A Standard House – what's that? Houses, standards, real life

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Ever since the 1980s, the notion grows that new or reconstructed buildings can be, as regards their energy demands, much better than those ones which are most usual nowadays. A set of mostly confusing designations is used in this context. Just one designation has an unequivocal meaning, holding a second decade already: passive house. This becomes the only real, stable, time-proven and world-accepted standard.

Buildings made as usual

Houses said to be “standard” don't offer any good example as to their heat and power demand, so why they are named so, setting no good standard? There is a reason for that: they are assumed to be erected or reconstructed according to the rules of the time, i.e., according to the existing standards. If they don't meet the standards of their time, they could be considered to be *substandard*. We can guess that a substantial number of the existing buildings can be like that – either not meeting the standards even in their planning stage, or by not adhering to the project during their construction. They can degrade to a substandard quality during their use as well.

Standards are changing over years, demanding ever lower heat losses. So the label “standard house” is to be accompanied by a remark, which standard is meant, at least from which year. And it should be considered whether the house meets that standard really. Saying *“building which corresponds to time of its erection”* would be more adequate, including an eventual failure to meet the standard from the very beginning or a subsequent degradation of its properties during years.

From sustainable housing to an unsustainable one

Buildings made according to the usual practices of their time functioned well over millennia, meeting the needs of their users without demanding non-disproportionate sources, unsustainable over long time. Countries with a cold winter witnessed rather well-insulated constructions, as thick wooden walls, thick snow layers or multiple wool layers over yurts [1]. Inhabitants of less cold countries were satisfied by heating themselves by the fireplace; sometimes a whole room could be heated. Still warmer countries used non-heated houses where people just wore warm cloths in winter and enjoyed stable temperatures indoors, without the night temperature drop of the outside air. Warm rooms were needed just for a fine manual work in our latitudes, feather bed ensured comfortable sleep even in strong frost otherwise. Heating the whole buildings to the “room temperature” [2] (surely not more than 12 or 15 degrees a century ago, 18 °C according to the mid-20th century standards, 20 °C according to the current standards, and up to 24 °C according to the nowadays reality) would seem like a crazy idea. It would not be feasible after all, too much money and labour would be needed.

