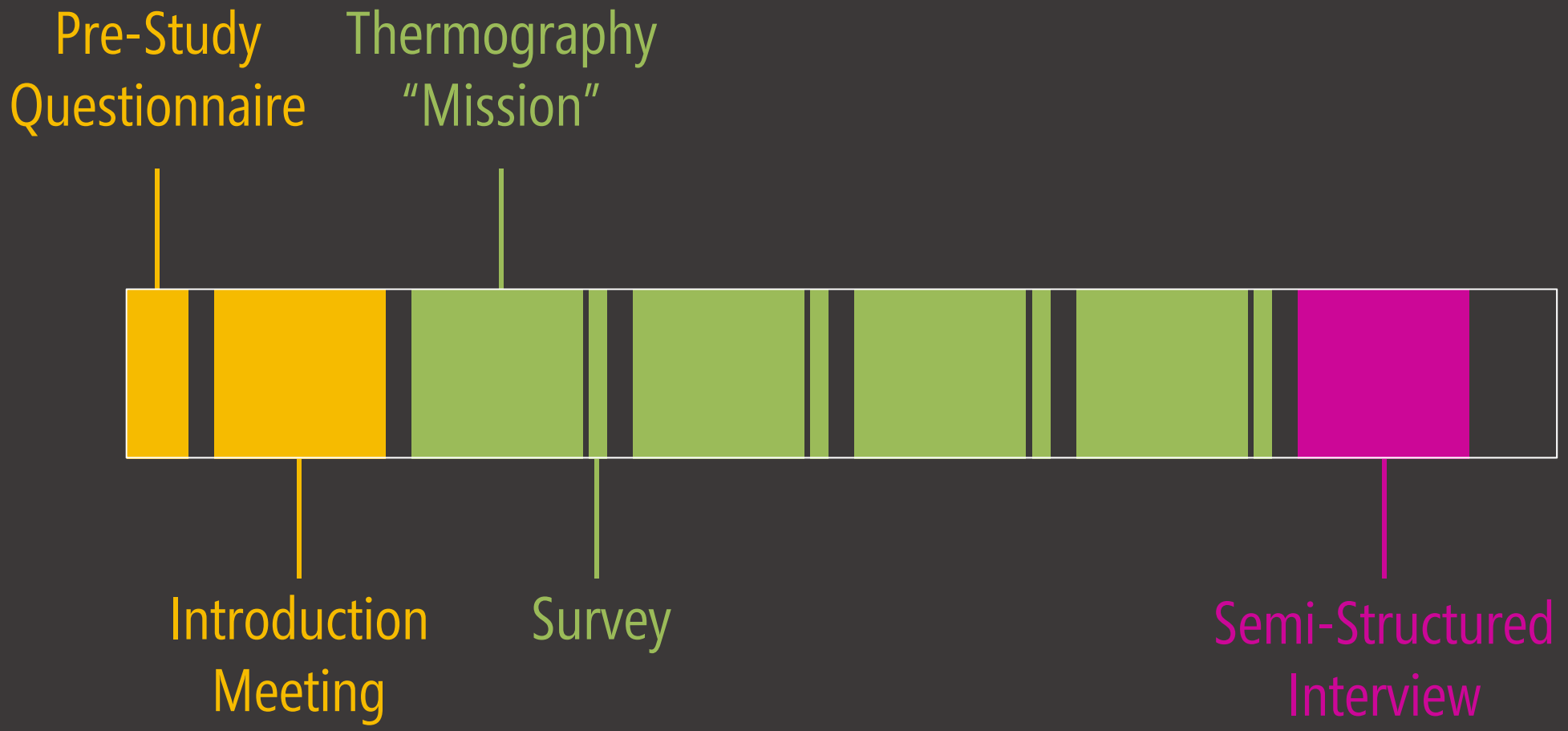


Study Design: Semi-Structured Interview



"It was pretty clear to me that the air seals around this door were not doing a very good job of preventing cold air from leaking into this room."

Study Design: Field Study Procedure



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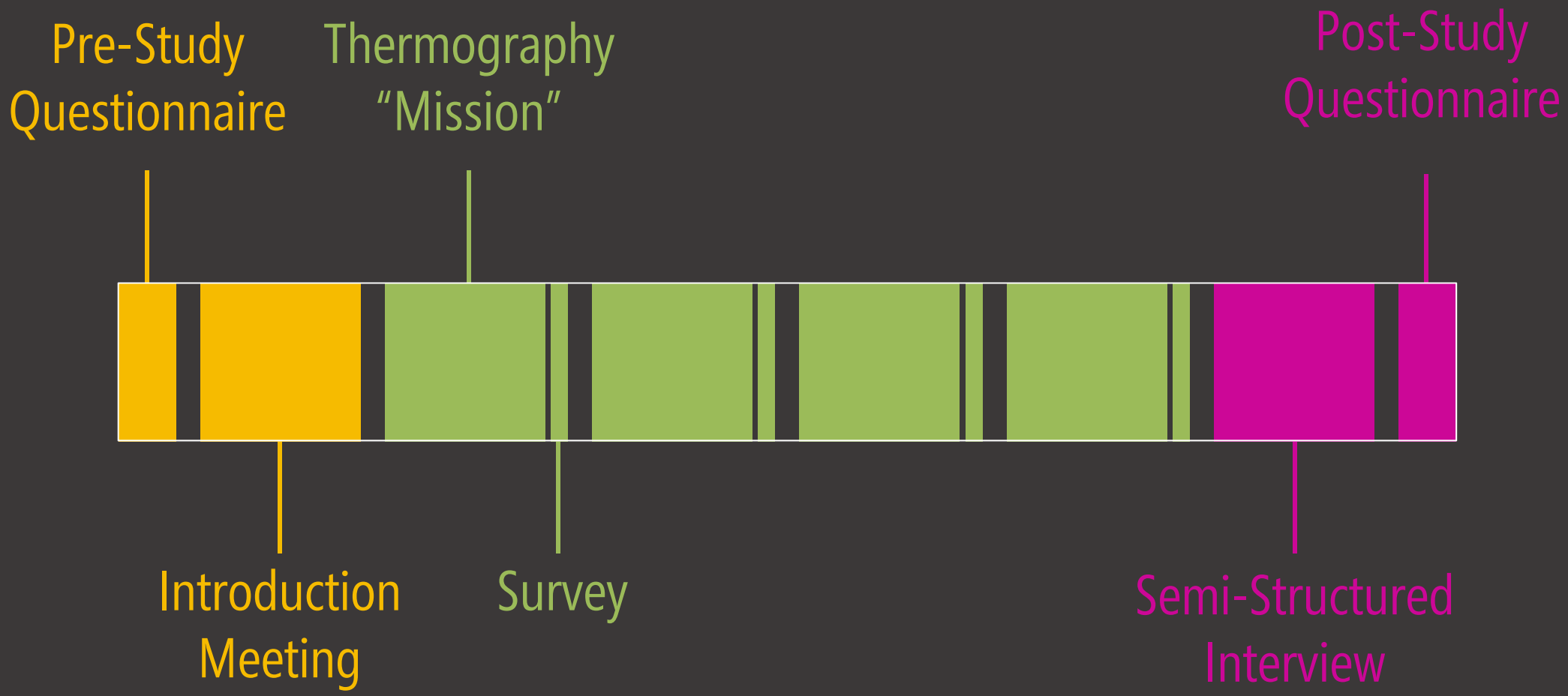
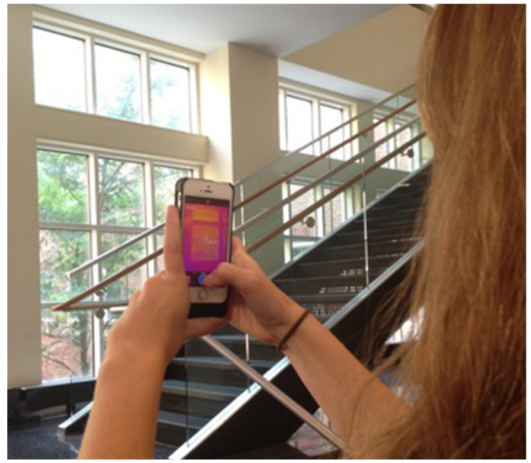


Study Design: Data Analysis

We qualitatively coded the survey, interview, and image data to uncover themes.

