**TECHNOLOGY FACTSHEET**

# INSULATION OF THE BUILDING ENVELOPE - OTHER DWELLING TYPES

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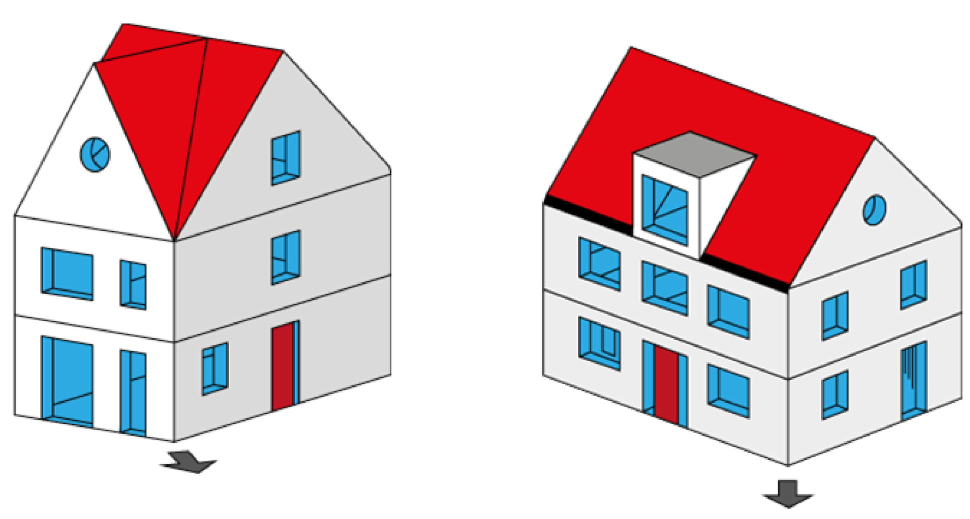
| Date of factsheet | 10-9-2021 |
| Author(s) | Robin Niessink |
| Sector(s) | Households |
| Subsector | Other dwelling type |
| ETS / Non-ETS | Non-ETS |
| Type of technology | Energy saving |
| Collective or individual application | Both |
| Description technology (incl system boundaries and boundaries for application) | Thermal insulation is a way to reduce the heat demand of a dwelling. Consequently this reduces the energy use related to space heating and improves thermal comfort. A good insulation level is also a requirement for a low temperature heating system. There are different insulation measures, different insulating materials and different layer thicknesses corresponding to different heat resistances/Rc-values in m2 K/W. This factsheet looks from an integrated modeling perspective to insulation. Based on a number of inputs, the factsheet presents costs, effect on heating demand (space heating only) and avoided CO2 emissions, associated with thermal insulation measures resulting in a specific label improvement. The figures in this factsheet are meant to model insulation on an aggregated level (the building stock).<br><br>Values on costs and savings are obtained from the TNO Variatietool (TNO, 2021). This tool comprises a dataset from the WoOn energy module that consists of socio-economic and energetic characteristics of a representative sample of approx. 4.500 dwellings in the Netherlands. The data contains different energy measures (insulation and/or installation measures, combined in packages) and associated costs and savings for these measures, resulting in different label improvements of these dwellings. The changes in energy use and energy labels are calculated by DGMR (more info in 'Effect on Heat Demand'). For this factsheet, it was opted to relate the heat demand and costs to the change in energy label (looking at Rc-values of the specific measures is also possible, but requires a more detailed approach). Only label improvements that are realised by improving the thermal insulation are taken into account (label improvements can also be realised by improving the heating installation or solar PV but these are out of scope). Moreover, an average investment and average heat demand reduction for dwellings that go from one specifc label (or label group) to a better label (or label group) is calculated. Types of thermal insulation measures that may be included in a label improvement are roof, wall, floor and improvement of glazing. In most cases only a selection of these measures is needed to achieve a specific label improvement.<br><br><br>*Figure 1. BENG reference corner house and BENG reference detached house*<br><br>Note that for each part of the dwelling envelope a variety of measures is possible in the packages in the Variatietool, for instance:<br>• Wall insulation can relate to either cavity wall, panel or inner/outer wall insulation (whichever applicable).<br>• Roof insulation can relate to either a sloping roof or a flat roof (whichever applicable).<br>• Energy efficient glazing replaces either single or double glazing (whichever applicable).