



8th Nordic Conference on Construction Economics and Organization

# A novel approach on assessing Daylight access in Schools

Leif D. Houck\*

*Norwegian University of Life Sciences, 1432 Ås, Norway*

---

## Abstract

Until recently, architects have designed school buildings with the aim of providing optimal conditions in the classrooms. But contemporary focus on environmental issues and energy saving has led to more compact school buildings, where the teaching rooms afford little access to daylight, and where much of the space designed for teaching lacks windows to the outside. This paper explores the use of the value (FMC, i.e.) façade meters per class spent on classrooms, group study rooms and other main teaching rooms directly attached to these teaching areas. It also shows how this value can reveal key information about a design's daylight accessibility and a project's potential to accommodate future change of layout.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Selection and/ peer-review under responsibility of Tampere University of Technology, Department of Civil Engineering

*Keywords:* School building, compact, daylight, evaluation, architecture competition

---

## 1. Energy friendly schools vs daylight

### 1.1. Introduction

Recent focus on creating more environmental and sustainable buildings has resulted in compact building types. *Traditionally, the design* of schools has focused on the distribution of daylight (Wu & Ng, 2003). Well documented studies have shown that daylight has a significant impact on human productivity (Heschong, Wright, & Okura, 2002; Nicklas & Bailey, 1997), health (Bakke & Nersveen, 2013; Dumont & Beaulieu, 2007; Küller, Ballal, Laike, Mikellides, & Tonello, 2006; Küller & Lindsten, 1992; Roennenberg, Allebrandt, Merrow, & Vetter, 2012) and behavior (Shemirani, Memarian, Naseri, Nejad, & Vaziri, 2011).

\* Corresponding author. Tel: +47 67 23 00 00  
E-mail address: [leifho@nmbu.no](mailto:leifho@nmbu.no)

The nature of a compact building is to minimize the building envelope, which again means that daylight becomes a scarce resource. It has been wide common knowledge to architects that useful daylight can hardly reach further than 7-8 meters into a room under normal conditions (Büning, 1948; Cold, 1980). Although school competition juries commonly assess several different building aspects (Rönn, 2011; Svensson, 2009; Volker, 2010), a recent study on architectural school competitions showed that the juries in most cases simply chose the projects providing the deepest and narrowest classrooms as the winners (Houck, 2013). Half of the winning entries in the investigated competitions spent as little as 6.4 façade meters or lower per class on classroom, group room and other main teaching areas (fig 2). When investigating the competition criteria and the competition briefs, the findings showed that the clients in most cases emphasized daylight and sustainable qualities, whereas the design teams emphasized creating compact buildings at the expense of daylight qualities (Houck, 2014). The juries often quantified the compactness of the different projects, compared the window area to the gross area, and judged the most compact ones and the ones with least window area as the most sustainable. Daylight qualities however, were never quantified. In two specific cases where the juries chose the project with the worst daylight capacity, they also commented that the daylight conditions should be improved in the further development of the design. However, these two projects have now since been completed, and both projects showing dramatically less daylight than in their competition designs.

Data from the research in 2013 on winners and losers in architecture school competitions reveal that the average façade meters spent on classrooms, group study rooms and other main teaching areas per class was 9.4 for the losing projects and 7.6 for the winning projects ones. Five winning projects had a lower FMC value than 6.4. The lowest value measured was 5.5 meters (a winner project), while the highest was 13.7 meters (a losing project).

In the hunt for compactness, one technique is also to reduce the size of the classroom, and spend the saved square meters on common teaching rooms without daylight (fig 2b). Small classrooms are known to have disadvantages, especially for smaller children (Ladegård, 1973).

Today, the most common method applied for quantifying daylight is to calculate the daylight factor (BREEAM Education, 2010; Department of the Environment, 1996; Groot, Zonnenveldt, & Paule, 2003). This requires software, expertise and decisions about details that are not adequate in an early design stage. The juries do not pick winners based upon a project's window size, the reflectance value of interior walls, or the light transmission values of the glass. When picking a winner, a project's organization will overrule a project's position, size and location of windows. As the documentation of daylight might be even more complicated to calculate in the future (Reinhart, Mardaljevic, & Rogers, 2006), there is a need for simpler methods at an early design stage.

