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# Energy Efficiency and Cost Effectiveness of Electrical Heating in Combination with Photovoltaic Systems

## — Phase 1 —

| | | |
|---|---|---|
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# Contents

# 1 Introduction

With decreasing energy consumption for the heating of residential buildings by means of increasing thermal insulation and air tightness, grid power becoming greener and photovoltaic systems (PV) becoming cheaper, the combination of electrical heating and PV may become a more viable option from both an economic and an ecologic perspective.

On behalf of the *Bundesverband Flächenehizungen und Flächenkühlungen e. V.* (BVF; Federal Association of Surface Heating and Surface Cooling), ITG has compared several heat generation options (fuel based as well as fully electric) combined with photovoltaic systems in terms of

- energy efficiency,
- cost effectiveness and
- the chosen method of crediting the usable PV output.

The present study converts the abovementioned considerations to exemplarily chosen European countries. This conversion accounts for national conditions regarding weather, primary energy and relevant costs – e. g. adjustment of net/final energy demand and PV output, use of country-specific primary energy factors, energy prices and investment costs. However, country-specific legislation, subsidies / support schemes and such will not be researched.

# 2 Calculation method and input data

## 2.1 General

This study compares different building system variants for a single-family building in terms of energy efficiency and cost effectiveness exemplarily for certain European countries. For that, the following country-specific quantities have to be known for each variant:

- Final energy demand and PV gains (basis for primary energy demand and energy costs)
- Primary energy factors
- (Household) Energy prices
- Investment cost of the compared building systems

The method for energy demand calculation used here is based on EN 15316 [1][1] (see 2.3).

Country-specific data is obtained from the following sources:

- Statistical Office of the European Union (Eurostat)
- National statistical offices
- Joint Research Centre of the European Commission (JRC)
- EUHA members (especially input on energy and investment costs)

## 2.2 Exemplarily chosen European countries

This study aims at a comparison of different building / building system variants from a European perspective. Results will be shown for the following countries:

- Federal Republic of Germany (Germany/DEU)
- Czech Republic (CZE)
- French Republic (France/FRA)
- The Netherlands (NLD)
- Kingdom of Sweden (Sweden/SWE)

## 2.3 Excursion: EN 15316 / DIN V 18599

This study uses energy demand values based on EN 15316 / DIN V 18599 [1, 2, 3][1]. These standards describe a method to calculate the yearly energy demand of a building on the basis of

- use parameters (inner temperatures, air change rates, times of use etc. for different use cases, such as residential use, offices, warehouses and so on),
- weather conditions (monthly mean external temperatures, insolation etc.)
- thermal properties and air-tightness of the building envelope and
- type and efficiency of building systems (HVAC).

The method accounts for energy demand regarding

- heating and cooling,
- ventilation and air conditioning,

[1] A commercially available comprehensive software for energy demand calculations based on DIN V 18599 is used – EN 15316 and DIN V 18599 mirror each other for the most part.

- hot water generation and
- lighting (only in non-residential buildings)

both in terms of heat/cold generation and auxiliary energy.

The starting point of any energy demand calculation is the calculation of the required amount of useful energy – for example a certain amount of heat required to heat a portion of a building or a building as whole, which is mainly determined by use parameters, thermal insulation, air tightness and external and internal heat gains. Based on that required amount of useful energy, final and primary energy demand are calculated by adding respective losses for emission systems, distribution and so on – Figure 1 illustrates the calculation flow (left to right vs. energy flow right to left) in a simplified manner.

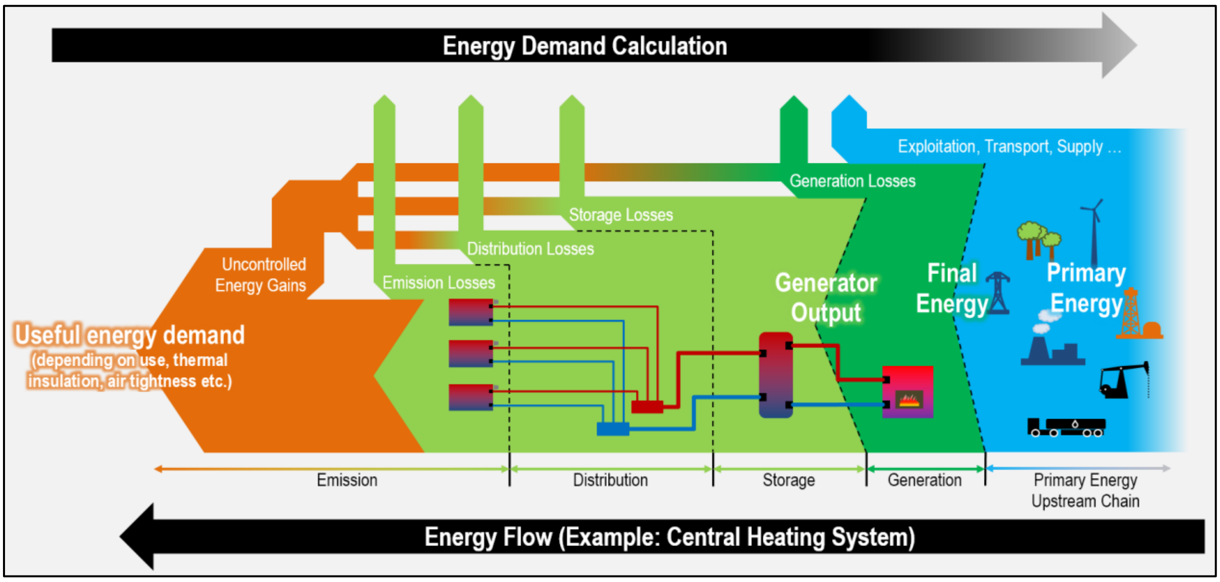


**Figure 1** **Direction of energy demand calculations in accordance with EN 15316 / DIN V 18599 vs. direction of energy flow.**

The method can be used to predict, among other things,

- generator output (e. g. amount of heat required from the heat generator factoring in all losses between heat emission and heat generation),
- final energy consumption and,
- based on final energy consumption, primary energy consumption, energy costs and pollutant emissions

under average conditions. It is therefore well suited for systematic parameter variations, e. g. comparisons of

- different options of building system for a given purpose (e. g. heat generation via gas boiler vs. heat pump etc.),
- different levels of heat insulation and so forth.

The method is, for the most part, based on monthly energy balances for each month of the year. It delivers both monthly results and results over a whole year.

## 2.4 Shared input data

### 2.4.1 Model Building

The calculations model a single-family house (detached, no common walls with other buildings) for two different levels of thermal insulation, both oriented towards the ambitious side of the scale found in new buildings.

The model building has 2 (1,5) storeys and a total living space of about 150 m². The thermal building envelope is made up of the outer walls, the floor slab (no cellar), the lower parts of the gable roof and the topmost ceiling.

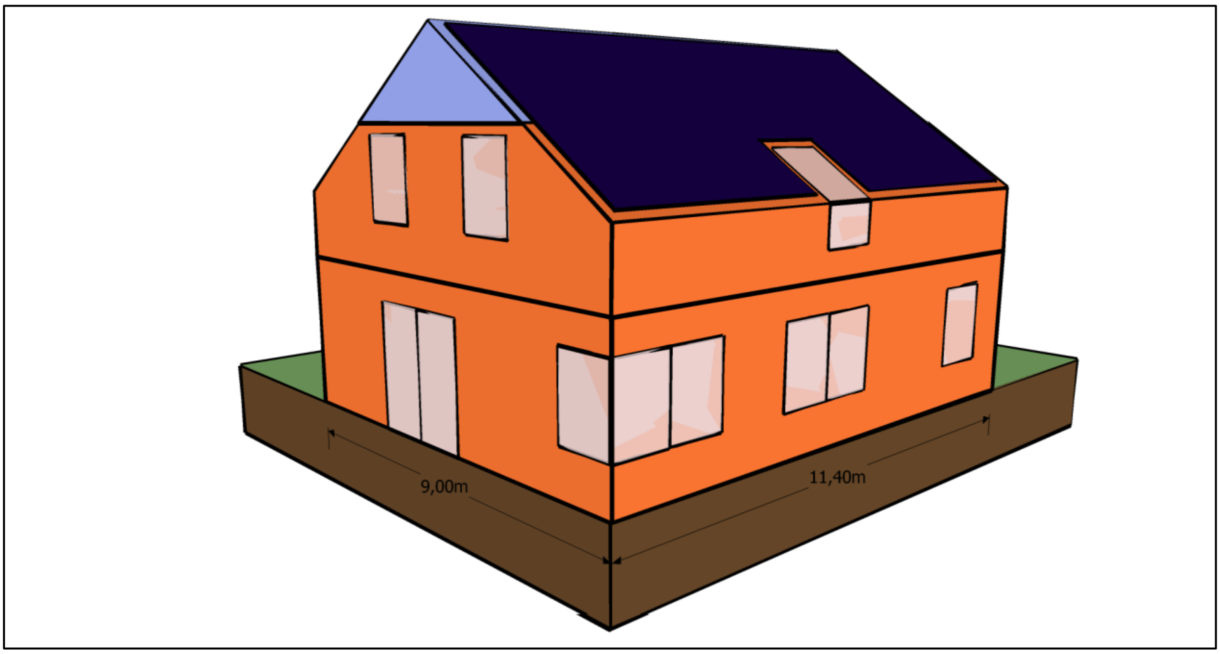


**Figure 2 Model building, simplified illustration**

**Table 1 Building properties**

| **Property** | | | **Level of thermal insulation[a]** | |
|---|---|---|---|---|
| | | | **High** | **Very high** |
| Thermal transmittance, U-value | Walls | W/m²K | 0,20 | 0,13 |
| | Roof | | 0,15 | 0,13 |
| | Floor slab | | 0,25 | 0,20 |
| | Window | | 0,90 | 0,70 |
| | Door | | 1,70 | 1,40 |
| | Thermal bridges[b] | | 0,03 | |
| Air tightness, $n_{50}$ | | $h^{-1}$ | 1,0 | |
| Geometry | External volume[c], $V_e$ | m³ | 554 | |
| | Net floor area[d], $A_{NGF}$ | m² | 162 | |
| | Living space area, $A_W$ | m² | 150 | |
| | $A/V_e$ | $m^{-1}$ | 0,74 | |

a Perception of the given numbers as a “very high”, “moderate”, “high”, etc. level of insulation depends on country-specific common building practise, regulation etc. Following input from EUHA members, it can be assumed that the given numbers, while not adjusted to each country’s EPBD-related requirements, are, in scale, representative for new residential buildings towards the more energy-efficient end of the spectrum.

b Added to each building-element U-value

c Volume defined by the thermal building envelope

d Total internal floor area, only excluding walls

### 2.4.2 Building Systems

The following combinations of building systems will be compared:

**Table 2 Building system variants**

| No. | Room heating | | Domestic water heating | PV battery | Abbreviation |
|---|---|---|---|---|---|
| | Generation | Emission | | | |
| 1 | Gas condensing boiler | Underfloor heating (35/28 °C) | Hot water storage tank, sharing heat generator with room heating | No | Boiler + Hot water tank |
| 2 | Electric air source heat pump | | | | ASHP + Hot water tank |
| 3 | | | Electric flow water heater | Yes | ASHP + Flow heater + Battery |
| 4 | Electric underfloor heating | | Electric heat pump water heater[a] | No | EUFH + HP water heater |
| 5 | | | Electric hot water storage tank | | EUFH + E hot water tank |
| 6 | | | | Yes | EUFH + E hot water tank + Battery |
| 7 | | | Electric Flow water heater | | EUFH + Flow heater + Battery |

[a] External air as heat source

All variants are equipped with the same ventilation system and the same photovoltaic modules.

It is assumed that one half of the gable roof is for the most part covered with PV modules. This translates to a module area of roughly 50 m² and a peak power of about 9 kW when new.

All variants with a flow water heater (no. 3 and 7) are equipped with a battery; of the two variants with directly heated water tanks (no. 5 and 6) one is equipped with a battery and one is not. The battery capacity is set to 1 kilowatt hour per installed kilowatt of PV-module power (→ 9 kWh).

**Table 3 Common building system properties for all variants**

| System/Property | | | Value |
|---|---|---|---|
| PV-System | Module surface area | m² | 49,8 |
| | Cell type | | Monocrystalline Silicon |
| | Peak power | $kW_{peak}$ | 8,16 average over 25 years[a] (9,06 for new modules) |
| | Orientation | — | S |
| | Angle (≙ roof slope) | ° | 37 |
| Ventilation system | Type | | Supply/exhaust with heat recovery |
| | Annual operating time | | Heating season only[b] |

[a] Overall PV degradation is taken into account in a simplified manner: The supposed peak power of new modules is lowered to 90 % (≙ average over 25 years when assuming a linear degradation from 100 to 80 %).

[b] In EN 15316 / DIN V 18599, the length of the calculated heating season depends on the overall heat balance and, as such, also takes into account internal heat gains. Therefore ventilation energy demand (setting: heating season only) is not only affected by thermal insulation, but also by the building system variant (differences in internal recoverable heat losses). Within this study however, the heating season length is set to a fixed value per country on the basis of country-specific degree days and a heating limit temperature representative for modern air-tight and highly insulated buildings (see also 2.4.1, 2.6) – this slight simplification has no significant influence on the overall results, but avoids situations where the energy demand of the ventilations system within one country and one thermal-insulation level could “jump” between different variants.

### 2.4.3 Use parameters

The following use parameters are assumed:

**Table 4 Use parameters**

| | | |
|---|---|---|
| **Operation time heating system** | **h/d** | 23 |
| **Internal temperature** | **°C** | 20 |
| **Minimum air change rate** | **$h^{-1}$** | 0,45 |
| **Useful energy demand for water heating** | **kWh/m²d** | 8,5 |

In reality, also “soft factors” like the perceived energy efficiency of a building and its HVAC systems – and thus the expectations of what energy costs their use causes – can influence user behaviour. For example, with increasing energy efficiency, it can often be seen that part of the energy saving potential is not utilised, but instead spent on higher comfort. However for the present study, it is assumed that all variants (thermal insulation and building systems) are operated based on the same use parameters and the same or a very similar level of comfort. This allows a clean comparison between the different variants based on objective/measurable efficiency parameters for a given use case.

## 2.5 Excursion: Electricity demand for household appliances

In this study, the amount of usable electric energy from the PV system is set off against the building’s electricity demand – including electricity required for room and water heating, ventilation and household appliances (white and brown goods).

National habits regarding the use of electricity can vary greatly depending on electric infrastructure, energy prices and so on. Table 5 shows estimated per-household consumption values based on statistical data. However, the source data does not break down the overall consumption into specific uses – e. g. which percentage goes into HVAC or into household appliances.

While Germany, the Czech Republic and the Netherlands show similar per-household consumption values, much higher values are found for France and Sweden.

**Table 5 Electricity consumption households (Eurostat)**

| Country | Overall consumption households 2011 [GWh/a] | Dwellings 2001 | Consumption per dwelling [kWh/a] | Notes |
|---|---|---|---|---|
| Germany | 128.200 | 37.957.000 | 3.378 | • Low percentage of electrical heating<br>• Value close to standard value DIN V 18599:2019 |
| Czech Republic | 15.050 | 4.216.085 | 3.570 | • Similar to Germany |
| France | 158.330 | 23.808.072 | 6.650 | • Presumably higher percentage of electrical heating (compared to Germany) |
| Netherlands | 22.971 | 6.866.302 | 3.345 | • Similar to Germany |
| Sweden | 45.068 | 3.115.399 | 14.466 | • Very high consumption<br>• Presumably very high percentage of electrical heating |

It is assumed that

- usage of electricity for
  - Germany,
  - the Czech Republic and
  - the Netherlands

  is very similar and that electric heating, while being used in these countries, is not predominant in the abovementioned numbers and
- the higher values for France and Sweden are mainly caused by a relative predominance of electric heat generation and not or only to a certain extend by differences in household appliances.

Comparing the per-dwelling electricity consumption values estimated in this subchapter electricity demand values calculated after chapters 2.1, 2.4 and 2.5, the following was found: For France the overall per-dwelling electricity consumption as estimated above lies in the range of hereafter calculated electricity demand values for the electrically heated model building variants if the demand for household appliances remains at 63 Wh/m²$_{NGF}$d[2]. For Sweden the estimated per-dwelling consumption from Table 5 seems on the high side when compared to the range of electricity demands that where calculated based on 63 Wh/m²$_{NGF}$d[2] – a better fit is seen with specific household electricity demand increased to about 100 Wh/m²$_{NGF}$.

