Upgrading of a Typical Norwegian Existing Wooden House According to the EnerPHit Standard

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Abstract. The building sector has a key role to play in implementing the EU energy efficiency objectives. Around 40% of the energy consumption and a third of CO_2 emissions comes from buildings. With the adoption of Nearly Zero Energy Buildings throughout the EU from 2020 onwards, these figures will be reduced in a perceptible and sustainable way [1]. To achieve such a significant reduction before 2030 with the current low new built rate, a comprehensive effort on upgrading existing buildings is necessary. Thus, we should aim for more optimized refurbishment solutions, in addition to building new and more energy efficient buildings. Upgrading existing buildings to higher energy standards is usually far more difficult than obtaining the same standards in new buildings. In many cases, upgrading to the nZEB-level [2] is unlikely to be cost effective. Thus, the Passive House Institute has published the international EnerPHit Standard for retrofit of existing buildings [3]. This article compares the Norwegian energy standards with the international EnerPHit Standard for retrofitting. The article also analyses the upgrade potential of a typical Norwegian wooden house from 1960-70 by following the EnerPHit Standard using the “step-by-step” method. Two different programs are used for energy simulation: The Passive House Planning Package and SIMIEN. Furthermore, the article briefly discusses how building automation can be used as a next step to increase energy efficiency. Upgrading of a typical Norwegian wooden house from 1960-70 is not free from challenges, but it is possible to achieve the EnerPHit Standard following the "step-by-step" method.

Keywords: Effective Energy Use · Retrofit · Building Simulation · Building Automation

1 The International Standard for Retrofit EnerPHit vs. the Norwegian Standards for Residential Buildings

1.1 Introduction

Upgrading existing buildings to higher energy standards is usually far more difficult than obtaining the same standards in new buildings. In many cases, upgrading to the nZEB-level [2] is unlikely to be cost effective.

Thus, the Passive Institute in Darmstadt has published a new standard for modernization of existing buildings, also called the "step-by-step" method [3]. The international EnerPHit Standard is an addition to the previously formulated international standards for new buildings in the classes: Passive House Classic, Passive House Plus and Passive House Premium [4]. Formulation of the EnerPHit Standard was preceded by the research project EuroPHit, supported by the Intelligent Energy Europe Program of the European Union and coordinated by the Passive House Institute in Darmstadt.

In Norway, in addition to the minimum energy requirements defined in the Norwegian Building Code, there are two standards for higher energy classes for residential [5] and commercial [6] buildings: low energy and passive house. These standards are however not coordinated with the cited international definition of the Passive House and they have lower ambitions than the international standards. There are no guidelines or standards for refurbishment of existing buildings in Norway, and the standards with higher energy classes are still not defined for other building typologies.

The standard NS-EN 15232: 2012 “Energy performance of buildings - Impact of Building Automation, Controls and Building Management” [7] is used in Norway, but there are only few reference projects that take into account energy savings as a result of a higher degree of automation in combination with the optimizing of building envelope. These kind of measures are also not included in the international standards, even though the benefits of it may be particularly relevant in countries with challenges related to difficult local climate conditions.

1.2 The International Energy Standard for Retrofit, EnerPHit Standard

The EnerPHit Standard proposed by the Passive House Institute is a guideline for reasonable thermal upgrading of existing buildings. The standard is versatile and applicable to different building typologies in different climatic zones [8].

The standard proposes two different methods to achieve the refurbishment criteria:

1. EnerPHit criteria for energy retrofit with passive house components, which is recommended to use for buildings with one or more obstacles concerning energy-relevant upgrades. This can be related to for instance the building location, geometry and the existing building technology.
2. EnerPHit criteria for energy retrofit with the energy demand method, which is recommended for buildings with favorable conditions.

Both methods take into account the climatic conditions of the building. The second method has been used for achieving the EnerPHit criteria for the case study in this article. These main energy-relevant criteria are related to maximum heating demand, 30 kWh/m^{2}a in the cold climate, and maximum cooling and dehumification demand, corresponding with Passive House requirements [3].