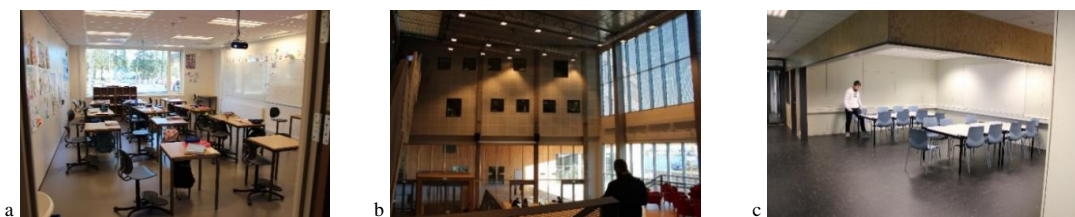


Fig. 1. Haukerød School, Sandefjord; (a); Deep and narrow classroom; Færder College, Tønsberg; (b) Group study rooms and teaching areas receiving poor daylight through windows inside the main hall; (c) Common teaching area without daylight

## 1.2. Research question

In the architectural competition field, a key question is how to secure sufficient daylight in future competitions, and how to evaluate the entries in the simplest way. This paper investigates different school layouts in relation to their *value of façade meters per classroom, group study room and teaching areas related to the main teaching activities per class* (FMC, i.e.). In this research, the value will also be referred to as façade meter per class, or FMC. The paper seeks to answer the following:

- 1) What FMC values will secure the possibility for good daylight conditions, and at the same time meet the need for compact energy efficient schools?
- 2) Could FMC be used efficiently to document and evaluate possible daylight qualities in architecture competitions?
- 3) Which school building properties could be linked to different values of FMC?

## 2. Method

The literature study has focused on daylight and architectural competition theory and is a result of both targeted searches and a more continuous collection over the last four years. The articles mentioned in this paper are only a segment of the collected papers, books, legislations, standards and so on. The first data set below is the result of a collection over several years, where the Norwegian Architects Association's list of architecture competitions has been studied and clients have been asked to send drawings. Other data sets have been achieved through commissions for the client (dataset 2 and 3), and the last data set has been collected through the Norwegian Architectural Review.

### 2.1. The collection of data

To answer the research questions, we will look at different school layouts, their characteristics and measure their FMC. We have looked into 4 sets of data:

- 1) Winning and losing school competition projects: The largest available databank of recent Norwegian school plans is from the research mentioned above (Houck 2013), where the FMCs are known, but we will investigate the characteristics of the plan layouts of the winners. The research was based on 10 school competitions from the year 2009 to 2011, with a total of 44 entries. Several of these competition programs express the wish for good daylight conditions, but there are no measurable requirements.
- 2) The Rykkinn competition: In 2014 I was asked to participate in the development of assessment criteria for a school competition in Rykkinn. The client both wanted a passive house project and good daylight conditions. This gave an opportunity not only to express the stated preferences for daylight in the competition program, but also specific measurable requirements. The Rykkinn competition was held from November 2013 to February 2014 and was a DBFO (design, build, finance and operate competition) with negotiations. In this research we will investigate how many meters of façade per class are proved necessary in order to fulfill the above daylight requirements.
- 3) Recent Oslo school: As the Oslo Department of Education showed interest in possible ways to secure sufficient daylight in future projects, we discussed the possibility of using the value façade meters per class. Four recent Oslo schools were analyzed. The FMC values were compared to the qualities of the school layouts in terms of the amount of daylight that they provided.

4) Reference projects: Several schools well known in Norway, were analyzed. The FMC values of four of them will be presented in this paper as a comparison to the school projects above. The purpose of this is to link the FMC value to well known plan layouts.

## 2.2. The FMC value - definition

The FMC value was developed in the earlier research mentioned above (Houck, 2013) and was defined as the *façade meters spent on classroom, group study room and teaching areas related to the main teaching activities – divided on the number of school classes the respective school was dimensioned for*. We are interested in measuring the façade meters that can be distributed into various rooms and provide daylight. Therefore, the first 8 meters around a corner are not counted, as this would only provide the possibility for daylight in a room where we have already measured an outer wall. See figure 2a.



Fig. 2. Example: Marienlyst School, Drammen (a); Measuring façade meters per class, blue lines are counted, while red lines are not counted. The average FMC for this school was measured to be 9.4 m (168.6 façade meters/18 classes). (b); This illustration demonstrates the amount of teaching area without direct daylight access. Teaching rooms with daylight are colored green, while teaching rooms without daylight are colored red. c) The Rykkinn competition; winner project

## 3. Results

### 3.1. Winning and losing school competition projects

The majority of the winners in investigated competitions were found to have the following common characteristics:

- Deep and narrow classrooms
- No group study rooms with daylight
- No other common teaching areas with daylight
- Reduced possibilities to develop the original design
- Reduced possibilities to change the plan layout in the future
- Reduced possibilities to integrate more pupils than what the school was originally planned for
- Reduced footprint compared to the other competitors
- Short internal distances

Also the average spread between the project with the highest and lowest FMC was calculated to 3.9 m.