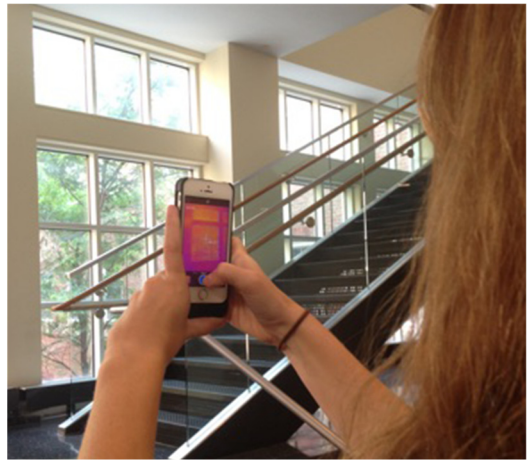
Study Findings

Study Findings



Field
Activities

Study Findings



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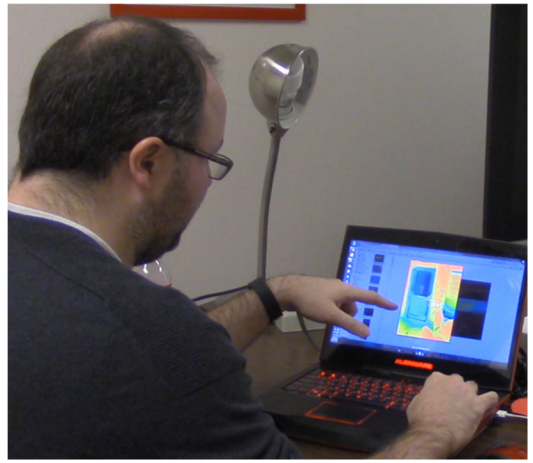
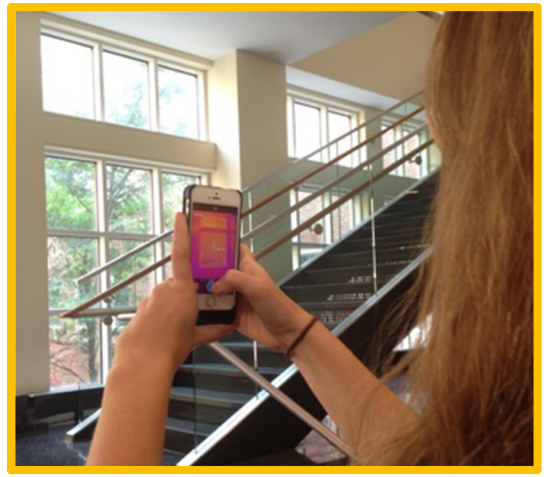


Semi-Structured
Interviews

Study Findings



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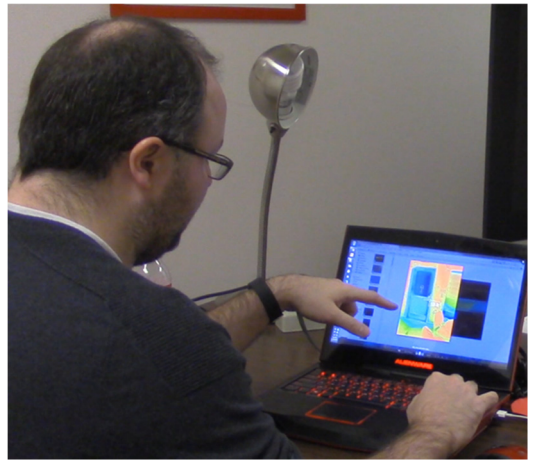

Semi-Structured
Interviews

Study Findings: Field Activities

Week

Home
Workplace
Commercial
Community

Study Findings: Field Activities

Week	Images
Home	572 (*Avg=52*)
Workplace	405 (*Avg=14*)
Commercial	415 (*Avg =16*)
Community	516 (*Avg =13*)
Total	*1,991* (*Avg=46*)

Study Findings: Field Activities

Week	Images	Time (mins)
Home	572 (*Avg=52*)	34 (*SD=15*)
Workplace	405 (*Avg=14*)	32 (*SD=14*)
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Study Findings: Field Activities

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Context

(a) Indoor (64.2%)

(b) Outdoor (35.6%)

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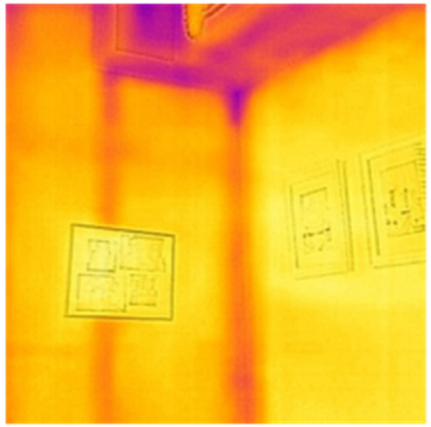
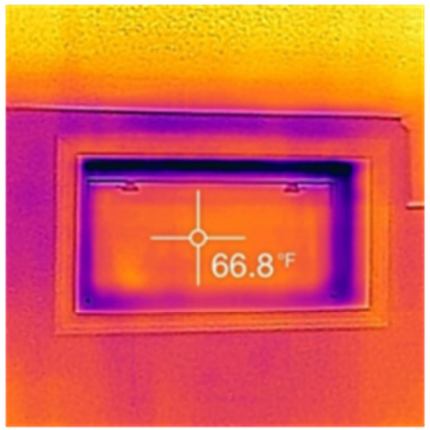
Subjects

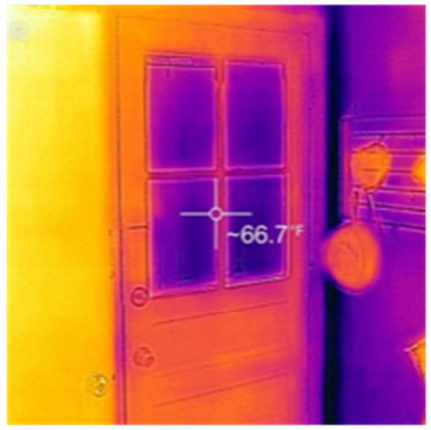


(c) Walls (71.6%)



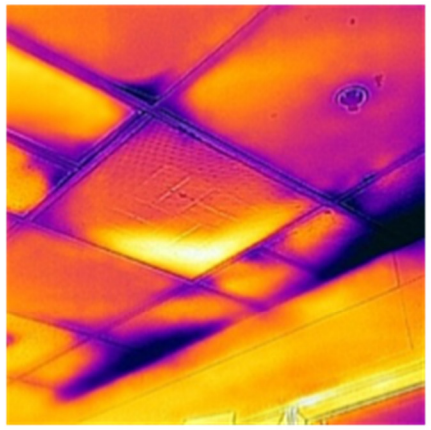
(d) Windows (30.3%)

(e) Electronics (24.7%)



(f) Doors (24.4%)

(g) Light Fixtures (23.8%)



(h) Ceilings (22.7%)

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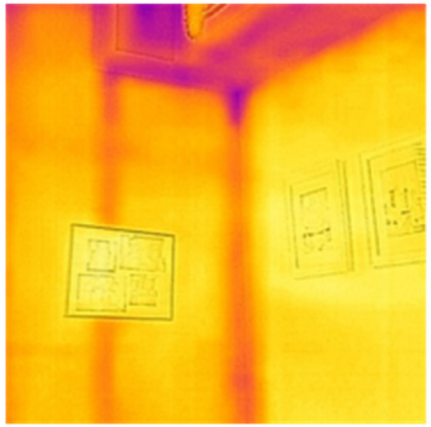
(a) Indoor (64.2%)

(b) Outdoor (35.6%)

Subjects



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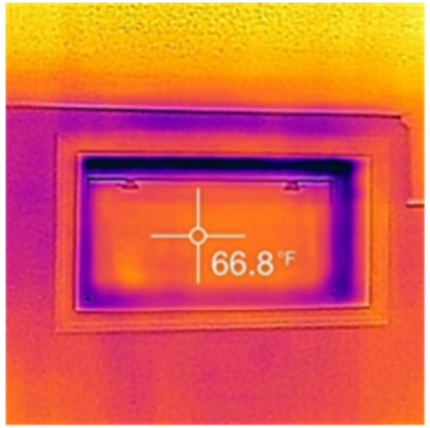

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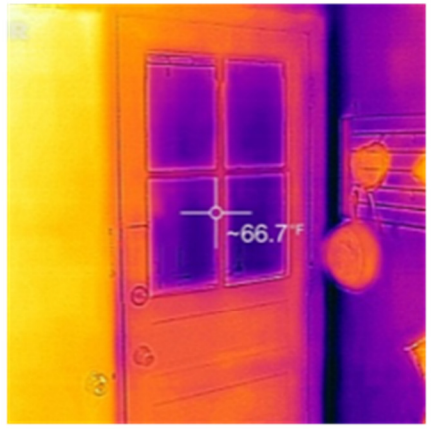