<br><br>Scope of this factsheet:<br>• This factsheet considers only a part of the residential sector (see field 'Subsector'). 'Other dwelling type' in this case refers to all non-terraced houses and non-apartments. This category consists of detached houses, semi-detached, and corner houses. (Detached house: https://en.wikipedia.org/wiki/Single-family_detached_home)<br>• A change in space cooling demand due to insulation measures is not taken into account.<br>• Although collective application of insulation by housing cooperatives (e.g. multiple dwellings in a single project) may reduce overall investment costs due to 'scaling up', this factsheet considers costs related to individual application. This also means further cost reductions are possible. More assumptions on costs can be found in the costs section.<br><br>*Disclaimer: The Variatietool is based on a relatively large dataset in which data from WoON and DGMR calculations on the impacts of energy-related measures are combined. Care has been taken in the data preparation for the factsheet. Nevertheless, because of the selections on specific label improvements (through insulation measures only) for specific housing types, sometimes no homes (indicated as N/A) or only few homes (i.e. less than 50) remain in the data set (resulting in a low sample size N). This introduces some degree of uncertainty, for instance in the representativeness of average savings on heat demand for certain label improvements. It is recommended that the user of this data is careful when drawing general conclusions at the housing stock level.* |
| Degree of industrialization (plug-and-play) | Nowadays, certain pre-fabricated (prefab) options exist to insulate a dwelling. For instance prefab walls which can be attached to the house. These prefab options are prefabricated in a factory. This option is plug-and-play and easy to fit in with a renovation (or new construction).<br><br>Collective application of insulation (e.g. multiple dwellings in a street) may reduce overall project related investment costs due to scaling benefits. Upscaling is also possible in the manufacturing industry, thereby reducing production costs.<br><br>A report by EIB suggests that standardization and streamlining of the production process could save 10% of total production costs (EIB, 2018). This potential can be realised through better use of production lines (by a single operator) and replacement of labor with capital (robotisation). This reduces material costs (extra material costs caused by manufacturing errors) and labor costs. A trend like this could eventually lead to reduced market prices for thermal insulation. |
| Contribution to reduction of peak energy demand | A substantial improvement of the insulation of the building envelope significantly reduces peak heat demand. This peak heat demand occurs on the coldest winter days, especially in the morning, when heating up the dwellings. At neighborhood level good insulation results in a reduction of peak load of the relevant energy network for heating (gas, heat or electricity). Eventually good insulation at neighborhood level means that the overall dimensions of new energy infrastructure (e.g. pipes, buffers) may be smaller which lowers costs. In case of neigborhood heating with electricity (e.g. heat pumps) no or limited grid reinforcement may be needed. |
| TRL in 2020 | TRL 9 |
| | Commercial technology |