1.3 Norwegian Energy Standards

The requirements for energy efficiency in the Norwegian Building Code, TEK 17 [9], are stated as a maximum netto energy demand, in kWh/m^2 BRA per year, for each building typology. An alternative solution to fulfilling the energy efficiency requirements for residential buildings is satisfying the energy characteristics for different components. The actual values can deviate from these requirements, as long as the building's heat loss factor does not increase and as long as the minimum requirements for energy characteristics are met.

The standard for passive house and low-energy classification for residential buildings in Norway, NS 3700:2013 [5], has criteria for the maximum netto energy demand for heating, as opposed to TEK 17, that gives requirements for the total netto energy demand. This is a fixed value for houses larger than 250 m^2, but for smaller houses, the value depends on the heated floor area and on the average outdoor temperature. In addition, the calculated amount of electrical and fossil energy should be less than the total energy demand minus 50% of the demand for domestic hot water. There are requirements regarding U-values of windows and doors and of system parameters, but for the opaque building envelope there are no requirements, only typical values. These standards only consider new residential buildings and commercial buildings, and do not take the specific situation in the case of existing buildings into account.

2 Case study: a typical wooden house

2.1 Introduction to the Case Study

A 60-70-year-old wooden house is usually still in good technical condition, and therefore often becomes an object of modernization. As a result, modernization of existing houses to adjust them to the present-day energy standards becomes an important construction task. However, building components have different life durations, and in many cases, they do not need to be replaced simultaneously which can be challenging. The "step-by-step" method of modernization of existing houses can therefore be a good solution for these refurbishment projects.

The research object (see Fig. 1), is a characteristic detached wooden house with a heated floor area (BRA) of ca. 90 m^2. This one floor house with a suspended floor above a ventilated crawl space and a ventilated, cold loft represents one of the smaller typical houses from the 60s and 70s. It has a simple economic floor plan, but the building form cannot be considered compact. The house is built with standard components from this period. The thickness of insulation for the building envelope is 100 mm in the floor, 150 mm in the external walls, and 150 mm in the loft. The construction method of the house is the traditional, most common wooden construction in Norway, timber framing [10], and was also common in the rest of Scandinavia in the 60s and 70s. Wood or brick was used as external cladding.

Four theoretical locations with different local climate in Scandinavia have been chosen – all classified as cold climates according to the Passive House Institute in order to compare the results of simulation. The locations are Bergen, Oslo and Trondheim in Norway and Gothenburg in Sweden.

Fig. 1. A typical Norwegian wooden house from the 60s and 70s [11].

2.2 Method.

Two simulation tools have been used to simulate the energy consumption for the case study. The Passive House Planning Package (PHPP) [12] was used to evaluate the refurbishment potential of the house following the EnerPHit Standard, preliminary in the energy class Classic. PHPP, developed by the Passive House Institute, offers the possibility to calculate versions of the building in parallel, which is particularly useful when evaluating the “step-by-step” method. SIMIEN [13] was used to simulate the building according to Norwegian standards. It uses a dynamic calculation method that is described in the Norwegian standards and is an approved tool in Norway for simulating the energy demand of a building.

3 Upgrading the Case Study Following the EnerPHit Standard and the Norwegian Standards

3.1 Results of Simulation According to the EnerPHit Standard

The software tool PHPP was used to simulate the energy demand for heating of the house as well as to evaluate the upgrade potential towards the EnerPHit Standard. The following steps were applied:

1. The existing windows and external doors are replaced with new components according to the Passive House Standard, and a new ventilation system with heating recovery and a heat pump are installed.

2. The existing insulation in the loft (150 mm) is replaced with 300 mm inflated cellulose insulation, still maintaining the cold loft principle.
3. For the floor, 150 mm is added to the existing insulation (100 mm). The new insulation fills the remaining free space in the existing floor construction. The existing floor may also be replaced with a slab-on-grade, which can provide even better safety against moisture damage.
4. For the external walls, 200 mm is added to the existing insulation (150 mm). The new insulation may be added as a double layer, ie. 100 mm on the outside and 100 mm on the inside of the existing wall or only on the inside or outside of the existing construction.

