Norwegian Passive House standard for non-residential buildings is less ambitious than previous criteria and completed projects

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SUMMARY

This paper provides an analysis of the Norwegian Passive House standard for non-residential buildings, including a comparison with preliminary Norwegian criteria for non-residential Passive Houses, as well as comparisons with built Norwegian projects, with the standard for residential buildings and with criteria according to the Passive House Institute. Also a rough calculation of a model building, using the Passive House Planning Package, is conducted. The results show that new non-residential Passive Houses can be built with significantly higher space heating demand than it was accepted within the preliminary criteria and also with inferior energy performance than many already built projects. Moreover, the standard cannot assure a comfort and energy efficiency level that normally would be expected in Passive Houses.

KEYWORDS

Norwegian Standard NS 3701, Passive House criteria, Non-residential buildings, Weak requirements, Step backwards

INTRODUCTION

In 2009 it was published a study with preliminary criteria for Norwegian non-residential Passive Houses and low-energy buildings, SINTEF Byggforsk project report 42. The criteria in Dokka et al. (2009) were used in subsidy schemes and were also the basis for a number of pilot projects for Passive House schools, kindergartens and office buildings. In fall 2012, it was launched a Norwegian Passive House and low-energy standard for non-residential buildings, NS 3701. Standards Norway (2012) does not only differ significantly from criteria used by Passive House Institute (PHI), but in most building categories it also allows higher heating demand than criteria from 2009. Thus, new Norwegian non-residential Passive Houses can be built with inferior energy performance than many already built projects. This paradoxical result was never discussed in greater forums, and the standard was hardly discussed at all after launch. Therefore, the objective of the paper is to raise challenges and the obvious lack of ambition up for discussion.

The article will show that the Norwegian Passive House standard for non-residential buildings

- cannot ensure a comfort and energy efficiency level that normally would be expected of Passive Houses,
- features unnecessarily a low level of ambition and
- is a step backwards compared with previous criteria, in relation to built projects and also in relation to the Norwegian Passive House standard for residential buildings.

METHODS

In addition to the standard itself and the above-mentioned 2009 report, the study is mainly based on an examination of the underlying material in connection with the public hearing of the standard, SINTEF Byggforsk project report 99 (Dokka, 2012), as well as own analyses and comparisons to criteria used by PHI, including a rough calculation of a model building, using the Passive House Planning Package, PHPP (PHI, 2012). The study builds also on previous results from a comparative analysis of Norwegian and PHI non-residential Passive House criteria, provided at the Passivhus Norden Conference 2013. However, the present study will concentrate on main criteria and distinctions and refers to Anton and Vestergaard (2013) concerning further details, as well as to Lexow and Dokka (2012) concerning a general description of the Norwegian standard NS 3701. Furthermore, the paper will focus on Passive Houses; criteria regarding low-energy buildings will not be discussed.

RESULTS

Project report 42: Non-residential Passive House criteria 2009

Dokka et al. (2009) provided preliminary criteria for non-residential Passive Houses, which so were used by the Norwegian energy agency Enova within its subsidy schemes for energy efficient example projects. The authors emphasised the preliminary character of the criteria set, which should be evaluated in the light of experience acquired in realised non-residential projects.

In accordance with energy requirements in the building regulations, overall criteria were related to 11 different non-residential building categories, as there are kindergartens, office buildings, hospitals and so on. The main criterion was net space heating demand (expressed as useful energy) with a maximum of respectively 15 kWh/m²a (office buildings, schools, universities and nursing homes), 20 kWh/m²a (hospitals, hotels and commercial buildings[1]) and 25 kWh/m²a (kindergartens, sports facilities, cultural buildings and factories/workshops). In addition, there were suggested overall requirements on cooling demand, thermal losses and CO_2 emissions. Furthermore, the report stated general minimum requirements for all categories, namely maximum U-values, minimum ventilation efficiency[2], air tightness and heat recovery as well as a maximum "normalised thermal bridge value" (which means the total of all thermal bridge values in a building, related to its heated floor area).

