NZEB requirements in Nordic countries

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National NZEB values are challenging to compare because of differences in primary energy factors, energy flows included and input data. A reference apartment building was set up to benchmark NZEB requirements against European Commission's NZEB recommendation. Only one national requirement out of four complied with the recommendation whereas the other ones showed significant deviation by the factor of 1.3-1.7.

Deadlines for nearly zero energy buildings (NZEB) set in EPBD [1] have practically reached. In public buildings the requirement is already in force and from January 2021 all new build construction should reach the target NZEB as defined at national level. From January 2021 means that the building handed over and getting the use permit should be NZEB. Therefore, NZEB requirements have been applied 1-2 year earlier as national deadlines are connected to building permit application. In the countries analysed, NZEB requirements are either already in force or will be in force since the 1st of January 2020.

Since the comparison and assessment of national NZEBs is challenging, the European Commission (EC) published EU 2016/1318 recommendations [2], 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 indoor air quality and comfort for building users. 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. European Commission's recommendations for NZEBs in different climate zones [2].

NZEB level of energy performance	Mediterranean Zone 1: Catania (others: Athens, Larnaca, Luga, Seville, Palermo)	Oceanic Zone 4: Paris (Amsterdam, Berlin, Brussels, Copenhagen, London, Prague)	Continental Zone 3: Budapest (Bratislava, Ljubljana, Milan, Vienna)	Nordic Zone 5: Stockholm (Helsinki, Tallinn, Riga, Gdansk, Tovarene)
Offices, kWh/(m² a)				

net primary energy	20-30	40-55	40-55	55-70
primary energy	80-90	85-100	85-100	85-100
on-site RES primary energy	60	45	45	30
New single-family houses, kWh/(m² a)				
net primary energy	0-15	15-30	20-40	40-65
primary energy	50-65	50-65	50-70	65-90
on-site RES primary energy	50	35	30	25

The primary energy values in Table 1 have been calculated from delivered energy without considering on-site renewable energy generation. Net primary energy is obtained when on-site renewable energy generation is subtracted. For Nordic residential buildings the upper limit energy performance (EP) value is EP=90-25=65. In this calculation, all on-site renewable energy generation is taken into account, independently is it used in the building or exported. Energy calculation steps needed for the net primary energy calculation are shown in Figure 1.

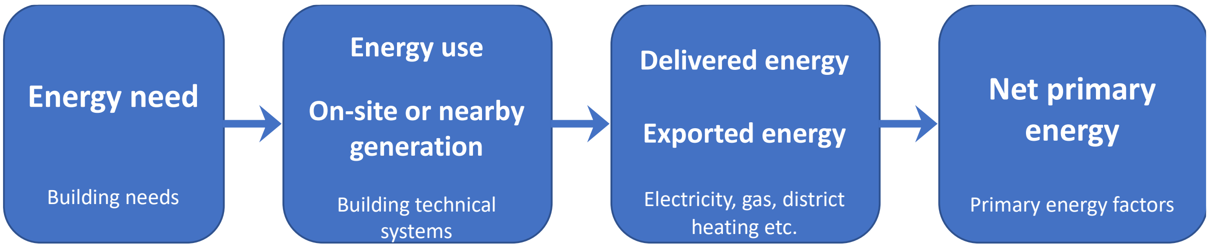

Figure 1. Energy calculation steps to obtain net primary energy EP-value.

The net primary energy values in Table 1 cannot be directly compared with national NZEB values shown in Table 2 because of different primary energy factors, input data and energy flows included.

Table 2. National NZEB requirements and primary energy factors for apartment buildings. EU Nordic primary energy factors are default values from ISO 52000-1:2017 [3].

	Energy flows included	NZEB kWh/(m² a)	NZEB, HVAC only[a]	Primary energy factor
EU Nordic [2]	Heating, DHW, ventilation, auxiliary	**65**	65	Electricity 2.3 District heating 1.3 Natural gas 1.1
Estonia [4, 5]	Heating, DHW, ventilation, auxiliary, lighting, appliances	**105**	47	Electricity 2.0 District heating 0.65 Natural gas 1.0
Finland [6]	Heating, DHW, ventilation, auxiliary, lighting, appliances	**90**	56	Electricity 1.2 District heating 0.5 Natural gas 1.0
Sweden [7]	Heating, DHW, ventilation, auxiliary, facility lighting	**85**	82	Electricity 1.6 District heating 1.0 Natural gas 1.0
Norway [8, 9]	Heating, DHW, ventilation, auxiliary, lighting, appliances	**95**	66	-

[a]NZEB, HVAC only is the primary energy requirement from which the contribution of appliances (small power plug loads) and lighting is excluded.