The following household-appliances demand values are assumed:

**Table 6 Estimated electricity demand of the model building for households appliances (i. e. without HVAC)**

| Country | Electricity household appliances | |
|---|---|---|
| | Specific [Wh/m²$_{NGF}$d] | Model building $A_{NGF}$ 162 m² [kWh/a] |
| Germany | 63 | 3.733 |
| Czech Republic | 63 | 3.733 |
| France | 63 | 3.733 |
| Netherlands | 63 | 3.733 |
| Sweden | 100 | 7.110 |

## 2.6 Final energy demand, weather and PV

Within this study, final energy demand values are based on EN 15316 and, for the sake of readily available comprehensive calculation software, its German counterpart DIN V 18599[1 (p. 6)]. Where energy demand values have to be translated between different European countries, a simplified approach based on the ratio of degree days between the source and the target country is used:

$$Q_{f,target,mth} = Q_{f,target,a} * \frac{DD_{target,mth}}{DD_{target,a}}$$

**Equation 1**
**Energy demand conversion annual → monthly**

$$Q_{f,target,a} = Q_{f,source,a} * \frac{DD_{target,a}}{DD_{source,a}}$$

**Equation 2**
**Energy demand conversion between countries**

$$DD_{...mth} = \left(\vartheta_{e,limit} - \vartheta_{e,mth}\right) * d_{mth}$$

**Equation 3**
**Monthly degree days**

| | |
|---|---|
| $Q_{f,target}$ | Final energy demand in the target country |
| $Q_{f,source}$ | Final energy demand in the source country |
| $DD_{target}$ | Degree days of the target country |
| $DD_{source}$ | Degree days of the source country |
| $\vartheta_{e,limit}$ | Mean external temperature at which the heating system will switch on/off<br>In case of good thermal insulation, as is assumed here (Table 1), a value around 10 °C can be assumed. |
| $\vartheta_{e,mth}$ | Monthly mean external temperature |
| $\ldots_{a}$ | annual / per year |
| $\ldots_{mth}$ | monthly / for each month of the year |

The usable amount of electricity delivered by the PV system is calculated on the basis of monthly mean solar radiation data and the parameters of the PV system (see Table 3). It is then set off against the building's electricity demand on the basis of Lichtmeß' method [4][3]: This approach converts electricity demand values (energy) into mean power values and then integrates these mean powers over the daily time span with significant solar insolation, thus converting them back into energy. Figure 3 illustrates the approach in a simplified manner.

2 Standard value DIN V 18599-10
3 Both approaches are also used in the 2018 Version of DIN V 18599 [3].

For heat generators, various adjustments are applied to factor in system-specific utilisation of PV output, e. g.:

- Generally lower utilisation for instantaneous/flow-through types of water heaters[4]
- Influence of heat generator / storage tank sizing (compensation for switch-off times)
- Influence of PV-optimised or "smart-grid-ready" control

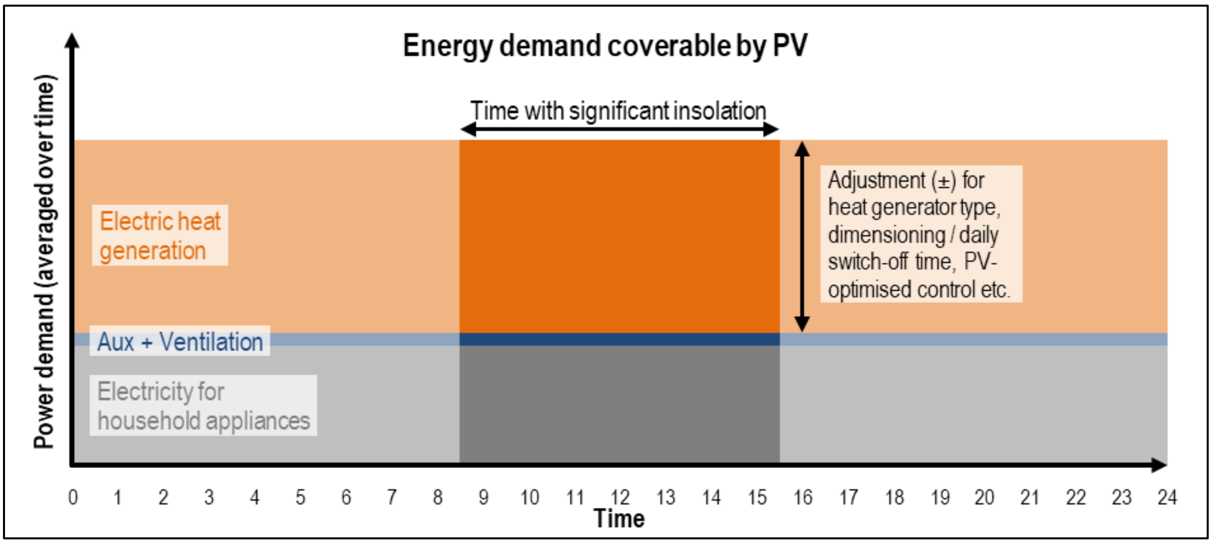


**Figure 3** **Portion of building energy demand that could be covered by a PV system; based on Lichtmeß' approach [4]**

In this study, the following source material regarding weather and solar radiation is used (see also Appendix: Degree days and Solar insolation):

**Table 7** **Sources weather data**

| Country | Source | | |
|---|---|---|---|
| Germany | German standard values for Potsdam[a] | | |
| Czech Republic | Monthly mean values calculated from TMY data[b] for | Prague | 50°05'N 14°25'E |
| France | | Paris | 48°51'N 02°21'E |
| Netherlands | | Amsterdam | 52°22'N 04°54'E |
| Sweden | | Stockholm | 59°20'N 18°03'E |

[a] Reference TMY (TRY) in accordance with DIN V 18599-10:2018-09 [3]

[b] The source data (Typical meteorological years / TMY) is obtained from the PVGIS project [5] of the Joint Research Centre of the European Commission (JRC) and is not input into the calculation as is, but processed beforehand:
- The hourly mean values for solar insolation onto a horizontal plane from the TMY are aggregated into monthly mean values and translated to factor in roof slope and orientation.
- The hourly mean values of the external temperature are aggregated into monthly mean values and converted into degree days for a heating limit temperature of 10 °C.

## 2.7 Primary energy

Primary energy demand is calculated from country-specific final energy demand values (see 2.3–2.6) and country-specific primary energy factors. The following primary energy factors are assumed:

[4] As flow(-through) water heaters heat water almost instantaneous while it flows through them, they require a comparatively large amount of power – models for universal use are typically found in the range between 18 kW and 24 kW. Roof-mounted PV systems, as assumed here, usually peak at a significantly lower amount of power and will deliver even less on average. Therefore, the power requirement of flow water heating can only be covered to a certain percentage by the PV system. With the addition of a battery, this effect will decrease somewhat, but still be there.

**Table 8 Primary energy factors**

| Country | Primary energy factor [$kWh_{prim}/kWh_{fin,HI}$] | |
|---|---|---|
| | Natural gas | Electricity (grid power) |
| Germany | 1,1 | 1,8 |
| Czech Republic | 1,0 | 2,6 |
| France | 1,0 | 2,3[a] |
| Netherlands | 1,0 | 1,45[a] |
| Sweden | 1,0[b] | 1,6 |

[a] As of 2021

[b] In Sweden, natural gas and district heating have the same primary energy factor (1,0).

Apart from country-specific primary energy factors, national regulation is not taken into account. Primary energy demands shown here can be seen as estimated primary energy consumption values (based on monthly mean values; see also 2.3). However, primary energy demand values calculated for energy performance certificates according to national regulation / EPBD implementation can deviate from these depending on country-specific regulation, calculation method and scope.

In this study, self-used electricity from a PV system is looked at as electricity not drawn. This equals either setting off self-used PV output against demand on the final energy level or, if doing it on the primary energy level instead, using the same primary energy factor as for drawn electricity. Fed-in PV output is looked at as electricity not produced conventionally and is rated the same as grid power. Thus both self-used and fed-in electricity will balance out with the building’s demand at the same per-kilowatt-hour value.[5]

## 2.8 Cost balance

### 2.8.1 General

In this study, annualised overall costs are based on the approach described in VDI guideline 2067 Part 1 [6] and given for each variant. These total annual costs include the following items:

- Capital costs (annualised investment costs)
- Overall energy costs including HVAC and household appliances
    - Energy drawn from grid (gas, electricity), taking into account both building demand and self-used PV output
    - Bonus for fed-in electricity based on feed-in tariff
- Maintenance and repair costs

### 2.8.2 Energy costs

Energy costs are calculated with country-specific energy prices either found in statistical data (Eurostat [7, 8]) or provided by EUHA members. The following prices are assumed:

[5] Other approaches are possible. For example, PV output could be seen as more beneficial or less beneficial to the grid and therefore rated differently from the grid power mix. There is no common European method or set of rules. To give an actual example, albeit not for PV: In Germany, the electricity output of CHP plants is rated differently than the general electricity mix – this is done on the basis of the argument that CHP mainly substitutes electricity from plants that are less efficient in terms of primary energy.

**Table 9 Consumer energy prices**

| Country | Consumer energy price [€/$kWh_{fin,HI}$], including tax etc. | | | | |
|---|---|---|---|---|---|
| | Natural gas | Electricity | | | |
| | | Drawn from grid | | PV Fed to grid | |
| | | Tariff | Applied to | Tariff | Balancing method |
| Germany | 0,0752 | General use: 0,3088 | Variant 1, HVAC + household | -0,0944 | Momentary values (feed in and draw count separately) |
| | | Heating: 0,2 | Variants 2–7, HVAC only | | |
| Czech Republic | 0,0586 | General use: 0,1748 | Variant 1, HVAC + household | -0,04 | |
| | | Heating: 0,117 | Variants 2, 4–6[a], HVAC + household | | |
| France | 0,1049 | High: 0,1667[b] | Variant 1, HVAC + household | -0,10 | |
| | | Low: 0,1195[b] | Variants 2–7, HVAC only | | |
| Netherlands | 0,0921 | General use: 0,2250 | Variants 1–7, HVAC + household (no low/heating tariff in place) | -0,05 | Annual value (only either feed in or draw at the end of the year) |
| Sweden | 0,087[c] | Low: 0,128 | Variants 1–7, HVAC + household (low tariff applicable to everything, no distinction) | -0,005 | Momentary values (feed in and draw count separately) |

[a] Flow-through water heaters are uncommon in CZE due to electricity base prices depending on the amperage requirement of the building. No costs/prices will be shown for variants with flow water heaters (3, 7).

[b] Averaged between numbers from different EUHA members as well as between high/low and day/night pricing schemes

[c] Natural gas costs about the same as district heating per kilowatt hour in Sweden.

It is assumed that the abovementioned prices are effective prices per kilowatt that also include base prices if/where in place and significant.[6]

Within one country, there are usually several energy providers delivering the same energy source at different prices and/or price schemes. It is assumed that the abovementioned numbers, provided/checked by EUHA members, represent average energy prices for each country.

The energy demands for both HVAC (see 2.3–2.6) and household appliances are taken into account. The energy demand for household appliances is estimated based on the DIN-V-18599 standard value of 63 $Wh/m^2_{NGF}$ and/or country-specific statistic data on per-household energy consumption (see 2.5).

Regarding the different electricity/PV tariff schemes the following should be noted:

1. In all countries looked at here, drawn electricity is more expensive than fed-in electricity – that means that per kilowatt hour drawn more has to payed than can be got per kilowatt hour fed in. This price difference can have a certain effect on the way PV systems are sized relative to the buildings' energy demands. However, for a given building and a given PV system, this price difference alone does not, per se, favour actual self-use or feed-in (see following bullet point).
2. For a given building (≙ fixed electricity demand) and PV system (≙ fixed PV output),
    - tariff schemes based on actual consumption values (Germany, Czech Republic, France, Sweden) can, depending on draw and feed-in prices, favour either actual self-use or feed-in – usually maximisation of self-use is promoted –, whereas

[6] Where energy prices were given as separate annual base prices and per-kilowatt-hour prices, fixed base prices have been translated into per-kilowatt-hour amounts based on averaged consumption numbers (see Appendix: *Average overall energy demand of the model building*) and added to the per-kilowatt-hour prices.

**Calculation example**
Energy price: 100 €/a and 0,10 €/kWh
Average energy demand for that energy source: 7.000 kWh/a
Effective energy price: $0{,}10\ €/\mathrm{kWh} + \frac{100\ €/\mathrm{a}}{7000\ \mathrm{kWh/a}} = 0{,}1143\ €/\mathrm{kWh}$

- o tariff schemes based on the overall annual balance (Netherlands) cannot distinguish in terms of actual self-use/feed-in and, therefore, favour neither.

This means that with the “Dutch approach” based on an annual balance, as far as energy costs are concerned, there is no incentive to use technologies that could increase self-use, like

- o PV-optimised control systems/strategies,
- o combinations of electric heating and thermal storage or
- o (electrochemical) batteries.

Of course, there could be other measures in place to influence the overall self-use/feed-in balance, like subsidies, restrictions etc.

### 2.8.3 Investment, maintenance and repair costs

Within this study, the term *investment costs* refers all building-system-related investment costs, which may differ significantly between the included variants. Table 10 gives a brief overview over the included cost items.

**Table 10 Investment-cost items, summarised overview**

<table>
<tr><th>Variant / Cost Item</th><th>1 Boiler + Hot water tank</th><th>2 ASHP + Hot water tank</th><th>3 ASHP + Flow heater + Battery</th><th>4 EUFH + HP water heater</th><th>5 EUFH + E hot water tank</th><th>6 EUFH + E hot water tank + Battery</th><th>7 EUFH + Flow heater + Battery</th></tr>
<tr><td>Heat generation for room heating<br>• Central heat generator (boiler or heat pump)<br>• Pump<br>• Control<br>• Mounting hardware</td><td colspan="3">●</td><td colspan="4">—</td></tr>
<tr><td>Underfloor heating system<br>• Underfloor heating for 150 m² of floor space<br>o Hydronic: Heating tubing and heat distribution inside the building (tubing, insulation, fittings, mounting hardware)<br>o Electric: Heating electric heating cable/mat<br>• Mounting system<br>• Room temperature control<br>• Floor screed</td><td colspan="3">●<br>(hydronic)</td><td colspan="4">●<br>(electric)</td></tr>
<tr><td>Domestic water heating<br>• Heat generator for water heating (central storage tank, flow heater etc.)<br>• Mounting hardware</td><td colspan="2">●<br>(central)</td><td>●<br>(decen-tral)</td><td colspan="3">●<br>(central)</td><td>●<br>(decen-tral)</td></tr>
<tr><td>Tap / Hot water distribution<br>• Tubing, insulation, fittings, mounting hardware<br>• Circulation pump in case of central water heating</td><td colspan="7">●<br>(depending on central/decentral water heating)</td></tr>
<tr><td>Gas/Electric installation<br>• Gas/Electric installation for heat generators etc. inside the building (not grid to building)</td><td colspan="7">●<br>(depending on components to be installed/connected)</td></tr>
<tr><td>Gas connection<br>• Gas connection from grid to building</td><td>●</td><td colspan="6">—</td></tr>
<tr><td>Chimney<br>• Chimney (structure) with flue gas system</td><td>●</td><td colspan="6">—</td></tr>
<tr><td>Ventilation system<br>• Supply/exhaust ventilation system with heat recovery<br>• Ducts, in-/outlets<br>• Mounting hardware</td><td colspan="7">●<br>(identical for al variants)</td></tr>
</table>

**Table 10 Investment-cost items, summarised overview**

| Cost Item \ Variant | 1 Boiler + Hot water tank | 2 ASHP + Hot water tank | 3 ASHP + Flow heater + Battery | 4 EUFH + HP water heater | 5 EUFH + E hot water tank | 6 EUFH + E hot water tank + Battery | 7 EUFH + Flow heater + Battery |
|---|---|---|---|---|---|---|---|
| PV system<br>• Panels for ~50 m² roof space with ~9 $kW_{p,new}$ (8,16 $kW_{p,25a}$)<br>• Inverter<br>• Installation material and mounting hardware | ●<br>(identical for al variants) | | | | | | |
| Battery<br>• Lithium-based battery with ~9 kWh<br>• Installation material and mounting hardware | — | | ● | — | | ● | |

Investment costs for HVAC systems can vary greatly between different countries with some major influences being

- national regulations,
- spending capacity and willingness,
- subsidies
- price adjustment to local markets,
- energy prices,
- tradition/habits/biases and so on.

Within this study, prices for the looked-at countries are, as far as possible, based on input from EUHA members that are active in these countries. Where no input is given, investment costs are estimated.

**Table 11 Sources for investment costs**

| Country | Source | Notes/Details |
|---|---|---|
| Germany | Own calculation | Based on averaged catalogue prices, usual vendor discounts, labour costs, margins and tax |
| Czech Republic | Fenix | Prices given for some items suggest an average cost level of about 80 % compared to Germany |
| France | Danfoss, Fenix | Prices given suggest an average cost level of about 110…120 % compared to Germany |
| Netherlands | Magnum | Similar to Germany, but lower costs for PV systems |
| Sweden | Ebeco | Similar to Germany |

For investments regarding HVAC components, an interest rate of 3 % and common service life spans are assumed. Costs for repairs are calculated based on standard values given in VDI 2067; regular ongoing costs (inspection, maintenance, insurance) are based on common hourly wages, service and insurance rates.

**Table 12 Common service life spans and annual costs for repair and maintenance**

| System/Component | Service life [a][a] | Annual costs as percentage of initial investment costs | |
|---|---|---|---|
| | | Repair[b] | Maintenance etc.[c] |
| Gas condensing boiler | 18 | 1,50 % | 2,92 % |
| Heat pump | 18 | 1,00 % | 1,32 % |
| Hydronic underfloor heating | 50 | 1,00 % | 0 |
| Electric underfloor heating | 50 | ~~2,00~~ 0,50 %[d] | 0 |
| Hot-water storage tank | 20 | 1,00 % | 0,63 % |
| Flow water heater | 15 | 1,00 % | 0 |

**Table 12 Common service life spans and annual costs for repair and maintenance**

| System/Component | Service life [a][a] | Annual costs as percentage of initial investment costs | |
|---|---|---|---|
| | | Repair[b] | Maintenance etc.[c] |
| Hot-water distribution | 30 | 0,50 % | 0 |
| Electric/Gas installation and connection to grid | 50 | 1,00 % | 0 |
| Chimney | 50 | 1,00 % | 1,59 % |
| Ventilation system | 20 | 0,60 % | 1,67 % |
| PV system (optionally with battery) | 25 | 0 | 0,86 % |

[a] Standard values VDI 2067 [6]

[b] Repairs not covered by regular maintenance, averaged over service life;
Standard values VDI 2067 [6]

[c] Regular ongoing costs for inspection/maintenance and insurance;
Own calculation/research (based on common hourly wages and/or service rates for inspection/maintenance work, insurance etc.), converted into percentages

[d] The VDI standard value for the repair costs of electric underfloor heating systems (2 %) seems unrealistically high – it would translate to average annual repair costs of 140…180 €. For this study, the value was changed to 0,5 % (≙ 35…45 €/a).

