Proceedings of the REHVA Annual Meeting Conference
Low Carbon Technologies in HVAC
23 April 2018, Brussels, Belgium

https://www.rehvam2018atic.eu/

NZEB ENERGY PERFORMANCE REQUIREMENTS IN FOUR COUNTRIES VS. EUROPEAN COMMISSION RECOMMENDATIONS

Jarek Kurnitski[1,2*], Kaiser Ahmed[1], Tero Hasu[3], Targo Kalamees[2], Nicola Lolli[4], Anne Lien[4], Thorsell Johan[5], Johansson Jan[5]

[1]Aalto University, Department of Civil Engineering, Finland
[2]Tallinn University of Technology, Department of Civil Engineering and Architecture, Estonia
[3]Kouvola Innovation Oy, Finland
[4]Sintef Building and Infrastructure, Architecture, Materials and Structures, Norway
[5]Växjö Kommunföretag AB, Sweden

ABSTRACT

In this study NZEB energy performance requirements of four North European countries participating in the H2020 NERO project were benchmarked against official recommendations of European Commission (EC). An apartment building with standardized input data from the prEN 16798-1 was used as a reference building. Energy simulations were conducted both with standardized and national input data, as the latter was needed for comparing with the national NZEB requirements. In this comparison, various technical solutions were selected so that the building complied with EC recommendations. Then the technical solutions were adjusted to achieve the closest compliance with the national NZEB requirements in the four selected EU countries. The technical solutions showing the highest energy performance highlighted the strictest national NZEB requirements. Energy performance with national NZEB solutions was benchmarked against the EC recommendation by using input data representing a standard use and applying the ISO 52000-1:2017 primary energy factors (PEF). Results showed that the direct comparison of the building energy performance between the EC recommendation and the national NZEB primary energy values produced inconsistent results because of the variation of both the PEF and the energy calculation input data in national regulations. The simulation of national NZEB technical solutions done with the prEN 16798-1 input data and the ISO 52000-1:2017 PEF showed that the primary energy use in the reference building met the EC recommendation in Estonia only. When district heating was considered the primary energy use was higher by a factor of 1.4, 1.6, and 1.7 in Norway, in Finland, and in Sweden, respectively.

KEY WORDS: National requirements, energy performance, primary energy, NZEB, European EPB standards

1. INTRODUCTION

The European Energy Performance of Buildings Directive (EPBD) recast from 2010 set an ambitious energy performance target for nearly zero energy buildings (NZEB) [1]. According to the NZEB definition in the directive, these buildings have a high-energy performance and use a significant amount of renewable energy. The definition of a high-energy performance is left to each Member State (MS) to decide based on the local climatic conditions and their own national method for the energy calculations. This variation of calculation methods and input data leads to the need of comparing the energy performance of buildings according to the requirements of different MS. The European Commission Joint Research Centre has recently evaluated all

*Corresponding Author: jarek.kurnitski@aalto.fi

Wood for Zero.
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754177

existing national NZEB definitions [2],which were found to be quite different in terms of values, building categories, boundaries of energy flows and renewable energy production, and national input data used in energy calculation.

Few studies have compared the ambition of NZEB energy performance between national regulations. Asdrubsli et al. [3] compared the energy performance of Italian and Spanish apartment buildings by considering national calculation methodologies and input data, and found that the Italian NZEB regulation was stricter for apartment buildings than the Spanish regulation. In a similar study, Kurnitski et al. [4] compared the 2012 national requirements of Finnish, Danish, Swedish, and Norwegian buildings and found that the Danish requirement for apartment buildings was the strictest. In addition to the differences of national input data and energy calculation methods, the climatic variation in the Northern EU countries is significant leading to different energy saving when applying same measures.

Since the comparison and assessment of national NZEBs is challenging, the European Commission (EC) published EU 2016/1318 [5] recommendations, to ensure that NZEB targets are met by 2020. These reflect the EC concerns regarding unambitious national NZEB targets and the little time left to deliver NZEB. The EC stressed the high level of ambition required in the national definitions of NZEB, which should not be below the cost-optimal level of minimum requirements. Similarly, the EC recommended the integration of renewables in buildings and optimal indoor environment to avoid low levels of IAQ and comfort of building users. The EC recommends for the NZEB ambition in new buildings to employ best technology available with a high market penetration, and to take into account legal and policy considerations at national level. To make easier the achievement of the NZEB ambitions, the EC set benchmarks for NZEB primary energy use in four climate zones for new office buildings and single family houses, as shown in Table 1.

