Measuring Energy & Health in Existing Massachusetts Schools:

Recommendations for Implementing Section 83 of Chapter 179 of the Acts of 2022

AIA Massachusetts

A chapter of The American Institute of Architects

Acknowledgments

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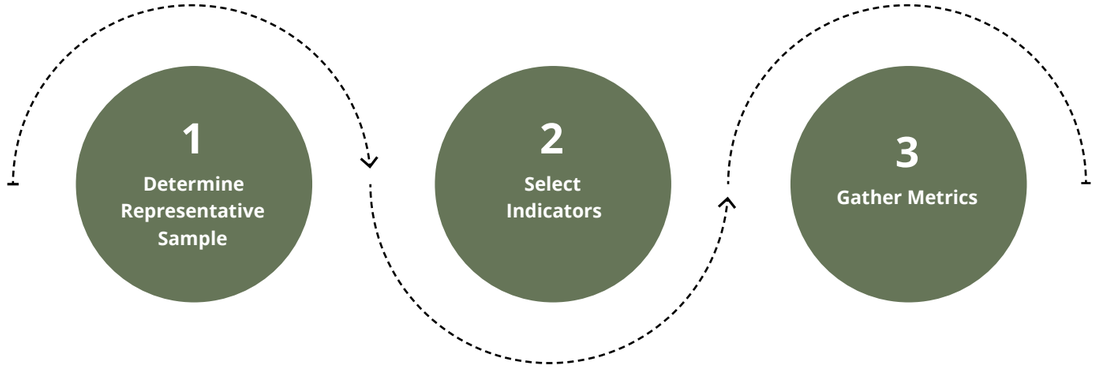
Overview

This document lays out a roadmap for implementing Session Act 2022, Chapter 179, SECTION 83 by December 31, 2024. This paper represents insights from diverse fields including architecture, public health, and engineering. Child learning environments require special consideration due to students' rapid biological, cognitive, academic, and social growth, and less mature immune systems. The current public school building portfolio is geographically diverse and spans decades of construction practices, demographic, environmental, and economic pressures. This document discusses the significance and methodologies for collecting the environmental determinants of health and energy metrics in SECTION 83. To properly identify building optimization strategies for energy and health, systematic data needs to be collected to inform decision-making. As outlined in Chapter 179, SECTION 83, there is a clear approach to filling this gap.

The goal of this document is to provide specific recommendations for the efficient implementation of the bill's requirements relative to the metrics, methods, and potential selection of sample sites.



Acronyms

To facilitate collaboration, please find common acronyms:

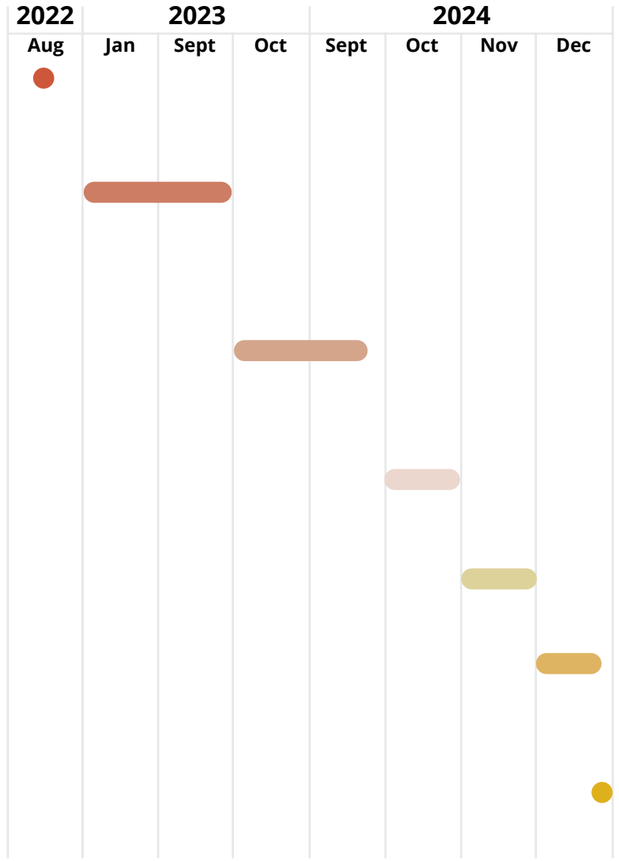
- **DESE:** Department of Elementary and Secondary Education
- **DOER:** Department of Energy Resources
- **MSBA:** Massachusetts School Building Authority
- **DPH:** Department of Public Health
- **BEH:** Bureau of Environmental Health

Contents

The report consists of the following sections:

This document does not provide standards for evaluation but outlines possible metrics to understand the condition and quality of learning environments in K-12 schools across the Commonwealth. Although building conditions impact human health and performance, the authors do not provide recommendations on collecting outcome measures related to health (e.g., obesity, asthma, mental health). These metrics may already be collected by other state agencies and can be added after the building assessment.

Timeline



Chapter 179 of the Acts of 2022 signed into law.

MSBA, in consultation with DPH, DESE and DOER, conducts an assessment of elementary and secondary school buildings relative to energy efficiency, building conditions, safety, and public health.

DESE, and DOER, DPH to develop, and report on, methods, best practices, and standards for achieving green and healthy schools strategies for the students of the Commonwealth.

DPH to issue a DRAFT report to be reviewed by MSBA, DESE and DOER.

DPH to review MSBA, DESE and DOER comments and suggestions and incorporate changes accordingly.

Report published on DPH website.

Report submitted to the House and Senate Committees on Ways and Means, the Joint Committee on Telecommunications, Utilities and Energy, the Joint Committee on Public Health, and the Joint Committee on Education not later than December 31, 2024.

Advancing healthy, green schools in the Commonwealth

The authors recognize numerous state agencies, coalitions, academics, non-profit organizations, and passionate individuals have worked decades to advance healthy, green schools in the Commonwealth. This report builds upon their work and hopes to inform the DPH, DESE, and DOER of existing opportunities that will increase the quality and rigor of this effort. Any omission of relevant efforts or expertise should notify the appropriate agencies.

Basis of Responsibility: DESE, DPH, DOER

Session Act 2022, Chapter 179, SECTION 83.

(a) The Massachusetts School Building Authority (MSBA) shall assess elementary and secondary school buildings relative to energy efficiency, building conditions, safety, and environmental health.

The Assessment shall:

- Include cataloging the age and condition of any building systems relying on the on-site combustion of fossil fuels.
- Be conducted in coordination with ongoing assessments or surveys of the MSBA.