Figure 4 illustrates the relation between the service life span of a component and its annualised investment costs – the given percentages refer to the initial investment costs of the component.

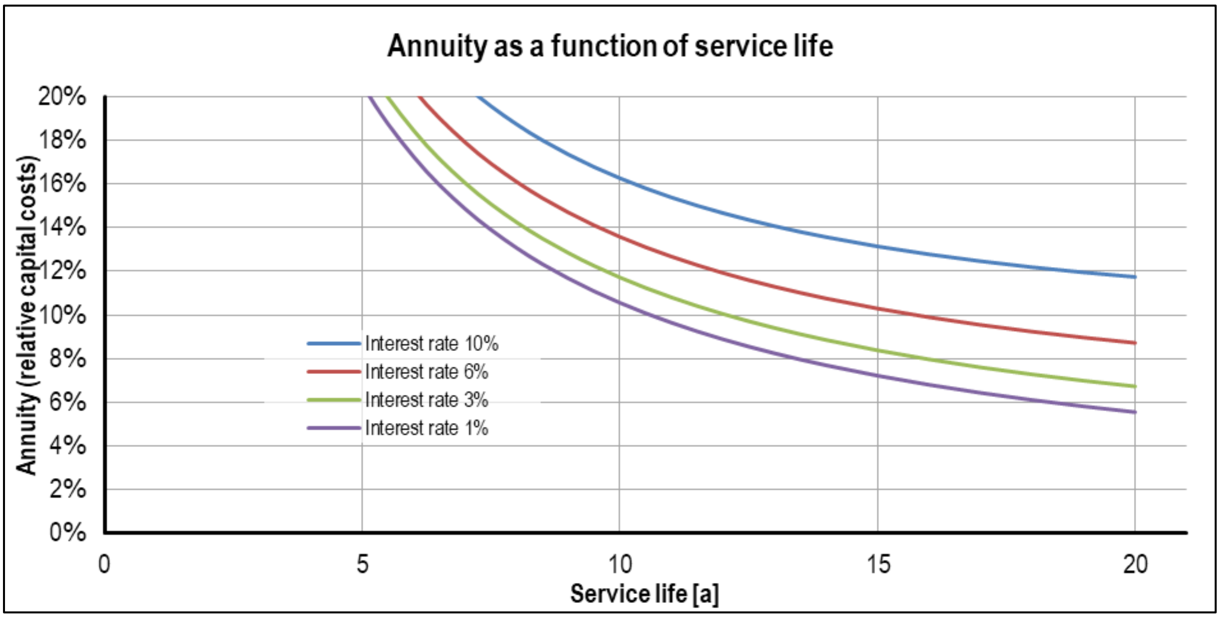


**Figure 4 Annualised investment costs of a component as a function of its service life for different interest rates**

Tables 13 to 17 give the investment costs assumed for each country. It is also assumed that these costs have to be paid in full – subsidies (if/where in place) are not researched.

**Table 13 Building-system-related investment costs including material, transport, labour and tax; Germany**

| Variant | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Heat generation for room heating<br>Central heat generator (boiler or heat pump), pump, control, mounting hardware | Gas condensing boiler<br>ca. 12 kW: 3.600 € | Electric air source heat pump<br>with domestic water heating<br>6,2 kW: 10.200 €<br>5,3 kW: 9.700 € | without domestic water heating<br>5,7 kW: 10.000 €<br>4,8 kW: 9.500 € | — | | | |
| Underfloor heating system 150 m²<br>Underfloor heating tubing/cable/mat, mounting system/hardware, room temperature control, floor screed | Hydronic underfloor heating (35/28 °C)<br>Underfloor heating tubing, manifold, heat distribution inside building (tubing, insulation, fittings, mounting hardware)<br>11.300 € | | | Electric underfloor heating<br>Electric Underfloor heating system (e. g. heating cable/mat)<br>9.000 € | | | |
| Domestic water heating | Hot water storage tank, sharing heat generator with room heating<br>standard tank<br>1.600 € | heat-pump-specific tank<br>2.900 € | Electric flow water heater<br>800 € | Electric heat pump water heater<br>4.200 € | Electric hot water storage tank<br>2.200 € | | Electric Flow water heater<br>800 € |
| Tap / Hot water distribution<br>Tubing, insulation, fittings, mounting hardware, circulation pump in case of central water heating | 1.300 € | 1.300 € | 200 € | 1.300 € | 1.300 € | | 200 € |
| Electric/Gas installation heating / hot water | 700 € | 500 € | 550 € | 150 € | | | |
| Gas connection to grid | 2.100 € | — | | | | | |
| Chimney | 2.900 € | — | | | | | |
| Ventilation system<br>Supply/exhaust ventilation system with heat recovery, ducts, in-/outlets, mounting hardware | 9.000 € | | | | | | |
| PV system ~50 m²; ~9 $kW_{p,new}$ (8,16 $kW_{p,25a}$)<br>including mounting hardware, inverter, installation material | 15.200 € | | | | | | |
| Battery ~9 kWh, lithium-based<br>including mounting and installation material | — | | 9.300 € | — | | 9.300 € | |

**Table 14 Building-system-related investment costs including material, transport, labour and tax; Czech Republic**

<table>
<tr><th>Variant</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>Heat generation for room heating<br>Central heat generator (boiler or heat pump), pump, control, mounting hardware</td><td>Gas condensing boiler<br>ca. 12 kW: 2.500 €</td><td colspan="2">Electric air source heat pump</td><td colspan="4" rowspan="2">—</td></tr>
<tr><td></td><td></td><td>with domestic water heating<br>6,2 kW: 8.160 €[a]<br>5,3 kW: 7.760 €[a]</td><td>without domestic water heating<br>5,7 kW: 8.000 €[a]<br>4,8 kW: 7.600 €[a]</td></tr>
<tr><td>Underfloor heating system 150 m²<br>Underfloor heating tubing/cable/mat, mounting system/hardware, room temperature control, floor screed</td><td colspan="3">Hydronic underfloor heating (35/28 °C)<br>Underfloor heating tubing, manifold, heat distribution inside building (tubing, insulation, fittings, mounting hardware)<br>10.100 €</td><td colspan="4">Electric underfloor heating<br>Electric Underfloor heating system (e. g. heating cable/mat)<br>7.000 €</td></tr>
<tr><td>Domestic water heating</td><td colspan="2">Hot water storage tank, sharing heat generator with room heating</td><td rowspan="2">Electric flow water heater<br>—[b]</td><td rowspan="2">Electric heat pump water heater<br>2.600 €</td><td colspan="2" rowspan="2">Electric hot water storage tank<br>340 €</td><td rowspan="2">Electric Flow water heater<br>—[b]</td></tr>
<tr><td></td><td>standard tank<br>1.280 €[a]</td><td>heat-pump-specific tank<br>2.320 €[a]</td></tr>
<tr><td>Tap / Hot water distribution<br>Tubing, insulation, fittings, mounting hardware, circulation pump in case of central water heating</td><td>1.040 €[a]</td><td>1.040 €[a]</td><td>160 €[a]</td><td>1.040 €[a]</td><td colspan="2">1.040 €[a]</td><td>160 €[a]</td></tr>
<tr><td>Electric/Gas installation heating / hot water</td><td>560 €[a]</td><td>400 €[a]</td><td>440 €[a]</td><td colspan="4">120 €[a]</td></tr>
<tr><td>Gas connection to grid</td><td>1.680 €[a]</td><td colspan="6">—</td></tr>
<tr><td>Chimney</td><td>2.320 €[a]</td><td colspan="6">—</td></tr>
<tr><td>Ventilation system<br>Supply/exhaust ventilation system with heat recovery, ducts, in-/outlets, mounting hardware</td><td colspan="7">7.500 €</td></tr>
<tr><td>PV system ~50 m²; ~9 $kW_{p,new}$ (8,16 $kW_{p,25a}$)<br>including mounting hardware, inverter, installation material</td><td colspan="7">12.160 €[a]</td></tr>
<tr><td>Battery ~9 kWh, lithium-based<br>including mounting and installation material</td><td colspan="2">—</td><td>7.440 €[a]</td><td colspan="2">—</td><td colspan="2">7.440 €[a]</td></tr>
</table>

[a] Estimated based on numbers given bei EUHA member

[b] Uncommon in CZE due to electricity base prices depending on amperage requirement

**Table 15 Building-system-related investment costs including material, transport, labour and tax; France**

| Variant | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Heat generation for room heating<br>Central heat generator (boiler or heat pump), pump, control, mounting hardware | Gas condensing boiler<br>ca. 12 kW: 4.250 € | Electric air source heat pump<br>with domestic water heating<br>13.200 € | without domestic water heating<br>11.700 € | — | | | |
| Underfloor heating system 150 m²<br>Underfloor heating tubing/cable/mat, mounting system/hardware, room temperature control, floor screed | Hydronic underfloor heating (35/28 °C)<br>Underfloor heating tubing, manifold, heat distribution inside building (tubing, insulation, fittings, mounting hardware)<br>11.000 € | | | Electric underfloor heating<br>Electric Underfloor heating system (e. g. heating cable/mat)<br>9.000 € | | | |
| Domestic water heating | Hot water storage tank, sharing heat generator with room heating<br>standard tank<br>1.920 €[a] | heat-pump-specific tank<br>2.850 € | Electric flow water heater<br>700 € | Electric heat pump water heater<br>3.200 € | Electric hot water storage tank<br>800 € | | Electric Flow water heater<br>700 € |
| Tap / Hot water distribution<br>Tubing, insulation, fittings, mounting hardware, circulation pump in case of central water heating | 650 € | 650 € | 300 € | 650 € | 650 € | | 300 € |
| Electric/Gas installation heating / hot water | 550 € | 480 € | 480 € | 250 € | | | |
| Gas connection to grid | 400 € | — | | | | | |
| Chimney | 0 € | — | | | | | |
| Ventilation system<br>Supply/exhaust ventilation system with heat recovery, ducts, in-/outlets, mounting hardware | 15.000 € | | | | | | |
| PV system ~50 m²; ~9 $kW_{p,new}$ (8,16 $kW_{p,25a}$)<br>including mounting hardware, inverter, installation material | 25.000 € | | | | | | |
| Battery ~9 kWh, lithium-based<br>including mounting and installation material | — | | 10.000 € | — | | 10.000 € | |

[a] Estimated based on numbers given bei EUHA member

**Table 16 Building-system-related investment costs including material, transport, labour and tax; Netherlands**

<table>
<tr><th>Variant</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>Heat generation for room heating<br>Central heat generator (boiler or heat pump), pump, control, mounting hardware</td><td>Gas condensing boiler<br>ca. 12 kW: 3.600 €</td><td>Electric air source heat pump<br>with domestic water heating<br>6,2 kW: 10.200 €<br>5,3 kW: 9.700 €</td><td>without domestic water heating<br>5,7 kW: 10.000 €<br>4,8 kW: 9.500 €</td><td colspan="4">—</td></tr>
<tr><td>Underfloor heating system 150 m²<br>Underfloor heating tubing/cable/mat, mounting system/hardware, room temperature control, floor screed</td><td colspan="3">Hydronic underfloor heating (35/28 °C)<br>Underfloor heating tubing, manifold, heat distribution inside building (tubing, insulation, fittings, mounting hardware)<br>11.300 €</td><td colspan="4">Electric underfloor heating<br>Electric Underfloor heating system (e. g. heating cable/mat)<br>9.000 €</td></tr>
<tr><td>Domestic water heating</td><td>Hot water storage tank, sharing heat generator with room heating<br>standard tank<br>1.600 €</td><td>heat-pump-specific tank<br>2.900 €</td><td>Electric flow water heater<br>800 €</td><td>Electric heat pump water heater<br>4.200 €</td><td colspan="2">Electric hot water storage tank<br>2.200 €</td><td>Electric Flow water heater<br>800 €</td></tr>
<tr><td>Tap / Hot water distribution<br>Tubing, insulation, fittings, mounting hardware, circulation pump in case of central water heating</td><td>1.300 €</td><td>1.300 €</td><td>200 €</td><td>1.300 €</td><td colspan="2">1.300 €</td><td>200 €</td></tr>
<tr><td>Electric/Gas installation heating / hot water</td><td>700 €</td><td>500 €</td><td>550 €</td><td colspan="4">150 €</td></tr>
<tr><td>Gas connection to grid</td><td>2.100 €</td><td colspan="6">—</td></tr>
<tr><td>Chimney</td><td>2.900 €</td><td colspan="6">—</td></tr>
<tr><td>Ventilation system<br>Supply/exhaust ventilation system with heat recovery, ducts, in-/outlets, mounting hardware</td><td colspan="7">9.000 €</td></tr>
<tr><td>PV system ~50 m²; ~9 $kW_{p,new}$ (8,16 $kW_{p,25a}$)<br>including mounting hardware, inverter, installation material</td><td colspan="7">11.250 €</td></tr>
<tr><td>Battery ~9 kWh, lithium-based<br>including mounting and installation material</td><td colspan="2">—</td><td>9.300 €</td><td colspan="2">—</td><td colspan="2">9.300 €</td></tr>
</table>

**Table 17 Building-system-related investment costs including material, transport, labour and tax; Sweden**

<table>
<tr><th>Variant</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>Heat generation for room heating<br>Central heat generator (boiler or heat pump), pump, control, mounting hardware</td><td>Gas condensing boiler<br>ca. 12 kW: 3.600 €</td><td colspan="2">Electric air source heat pump</td><td colspan="4" rowspan="2">—</td></tr>
<tr><td></td><td></td><td>with domestic water heating<br>6,2 kW: 10.200 €<br>5,3 kW: 9.700 €</td><td>without domestic water heating<br>5,7 kW: 10.000 €<br>4,8 kW: 9.500 €</td></tr>
<tr><td>Underfloor heating system 150 m²<br>Underfloor heating tubing/cable/mat, mounting system/hardware, room temperature control, floor screed</td><td colspan="3">Hydronic underfloor heating (35/28 °C)<br>Underfloor heating tubing, manifold, heat distribution inside building (tubing, insulation, fittings, mounting hardware)<br>11.300 €</td><td colspan="4">Electric underfloor heating<br>Electric Underfloor heating system (e. g. heating cable/mat)<br>9.000 €</td></tr>
<tr><td>Domestic water heating</td><td colspan="2">Hot water storage tank, sharing heat generator with room heating</td><td rowspan="2">Electric flow water heater<br>800 €</td><td rowspan="2">Electric heat pump water heater<br>4.200 €</td><td colspan="2" rowspan="2">Electric hot water storage tank<br>2.200 €</td><td rowspan="2">Electric Flow water heater<br>800 €</td></tr>
<tr><td></td><td>standard tank<br>1.600 €</td><td>heat-pump-specific tank<br>2.900 €</td></tr>
<tr><td>Tap / Hot water distribution<br>Tubing, insulation, fittings, mounting hardware, circulation pump in case of central water heating</td><td>1.300 €</td><td>1.300 €</td><td>200 €</td><td>1.300 €</td><td colspan="2">1.300 €</td><td>200 €</td></tr>
<tr><td>Electric/Gas installation heating / hot water</td><td>700 €</td><td>500 €</td><td>550 €</td><td colspan="4">150 €</td></tr>
<tr><td>Gas connection to grid</td><td>2.100 €</td><td colspan="6">—</td></tr>
<tr><td>Chimney</td><td>2.900 €</td><td colspan="6">—</td></tr>
<tr><td>Ventilation system<br>Supply/exhaust ventilation system with heat recovery, ducts, in-/outlets, mounting hardware</td><td colspan="7">9.000 €</td></tr>
<tr><td>PV system ~50 m²; ~9 $kW_{p,new}$ (8,16 $kW_{p,25a}$)<br>including mounting hardware, inverter, installation material</td><td colspan="7">15.200 €</td></tr>
<tr><td>Battery ~9 kWh, lithium-based<br>including mounting and installation material</td><td colspan="2">—</td><td>9.300 €</td><td colspan="2">—</td><td colspan="2">9.300 €</td></tr>
</table>

# 3 Results

## 3.1 General

Chapter 3.2 shows the final energy balance and the primary energy demand. Chapters 3.3 and 3.4 show the annual energy and overall cost balance.

**All results are based on the calculation method(s) and assumptions / input parameters described in Chapter 2. The tendencies shown here cannot necessarily be applied to significantly deviating scenarios (e. g. significant changes to the size/power of the PV system and/or battery in relation to the building's demand).**

## 3.2 Energy balance

### 3.2.1 General

The results shown here are based EN 15316 [1] / DIN V 18599 [2, 3].