The new construction maintains the general principle for heat and moisture transport. In addition to a better thermal comfort and a significantly lowered energy demand for heating, the new construction is better protected against any moisture damage due to the fact that the new construction is designed as a nearly thermal-bridge-free construction and the new, replaced and continuous vapor barrier layer ensures a high air tightness from the inside. The air change rate at 50 Pa of the new building envelope is less than 0,6 1/h. Assuming that the general rules for the placement and installation of the new moisture barriers are taken care of, the new construction will provide a good protection against moisture.

A new balanced passive house ventilation with heat recovery of ca. 80% will be installed already during step 1 of renovation to ensure a proper ventilation according to the increased airtightness of the renovated envelope.

The climate in Gothenburg, Sweden is similar to the climate in Bergen, Norway according to the standard climate data in PHPP for these locations, and the results of simulations are nearly identical when the same components are used. Fig. 2 illustrates the preliminary results of the simulations of the analyzed house for location in Gothenburg and in Bergen. The simulations show how much the heating demand of the building varies during the “step by step” renovation (see Fig. 2, 3 and 4).

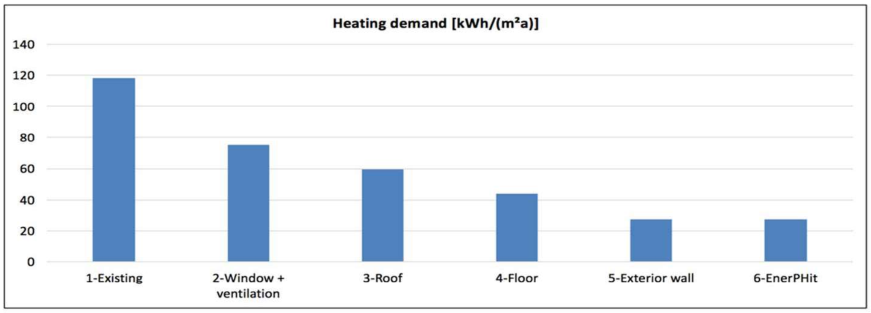
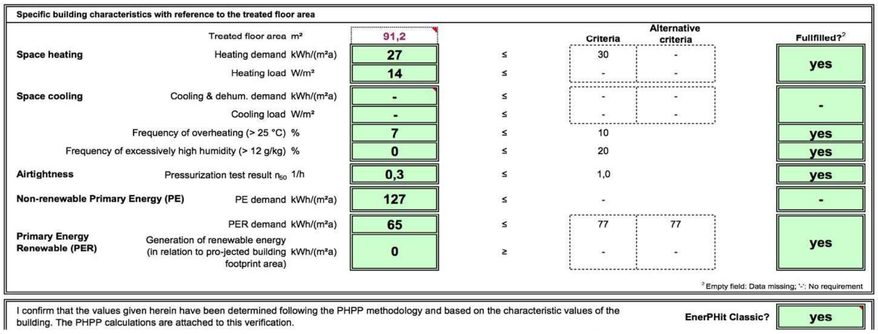


Fig. 2. Summary of the modernization steps in the PHPP, Gothenburg/Bergen.

The simulation shows that it is possible to reduce the energy demand for heating of the house from ca. 118 kWh/m^2 per year to ca. 27 kWh/m^2 per year, i.e. under the maximum 30 kWh/m^2 per year required by the EnerPHit Standard.