### 3.2. The Rykkinn school competition

Regarding the prime teaching areas, the competition program required the following:

- Classrooms should be approximately square (to prevent deep and narrow class rooms)
- At least 50% of the group study rooms should have daylight

- The minimum average daylight factor in the teaching rooms should be 2.5% or better
- Daylight calculations for typical rooms
- Each teaching level should have 3 classrooms and 2 group study rooms in direct contact with a common teaching area. This common area should have daylight, and should allow the option of conversion into a classroom if necessary sometime in the future

After measuring the meters of façade per class for the new school in Rykkinn, we arrived at the following results:

Competitor	Meters of façade per class FMC	Energy Consumption NS3031	Fulfills NS 3701 (Passive house standard)
1	13.4	62 kWh/m <sup>2</sup> /a	Yes
2	12.3	65.8 kWh/m <sup>2</sup> /a	Yes
3 (winner, see fig. 2 c)	12.0	68.4 kWh/m <sup>2</sup> /a	Not documented
4	12.9	67.8 kWh/m <sup>2</sup> /a	Yes

Table 1. Meters of façade per class for a school in Rykkinn

The table shows that the competitors spend between 12.0 and 13.4 meters of façade per class. These values are far beyond the previous investigated competition entries from the research in 2013. At the same time, three out of four competitors document their project's ability to meet the requirements in the *NS 3701 Criteria for passive houses and low energy buildings, non-residential buildings*.

### 3.3. Recent Oslo schools

The results from the measuring of newly built, or soon to be built, Oslo schools were as follows:

School	FMC	Year	Comments/plan lay out characteristics
Gran (passive house)	8.1	Under construction 2014	Local common areas without daylight (90 m <sup>2</sup> ), 3 group study rooms with daylight (73 m <sup>2</sup> ) and 6 without daylight (180 m <sup>2</sup> ). A total of 18 classrooms (59.4 m <sup>2</sup> -62.4 m <sup>2</sup> ). Compact plan layout.
Teglverkstomta (passive house)	8.9	Under construction 2014	4 out of 9 group study rooms with daylight. Classrooms 7.5 m x 8.6 m. Deep and narrow classrooms when split in two with folding wall; 3.25 m x 8.6 m. Central glass roof providing daylight into the core of the building. Compact plan layout.
Bjørnsletta (passive house)	10.3	Completed 2014	8 of 24 group study rooms with daylight. 8 deep and narrow classrooms, 13 square classrooms, 7 traditional classrooms (windows on the long side). Plan layout; 3 classroom pavilions placed upon a compact ground floor.
Tokerud (passive house)	9.6	Under construction 2014	Long and narrow building shape; 98.2 m x 21.3 m. 12 classrooms 7.1 m (window side) x 8.5 m. 3 out of 6 group study rooms with daylight. Local common areas with daylight.

Table 2. Meters of façade per class for different various new Oslo schools

It should also be mentioned, that in the evaluation of the Gran competition, the FMC values were measured and successfully used to give a score on the different projects' daylight properties.

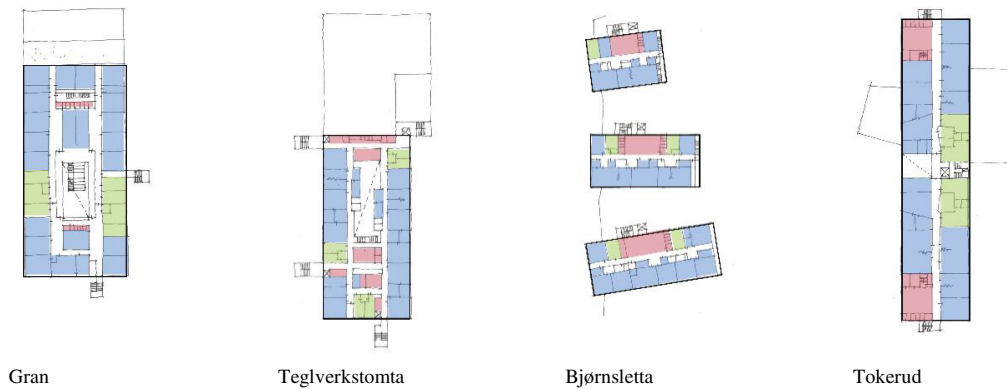


Fig. 3. Recent Oslo schools – typical plans. Blue: Classrooms/group study rooms, Green: Teacher offices, Red: Wardrobes