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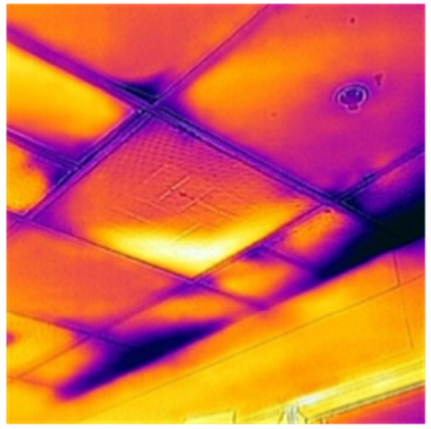
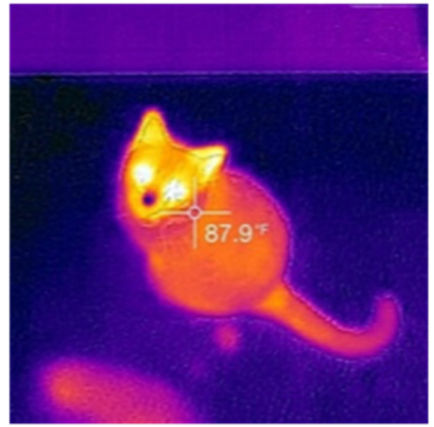
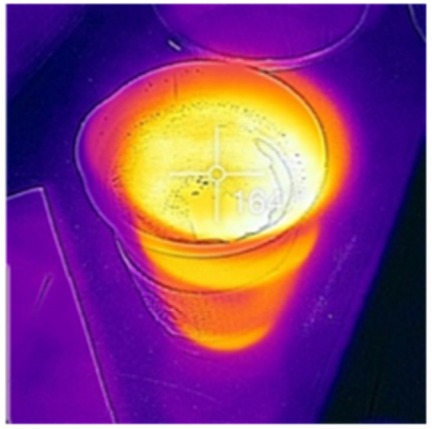


(h) Ceilings (22.7%)

Misc./Fun



(i) People/Pets (4.7%)



(j) Play/Experiments (1.0%)

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Home Mission

During the home mission, participants:

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- Collected 572 photos (AVG=57.2, SD=52.27).

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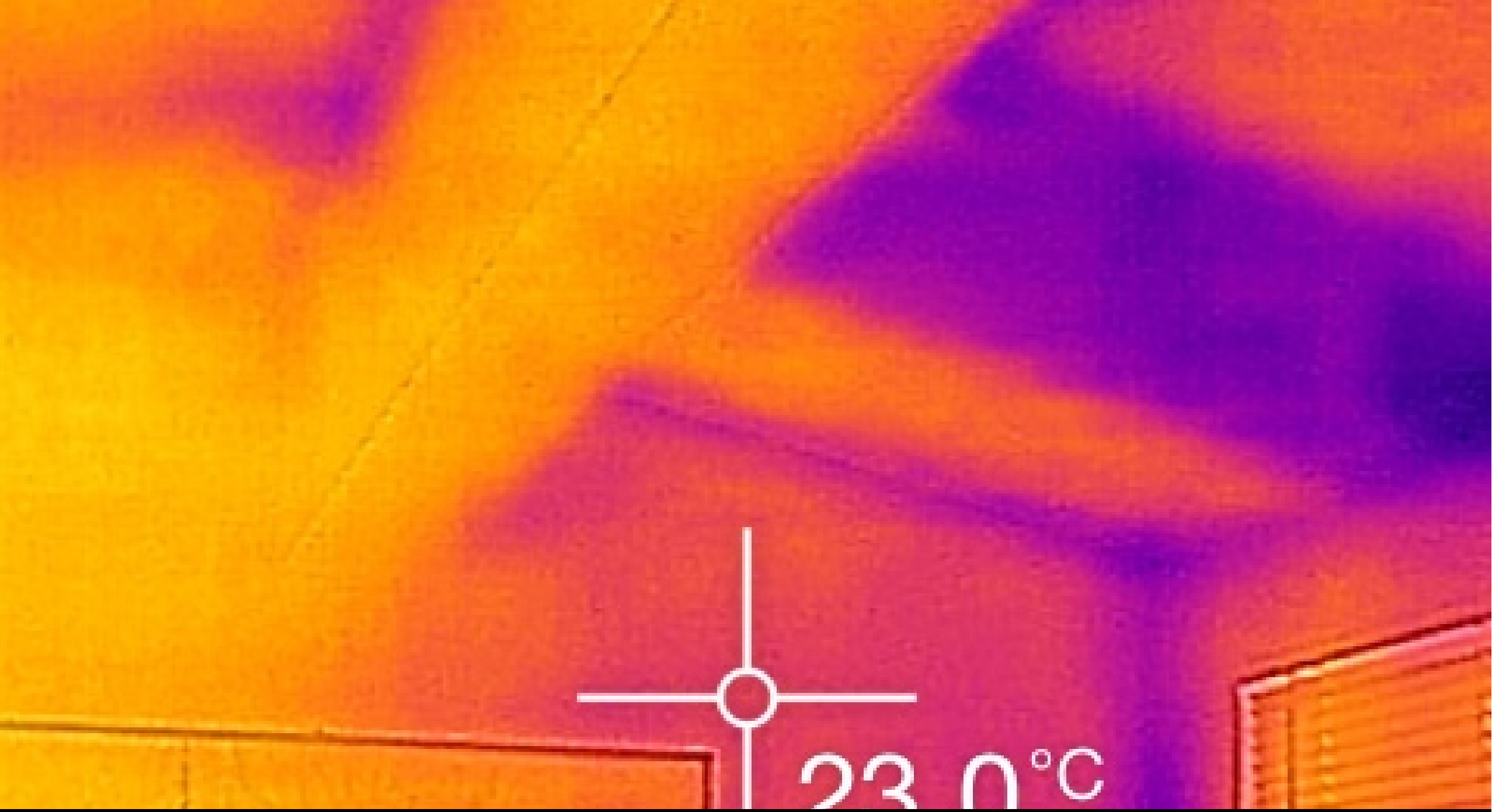
66.8 °F


23.0°C

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- A few (3) reported investigating electrical issues due to safety concerns (e.g., fire).

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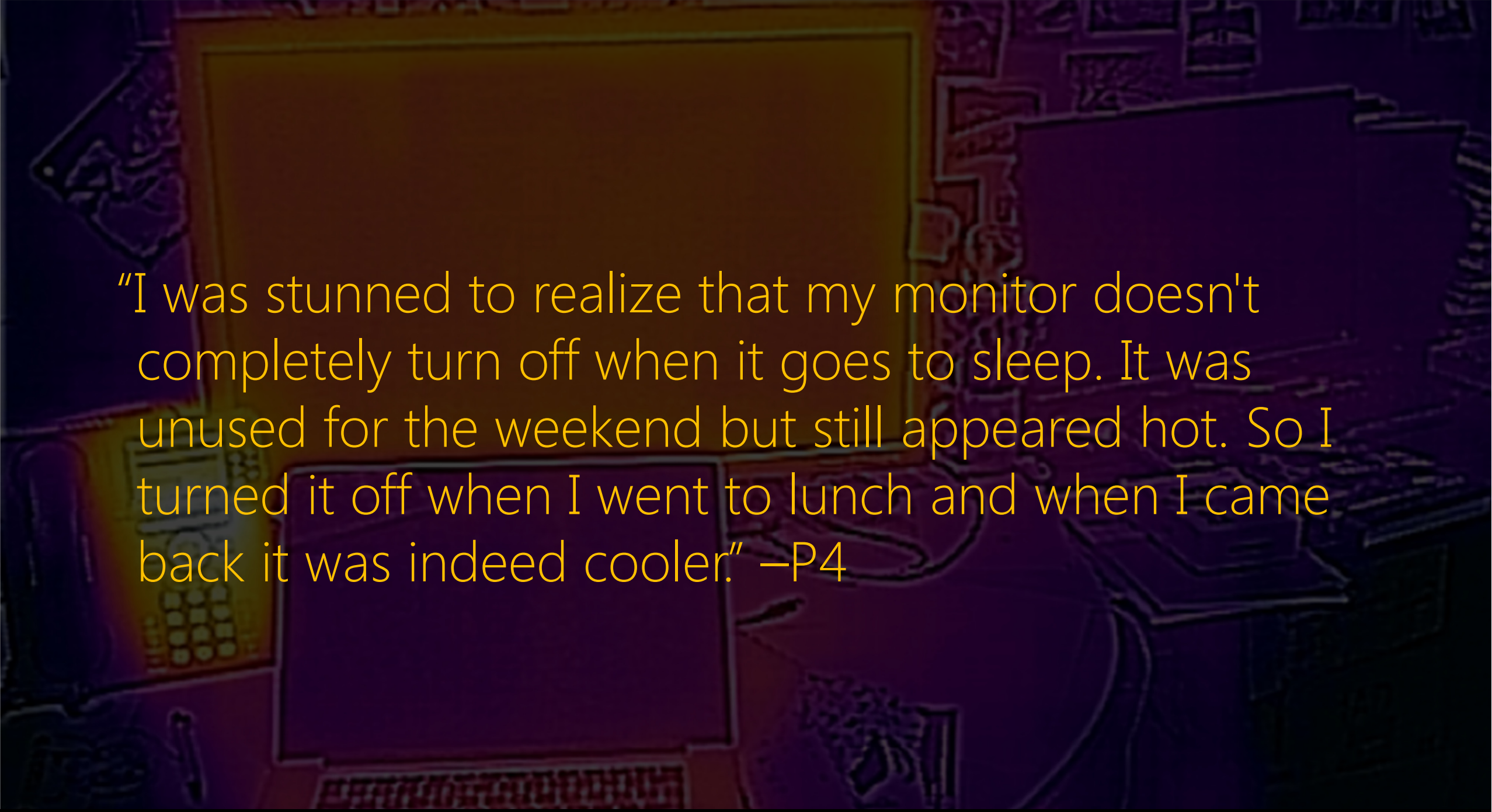
- All participants (10) reported looking for leaky windows, doors, and noted interesting heat signatures produced by electronic devices. Half (5) reported finding concerning issues.