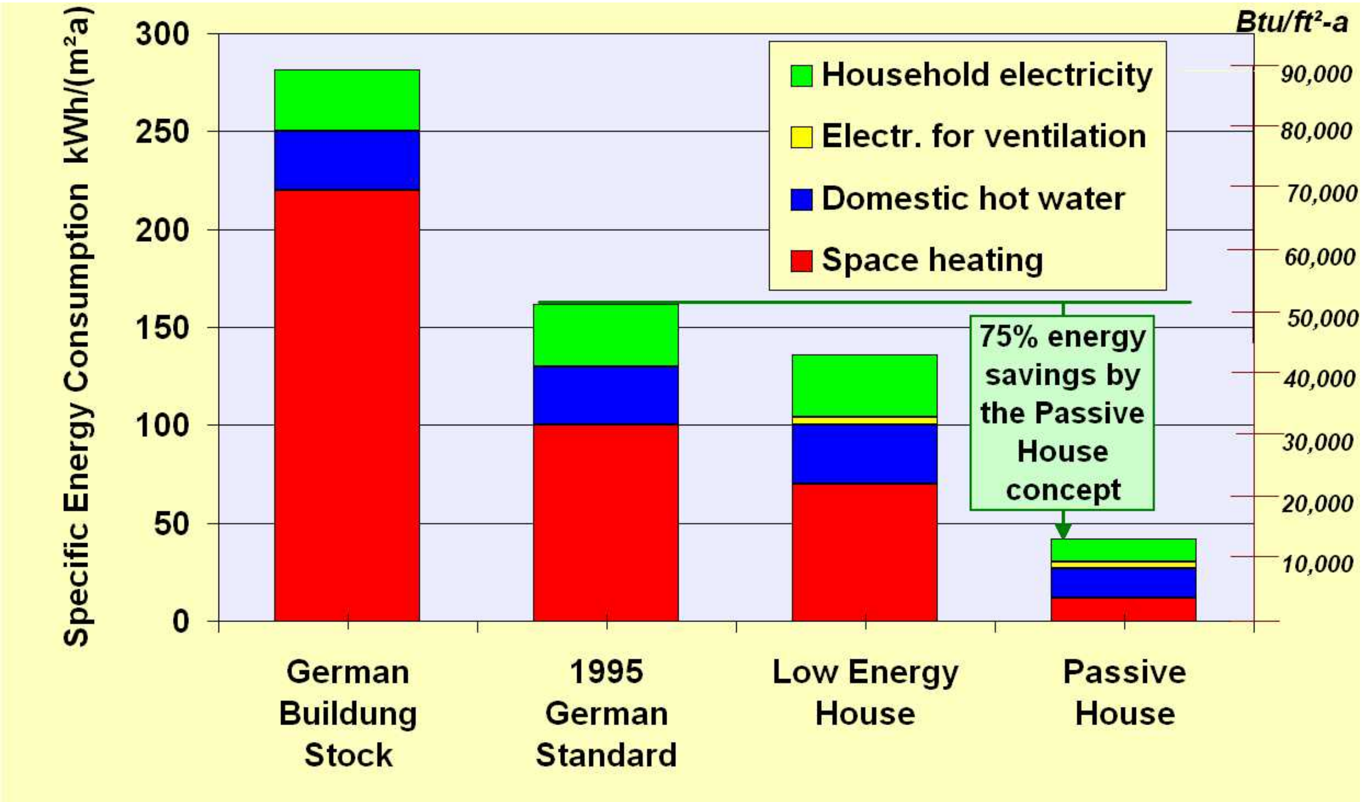
Central heating systems enabled one man to heat up the whole building easily, town heating networks made it even easier, and natural gas made it possible everywhere. I guess that an idea to heat up non-insulated buildings by electricity would not occur even to Jules Verne, but even this is what became common at the end of millennium. The practice of using buildings departed from their real capabilities entirely. Aside from yurts or thick-log cabins, no old buildings were meant to be kept at 20 °C even in freezing weather. The new buildings built since mid 20th century were supposed to be used like that, but their properties did not correspond to that goal: this situation, adequate to the outdated assumption of the coming time of unlimited wealth – let's give everybody what he/she needs – is, however, persisting in the mainstream building industry.

Houses better in some respect

Buildings which are appreciably more efficient in term of heat (or fuel) and electricity supply than those of the same time corresponding to the mainstream are commonly said to be low-energy. Perhaps everybody called his/her house like that if an insulation layer had been applied which was thicker than the minimum one demanded by contemporary building code.

To make the label "low-energy building" less vague, just buildings with external heating demand below 70 kWh/m^{2}a became to be included – those satisfied with a yearly supply of 70 kWh per square metre of the floor of habitable, heated spaces. Assuming a house with 100 m^2 of such floor, the upper limit for room heating was 7 MWh or (× 3,6 GJ/MWh) 25 GJ. However, as such houses began to be erected commonly in Germany, becoming a standard in a sense of the lowest quality permissible by the building code later, the limit for *low-energy* label went down to 50 kWh/m^{2}a – this is the current value [3]. Anyway, pay attention: even if some building is called like that, it's not clear what consumption it has really. Inspection of the bills for heat, fuels and power is the only reliable check. For important buildings, parts of the bills should be published, namely the consumption in units of work, heat or energy which had been paid for.