To distinguish the countries with the easiest requirements to the strictest ones, and to assess the compliance with EC recommendations the analyses were performed for the reference apartment building as follows:

1. The reference apartment building was set up so that it closely corresponded to EC primary energy recommendation with standard use input data from the EN 16798-1:2019 [10] including ventilation, appliances and lighting and occupancy schedules;
2. The energy use of the reference building was simulated with the national input data and corresponding climate files of four selected North European countries;
3. The building and system parameters were changed so that as close as possible compliance with the national NZEB requirements was achieved;
4. The national NZEB configurations given at step 3 were used for energy simulations fed with the EN 16798-1:2019 input data and the ISO 52000-1:2017 primary energy factors in order to assess the compliance with the EC recommendation.

A reference apartment building with seven stories as shown in Figure 2 was used. The net floor area, envelope area and windows area were 3071, 2787, and 694 m^2, respectively. To comply with EC EU Nordic EP=65, the following configuration was used:

- 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 temperature ratio was 80% with a minimum exhaust air temperature limit of 0 °C to avoid frosting;
- The U-value of the external walls, roof, external floor, and internal floor were 0.14, 0.1, 0.12, 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, windows perimeter, and the roof and the internal wall were 0.06, 0.03, 0.05, 0.05, 0.024 and 0.024 W/(m K), respectively;
- The leakage rate of the building envelope was 1.0 m^3/(h m^2) at pressure difference of 50 Pa.

With this configuration and EU input data (Table 3) the reference building with gas boiler and Estonian TRY climate file resulted in 65.9 kWh/(m^2 a) primary energy.

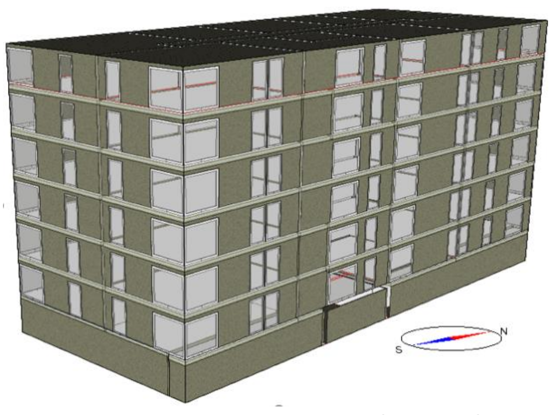

Figure 2. Simulation model of the reference apartment building.

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 [7]. A well-validated simulation software IDA-ICE 4.7 was used to perform dynamic whole year simulations. More details of the analyses are reported in [11].

Table 3. EN 16798-1:2019 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
Boiler efficiency, gas boiler, -	0.95	0.95	1.0	0.95	0.86
Boiler 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

Delivered energy results of the reference building simulated with national input data (Table 3) and climate files are shown in Figure 3. Swedish and Norwegian slightly lower ventilation rate values, high DHW value of Finland and also climate differences explain the difference brought by national input data. In Estonia, it was needed to add on-site electricity generation in order to reach Estonian national requirement. When calculating primary energy, the lowest primary energy factors in Finland and the exclusion of lighting and appliances in Sweden affect the results, Figure 4. In Norway, 1.0 factors for all energy carriers were used as primary energy factors are not in use.

