ZERO CARBON-READY RETROFIT STUDY

WEST TISBURY ELEMENTARY SCHOOL
WEST TISBURY, MA

PREPARED FOR
UP-ISLAND REGIONAL SCHOOL DISTRICT
SEPTEMBER 09, 2022

RDH BUILDING SCIENCE

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

RDH was retained by the Up-Island Regional School District to assess retrofit options for the West Tisbury School with the goal of defining the necessary measures for the building to become **net zero operational carbon ready/net zero energy ready.** The town of West Tisbury, along with the other Up-Island towns of Chilmark and Aquinnah, passed a resolution setting a goal that the town's energy will come from 100% renewable sources by 2040.

Per the RFQ provided by the UIRSD dated 2/04/2022, RDH was tasked with the following scope:

→ Become familiar with the building

→ Review existing energy use

→ Develop packages of options

→ Recommend package with best result such that all resulting benefits including but not limited to energy savings can be communicated to voters/UIRSD

→ Provide sequenced plan for how work may be implemented and prepare cost estimate

→ Prepare presentations and attend meetings

→ Prepare one hard copy and an electronic copy of the final study report

BECOME FAMILIAR WITH THE BUILDING

In addition to reviewing existing drawings and reports provided by the UIRSD, RDH visited the West Tisbury School on May 26th - 27th, 2022 to survey the building enclosure and mechanical systems. RDH team members were accompanied by Head Custodian, Jamie Labbe, with whom the team reviewed how the building currently operates, including areas and components where known problems occur. RDH recorded observations about the mechanical systems and the condition of the building enclosure, included in the Existing Building Summary section of this report. During our site visit, the interior of the building was heated by turning up the building's boilers for approximately 4-5 hours achieving an interior temperature of approximately 80 degrees F. Later that day when the outdoor temperature had dropped to approximately 55 Degrees F, thermal imaging was done from the exterior of the building to identify sources of air leakage and thermal bridging in the building enclosure.

On June 17th - 18th, 2022 RDH returned to site, accompanied by Advanced Building Analysis (ABA), RDH's blower door testing partner, to perform a whole-building airtightness testing. This test pressurizes the building and detects how much air leaks through the building enclosure at a given constant pressure. Areas of air leakage were noted with further thermal imagery while the building was under pressure, and airtightness rates were used to inform the existing energy model. The whole-building airtightness testing report is included in Appendix A of this report, and observations from that testing are also included in the Existing Building Summary section of this report.

REVIEW EXISTING ENERGY USE

RDH completed a preliminary energy assessment to summarize energy consumption and carbon emissions using four years of utility data provided by the UIRSD. When required information was not explicitly stated in the provided documentation, assumptions were made based on previous experience.

The school is currently heated by three oil-fired boilers, with 2-pipe unit ventilators providing heat to the classrooms and hydronic radiator fins heating the corridors. One heat pump provides heating and cooling in the computer lab and two air-conditioning units provide cooling to the office/admin area. There is also air conditioning serving the library. Domestic hot water to the kitchen is supplied by two propane on-demand hot water heaters, while the rest of the school is served by the oil-fired boilers in the heating season and one electric hot water heater in the summer months. Air handling units provide heating and ventilation to the gym, music/band room, cafeteria, and science labs, and a propane-fired make-up air unit serves the kitchen.

Annually, the calibrated existing building model generates approximately 380 tons in Greenhouse Gas emissions, has a Total Energy Use Intensity of 64 kBTU/ft^2, and a Thermal Energy Demand Intensity of 31 kBTU/ft^2. These numbers would be higher if the mechanical systems were being used as intended. **Many of the mechanical systems in the existing building are currently not working or have been turned off because they are too noisy, therefore the building is not being ventilated and heated as intended and is not achieving the designed indoor conditions.**

RDH performed an analysis of the heat loss through the existing building enclosure (all the walls, roof floors, windows, etc.), using areas of existing building enclosure components and their R-values, which is a measure of the thermal resistance to heat transfer through those assemblies. The results of this analysis can be viewed in the pie chart under the Energy Analysis section of this report.

The roof was the largest area of heat loss through the building enclosure as it contains varying thicknesses of insulation based on the era in which it was built. Some of the 1973 roof assemblies have no insulation above the roof deck. This analysis was also informed by the measurement of air infiltration from the whole-building airtightness testing. While the walls contribute a small portion of the pie chart, the air leakage through the walls constitutes a large portion of the air leakage, which accounts for 34% of the heat loss through the building enclosure. The building is very leaky, which is why the retrofit strategies RDH is recommending involves re-cladding the entire building, with a properly installed air barrier that transitions from foundation to wall, wall to roof, and around doors and windows in a continuous fashion to eliminate the air leaks we observed.

The oil-fired boilers used to heat the school are the single largest contributing factor to energy use and greenhouse gas emissions. By switching the current oil-fired boilers to an all-electric plant, like the air-to-water heat pump system proposed in the Retrofit Strategies section of this report, operational carbon emissions of the school will be reduced by approximately 24% with upgrades to the enclosure. More information can be found in the Energy Analysis section of this report.

EXECUTIVE SUMMARY

DEVELOP + RECOMMEND PACKAGES OF OPTIONS

RDH evaluated what we learned from our studies of existing documentation, field observations and existing building energy analysis to compile recommended lists of both Mechanical and Enclosure system retrofit options that make sense for the specific practical and technical considerations of the existing West Tisbury School building. Our assessment considers both the mechanical system and building envelope relative to carbon and energy savings after implementing the recommended retrofits.

This document outlines two retrofit paths:

- → **Retrofit Option 1**: This retrofit strategy focuses on achieving net zero carbon immediately. The strategies include replacing the mechanical system and performing a building enclosure deep-energy retrofit, all at once.
- → **Retrofit Option 2**: This retrofit strategy implements the same energy conservation and carbon reduction measures as the Retrofit Option 1, replacing the mechanical systems and performing limited enclosure upgrades initially. The implementation of building enclosure retrofits by each wing of the building, from oldest to newest, are then phased over time in line with the life cycle of the installed components. This "zero over time" approach achieves net zero carbon by 2040.

In addition to reducing energy consumption and greenhouse gas emissions, both recommended retrofit paths will have the following benefits:

- → A correctly operating building that minimizes extraneous triage efforts by custodial staff on building systems.
- → Superior thermal comfort and indoor air quality for students and teachers that creates a healthy indoor environment and promotes learning.
- → Improved resiliency against extreme weather events and future climate impacts ensuring the long-term continued operation of the building, allowing it to function as a space to educate children.
- → A cooling system for the whole building that does not exist today, allowing year-round operation, flexibility in summer programming and futureproofing against hotter future temperatures anticipated with climate change.
- → Materials that have come to end of life will be replaced.
- → Demonstrated leadership in sustainable building practices.

PROVIDE SEQUENCED PLAN + COST ESTIMATE

RDH developed the lists of Mechanical and Enclosure system upgrades into the two options, previously noted, based on sequencing that would allow retrofit of all interfacing building enclosure components to achieve the best continuity between air, water, vapor, and thermal control layers of the different enclosure assemblies. These options were evaluated using RDH's "Scheduler" tool, as shown in the Retrofit Results section of this report. Priority was given to building components at the end of their life span. Therefore, both options replace the mechanical systems immediately given the age of the equipment, and that much of the mechanical equipment is currently failing. As best as possible, as shown in Option 2, we attempted to sequence upgrades of building enclosure components relative to the end of their useful lifespans.

RDH engaged a third-party cost estimator with recent experience performing cost estimating for the West Tisbury Elementary School project, who is familiar with on-island cost mark-ups and current supply chain issues. The cost estimator provided high-level cost estimating of both Retrofit Option 1 and Retrofit Option 2, based on the narratives contained in this report which included rough sizing of mechanical systems, specifications of components of the proposed mechanical system, and building enclosure details contained in the Enclosure Matrix in the Building Enclosure Retrofit section of this report.

A project bid set of drawings and specifications, which are beyond the scope of this study will form the basis of a more accurate cost estimate. The information that RDH provided to the cost estimator constitutes as detailed information as possible for this Study Phase of the project.

EXECUTIVE SUMMARY

PREPARE PRESENTATIONS + ATTEND MEETINGS

RDH met with members of the Environmentally Friendly School Building Task Force on the following dates:

- → 4/7/22 Project Kickoff with Mark Friedman and RDH Team
- → 4/19/22 RDH Team met with members of the Task Force and Marc Rosenbaum to discuss airtightness testing
- → 5/26/22 RDH Team met with members of the Task Force to discuss project while on site visit
- → 7/19/22 RDH Team presented Draft report and initial recommendations to Committee
- → 8/11/22 RDH Team presented updated Draft report including cost estimating to the Committee
- → 8/12/22 RDH Team met with Mark Friedman to discuss work plan and next steps
- → 8/23/22 RDH distributed Final Draft report and received feedback from the Task Force
- → 9/6/22 RDH met with Marc Rosenbaum to review and address technical feedback comments being incorporated into final report
- → 9/9/22 RDH distributed final report

RDH is currently scheduled to present the final report to the UIRSD Committee on 9/19/22 which will conclude the scope of this study.

NEXT STEPS

This report presents conceptual-level recommendations with respect to retrofit options. It is important to understand that these recommendations do not provide a basis for implementing retrofit work.

RDH anticipates that the findings and recommendations in this report will be used by the UIRSD committee and other stakeholders (town's people, individuals like Marc Rosenbaum, members of the Environmentally Friendly School Building Task Force) to assess the viability of this project in the context of other major capital projects, such as the Martha's Vineyard Regional High School, Tisbury Elementary School and the Chilmark School. Their feedback is certain to raise questions about the timing, sequence and costs that we have not anticipated as part of this preliminary effort.

During the design phase, the conceptual recommendations contained in this report will need to be developed, refined, and specified in detail before the construction work can be put out to bid to contractors.

The Design Phase typically begins with the Owner's Project Manager and the Consultant assisting in the decision-making process related to the proposed retrofit options. Once decisions are made by the Owner, the selected design is developed and documented in greater detail with drawings and specifications by the Design Team. These contract documents describe the exact extent and nature of the proposed renovation work. Specific energy targets should be defined during the beginning of the design process, with the energy consultant updating the energy model to reflect changes to the design as they occur, ensuring design compliance with the established energy targets.

The drawings and specifications are used to obtain bids from pre-qualified contractors and to obtain a building permit to commence the construction process.

During the Construction Phase the retrofit work that has been designed is constructed by the Contractor. The Consultant administers the construction contract and undertakes periodic field review of construction as the work proceeds. The Consultant should continue to update the energy model through construction to track construction progress against the project goals and energy targets.

Post-Construction, Measurement and Verification services are required to ensure the building is performing and operating as designed.

