State of Alaska **Department of Education & Early Development**
Bond Reimbursement & Grant Review Committee

Design Ratios

D E E D P o s i t i o n P a p e r

September 1, 2022

Purpose

The purpose of this paper is to provide recommendations for design ratios that will assist in achieving efficient and cost-effective school construction in Alaska and to establish how those design ratios should be implemented, via regulation or within department publications.

Background

This paper builds on the work of the Design Ratios Subcommittee, established by the BRGR in 2017 and currently still active. It also uses two contracted consultant reports. The first was published in July 2019. A second, companion report was finalized in June 2022. (For additional background on legislation, ratio development and past committee involvement, see the February 28, 2022 DEED Position Paper.)

Proposed Ratio Types

Three design ratios have been developed, analyzed for operations and construction cost variables, and vetted by the subcommittee as capable of enhancing the cost-effectiveness of school facilities in Alaska when limited to a desirable range. Those are:

1) The ratio of exterior openings (windows, doors, etc.) to exterior walls (in square feet).
2) The ratio of a building's volume to the building's gross square footage, and
3) The ratio of a building's volume to the building's exterior surface (roof, walls, floors) exposed to the environment.

Proposed Ratio Values

The values presented below have been gleaned from the data contained in the 2019 and 2022 Building Energy Modeling (BEM) Reports. Though some may be hard data points from the analyses, most are based on extrapolation and measured inference.

<u>Openings to Exterior Wall (O:EW)</u>
The following targets and allowable ranges are established for O:EW by climate zone:

Zone 6 – Target 14%; Range [12% - 20%]
Zone 7 – Target 13%; Range [11% - 18%]
Zone 8 – Target 9%; Range [8% - 14%]
Zone 9 – Target 8.5%; Range [6% - 11%]

<u>Volume to Gross Square Feet (V:GSF)</u>
The following target and allowable range is established for V:GSF (Note: climate zone is not statistically significant for this ratio):

All Zones – Target 22.5%; Range [20% - 23.5%]

Volume to Exterior Surface (V:ES)
The following targets and allowable ranges are established for V:ES by building type (Note: climate zone is not statistically significant for this ratio):

Baseline Design (Slab) – Target 8.5%; Range [8% - 10%]
Elevated Floor Design – Target 6.5%; Range [6% - 8.5%]
Two Story Design – Target 8.5%; Range [8% - 9.5%]

Discussion

Impact of Ratios on Costs
While results may vary in actual projects, the theoretical impacts on cost for the proposed design ratios is moderate. The forecasted cost savings across the ranges listed in the proposed ratios is less than 4% and modeled extremes rarely reached 10%. Designing within the proposed ranges in these ratios simply demonstrates good design; the kind of design that is generally occurring day-to-day, year-to-year for Alaskan schools.

Ratios Placement in Regulation
The normal method for implementing a statute that directs the development of additional standards is to promulgate regulations in the state's administrative code. AS 14.11.017(d) clearly calls for development of additional standards. However, in order for regulations to be an effective vehicle for developed standards, those standards must be sufficiently definable so as to be clear and relatively succinct (i.e., short), and sufficiently durable so as to not required change except at reasonable intervals—maybe five years or more. These factors are discussed in the following paragraphs.

Definable: Earlier this paper mentioned the ratio descriptions format (and content for some) proposed and accepted by the BRGR. In this format, the definition is proposed as a title and two supporting sentences. The ratio(s) themselves are also relatively straightforward terms such as "target" and "ratio" followed by numeric values. The format also includes three additional areas of information: calculation clarifications, guidance (on implementation), and references. The *definition* and *ratio* elements are suited to regulation, the remaining three areas would not be included in regulation, but would be best implemented as department procedures.

Durability: The O:EW ratio establishes cost-effective design by measuring impact of windows on the energy performance of a school building. There are two primary factors which could influence the underlying basis for the ratio: the cost of energy and the thermal performance of windows relative to exterior wall assembly. While change can be expected in both of these factors, it is reasonable that it will occur incrementally over time.