Table 1. Numeric benchmarks for NZEB primary energy use set by EC recommendations EU 2016/1318. *Net primary energy* means that primary energy from that on-site renewable energy is reduced. Default values of on-site renewables are also provided.

	Mediterranean Zone 1: Catania, Athens, Larnaca, Luga, Seville, Palermo	**Oceanic** Zone 4: Paris, Amsterdam, Berlin, Brussels, Copenhagen, Dublin, London, Nancy, Prague, Warszawa	**Continental** Zone 3: Budapest, Bratislava, Ljubljana, Milan, Vienna	**Nordic** Zone 5: Stockholm, Tallinn, Helsinki, Riga, Stockholm, Gdansk, Tovarene
	New single family house kWh/(m² a)			
Net primary energy	0-15	15-30	20-40	40-65
Primary energy use	50-65	50-65	50-70	65-90
On-site RES sources	50	35	30	25

The objective of this study is to assess and compare the national NZEB requirements of four countries participating in the H2020 NERO project. The Estonian, Finnish, Swedish, and Norwegian regulations were compared to the EC recommendations. Because the national energy performance values depend on the energy calculation input data and calculation method, the variation of these parameters is an important variable in this study. To compare the requirements of the different cases, a reference building is used in the energy calculations. The energy simulation of the reference building is performed by using the input data and the calculation methods applied in each of the selected countries. The results of the simulations are meant to evaluate to what extent the technical solutions implemented in the reference building are close to the energy performance requirements of each of the selected countries. Should we find a difference, changes to the technical solutions are implemented to minimize it. The requirement needed for the technical solutions with the highest performance level showed the strictest NZEB level in the MS. For the comparison with the EC requirements the primary energy factors described in the EPB standard ISO 52000-1:2017 [6] and the input data of prEN 16798-1:2017 [7] were used.

2. METHOD

The NZEB requirements for the max primary energy (PE) use for apartment buildings are listed in Table 2. The PE value (in kWh/(m^2 a)) is fixed for Estonia, Finland and Norway. For Swedish apartment buildings, the max PE use depends on the Swedish climatic zone. The boundaries of the calculation method are different for Estonia, Finland, Norway, and Sweden. The EC value is the upper limit of the EC recommendation for a single family house in Nordic climate [5].

Table 2. The PE use, national requirements, energy flows accounted, and primary energy factors (PEF) for residential apartment buildings according to national regulations and ISO 52000-1:2017 [6].

	PE Indicators	Energy flows included	NZEB	Primary energy factor
EC [5]	$[\frac{kWh}{m^2\,a}]$	Heating, DHW, ventilation, auxiliary	65	Electricity 2.3 District heating 1.3 Natural gas 1.1
Estonia [8, 9]	E, $[\frac{kWh}{m^2\,a}]$	Heating, DHW, ventilation, auxiliary, lighting, appliances	100	Electricity 2.0 District heating 0.9[b] Natural gas 1.0
Finland [10]	E, $[\frac{kWh}{m^2\,a}]$	Heating, DHW, ventilation, auxiliary, lighting, appliances	90	Electricity 1.2 District heating 0.5 Natural gas 1.0
Sweden [13]	EP_{pet}, $[\frac{kWh}{m^2\,a}]$	Heating, DHW, ventilation, auxiliary, facility lighting	[a]85	[c]Electricity 1.6 District heating 1.0 Natural gas 1.0
Norway [11, 12]	$[\frac{kWh}{m^2\,a}]$	Heating, DHW, ventilation, auxiliary, lighting, appliances	95	--

[a] Addition can be made with 70 (q_{medium} - 0.35) in multi-family houses where A_{temp} is 50 m^2 or larger and as predominantly (> 50% A_{temp}) contains apartments with a living space of up to 35 m^2 each and q_{med} the outdoor air flow in temperature controlled spaces exceeds 0.35 l / s per m^2. The extension can only be used due to the requirement for ventilation in special areas such as bathroom, toilet and kitchen.
[b] PE factor is planned to change to 0.75 in 2018.
[c] PE factor is planned to change to 2.5 in 2021.