INTRODUCTION

INTRODUCTION & BACKGROUND

PROJECT DESCRIPTION

Location	401 Old County Rd, West Tisbury, MA
Building Use	Elementary and Middle School
Number of Stories	1 story
Floor Area	61,000 ft^2
Construction Date	1973, 1985, and 1995

METHODOLOGY

RDH reviewed the documents listed in the references. These documents, in addition to a site visit on May 26, 2022 to survey building enclosure and mechanical systems, a site visit on June 18, 2022, to perform airtightness testing, as well as correspondence with MV Public Schools, allowed RDH to complete a preliminary energy assessment of the existing building using a representative building typology energy model. We compared the model to the utility data provided by UIRSD and adjusted our energy analysis to align.

RDH does not endorse specific products even if they are mentioned by name in this report. Product references are provided as technology examples; however, the stated efficiency and performance of the references are integral to the evaluated energy performance, not the specific product. Testing performed on site was qualitative in nature to identify areas of thermal anomalies The energy model completed using a block model is intended to represent the existing building at a high level to support retrofit decision making.

This retrofit study is intended as a tool to facilitate communication between UIRSD, all project stakeholders, including Town Meeting, as well as future project design team members. This document represents the energy retrofit design intent and should be carefully considered by the design team during the development of the design and construction documents, should retrofit projects be undertaken.

REFERENCES

MV Public Schools provided the following documents to us for our assessment:

→ 1973 Drawing Set for West Tisbury School from Rich, Land & Cote, Inc.

→ 1985 Drawing Set for West Tisbury School from DiNisco Kretsch & Associates, Inc.

→ 1994 Drawing Set for West Tisbury School from The Design Partnership of Cambridge Inc.

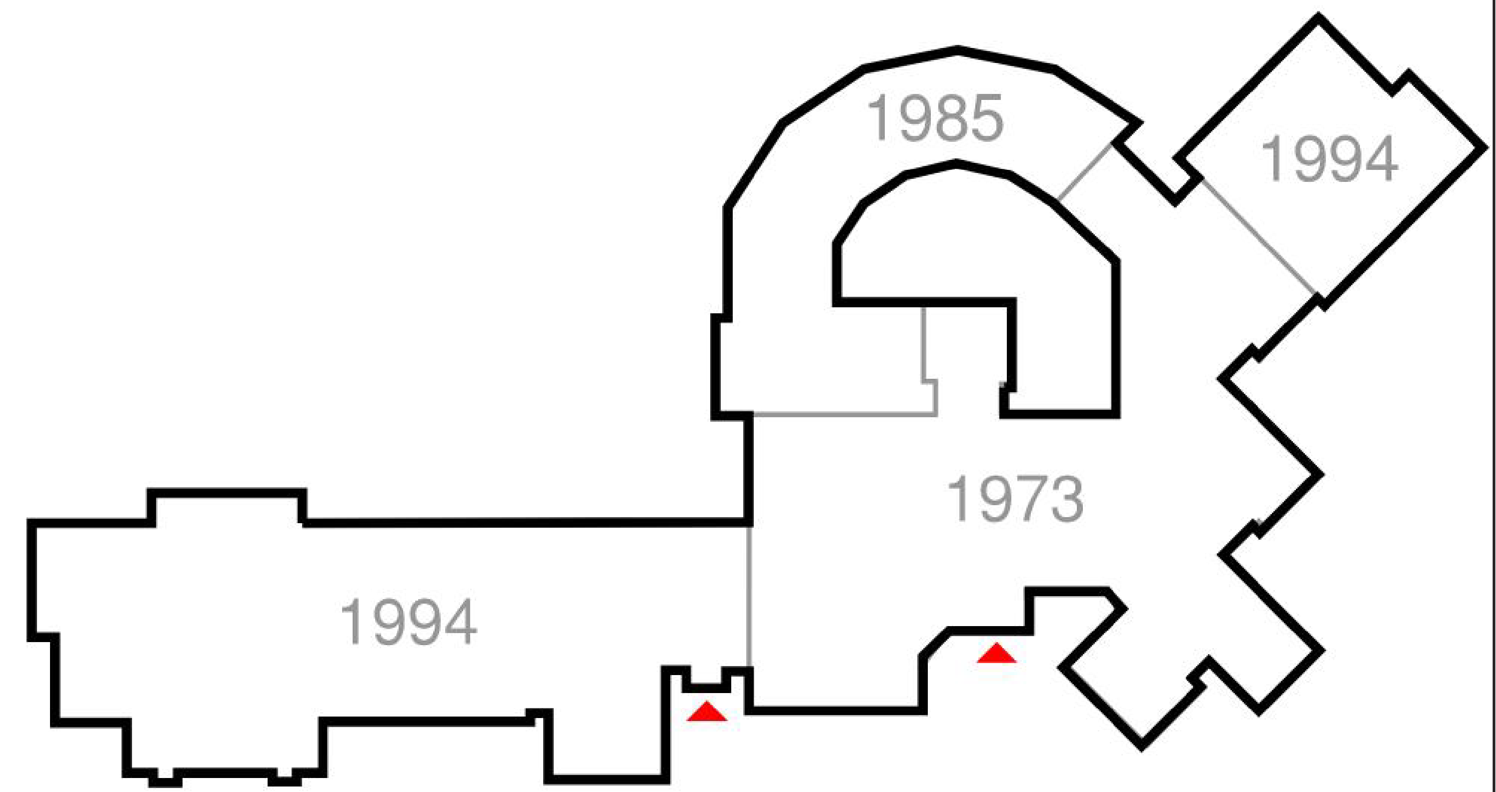
→ 2011 Exterior Renovations Drawing Set from Keenan + Kenny Architects, LTD.

→ 2016 Ramp, Deck, and Roof Renovation Drawing Set from Keenan + Kenny Architects, LTD.

→ 2021 Roof Replacement Plan from Russo Barr Associates

→ RISE Engineering Energy Audit Reports from October 2018 and January 2021

→ Utility data from 2018 to 2022



W TISBURY ELEMENTARY SCHOOL KEY PLAN

CLIMATE CHANGE ADAPTATION & MITIGATION

WHY RETROFITS?

Climate change is projected to have a significant impact on society and the built environment. Shifting climate norms result in changing weather patterns. The underlying cause of this change has been identified as anthropogenic greenhouse gas (GHG) emissions.

To achieve a sustainable future, both climate change *Adaptation* and *Mitigation* are required.

→ **Adaptation** is ensuring our buildings will be able to withstand changing and ever stronger environmental loads.

→ **Mitigation** is minimizing the severity of these future environmental loads by reducing GHG emissions or increasing GHG sinks.

As all levels of government target more stringent carbon emission reduction goals, there is an increased focus on reducing emissions related to operating existing buildings. Deep energy retrofits are fast becoming a key strategy to reach carbon emission goals in the United States

ADAPTATION

HEATING, COOLING & THERMAL COMFORT

Buildings require active heating and cooling systems. Passive systems should be considered to supplement active systems for energy savings and resiliency to maintain comfort and livability in the event of power loss.

DURABILITY

Building enclosures require water control strategies that can handle higher levels of precipitation and wind loads due to increased extreme storm events. Using durable enclosure materials, assemblies, and systems extends the period between significant repairs and renewals and reduces lifecycle maintenance costs.

AIR QUALITY

Providing fresh air promotes resident well-being. Adding air filtration within ventilation systems should be considered to manage contaminants from interior or exterior sources.

WATER USE

Buildings should incorporate water reduction strategies such as low flow fixtures, rainwater harvesting, and water efficient landscaping.

FLOODING

Buildings that may be exposed to flooding and elevated ground water levels should have resilient ground-level and below-grade enclosure assemblies and details.

MITIGATION

The *Global Status Report 2017 by the United Nations Environment Programme* found that the building industry is responsible for over 28% of global GHGs due to operations and 11% due to construction and material extraction. Buildings that produce less GHGs during operation are critical for a sustainable future.

Tiered mitigation builds off the strategy of reducing loads passively with an improved building enclosure. This strategy starts by reducing building loads. Next, mechanical systems with improved efficiency can be implemented to reduce energy consumption. Finally, renewable energy systems may be used to fully offset energy and carbon usage in a building.

Windows are typically the weakest link in the building enclosure and may account for significant heat loss, cold surfaces, and air leakage (drafts). Upgrading windows can reduce loads, deliver energy savings, and provide more comfortable living spaces.

Adding exterior insulation through a cladding renovation project further reduces heating demand and improves the durability of the building enclosure. Adding a continuous air barrier can significantly reduce air leakage which can improve indoor air quality, building durability, and occupant comfort. With increased airtightness, it is important to ensure adequate ventilation will be provided. Ventilation can be delivered efficiently through Energy Recovery Ventilators (ERVs).

Other retrofit opportunities to reduce energy consumption and greenhouse gas emissions include upgrading HVAC systems with higher efficiency equipment, switching to low flow water fixtures, fine tuning controls, etc.

NET ZERO CARBON IN MASSACHUSETTS

CARBON REDUCTION GOALS

It is necessary to reduce the greenhouse gas emissions that drive climate change, to keep the global temperature increases below 1.5°C, the highest increase that the Earth can withstand before severe and irreversible changes occur.

The MA 2030 Clean Energy and Climate Plan calls for net zero emissions by 2050 and an emissions reduction of 45% by 2030. The MA Climate Road map Bill, signed into law on 3/26/21 updates that goal by requiring a 50% reduction of carbon emissions by 2030 and net zero emissions by 2050 (vs 1990 baseline). The Massachusetts 2050 Decarbonization Roadmap, published by the Massachusetts Executive Office of Energy and Environmental Affairs in December of 2020, highlights strategies to Achieve Net Zero. This includes recommendations for transportation, shipping, residential and commercial buildings, electricity and energy, industry, as well as through natural carbon sequestration and carbon dioxide removal. For buildings, the report emphasizes the importance of the combination of energy efficiency retrofits to passively reduce energy loads, then introduction of all electric equipment, particularly for space heating, cooling and domestic hot water.