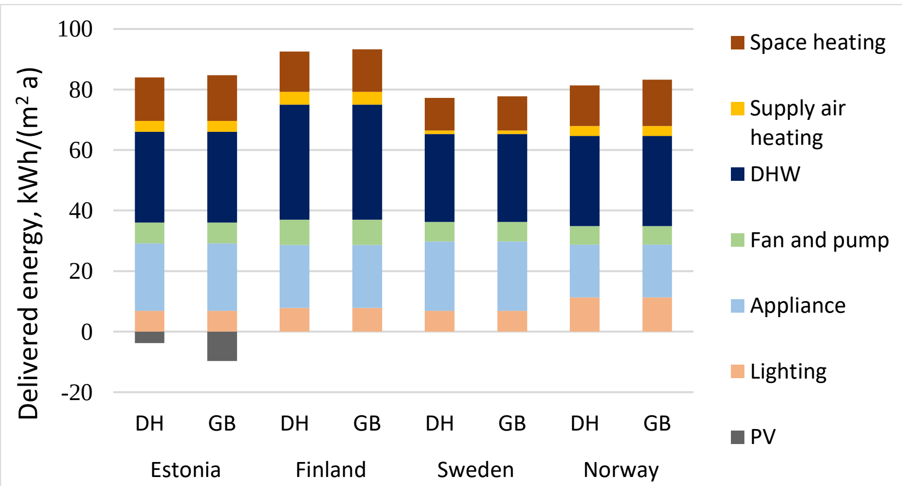

Figure 3. Delivered energy of the reference apartment building calculated with national input data and climate. DH = district heating, GB = gas boiler.

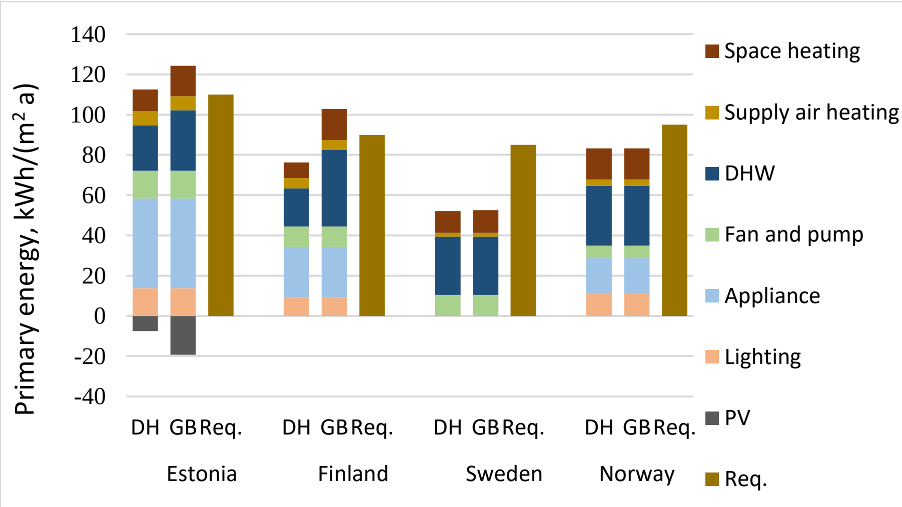

Figure 4. Primary energy of the reference apartment building calculated with national input data and climate. DH = district heating, GB = gas boiler.

Primary energy values in Figure 4 are below national limits for Finland, Sweden and Norway. For Finland, the results with district heating were considered only, because the gas boiler result is rather theoretical as gas networks are almost not existing in Finland. In Estonia, especially with gas boiler, significant amount of photovoltaic has been needed to install in order to comply with national limit. Therefore in Finland, Sweden and Norway there is a room to change some technical solutions in order to end up with primary energy closer to the national NZEB requirements. The following changes were made and the results are shown in Figure 5:

- 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^2K 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.