The EC value in Table 2 does not include the energy use for lighting and appliances, which are included in the Estonian, Finnish, and Norwegian requirements. The analyses were performed as follows:

1. The energy use of the reference apartment building was simulated with standard use input data from the prEN 16798-1 that include ventilation, heating and cooling set-points, energy use for appliances and lighting and occupancy schedule;
2. The Energy use of the reference apartment building was simulated with the national input data and corresponding climate files of the four selected North European countries;
3. The building and system parameters were varied to achieve as close as possible compliance with the national NZEB requirements;
4. The optimal settings given at step 3 were used for energy simulations fed with the prEN 16798-1 input data [7] and the ISO 52000-1:2017 PEF [6], to assess the compliance with the EC recommendation.

2.1 The reference apartment building

A reference apartment building with seven stories was used for the energy simulations, as shown in Fig. 1. The net floor area, envelope area and windows area were 3071, 2787.1, and 693.9 m^2, respectively. The building was equipped with heat recovery ventilation. The external walls, roof, external floor, and internal floor consisted of a concrete structure with mineral wool insulation. The U-value of the external walls, roof, external floor, and internal floor were 0.14 W/m^2 K, 0.1 W/m^2 K, 0.12 W/m^2 K, and 1.5 W/m^2 K, respectively. Three-glazed windows with a total U value of 0.9 W/m^2 K, and solar heat gain coefficient of 0.45 were used. The linear thermal bridge between the external walls and the internal slab, the external walls, the roof, the external slab, and windows perimeter, were 0.06, 0.03, 0.05, 0.05, 0.024, W/m K, respectively. The linear thermal bridge between the roof and the internal wall was 0.024 W/m K. The building air leakage rate of the building envelope was 1.0 m^3/(h m^2) at pressure difference of 50 pa.

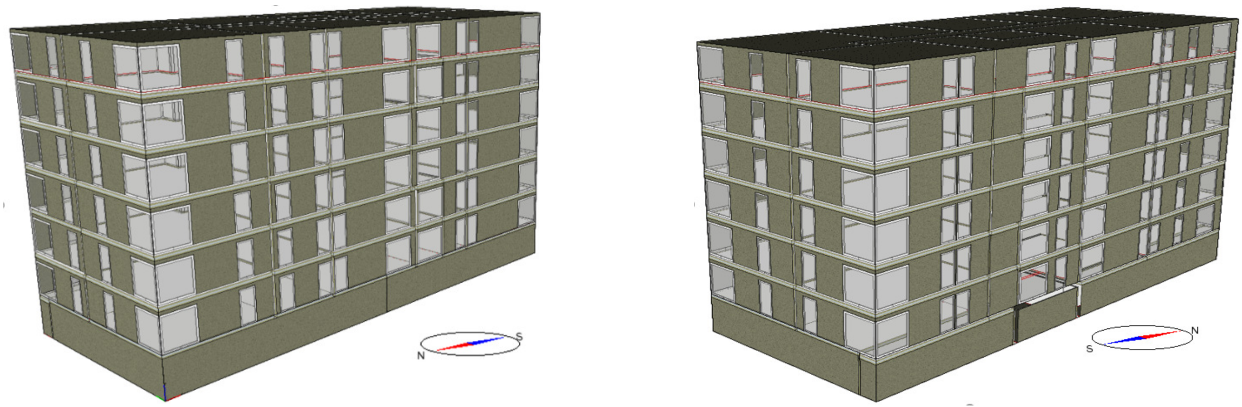


Fig. 1 Simulation model of the reference apartment building.

The specific fan power (SFP) was 1.5 kW/(m^3/s) and the balanced heat recovery ventilation system with electric reheating coil was operated 24 hours a day. The heat recovery efficiency was 80% with a minimum exhaust air temperature limit of 0 °C to avoid frosting. The energy calculation input data and systems' efficiencies are shown in Table 3. DHW values include typical losses, and for Sweden, an additional heating energy use of 4 kWh/m^2 a of window airing was taken into account according to [13]. A well-validated simulation software IDA-ICE 4.7 was used to perform dynamic whole year simulations.