There are not many low-energy buildings in Czech Republic, adhering to the upper heating supply limit of 50 kWh/m^{2}a; even for the older limit of 70 kWh/m^{2}a the numbers are low. In Germany or Scandinavian countries the numbers are large, however. A part of such buildings obey the limit just by relying on relatively expensive and complicated technologies, like large solar systems with several-week or even seasonal accumulation of enthalpy. Some of these buildings became examples of bad solutions – a disproportionately large heating demand is covered by maximising solar gains or installing large heat-pump systems. Reducing the heat losses would be a better option. Such buildings contributed to the present knowledge that this evolutionary branch was not the proper one. In Czechia, a contemporary example is the experimental house in Podolí.



from: CEPHEUS final public report [14]

Introduction to the passive standard

Passive houses, having an upper limit for artificial heating supply of 15 kWh/m^{2}a in our climate, are simple compared to those technology-packed low-energy houses. They need a minimum of active elements for their perfect function [5-7]. Active elements are necessarily shorter-lived than walls or windows, can be prone to faults and need maintenance. The basic active part of passive buildings is mechanic ventilation with heat recovery (or "coldth recovery" in summer, when heat flows from fresh air to exhaust air). The ventilation system can contain a small heat pump to prepare warm water as well. Eventual subsequent heating of the pre-heated fresh air is to be sufficient to keep the house at comfortable temperature. Passive house needs no further heating system – its name stems from this fact. A nice definition of passive house is given in [8]: "A Passive House is a building, for which thermal comfort (ISO 7730) can be achieved solely by postheating or postcooling of the fresh air mass, which is required to fulfil sufficient indoor air quality conditions (DIN 1946) – without a need for recirculated air."

The requirement that heated fresh air is to be enough for space heating implies the first parameter of passive living house, namely the upper limit for the heating demand. The air is to be not heated over 50 °C (to avoid dust pyrolysis, with adverse effect to the air quality), and there is a maximum of 30 m^3/h of air which can be let in per person. Each cubic metre of heated air brings 36 kJ (30 K temperature difference, 1.2 kJ/m^3 specific heat), per person and hour it means 1.1 MJ. It would amount to 300 J per second, so the achievable heat flux is 300 W per person. Slower ventilation, more reasonable in frosts (20 m^3/h per person), brings some 200 W only. If there is 20 m^2 of floor per person, the implied maximum specific heat loss of the building is 10 W/m^2. The real need of ventilation may be lower for a part of the day, if there is not a full number of persons present. Fortunately, this is balanced by the fact that if some people are present, everybody contributes another one hundred watts of metabolic heat (our body takes some 10 MJ chemical energy in the form of food and air daily, releasing it by oxidation; this energy is to be disposed off as heat to the surroundings). So the limit of 10 W/m^2 (total heat loss of the house in the coldest days, divided by the area of the floor of living spaces) is taken as universally valid limit, whenever space heating is to be provided by fresh air only.

The other passive house parameter, 15 kWh/m^2a, follows from a time integral of temperature difference between indoor and outdoor environment through the heating season in our climate, assuming the worst case as −12 degrees outdoors and 20 °C indoors and the above computed limit of 10 W/m^2 for this case. The usable heat gains from people, appliances, passive solar (through windows) and active solar (from collectors) are subtracted from the theoretical yearly heat demand (from that time integral). A house with large southern glazed areas can easily achieve less than 15 kWh/m^2a even if it needs up to 15 W/m^2 in overcast winter days – from the viewpoint of its yearly balance it behaves well. Such alternative solutions, relying on some form of occasional additional renewable heating (pellets or another stove with a surplus of available thermal output) are as common as the "true passive solutions". Let's remark that warmer climates imply less than 15 kWh/m^2a for the basic passive limit of 10 W/m^2, whereas northern Finland has inevitably larger yearly consumption even if adhering to the basic passive limit.