"I was stunned to realize that my monitor doesn't completely turn off when it goes to sleep. It was unused for the weekend but still appeared hot. So I turned it off when I went to lunch and when I came back it was indeed cooler." –P4

Workplace Mission

During the workplace missions, participants:

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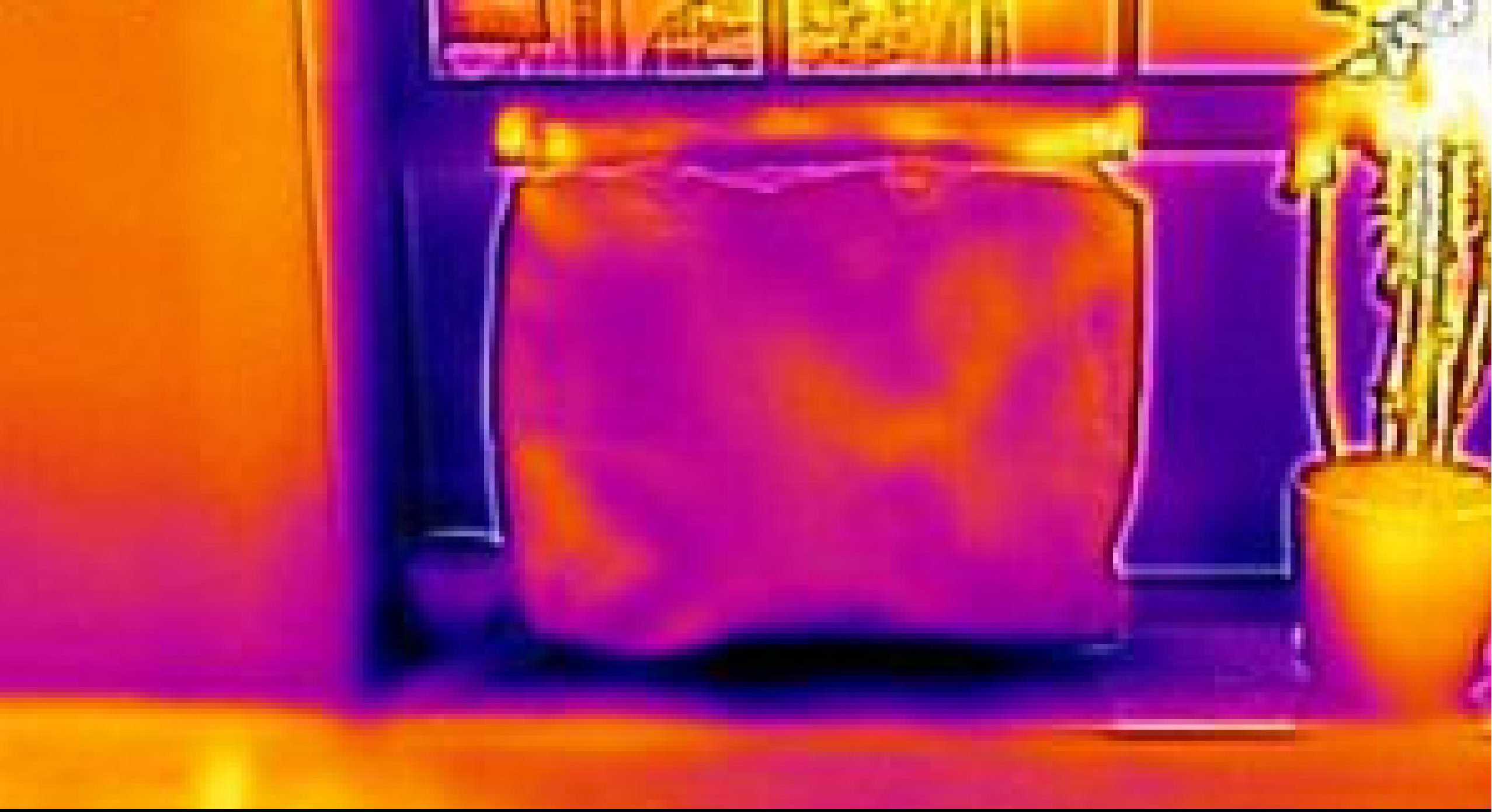
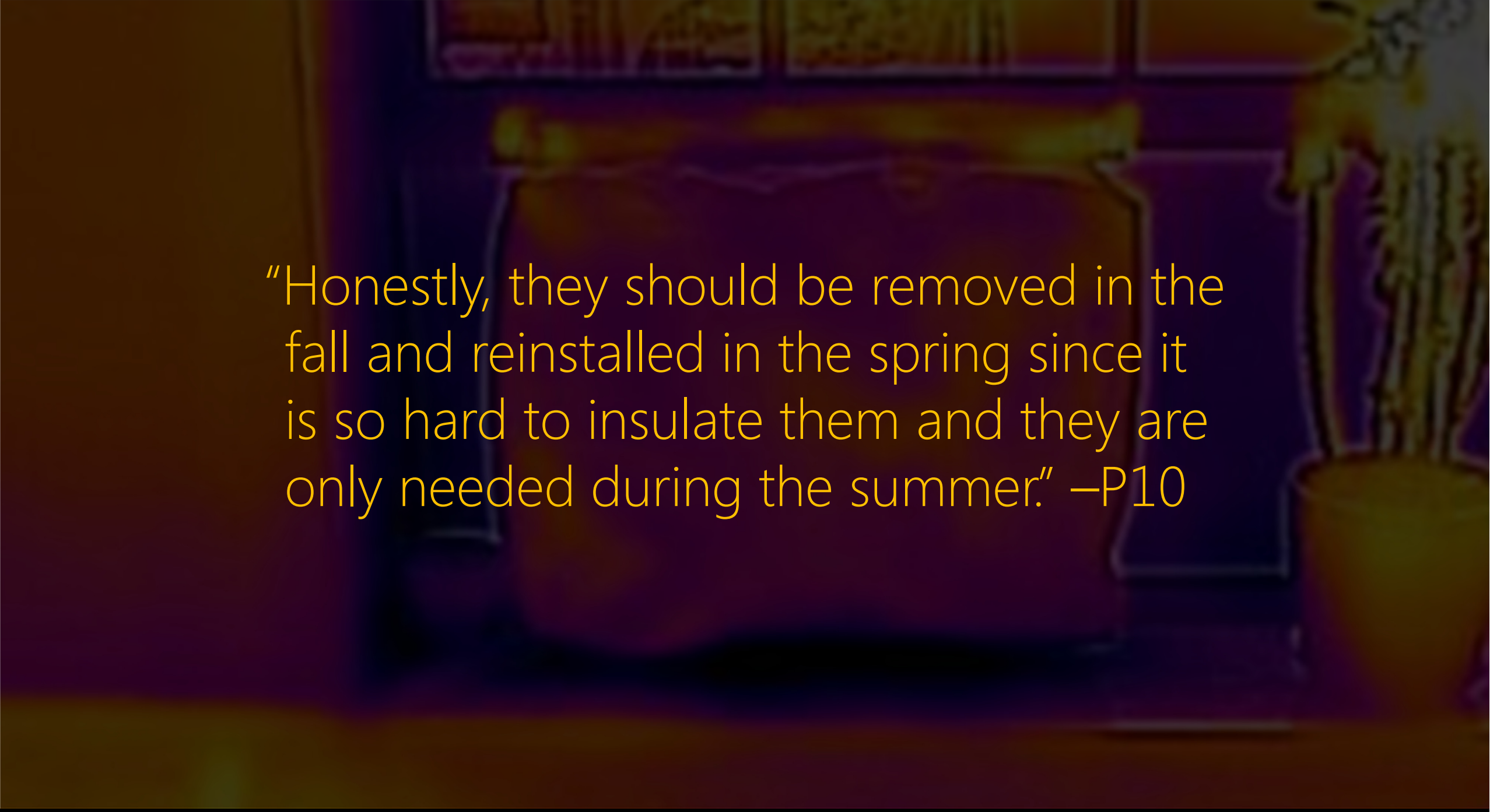
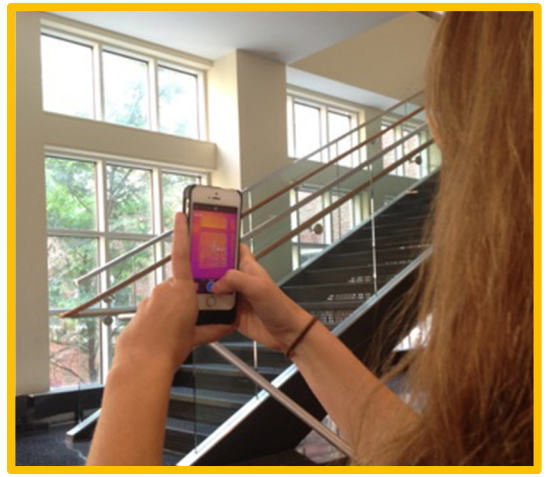
- A few (2) explored comfort issues in shared office spaces.