The underlying calculations and analyses were based on Oslo climate with an annual mean temperature of 6.3 °C. The suggested requirements were considered to be realistic for new non-residential buildings within these climatic conditions. In fact, approximately 70 – 75 percent of the Norwegian building stock is situated in areas with mean temperatures just as Oslo, or warmer. Concerning the remaining 25 – 30 % in colder areas, it was considered to be hard to fulfil the main criterion on space heating demand, taking into account current technical solutions, their availability and costs. Providing a practical solution for subsidy schemes, it was recommended to state an adapted requirement: Buildings erected in areas with annual mean temperature below 6.3 °C should fulfil identical criteria, yet calculated by using Oslo climate data. Nonetheless, the building itself had to be designed according to local climate. Finally, the authors expressed their expectation that further development of advanced technology would make it possible to build Passive Houses in colder areas than at the present time (in 2009).

NS 3701: Non-residential Passive House criteria 2012

Standards Norway (2012) covers a comprehensive standard for non-residential Passive Houses, building on the work done for Dokka et al. (2009), but with some significant modifications. The main changes are related to space heating, but there are also some minor modifications connected to other criteria. All in all, the criteria set has been much more complicated and minor ambitious, but some parts are also somewhat easier to handle.

Space heating demand

The "basic" maximum net space heating demand is the same as stated in Dokka (2009) concerning kindergartens, hospitals, cultural buildings and factories/workshops. Sports facilities have to meet stricter requirements. For all the other building categories apply less stringent requirements (office buildings, schools, universities, nursing homes, hotels and commercial buildings). These "basic" space heating maxima apply buildings with at least 1000 m² heated floor area, erected in areas with an annual mean temperature of 6.3 °C or more. Smaller buildings may have higher space heating demand, and also buildings in colder areas may have higher space heating demands. Aiming to allow higher space heating demand for smaller buildings and buildings in colder areas, there are introduced adjustments for climate and adjustments for heated floor area. For buildings which are *both* smaller than 1000 m² *and* located in colder climate, both corrections apply. This results in complex equations which have to be used to find out the maximum acceptable net space heating demand for the present

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[1] Shops and shopping centres, not offices.

[2] SFP factor

building within a given category and located in a region with a specific annual mean temperature. The equations are presented in Table 1, and the coefficients to be used in these equations are shown in Table 2.

Table 1: Maximum acceptable specific net space heating demand (useful energy, kWh/m²a), corresponding to the building's heated floor area (A_{fl}) and annual mean temperature (θ_{ym}) on the building site. $EP_{H,0}$ is the basic specific net space heating demand, X is an area coefficient and K_1, K_2 are climate coefficients. The applicable numbers for $EP_{H,0}$ and the coefficients are given in Table 2. Source: NS 3701, Standards Norway (2012).

Årsmiddel-temperatur, θ_{ym}	Høyeste beregnede netto spesifikt energibehov til oppvarming kWh/(m²·år)	
	Bygning der $A_{fl} < 1\,000$ m²	Bygning der $A_{fl} \geq 1\,000$ m²
≥ 6,3 °C	$EP_{H,0} + X\frac{(1\,000 - A_{fl})}{100}$	$EP_{H,0}$
< 6,3 °C	$EP_{H,0} + X\frac{(1\,000 - A_{fl})}{100} + \left(K_1 + K_2\frac{(1\,000 - A_{fl})}{100}\right)(6{,}3 - \theta_{ym})$	$EP_{H,0} + K_1\,(6{,}3 - \theta_{ym})$

Table 2: Numbers for basic specific net space heating demand ($EP_{H,0}$) and coefficients used for calculation of maximum acceptable specific net space heating demand, related to the different building categories in the first column. The categories are as follows: kindergartens, office buildings, schools, university buildings, hospitals, nursing homes, sports facilities, commercial buildings, cultural buildings and factories/workshops. The section on the right-hand side applies to low-energy buildings. For further explanatory notes, see Table 1 above.

Bygningskategori	Passivhus				Lavenergibygning			
	$EP_{H,0}$	X	K_1	K_2	$EP_{H,0}$	X	K_1	K_2
Barnehage	25	1,55	3,6	0,15	40	2,2	4,8	0,15
Kontorbygning	20	0,85	3,6	0,10	35	1,3	4,9	0,13
Skolebygning	20	1,30	3,5	0,15	30	1,7	4,1	0,22
Universitets- og høgskolebygning	20	1,50	3,7	0,10	35	2,0	4,7	0,10
Sykehus	20	1,30	4,7	0,15	35	1,9	6,0	0,10
Sykehjem	20	1,20	4,3	0,12	30	1,6	5,0	0,15
Hotellbygning	25	1,40	4,0	0,10	40	1,8	4,8	0,03
Idrettsbygning	20	0,80	3,8	0,10	35	0,8	5,1	0,10
Forretningsbygning	25	1,40	4,6	0,12	40	1,9	5,7	0,11
Kulturbygning	25	1,30	3,5	0,11	40	1,8	4,6	0,08
Lett industribygning, verksted	25	1,70	3,8	0,15	40	2,3	5,0	0,15