So far, national regulation concerning energy performance certificates, EPBD implementation and definition of the nearly zero-energy building (NZEB) is not harmonised across Europe (other than all countries technically following the EPBD). Therefore, there is no common approach as to how to balance a building's energy demand, which parts of the energy demand to include (e. g. HVAC only or household appliances as well) and how to set off the building's electricity demand against the output of a PV system. The results shown here can deviate from what would be calculated in the context of energy performance certificates in accordance with national regulation.

### 3.2.2 Final energy

The following figures show from left to right these results for each variant:

- Final energy demand of the whole building before PV
  - Gas
  - Electricity: HVAC, household
- Electricity balance including PV system
  - Momentary values
    - Total PV output: HVAC, household, fed in to grid
    - Drawn electricity: HVAC, household
  - Annual grid-building balance

  The electricity balance based on momentary values gives an estimate of actual draw and feed-in as could be measured with either a combination of separate meters or types of two-way meters that show draw and feed-in separately. In contrast, the annual balance only shows the difference between annual draw and annual feed-in – here, the overall result can only be either draw or feed-in; this value gives an estimate of what would be measured with a single-value fourth-and-back type of meter. Which of these two approaches is actually used to determine the annual energy costs, depends on the chosen/available tariff scheme. Within this study, energy costs are based on momentary values except for the Netherlands (where the annual balance is used instead).