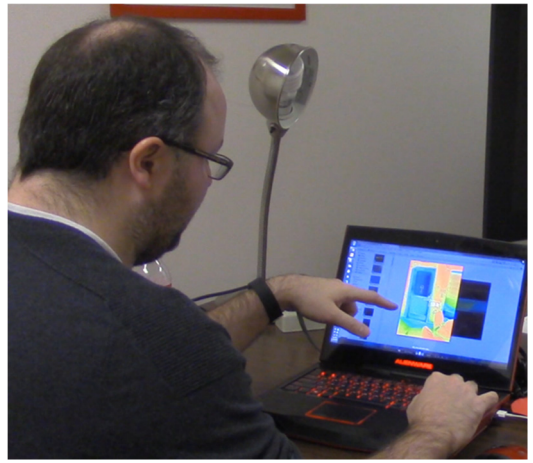



"Honestly, they should be removed in the fall and reinstalled in the spring since it is so hard to insulate them and they are only needed during the summer." –P10

Study Findings

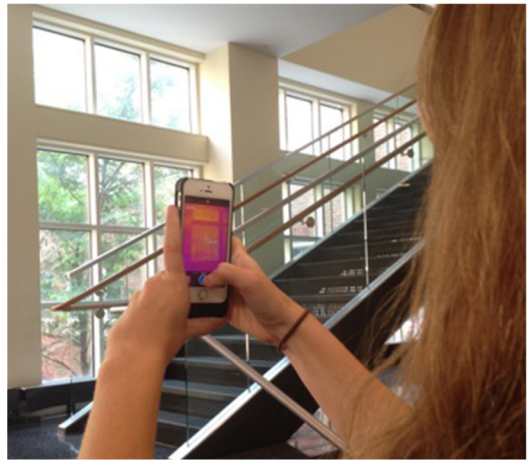


Field
Activities

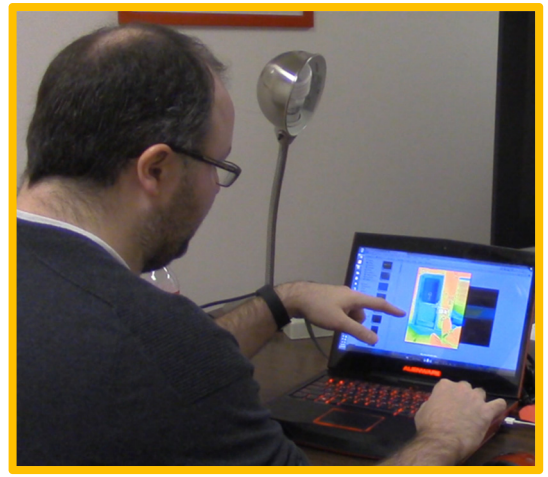


Semi-Structured
Interviews

Study Findings



Field
Activities



Semi-Structured
Interviews

Study Findings: Interviews

Knowledge Discovery

Current Practices

Potential Benefits

Locus of Control

Hardware Issues

Software Issues

Interpretative Issues

Design Ideas

Study Findings: Interviews

Knowledge Discovery	Hardware Issues
Current Practices	Software Issues
Potential Benefits	**Interpretative Issues**
Locus of Control	Design Ideas