As an input to the discussions within the Standard committee, while preparing the prestandard, Dokka (2012) calculated requirements for the different building categories, based on simulation of presumed representative building models. The models are the same for all categories – apart from sports facilities and factories/workshops – and take a two story building with heated floor area of 1000 m² as a starting point. In addition, there were simulated building models of respectively 600, 300 and 150 m². The 1000 m² building model is shown in Figure 1.For each of the categories, there was used a specific set of component values for building envelope, ventilation and so on, assumed as typical and realistic.

An example for office buildings is shown in Table 3.Calculations were conducted for Oslo climate with an annual mean temperature of + 6.3 °C as a basis and then for Stavanger (+ 8.4 °C), Mo i Rana (+ 3,4 °C), Røros (+ 1,0 °C) and Karasjok (- 2,5 °C). The results for office buildings are given in Table 4.

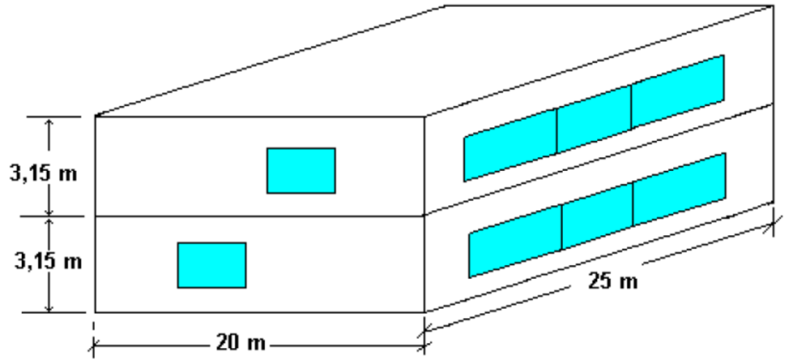

Figure 1: Model for a building with 1000 m² heated floor area, interior measures 20 m * 25 m, south facing main facade, 80 m² windows towards north and south (symmetric) and 20 m² towards west and east. The model is used for all categories, except sports facilities and factories/workshops (still, despite modifications, total heated area is the same also for these categories). Source: Dokka (2012).

Table 3: Specific input data for office building simulations (from top to bottom): U-values for exterior walls, slab on ground (equivalent, including thermal resistance of the soil), roof, windows and doors; efficiency of heat recovery. Source: Dokka (2012).

Inndata	Verdi
U-verdi yttervegg	0,12 W/m²K
U-verdi gulv (på grunnen)	0,08 W/m²K
U-verdi yttertak	0,09 W/m²K
U-verdi vinduer og dører	0,80 W/m²K
Virkingsgrad gjenvinner	82 %

Table 4: Calculated net space heating demand [kWh/m²a] for office building models with different heated area and different locations. Source: Dokka (2012).

Størrelse/Sted	Stavanger	Oslo	Mo i Rana	Røros	Karasjok
1000 m² BRA	10,1	19,9	28,1	34,5	50,8
600 m² BRA	11,0	20,6	29,4	36,2	53,2
300 m² BRA	13,7	24,3	34,1	41,7	60,2
150 m² BRA	16,6	27,8	39,1	47,8	67,9

In the case of office buildings, the calculation results in Table 4 show that the 1000 m² model, built in Stavanger, easily could fulfil a sharpened requirement of 10 kWh/m²a. Also smaller buildings in Stavanger could meet the preliminary 2009 requirements of 15 kWh/m²a. Nonetheless, according to the current standard, in warmer regions it would be sufficient to reach the less stringent "basic" target for Oslo-climate. The standard equations in Table 1 would give results close to these model calculations shown in Table 4.

Cooling demand

While the 2009 preliminary criteria stated maximum net cooling demand requirements of respectively 0, 10 or 20 kWh/m² – only depending on the building category – , NS 3701 allows maximum net cooling demand depending on both building category and local design summer temperature, calculated according to the equation shown in Table 5. The cooling demand coefficient β to be used in the equation depends on the building category and differs as follows: kindergartens and schools 0.75, office buildings 1.4, university buildings and hotels 1.5, hospitals 2.9, nursing homes 1.6, sports facilities 0.9, commercial buildings 3.3, cultural buildings 1.2 and factories/workshops 1.1.