The MSBA shall:

- Determine the means of conducting the assessment which may include a representative sample of schools.
- Consult with the department of public health (DPH), the department of elementary and secondary education (DESE) and the department of energy resources (DOER).

Following completion of the assessment, the department of public health, in consultation with the Massachusetts School Building Authority, the department of elementary and secondary education, and the department of energy resources, shall develop, and report on, methods, best practices, and standards for achieving green and healthy school strategies for the students of the commonwealth. Methods, best practices, and standards may involve, but shall not be limited to: (i) increasing energy efficiency, increasing electrification, and shifting to fossil-free fuels; (ii) efficiently using resources, including, but not limited to, low flow water fixtures; (iii) improving water and air quality, ventilation, and air circulation systems; (iv) maintaining thermal comfort, humidity, and temperature controls; and (v) taking other actions the department may determine.

The department of public health shall issue a report on the methods, best practices and standards and may include recommendations to prioritize schools with the greatest needs, consider the unique environmental differences of schools located in urban, industrial, rural, and other areas facing site challenges. Additionally, they may consider the need to address historic patterns of inequity in education and schools including, but not limited to, environmental justice areas, areas with high asthma rates, patterns of inequity involving students in special education programs. The report shall include projected cost estimates for implementing its recommendations in a cost-effective manner.

(b) The report shall be published on the website of the department of public health and submitted to the house and senate committees on ways and means, the joint committee on telecommunications, utilities and energy, the joint committee on public health, and the joint committee on education not later than December 31, 2024.

(c) Any findings or recommendations may be used to guide the department of elementary and secondary education in its implementation of item 1599-2055 of section 2A of chapter 102 of the acts of 2021.

Cost Considerations

The MSBA has effectively delivered billions of dollars for design and construction to public school facilities in the Commonwealth. However, the implementation of Section 83 of Chapter 179 of the Acts of 2022 aims to inform the financial needs of the entire public school portfolio, so that future investment can establish equitable health and energy improvements.

Cost of Measurement

There will be incurred cost from measuring health and energy metrics across Commonwealth schools. This document hopes to provide existing measurement efforts across agencies to increase efficiency, identify possible methodologies, and simplify implementation.

Cost of Implementation

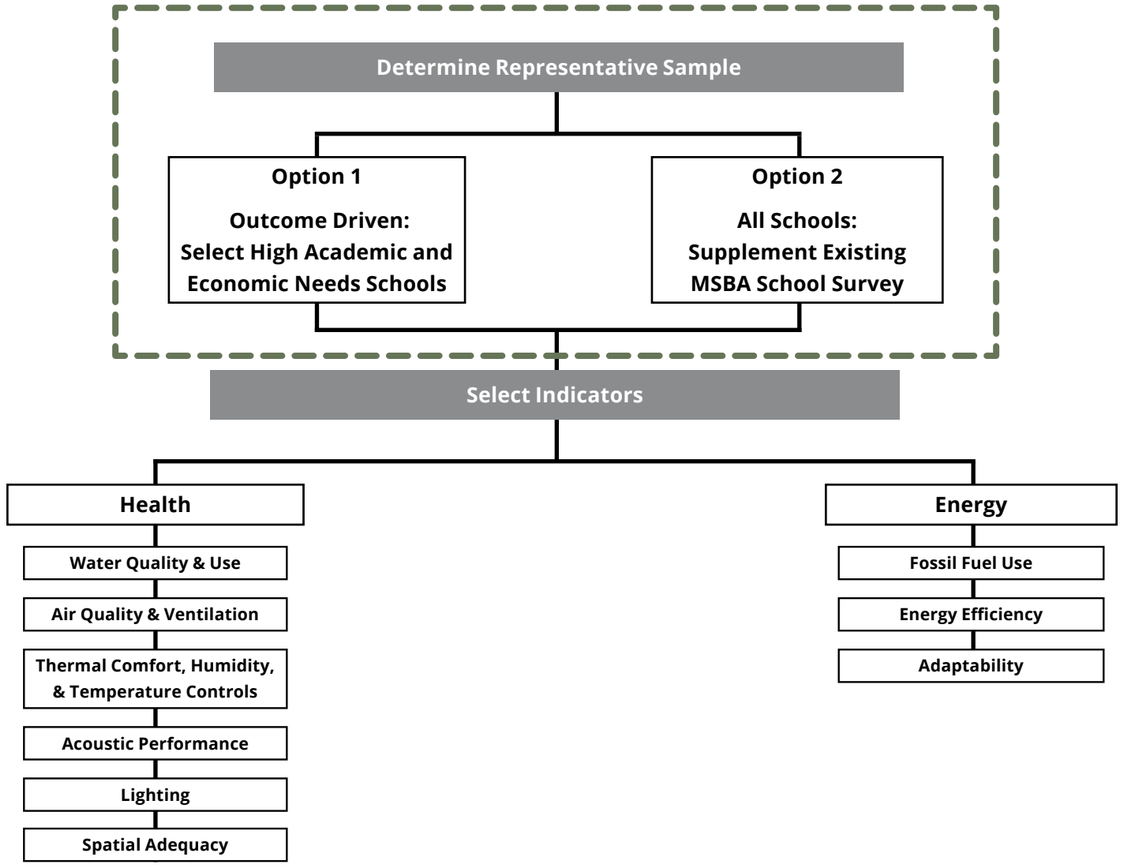
Once health and energy metrics have been collected and solutions or standards identified, there will be a cost to implement these strategies and standards across the Commonwealth. Existing buildings may have legacy pollutants, industry-made chemicals that persist in the environment, which may require large capital outlay to remediate or replace systems (e.g., plumbing containing lead). However, the U.S. Environmental Protection Agency (EPA) is committed to addressing and funding environmental justice areas of potential concern, which may align with opportunities identified in our K-12 facilities. This report will not provide estimates for implementation due to lack of data on the state of schools, bidding uncertainty, or building needs.

Getting Started

Options to Determine Representative Sample

The goal of sampling is to provide a cross-section of schools that will be representative of the larger school building portfolio in Massachusetts. To make accurate and generalizable recommendations, the Department of Public Health needs information that provides specificity and accurately identifies the source of potential harm to achieve the greatest benefit from repairs, renovations, and replacement.

1
Determine Representative Sample



Option 1 | Outcome-Driven:

Select High Academic and Economic Needs Schools

Evidence shows the health and performance of students is associated with indoor environmental quality features including indoor air, thermal comfort, acoustics, and lighting.

There are buildings spanning nearly 100 years of varying construction types, building codes, standards, and maintenance in the Commonwealth. Over time, schools have consolidated, renovated, introduced modular classrooms, and been expanded to increase capacity.