Table 3. prEN 16798-1:2017 and national energy calculation input data.

	EU	Estonia	Finland	Sweden	Norway
Occupant, m^2/person	28.3	28.0	28.0	28.0	78.0
Appliances, W/m^2	3.0	[a]3.0	4.0	4.4	3.0
Lighting, W/m^2	9.0	8.0	9.0	8.0	1.95
Usage time	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00
Ventilation operation hour	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00
Lighting usages rate	0.14	0.1	0.1	0.1	0.67
Occupancy usages rate	0.6	0.6	0.6	0.6	0.67
Appliance usages rate	0.6	0.6	0.6	0.6	0.67
Domestic hot water use, kWh/m^2 a	25	30	38	29	29.8
Ventilation rate, l/m^2 s	0.5	0.5	0.5	0.35	0.33
Heating set point, °C	20	21	21	21	21
Generation efficiency, gas boiler, -	0.95	0.95	1.0	0.95	0.86
Generation efficiency, district heating, -	1.0	1.0	0.97	1.0	0.98
Distribution & emission efficiency, -	0.91	0.97	0.85	0.97	0.97
Circulation pump, kWh/(m^2 a)	2.0	0.5	2.0	2.0	2.0

[a] Internal heat gain value which is divided by factor 0.7 in order to obtain the electricity use

3. RESULT AND DISCUSSION

The technical specifications described in Section 2.1 were chosen for the reference building to comply with EC recommendation for NZEB residential buildings. The simulated delivered energy, expressed in kWh/m^2 a was converted to primary energy and different PEF for gas boiler (GB) and district heating (DH) system were used. The results show that the building with GB is very close to EC recommendation, and the building with DH system slightly exceeds the limit, as shown in Fig. 2. This due to the different PEF for GB and DH in the ISO 52000-1:2017 (Table 2). To comply with DH the reference building specification would need an improvement, but this was not implemented as GB is a common solution in European countries.

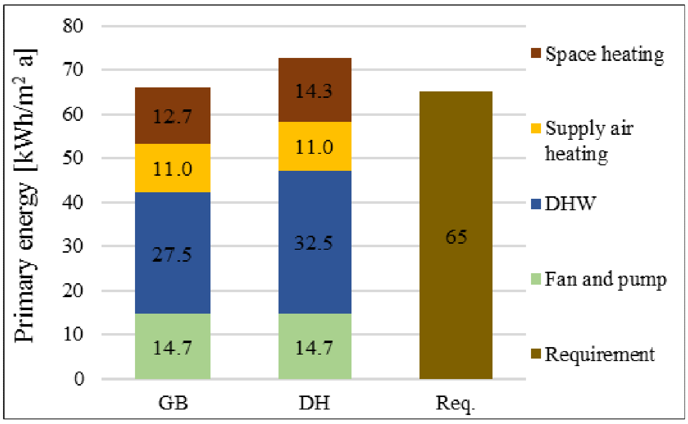


Fig. 2 Primary energy of the reference building with EU's input data (Table 3) and EC energy performance recommendation for residential building.

The national input values shown in Table 3 and the national PEF from Table 2 were used to assess the differences of energy use between the NZEB regulations of the four countries. The results calculated with the reference building and national data are presented in terms of delivered energy (DE) and primary energy (PE) in Fig. 3. The national input values for Estonian and Finnish buildings are nearly the same, with the exception of the power for installed lighting and appliance, and the energy use for DHW. Since both the Swedish and the Norwegian NZEB regulations have the lowest ventilation rate, the lowest energy use for DHW, and the lowest installed power for lighting and appliances, the results of the DE are the lowest of the four countries. The results show that the highest DE occur in the Finnish case, which is followed by the Estonian, Norwegian, and Swedish buildings. The PEF and the calculation of the energy flows significantly influence the results of the DE when this is converted to primary energy, as in Fig. 3b. Notable changes are observed in Fig. 3b due to the lowest PEF in the Finnish NZEB regulation and the exclusion of installed power for lighting and appliances in the Swedish NZEB regulation. The PEF values are not included in the Norwegian regulation where the energy performance is evaluated on the DE only. In this study we used PEF of 1.0 for electricity, DH, and GB for the Norwegian case.