Own calculations for the present paper show that hospitals and commercial buildings could have a cooling demand of respectively 19.4 and 22.1 kWh/m²a in Oslo, which has the highest design summer temperature within the locations calculated in Dokka (2012). Buildings within all other categories would have a limit of 5 – 10.7 kWh/m²a in Oslo, and even lower in other locations.

Table 5: Maximum acceptable specific net cooling demand (useful energy, kWh/m²a), corresponding to design summer temperature DUT_s on the building site. β is a cooling demand coefficient, depending on the different building categories. For applicable numbers, see body text. Source: NS 3701, Standards Norway (2012).

DUT_s	Høyeste beregnede netto spesifikt energibehov til kjøling kWh/(m²·år)
> 20 °C	$\beta\,(DUT_s - 20)$
≤ 20 °C	0

According to the NS 3701 calculation method, most of the resulting limits are situated between 1 and 5 kWh/m²a for all categories and all locations. There are small differences between categories, for example in Tromsø 1.1 for schools, 2.1 for office buildings, 2.3 for university buildings, 2.4 for nursing homes and 4.4 for hospitals. Similarly, the distinctions between locations are often very small, i.e. for office buildings 2.1 in Tromsø, 2.9 in Bodø, 4.5 in Stavanger, 5.6 in Mo i Rana, 5.7 in Karasjok, 8.1 in Rygge and 9.4 in Oslo.

General minimum requirements

After the public hearing of the standard, inter alia, the general minimum requirements for all categories were somewhat simplified, and there are no longer specified maximum U-values for walls, roofs and slab on ground/basement floor. Requirements on maximum U-value for windows and doors, minimum ventilation efficiency, air tightness and heat recovery as well as a maximum "normalised thermal bridge value" are kept, and in addition it is introduced a particular requirement on lighting efficiency.

The maximum U-value for windows and doors – 0.80 W(m²K) – is defined as an average value for all windows and doors within the building envelope[3]. Individual windows or doors may perform worse, but the average of all has to fulfil the obligation. From this it follows that comfort requests regarding a particular window cannot be guaranteed. On the other hand, it will not be possible to compensate a somewhat higher U-value for windows by better solutions for walls or the roof, even if comfort requests are achieved by placing a parapet under a window with U-value 0.9.

As mentioned before, the maximum "normalised thermal bridge value" restricts the ratio of all summed up thermal bridge values in a building, divided by its heated floor area. The requested value of at most 0.03 W/(m²K) is hard to fulfil in case of heavy concrete buildings with large foundations or basement garage. For all that – the requirement simply considers the average and is in no way appropriate to assure low thermal bridge values at the particular connections and joints.

Calculations using Passive House Planning Package

There are a lot of distinctions between Norwegian Passive House standard and the Passive House concept developed by Passive House Institute, concerning both criteria, calculation methods and underlying procedures and rules, see Anton and Vestergaard (2013). Area calculations are one of these distinctions. For residential buildings, particularly for small houses, the differences are limited, but in the residential sector they may have significant impact on the results. The reason is that stairs, lifts and vertical ducts are not included in the treated floor area, while corridors and technical rooms only account for 60 % of their area, see PHI (2007). In contrast, in Norway are these areas a part of the heated space, in addition to interior walls, which according to PHPP are not included as well. Meanwhile, the actual impact on space heating (or cooling) demand may differ substantially, depending on the characteristics of the considered building. Also the calculated internal heat gains have a significant impact (e.g. PHPP: 3.5 versus NS 3031: 5 W/m² in case of office buildings).

[3] The standard does not state whether the average may be calculated separately for windows and doors, or as one value for both components.