The oldest school buildings are disproportionately occupied by student populations with the greatest percentage of free and reduced lunch. The students that have the most to benefit from school improvements may be attending schools with the greatest economic and academic needs.

1. Identify a geographically diverse sample of schools of different grades served across Massachusetts counties.
2. To select a representative sample, it may be necessary to collect information from various building eras. Stratify school population by:
   - 25%: Built prior to 1965 (Building Boom)
   - 25%: Built 1965-1980 (Energy Crisis)
   - 25%: Built 1981-2000 (Pre LEED & CHPS)
   - 25%: Built 2001-2019 (Post LEED & CHPS)
3. Select a subset of schools by:
   - Higher than average MSBA reimbursement rate
   - Lower than average MCAS performance at the school-level
   - Higher than average prevalence of pediatric asthma at the district-level

PROS of Option 1	CONS of Option 1
• Selection of schools increases the generalization of findings and prioritizes schools that have the greatest socioeconomic, academic and health needs. • Accounts for different building design and construction that may affect energy and health outcomes. • Smaller sample allows for each environmental and energy parameter to be collected with greater depth. DPH can provide more informed, holistic recommendations.	• Smaller sample size limits the full representation of the diverse school building portfolio and we may not be able to extrapolate findings to all schools. • Requires RFQ for services for field work and data analysis.

Option 2 | All Schools:

Supplement Existing MSBA School Survey

The MSBA has collected systematic data on all public schools in 2010 and 2016 in their School Survey. This information provides a foundational understanding of building needs and repairs across seven site and 18 building system categories. However, the data has limited specificity on health and energy outcomes. The 'building condition rating' provides an overall score of a school's major systems on a scale of 1-4 (1: Good Condition, 4: Needs Major Renovation or Potential Replacement). In the following section, metrics for energy and health are provided to holistically understand the needs for building occupants and performance.

This option leverages the next School Survey by supplementing data collection with indoor measurements when the building is occupied or unoccupied and can be collected subjectively or objectively. Alternatively, proxy measures have been identified through site analysis that utilize existing datasets. Recognizing the bill is unfunded, capacity to measure this information may be limited.

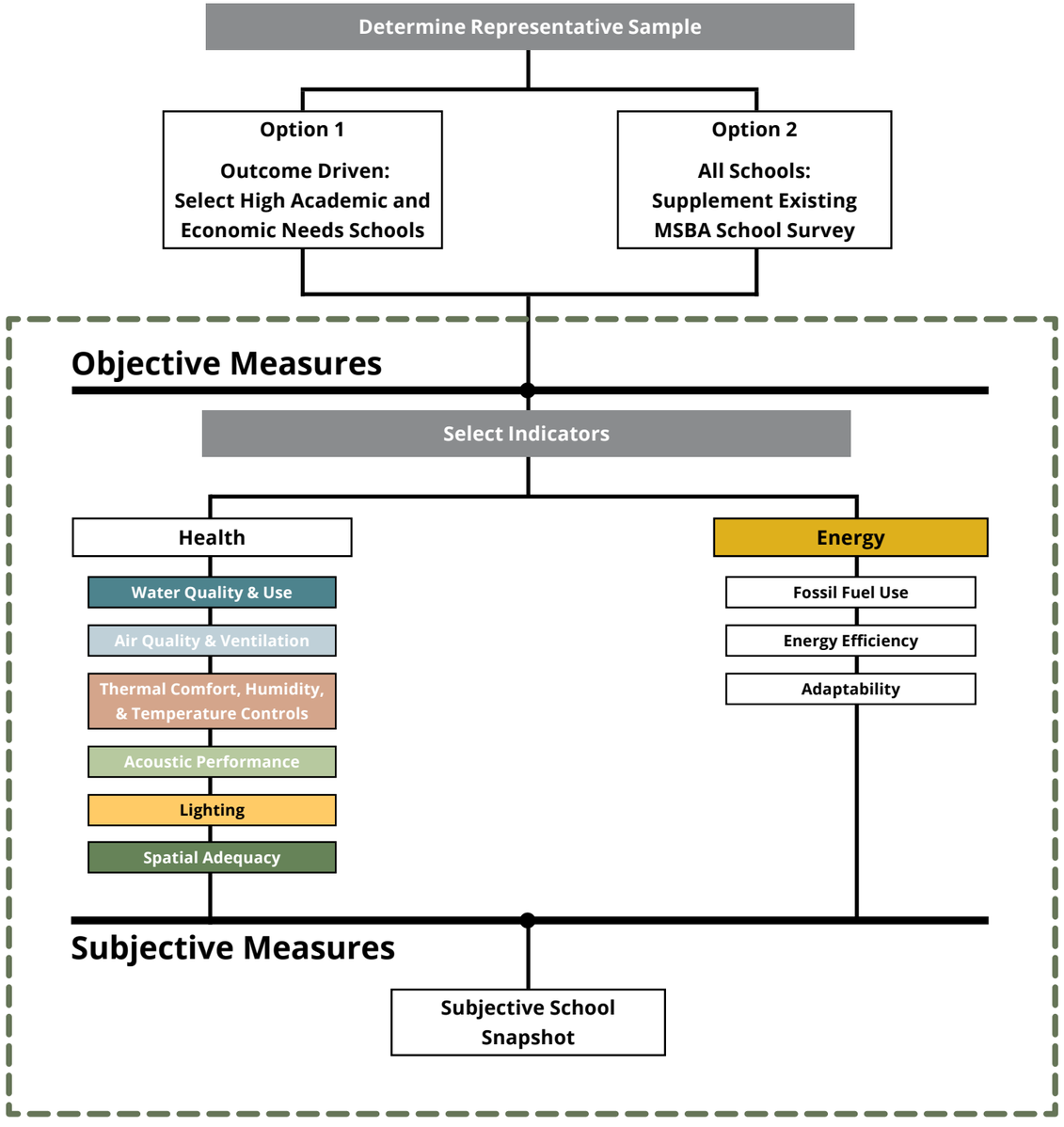
1. Data taken from all schools in MSBA system
2. Review MSBA School Survey
3. Consider energy and health metrics from survey

PROS of Option 2	CONS of Option 2
• Less costly to administer because Option 2 uses the existing mechanism of MSBA's School Survey . • Larger sample of school buildings evaluated. • Creates a mechanism for ongoing energy and health data collection over time.	• More schools may increase costs and may limit the number of variables schools can collect. • Requires expansion of existing RFQ for services for field work and data analysis.

