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How much insulation is needed? A low-consumption, smart comfort standard for existing buildings

Minimum standards for existing buildings can guide owners along the most efficient route to end reliance on fossil fuels for heating.

Knowing the destination

For every building, reaching the destination of decarbonisation is contingent upon a combination of an efficient building fabric and a zero-emissions heating source for hot water and residual space heating. To efficiently arrive at this destination in the short time we have, and being cognizant that buildings are renovated only once every 25 to 30 years, each building needs a clear path to zero emissions in as few steps as possible.

Unless a full retrofit can happen in one go, the first step is often to improve the efficiency of the building's envelope. The second step tends to be fitting or connecting to the low-carbon heat source. *But what is the appropriate insulation standard to support the efficient use of zero-emissions heat?* Approaches to setting standards for existing buildings are commonly based on economic assessments and political viability. Building physics and technical solutions should underpin this assessment, however, not just economic evaluation. Point-in-time economic analyses are unsuitable to dictate standards that will serve buildings for decades, as is made clear by recent energy price volatility.

A minimum building efficiency or insulation standard should define the level that enables a switch to renewable heat and ensures this heat is delivered and used efficiently.

A practical minimum building performance standard

A standard is needed that defines the insulation, draught proofing and ventilation levels, which, when combined with appropriately sized pipes and radiators to deliver the heat, ensure the building can be heated to the required internal temperatures using lower temperature water.

Heat generators delivering lower flow temperature water are more efficient. This is particularly important for the primary zero-emissions solutions of electrification mainly via heat pumps,[1] and district heating,[2] but also allows combustion appliances to work more efficiently. More efficient heating means lower energy use and lower bills.

Commonly, gas and other fossil fuel boilers deliver heat in pipes and radiators at around 70 degrees centigrade, but heat can be delivered more efficiently at around 50 degrees or below. Higher levels of insulation hold in the heat longer and larger radiators and pipes have greater heat emitting surfaces, delivering more heat into a space. A combination of the two enables target internal temperatures to be met with lower flow temperature water.

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[1] Rosenow, J., & Lowes, R. (2020). *Heating without the hot air: Principles for smart heat electrification*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/heating-without-hot-air-principles-smart-heat-electrification

[2] International Energy Agency (IEA) Technology Collaboration Programme on District Heating and Cooling. (2021). *Low-temperature district heating implementation guidebook*. https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts2

This benefits existing fossil fuel heating systems as condensing boilers often do not condense because the temperature at which they run is set too high.

The standard should also enable heating schedules to operate flexibly at different times of the day without compromising comfort. By holding heat longer, the energy efficiency of the building envelope and heat storage in tanks and pipes enable heating to be flexible, in other words, scheduled to scale back at times of high electricity demand and scale up when there is abundant renewable electricity available. Smart controls can ensure comfort levels are maintained.[3]

Enabling homes to be heated flexibly is extremely useful for electrified heat, allowing new electric loads to be absorbed efficiently by the electricity system, reducing costs for all.

Why do we need it?

- **Provides a clear, practical pathway:** Standards clearly define the energy efficiency and building characteristics needed to prepare a building for zero-emissions technologies.
- **Offers a no-regrets solution:** A standard that defines the minimum characteristics that will enable cost-effective decarbonisation, whatever the final heat source, is a no-regrets solution. Building elements do not need to be altered at a later date. Building owners can go further if they choose, and select heat storage, smart controls and rooftop solar to reduce energy costs, further improve resilience and reduce demand.
- **Offers access to flexibility benefits:** A standard allows consumers to safely subscribe to beneficial tariffs and other retail offers that reward demand-side flexibility.

Economic benefits of low-temperature district heating

The International Energy Agency (IEA) Technology Collaboration Platform identified nine efficiency gains for low-temperature district heating. These benefits are available when the building stock is suitable for lower flow temperatures.