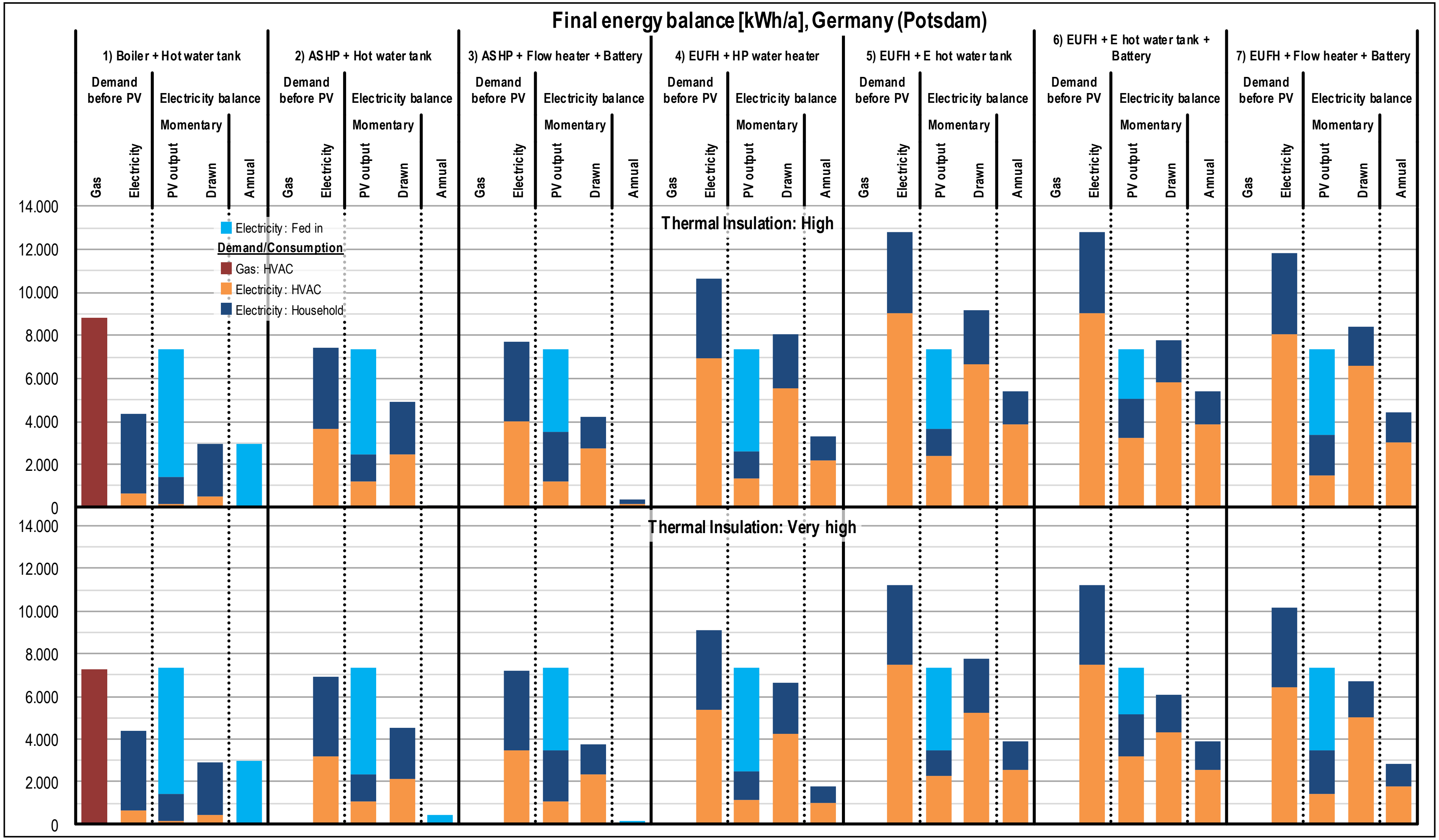


**Figure 5** Final energy balance, Germany

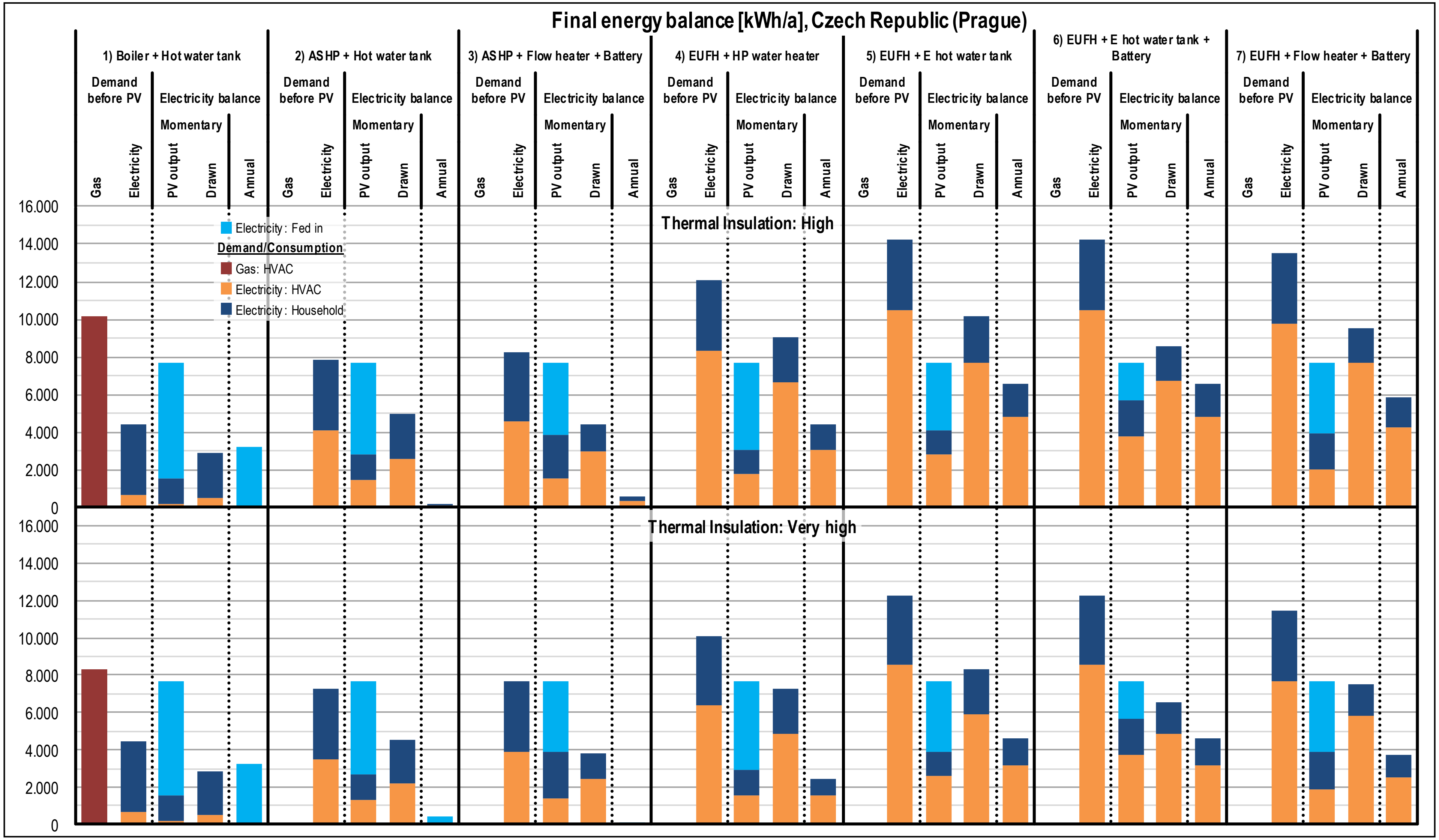


**Figure 6** Final energy balance, Czech Republic

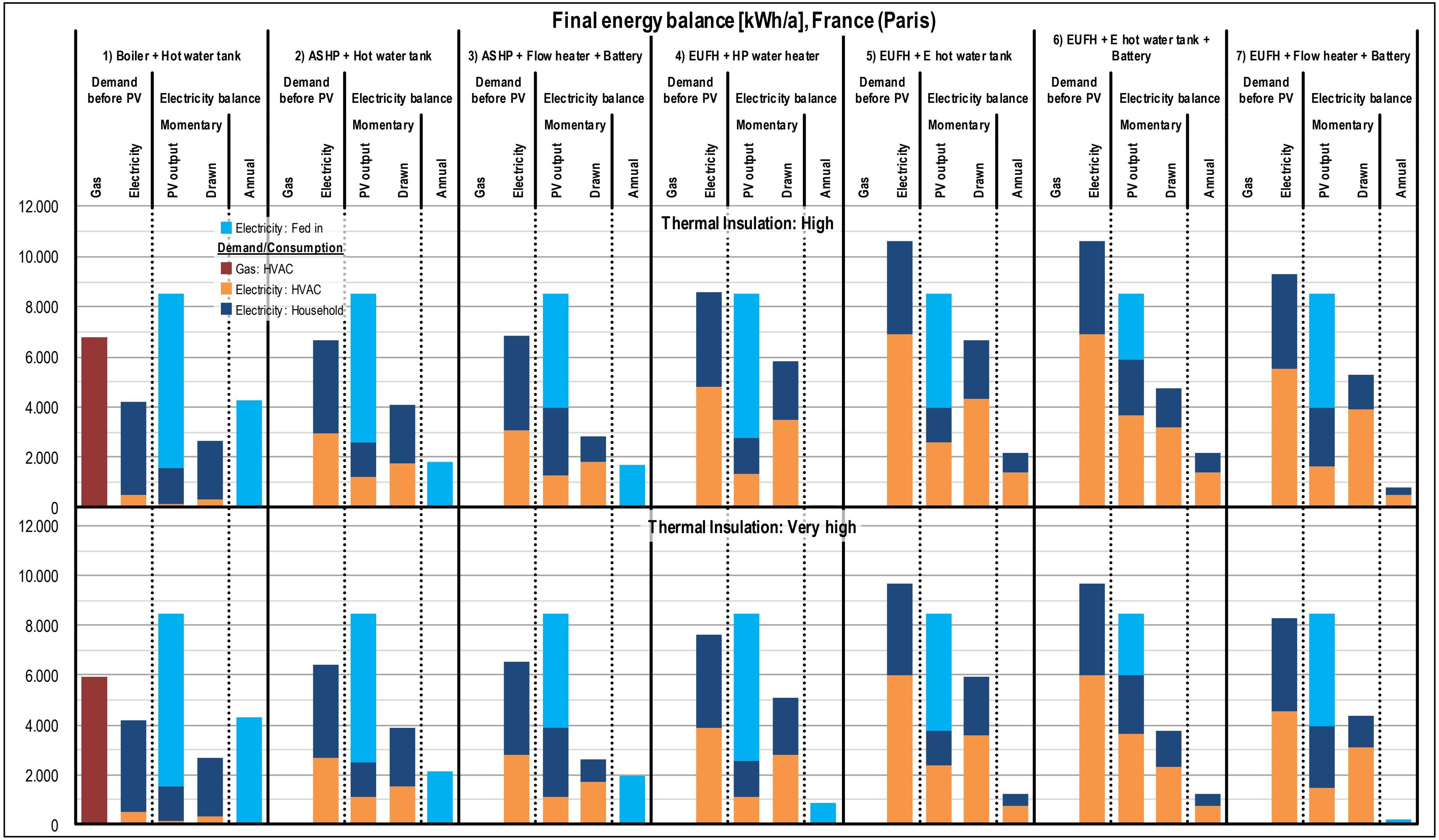


Figure 7 Final energy balance, France

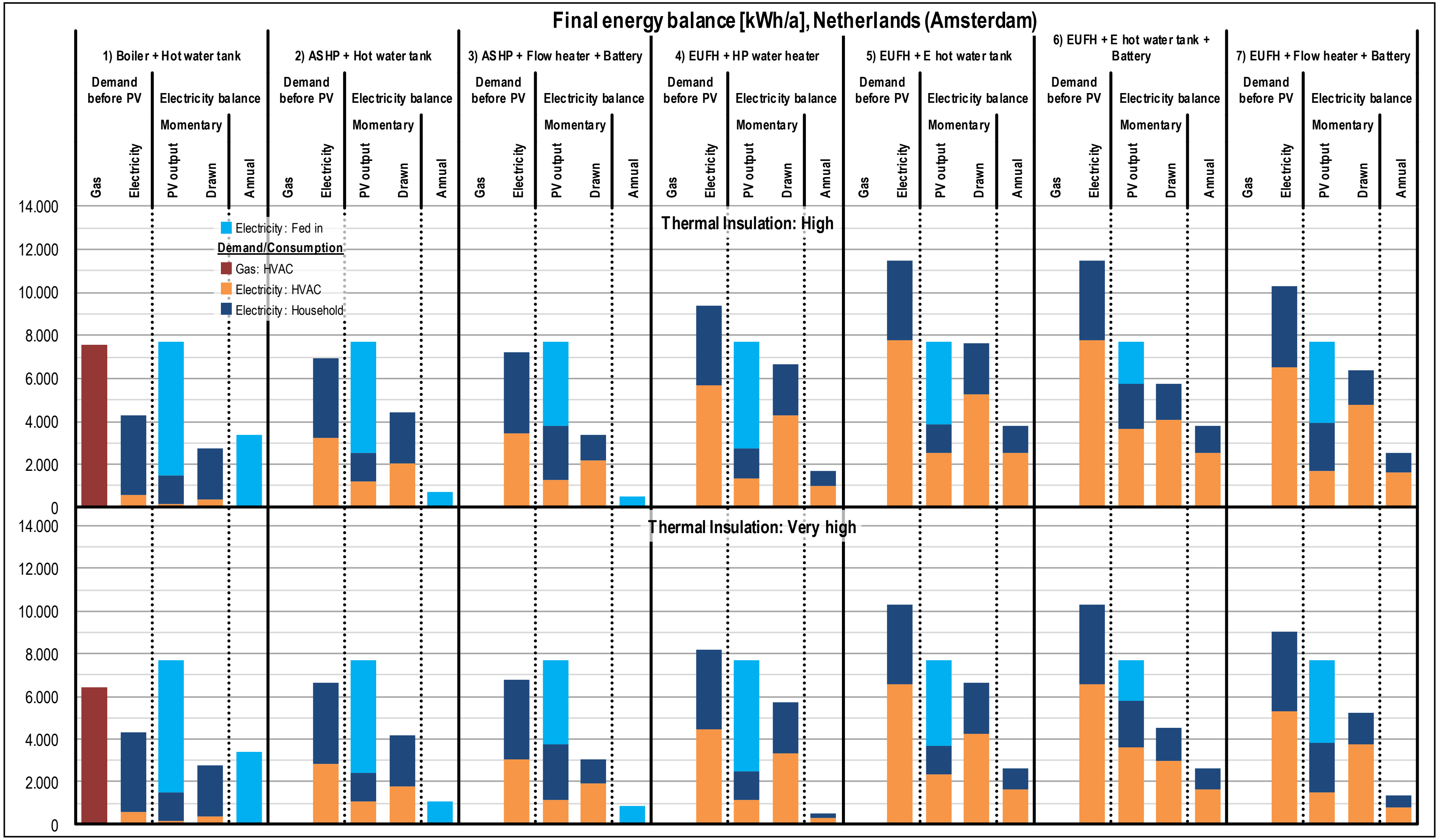


**Figure 8** **Final energy balance, Netherlands**

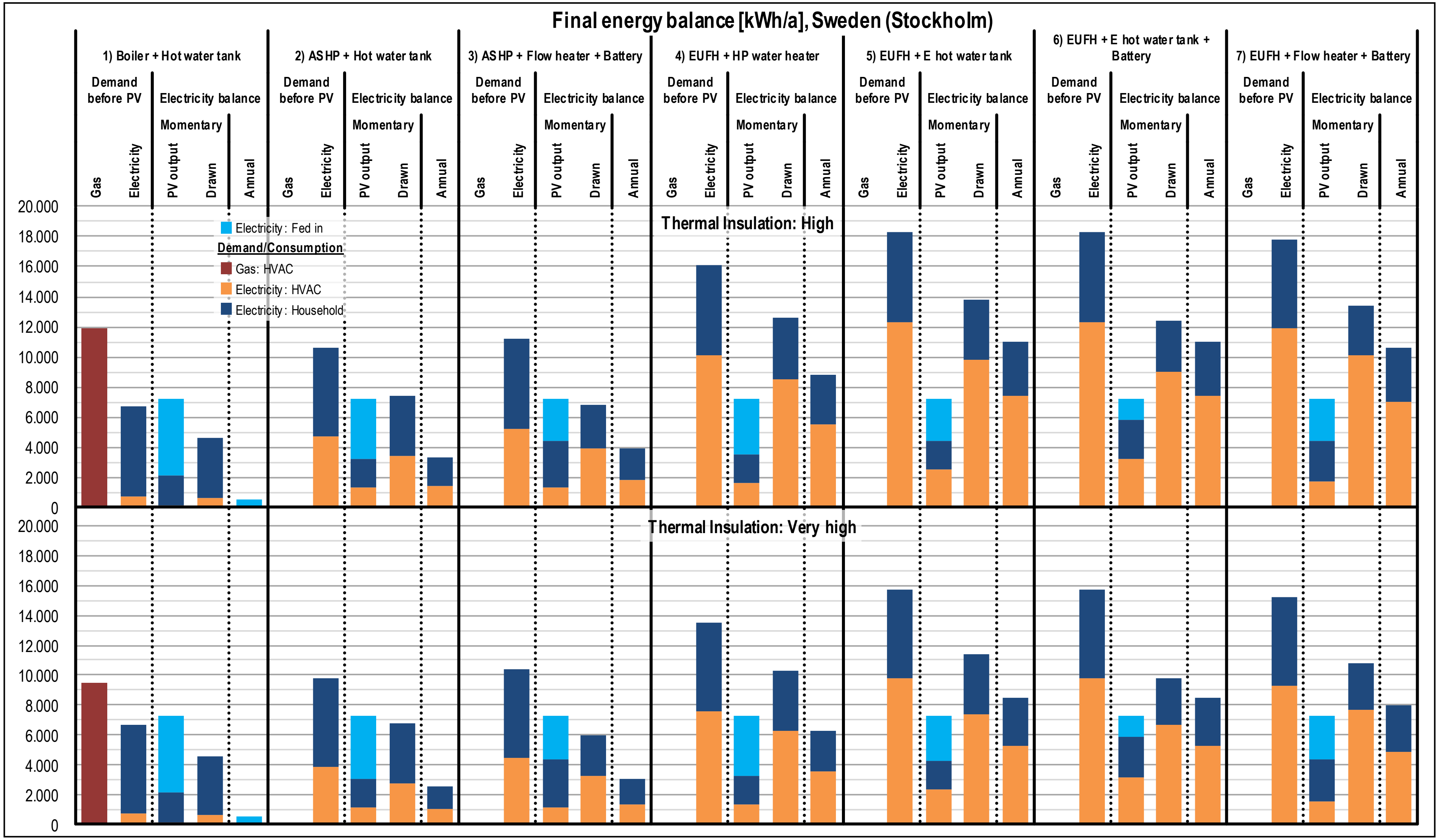


**Figure 9** **Final energy balance, Sweden; results for variant 1 (gas) apply in good approximation to district heating as well**

## Findings

Among the electrically heated variants, the two variants with heat pumps for room heating (2, 3) show the lowest final energy demands before and after PV gains. While there is a difference on the hot-water side between heat pump and flow heater, it is comparatively small.

For the variants with electric underfloor heating, the final energy demand before PV depends on the hot-water system as follows (from lowest to highest demand):

- Heat-pump water heater (4)
- Flow water heater (7)
- Central hot-water tank (5/6)

When looking at the final energy demand after taking into account PV gains, this order can change:

- **Energy (demand) efficiency**

  Generally, instantaneous water heating without thermal storage and with almost no distribution tubing is more efficient than a hot-water tank with central hot-water distribution before taking into account PV gains. The lower final-energy efficiency of a hot-water tank, when compared against a flow-through heater, is caused by heat losses due to storage and distribution of hot water.

- **Utilisation of PV output**

  As flow water heaters heat water while it flows through them (at the rate the water is drawn from the tap), they require a comparatively large amount of power7 and they require it at the time hot water is drawn – whether the sun is up or not. Additionally, roof-mounted PV systems, as assumed here, usually peak at a significantly lower amount of power and will deliver even less under average weather conditions. Therefore, the power and energy requirement of flow water heating can only be covered to a certain percentage by the PV system. With the addition of a battery, this effect will decrease somewhat, but still be there.

  A hot-water tank heats up water much slower with comparatively little power whenever the water temperature drops below a certain threshold and then stores that heat – thus it can utilise PV output much better in terms of both power requirement and time.

These two effects work against each other. Depending on the country-specific PV potential in relation to the electricity demand, either a flow heater or a hot-water tank can be more efficient overall (including PV). Under the conditions assumed here, the flow-heater scenario (variant 7) will require less electricity from the grid than the hot-water-tank scenario without additional battery (variant 5) for Germany, Czech Republic, France and the Netherlands, but slightly more for Sweden. If both the hot-water tank and the flow water heater are equipped with a battery (variant 6 vs. 7), the hot-water tank (6) will draw less electricity from the grid in all 5 countries.

[7] Models for universal use typically range around 18 kW to 24 kW.

### 3.2.3 Primary energy

The following figures show from left to right for each variant the total annual primary energy demand:

- HVAC systems after PV; no household appliances
- HVAC systems less the PV output self-used for household appliances
- HVAC systems less the PV output fed in to grid
- HVAC systems less the PV output both self-used for household appliances and fed in to grid

Please note that the shown results do not include household appliances on the demand side. Thus, applying a bonus for PV output self-used in household appliances can lead to a negative primary energy demand.