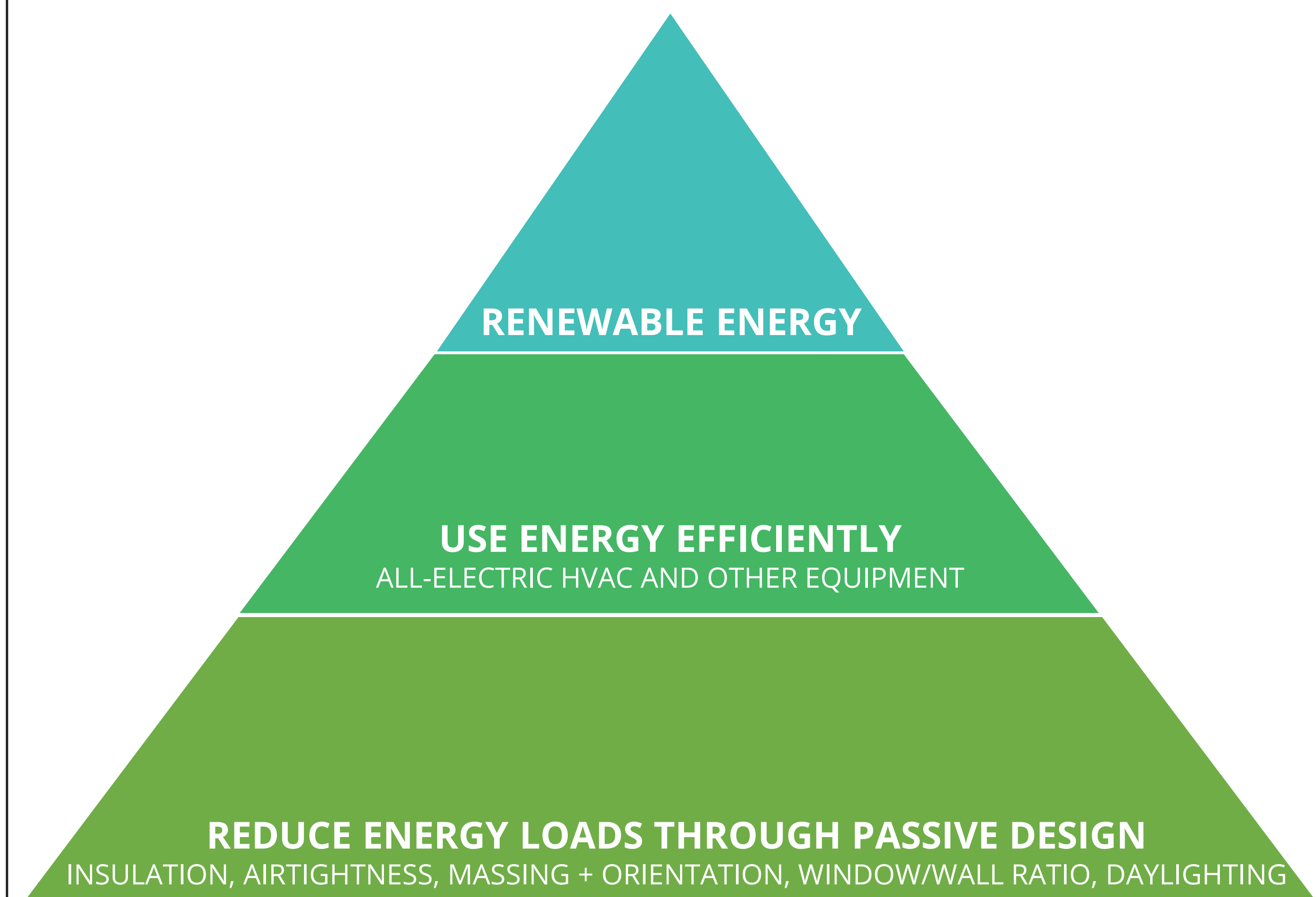
The Massachusetts 2050 Zero Carbon Roadmap also maps out how the energy system will need to transition to renewable sources, from the current mix, which has natural gas as the largest generation source. The Town of West Tisbury, in addition to Chilmark and Aquinnah, has passed a resolution setting a goal that the town's energy will come from 100% renewable resources by 2040.

ENERGY CODE

The current 9th edition of the Massachusetts Building Code adopts the 2018 International Energy Conservation Code (IECC 2018) with amendments. Massachusetts also currently has a "Stretch Energy Code" (780 CMR Chapter 115AA) which was adopted by 299 out of 351 municipalities in the Commonwealth.

As of January 1, 2023 there will be a new base Energy Code, Stretch Energy Code, as well as a second, more advanced tier of stretch energy code known as the "Specialized Stretch Code". Towns already enrolled in the current Stretch Energy Code will continue to follow the updated Stretch Energy Code. Towns that vote to adopt the new Specialized Stretch Code will be held to the requirements of that code. For commercial buildings like schools, there will be limits imposed on the Thermal Energy Demand Intensity (TEDI), the amount of energy needed for heating the building over the course of one year. To demonstrate compliance, design teams will need to follow an energy model driven design process. The design measures to achieve these TEDI limits in buildings will include a reduction of energy loads through passive design, maximizing the efficiency of the building enclosure, to allow for the efficient use of all-electric heating and cooling equipment.

The implementation of these more stringent building codes will advance progress towards the state's 2030 and 2050 carbon reduction goals for buildings.



HOW TO ACHIEVE NET ZERO CARBON IN BUILDINGS

EXISTING BUILDING SUMMARY

EXISTING BUILDING COMPONENTS & SYSTEMS

RDH SITE VISITS

Based on RDH's review of existing documents, observations made during two site visits, discussions with school staff, and meetings with the West Tisbury School Study Committee, the following existing conditions were documented:

BUILDING ENCLOSURE

The building's foundation consists of uninsulated concrete foundation walls as either slab-on-grade or crawlspaces. The construction of the above-grade walls varies by the year built, but mostly consists of wood framed walls with batt insulation and cedar shingles. Per the drawing sets reviewed by RDH, there appears to be a polyethylene vapor retarder on the interior side of the wall and an air barrier outboard of the sheathing.

We understand that many, if not all, the windows and doors have been replaced at some point from the original. Most of the windows currently in the building are Anderson brand, composite clad wood windows installed in 2011.

Varying by year and construction, the roofs are comprised of two main types: asphalt shingled pitched roofs and low slope EPDM membrane roofing.

THERMAL BRIDGING

Thermal bridging is heat transfer by conduction through elements of the building enclosure. Thermal bridging contributes to energy loss in a building. During onsite investigations, RDH and ABA used thermal imaging cameras to observe any thermal bridging occurring in the building envelope. Thermographic imaging can be used as a diagnostic technique to identify areas of interest. We used techniques described in ASTM C1060 and ASTM E1186, with modifications based on our experience, to survey select conditions of the building. This section includes several thermal images that illustrate the typical survey conditions and thermal anomalies. The likely nature of these anomalies is noted in the caption of the descriptions. Thermal imaging provides a way to visualize differences in the surface temperatures that are indicative of thermal anomalies and building deficiencies related to conductive or convective heat loss.

In the energy model of the existing building, the enclosure performance accounts for regular thermal bridges at cladding connections (i.e., masonry ties and cladding attachment clips). Thermal bridging of linear interfaces at the window and door perimeters, roof parapet, and structural transitions were not included in our energy model analysis.

THERMAL PERFORMANCE

RDH calculated the existing whole wall effective thermal performance for each enclosure component. R-values are the capacity of materials to resist heat flow, therefore the higher the R-value, the more insulated the material is. U-values, the inverse of R-values, is the rate of heat transfer through a material, therefore the lower the U-value, the better the thermal performance is

AIR INFILTRATION

RDH used thermographic imaging techniques described in the thermal bridging section to conduct a limited survey of building conditions to identify air leakage pathways.

Advanced Building Analysis (ABA) set up and performed multi-fan airtightness testing, supported by RDH, at the West Tisbury School on June 18, 2022. ABA was not able to achieve the typical measured pressures of 50 Pa and 75 Pa because of the large amount of air infiltration through the building enclosure. The air leakage rates were estimated using the Power Law Flow Equation from the 11 Pa of pressure ABA was able to achieve and a flow exponent of 0.65.

The air leakage rates were normalized against the surface area takeoffs completed by RDH. The resultant estimated air leakage rate for the building was calculated to be 0.65 cfm/ft^2 at 75 Pa without the rooftop ventilation sealed. This means that the building is very leaky leading to large amounts of heat loss via air movement through the enclosure. Images from both RDH and ABA are included in this section

HEATING & VENTILATION

Heating is provided by three standard efficiency oil boilers, with 2-pipe unit ventilators providing heating and ventilation to the classrooms. We understand that one of the oil boilers is currently not in operation and that the unit ventilators only run during the heating season and are turned off for the cooling season. Heated water is distributed to hydronic baseboard perimeter heaters in the corridors. One heat pump provides the heating and cooling in the computer lab while two air-conditioning (AC) units provide cooling to the office/admin area. There are air-conditioning units serving the library as well.

Two air handling units (AHUs) are located in the gym, two AHUs in the band/music room, and one AHU in the cafeteria. Two smaller AHUs are also located in the science labs. We understand that the AHUs are not currently in operation, as they are either in need of repair or have been turned off due to noise concerns. A propane-fired make-up air unit (MAU) serves the kitchen.

The kitchen includes a rangehood, as well as several large freezers and refrigerators. A stand-alone walk-in refrigerator is also located beside the school.

DOMESTIC HOT WATER

There are two propane on-demand hot water heaters that serve the domestic hot water load to the kitchen. The domestic hot water load to the remainder of the building is served by one electric hot water heater located in the basement mechanical room supplemented by the oil boilers in the winter. During the site visit, the Head Custodian conveyed that the washroom sinks in the wings furthest from the electric water heater take a very long time to provide hot water.

ELECTRICAL

Based on correspondence with the team at the West Tisbury School, we understand that the lighting fixtures are primarily LED. We have estimated the electrical loads associated with lighting and other miscellaneous loads as noted in the Energy Analysis section of this report.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022

CURTAINWALL ENTRANCES.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022

TYPICAL EXTERIOR WALL.

WARPED AND WEATHERED CEDAR SHINGLES NEARING THE END OF THEIR LIFE.