- More heat is extracted from geothermal wells because lower temperatures of the geothermal fluid can be returned to the ground.
- Less electricity is used in heat pumps when extracting heat from sources with temperatures below the heat distribution temperatures because lower pressures can be applied in the heat pump condensers.
- More excess heat is extracted because lower temperatures of the excess heat carrier will be emitted into the environment.
- More heat is obtained from solar collectors because of lower heat losses.
- More heat is recovered from flue gas condensation because the proportion of vaporised water (steam) in the emitted flue gases can be reduced.
- More electricity is generated per unit of heat recycled from steam in combined heat and power plants because higher power-to-heat ratios are obtained with lower steam pressures in the turbine condensers.
- Higher heat storage capacities, because lower return temperatures can be used in conjunction with high-temperature outputs from high-temperature heat sources.
- Lower heat distribution losses with lower average temperature differences between the fluids in heat distribution pipes and the environment.
- Ability to use plastic pipes instead of steel pipes to save cost.

(IEA, 2021.)

[3] Rosenow & Lowes, 2020.

- **Can speed up decarbonisation**: When the building has met the standard and is ready for zero-emissions heat, building owners who are willing and able can decarbonise immediately either via an individual solution or a district heating system. Meeting the standard assures them that zero-emissions heating will be efficient and comfortable.
- **Enables efficient integration of buildings into the electricity system**: A standard ensures heat is electrified efficiently, and flexibly allows new loads to be absorbed into the system at the lowest cost to all. The standard also enables buildings to offer important storage and demand response services to the grid.
- **Enables district heating to run more efficiently:** The cost reduction potential of running district heating on lower temperatures across Europe is estimated at €14 billion per year, representing a net present value of more than €200 billion.[4]
- **Helps supply chain to scale up:** A minimum standard that all buildings must meet enables the supply chain to define standard packages and encourages the integration of efficiency and heating industries to better serve the customer.
- **Provides immediate benefits**: Shifting to lower flow temperatures creates efficiency savings immediately and reduces fossil fuel use. Heating with lower flow temperatures also creates less wear and tear on heating system elements, meaning less breakdown and maintenance.

Development of the standard in the Netherlands

In March 2021, the government of the Netherlands published a home insulation standard designed to future-proof homes in readiness for connection to a sustainable heat source with lower temperature heat.[5] The standard supports the national, area-based phaseout of the fossil gas system by 2050. The standard is designed so that the homes improved to meet it will not have to be insulated again and will be ready for whichever sustainable heat solution is defined by the local authority as most suitable in their area. The standard thereby links individual actions at the building level to the neighbourhood approach.

A practical and proportional approach was taken to the design of the standard, limiting architectural intervention, ensuring space within the building envelope is protected rather than encroaching on living space, avoiding radical adjustments to the heat emitting system (pipes and radiators/underfloor heating), and limiting the requirement for neighbours to cooperate.

The standard sets out the maximum heat demand per square metre for different home types as shown in Table 1.[6] In development, the insulation requirements for 16 home archetypes were analysed. By including a measure of compactness of the house, the number of archetypes could be reduced to just four: pre- and post-1945 single-family homes and multi-family homes. The compactness of the dwelling is measured as a relationship between the internal floor area and the area of the external shell.

[4] Assuming future annual EU district heat sales of 950 TWh and a temperature reduction of 30 °C. IEA, 2021.

[5] Lower temperature heat is defined as a delivery temperature of 50 degrees.

[6] Ministry of the Interior and Kingdom Relations of the Netherlands. (2020). *Standaard en Streefwaarden uitkomst traject begeleidingscommissie* [Standard and target values outcome of the supervisory committee]. https://www.tweedekamer.nl/kamerstukken/brieven_regering/detail?id=2021Z04724&did=2021D10454