**TECHNICAL DIMENSIONS**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Factsheet unit | Functional unit<br>GJ | | | | | | | | | | |
| | NL | PJ | Current (2020) | | | 2030 | | | 2050 | | |
| Potential heat demand reduction (for this Subsector) | | | | 12 | | | - | | | - | |
| | | | 12 | – | 12 | Min | – | Max | Min | – | Max |
| Market share | Dwellings in the NL | % | | - | | | - | | | - | |
| | | | Min | – | Max | Min | – | Max | Min | – | Max |

| | |
|---|---|
| Technical lifespan (years) | 75-100 |
| Progress ratio | |
| Hourly profile | Yes |
| Explanation | The unit used in this factsheet is 'annual heat demand in GJ/year per dwelling'. Heat demand is provided by a heating installation (such as a gas-fired boiler, heat pump or district heating) with a specific efficiency. This factsheet does not indicate what the energy use and savings for a certain energy carrier are. Only the effect on heat demand of the dwelling is shown.<br><br>For the purpose of this factsheet potential heat demand savings have been calculated for this subsector (see field 'Subsector') of the dwelling stock. The total number of dwellings with a certain label (or within a certain label cluster) is determined from the label distribution for this housing type which comes from the ENSYSI-model (PBL, 2015). From the Variatietool's frequency distribution of label improvements (by insulation measures only), it is known what percentage of dwellings is improved to DC, B, A and to A+. From this, the total number of dwellings in the stock corresponding to each of these label improvements is calculated (extrapolated). These numbers are multiplied with the corresponding heat demand savings (the figures shown in the table in the 'Effect on Heat Demand'). The savings are aggregated over the possible label improvements. This means that, in the aggregated savings, all the dwellings reach at least label DC and a smaller share reaches labels B, A and A+ (label improvements denoted with N/A in the 'Effect on Heat Demand' are omitted in the calculation). The resulting total potential is shown in the field 'Potential heat demand reduction' (out of the total savings, 6,8 PJ savings comes from dwellings from GFE, 4,6 PJ savings comes from dwellings from DC, and 0,5 PJ of savings comes from labels better than C).<br><br>Technical lifespan: Most insulation materials last 75 to 100 years if applied correctly. Only cellulose and flax plates have a slightly short lifespan of at least 50 years. (Milieucentraal, 2021)<br><br>Heat demand profiles (on hourly basis) on the level of neighborhoods as well as for individual dwellings are developed and available within another TNO project (reference to project TNO Warmteprofielengenerator). |

**COSTS**

| | |
|---|---|
| Year of Euro | 2015 |

| Type of building | Unit | Reference label | | Label after insulation | Current | | | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other dwelling type | €/dwelling | GFE | to | DC | | 15,353 | | | 14,032 | | | 13,050 | |
| | | | | | 15,353 | – | 15,353 | 14,032 | – | 14,032 | 13,050 | – | 13,050 |
| Other dwelling type | €/dwelling | GFE | to | B | | 35,085 | | | 32,068 | | | 29,823 | |
| | | | | | 35,085 | – | 35,085 | 32,068 | – | 32,068 | 29,823 | – | 29,823 |
| Other dwelling type | €/dwelling | GFE | to | A | | N/A | | | N/A | | | N/A | |
| | | | | | - | – | - | - | – | - | - | – | - |
| Other dwelling type | €/dwelling | GFE | to | A+ | | N/A | | | N/A | | | N/A | |
| | | | | | - | – | - | - | – | - | - | – | - |
| Other dwelling type | €/dwelling | DC | to | B | | 16,829 | | | 15,382 | | | 14,305 | |
| | | | | | 16,829 | – | 16,829 | 15,382 | – | 15,382 | 14,305 | – | 14,305 |
| Other dwelling type | €/dwelling | DC | to | A | | 31,443 | | | 28,739 | | | 26,727 | |
| | | | | | 31,443 | – | 31,443 | 28,739 | – | 28,739 | 26,727 | – | 26,727 |
| Other dwelling type | €/dwelling | DC | to | A+ | | N/A | | | N/A | | | N/A | |
| | | | | | - | – | - | - | – | - | - | – | - |
| Other dwelling type | €/dwelling | B | to | A | | N/A | | | N/A | | | N/A | |
| | | | | | - | – | - | - | – | - | - | – | - |
| Other dwelling type | €/dwelling | B | to | A+ | | N/A | | | N/A | | | N/A | |
| | | | | | - | – | - | - | – | - | - | – | - |
| Other dwelling type | €/dwelling | A | to | A+ | | 10,034 | | | 9,171 | | | 8,529 | |
| | | | | | 10,034 | – | 10,034 | 9,171 | – | 9,171 | 8,529 | – | 8,529 |