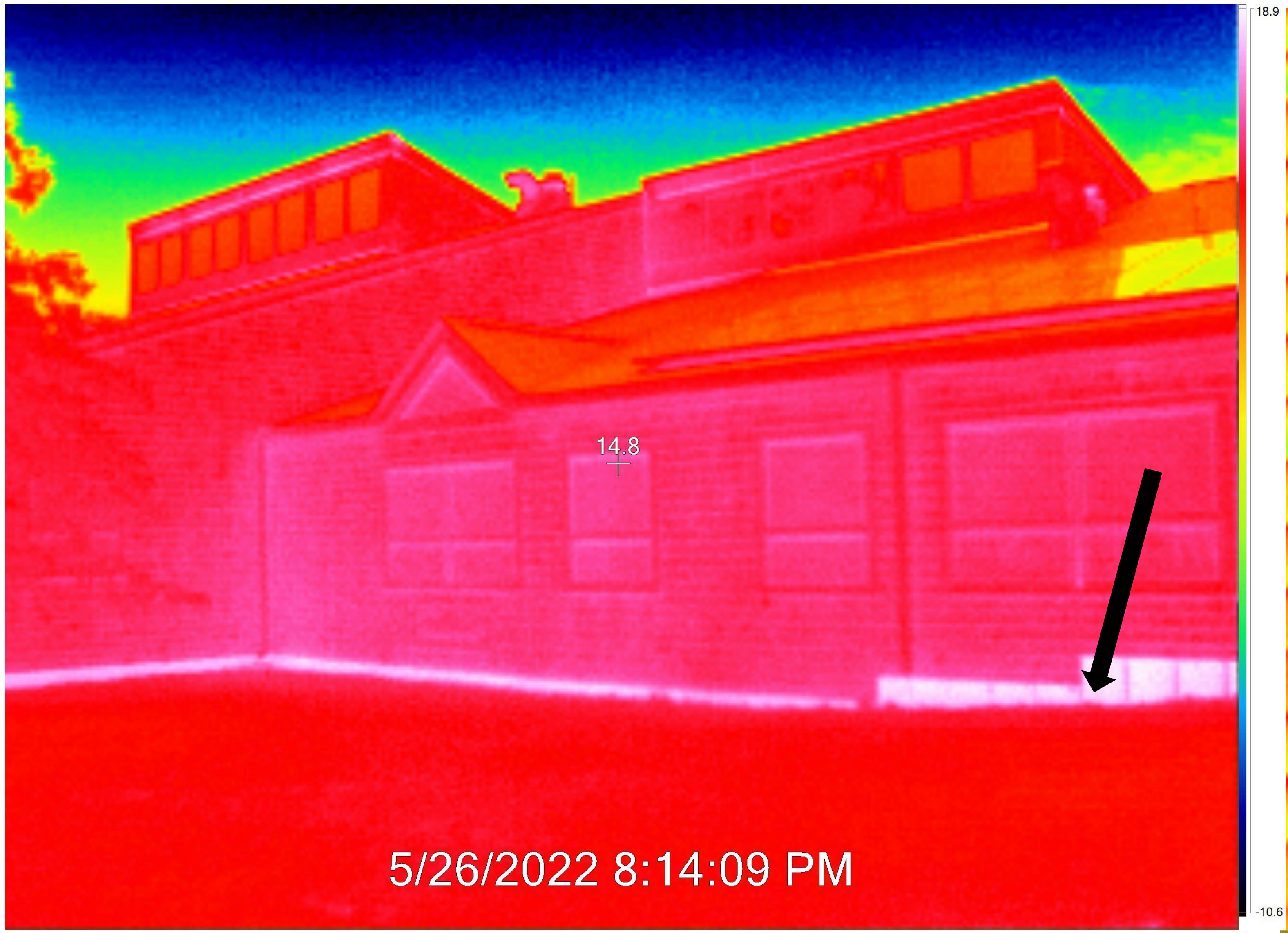
FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022

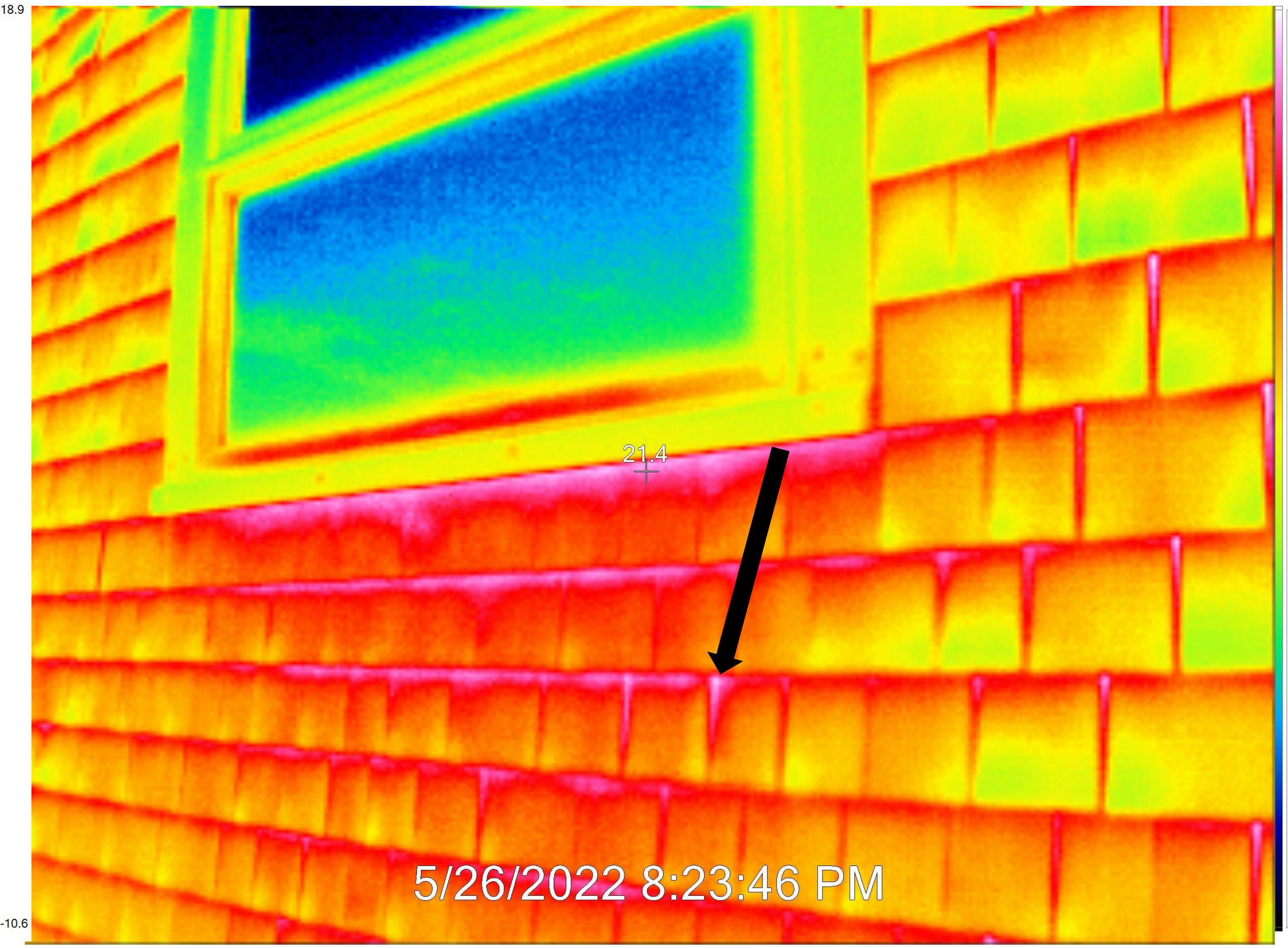
STEEP SLOPE AND LOW SLOPE ROOFING.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022



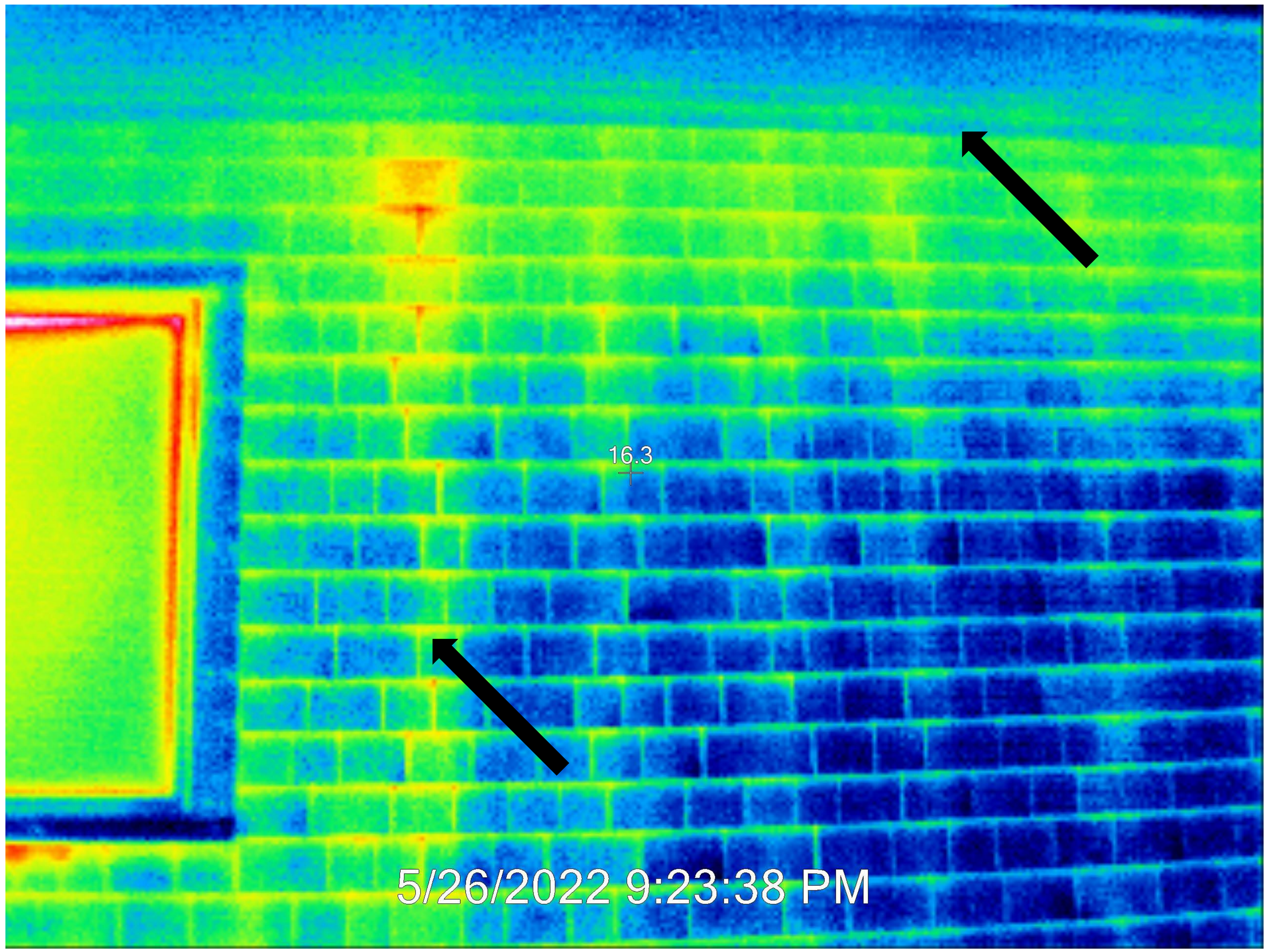
THERMAL ANOMOLIES INDICATINGING LIKELY THERMAL BRIDGING AT EXPOSED FOUNDATION WALL AND EDGE OF SLAB.