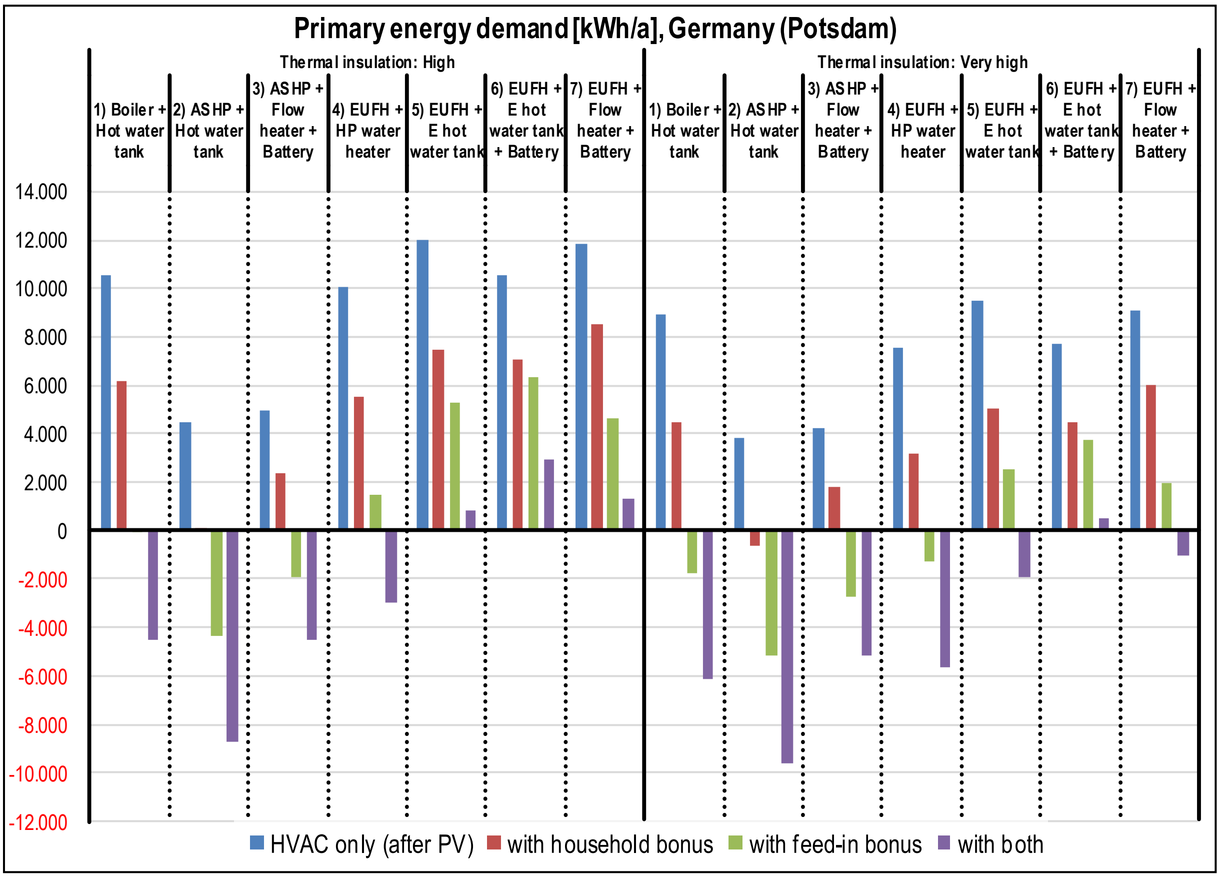


Figure 10 Primary energy demand, Germany

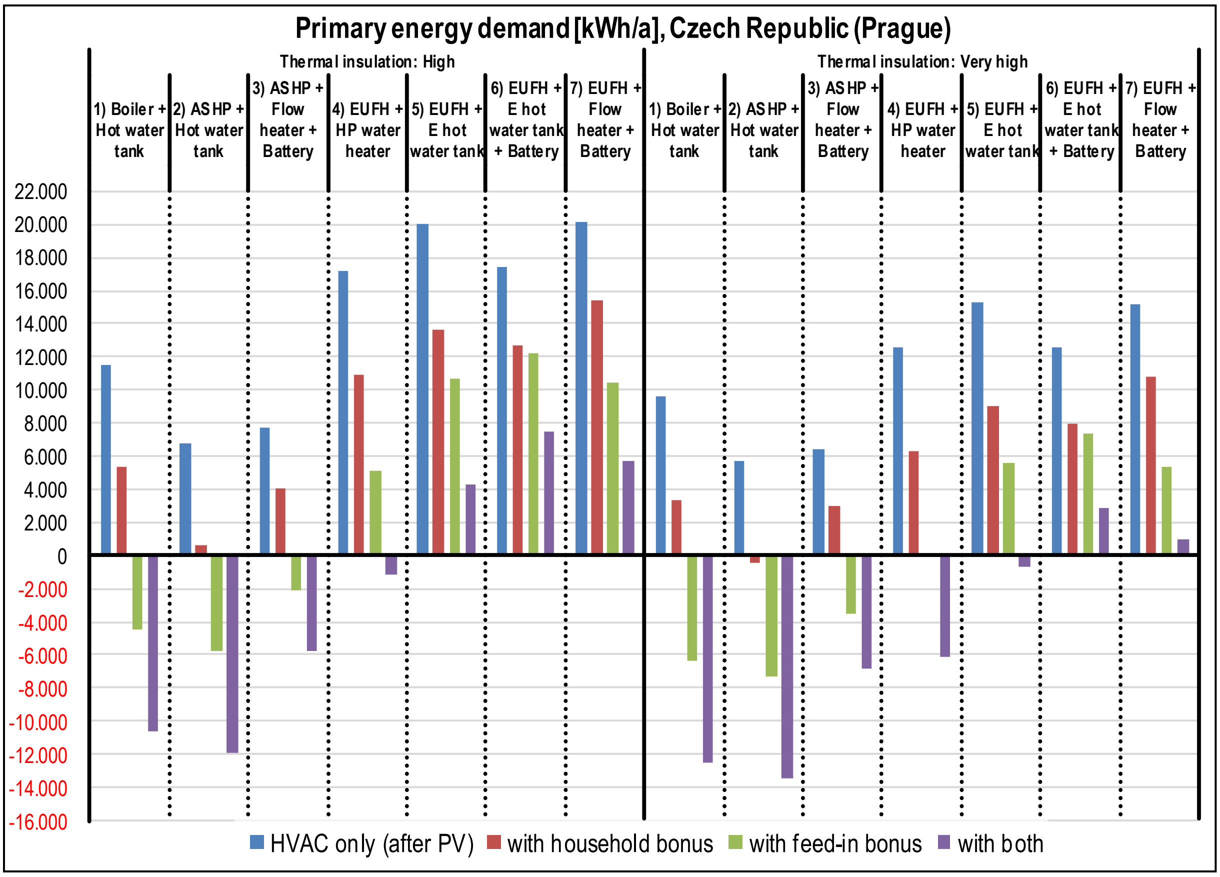


**Figure 11** Primary energy demand, Czech Republic

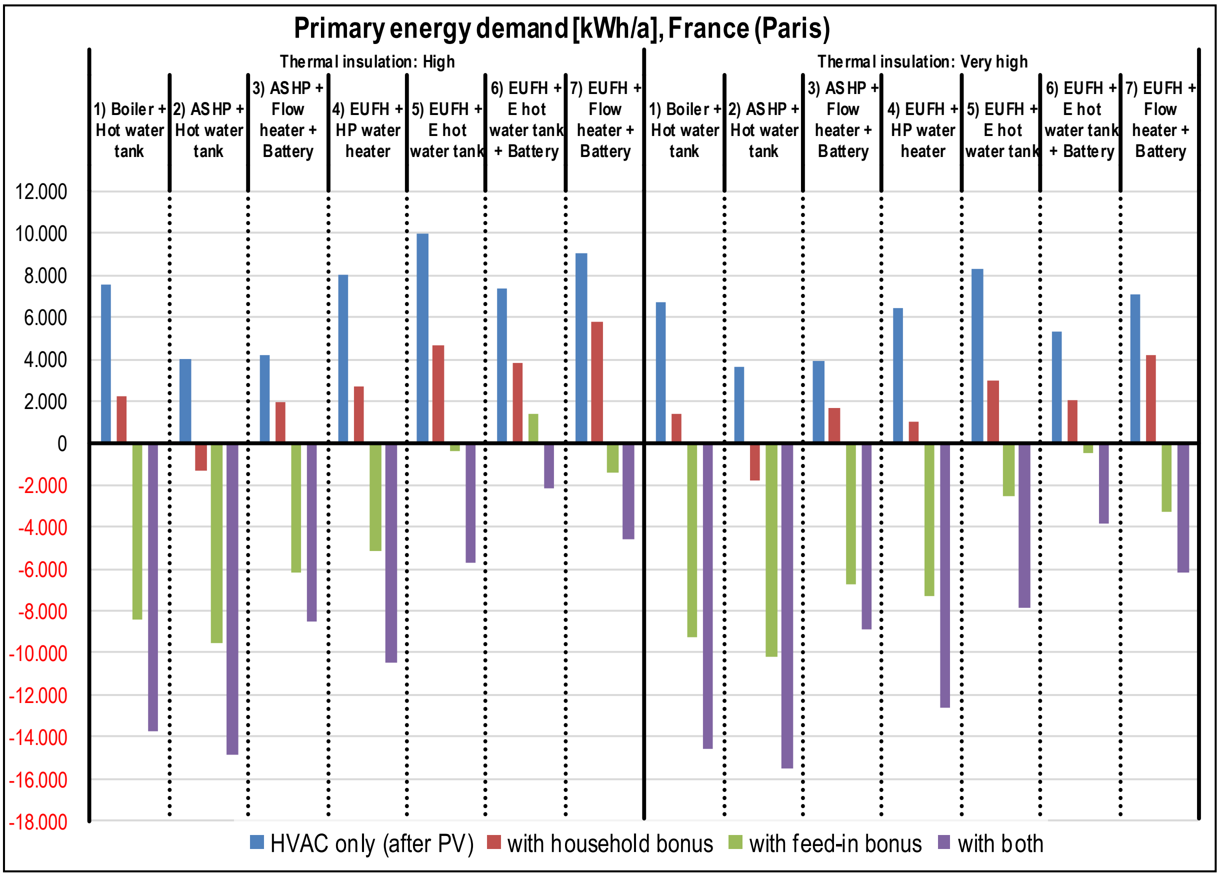


**Figure 12** Primary energy demand, France

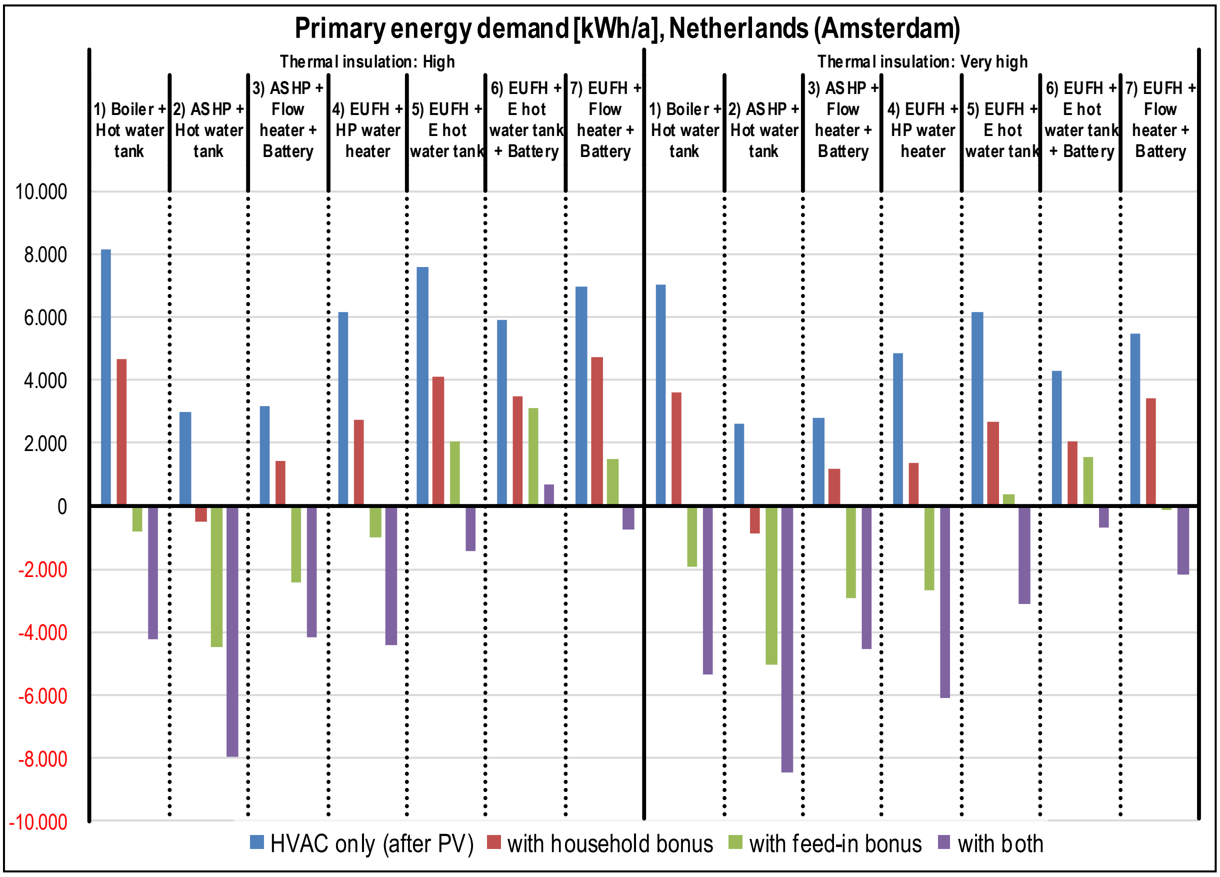


**Figure 13** Primary energy demand, Netherlands

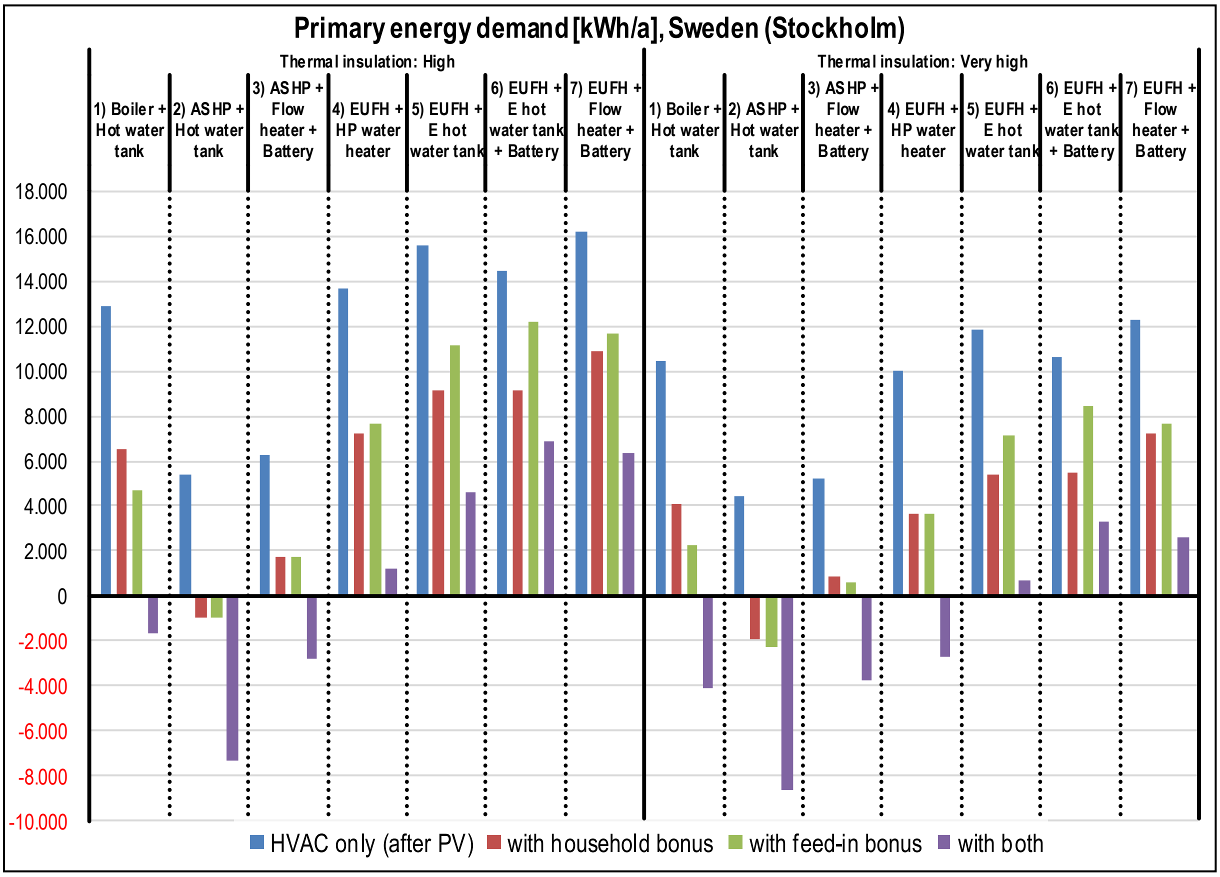


**Figure 14** Primary energy demand, Sweden; results for variant 1 (gas) apply in good approximation to district heating as well

### Findings

A comparison of the variants shows a similar trend to what was found for the final energy demand (3.2.2). However, with primary energy factors for electricity and natural gas being significantly different and also deviating from country to country (electricity), larger deviations between the primary energy demand for the gas-boiler variant and the electric variants can be found:

- For Germany ($PEF_{Gas}$ = 1,1; $PEF_{El}$ = 1,8), direct electric heating will, on average, cause the same primary energy demand as heating via gas condensing boiler – slightly more with less thermal insulation and/or hot-water systems not optimised for PV and slightly less with better thermal insulation and/or better hot-water systems.
- In the Czech republic ($PEF_{Gas}$ = 1,0; $PEF_{El}$ = 2,6), direct-electric heating causes significantly more primary energy demand than heating with a gas condensing boiler – this difference is mainly caused by the high primary energy factor for electricity in the Czech Republic.
- In France ($PEF_{Gas}$ = 1,0; $PEF_{El}$ = 2,3), direct-electric heating causes, on average, the same or slightly more primary energy demand than gas heating, but can become comparable or even better in highly insulated buildings with a hot-water system that is highly efficient or/and optimised for self-use of PV output. France still has a rather high primary energy factor for electricity, but also a relatively high potential for PV.
- In the Netherlands ($PEF_{Gas}$ = 1,0; $PEF_{El}$ = 1,45) with the lowest primary energy factor for electricity of all included countries, electric heating will usually cause less or substantially less primary energy demand than gas heating.
- In Sweden ($PEF_{Gas}$ = 1,0; $PEF_{El}$ = 1,6), direct-electric heating will, on average, cause slightly more primary energy demand than gas heating, but can reach a similar level for highly insulated buildings and PV-optimised hot-water systems. While Sweden already has a very low primary energy factor for electricity, its potential for PV is also comparatively low.

With primary energy factors for electricity being significantly higher than for gas, direct-electric heating scales better with the building’s heat demand (thermal insulation, air tightness) than gas heating in terms of primary energy.

If bonuses for PV output self-used for household appliances or/and for fed-in PV output are applied, annual primary energy demand is reduced drastically.

## 3.3 Energy costs

The following figures show the annual energy costs including HVAC systems as well as household appliances. Fed-in PV output is taken into account.

Overall energy costs are determined by energy demand, PV output, energy prices and, where in place, feed-in tariffs.

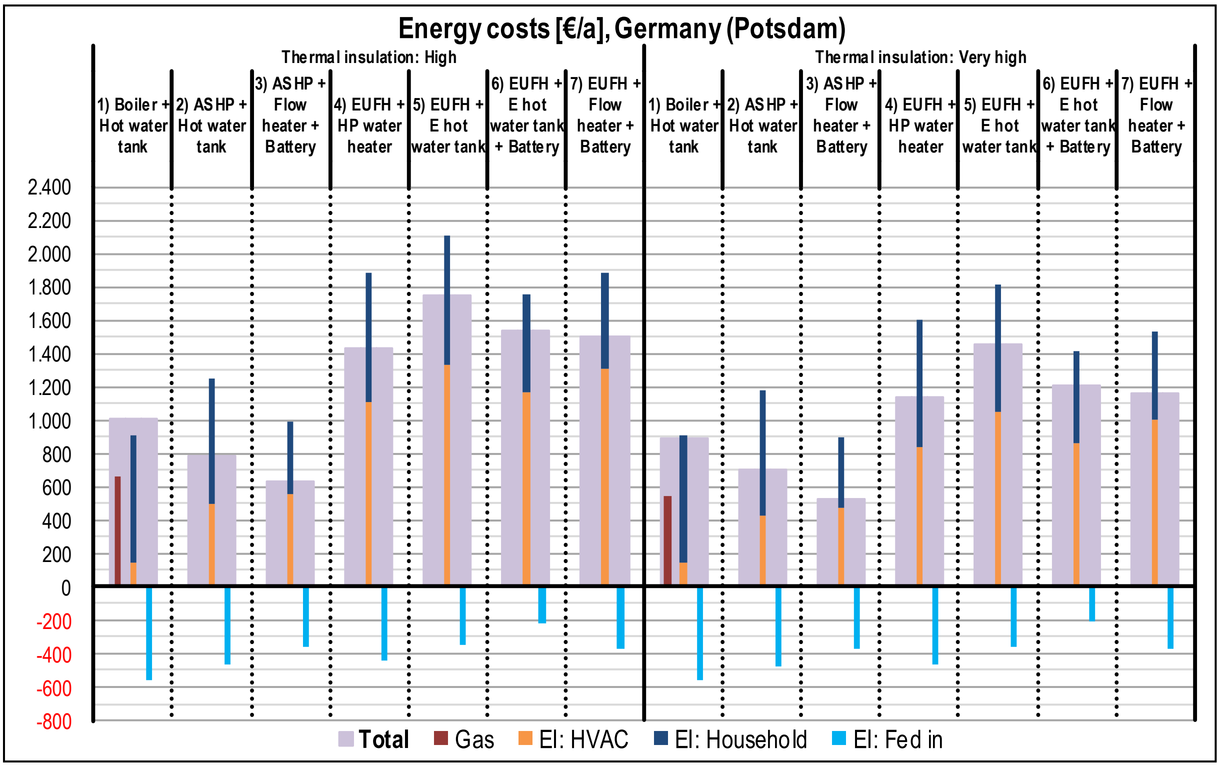


Figure 15 Energy costs, Germany

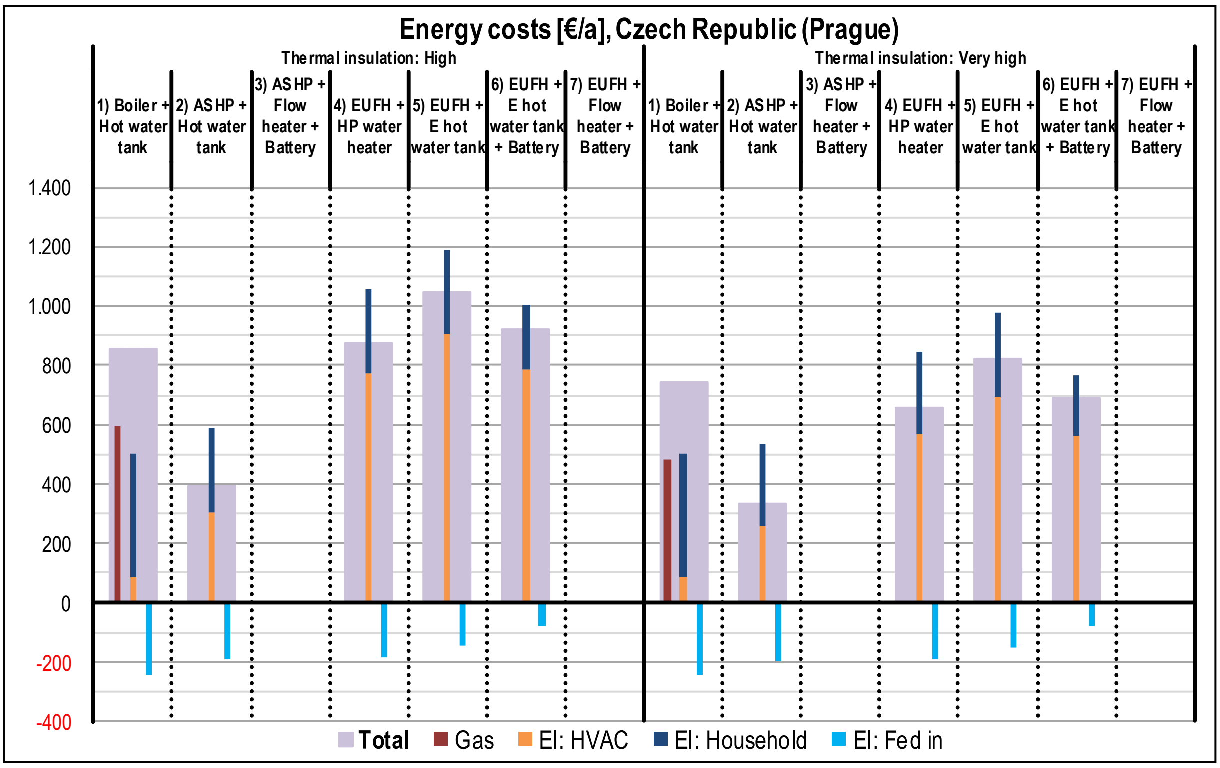


Figure 16 Energy costs, Czech Republic; Missing columns 3 and 7: Flow water heaters are uncommon in CZE due to electricity base prices depending on the amperage requirement of the building