Study Findings: Interviews

Knowledge Discovery

Current Practices

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Potential Benefits Mission

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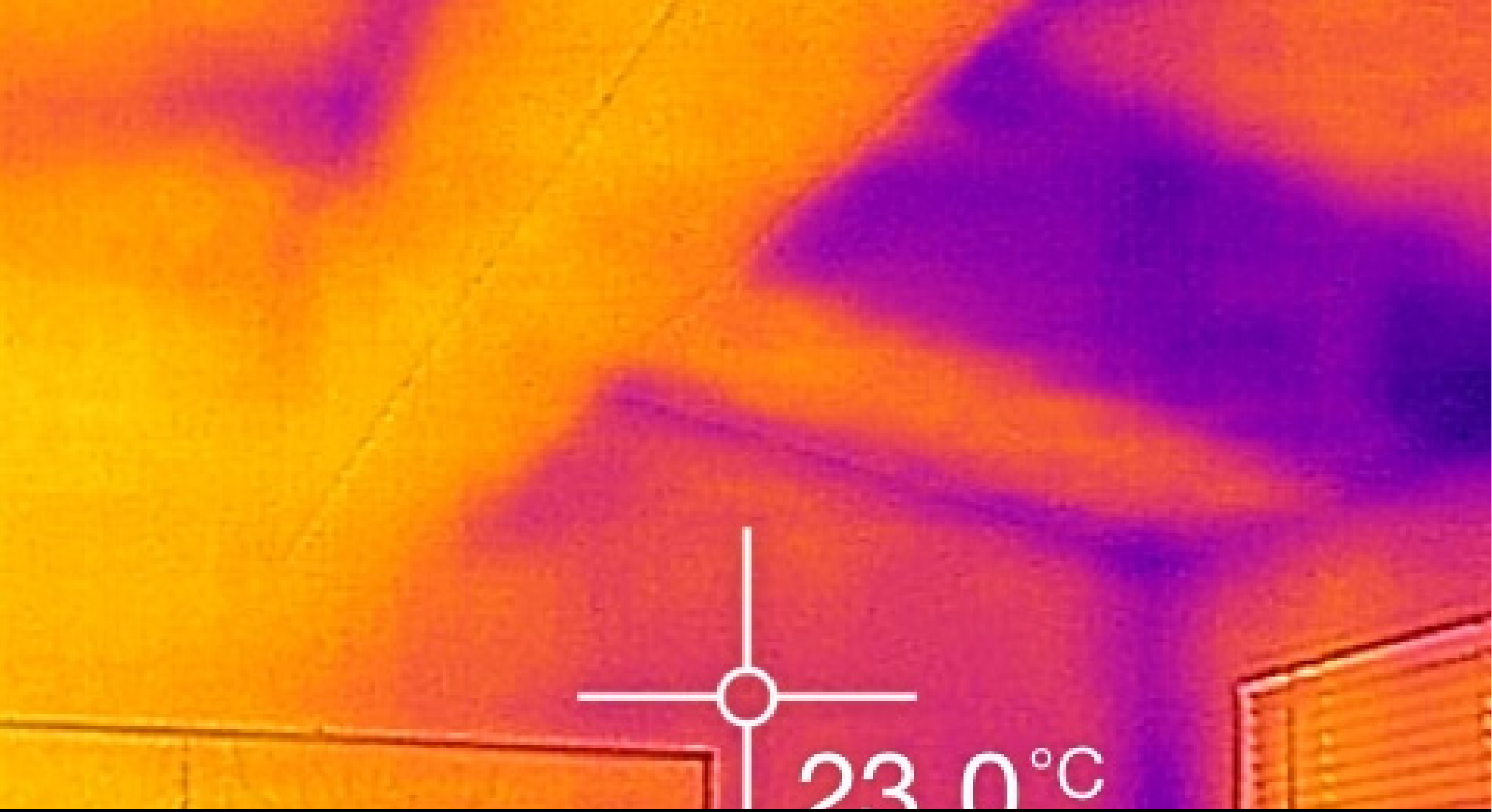
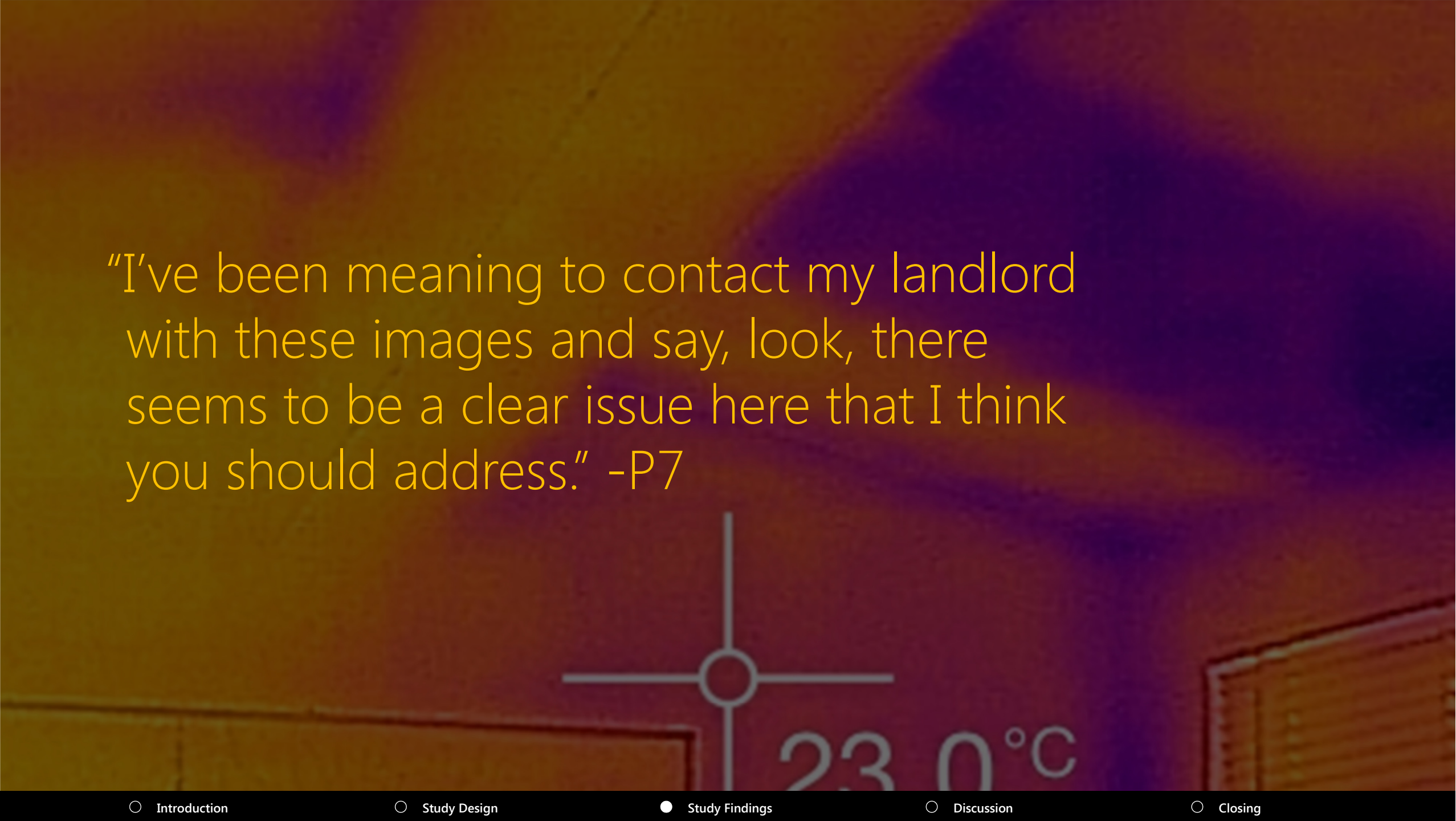

23.0°C



"I've been meaning to contact my landlord with these images and say, look, there seems to be a clear issue here that I think you should address." -P7

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Study Findings: Interviews

Knowledge Discovery

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Hardware Issues

Software Issues

Interpretative Issues

Design Ideas

Study Findings: Interviews

Knowledge Discovery	Hardware Issues
Current Practices	Software Issues
Potential Benefits	**Interpretative Issues**
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Interpretative Issues

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- Most (8) believed that their ability to interpret thermographic images was limited by confounding variables (e.g., heating elements, lack of materials knowledge).

"This is all glass, so it's reflective. It's not clear to me if it's really that much warmer on the inside of this building than the outside." -P3

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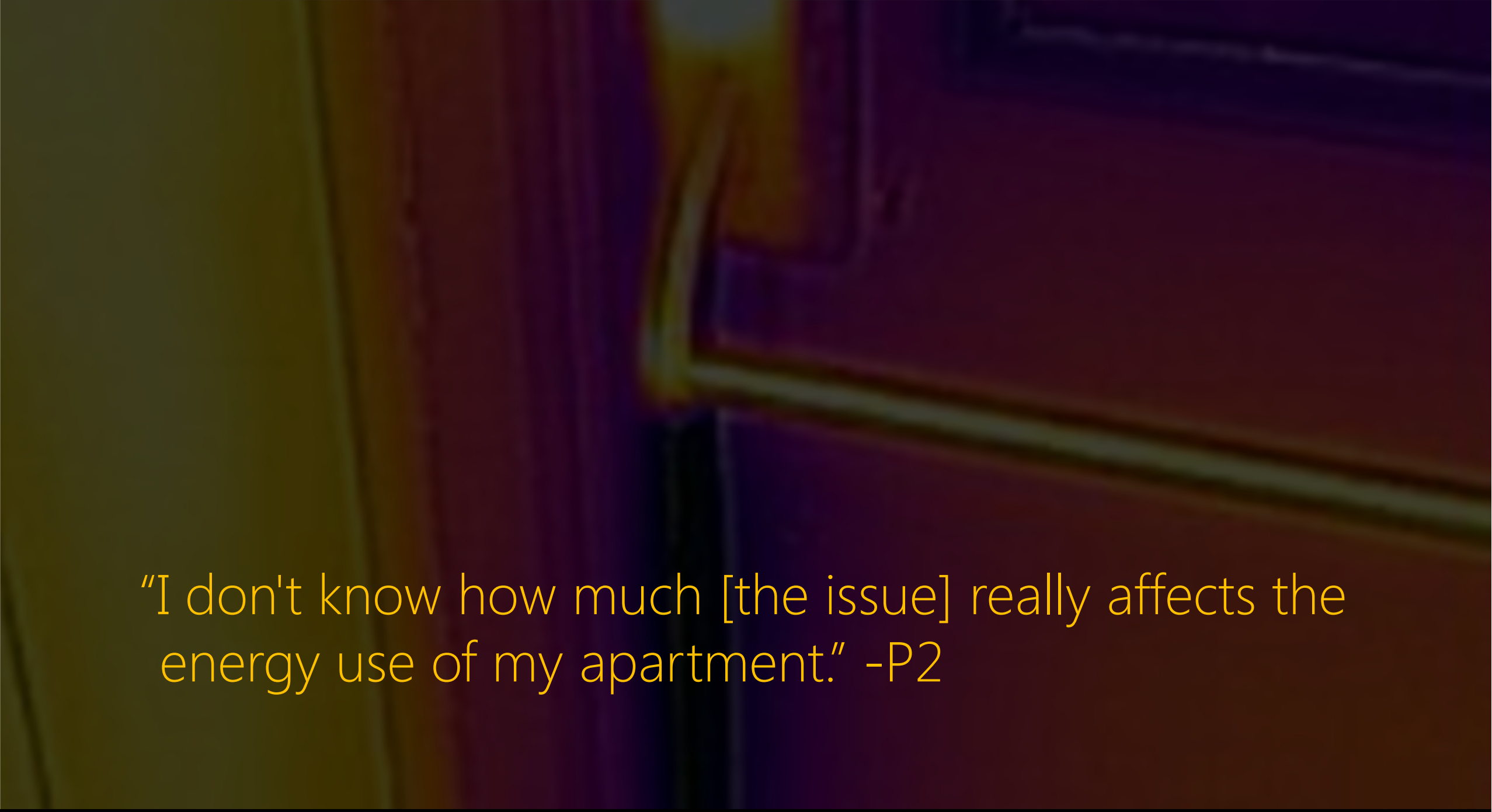
- All participants (10) described capturing imagery that they could comfortably interpret and imagery that they did not understand.
- Most (8) believed that their ability to interpret thermographic images was limited by confounding variables (e.g., heating elements, lack of materials knowledge).
- Most (6) found it difficult to determine the significance of an issue they discovered.