THERMAL ANOMOLY, LIKELY AIR LEAKAGE THROUGH EXISTING WALL ASSEMBLY.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022

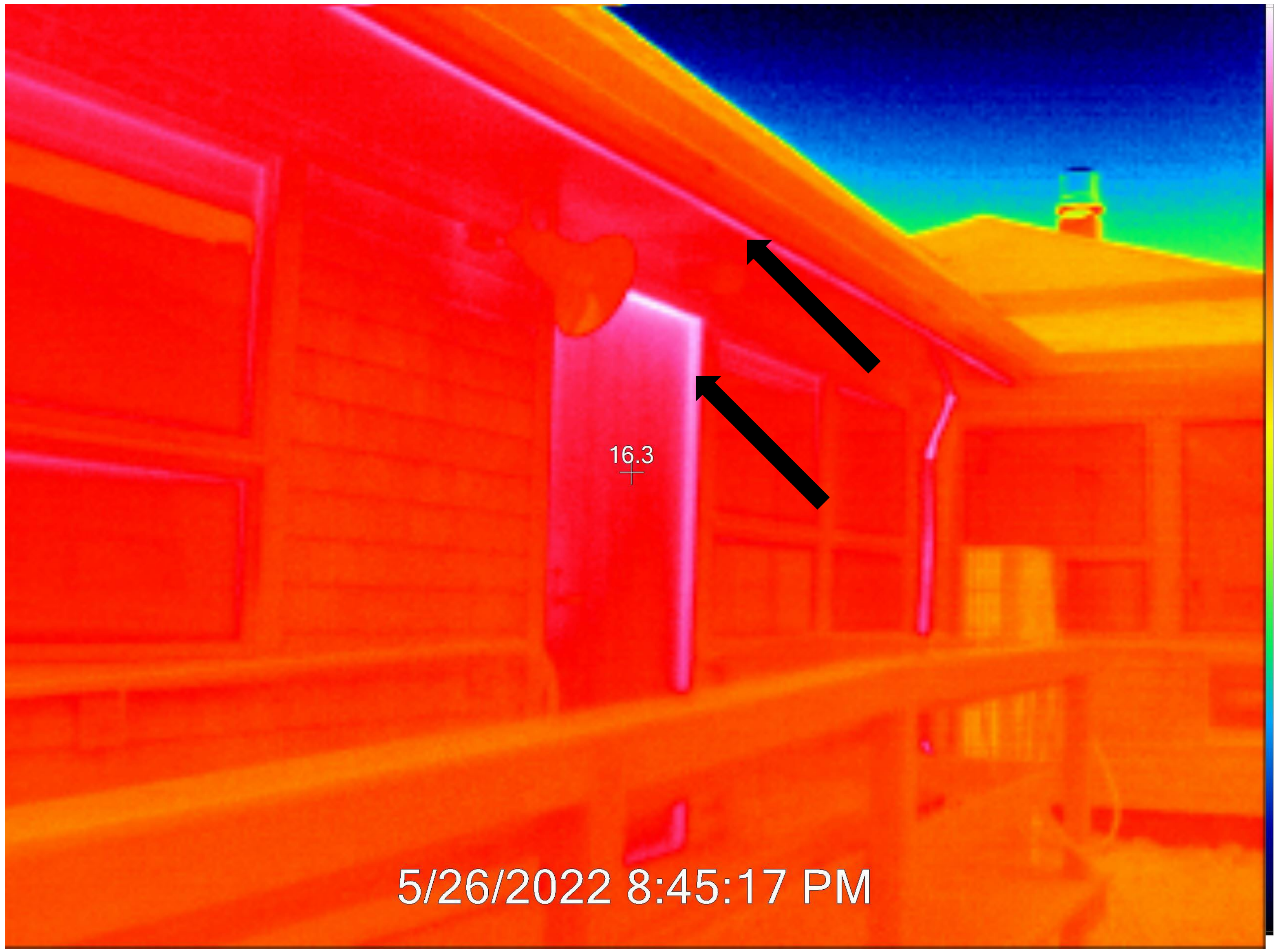


THERMAL ANOMOLIES AT TYPICAL EXTERIOR WALLS AT 1985 WING CLASSROOM. IMAGE DEPICTS LIKELY THERMAL BRIDGING AT STUDS AND LIKELY AIR LEAKAGE AT ROOF TO WALL CONNECTION. IMAGE TAKEN WHILE CLASSROOM WAS UNDER POSITIVE PRESSURE FROM BLOWER DOOR IN EXTERIOR DOOR OF CLASSROOM.

THERMAL ANOMOLIES AT TYPICAL EXTERIOR WALLS AT 1985 WING CLASSROOM. IMAGE DEPICTS LIKELY AIR LEAKAGE AT ROOF TO WALL CONNECTION. IMAGE TAKEN WHILE CLASSROOM WAS UNDER POSITIVE PRESSURE FROM BLOWER DOOR IN EXTERIOR DOOR OF CLASSROOM.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022



THERMAL ANOMOLIES INDICATING LIKELY AIR LEAKAGE AT DOOR AND ROOF TO WALL CONNECTION

THERMAL ANOMOLIES AT TYPICAL WINDOW ROUGH OPENINGS AT 1985 WING CLASSROOM. IMAGE DEPICTS LIKELY AIR LEAKAGE ROUGH OPENING. IMAGE TAKEN WHILE CLASSROOM WAS UNDER POSITIVE PRESSURE FROM BLOWER DOOR IN EXTERIOR DOOR OF CLASSROOM.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022

THREE EXISTING BOILERS, ONE NOT WORKING.

FOUR EXISTING PUMPS, TWO NOT WORKING.

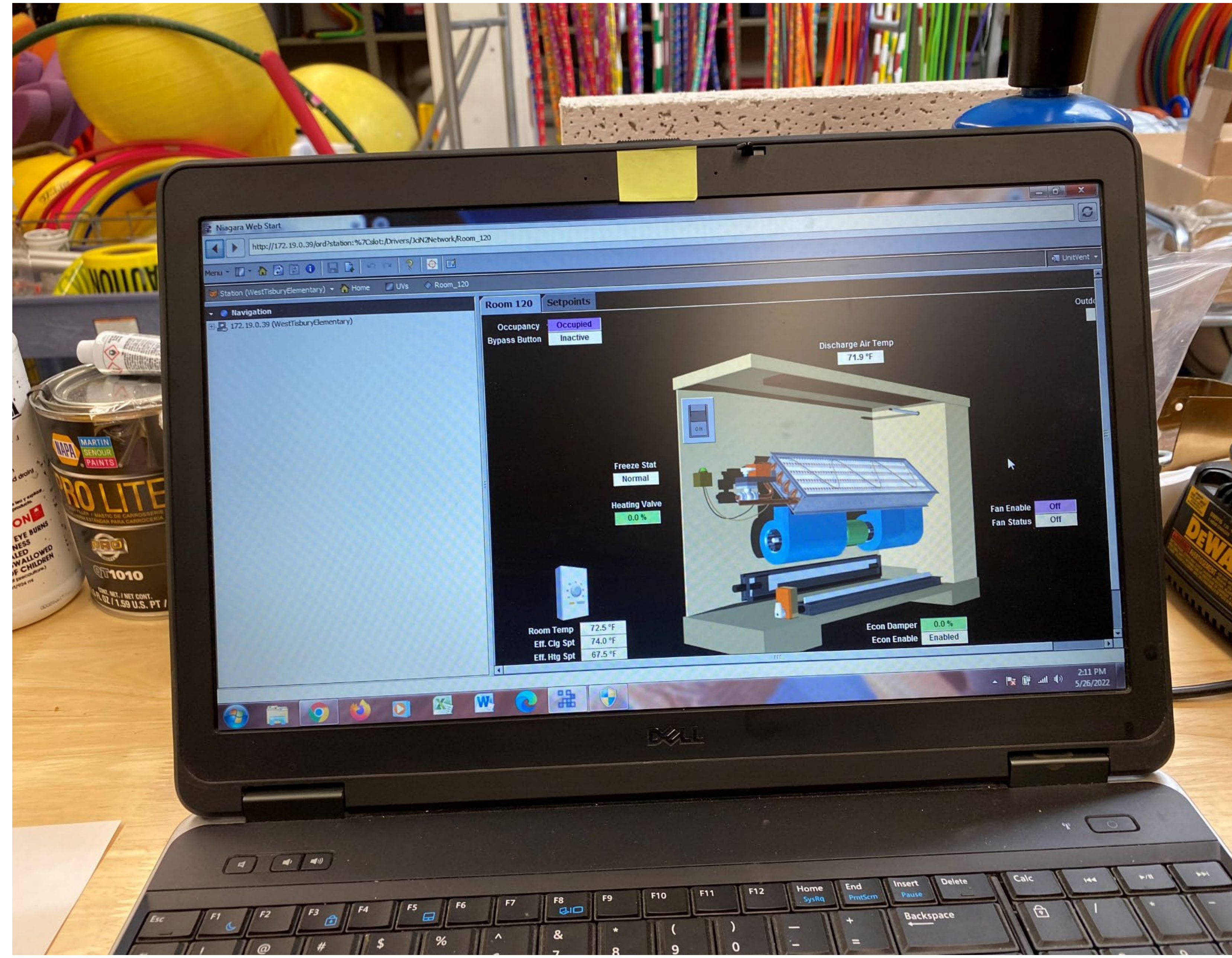
FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022

EXISTING AIR HANDLERS THAT REMAIN TURNED OFF BECAUSE THEY ARE BROKEN OR ARE TOO LOUD FOR CLASSROOMS. MUSIC ROOM AND SCIENCE ROOM SHOWN, GYM AIR HANDLERS ALSO TOO LOUD TO OPERATE.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022



HEAD CUSTODIAN, JAMIE LABBE, MANUALLY CONTROLS EACH CLASSROOM'S THROUGH-WALL HEATING AND VENTILATION UNIT DEPENDING ON HOW OVERHEATED EACH CLASSROOM IS, BASED ON FREQUENT FEEDBACK FROM TEACHERS AND STAFF. THROUGH-WALL UNIT THERMOSTATS MIS-READ CLASSROOM TEMPERATURE BECAUSE WINDOWS ABOVE UNITS ARE SOMETIMES OPEN FOR ADDITIONAL DESIRED DIRECT OUTSIDE VENTILATION AIR. THESE UNITS ARE NOT OPERATING AS INTENDED AND REQUIRE AN INORDINATE AMOUNT OF MANUAL MONITORING BY JAMIE.

FIELD OBSERVATIONS

ENCLOSURE AND MECHANICAL SURVEY– MAY 26 - 27, 2022

AIR SOURCE HEAT PUMPS IN COMPUTER LAB AND LIBRARY PROVIDE COOLING AND DEHUMIDIFICATION. WE UNDERSTAND COOLING IS DESIRABLE THROUGHOUT THE SCHOOL BUILDING, NOT JUST IN THESE LIMITED SPACES.

FIELD OBSERVATIONS

WHOLE BUILDING AIRTIGHTNESS SURVEY – JUNE 17-18, 2022

THE BUILDING WAS TESTED WITH AND WITHOUT ALL MECHANICAL PENETRATIONS SEALED AND AIRTIGHTNESS LEVELS WERE USED AS INPUTS IN THE BASELINE ENERGY MODEL.