There exist another two limits for passive houses, differing from all previous "standards". For these, space heating comprised the major part of their energy consumption. Passive standard behaves the other way, sum of another consumptions is always larger than space heating consumption. That new majority is to be limited too! The total consumption of supplied heat, fuels and electricity should be 42 kWh/m^2a at most. However, that's not the final limit, as there is a vast difference if the supply is electricity mostly, or fire-wood. In case of electricity, each unit of supplied power caused a release of at least thrice that amount of so-called primary energy, like in a form of burnt coal (thermal power plants produce heat mainly, dispersed into air or water, just one third of their production is electric work)[1]. The upper limit for primary energy needed to supply a passive house for one year is 120 kWh/m^2a – as the experience shows, this can be achieved even if the house is purely electricity-driven.

These four limits (two latter ones are the most important as sustainability is concerned) imply that passive house standard could be a vital contribution to the climate protection..

[1] A remark on the ratio of final energy – the supply to the very house – and primary energy: for water power plants, it is of course much larger than one third. However, for any electricity saved we have to assume that it leads to switching-off or reducing the load of those plants whose use is expensive, namely the fossil power plants. For these we can take their CO_2 emissions as one kilogram per one kWh of electricity. Water, wind and nuclear plants work at full load all the time, having zero or very low fuel costs.

Verifying if the limits are obeyed

Limits for passive houses are relative to living space floor. As the only satisfactory theoretical verification if they are obeyed, a computation with help of PHPP [9] is considered. As measurements show, it agrees with real consumption of passive houses well. Of course, measurements are the final proof whether the limits are obeyed or not. Energy bills from several years of using the building are usually the only accepted final document, if there are public subsidies offered for construction in passive standard or reconstruction to this standard.

Another standard exists in Austria, *klima:aktiv Haus*. Apart from energy consumption it contains further parameters concerning the quality of the house. [10]

Super-standard passive houses

Since 1970s, people began to be interested to build a bit better than the contemporary mainstream. Even for the passive standard such efforts exist. They are of two types, essentially. The first kind consists in using even better thermal insulation employing natural insulation materials (no-regret ones, whose generous application does not increase fossil fuel use), and natural construction materials (wood, earth). The energy consumption of the building can be reduced this way, as well as the fossil energy embodied in its construction. The house can be a hundred-year stable store of non-oxidised carbon (the more straw and wood the better), whose very construction can be favourable for climate protection, instead of being a burden. This approach is very popular in German-speaking countries.

An even simpler way to minimise energy consumption consists in increasing the ratio volume / surface area: building either continuous rows of houses or, preferably, large houses with many flats. Compared to single family houses, each flat has a lower number of cooled outer surfaces.

Such top-quality passive houses can be further equipped with improved windows (with larger solar gains and lower night heat and light losses [11]) and get below the 5 W/m^2 as maximum specific heat loss. This can be covered e.g. by a bioethanol burner or by the people present in the house. The yearly supply of external heat may go down to 5 kWh/m^{2}a; assuming 100 m^2 of floor of living spaces, this amounts to 500 kWh/a or 1,8 GJ/a. 80 l of ethanol or 80 m^3 of biogas would give that, or 50 m^3 of natural gas. No separate heating device is needed, just more frequent cooking on a gas stove during dark winter weeks might suffice. Burning ethanol or methane, even a part of the difference between their lower and upper heating value can be harvested [12], as about one half of the produced water vapour is condensed in the core of the ventilation system, the heat-recovery device.

Another technology can increase the summer comfort in hot weather – draft ventilation during the night, cooling the house well. The draft should lead through two storeys at least, using open doors and windows. Ingress of people, ground animals or bats can be prevented by a lattice, sufficient overhangs or tilted blinds may provide enough protection against sudden storms.

Super-standard passive houses offer an excellent possibility of flame heating without any chimney and a guaranty that even with heating system failure they will attain much of their comfort. However, this improvement should not be overrated. Majority of consumption is not due to heating, and further minimising the minority is not worth too much effort. Even a “common” passive house brings the basic contribution to the climate protection. A contribution which is not easy to increase, as far as the burden represented by using the house is concerned.