Selecting Health & Energy Indicators for K-12 Schools

In Section 83 of Chapter 179 of the Acts of 2022, key categories of environmental health and energy metrics are identified. The authors provide additional specificity and possible metrics to establish overall quality of school facilities. Some measures are likely to be a matter of record in the school, district or municipal offices or are recorded as a matter of regulatory obligation. Some measures are not collected by any agency, or the public record has yet to note significant consequence for student cognitive and physiological wellbeing. The following section casts a wide net to inform a broader discussion of what records the Commonwealth should prioritize in the required collection and analysis.

2
Select Indicators



For each metric we identify:

- **Building Occupancy Status:** Does the building need to be occupied or unoccupied to collect accurate measurements that impact occupant and building performance? Unoccupied measurements limit the disruption to students during the school day. Occupied measurements may better capture the lived experience of building occupants.
- **Ability to Collect Information:** Is it easy, medium, or hard to collect information on this metric? This variable is a composite of the amount of anticipated time, money, expertise, or technology required to accurately capture data. The metrics are bolded and color-coded
- (● **Green** – Easy; ▲**Orange** – Medium; ■ **Red** – Difficult).
- **Rationale:** What is the significance of each metric? Are there any other key considerations for data collection? This provides additional context for each metric.

Potential Metrics for

Water Quality & Use

The age of water fixtures and plumbing in a school building can result in the use of more water than is needed and expose drinking water to harmful organic and inorganic substances including microbes and heavy metals. A school water audit can quickly identify water conservation strategies and support human behavior and decision-making. Access to clean drinking water is critical for child growth and brain development. Other water and health considerations include Legionella growth and spread when buildings are unoccupied for extended periods of time and may require flushing all water from building pipes.

MSBA School Survey Collected the Following Variables:

- **Plumbing** – Building Condition Rating
- **Site Condition** – Drainage
- **Site Condition** – Water Supply
- **Site Condition** – Septic/Sewage/Waste Water Disposal System

● Easy ▲ Medium ■ Difficult

OCCUPANCY STATUS	METRIC	RATIONALE
Unoccupied	**Water Composition – Heavy Metals** ▲ (lead, copper, magnesium) • Complete a voluntary drinking water test provided by MA Dept. of Environmental Protection (MassDEP) and MA Water Resource Authority (MWRA) through the Assistance Program for Lead in School Drinking Water. • Measure PFAS chemicals in drinking water	There is no safe level of lead in drinking water because at low levels lead can result in children's slowed growth, hearing and behavior problems, lower IQ and anemia. When copper in the drinking water is more than the EPA action level of 1300 ug/L it may cause individuals to experience nausea, vomiting, diarrhea, and stomach cramps. For some schools the short-term solution is flushing systems to achieve low lead thresholds in drinking water, which wastes water. The long-term solution to reduce heavy metal exposure is replacing plumbing, fixtures, and install bottle fillers.
N/A	**Site Contamination (Well Water)** ● • Identify hazardous waste cleanup locations near the school. Use the Environmental Protection Agency's 'Cleanups in my Community' to identify potential risks.	This site analysis identifies contaminated groundwater or surface water and air in the area, which can impact well water or the surrounding site.
Occupied/ Unoccupied	**Low Flow Water Fixtures** ● • Are there low flow water fixtures present, including toilets, sinks, or showers? (yes/no) • Does the faucet have an aerator that has a flow rate of one gallon per minute or less? (yes/no)	Identification of these fixtures can pinpoint where water is wasted daily.
Occupied	**Indoor Water Use Intensity** ▲ • Calculated by dividing all indoor water meters by the building's square footage and accounts for toilets, kitchens, showers, restrooms.	This measurement allows benchmarking across public schools to identify opportunities for water conservation in the building portfolio.

Potential Metrics for

Air Quality & Ventilation

Indoor air quality (IAQ) is critical for child health and performance since they breathe 50% more air than adults, have immature immune systems, and are more likely to be exposed to dust in learning environments. The COVID-19 pandemic highlighted the need for expansive improvements in our school's ventilation and filtration capacity. Existing buildings often exceed the acceptable level of Indoor Air Quality in schools (ASHRAE 62.1) by 2-5 times.

The MA DPH, Bureau of Environmental Health has an existing Indoor Air Quality Program under M.G.L. c. 111 sec. 5, which "conducts sanitary investigations and investigations as to the causes of disease" and "advises the government concerning the location and other sanitary condition of any public institution." They conduct both an IAQ and radon assessment and already have methods for improving air quality in schools, public buildings, and housing, completed reports and assessments of public buildings, and guidelines and checklists. The Bureau of Environmental Health will be a valuable partner in identifying the appropriate IAQ metrics and assist in training assessors or collecting the subsequent metrics.

The Massachusetts Asthma Action Partnership released their 2021-2026 Strategic Plan, which identified eleven cities due to the highest asthma burden across the state. Their plan highlights increasing capacity of statewide partnership, reducing environmental exposures that trigger asthma, and advancing primary prevention of asthma by using innovative evidence-based interventions

MSBA School Survey Collected the Following Variables:

- **HVAC Heating Type**
- **Ventilation/ AC Type**
- **Ventilation/ AC Coverage**
- **HVAC -** Building Condition Rating

● **Easy** ▲ **Medium** ■ **Difficult**

OCCUPANCY STATUS	METRIC	RATIONALE
Occupied	**Indoor Carbon Dioxide/PM2** ▲ Deploy portable sensors or use building management system to measure classroom conditions for two weeks. Many sensors provide the ability to measure multiple indoor air conditions.	Classrooms with high levels of CO2 and PM2.5 have been shown to have higher levels of asthma and lower test performance. This indoor measurement approach captures weather variation, rush hour traffic, and vary indoor pollutions sources. If using portable indoor air quality, repeat seasonally to capture different conditions driven by human behavior or temperature (e.g., use of windows or AC).
Occupied/ Unoccupied	**Airflow/ Air Change Rate** ▲ Using an anemometer measure airspeed in duct work and calculate air change rate. Air change rate is calculated by (Airflow (cubic ft./ min.) x 60 min.) / Room Volume (cubic ft.)	This indoor measurement allows us to understand the rate of removal or dilution of indoor air pollutants.
Occupied/ Unoccupied	**Volatile Organic Compounds** ■ Measure total volatile organic compounds using Flame Ionization Detection and Photo Ionization Detection. Measure specific VOCs in the air using a thermal desorption tube.	These gaseous air pollutants can be measured indoors with the assistance of an industrial hygienist and external lab analysis once samples are collected. Measuring for two weeks can identify different air pollution sources (e.g. traffic-related air pollution, cleaning, office/ school supplies).
N/A	**Outdoor PM2.5** ▲ Deploy portable sensors to measure ambient conditions for two weeks.	This continuous outdoor site measurement captures weather variation, rush hour traffic, and various outdoor pollutions sources.
N/A	**Proximity to Outdoor Air Pollution Sources** ● Via EPA's EJ Screen, we can rapidly evaluate sources of outdoor air pollution by community. • Proximity to Major Roadway • Proximity to Superfund Site • Proximity to Hazardous Waste • Proximity to RMP Facility • Built on a Brownfield	This site analysis can be completed prior to a building visit to identify sources of air pollution that may infiltrate indoors.