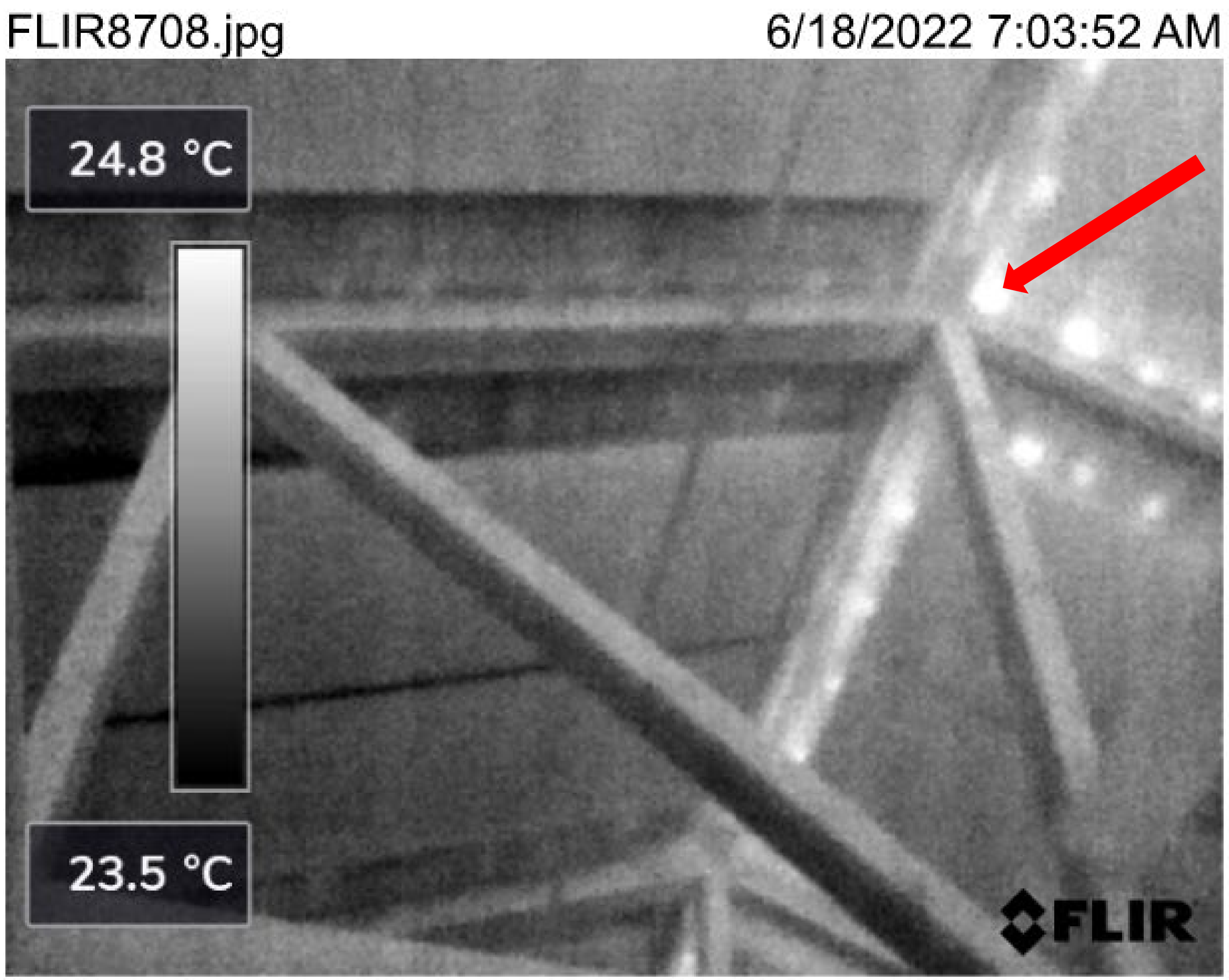
FIELD OBSERVATIONS

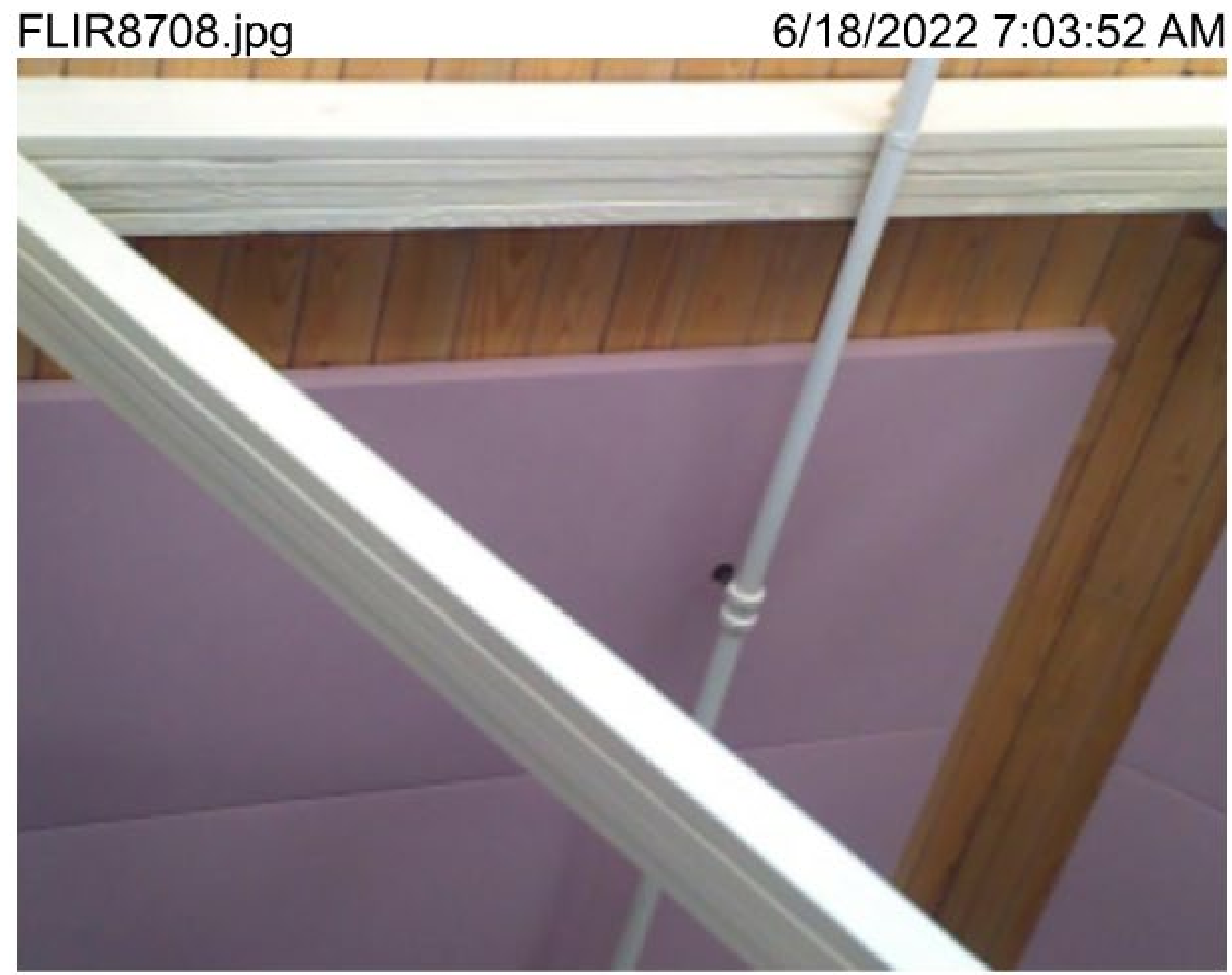
WHOLE BUILDING AIRTIGHTNESS SURVEY – JUNE 17-18, 2022

A TOTAL OF FIVE BLOWER DOORS WERE SET UP AROUND THE SCHOOL TO PRESSURIZE THE WHOLE BUILDING.

FIELD OBSERVATIONS

WHOLE BUILDING AIRTIGHTNESS SURVEY – JUNE 17-18, 2022





LIKELY AIR LEAKAGE WAS OBSERVED WITH THERMAL IMAGING, AT ROOF GEOMETRY INTERSECTIONS, INCLUDING ROOF RIDGES, WHILE WHOLE BUILDING WAS UNDER NEGATIVE PRESSURE.

FIELD OBSERVATIONS

WHOLE BUILDING AIRTIGHTNESS SURVEY – JUNE 17-18, 2022

LIKELY AIR LEAKAGE AT ROOF VALLEYS

FIELD OBSERVATIONS

WHOLE BUILDING AIRTIGHTNESS SURVEY – JUNE 17-18, 2022

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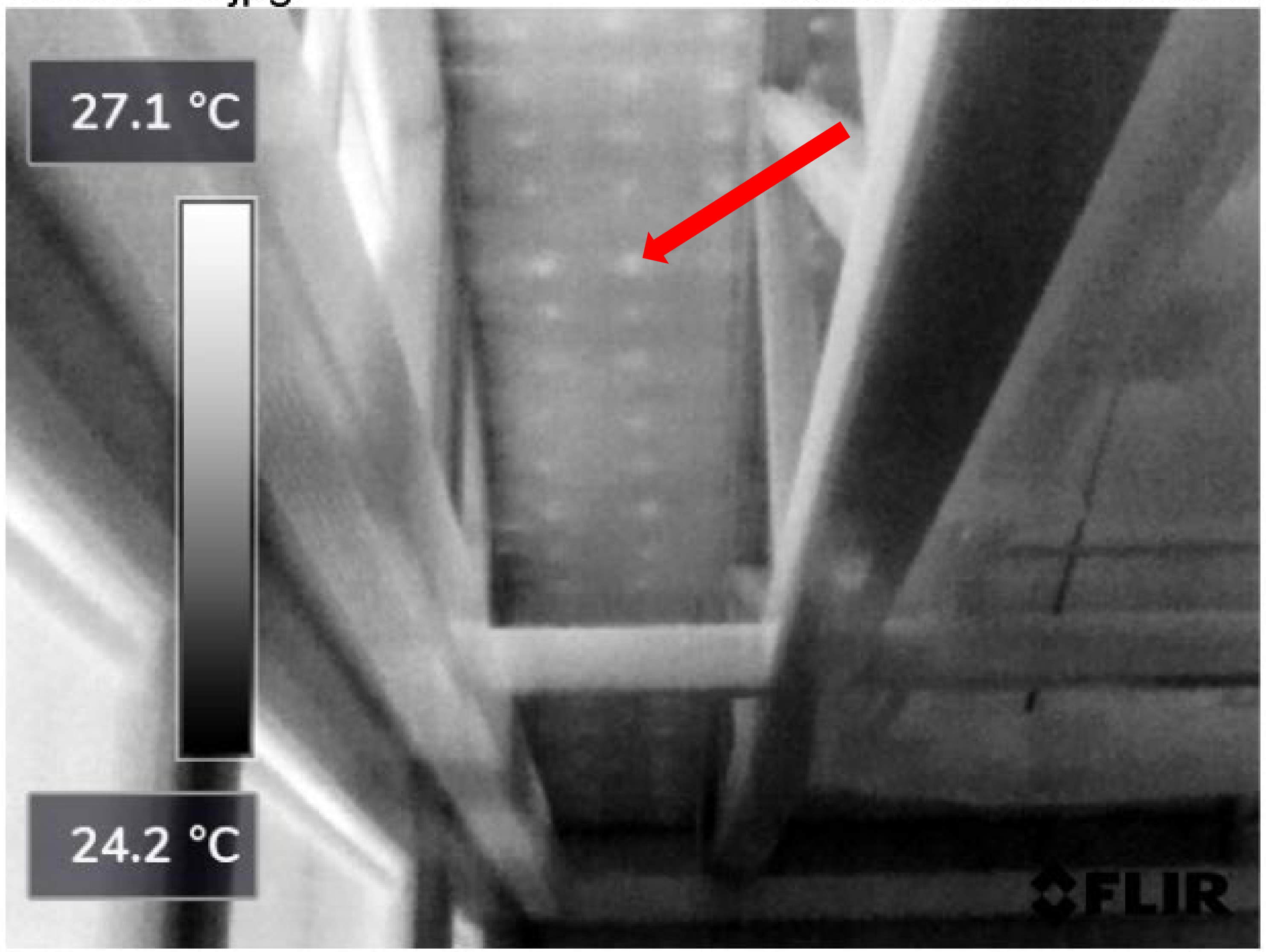