Houses as energy suppliers

The second type of efforts consists in integrating expanded renewable energy sources to the new passive buildings and retrofits. In principle, a passive house needs not have any active solar system, neither a warm-water one nor a photovoltaic one. Many houses do have a small thermal solar system at least, to cover the summer demand for warm water.

A more generously dimensioned solar collector area can produce large summer gains to be supplied to the surrounding buildings, void of their own solar systems. In a yearly balance, the total energy consumption of the house can go far below those 42 kWh/m^{2}a. If it is below 5 kWh/m^{2}a, the house can be labelled “zero energy” [13], if the yearly balance goes below zero (the house produces more than it takes), the label is “energy-plus”. But this is no matter of building technologies and standards, being just a matter of placing the renewable sources into the building (they may be part of the construction, as whole pieces of roof or insulation facade). Large solar collectors may be nice on a modern building and some less suitable area for their placement can be kept free. Integrating them during the construction can be cheaper than installing them separately elsewhere.

A passive house can incorporate even a vegetable oil-fuelled motor producing a surplus of heat and electricity, or a wood-chip boiler heating the surrounding buildings as well. But, rigorously taken, this does not improve the energy balance of the house, even in the heating season, on the contrary: the device produces a bit less usable heat (and electricity) than the original energy of fuel+oxygen system was, as part of the reaction heat escapes through the chimney.

Buildings being far from another ones, having no customers for summer surpluses of warm water, can be covered with PV panels and supply electricity to the grid. An oil or biogas engine can feed the power grid as well, covering the building's heat demand.

Zero-energy and energy-plus houses are appropriate for institutions or experts who love the installed technologies and are able to maintain them. A third-party alternative may be OK too. E.g., the cellar can be rented to somebody, who supplies a group of houses by heat from a wood-chip or pellet boiler.

Speaking about zero-energy and energy-plus buildings, it should be discriminated if just their winter space heating is compensated, or the whole external energy supply of the house. Both cases are common, but there is of course a large difference between them. Compensating just the space heating demand means targeting just the minority of yearly consumption, if it's a passive house. Further, it's not the same if the winter consumption is fossil electricity and the summer production is heat – the local balance of the house can be below zero, but the primary energy consumption can be still some 80 kWh/m^{2}a.

Cost-efficient Passive Houses as EUropean Standards

– this is a name of CEPHEUS [14] project, running 1998 to 2001. The project and its outcomes [15] launched a steep expansion of building in passive standard, as well as reconstructions to this standard. Reconstructions have by far the largest potential for increasing the living comfort, European energy security and, above all, for climate protection. The first part of the project's name emphasises that passive standard is no misplaced luxury, but a profitable measure: extra costs (some ten per cent of the investment) offer “lot of music”, even if ignoring the better comfort, considering just the reduced running costs. Any return to the low fossil fuel prices seems to be excluded. And the fossil carbon prices will be increased artificially as well, through tradable permits or taxes; this is utterly indispensable for climate protection.

Taking the passive standard for the proper European standard implies that building of lower quality are substandard, inferior. Those people who live or work in passive houses do look at non-passive houses this way. They would never return to a “mainstream house”. Demand for passive houses is several times the offer, market prices of passive houses are so high, that extra costs for their erection are negligible in comparison. Number of newly built passive houses (and passive reconstructions) rises almost twice each year in Austria [16].

Many texts on passive houses summarise basic principles to be kept. I've mentioned the energy parameters:

Upper allowable specific values for passive house	
heat supply (-12 °C outside)	10 W/m^2
yearly space heating consumption	15 kWh/m^{2}a
yearly supply to the house	42 kWh/m^{2}a
primary energy released for that	120 kWh/m^{2}a

To obey these limits, the needed measures are:

Contain the house in an excellent thermal insulation with no thermal bridges	$U \leq 0{,}15$ W/m^{2}K
Employ the best triple glazing and adequate frames (integrated to the surrounding insulation layer)	$U \leq 0{,}8$ W/m^{2}K
Ensure an excellent air-tightness of the house, repeatedly checked	$n_{50} \leq 0{,}6$ h^{-1}
Use a mechanic ventilation, recovering vast majority of heat,	$\geq 0{,}8$
with excellent ratio *recovered heat / fan electricity*	≥ 10
Using the most energy-efficient technologies for all other appliances	