Table 1. Dutch home insulation standard formula

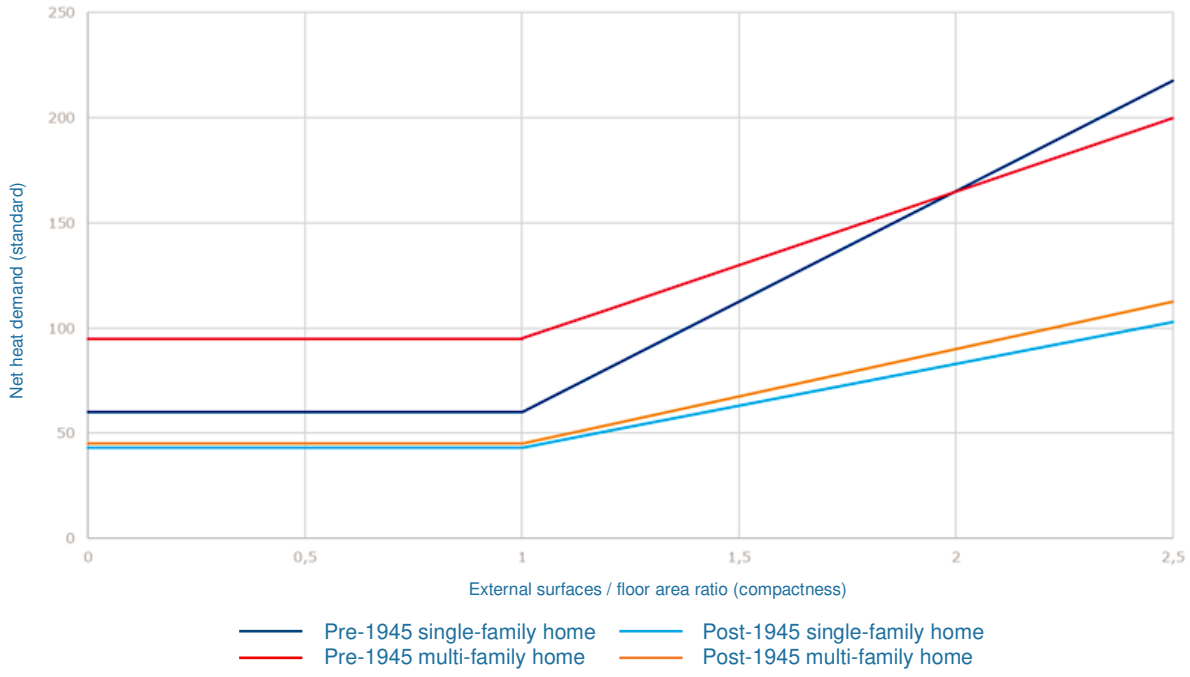
House type	Proposed standard	
	Compactness*	Net heat demand (kWh/m^2)
Pre-1945 single-family home	< 1.00 ≥ 1.00	60 60 + 105**
Post-1945 single-family home	< 1.00 ≥ 1.00	43 43 + 40**
Pre-1945 multi-family home	< 1.00 ≥ 1.00	95 95 + 70**
Post-1945 multi-family home	< 1.00 ≥ 1.00	45 45 + 45**

* Sum of external surfaces of the building divided by total floorspace.

** The higher value is applied to units above 1.00 on the compactness indicator.

More compact homes, for example apartments, with a compactness measure of 1, have one net heat demand standard. For less compact homes, with a compactness value of 1 or higher, the standard is adjusted in line with the proportion of external shell to internal floor area as illustrated in Figure 1.[7]

Figure 1. Graphical representation of the standard for archetypes of different compactness



The standard for pre-war (pre-1945) homes is less reaching than for post-war homes as shown in Figure 1 and through the reference homes in Table 2. This is due to avoiding a requirement for solid wall insulation. Solid wall insulation installation has greater aesthetic, social and economic barriers than cavity wall insulation. For pre-war homes, complying with the standard alone will not enable them to be heated with low-temperature sources. Improvements to heat emitters, extra insulation measures or a higher temperature heat source is needed.

[7] Aedes. (2022). (online) Standaard: netto warmrevraag. https://aedes.nl/media/afbeelding/grafiek-standaard-netto-warmaanvraagpng

Table 2. Example or reference home types and applicable standard[8]

Example/reference house	Proposed standard	
	Floor area and compactness	Net heat demand (kWh/m^2)
Mid terrace, built 1920	103.6m^2 1.8*	144
Detached house, built 1988	225.4m^2 2.1*	87
Apartment built, 1925	47.4m^2 1.3*	116
Apartment built, 1968	92.1m2 0.9*	45

* Sum of external surfaces of the building divided by total floorspace

The standard is defined as a performance metric for the whole house as outlined above and expressed as *minimum* and *target* values for each building component, coupled with values for gap sealing and ventilation. This allows building owners to renovate in one step or work towards the standard at the natural maintenance, replacement and conversion triggers. The minimum values show the minimum threshold that each element must meet for the home to reach the standard. The target values show the target performance which, if met by all elements, means the house would exceed the standard. If some elements meet the standard, others may not need improvement. Table 3 below shows these values.

Achieving the standard for post-war homes would align with an Energy Label A or B class, pre-war homes would indicatively achieve a D label.