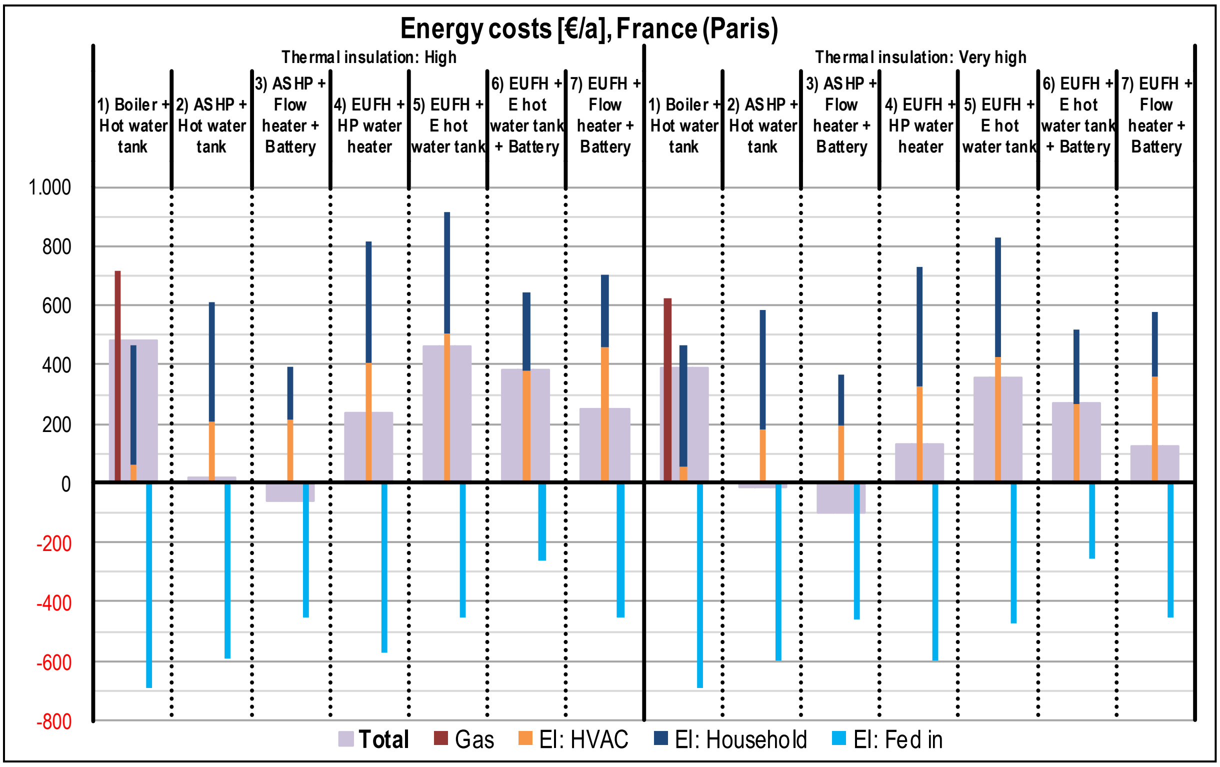


Figure 17 Energy costs, France

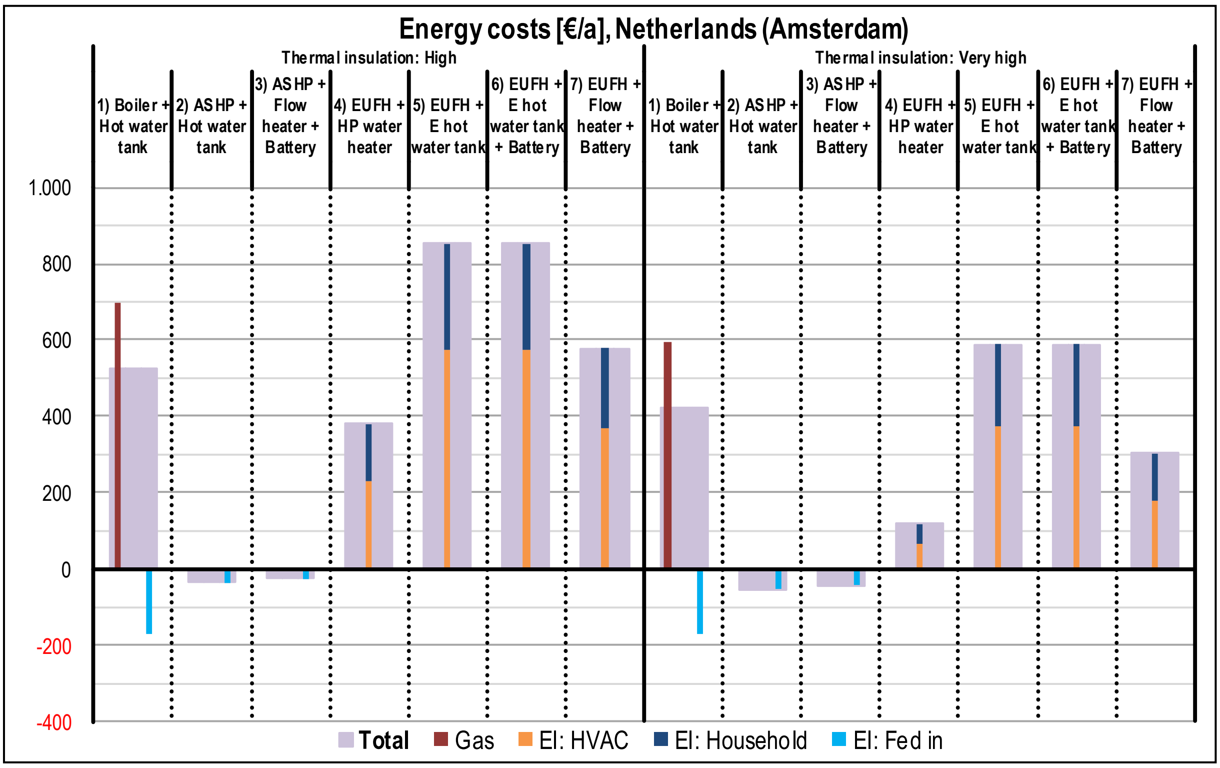


Figure 18 Energy costs, Netherlands; Costs based on annual balance

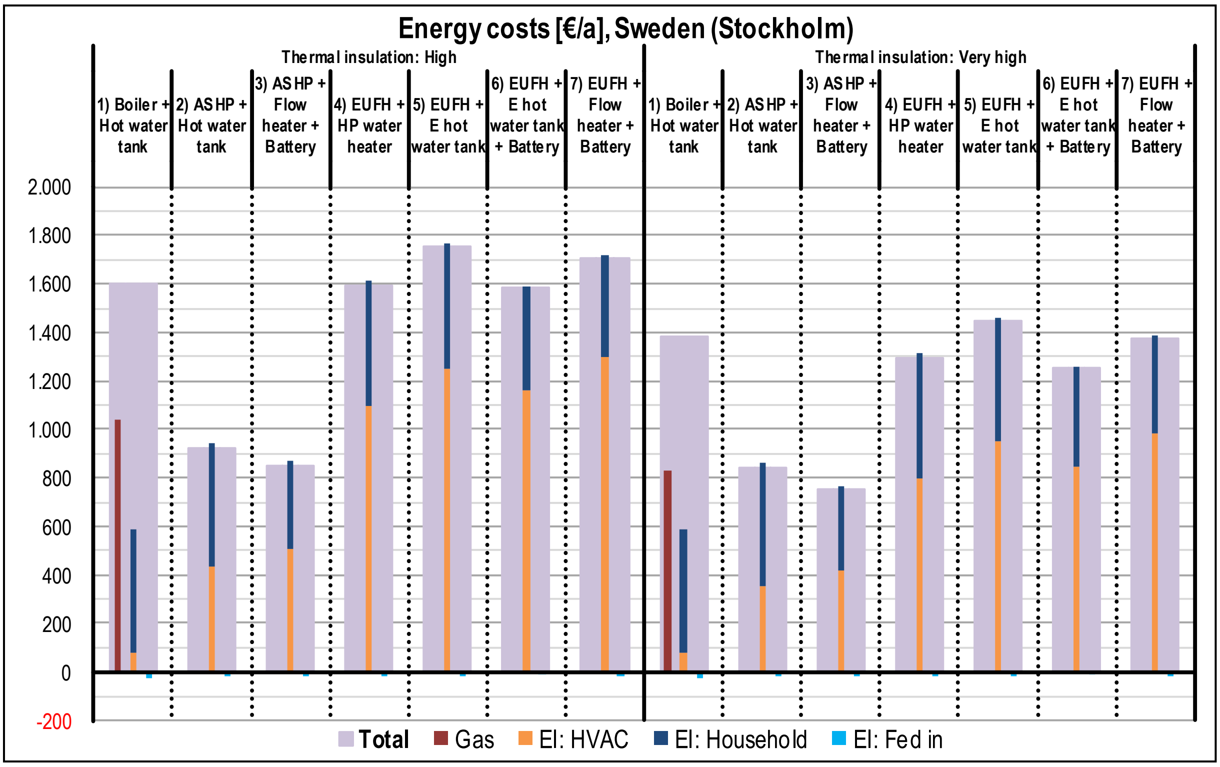


**Figure 19** **Energy costs, Sweden; results for variant 1 (gas) apply in good approximation to district heating as well**

## Findings

- In Germany, direct-electric heating usually causes significantly higher energy costs than gas heating (up to factor 2 in the example calculations).
- In the Czech Republic and the Netherlands, direct-electric heating is, on average, comparable to gas heating – sometimes higher/lower depending on thermal insulation and the hot- water system. However, it should be noted that, depending on the absolute cost level, relative differences in energy costs can be quite substantial (up to around factor 1,6 for the Netherlands).
- In France, direct-electric heating causes similar to substantially lower energy costs than gas heating.
- In Sweden, electric heating causes similar energy costs as gas or district[8] heating.

With electricity usually being significantly more expensive than gas per kilowatt hour, direct-electric heating scales better with the building's heat demand (thermal insulation, air tightness) than gas heating in terms of energy costs.

## 3.4 Total annual cost balance

The following figures show the initial HVAC-related investment costs (see Tables 13 to 17) and the total annual costs as the sum of costs related to operation (maintenance/insurance, repair), invested capital and energy consumption.

[8] In Sweden, district heating is very common and costs about as much as natural gas per kilowatt hour final energy delivered to the building. In terms of heat / final energy demand, the difference between heating a building either via gas condensing boiler or via connecting to a district heating grid is negligible; therefore, variant 1, while modelling a gas condensing boiler, also approximates district heating very closely.

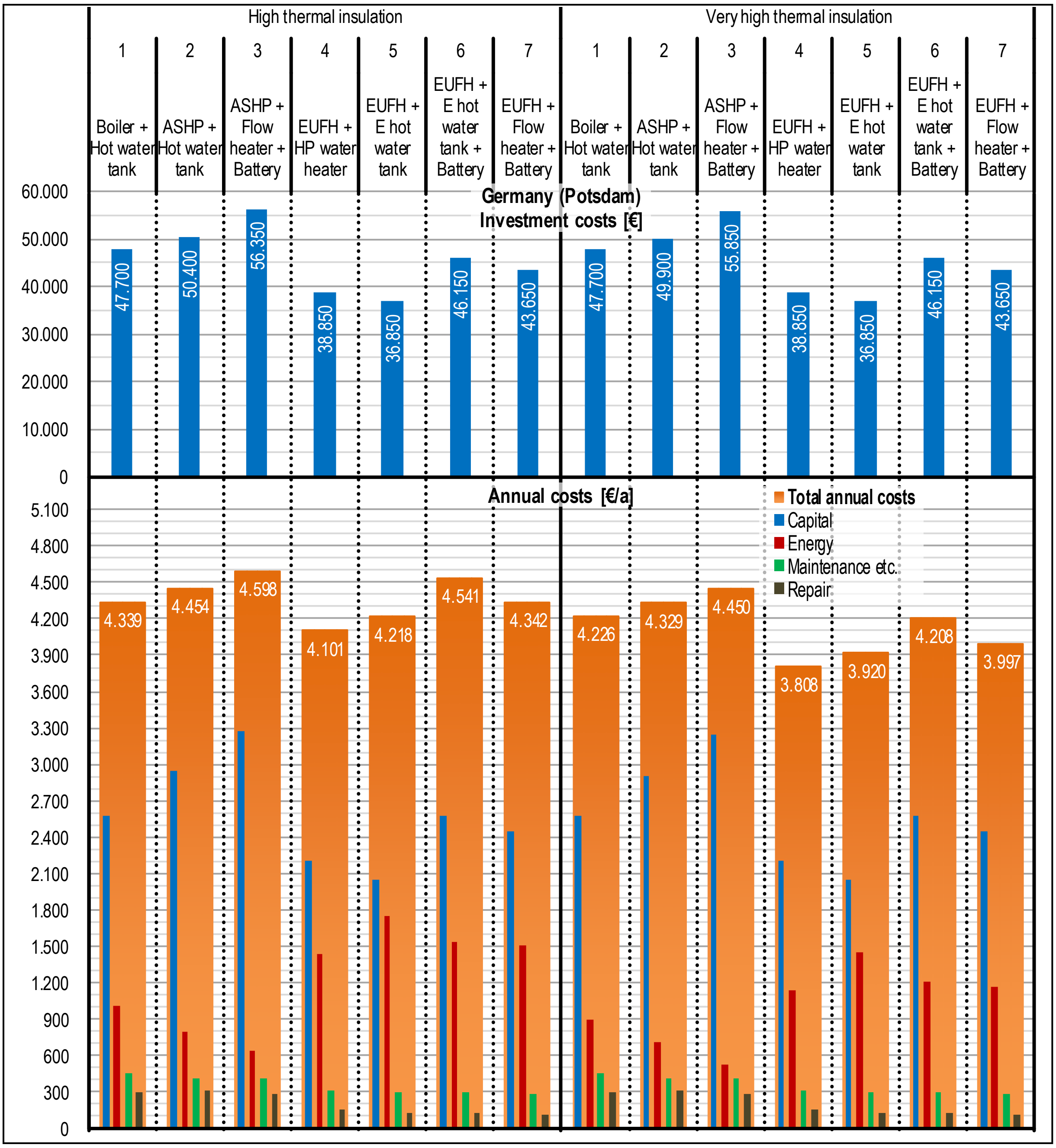


**Figure 20** Cost balance, Germany

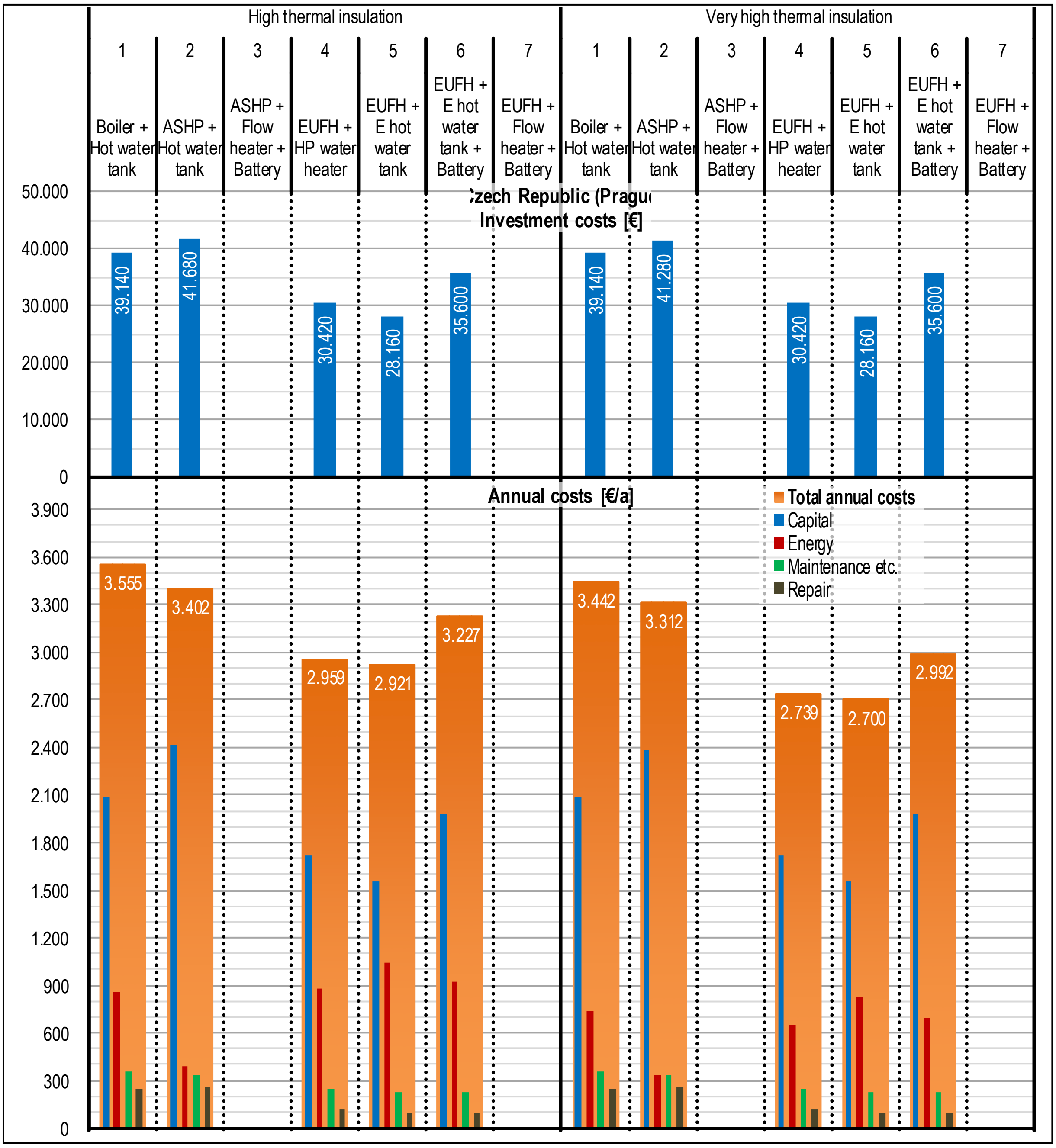


**Figure 21** Cost balance, Czech Republic; Missing columns 3 and 7: Flow water heaters are uncommon in CZE due to electricity base prices depending on the amperage requirement of the building