### 3.4. Reference projects

Several published Norwegian schools were analysed. Four projects are presented in the table 3: Gulslogen School was published in the *The Norwegian Review of Architecture* (1/2002); it was carried out for the municipality of Drammen and saw its completion in the year 2001. Marienlyst School was planned for the same client, completed in the year 2009 and was also published in *The Norwegian Review of Architecture* (6/2010), together with Mæla School. Storøya School was one of the first schools published in the Ecobox data base, a Norwegian data base for sustainable, environmentally friendly model buildings.

School	FMC	Completion	Comments/plan lay out characteristics
Gulslogen	13.2	2001	18 group study rooms with daylight, 12 group study rooms with daylight. Local common areas with daylight. Finger plan layout.
Mæla	12.2	2007	Open plan layout, daylight on two sides. Part of the project executed as passive house. Semi-transparent outer walls. Finger plan layout.
Marienlyst	9.4	2009	Norway's first passive house school. Compact plan layout with extensive teaching areas without daylight in the core. 18 classrooms. Additionally 6 teaching rooms without daylight, 3 group study rooms without daylight, 2 group study rooms with daylight. Compact plan.
Storøya	6.8	2008	Open plan layout, 12 m deep. Daylight on one side. 7 group study rooms with daylight, 7 without. Compact, oblong plan layout.

Table 3. Meters of façade per class for selected Norwegian schools

## 4. Discussion

In a building's early programmatic or competition stage, it is mostly of little relevance to discuss details pertaining to the size, shape and light transmission of a project's windows. Daylight simulation is not an adequate tool for comparing the daylight potential of different concept designs and footprints. What turned out to be useful was the measuring of key values, such as room depths, ceiling heights, and a critical view on rooms and areas without daylight. Most interesting was the measuring of facade meters. In this case the facade meters dedicated to each school class on classrooms, group study rooms and other rooms related to the prime teaching area, turned out to be a most relevant parameter - not only in comparing different school designs, but also in the discussion of the different concepts' capacities.

The study shows, that there is no contradiction in designing non-compact school buildings with good daylight conditions, while at the same time meeting the need for low energy buildings. The Rykkinn competition shows that the value façade meters per class at least can be as high as 13.4 meters, while still allowing the project to meet the passive house requirements.

In the projects with the lowest FMC values, there seem to be a trend to define spaces where the legislation does not demand daylight. Additionally there seems to be a strategy in the early programmatic phase to “steal” some area from each classroom and spend it on more rooms for common use. However these common rooms are often devoid of daylight. The client should reflect upon the following: The more such rooms for common use are expected to be extensively occupied, the more the importance of daylight. And the less such rooms for common use are left unused, they should be considered a less worthwhile investment. As long as pupils and teachers prefer to stay in rooms with daylight, the practice of squeezing classrooms down to a mere 60 square meters in order to “finance” common teaching areas without daylight remains questionable.

A school is always designed for a specific number of pupils, but most schools will experience periods with a higher number of pupils than what the design was originally planned for. For this reason, the client should consider a project’s potential to accommodate a higher number of pupils. First of all there will be a need for rooms with daylight.

Based on the described research, table 4 shows a schematic relationship between a school project’s FMC and the project’s daylight capacity.

Façade meters per class FMC	Typical predictable project characteristics
5.5-6.5	Only daylight for classrooms. No daylight in any group study rooms or other common teaching areas. Deep and narrow classrooms. Hardly room for future change of plan layout.
7-9.5	Daylight in classrooms and up to half of the group study rooms. For lower values: either deep and narrow classrooms, or no group study rooms with daylight.
10-12.5	Daylight in classrooms, daylight in at least half of the group study rooms, daylight in some other common teaching areas
13-	High degree of freedom with concern to daylight distribution into most, or all classrooms, group study rooms and common teaching areas

Table 4. Schematic relationship between a school project’s façade meters per class and the project’s daylight capacity