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|---|---|
| Explanation | • Unit: € per dwelling (Price level 2015)<br>• Source: Investment costs to realise label improvement with insulation measures per dwelling from TNO Variatietool (TNO, 2021)<br>• Original source: Arcadis Kosten kentallen EPA-maatwerkadvies woningbouw (price level: 2020). Obtainable at RVO (RVO, 2020)<br><br>Explanation:<br>• Average investment costs for dwellings that are improved from the reference label (label cluster) to a better label (after insulation) are shown. The data from the Variatietool was filtered to only include label improvements realised by improving thermal insulation. Due to the data processing to calculate an average for different packages, no representative cost-breakdown of a package into individual insulation measures can be provided.<br>• Type of costs: Investment costs, excluding taxes, VAT, and without subtraction of possible investment subsidies. Costs that are included are costs made during preparation and execution of an individual project; preparation works, costs of insulating materials, labor costs, etc. (more information about the specific costs breakdown per measure can be found in Arcadis' costs breakdowns per measure in the original dataset). Costs are given at an autonomous moment (Dutch: 'zelfstandig moment'). This means the investment to prematurely replace the insulation, e.g. before a natural refurbishment moment (e.g. end-of-life replacement). In case costs would be expressed as costs on a refurbishment moment, these would be lower because a share of total costs would have been made anyway (the non-additional costs). These costs would have to be subtracted from the total costs to get the additional costs. Based on the Variatietool, the investment costs are roughly halved in case of a refurbishment moment compared to an autonomous moment.<br>• Cost reduction: The Dutch climate agreement aims to accomplish learning effects that will make the investment costs of measures fall between 2019 and 2050. In this factsheet, a mean investment costs reduction of 8,6% is projected for 2030 compared to 2020. This is based on the 'TNO eindverbruikerskosten project' (e.g. assumed is a mean costs reduction of 8-9% compared to 2020, with uncertainty intervals of 0-16% for label D+ and 0-18% for label B+) (TNO, 2021b, table 10-2). Moreover, a 15% costs reduction is assumed toward 2050 compared to 2020.<br><br>Notes:<br>• In the Variatietool not all dwellings can be upgraded to all the labels. The label that can be reached is also dependent on building energetic characteristics and what measures are technically possible. The majority of the dwellings can only be upgraded to DC (by insulation only). This means that dwellings upgraded to label DC are much more frequent than upgrades to B, A and A+.<br>• N/A = not available. In this case this particular dwelling type cannot be improved from one label to another (e.g. GFE to A), because according to the calculation of DGMR based on the initial analysis of packages of measures, that type of house from the WoON energy module can not technically achieve the label improvement on the basis of insulation measures alone.<br>• Please note that costs of different improvements are not cumulative. For example: the costs from GFE to DC added to from DC to B are not equal to from GFE to B (directly). The specific measures within the packages differ, and therefore the average costs of the packages differ. These can be higher or lower depending on the measures included. Also the fact that costs are project-based has an effect. For two separate projects there are additional costs (preparatory) compared to one project where two measures are combined. |

**EFFECT ON HEAT DEMAND**

| Type of building | Unit | Reference label | | Label after insulation | Current (2020) | | | | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other dwelling type | GJth/year | GFE | to | DC | -10.0 | -10.0 | – | -10.0 | -10.0 | -10.0 | – | -10.0 | -10.0 | -10.0 | – | -10.0 |
| Other dwelling type | GJth/year | GFE | to | B | -11.6 | -11.6 | – | -11.6 | -11.6 | -11.6 | – | -11.6 | -11.6 | -11.6 | – | -11.6 |
| Other dwelling type | GJth/year | GFE | to | A | N/A | - | – | - | N/A | - | – | - | N/A | - | – | - |
| Other dwelling type | GJth/year | GFE | to | A+ | N/A | - | – | - | N/A | - | – | - | N/A | - | – | - |
| Other dwelling type | GJth/year | DC | to | B | -7.6 | -7.6 | – | -7.6 | -7.6 | -7.6 | – | -7.6 | -7.6 | -7.6 | – | -7.6 |
| Other dwelling type | GJth/year | DC | to | A | -11.3 | -11.3 | – | -11.3 | -11.3 | -11.3 | – | -11.3 | -11.3 | -11.3 | – | -11.3 |
| Other dwelling type | GJth/year | DC | to | A+ | N/A | - | – | - | N/A | - | – | - | N/A | - | – | - |
| Other dwelling type | GJth/year | B | to | A | NA | - | – | - | NA | - | – | - | NA | - | – | - |
| Other dwelling type | GJth/year | B | to | A+ | N/A | - | – | - | N/A | - | – | - | N/A | - | – | - |
| Other dwelling type | GJth/year | A | to | A+ | -7.1 | -7.1 | – | -7.1 | -7.1 | -7.1 | – | -7.1 | -7.1 | -7.1 | – | -7.1 |