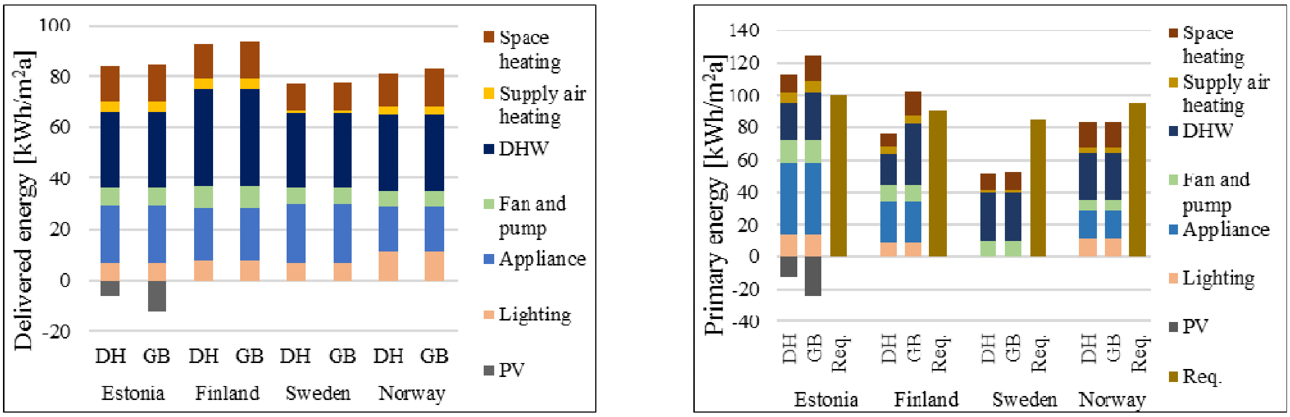
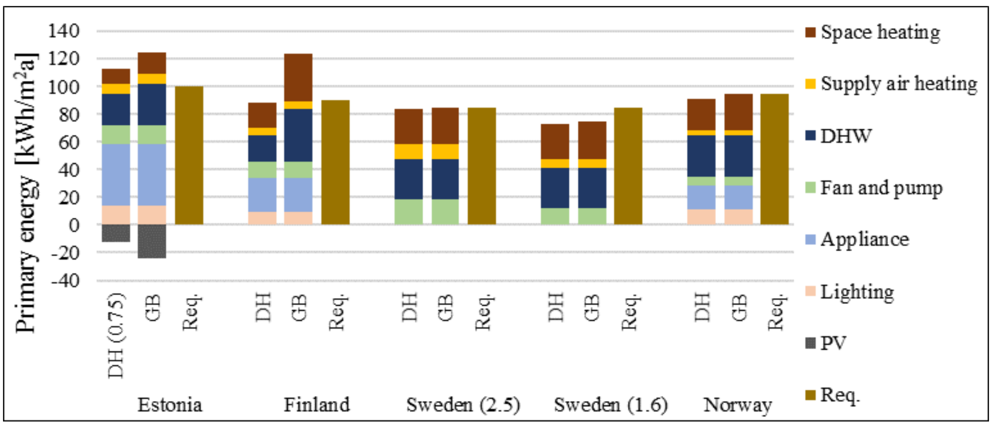


Fig. 3 Energy performance of the reference apartment building calculated with national input data and primary energy factors, a) Delivered energy, b) Primary energy.

When comparing the NZEB requirements of the four countries to the corresponding national requirements, the national requirement was fulfilled in all cases with the exception of the Estonian case. Therefore, the Estonian regulation appears to be the strictest among the other NZEB regulations. Photovoltaic panels were needed in the Estonian case to fulfill the NZEB requirements. The planned new PEF factor of 0.75 for DH was taken into account in the Estonian case, thus allowing to reduce the PV panel size. In Finland, DH is a common heating solution and the gas network is not available for residential buildings. Therefore, in Finland the NZEB regulation was targeted with DH, which allowed using more DE due to the lower PEF. The PE use in Finnish, Swedish, and Norwegian buildings were much lower than the requirement, indicating less strict NZEB regulations. In these countries, there was room to change some technical solutions in order to end up with PE closer to the national NZEB requirements. The following changes were made and the results are shown in Fig. 4:

- In Finland, Sweden and Norway, the U-value for external wall, external floor and roof were increased to 0.2, 0.17, 0.14 W/m^{2}K respectively, and glazing U-value was increased to 1.2 W/m^{2}K;
- In Finland and Sweden, glazing U-value was increased to 1.6 W/m^{2}K and the specific fan power of ventilation system was increased to 1.8 kW/m^3/s;
- In Sweden, the heat recovery efficiency was decreased to 0.7.



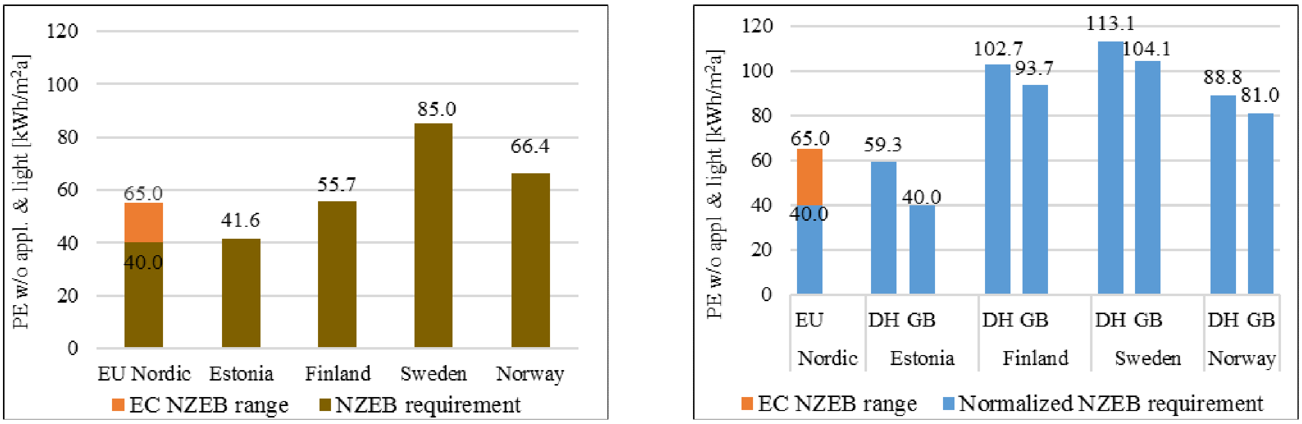
*Corresponding Author: jarek.kurnitski@aalto.fi

Wood for Zero.
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754177

Fig. 4 PE in NZEB apartment buildings with changed technical solutions aiming to close compliance with national NZEB requirement.

The results show that the Norwegian NZEB requirement can be considered as the second strictest regulation followed by Finland and Sweden, as a lesser number of changes were made in Norway than in the other two countries. In the Swedish NZEB regulation, the PEF for electricity is 1.6, but this is planned to be increased to 2.5 in 2021. The building with changed technical solutions complied to the requirement also with this PE value (reported as Sweden (2.5)), as shown in Fig. 4

Because appliances and lighting are excluded from the energy flows in the EC recommendation (Table 2), the contribution of appliances and lighting were deducted from the NZEB requirements of Estonia, Finland, and Norway. The contribution of appliances and lighting is not in the Swedish requirement (Table 2), hence the PE requirement was not changed (Fig. 5a). The national NZEB requirements are compared to the EC recommendation without including the national input data and the resulting PEF are shown in Fig. 5a. To take into account the differences caused by the national input data and primary energy factors, the reference building with changed technical solutions (which complies with national NZEB requirements, Fig. 4) were simulated with input data from the prEN 16798-1 (Table 3) and PEF from the ISO 52000-1:2017 (Table 2). These final results with normalized input data and primary energy factors show that the Estonian NZEB requirement only complies with EC recommendations, as shown in Fig. 5b. In the other three countries with the DH solution the normalized primary energy was higher than the EC recommendation by approximately a factor of 1.4, 1.6, and 1.7, in Norway, in Finland, and in Sweden, respectively. The remarkable differences between Fig. 5a and 5b shows that a direct comparison of the national requirements leads to inconsistent results.