## 5. Conclusion

The Rykkinn competition shows that even projects with FMC values up to 13.4 m can fulfill the passive house standard. This value is sufficient to give a high degree of daylight access. Additionally the case shows how measurable daylight requirements make the competitors compete much more targeted. The spread in FMC is only 1.4 m compared to the average value of 3.9 in the competitions without measurable measurable daylight requirements. Based on the results in the investigated cases, the parameter façade meters per class spent on prime teaching area has the following advantages:

- The FMC parameter reveals a design's key abilities in an early design stage. Additionally, the parameter helps to compare different designs, and tells the client about the design’s daylight abilities for both the proposed plan as well as the project’s capability to adopt future changes (table 4)
- Facilitates quick and easy measurement, both in the early stages and after completion
- The parameter reveals a design's key abilities concerning daylight
- Makes different projects comparable in a quantified way
- Tells the client about a project’s daylight ability without complicated daylight simulations
- Tells the client about a project’s flexibility for future changes

The FMC method is a rough measure, but the advantages are considered to outweigh the disadvantages connected to FMC. Additionally, more accurate methods are often both inadequate and not possible in an early design stage.

## References

- Bakke, J. W., & Nersveen, J. (2013). Ikke glem dagslys og utsyn. *Helserådet*, 21(12/13), 8-11.
- BREEAM Education. (2010). *breeam, Scheme Document SD 5051*: BRE Global Ltd.
- Büning, W. (1948). *Die neue Bauanatomie, Einführung in den Wohnbau*. Berlin: Gebr. Mann Verlag.
- Cold, B. (1980). *Et bedre skolemiljø*. Trondheim: Tapir.
- Department of the Environment, T. a. t. R. (1996). *Desktop guide to daylighting - for architects*.
- Dumont, M., & Beaulieu, C. (2007). Light exposure in the natural environment: Relevance to mood and sleep disorders. *Sleep Medicine*, 8, 557-565.
- Groot, E. d., Zonnenveldt, L., & Paule, B. (2003). *DIAL Europe: A decision support tool for early lighting design*. Paper presented at the Eighth International IBPSA Conference, Eindhoven, Netherlands.
- Heschong, L., Wright, R. L., & Okura, S. (2002). Daylight impact on Human Performance in School. *Journal of the Illuminating Engineering Society*(Summer), 12.
- Houck, L. D. (2013). Daylight in schools? *Arkitektur N*, 95(2), 16-25.
- Houck, L. D. (2014). *Are clients, architects and juries becoming environmental?* Paper presented at the 5th International Conference on Competitions 2014, Delft.
- Küller, R., Ballal, S., Laike, T., Mikellides, B., & Tonello, G. (2006). The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments. *Ergonomics in Design*, 49(14), 1496-1507.
- Küller, R., & Lindsten, C. (1992). Health and behaviour of children in classrooms with and without windows. *Journal of Environmental Psychology*, 12, 305-317.
- Ladegård, I., Bjørnland, I., Haugeland, K., Odden, H. M., Vonheim, A., Tobiassen, B., Hongset, H. (1973). Norsk Lærerlags skolebyggkomite om skoleutbygging og utforming av skoleanlegg. *Vår skole* 59(6).
- Nicklas, M. H., & Bailey, G. B. (1997). *Analysis of Performance of Students in of Daylit Schools*. Paper presented at the Annual Conference, American Solar Energy Society.
- Reinhart, C. R., Mardaljevic, J., & Rogers, Z. (2006). Dynamic Daylight Performance Metrics for Sustainable Building Design. *LEUKOS*, 3(1), 25.
- Roennenberg, T., Allebrandt, K. V., Merrow, M., & Vetter, C. (2012). Social Jetlag and Obesity. *Current Biology*, 22, 939-943.
- Rönn, M. (2011). Architectural quality in competitions. *Form Akademisk*, 4(1), 15.
- Shemirani, S. M. M., Memarian, G. H., Naseri, S. P., Nejad, H. H., & Vaziri, V. (2011). Investigating the Behaviors of the Elementary School Students in Reference to Factors Associated with Daylight. *Asian Social Science*, 7(3), 11.
- Svensson, C. (2009). Speaking of Architecture - A study of the jury's assessment in an invited competition. *Nordic Journal of Architectural Research*, 21(2/3).
- Volker, L. (2010). *Deciding about Design Quality Value judgements and decision making in the selection of architects by public clients under European tendering regulations* (pp. 323).
- Wu, W., & Ng, E. (2003). A review of the development of daylighting in schools. *Lighting Res. Technol.*, 35(2), 111-125.