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| Explanation | • Unit: GJ heat demand per dwelling per year<br>• Source: Energy savings from TNO Variatietool (TNO, 2021), converted to heat demand savings. Afterwards, correction factors are applied to the Variatietool savings, based on a study by PBL (PBL, 2020). The corrected heat demand savings are shown in the table above.<br><br>Explanations:<br>• Heat demand savings (shown as negative values in the table above) are based on the average reduction in heat demand for dwellings in the data set that are subjected to a label improvement due to insulation measures only. The reference label (cluster) and label (cluster) after insulation for which an average value is calculated are indicated.<br>• In the Variatietool the (changes in) energy use and energy label after implementation of the packages of measures are calculated by DGMR. First of all, the calculated energy use is fitted to the actual energy use of the dwelling. This is done by means of adjusting the indoor temperature parameter in the engineering model. The indoor temperature has been adjusted so that, in the starting situation, the energy use corresponds with the measured energy use. This way the effect of different behaviour (compared to standardized behaviour) is better taken into account. One of the important reasons for the temperature correction is that it improves the accuracy of the calculated savings. Furthermore, the indoor temperature after renovation is also adjusted. This is done since the indoor temperature after renovation is slightly higher because the improved insulation traps more heat. To represent this in the calculation, a premium (i.e. a label-improvement dependent temperature premium) was added to the 'adjusted temperature before renovation'. After temperature corrections the calculation for the Variatietool results in lower savings. However, in this factsheet, savings had to be corrected downwards once more in order not to overestimate them. To do so, one more set of correction factors are applied, which are based on the study by PBL (2020). In this study, an extensive analysis on the difference between Variatietool savings (after both these temperature adjustments before and after renovation) and savings based on measured energy use is done for thermal insulation to label D and B. The difference in Variatietool savings compared to measured savings is shown (see Table 5-4 in the PBL report). Measured savings in PBL are based on CBS data on measured energy use per label category. Depending on label improvement, the corrected heat demand savings for label improvements are 30% to 60% of what is expected based on the (two times temperature adjusted) savings from the Variatietool.<br>• The Variatietool shows energy use, not the heat demand. Average heat demand savings are calculated for dwellings with different energy carriers by first converting the energy demand to heat demand. Values shown are thus an average based on natural gas savings for natural gas heated dwellings, electricity savings for the dwellings that are heated with electricity, and heat savings for dwellings heated with district heating. (To convert to heat demand the following conversion factors are used: m3 converted to GJ heat assuming: 31,65 MJ/m3 and 100% efficiency gas-fired boiler, average COP heat pump 400%, efficiency district heating 100%).<br>• This factsheet also includes heat demand savings to label A and A+. For these variants the same correction factors are used as for label B (relatively low numbers of dwellings are insulated to A and A+).<br><br>Notes:<br>• In the Variatietool not all dwellings can be upgraded to all the labels. The label that can be reached is also dependent on building energetic charateristics and what measures are technically possible. The majority of the dwellings can only be upgraded to DC (by insulation only). This means that dwellings upgraded to label DC are much more frequent than upgrades to B, A and A+.<br>• N/A = not available. In this case this particular dwelling type cannot be improved from one label to another (e.g. GFE to A), because according to the calculation of DGMR based on the initial analysis of packages of measures, that type of house from the WoON energy module can not technically achieve the label improvement on the basis of insulation measures alone.<br>• savings ratio can be calculated as - EFFECT ON HEAT DEMAND / HEAT DEMAND (REFERENCE)<br>• additional (small) effects on electricity use (e.g. on auxiliary energy for the heating installation or ventilation system) could occur, but they cannot be quantified at this moment. |

**HEAT DEMAND (REFERENCE)**

| Type of building | Unit | Reference label | Current (2020) | | | | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other dwelling type | GJth/year | GFE | 70.3 | 70.3 | – | 70.3 | 70.3 | 70.3 | – | 70.3 | 70.3 | 70.3 | – | 70.3 |
| Other dwelling type | GJth/year | DC | 61.7 | 61.7 | – | 61.7 | 61.7 | 61.7 | – | 61.7 | 61.7 | 61.7 | – | 61.7 |
| Other dwelling type | GJth/year | B | 52.2 | 52.2 | – | 52.2 | 52.2 | 52.2 | – | 52.2 | 52.2 | 52.2 | – | 52.2 |
| Other dwelling type | GJth/year | A | 43.9 | 43.9 | – | 43.9 | 43.9 | 43.9 | – | 43.9 | 43.9 | 43.9 | – | 43.9 |
| Other dwelling type | GJth/year | A+ | 20.3 | 20.3 | – | 20.3 | 20.3 | 20.3 | – | 20.3 | 20.3 | 20.3 | – | 20.3 |