As an example for the present paper, a PHPP calculation was conducted for the 1000 m² building model shown in Figure 1, using the input data for office buildings specified in Table 3. The share of stairs, corridors and so on is not known and had therefor to be assumed. Thus, the result has to be considered as an indication, not as a precise number. With this reservation, the net space heating demand of the 1000 m² office building located in Oslo was calculated to 19 – 22 kWh/m²a, depending on the chosen ventilation design. Surprisingly, despite different area rules and internal gains: The PHPP calculation gives a result in line with the calculation according to the Norwegian standard (19.9 kWh/m²a, see Table 4). Notwithstanding: There are also big air flow differences between PHPP and Norwegian standard. The impact becomes clear if there are used ventilation rates according to the Norwegian standard instead of air volumes recommended by PHI. Under this condition, the PHPP calculation result for space heating may raise up to 35 kWh/m²a, or 75 % higher than the result according to the Norwegian standard, also this somewhat depending on the chosen solutions in the present building. On the other hand: PHPP calculation with "Norwegian" internal heat gains would decrease the heating demand. Anyway, all these factors – area quantities, internal gains and ventilation numbers – have significant impact on results for a real building, calculated according to PHPP or NS 3701.

DISCUSSION

Comparison with preliminary Norwegian criteria

For most of the building categories, already the "basic" maximum net space heating requirement is higher than according to the preliminary criteria in 2009, see Table 6. In addition, smaller buildings and buildings located in colder climate than Oslo may have even higher energy demand. The main reason for the less stringent requirements is caused by the building models used in the preparatory work[4].

Table 6: Net space heating demand and heated area of the used building models, related to different building categories and according to respectively preliminary criteria (2009) and NS 3701 criteria (2012). Source: Dokka et al. (2009), Dokka (2012) and Standard Norway (2012). The rightmost column shows the requirements for the building models used in 2009, according to the 2012 criteria, and the difference (+/-) for the 2009 model using 2012 instead of 2009 criteria. + 11 means the 2009 model may have 11 kWh/m²a higher heating demand using the 2012 criteria than it was allowed by using the 2009 criteria (source: calculations by paper-author).

Building category	Maximum heating demand 2009 [kWh/m²a]	Building model 2009, heated floor area [m²]	Basic max. heating demand 2012 [kWh/m²a]	Basic building model 2012, heated fl. area [m²], 2 stories	2012: Max. heating demand for 2009 model
Kindergarten	25	300, 1 storey	25	1000	36 = + 11
Office building	15	3600, 3 stories	20	1000	20 = + 5
School building	15	2400, 2 stories	20	1000	20 = + 5
University build.	15	3600, 3 stories	20	1000	20 = + 5
Hospital	20	3600, 3 stories	20	1000	20 = +/- 0
Nursing home	15	2400, 2 stories	20	1000	20 = + 5
Hotel	20	3600, 3 stories	25	1000	25 = + 5
Sports facility	25	3200, 1 storey	20	1000*	20 = + 5
Commercial build.	20	3600, 3 stories	25	1000	25 = - 5
Cultural building	25	2400, 2 stories	25	1000	25 = +/- 0
Factory/workshop	25	1200, 1 storey	25	1000*	25 = +/- 0

* Only 1 story in parts of the model building

[4] There are also some smaller adjustments on input data, but the impact of these amendments is more limited.

The authors of Dokka et al. (2009) considered varying "typical" building models for the different building categories. In contrast, Dokka (2012), preparing the standard, used only one building model for (nearly) all categories. As shown in Table 6, is the 2012 basic building model smaller than all building models used in 2009, apart from kindergartens. Since the larger 2009 models in most cases can be considered as more typical than the smaller ones from 2012, it should normally not be a big challenge to fulfil the 2009 requirements also nowadays. Dokka (2012) refers to discussions within the Standard committee, but gives no further substantiation for the chosen model dimension.

For this reason, also 1000 m² heated floor area as a "buckling point" for even lower requirements for smaller buildings seems to be poorly underpinned. Concerning kindergartens, the 2012 area correction results in an acceptable space heating demand as high as 36 kWh/m²a for the 300 m² model which was used in the 2009 preparatory work. This is 11 kWh/m²a more than the 25 kWh/m²a which were allowed according to the 2009 criteria. The preliminary 2009 kindergarten requirements were based on a 300 m² model consisting of only one level. Since it is no challenge to build a more compact two-storey kindergarten, it can be argued that already the 2009 kindergarten requirements were too weak.

Comparison with built Norwegian projects

A rough examination of Norwegian project databases shows a lot of well-documented built projects which are calculated to meet the preliminary 2009 Passive House requirements, for example 2 kindergartens (24 and 25 kWh/m²a), 5 office buildings (9 – 13 kWh/m²a), 5 schools (11 – 15 kWh/m²a, 1 school 16 kWh/m²a including gym), 1 university college (15 kWh/m²a) and 1 hospital building (12 kWh/m²a), see Enova (2015) and NAL (2015). This picture should be sufficient to prove that the preliminary requirements had not been too ambitious.