Potential Metrics for

Thermal Comfort, Humidity & Temperature Controls

The temperature and humidity in a learning environment have direct and indirect impacts on student and teacher outcomes from influencing infectious disease survival, cognitive function, and academic performance. For example, a large study of New York City students found a 0.2% decrease in exam scores was observed for every 1°F increase in temperature, suggesting a student taking an exam on a 90-degree day was 12.3% more likely to fail an exam than on a 75-degree day. Thermal comfort is a common metric for defining satisfaction with the environment, but this highly subjective measure does not account for student activity level, metabolic rate, or clothing choices.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), a national association that guides indoor environmental quality uses ASHRAE 55 to specify conditions for acceptable thermal environments. Also, ASHRAE recommends humidity levels below 65%. There are no lower-level recommendations for relative humidity, however, it should be noted that humidity levels that are too low (below 30%) leads to health issues like skin irritation and increased indoor humidity during winter months and can lower influenza virus transmission.

MSBA School Survey Collected the Following Variables:

- **HVAC Heating Type**
- **Ventilation/ AC Type**
- **Ventilation/ AC Coverage**
- **HVAC -** Building Condition Rating
- **Oldest Boilers** - Building Condition Rating
- **Second Oldest Boilers** - Building Condition Rating

● **Easy** ▲ **Medium** ■ **Difficult**

OCCUPANCY STATUS	METRIC	RATIONALE
Occupied/ Unoccupied	**Indoor and outdoor dry bulb temperature and relative humidity** ▲ • Deploy portable sensors or use a building management system to measure classroom conditions for two weeks to capture weekly and daily weather variation. Measure outdoor conditions at the same time. • Select multiple classroom locations across the school to identify different conditions or temperature extremes	The continuous indoor measurement of temperature and humidity allow schools to determine if they are meeting current ASHRAE standards. Identifying higher temperatures in the classroom may be associated with occupant discomfort and lower academic outcomes. Higher relative humidity levels (>40%) has been associated with mold growth, respiratory infections, asthma and allergic reactions or hardwood floor warping. Single day measurements or individual classroom measurements will not identify variation in mechanical system performance, impact of south- or north-facing windows, or the impact of weather on the building's indoor environment.

Potential Metrics for

School Acoustic Performance

Students spend a large percentage of time focused on listening, especially early in their educational process. Children are still developing mature language skills and have poorer speech perception than young adults. Background noise can interfere with concentration, learning, comprehension, and memory. Many learners may also have undiagnosed hearing disabilities, second language learning challenges or attention deficit issues that make learning in acoustically busy spaces more difficult. Therefore, other sound considerations should include reverberation, echogenicity, and the duration or frequency of high noise levels. Chronic outdoor noise such as road and aircraft noise can also impede learning and can trigger cardiovascular health issues and vocal strain in both students and staff. Achieving modern acoustic standards (ANSI 12.60) is difficult in older buildings. The age of the building, building envelope, and HVAC system can identify common acoustic problems.

The American Speech-Language-Hearing Association (ASHA) provides resources tailored for school buildings and students.

MSBA School Survey Collected the Following Variables:

- **No metrics relevant** in 2016 School Survey

This category was not identified as a health indicator in Section 83 of Chapter 179 of the Acts of 2022. However, these environmental parameters are a part of a healthy school facility and may influence energy use or interact with the other health indicators including indoor air quality and thermal comfort.

● Easy ▲ Medium ■ Difficult

OCCUPANCY STATUS	METRIC	RATIONALE
Unoccupied	**Background Noise** ● • Decibel measurements of unoccupied, space where the worst-case receiver is located (e.g. by the window unit, collect 30 seconds uninterrupted).	Evening data collection allows for accurate background noise measurements because the space is unoccupied and can measure noise or sound from mechanical systems. Make sure HVAC is on or air conditioning if samples are collected during the winter.
Occupied/ Unoccupied	**Area of acoustical absorption** ● • Measure Classroom Acoustical Ceiling Tile (ACT) or Acoustical Ceiling Panel (ACP) Area relative to room area • Visual counting of acoustical finishes in percentage of surface area to total ceiling area (acoustical ceiling panel area / total ceiling surface area inclusive of lights and soffits). • Same typical count for other room types • Count of rooms lacking absorption	This observational assessment of classroom acoustics helps to determine whether the room is reducing reverberation and the amplification of noise to appropriate levels. (ANSI S12.60) While not all acoustic tiles have the same Noise Reduction Coefficient, 80% of the ceiling surface should be made up of sound absorptive acoustical panels. Different standards apply to specialized classrooms.
Unoccupied	**Sound transmission between floors, windows, and walls** ▲ • Impact sound transmission floor to floor • Impact sound transmission (metered/two person process) • Laterally (metered/two person process)	This indoor measurement captures sources of noise that may disrupt a student's ability to hear, especially when mastering language skills. Measuring sound transmission helps understand acoustical privacy, disruption from surrounding environments, and exposure to common daily outdoor noises (e.g., traffic, aircraft noise). Collecting the measurements during the school day can capture the lived experience. This is interior-source background noise.
Occupied/ Unoccupied	**Sound Leakage** ● • Observation of ceiling cavity (wall/ ceiling/floor seal) • Observation of doorway (gasketing) • Sound transmission at windows and doors, directly measurable with decibel meter. (Relates to air sealing and energy also) • Visual assessment of windows: Are they single-paned? Well-sealed?	Sound can travel through the building or from outside. Visual observations highlight opportunities for improving the acoustical quality of the building. These metrics also relate to air sealing and energy savings.
N/A	**Outdoor Sources of Noise** ● • Map proximity to roadway, highways, airport or other high impact source. • Measure the shortest distance between the school campus and the source.	Objective site analysis does not capture the experience inside the classroom but identifies a well-studied source of noise that impacts academic performance. This information can be collected in advance of a site visit.