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| Explanation | • Unit: GJ heat demand per dwelling per year<br>• Source: Energy use from TNO Variatietool (TNO, 2021), converted to heat demand.<br><br>• Explanation: Values show the average heat demand per label (cluster) for the dwellings in the reference situation (situation before insulation measures are taken). This also includes heat demand for hot tap water. The average heat demand is based on dwellings heated with natural gas, electricity and district heating, all converted to GJ heat demand. To convert to heat demand the following end-use conversion factors are used: m3 converted to GJ heat demand assuming: 31,65 MJ/m3 and 100% efficiency gas-fired condensing boiler, average COP heat pump 400%, efficiency district heating 100%.<br>• The values on the reference heat demand are based on the actual (measured) energy use for heating. In the Variatietool the energy use is fitted to the actual energy use of the dwelling.In case of natural gas it is based on the Standard Year Consumption of the dwelling in 2018 (Dutch: StandaardJaarVerbruik or SJV). The SJV is temperature corrected (which means the energy use is given for weather conditions in a 'standard climate year'). The indoor temperature in the engineering model has been adjusted so that in the starting situation the energy use corresponds with the measured energy use. This way it is tried to correct for the effect of different behaviour of residents on energy use (compared to a situation assuming standardized behaviour). |

| AVOIDED EMISSIONS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Substance | Unit | Current (2020) | | | 2030 | | | 2050 | | |
| Emissions | $CO_2$ | Mton $CO_2$-eq | - | | | - | | | - | | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | - | | | - | | | - | | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | - | | | - | | | - | | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | - | | | - | | | - | | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| Explanation | Avoided $CO_2$ emissions can be calculated from the heat demand savings. First, calculate energy savings from the heat demand savings by assuming a conversion efficiency of the heating installation. Then, the emission reduction can be calculated. For instance, in case of natural gas, by assuming an emission factor of natural gas of 56,4 kg$CO_2$/GJ (RVO, 2019). This is equal to 1,78 kg$CO_2$/m3. In case of district heating or electric heating a specific source emission factor or a national representative emission factor can be used. | | | | | | | | | | |

| OTHER | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Unit | Current (2020) | | | 2030 | | | 2050 | |
| | | - | | | - | | | - | |
| | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | - | | | - | | | - | |
| | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | - | | | - | | | - | |
| | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | - | | | - | | | - | |
| | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| Explanation | | | | | | | | | |


**REFERENCES**

| | |
|---|---|
| 1 | TNO (2021) Variatietool. Input data originates from Energiemodule WoOn (dataset developed by ministry BZK and CBS). Variations on label improvements calculated by DGMR. |
| 2 | EIB (2018). Klimaatbeleid en de gebouwde omgeving - Mogelijkheden voor het verkleinen van de efficiency gap. |
| 3 | PBL (2020). Bepaling energiebesparing door isolatie van woningen in de Startanalyse 2020 - Schatting op basis van gemeten en berekend aardgasverbruik. |
| 4 | RVO (2019). Berekening van de standaard $CO_2$-emissiefactor aardgas t.b.v. nationale monitoring 2020 en emissiehandel 2020. |
| 5 | Milieucentraal (2021). Isolatiematerialen vergeleken. URL: https://www.milieucentraal.nl/energie-besparen/isoleren-en-besparen/isolatiematerialen-vergeleken/ |
| 6 | RVO (2020). Investeringskosten energiebesparende maatregelen URL: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/technieken-beheer-en-innovatie/investeringskosten-energiebesparende-maatregelen |
| 7 | TNO (2021b) Eindgebruikerskosten- Technische achtergrondrapportage URL: https://energy.nl/wp-content/uploads/2021/06/TNO-2021-P10711-Achtergrondrapportage-Eindgebruikerskosten-v1.2.pdf |
| 8 | PBL (2015). ENSYSI A simulation model for the Dutch energy system. Background Report. |