At present, the standard is advisory rather than regulated. The decision on whether to require landlords to comply with the standard has been deferred to the next Parliament. In the interim, the government is considering adaptation of the rent regulations and the house valuation system to stimulate adoption in the rented sector. Since August 2021, the standard has been incorporated into and communicated via the Energy Label for homes assessed since January 2021.[9] The standard is also included in public information on home renovation.[10]

The National Home Insulation Plan launched in April 2022 aims to address the homes that do not yet meet the home insulation standard. It aims to insulate 2.5 million homes by 2030, starting with the worst performing homes, those with an energy label of E, F or G. These homes will take one or two steps towards the standard coupled with the aim that 1 million homes will go all the way to achieving the standard.[11]

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[8] Example home size and compactness taken from Annex 7 of Nieman. (2021). *Rapport standaard en streefwaardes bestaande woningbouw.* [Report on standard and target values for existing housing]. https://www.rijksoverheid.nl/documenten/rapporten/2021/02/28/rapport-standaard-en-streefwaardes-bestaande-woningbouw

[9] Rijksdienst voor Ondernemend Nederland (RVO). (2021). *Standard and target values for homes insulation.* https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/standaard-en-streefwaarden-voor-woningisolatie

[10] Rijksoverheid. (2022). *National Improve Your Home platform.* https://www.verbeterjehuis.nl/waarom-duurzaam-en-aardgasvrij-wonen/wanneer-is-mijn-isolatie-goed

[11] Rijksoverheid. (2022, April 2). *Kabinet start landelijke Energiebesparingscampagne en komt met Nationaal Isolatieprogramma om 2,5 miljoen woningen snel te isoleren* [Cabinet starts national Energy Saving Campaign and develops National Insulation Program to quickly insult 2.5 million homes]. https://www.rijksoverheid.nl/actueel/nieuws/2022/04/02/kabinet-start-landelijke-energiebesparingscampagne-en-komt-met-nationaal-isolatieprogramma-om-2.5-miljoen-woningen-snel-te-isoleren

Appendix

Table 3. Comparison of standard and target values for building elements in the Dutch home insulation standard[12]

	Minimum values that add up to the standard	Target values
Explanation	**Each element should meet this minimum threshold for the house to reach the standard.**	**If the target for all elements is met, the house would exceed the standard. If some elements achieve the target value, others may not need improvement.**
Roof	Insulation R value = 3.5 m^2K/W (8-15cm, depending on the insulation material).	8 m^2K/W (about 35cm of insulation).
Floor	Insulation R value = 3.5 m^2K/W (7-14cm, depending on the insulation material and type, under the floor).	3.5 m^2K/W (about 14cm of insulation).
Facade	1.7 m^2K/W (pearls, flakes or foam in the cavity), for post-war homes only.	6 m^2K/W (about 26cm of insulation).
Panel (unglazed panel in window/door)	If present: insulation value of 1 m^2K/W (40mm sandwich panel).	1.4 W/m^2K (insulated).
Windows and frames	U-value window = 1.4 W/m^2K (HR++ glass[13]), in combination with an insulated door or 1.0 W/m^2K (triple glass).	1.0 W/m^2K (new triple-glazed door).
Front door	1.4 W/m^2K (insulated).	1.4 W/m^2K (insulated).
Ventilation	Natural supply and mechanical extraction in toilet, kitchen and bathroom, or balanced ventilation with sensor control in living room and master bedroom.	Balanced ventilation with heat recovery, control on inlet or removal by CO^2 measurement.
Gap sealing	Airtightness qv;10 = 0.7 dm3/sm2 (improved crack sealing of windows and doors and connection façade and roof)	Airtightness qv;10=0.4 dm3/sm2 (further improved gap sealing of windows and doors and connection façade and roof through a professional)

[12] Government of the Netherlands. (2021). *Standaard en Streefwaarden: uitkomst traject begeleidingscommissie* [Standard and Target Values: outcome of the process of the supervisory committee]. https://www.rijksoverheid.nl/documenten/rapporten/2021/03/18/standaard-en-streefwaarden-uitkomst-traject-begeleidingscommissie

[13] Highly efficient, coated and gas filled double glazing. For example, AA glas. https://www.aaglas.nl/alles-over-glas/het-verschil-tussen-verschillende-soorten-hr-glas

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