Potential Metrics for

Lighting

The goal of good classroom lighting is to balance stimulus and health with energy efficiency in order to enable visual attention without incurring unnecessary eye strain. Light may have direct effects on cognitive function: attention, executive function, and memory. High color temperature is associated with active atmospheres, productive workplaces, slowing cognitive deterioration in elderly, and reducing depression. Low color temperature has been associated with serene, stable, and relaxed spaces. Consistent, controllable lighting with good color range and access to natural light is highly beneficial to room occupants Controllability allows occupants to directly manage light levels and glare. Overly aggressive use of window shades on the other hand denies the health benefits of views and exposure to daylight.

The Illuminating Engineering Society (IES) provides additional reports, educational resources, and standards on the impact of lighting and illumination on energy and health.

MSBA School Survey Collected the Following Variables:

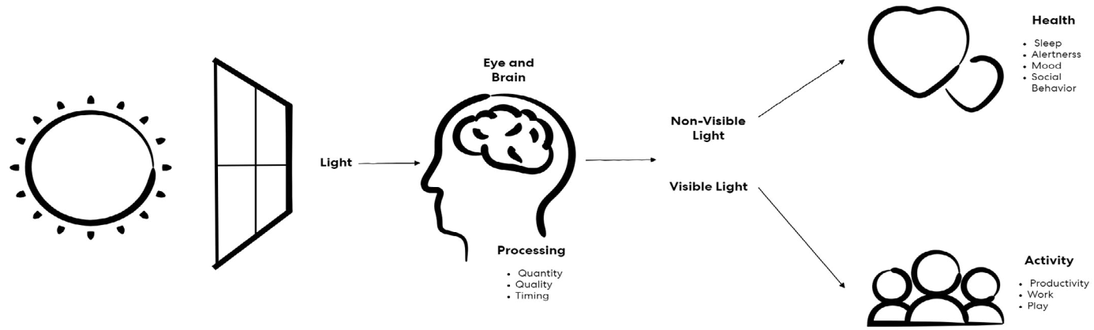
- How many classrooms lack natural daylight (windows)?
- **Electrical Lighting** - Building Condition Rating
- **Electrical Services and Distribution** - Building Condition Rating

This category was not identified as a health indicator in Section 83 of Chapter 179 of the Acts of 2022. However, these environmental parameters are a part of a healthy school facility and may influence energy use or interact with the other health indicators including indoor air quality and thermal comfort.

● Easy ▲ Medium ■ Difficult

OCCUPANCY STATUS	METRIC	RATIONALE
N/A	**Amount of Light** ● • Measure illuminance levels (Lux) with lux meters at student desk height and capture vertical light levels on front wall, board, or where the focus is. Collect data per ANSI/ IES RP-3-13, American National Standard Practice on Lighting for Educational Facilities standards at task areas and assignable locations in and around building per student	Brightness of light drives how well students can see instruction at the front of the room or down a long corridor. Standards recommend that illuminance is between 300-3000 lux, but studies show 500-1,000 lux may be more appropriate for classroom tasks like reading. For students with visual, intellectual or cognitive impairments, lighting levels may need to be adjusted or tailored to their needs.
N/A	**Color Temperature** ▲ • Measure with chromameter/spectrometer	This indoor measurement helps to identify the non-visual impact on light such as the alerting or calming effects of natural light. Correlated Color Temperature provides the electrical lighting equivalent to daylight. Measuring in a classroom environment helps to understand the impact on occupants' circadian rhythm.
N/A	**Energy Use** ● • Is the lighting system triggered by occupancy or movement? • Observation of fixture type (LED or other) • Review of utility bills • Maintenance Records	This inventory can highlight opportunities for more energy efficient lighting.

Impacts of Daylight on Health



— Image courtesy of Tyrone Marshall

Potential Metrics for

Spatial Adequacy

Adequate space for teaching and learning is a baseline programmatic requirement of any educational facility, yet no national standard exists to determine adequacy of a space as a K12 classroom in part because teaching methods are continually evolving. Traditional 19th century high schools provided less than 20sf per student because teaching was primarily lecture based. In the late-20th century teaching methods widened to prioritize project-based learning, collaboration, and critical thinking over rote learning. Adequate space also remains a critical health and wellness concern in that it provides a sense of security, enables movement, allows for classroom management, and provides for agency in learners. Adequacy of space is also critical to the reduction of disease transmission.

While existing school buildings not subject to these standards, they are subject to DESE curriculum requirements and an increasing attempting to serve students along a spectrum of differentiated needs within undersized classrooms. The state of Massachusetts has codified standards for allocation of space per student in K12 new school construction in 963CMR.200 Reg.206 and regularly reviews specific standards for classrooms by grade range and type.

MSBA School Survey Collected the Following Variables:

- All floors accessible via ramp or elevator?
- Any accessible restrooms?
- Number of Modulars
- Age of Modulars
- Classroom Counts in Modulars
- Number of Chair Lifts in this building
- Main Entrance access without stairs
- Secondary entrance without stairs
- Playgrounds and other site areas access without stairs
- Designated handicap parking

This category was not identified as a health indicator in Section 83 of Chapter 179 of the Acts of 2022. However, these environmental parameters are a part of a healthy school facility and may influence energy use or interact with the other health indicators including indoor air quality and thermal comfort.

● Easy ▲ Medium ■ Difficult

OCCUPANCY STATUS	METRIC	RATIONALE
N/A	**Capacity** ● • Student per floor area: Calculation of room area divided by room occupancy	Adequate space to work, move and interact comfortably with peers and instructors directly impacts one's ability to focus. MSBA guidelines for new construction suggest that less than 30sf per student is suboptimal.
N/A	**Accessibility** ● • Review of corridor, stairwell and bathrooms and passage areas. Comparison to current MGL building code expectations and ADA guidelines to assess conditions that may impact student safety and well-being.	Evaluating these features helps increase disability inclusion in our schools. ADA provides foundational considerations, but more information is needed to support students living with impairments or disabilities.

Potential Energy Metrics for

Massachusetts Public Schools

Assessment of existing building Mechanical, Electrical, and Plumbing (MEP) systems could capture data on the age, condition, and distribution of heating and cooling as a measure of system resiliency and as a step towards planning for replacement of existing fossil fuel burning systems with more efficient all-electric systems. Vulnerable fossil fuel burning systems will become more challenging to replace in the next ten to fifteen years leaving schools at risk of unexpected closure. Metrics might also help to observe building and site conditions that relate to the suitability of schools for electrification projects and the potential for installation of renewables, presently identified as photovoltaic or geothermal.