The V:GSF ratio establishes cost-effective design by measuring the impact of the volume on initial cost and operating performance of a building relative to its floor area. The two factors that could influence the underlying basis for this ratio are: the cost of building enclosure and the cost of conditioning building volume. While future efficiencies might mitigate the high-to-low spectrum of these factors, it's hard to imagine a gain in either enclosure construction or conditioning efficiency that would be disassociated from cost.

The V:ES ratio establishes a cost-effective design by measuring the impact of volume on the initial cost (and operating cost) of a building relative to its enclosure. The two factors that could influence the underlying basis for this ratio are again: the cost of building enclosure and the cost of conditioning building volume. The stasis, or durability, of these factors seems again, almost guaranteed with gains unlikely to be coming at no increase in cost.

Summary

Analysis and study from 2017 to the present has validated three design ratios that can be used to demonstrate efficient school design with respect to efficient building enclosure, building complexity, and building massing. Achieving these design ratios in high performance, 21st century learning environments has been accomplished in the past and can be accomplished in the future.

Options

1. Request DEED Facilities staff prepare draft language for review by the BRGR in December to incorporate O:EW, V:GSF and V:ES in regulation. (Note: it is assumed that following review/revision of language, the committee would open a period of public comment.)
2. Direct the Design Ratios Subcommittee to conduct a validation and analysis of the proposed design ratios (targets and ranges) and prepare a summary report for review by the BRGR in December. (Note: it is assumed that following validation, DEED staff would prepare regulation language as in Option 1.)

Recommendation(s)

None

Attachments

State of Alaska **Department of Education & Early Development**
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Openings to Exterior Wall
School Construction Standard
DEED RECOMMENDATION

Ratio Definition

Openings Area to Exterior Wall Area (O:EW).

Opening Area is defined as:the square footage of all windows, doors, and translucent panels measured to the outside of their frame elements.

Exterior Wall Area is defined as: the square footage of the exterior vertical enclosure bounding heated space, inclusive of all openings.

Calculation Clarifications

1) Boundary edges of EW top/bottom are the intersection with horizontal (i.e., roof, floor) thermal construction.
2) Boundary edges of EW sides are the 'corners' used for GSF measurements in 4 AAC 31.020.
3) Roof gables and vertical faces of floor soffits are included in EW if enclosing heated space.
4) Be conscious of eave overhang lines when setting top boundary edges.
5) Mechanical louvers in exterior walls are not counted as Openings Area (O) but are included in the EW.

- Skylights are Premium construction and not supported with state funds. If included, they will be counted as openings.
- Light Monitors/Clerestories are acceptable construction and will be included as defined in the O:EW calculation.

Regional O:EW Ratio

Zone 6	**Comments**
Target: 14% Range: [12% - 20%]	Target is based on lowest first cost/operating cost from DEED BEM Study July 2019, and Follow-up Study June 2022. Ranges are calculated +/- 20% costs of target.

Zone 7	**Comments**
Target: 13% Range: [11% - 18%]	Target is based on lowest first cost/operating cost from DEED BEM Study July 2019, and Follow-up Study June 2022. Ranges are calculated +/- 20% costs of target.

Zone 8	**Comments**
Target: 9% Range: [8% - 14%]	Target is based on lowest first cost/operating cost from DEED BEM Study July 2019, and follow-up Study June 2022. Ranges are calculated +/- 20% costs of target.

Zone 9	**Comments**
Target: 8.5% Range: [6% - 11%]	DEED BEM Study July 2019, and Follow-up Study June 2022, showed no lower boundary for O:EW cost savings (i.e., less openings always saved money). Target is set at 15% below Zone 8. Ranges are calculated +/- 20% of target except that lower boundary is a fixed 6% to reflect the importance of visual access to the exterior on teaching and learning.

Guidance

In applying the ratio to school design and construction, designers and DEED reviewers are encouraged give consideration to the following items.

- Distribution and sizes of openings versus concentration
- Ability to incorporate daylighting elements
- Window placement for visual access to the exterior in student and staff performance
- Variation in local climate (local average heating degree difference from zone, local average wind speed variance from zone, local average precipitation (overcast) from zone, etc.)

References

Building Energy Modeling Services: Final Report Prepared for DEED, July 2019, HMS Inc. and Coffman Engineers, Inc., Alaska Department of Education & Early Development.