"I don't know how much [the issue] really affects the energy use of my apartment." -P2

Study Findings: Interviews

Knowledge Discovery	Hardware Issues
Current Practices	Software Issues
Potential Benefits	**Interpretative Issues**
Locus of Control	Design Ideas

Study Findings: Interviews

Knowledge Discovery

Hardware Issues

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Design Ideas

Locus of Control

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Locus of Control

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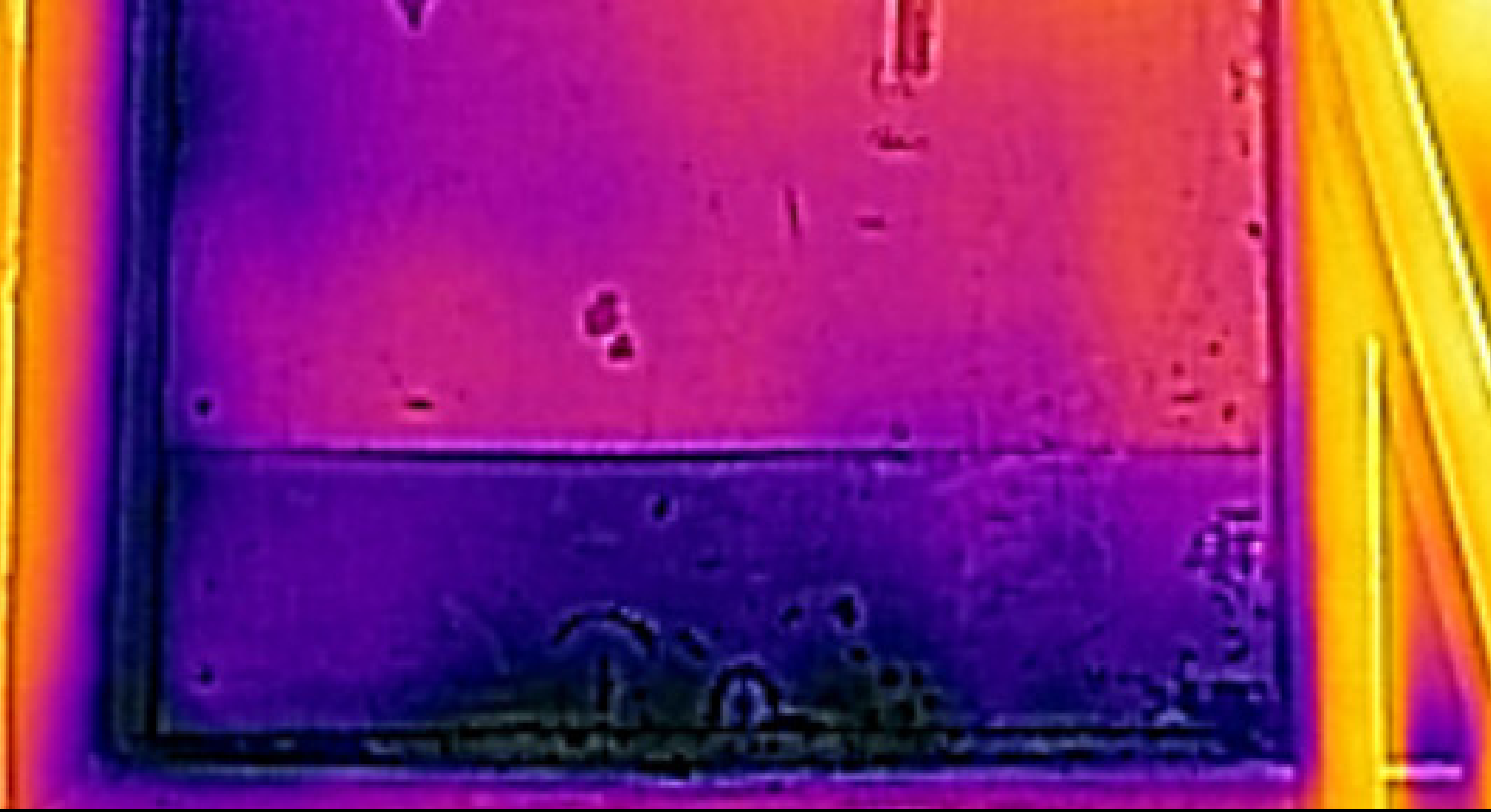
- 4 participants (who rented or lived in a housing cooperative) were concerned that if they found evidence of a problem they would not be in a position to make retrofit decisions.



"If I took a picture that showed an issue, I don't necessarily think the owner would get on top of fixing it." -P5

Locus of Control

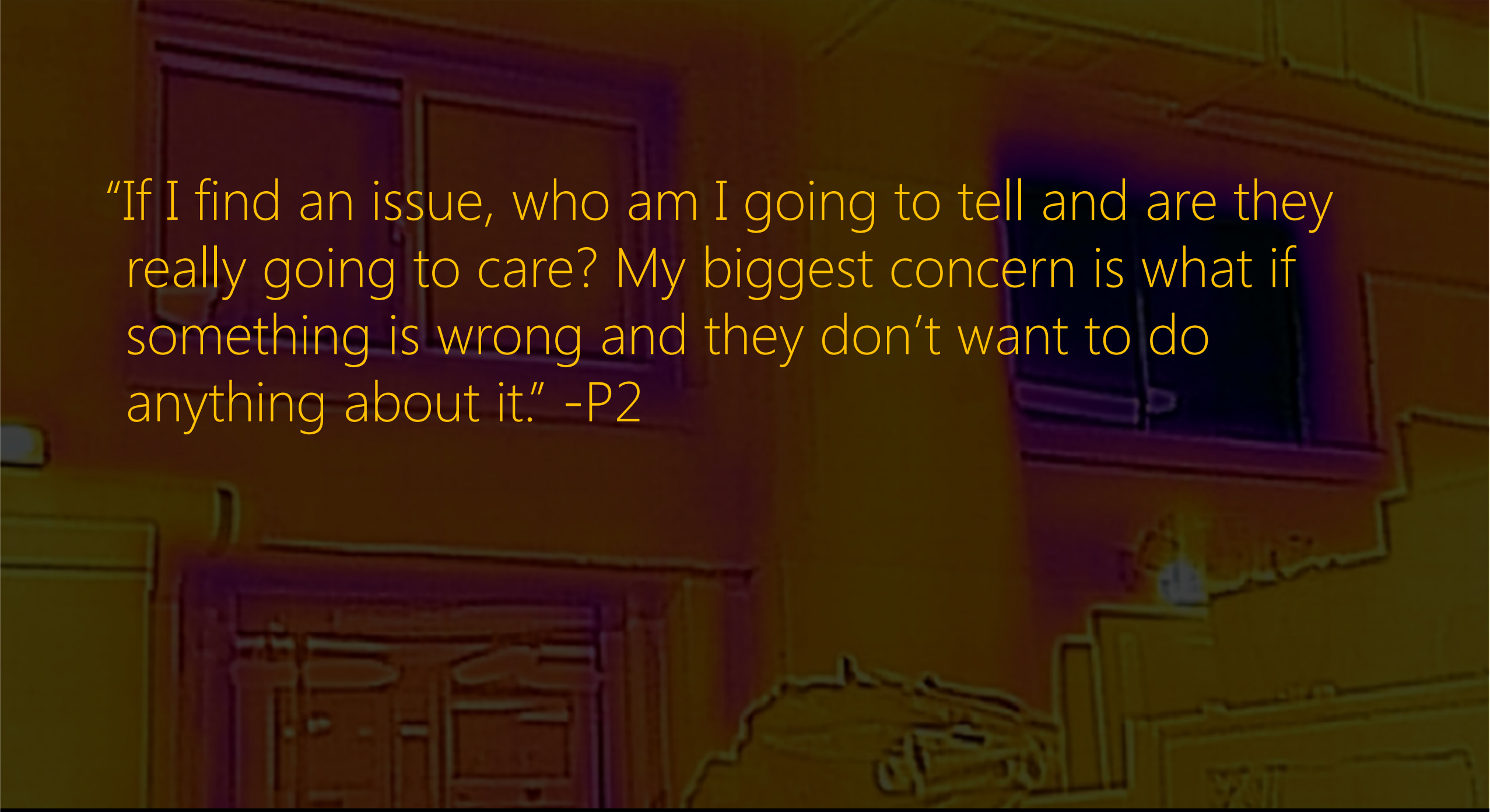
Participants frequently discussed challenges associated with their ability to effect change:

- 4 participants (who rented or lived in a housing cooperative) were concerned that if they found evidence of a problem they would not be in a position to make retrofit decisions.