(a) (b)

Fig. 5 National NZEB requirements directly compared with EC recommendation a), and national input data and primary energy normalized national NZEB requirements, b). Estonian TRY climate file was used for all countries in b) as a reasonable climate normalization within the same climatic zone.

4. CONCLUSION

This study benchmarked the NZEB energy performance requirements for apartment buildings in four Nordic countries against the EC official recommendations. A reference apartment building was simulated with the prEN 16798-1 input data and the ISO 52000-1:2017 PEF, and with technical solutions closely complying with EC recommendation with gas boiler and district heating. Then the national input data was applied to the reference building and a comparison with the national NZEB requirements was done. The results showed that the NZEB requirements of the four countries allowed downgrading the energy performance and the corresponding technical solutions to comply with national NZEB requirements, with the exception of the Estonian case. The technical solutions were then varied to achieve as close as possible compliance with the national NZEB requirements. With these NZEB technical solutions, a comparison with EC recommendation was then conducted by applying the prEN 16798-1 input data and the ISO 52000-1:2017 PEF. The following conclusions can be drawn:

- National input data, primary energy factors and calculation methods of the energy balance had remarkable effect in the PE calculation. The lowest value of PE requirement did not correspond to the strictest national NZEB requirement;
- The Estonian NZEB requirement was the strictest, followed by the Norwegian, Finnish, and Swedish requirements;
- The direct comparison between the EC recommendation and the national PE gave inconsistent results because of the differences in the PEF and the energy calculation input data in the national regulations;
- The simulation of national NZEB technical solutions with the prEN 16798-1 input data and the ISO 52000-1:2017 PEF revealed that national input data and primary energy factor normalized NZEB requirements complied with EC recommendation only in Estonia. When district heating was considered the primary energy use was higher by a factor of 1.4, 1.6, and 1.7 in Norway, in Finland, and in Sweden, respectively.

ACKNOWLEDGMENT

This research was supported and by European Union’s Horizon 2020 research and innovation programme, NERO project No 754177, by the grant of K.V. Lindholms Stiftelse foundation and by Estonian Centre of Excellence in Zero Energy and Resource Efficient Smart Buildings and Districts, ZEBE, grant 2014-2020.4.01.15-0016 funded by the European Regional Development Fund.

REFERENCES

[1] EU, "Directive 2010/31/EU. European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)," , pp. 13-35, 2010.

[2] "Science for policy report: Synthesis report on the national plans for nearly zero energy buildings (NZEBs), http://publications.jrc.ec.europa.eu/repository/handle/JRC97408," 2016.

[3] F. Asdrubali, M. Bonaut, M. Battisti and M. Venegas, "Comparative study of energy regulations for buildings in Italy and Spain," *Energy Build.*, vol. 40, no. 10, pp. 1805-1815, 2008.

[4] J. Kurnitski, V. Grönlund and E. Reinikainen. "Comparison of energy performance requirements in selected countries," CLIMA 2013. In: 11th REHVA World Congress and the 8th international conference on indoor air quality, ventilation and energy conservation in buildings, Prague, Czech Republic, June 16–19, 2013.

[5] "Commission Recommendation (EU) 2016/1318 of 29 July 2016 on guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings." 2016.

[6] "ISO 52000-1:2017 Energy performance of buildings — Overarching EPB assessment —Part 1: General framework and procedures." 2017.

[7] "FprEN 16798-1:2017 Energy performance of buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6." 2017.

[8] "Estonian government. Methodology for calculating the energy performance of buildings," 2012.

[9] " Estonian government. Minimum requirements for energy performance," 2014.

[10] "Ympäristöministeriön asetus uuden rakennuksen energiatehokkuudesta," 2017.

[11] "Standard Norge, SN/TS 3031:2016, in: Energy performance of buildings. Calculation of energy needs and energy supply," 2016.

[12] "Direktoratet for Byggkvalitet, Byggteknisk forskrift (TEK17), in: 14-2. Krav til energieffektivitet," 2017.

[13] Boverkets byggregler, BBR, BFS 2011:6 med ändringar till och med BFS 2017:5