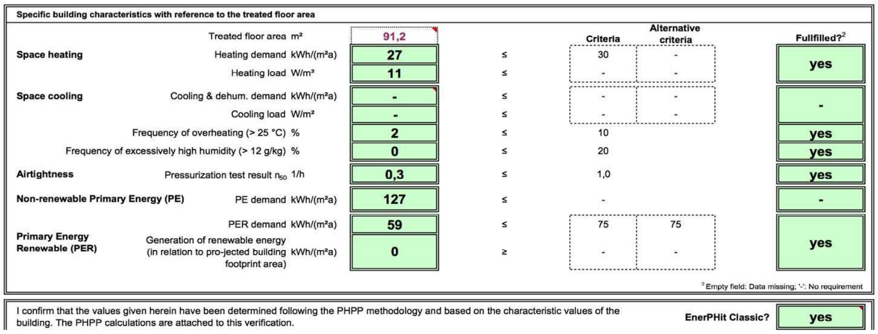
Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria	Fullfilled?²
	Treated floor area	m²	91,2				
Space heating	Heating demand	kWh/(m²a)	27	≤	30	-	yes
	Heating load	W/m²	14	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	7	≤	10		yes
	Frequency of excessively high humidity (> 12 g/kg)	%	0	≤	20		yes
Airtightness	Pressurization test result n_{50}	1/h	0,3	≤	1,0		yes
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	127	≤	-		-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	65	≤	77	77	yes
	Generation of renewable energy (in relation to pro-jected building footprint area)	kWh/(m²a)	0	≥	-	-	

[2] Empty field: Data missing; '-': No requirement

I confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification. **EnerPHit Classic?** yes

Fig. 3. Verification in the PHPP according to the energy demand method, Gothenburg.



Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria	Fullfilled?²
	Treated floor area	m²	91,2				
Space heating	Heating demand	kWh/(m²a)	27	≤	30	-	yes
	Heating load	W/m²	11	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	2	≤	10		yes
	Frequency of excessively high humidity (> 12 g/kg)	%	0	≤	20		yes
Airtightness	Pressurization test result n_{50}	1/h	0,3	≤	1,0		yes
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	127	≤	-		-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	59	≤	75	75	yes
	Generation of renewable energy (in relation to pro-jected building footprint area)	kWh/(m²a)	0	≥	-	-	

[2] Empty field: Data missing; '-': No requirement

I confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification. **EnerPHit Classic?** yes

Fig. 4. Verification in the PHPP according to the energy demand method, Bergen.

The preliminary results also show that it is impossible to successfully upgrade the house if it were located in Oslo or Trondheim using the same components (see Fig. 5).

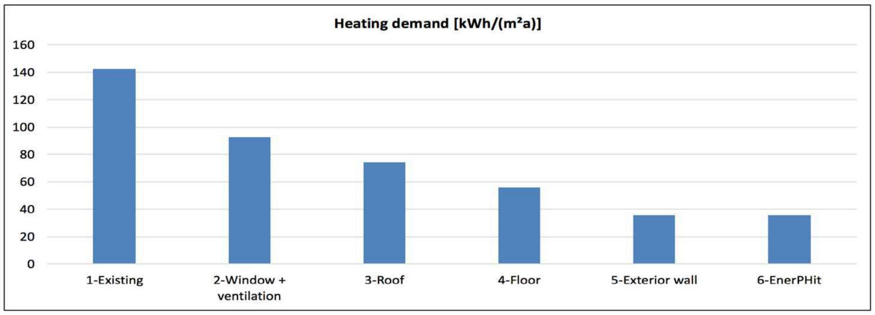


Fig. 5. Summary of the modernization steps in the PHPP worksheet "Variants", Oslo.

However, it is relatively easy to achieve the EnerPHit Standard in Oslo using for instance 150 mm insulation extra in the roof (450 mm in total). In Trondheim it is also possible by adding 300 mm additional insulation, for instance by adding an extra 150 mm in the roof and 150 mm in the floor. In this case, other measures may also be considered that improve efficient energy management, for instance using building automation (read more in Chapter 4).

3.2 Results of Simulation According to the Norwegian Standards

The software tool SIMIEN was also used to simulate the energy demand of the house as well as to evaluate the upgrade potential of the house towards Norwegian standards.