Locus of Control

Participants frequently discussed challenges associated with their ability to effect change:

- 4 participants (who rented or lived in a housing cooperative) were concerned that if they found evidence of a problem they would not be in a position to make retrofit decisions.
- In missions outside of the home (or the workplace), 2 participants expressed that it was not clear who they should talk to if they discovered an issues.


"If I find an issue, who am I going to tell and are they really going to care? My biggest concern is what if something is wrong and they don't want to do anything about it." -P2

Discussion

Discussion

Barriers to Novice Thermography

Privacy and Sharing

Implications for Public Auditing

Limitations

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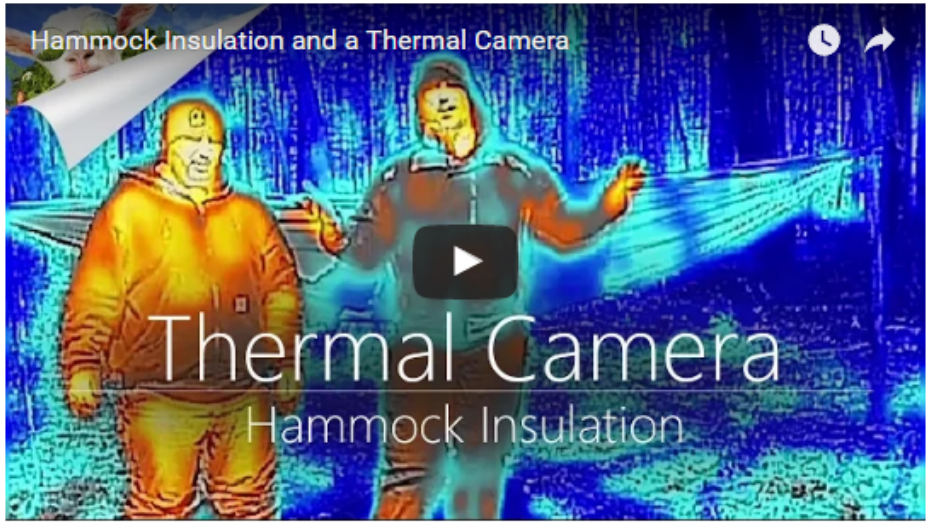


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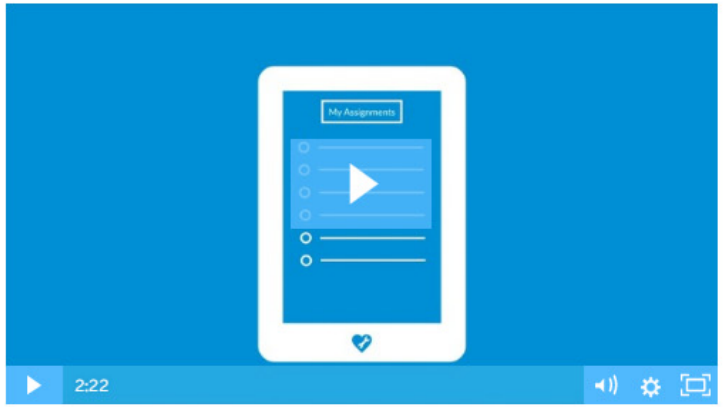

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DISCUSSION: LIMITATIONS

Some limitations of this work include:

- As our field study was semi-structured, findings may not translate to unguided use.
- While a trained thermographer reviewed participant data, we did not try to systematically verify participant reporting accuracy.
- While participant discussed potentially taking actions based on their audits, we did not conduct follow-ups.

Closing: Summary

CLOSING: SUMMARY

1 First human-centered study of novice smartphone-based thermal camera use.

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2 Through weekly missions, we assessed how novice users approach auditing tasks and the challenges they encounter.

CLOSING: SUMMARY

1. First human-centered study of novice smartphone-based thermal camera use.
2. Through weekly missions, we assessed how novice users approach auditing tasks and the challenges they encounter.
3. Through semi-structured interviews, we explored potential benefits and barriers to effecting change.

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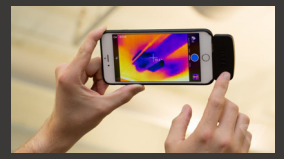

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Person – Wilson Joseph
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Closing: More Information

The full paper is available at:
https://doi.org/10.1145/3025453.3025471

For more information about this project, please visit:
http://makeabilitylab.io/projects/thermography/

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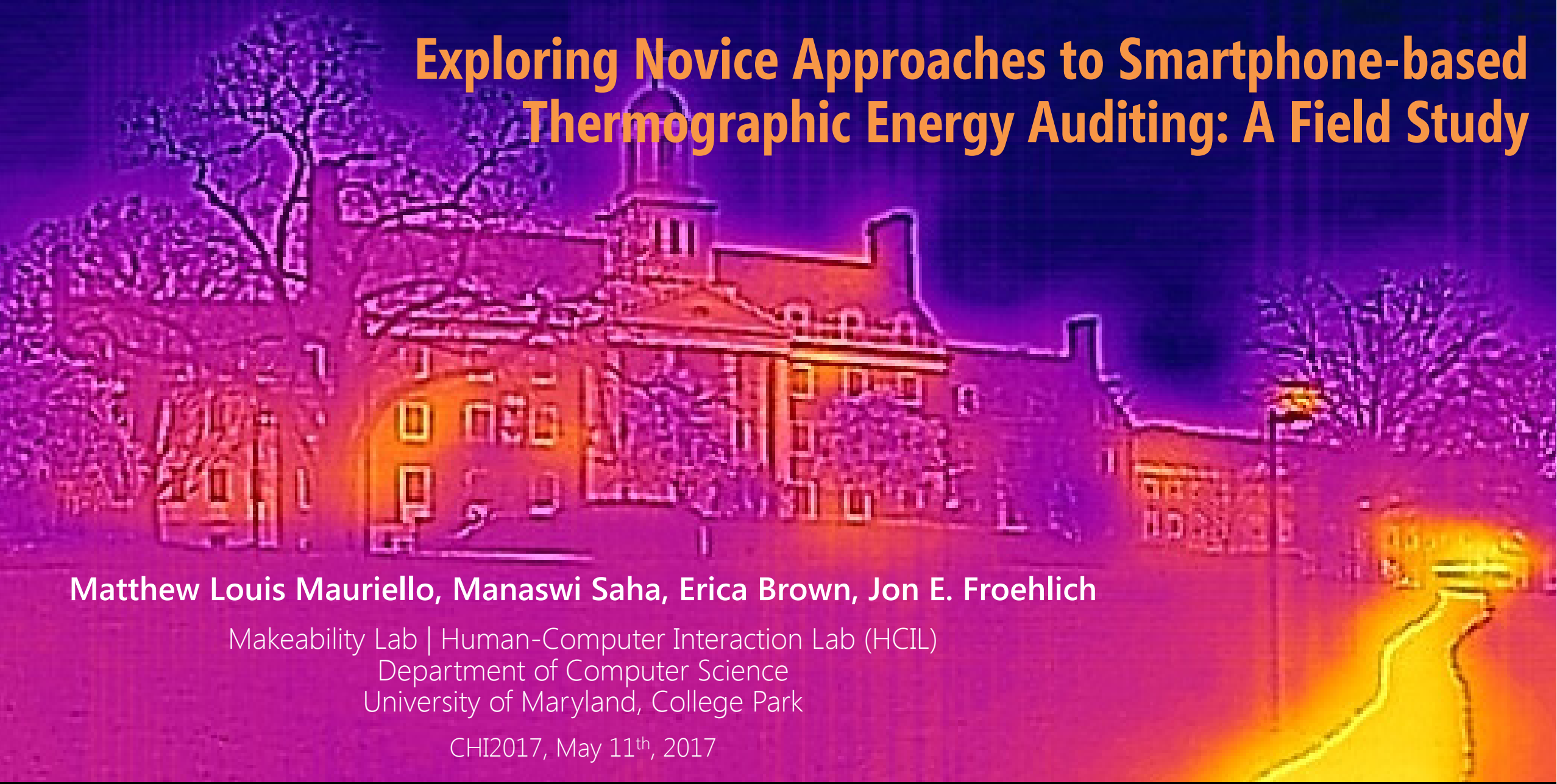
Exploring Novice Approaches to Smartphone-based Thermographic Energy Auditing: A Field Study



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