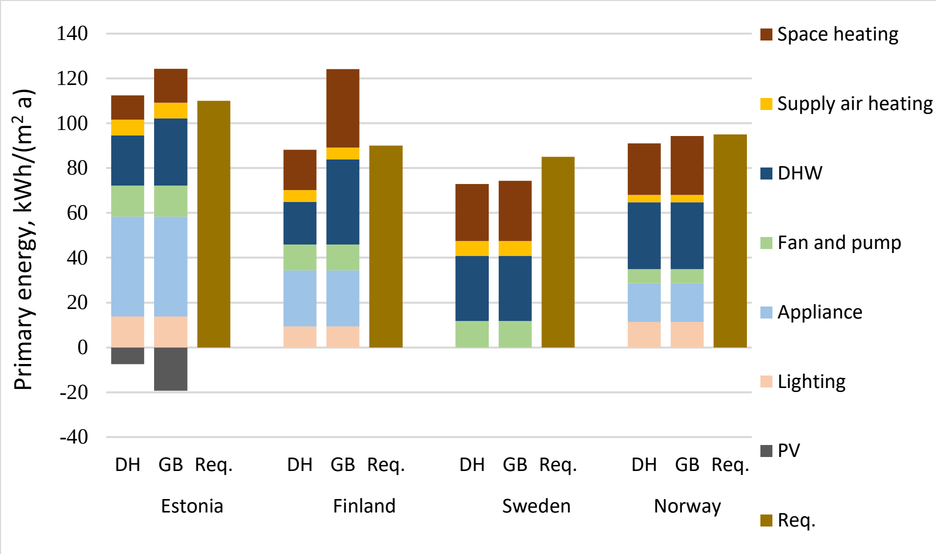

Figure 5. Primary energy in NZEB apartment buildings with changed technical solutions aiming to close compliance with national NZEB requirements.

The results with changed technical solutions show that after Estonia, 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.

To compare national NZEB requirements with the EC recommendation, the reference building configurations with changed technical solutions (= national NZEB, Figure 5) were simulated with input data from the EN 16798-1 (Table 3) and primary energy factors from ISO 52000-1:2017 (Table 2). These final results with normalized input data and primary energy factors show that the Estonian NZEB requirement is the only one which complies with EC recommendations, Figure 6. In the other three countries with the district heating the normalized primary energy was higher than the EC recommendation by approximately a factor of 1.3, 1.5, and 1.7, in Norway, in Finland, and in Sweden, respectively.

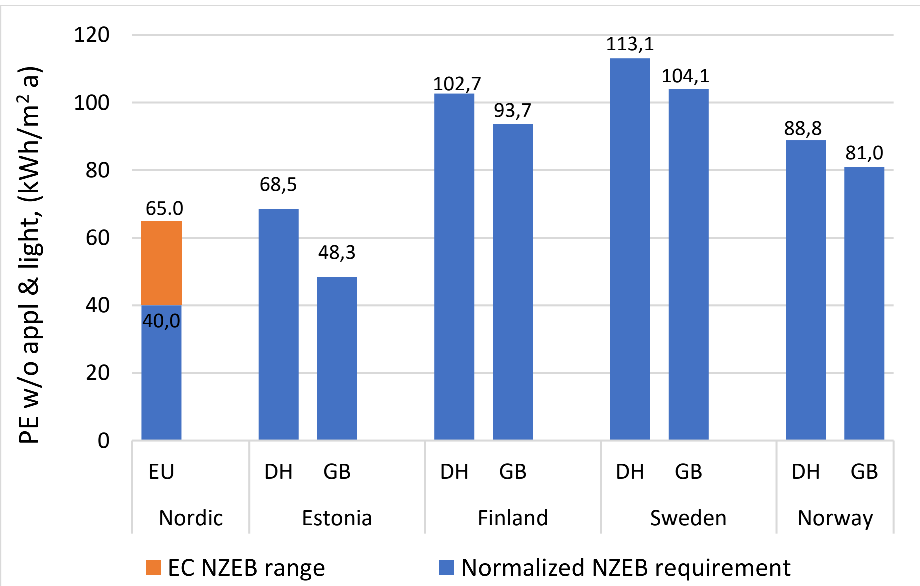

Figure 6. National input data and primary energy normalized national NZEB requirements. Estonian TRY climate file was used for all countries as a reasonable climate normalization within the same climatic zone.

Conclusions

- The results show that because of differences in primary energy factors, energy flows included and input data, the national values cannot be directly compared, but an energy calculation with a reference building is needed for the comparison.
- Benchmarking national NZEB requirements of apartment buildings against European Commission's NZEB recommendation showed that the Estonian NZEB requirement was the only one complying with the recommendation.
- With district heating, the other NZEB requirements were higher than the EC recommendation by a factor of 1.3, 1.5, and 1.7, in Norway, in Finland, and in Sweden, respectively.
- The deviation is unexpectedly high in Finland and Sweden. Some explanation is provided by the fact that in these countries the draft regulation was much stricter than the final NZEB requirements. In Finland, very low primary energy factor values, and in Sweden, not including lighting and appliances, are the main technical reasons explaining a low ambition of the requirements.

References

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