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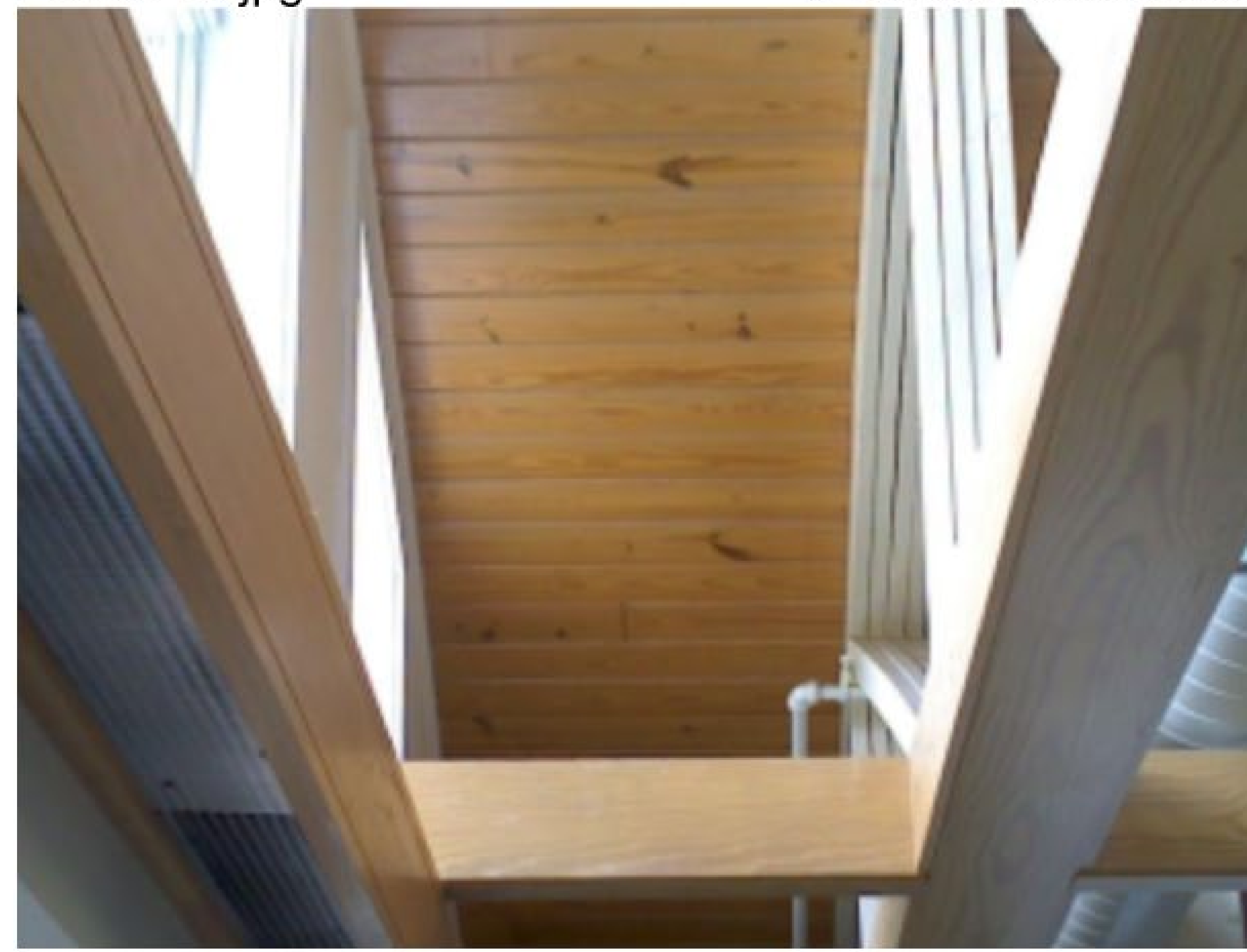


LIKELY AIR LEAKAGE AT ROOFING FASTENERS, VISIBLE IN A REGULAR PATTERN

ENERGY ANALYSIS

ENERGY ANALYSIS & MODELING PROCESS

OVERVIEW

Using data collected from the documents provided, site visit notes, and our conversations with MV Public Schools, we performed a preliminary energy assessment of the existing building using a representative building typology in a simplified energy model.

ENCLOSURE HEAT LOSS

The pie chart shows the breakdown of the existing building enclosure and infiltration heat losses using a steady state analysis for an ASHRAE 99.6% Winter Design Day condition. We estimated the thermal performance of the enclosure systems based on existing documentation provided by MV Public Schools.

Air leakage is one of the largest contributing factors to heat loss through the building enclosure. High levels of air infiltration were confirmed through the blower door testing that was performed by RDH and ABA on June 17-18, 2022. Approximately 36% of the heat loss is through the roofs. The slab edges (crawlspace and the slab-on grade foundation walls) contribute 14% of heat loss, and a combined 8% of the enclosure heat loss is due to the windows and doors. The exterior wall assemblies minimally contribute to heat loss in this building, contributing only 5%.

Despite the minimal percentage the exterior walls contribute, retrofitting the walls is vital to reducing the amount of air leakage though the creation of a continuous air barrier, including transitions to adjacent wall and roof assemblies as well as the primary seal of windows and doors.