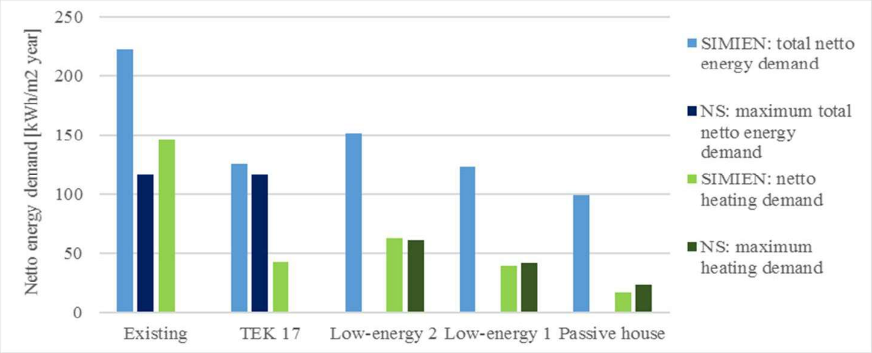


Fig. 6. Simulation results in SIMIEN from different scenarios in the Oslo climate.

Fig. 6 shows the results from five different scenarios in the Oslo climate: the existing building, and four levels of refurbishment according to the Norwegian standards. It shows the simulated netto energy demand, both the total and the specific demand for heating, and the maximum demand according to the standards. Since TEK 17 was recently published with stricter energy efficiency requirements, and there has not been an update for NS 3700:2013, the low-energy 2 scenario results in a higher energy demand than the TEK 17 scenario. The simulated netto energy demand in the TEK 17 scenario is higher than the maximum value. However, the results showed that the criteria for the alternative solution, satisfying energy characteristics for components, are met.

4 Effective Energy Use in Residential Buildings with the Use of Building Automation

In general, building automatic control systems (BACS) can be said to function at several levels: following a fixed user-defined set point (D), or following a schedule or pattern depending on time (C), presence (B) or demand (A). The standard NS-EN 15232: 2012 [7] gives an overview of efficiency factors of the building automation control system (BACS) in different types of buildings and for different levels of automation. These factors for residential buildings are given in Table 1, and can be used to estimate the energy savings potential of implementing building automation.

Table 1. BACS efficiency factors for residential buildings [7]

Category	**Electrical energy**				**Thermal energy**			
	D	**C**	**B**	**A**	**D**	**C**	**B**	**A**
Housing	1,08	1	0,93	0,92	1,10	1	0,88	0,81

The case study uses electricity for heating and lighting, and has a balanced ventilation system after refurbishment. This means that the building control system can be kept reasonably simple. The number of possible functions involved is however still considerable. The house classifies as D, which means that the BACS system is non-efficient and in need for retrofitting. The energy savings potential is 8-16% for electrical energy and 10-29% for thermal energy, depending on the BACS level after upgrading (see Table 1 and Fig. 7). The actual savings depend on the choice of HVAC systems and energy sources, and on the complexity of the BACS. Fig. 7 also shows that implementing building automation alone is not enough to reach Passive House ambitions. Retrofitting of the building envelope is needed first, after which building automation can be implemented to further increase energy efficiency.

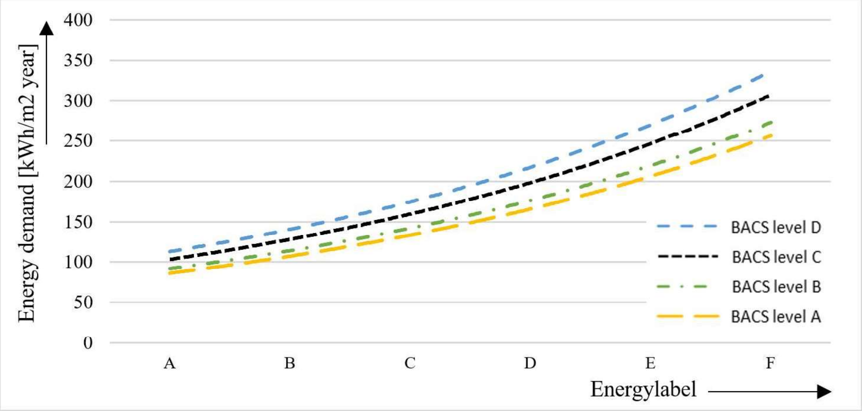


Fig. 7. Energy savings potential for implementing building automation

5 Discussion

The preliminary results of the calculations in PHPP according to the energy demand method from EnerPHit Standard show that the “step-by-step” method can be successfully used for retrofitting existing wooden houses in Scandinavia. Of course, the method can also be used to simulate a comprehensive retrofitting that is carried out during one phase only. The parallel simulation options in PPHP can be used to compare both complete refurbishments as well as compare the benefits of individual components.