Comparison with Norwegian Passive House Standard for residential buildings

The Norwegian Passive House standard for residential buildings, NS 3700, is built on similar principles. Also the residential standard includes correction factors for colder climate and smaller heated area. Nevertheless, the "basic" heating demand is stated to only 15 kWh/m²a, and the "buckling point" for less stringent requirements for smaller buildings is defined as low as 250 m² heated area, see Standards Norway (2013). As a consequence, the same building would have to meet much stronger requirements in case of residential use, than if it is a non-residential building. In case of a small office building, the 2012 area correction results in an acceptable space heating demand of 26.4 kWh/m²a for 250 m² heated area. This is 11.4 kWh/m²a more than 15 kWh/m²a, which a 250 m² residential building would have to fulfil. A large, but nevertheless typical 3600 m² office building could require 20 kWh/m²a, while a smaller and much less compact residential semi-detached house would have to meet 15 kWh/m²a. It is implausible why the requirements for large, compact non-residential buildings in general should be minor ambitious than for smaller residential buildings.

Comparison with PHI criteria

Beside overall primary energy demand and air tightness, there are only two straight, unmodifiable technical requirements stated by Passive House Institute concerning certification of non-residential buildings (PHI, 2013):

- Specific space heating demand ≤ 15 kWh/(m^2a) *or alternatively:* heating load ≤ 10 W/m^2
- Specific useful cooling demand ≤ 15 kWh/(m^2a)

Concerning space heating demand, the Norwegian Passive House standard for *residential* buildings is approximately in line with the PHI Passive House criteria, as far as the buildings are not very small and located in a climate not colder than Oslo. In contrast, the standard for *non-residential* buildings is already from the starting point "far away" from the PHI criteria. Even typical large non-residential buildings could be erected according to requirements significantly less ambitious and not necessarily suited for heating by ventilation air. Smaller buildings and buildings in colder climate could have space heating demand on a level that makes it totally unrealistic to use simplified heating systems, see Table 4 as an example for office buildings.

When it comes to cooling, the Norwegian requirements are stricter than the PHI criteria, apart from hospitals and commercial buildings (which are not mentioned explicitly in the PHI criteria). However, the benefit of the sophisticated small distinctions within the Norwegian requirements for different building categories, different area and different climate is highly questionable.

Since the Passive House concept basically is function-based, there are no straight, unmodifiable technical requirements like strict U-values beyond recommendations, and a lot of specific criteria only apply in case of component certification. In contrast, there are some general minimum requirements in the Norwegian standard. But, as shown under "results" above: Requirements on windows U-value and "normalised thermal bridge value" consider the average and are not appropriate to assure required comfort and quality at the particular building element.

Another obvious distinction between PHI and Norwegian criteria is the clear, simple structure of the first and the cloudy, very complex "assembly" of the latter. Confusing equations and a lot of varying coefficients in NS 3701 makes it difficult to find out what the finally requirements for a particular building are. On the other hand: The result of the effort is very detailed, with an accuracy of one digit after the decimal point. Yet, this is really misleading. In practice (using a lot of uncertain assumptions), it would not be possible to calculate heating or cooling demand within such accuracy. Therefore, PHI requirements always are rounded to integer numbers.

CONCLUSIONS

In the author's opinion, the Norwegian Passive House standard is over-complex. The results of the complicate equations are very accurate, but this accuracy may be misleading, considering the many uncertainties within a calculation. This gives no real benefits. Criteria on average U-values and average thermal bridges cannot assure quality and comfort. The requirement level of space heating demand is lower than for residential Norwegian Passive Houses, lower than in former criteria and lower than realised in built projects. The tolerable level makes it in many cases unrealistic to use simplified heating systems. The paper has shown that stronger requirements would be possible without exorbitant challenges.

Thus, the weak standard does not utilize technical potentials and will not push further technological development. In addition, the standard may contribute to confusion of marked players which expect a better level when it comes to Passive Houses.

Concerning very cold areas, it is obvious that it would be a big challenge to build genuine Passive Houses. Nevertheless, there is no reason to put ambitious buildings under the Passive House label, if they do not achieve the qualitative level of the Passive House concept.

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