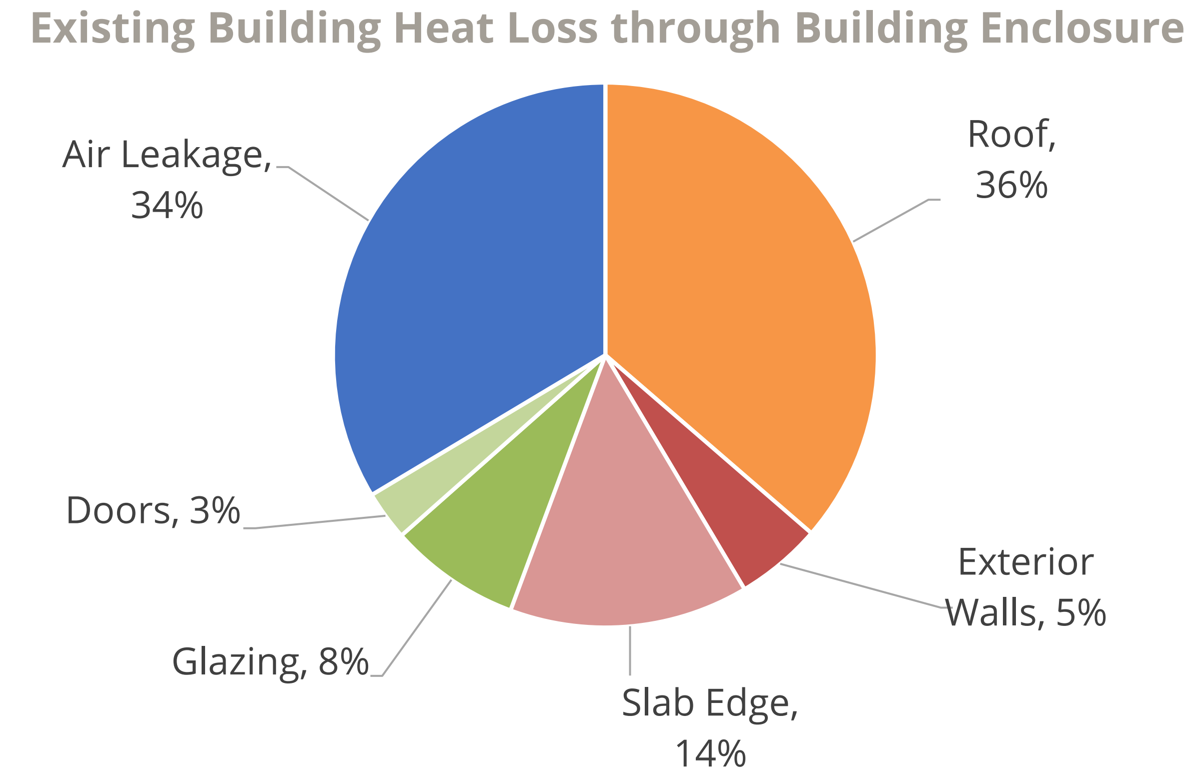
UTILITY BILL ANALYSIS

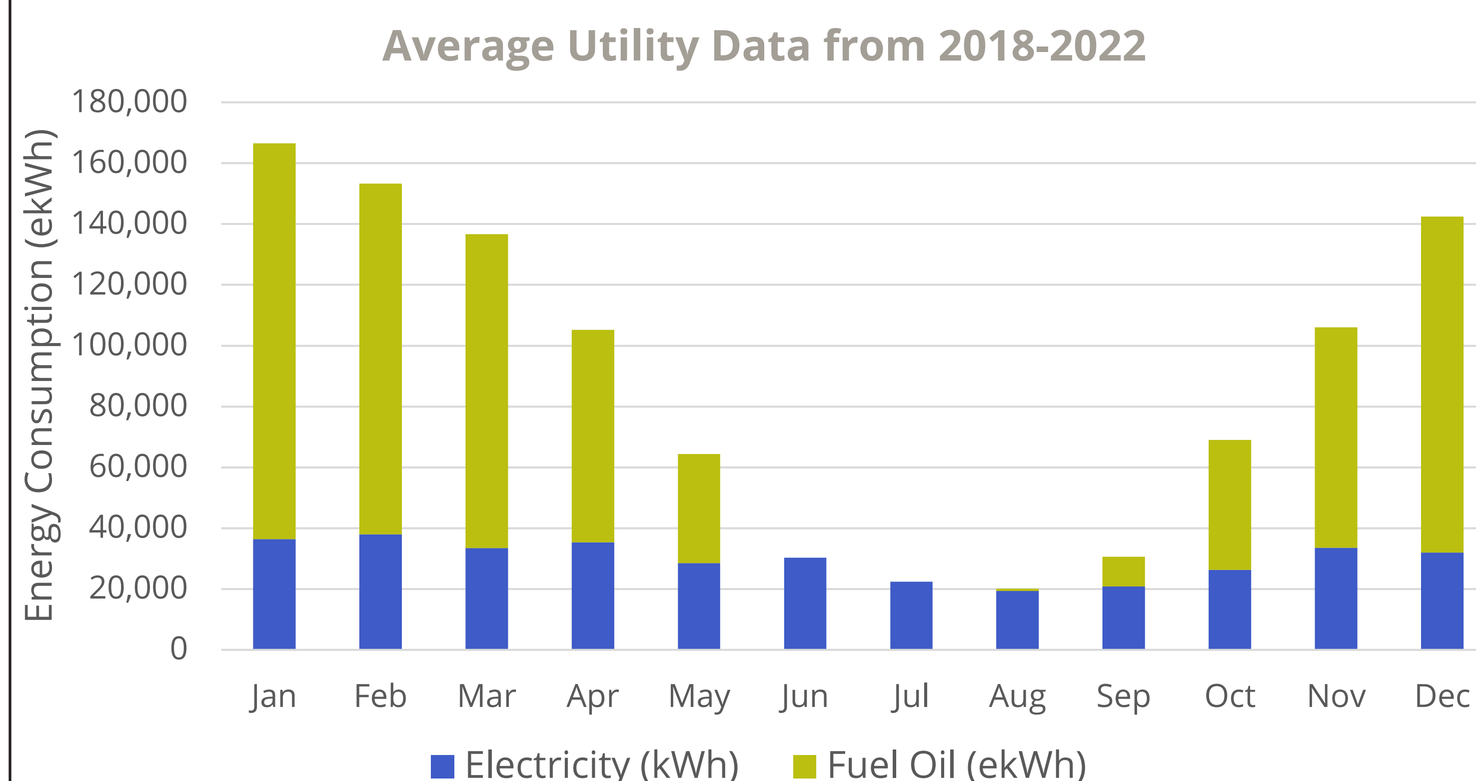
We performed a high-level calibration of a representative energy model to align with the building's electricity and fuel oil utility data. Inputs for the energy model were adjusted to approximate the reported consumption of the building. This preliminary energy analysis is intended to highlight strategic opportunities to improve energy performance with retrofit strategies.

The average electricity and fuel oil consumption in equivalent kilowatt hours from 2018 through 2022 is shown in the figure below. The electrical loads remain relatively constant year-round, as there is limited electric space conditioning. The fuel oil heating in the winter contributes to most of the yearly energy consumption and will be the most impactful system to tackle to reduce GHG emissions.

ENERGY MODELING PROCESS

The energy assessment was completed using a representative block model, informed by the building drawings and information collected on-site. RDH utilized the utility bills provided to approximate a calibration of the model to reflect the real energy consumption of the building. This calibration followed guidelines outlined in International Measurement and Verification Protocol and ASHRAE Guideline 14 but given the high-level nature of the energy modelling scope, the energy modelling results provided here should be considered "high level" and approximate, to be used for comparing options.





CALIBRATED EXISTING BUILDING MODEL

ENERGY MODEL INPUTS

Construction	Weighted Average Thermal Performance
Exterior Walls	R-15
Roof	R-15
Upgraded double-glazed punched window (GL-1)	U-0.27
Existing double-glazed window (GL-2)	U-0.32

Zone	Lighting Power Density (W/ft^2)
All Spaces	0.41

Zone	Plug Load (W/ft^2)
Classrooms/Library	0.5
Cafeteria	2.36
Kitchen/Admin Offices/Computer Lab	1.0
Gym	0.46
Corridors	0.37
Mechanical Room	0.93

CALIBRATED EXISTING BUILDING MODEL

ENERGY MODEL RESULTS

The energy model has been calibrated to simulate the energy usage of the existing building, based on the components and systems discussed in this report and the utility bill data provided. The figures on the following page illustrate the modelled Greenhouse Gas Intensity (GHGI), Total Energy Use Intensity (TEUI), and Thermal Energy Demand Intensity (TEDI). These metrics are defined as:

→**GHGI:** The total greenhouse gas emissions associated with the use of all energy utilities on site divided by the Modelled Floor Area. GHGI is calculated based on the emissions factors associated with the utilities. For the West Tisbury School, these are electricity, fuel oil, and propane, and the emissions factors are provided in the table to the right.

→**TEUI:** The sum of all energy used on site (i.e., electricity, fuel oil, and propane), minus all Site Renewable Energy Generation, divided by the Modelled Floor Area.

→**TEDI:** The annual heating delivered to the building for space conditioning and conditioning of ventilation air divided by the Modelled Floor Area.

As illustrated in the figures on the following page, energy consumption and GHG emissions are driven by fuel oil space heating. **The oil-fired boilers used to heat the school are the single largest contributing factor to energy use and greenhouse gas emissions.** By switching the current oil-fired boilers to an all-electric plant, like the air-to-water heat pump system proposed in the Retrofit Strategies section of this report, and by incorporating enclosure upgrades, operational carbon emissions of the school will be significantly reduced.

EMISSIONS FACTORS	
ELECTRICITY MA State Grid (LBS CO2/KWH) [1]	0.8712
FUEL OIL (LBS CO2/KWH) [2]	557,812

ANNUAL METRICS	CALIBRATED EXISTING BUILDING MODEL
GHGI (LBS/FT²/YR)	12
TEUI (kBTU/FT²/YR)	64
TEDI (kBTU/FT²/YR)	31
FUEL OIL (MBTU)	2,700
ELECTRICITY (kWh)	369,000
CO2E (TONS)	380

[1] EPA factor for the State of Massachusetts (https://www.epa.gov/egrid/power-profiler#/NEWE)
[2] EIA factor (https://www.eia.gov/environment/emissions/co2_vol_mass.php)

RDH BUILDING SCIENCE

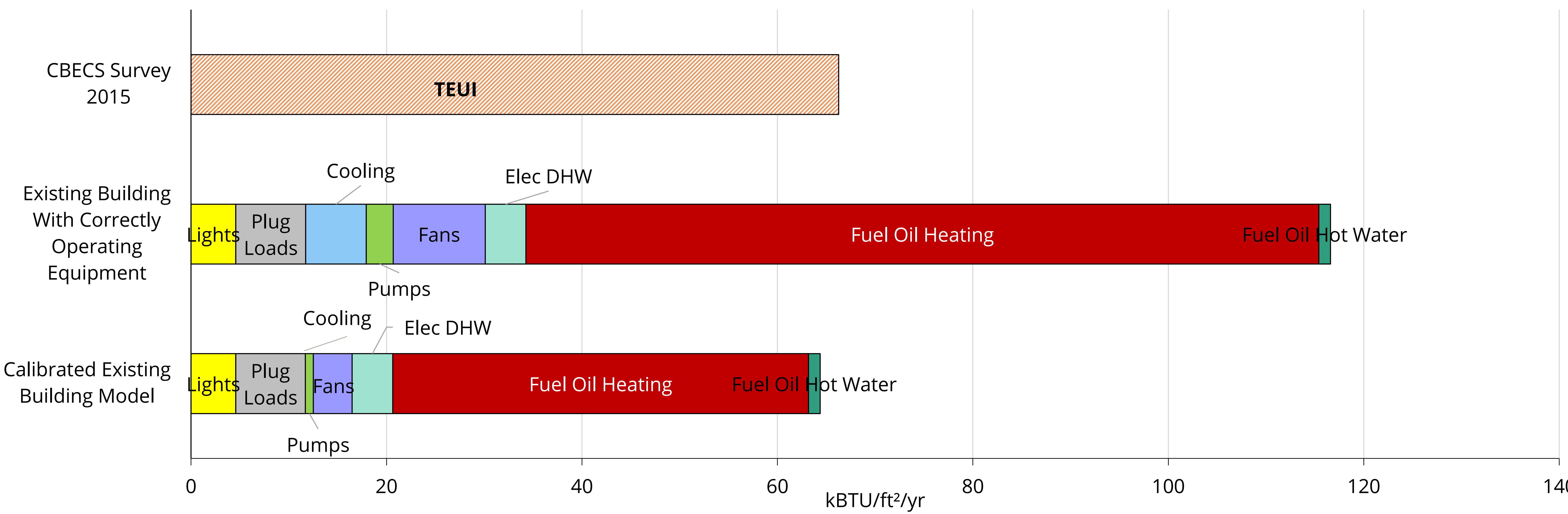
CALIBRATED EXISTING BUILDING BASELINE

ENERGY MODEL RESULTS

The top bar on the TEUI graph provides the average TEUI in kBTU/ft²/yr for buildings classified as education (all education buildings except college/university) for climate zone 5A from the Commercial Building Energy Consumption Survey (CBECS) prepared by the U.S. Energy Information Administration. CBECS is a benchmark for energy use by building typology. It evaluates the existing U.S. building stock and was used as the main data source for ASHRAE Standard 100-2015 Energy Efficiency in Existing Buildings. The **Calibrated Existing Building Model** represents the existing building's energy consumption as the building is currently operated and shows a lower TEUI than the CBECS average non-college/university education building in climate zone 5A. It should be noted that many of the mechanical systems in the existing building are **currently not working or have been turned off because they are too noisy, therefore the building is not being ventilated and heated as intended.**

The **Existing Building With Correctly Operating Equipment** provides an indication of what the building's TEUI and GHGI would be if all heating and ventilation systems were functioning as intended. As shown in the figure, the TEUI of the existing building would significantly increase if all the air-handling units were running correctly and the building was being properly ventilated.

Total Energy Use Intensity (TEUI)



CALIBRATED EXISTING BUILDING BASELINE

ENERGY MODEL RESULTS

The GHGI graph compares the GHG emissions associated with the **Calibrated Existing Building Model** and the **Existing Building With Correctly Operating Equipment**.

→ Fuel oil heating is the largest contributor to GHG emissions, due to a high heating demand and high emissions associated with the on-site combustion of fuel-oil

→ The GHG emissions associated with electrical end-uses result from the electrical grid emission factors. Currently, the primary energy source for the electrical grid in the state of Massachusetts is natural gas. The town of West Tisbury, along with the other Up-Island towns of Chilmark and Aquinnah, passed a resolution setting a goal that the town's energy will come from 100% renewable sources by 2040. This will significantly reduce the greenhouse gas emission factor for the electrical use.