The preliminary results show that with some reasonable measures it is possible to reduce the existing building energy demand for heating by almost 80%. The “step-by-step” method is especially relevant for upgrading the chosen house located in Bergen, Norway as well as in Gothenburg, Sweden. For other locations, such as Oslo and Trondheim in Norway, more measures need to be implemented to reach the level from the EnerPHit Standard, but it is still reasonable. The simulations indicate that for buildings with more favorable conditions, for instance more compact buildings, even better results can be expected.

The Norwegian standards does not take into account limitations related to refurbishment existing building. The preliminary results of the simulations in SIMIEN show that it can be more challenging to meet the requirements for some typical building components (see Table 1), compared to the preliminary results of calculations in PHPP according to the international EnerPHit Standard (read more in Chapter 3). The preliminary results of calculations in PHPP according to the EnerPHit Standard demonstrate that the standard can be successfully used in Scandinavian.

For more challenging climates, building automation could be used as an energy saving measure when it is difficult to reach the EnerPHit criteria with thermal upgrades only. The savings potential of building automation alone is however not enough to reach the Passive House ambitions. Therefore, retrofitting of the building envelope is needed first. Building automation can then be implemented to further reduce the energy demand by increasing energy efficiency of the HVAC systems. The savings potential of building automation is further limited by factors such as feasibility and cost-efficiency. Most energy savings can be achieved when HVAC systems are demand-controlled, but for residential units with poor existing HVAC structures this could result in high costs. It may be more realistic to upgrade to a time or presence controlled system.

5.1 Limitations and Further Research

- The existing house's energy demand for heating is currently covered completely by electricity. In the preliminary calculation in PHPP, a heat pump is implemented during step 1, which will reduce the amount of the delivered energy, (see Fig. 8).

	Select the active variant here >>>>>>>	6-External wall	Existing	Windows + ventilation	Heat pump	Roof	Floor	External wall
	Units	6	1	2	3	4	5	6
Heating demand	kWh/(m²a)	26,7	118,2	75,3	74,4	59,7	47,0	26,7
Heating load	W/m²	11,3	41,5	23,3	23,2	19,4	16,8	11,3
Cooling & dehum. demand	kWh/(m²a)							
Cooling load	W/m²							
Frequency of overheating (> 25 °C)	%	1,5	0,1	0,2	0,2	0,2	1,0	1,5
PER demand	kWh/(m²a)	58,9	209,5	154,3	97,9	85,5	75,1	58,9
EnerPHit Classic?	yes / no	yes	no	no	no	no	no	yes

Fig. 8. Summary of the modernization steps in the PHPP, Bergen.

- The use of Photovoltaic panels may be considered to cover the remaining electricity demand, but it is not taken into account in this article. Other heating alternatives are not taken account in this article, but heating systems based on non-renewable energy sources or heating systems that increase the amount of the delivered energy, like district heating, are not recommended.
- The benefits of building automation are not taken into account in the simulations, neither in PHPP nor in SIMIEN.

- Standard climate conditions for these four analyzed locations according to PHPP are taken into account in the preliminary calculations. It is recommended to use specific local climate data for specific individual locations in practice.
- The architectural measure to make the building form more compact, by for example adding an extra floor, is not taken account in the calculations.

6 Conclusion

Upgrading of a typical Norwegian wooden house to the EnerPHit Standard is not free from challenges. These challenges can be related to the existing building location, geometry, construction, and building technology. Despite the limitations, it is possible to upgrade this house to the EnerPHit Standard using the "step-by-step" method. By using modern technology and components as well as renewable energy sources, it is possible to achieve not only a more energy efficient building, but also an environmentally friendly, user friendly and cost-effective living space, even in the challenging cold climate.

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