A school's energy use does not directly correlate with health impacts but is a critical source of operational vulnerability to the school building and district budget due to energy cost fluctuation and changing code requirements. Assessment of a school's energy consumption and efficiency offers useful diagnostic information that can aid capital planning efforts. The same data can also be used by DOER to determine progress on Commonwealth climate goals.

Augmenting school infrastructure through the installation of renewable energy systems is recommendation of the state's Climate Plan and DOER's updated Stretch Code requirements, such systems can increase building and community resiliency and reduce electrical costs. Existing buildings and sites should be assessed for factors that can indicate suitability or unsuitability for installation of onsite renewables, including photovoltaics and geothermal systems.

Criterion for Energy Metrics:

01.
Fossil Fuel Use and Replacement Planning

02.
Energy Efficiency

03.
Adaptability

Criterion 1: Fossil Fuel Use and Replacement Planning

● Easy ▲ Medium ■ Difficult

METRIC	RATIONALE
Fuel Source - Fossil Fuel Combustion System ● • What is the age, condition and life expectancy of the primary furnace or boiler? • Is there a working redundant furnace or boiler? • Is the efficiency of the system greater than, equal to or less than 80%.	Replacement of fossil fuel burning heating systems is discouraged under the proposed IECC 2021 and MA Stretch Code. The vulnerability of aging combustion systems is a critical measure of resilience or vulnerability.
Heating Distribution - Describe systems in place. ● • If water-based, is the system steam or hot temp water or low temp water? Steam systems are older, less energy efficient to operate and harder to retrofit.) • If air-based—what is the fuel source of the heating coil? • What is the age, condition, and life expectancy of the handling system?	Similarly, the heat delivery system and its capacity to serve the needs of the school are a critical measure of resilience or vulnerability.
Cooling Distribution - Describe systems in place. ● • Does the system provide cooling? If so, is cool air delivered centrally or through wall units? • What is the age, condition, and life expectancy of the system? • How much outdoor ventilation is provided compared to current code requirements?	The availability of cooling is increasingly important to the learning environment as extreme heat events grow more frequent Data on the presence of cooling systems has not historically been collected but is an important measure of school and district climate vulnerability.
Dependencies ● • Does the school have an onsite generator sized to maintain operation of existing ventilation units and emergency systems? • Does the mechanical room have capacity for a major electrification project? • Electrical system capacity/condition • Is there adequate ceiling space for ductwork (~12' ft)? – Calculate Floor to Floor Height and roof framing size/ spacing • Roof condition	The ability of the school to support an electrification conversion (air sourced or ground-sourced, depends on the capacity of the existing structural systems, roof system, electrical room and electrical panels as well as the ability to maintain the electrical heating/cooling with adequate emergency power. Gathering data on these existing systems will be essential to reviewing the cost of system conversion.

Criterion 2: Energy Efficiency

● Easy ▲ Medium ■ Difficult

METRIC	RATIONALE
Energy Use Intensity (EUI) Calculation ● • Total energy use in kBTU divided by total gross square footage. EUI is an understood measure that allows for comparison to other buildings of similar use and type.	Buildings with a high EUI relative to others in the same class of buildings are understood to have inefficient insulation, significant air leakage, inefficient mechanical systems or all three. The high EUI predicts a higher cost of renovation to improve the building or a high operating cost if left unimproved, even after electrification.
Envelope Performance ▲ • Levels of insulation (R and U values) determined by review of building plans and, when possible, by physical observation. • U-value of 1.0 single pane (very poor) • U- value of .5-.9 (poor) • Wall R-value 10 or less (poor) • Roof R-value of 20 or less (poor)	Assessment of insulation levels can further determine the source of a building's energy inefficiency and can influence the scope and cost of improvements. Some insulation levels are easily observable. Others are typically details present in building plans and known to maintenance and facilities staff.
Envelope Performance ■ • Air Infiltration – Measurable Data	Typically measured by a blower door test in a contained area of a building, this is a valuable diagnostic for establishing a baseline measure of whole building infiltration levels, which relate to the overall building energy efficiency levels measured by EUI.

Criterion 3: Adaptability

● Easy ▲ Medium ■ Difficult

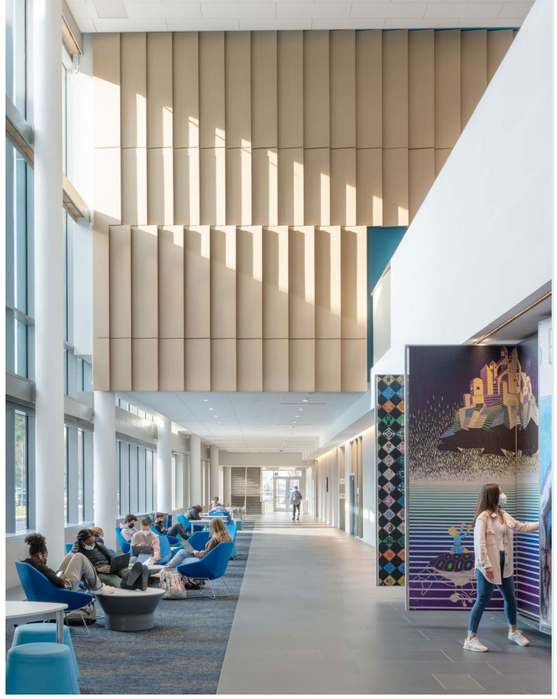
METRIC	RATIONALE
Determining Geothermal Potential ■ • How much site area is available for drillable ground area for geothermal wells? • Soil conditions (well testing) • Envelope performance (see C2) • Utility room space • Ceiling space for ductwork • Floor to Floor Height	**Text Needed**
Rooftop PV Potential ▲ • Roof framing size/spacing • Roof condition	**Text Needed**
Building Management Upgrade ▲ • Existing Control System • (Related to assessment of age/condition and control of MEP systems)	**Text Needed**

Creating a Snapshot:

Subjective & Observational Assessment

In the previous section, objective measures provide factual, consistent data collection methods. However, subjective, or self-reported data may come from students, staff, facilities, or teachers. Their lived experience is easier to access and does not require a hired professional who may be unfamiliar with the building.