The above technology demands hold for any house which is to be comfortable during hot periods. Just in winter the last item could be skipped. It might seem that even the preceding item has nothing to do with comfort, but: low electricity consumption can be achieved just by low velocities of airflow in the system, and low velocities reduce the noise level. It is possible to achieve low noise level, such that nobody is inclined to switch the ventilation off to get rid of noise, even through dampers, but their inclusion increases power demands further. And finally, just a house obeying the first three rules is really durable, not degrading due to moisture condensing in its construction.

Conclusion

Passive standard is the only one to be regarded a proper *standard for today's and future buildings inhabited by people all the year round*. Majority of existing buildings may achieve it when reconstructed, or miss it just a bit and become not-so-much substandard – with a thorough reasoning why a passive limit was not reached. The mainstream way of building and repairing persists just because the passive quality is offered still by a minority of planners, contractors and craftsmen. Let's hope it will turn to majority soon.

Additional requirements, relevant for climate protection, may include preferring wood and natural insulation materials and minimising energy-intensive components (aluminium, steel). New or reconstructed buildings may offer large insolated areas not used as windows, where large active solar systems can be attached. Photovoltaic panels can be used everywhere, even in our climate their energy payback is good. Thermal solar collectors sized so that they give large surpluses in summer are a good option wherever they can supply neighbours for decades, or feed their heat into the existing grid. Solar technologies can improve the yearly energy budget of the house substantially, compared to the basic limits of 42 and 120 (kilowatthours per square metre and year) – Austrian SOL4 is an example, with the yearly sum for heating being compensated by PV power production (the largest passive office building in Austria in 2005, over 2 thousand square metres floor space, Nullheizenergiehaus).

A further suitable supplement of passive and substandard houses is rainwater collection and use. It improves comfort a lot (esp. for washing), decreasing the consumption of chemicals, potable water, sewage system load during rains and landscape drying (ever more serious with climate change). It calls for another water piping in the house; this can be supplemented even by “graywater” pipes, or solar-heated rainwater for washing machines. A poor-man alternative is behaviour change – water can be even carried for some purposes.

For non-passive houses, the user behaviour influences energy consumption a lot. It becomes smaller, surely in absolute values, in passive houses. People don't let open windows in cold or hot days; they prefer fan-driven ventilation with heat recovery as a more comfortable option. But one principal influence exits: *how large floor area is demanded* by the user. Even the world's best passive house or flat, having 50 m^2 per person, cannot match a bit less efficient, but much smaller residence. Computing specific consumption per square metre is adequate as far as buildings are regarded. Relating it to one person and year is the proper metrics as far as equity and climate protection are concerned. Consumption not related to the building itself should be included in the latter case: daily commuting to school or workplace, holiday travels. An inferior dwelling, whose inhabitants avoid using cars and planes, may result in a smaller ecological footprint than a passive building not accessible by public transport or by bike.

I'm adding that to encourage those who don't work or live in a passive building, there is a majority of us unfortunately. Even another activities of ours do count. However, if we are to build or reconstruct, I know no alibi why the passive standard should not be striven for. It is not only the best "supplementary pension insurance", but also a guaranty of good conscience, when somebody asks twenty, thirty years later what we've done to slow down the climate change [17], [18], [19].

The European Parliament is aware of that. Its *resolution of 31 January 2008 on an Action Plan for Energy Efficiency: Realising the Potential* in its point 29: "Calls on the Commission to propose a binding requirement that all new buildings needing to be heated and/or cooled be constructed to passive house or equivalent non-residential standards from 2011 onwards, and a requirement to use passive heating and cooling solutions from 2008". [20]

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