Building Energy Modeling Services-Follow Up Study: Final Report Prepared for DEED. June 2022. Coffman Engineers, Inc. and HMS Inc. Alaska Department of Education & Early Development.

Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance, August 1999, Heshong Mehone Group, © 1999 by Pacific Gas and Electric Company.

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Building Volume to Gross Floor Area School Construction Standard DEED RECOMMENDATION

Ratio Definition

Building Volume to Gross Floor Area (V:GSF).

Building Volume is defined as: All conditioned cubic square footage within a building vapor retarder or elements acting as a vapor retarder at the exterior wall, roof or soffit.

Gross Square Footage is defined by DEED 4 AAC 31.020 (e).

Calculation Clarifications

1) Square Footage calculation is intended to capture all normally occupied and conditioned square footage.
2) Does not included crawl spaces or area accessible only for building utility system distribution
3) Based on allowable area calculation requirements

Regional V:GSF Ratio

Zone 6 ,7, 8 and 9	**Comments**
Target: 22.5 Range: 20 – 23.5	Target is based on optimal *life cycle costs* identified as approx. 22.5% in the "Building Energy Modeling Services Report, June 2022" and follow-up Study June 2022. *Life Cycle costs track consistently across* each region, allowing one *overall* ratio recommendation..

Guidance

In applying the ratio to school design and construction, designers and DEED reviewers are encouraged give consideration to the following items.

- Building compactness should be a goal in a heating climate with two story options considered as overall square footage allows.
- Within the modeling services report, increases in "commons" or "multipurpose" areas height showed increases in energy use and should be reviewed to confirm appropriateness in relation to overall building form, (i.e. roof design, snow drifting or other influences.)

References

Building Energy Modeling Services: Final Report Prepared for DEED. July 2019. HMS Inc. and Coffman Engineers, Inc. Alaska Department of Education & Early Development.

Building Energy Modeling Services-Follow Up Study: Final Report Prepared for DEED. June 2022. Coffman Engineers, Inc. and HMS Inc. Alaska Department of Education & Early Development.

A compactness measure of sustainable building forms. June 12, 2019. D'Amico, Bernardino and Pomponi, Francesco. The Royal Society Publishing. royalsocietypublishing.org/doi/10.1098/rsos.181265 (accessed 11/19/2020).

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Building Volume to Exterior Surface Area School Construction Standard DEED RECOMMENDATION

Ratio Definition

Building Volume to Exterior Surface Area (V:ES).

Building Volume is defined as: all conditioned cubic square footage within a building vapor retarder or elements acting as a vapor retarder at the exterior wall, roof or soffit.

Exterior Surface Area is defined as: the square footage of wall, roof, or underbuilding soffit system at the line of the exterior air barrier or outward most element acting as an air barrier surrounding conditioned space.

Calculation Clarifications

1) Buildings with a combination of the design variations will need to account for each corresponding section of the building and use a combined ratio.

Regional V:ES Ratio

Baseline Design (Slab)	**Comments**
Target: 8.5 Range: 8 - 10	Target is based on optimal *life cycle costs* identified as approx. 8.5 in the "Building Energy Modeling Services Report, July 2019", and follow-up Study June 2022.

Elevated Floor Design	**Comments**
Target: 6.5 Range: 6 - 8.5	Target is based on optimal *life cycle costs* identified as approx. 6.5 in the "Building Energy Modeling Services Report, July 2019", and follow-up Study June 2022.

Two Story Design	**Comments**
Target: 8.5 Range: 8 - 9.5	Target is based on optimal *life cycle costs* identified as approx. 8.5 in the "Building Energy Modeling Services Report, July 2019", and follow-up Study June 2022.

Guidance

In applying the ratio to school design and construction, designers and DEED reviewers are encouraged give consideration to the following items.

- TBD

References

Building Energy Modeling Services: Final Report Prepared for DEED. July 2019. HMS Inc. and Coffman Engineers, Inc. Alaska Department of Education & Early Development.

Building Energy Modeling Services-Follow Up Study: Final Report Prepared for DEED. June 2022. Coffman Engineers, Inc. and HMS Inc. Alaska Department of Education & Early Development.