	IN YOUR SCHOOL OR CLASSROOM...		INTERPRETATION
Water	**Lead/Copper in Drinking Water:** Was the plumbing system replaced after 1991?	O Yes O No	No, your plumbing system likely has elevated lead levels because it predates EPA's Lead and Copper Rule. Get water tested.
	Low flow water fixtures: Are there low flow water fixtures present throughout the building (e.g., toilets, faucets, or showers)?	O Yes O No	No, count the number of high flow fixtures to identify water conservation opportunities.
Indoor Air Quality	**Presence of Mold or Mold Odor:** Can you see or smell mold or musty smell?	O Yes O No	Yes, even without visible signs of mold, smell can indicate hidden mold, a known trigger of asthma in the classroom.
	Mechanical System Optimization: Do you have a mechanical ventilation system? Is the MERV Filter Rating 13 or higher?	O Yes O No	Yes, identify when the filter was last changed. No, complete additional IAQ measurement.
	Does your facility use **temporary buildings or modular classrooms**?	O Yes O No	Yes, modular classrooms have been shown to have high levels of harmful chemicals, background noise, water intrusion, mold, and poor indoor air quality. More sampling needed.
Thermal Comfort	**Temperature:** When collecting self-reported thermal comfort satisfaction, are more than 20% of people dissatisfied within a specific thermal environment? Note: Occupant surveys can identify preferences: "Do you feel hot/cool?" or "Would you prefer it to be warmer or colder?"	O Yes O No	Yes, thermal comfort exceeds ASHRAE 55 standards. Collect information seasonally and by occupants in diverse locations across the school.
	Controllability: Can you control the temperature of your classroom (e.g., thermostat, pulling window blinds)?	O Yes O No	No, differences in metabolism and activities levels can reduce thermal comfort for occupants and modifications are needed.
	Presence of Cooling: Does your classroom or building have the ability to be cooled (e.g. air conditioning, operable windows)?	O Yes O No	No, building system upgrades need to be evaluated to see how the building can provide comfortable temperatures during hot days.
Acoustics	**Background Noise:** Do you hear clear disruption from adjacent classroom's activities? Do you see an interconnecting door or movable wall, unit ventilator, central HVAC air system, corridor plenum or duct work? Do occupants hear activities from other areas during the day (e.g., Cafeteria, Gymnasium, Musical Practice Space)?	O Yes O No	If yes, there is likely increased sound transmission and opportunities to improve acoustical performance.
Lighting/Daylight	**Views**: Are there views to the outdoors available to room occupants?	O Yes O No	No, views and access to nature are associated with better student satisfaction and comfort. Strategies to improve access to views or biophilic design should be considered.
	Pattern, Orientation & Condition: Do you notice stark unevenness in lighting, glare, inadequate distribution, hum, flicker or other light concerns?	O Yes O No	Yes, uneven, flickering light can lead to headaches. Consider age of lighting system and available improvements for energy efficiency and controllability.
	Visual assessment of windows: Are they single-paned? Well-sealed? Do not open?	O Yes O No	No, older windows may include legacy pollutants (e.g. lead in paint, PCBs in window caulking) that can be sloughed off in operable windows. Test samples for pollutants and measure for air leakage.
	Artificial Lighting Control: Can teachers dim lighting? Do teachers have access to tunable lighting systems? Can teachers readily switch on or off lights?	O Yes O No	No, the lack of this controllability may adversely impact teaching or individuals with different sensory needs.
	Daylighting Control: If there are windows in the classrooms, do you have operable window shades? Are they pulled during the school day? Are there effective exterior louvers on south, east and west elevations?	O Yes O No	No, more exploration is needed to understand the impact of glare, which can be distracting to students and prevent computer work.
Energy	Is there a lack of consistent and reliable heat in occupied spaces? Is there a history of temperature fluctuations or uneven distribution? Is there localized control (within a range of 8 degrees or less) of the temperature?	O Yes O No	Yes, additional energy analysis is required.



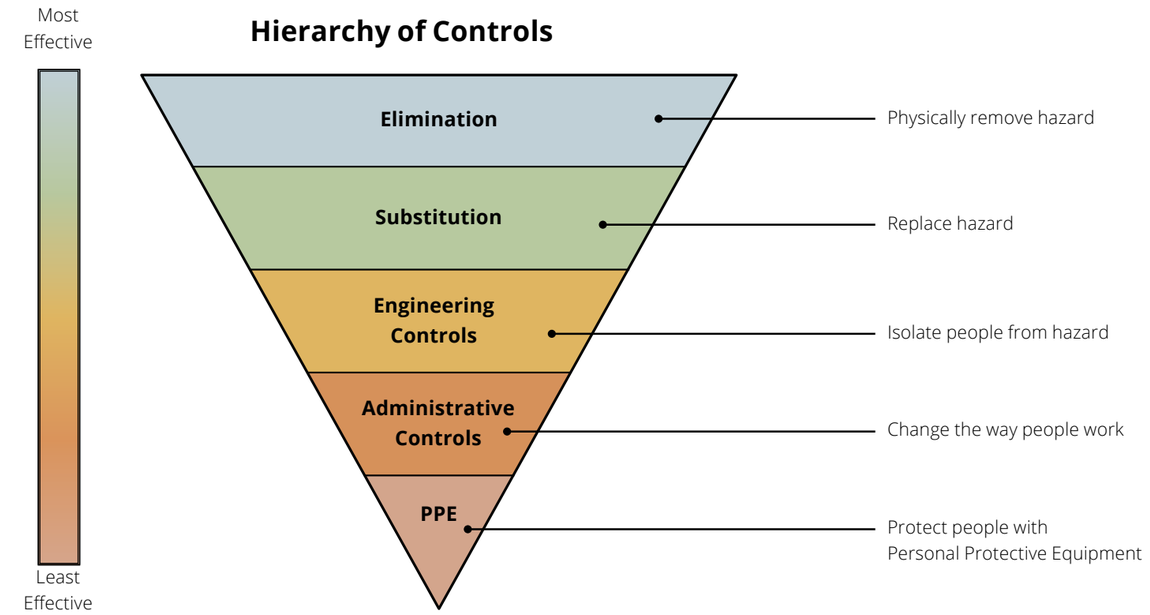
Conclusions:

From Data Collection to Action

Hierarchy of Controls

This white paper aims to support the implementation of Section 83 of Chapter 179 of the Acts of 2022 by proposing potential school selection options and environmental and energy metrics. There are many opportunities available to the State and the authors hope this report can facilitate an efficient start to data collection and action. We believe observational data can create a transparent, inclusive process, and when paired with measured, objective findings we can most effectively understand the health impact and energy potential of our diverse building portfolio.

We also believe that the public health solutions for our K-12 school facilities exist across the hierarchy of controls. Although short-term fixes may reduce initial adverse impacts on students, teachers, and staff, the Commonwealth should provide long-term recommendations that remove the hazard holistically. For example, temporary strategies to improve indoor air quality like portable air purifiers may create background noise and unpleasant teaching environments. Therefore, it is important to think about the interaction across different environmental parameters.



—Measures as recommended by the CDC

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