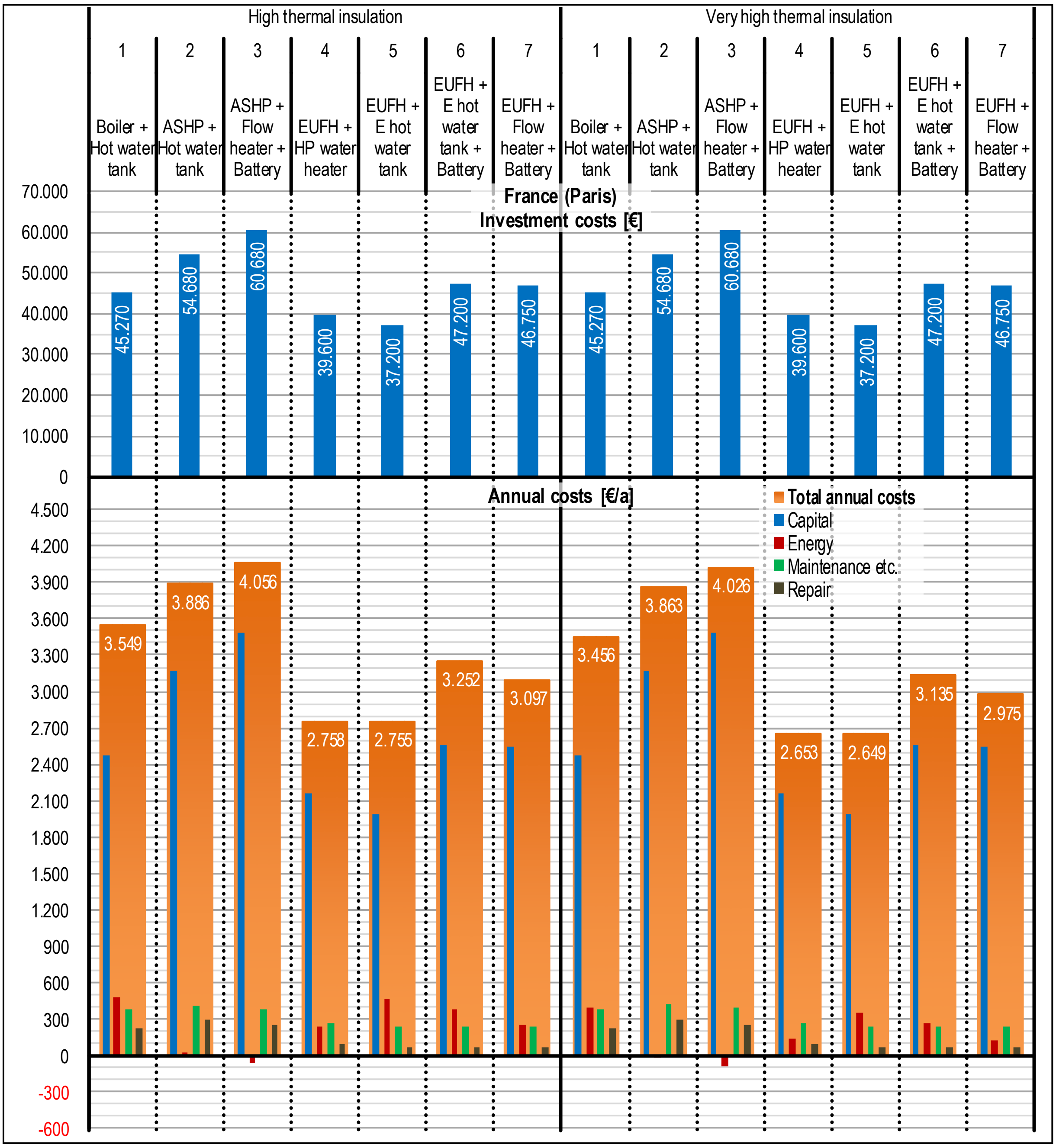


**Figure 22** Cost balance, France

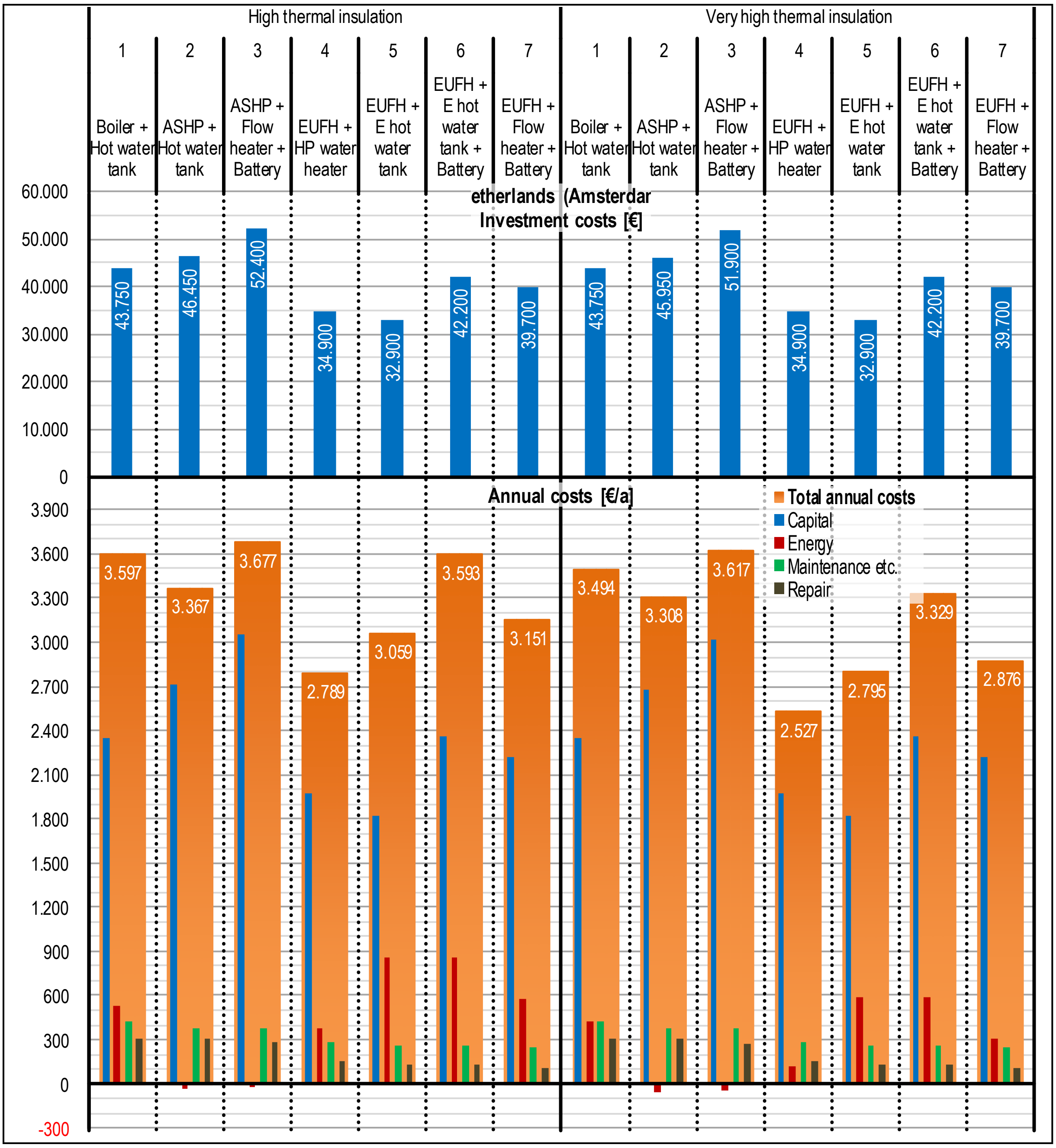


**Figure 23** Cost balance, the Netherlands

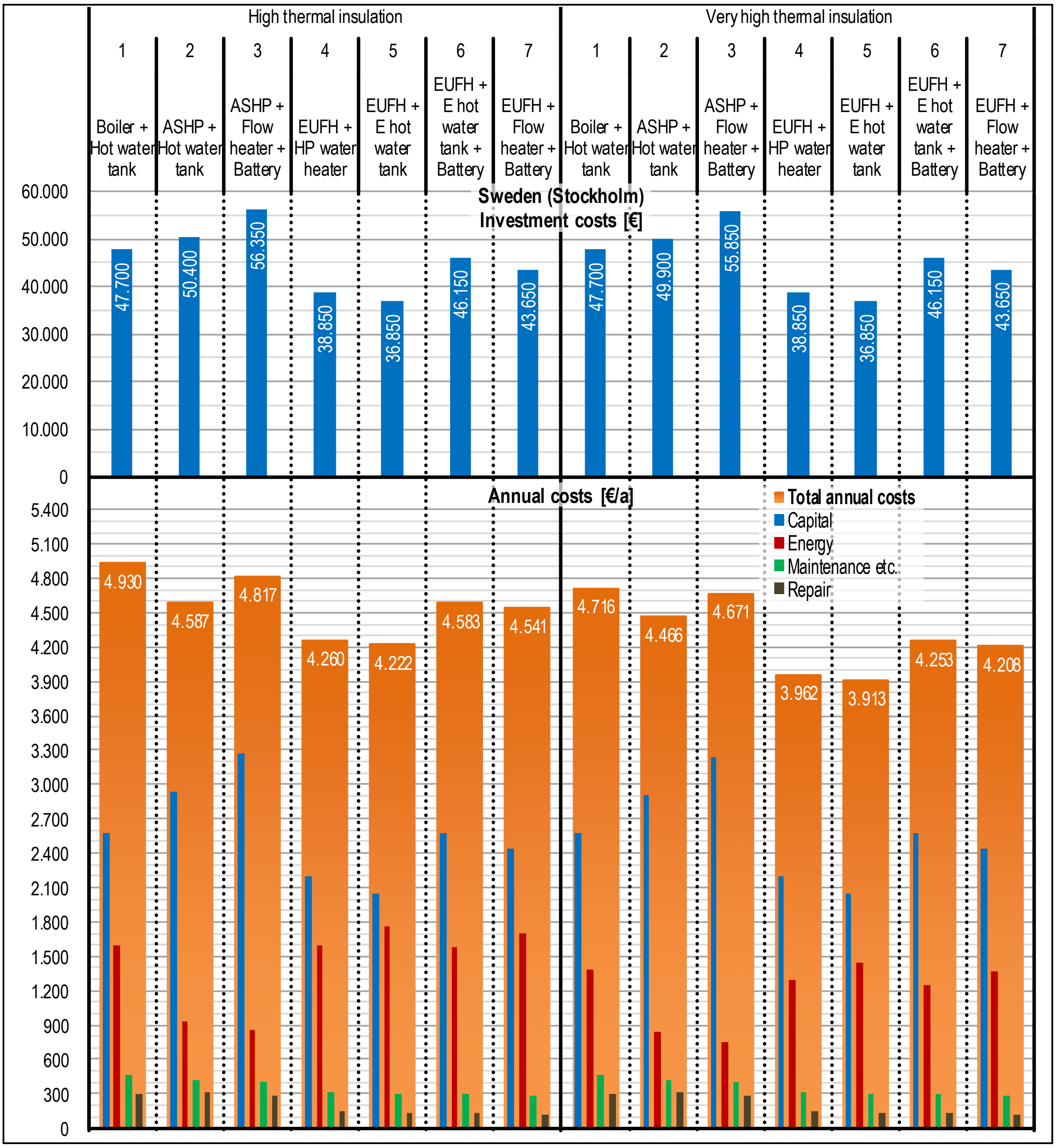


**Figure 24** **Cost balance, Sweden**

## Findings

- In Germany, the variation of annual costs is relatively small in relation to the absolute cost level. Direct-electric heating with PV will cause similar total annual costs as gas heating with PV – slightly higher with only moderately high thermal insulation and visibly lower in case of the higher thermal-insulation level.
- In the Czech Republic, France, the Netherlands and Sweden, direct-electric heating seems to cause lower total annual costs than gas heating as a rule (except for the combination of central hot-water tank and PV battery in the Netherlands[9]). Depending on thermal insulation and hot-water system, the found differences can be substantial.

[9] In the Netherlands, energy costs are not based on actual electricity draw and feed in, but on an annual feed-in/draw balance where draw and feed-in can cancel each other out. Thus, a battery does not influence the annual energy costs; but it does significantly increase the capital costs.

In terms of total annual costs, direct-electric heating profits more from better thermal insulation than gas heating. But it should be kept in mind, that better thermal insulation will also cause higher costs on the building side – building costs are not included here.

Overall, in highly insulated residential buildings, direct-electric heating in combination with PV systems seems economically interesting, and often even favourable, when compared to gas heating with PV under similar conditions. While gas condensing boilers are an established, well-tried and mature technology, they also have no more substantial potential for efficiency and price optimisations. In contrast, the use of PV systems and electrochemical batteries in the context and scale looked at here is still comparatively new.

Since the introduction of roof-mounted PV systems to a broad market, prices for PV panels have dropped significantly. However, when looking at panel prices over time, a lot of sources will suggest that the price curve is moving towards stagnation. Therefore further price drops in the foreseeable future, while still possible, will most likely be less significant than in the past.

In comparison to that, electrochemical batteries as a means for short-term storage of PV output only just began to penetrate the broader market. While there was a time where the still young market for PV batteries was shared between lead- and lithium-ion-based technologies, today lithium-ion-based technologies dominate by far. This rapid and still ongoing development is mainly driven by electromobility and its huge demand of high-power high-capacity cells and the accompanying technical developments and scale effects. Also, at present it is being hypothesised that old traction batteries, which may become an issue at some point in time, could be reconfigured into and reused as stationary PV batteries in an economically viable way (compared to the production of new cells).

With growing use of volatile renewable energy sources and means of energy storage becoming more and more important, there is also more development going on towards alternative battery technologies more suited for stationary use (e. g. redox-flow systems) – albeit not driven by an economical force comparable to the car industry.

Taking all this into account, it can be assumed that prices for PV batteries may still drop in the foreseeable future.

Also it is expected that electricity from renewable sources will become cheaper in relation to conventional energy sources than it is now (e. g. due to implementation/increase of national carbon taxes).

It should be noted that the given numbers highly depend on the assumptions made. For example, a shortened service life of a component – in comparison to what was planned or initially assumed – would lead to higher capital costs for that component (see also Figure 4). If subsides were in place (e. g. lowered investment costs or lowered interest rate), these would lead to lower capital costs.

# 4 Relevance and impact of direct-electric heating in residential buildings

## 4.1 Number of suitable dwellings

The generation of electricity is – depending on the technology used – often associated with high costs and high environmental impact. Also, electricity – being pure exergy – is universally usable high-quality energy. Therefore, “burning” electricity to heat buildings could be seen as a wasteful use of this energy form. On the other hand, with ongoing and growing efforts towards electricity generation from renewable energy sources (grid and decentralised), some voices even envision an energy industry that is based on electricity alone (sometimes referred to as *all-electric world* or *all-electric society*).

Taking into account the increasing portion of renewable energy in the electricity mix as well as buildings becoming more energy efficient and therefore requiring less energy to be heated, electric heating can become more viable both in terms of overall costs and environmental impact. Still, keeping in mind the high value of electricity, direct-electric heating should only be used in highly energy efficient buildings.

Within this study, it is assumed that – for a large part due to national implementations of the EPBD – new residential buildings from around 2016 onwards are suited for direct-electric heating. Figure 25 gives an idea of how many dwellings are built each year in Germany [9], the Czech Republic [10], France [11], the Netherlands [12] and Sweden [13].[10] From 2016 to 2019 about 3,4 million dwellings were built in these countries; it can be assumed that between 700.000 and 900.000 new dwellings are added per year.

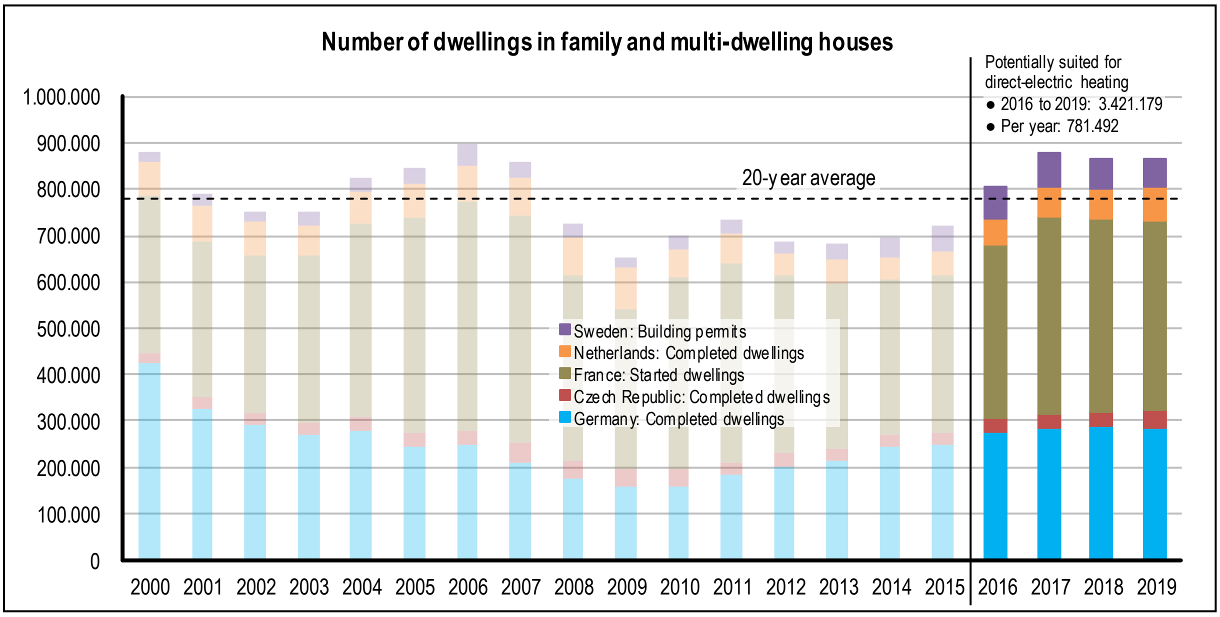


**Figure 25** **Number of new dwellings each year**[10]

[10] The numbers used here refer to slightly different quantities (dwelling building permits vs. started vs. completed dwellings) because they were available in that form as English publications from each country’s statistical office. While using the same quantity (preferably either starts or completions) might provide slightly better comparable numbers, there should be no large deviations; the shown numbers still give a good idea of the scale.

Germany: No numbers for 2019 yet; shown value is estimated based on previous years

Sweden: Value for 2019 slightly corrected as suggested by the source material [10]

## 4.2 Primary energy demand

### 4.2.1 General

Chapter 3.2.3 showed primary energy demand values for the model building in 2 different thermal-insulation levels and 7 different building-system variants based on current primary energy factors. Within the present chapter, the abovementioned results will be aggregated by main heat generator and subjected to a sensitivity analysis for the Primary energy factor of electricity (4.2.3). This allows a more general consideration of the impact and/or possibilities of direct-electric heating with PV in highly insulated residential buildings now and in the near future – in comparison with gas heating (with PV as well).

This consideration concentrates on primary energy as the major quantity defined by the EPBD – to be used nationally in building performance certificates. Each country following the EPBD should have some type of energy saving legislation for buildings in place that limits the amount of primary energy a new building is allowed to consume per year. But there are also other indicators to describe energy supply chains in terms of environmental impact. For example, greenhouse-gas emissions (most prominently $CO_2$, which is also used as a reference to normalise other greenhouse gases) and the amount of renewables utilised are often used. Chapter 4.2.2 will give a short excursion on the topic of *primary energy* and its correlations with the abovementioned indicators.

### 4.2.2 Excursion: Primary energy and other indicators of environmental impact

Primary energy summarises the overall effort or cost that is required to extract/obtain, process and transport/supply a certain amount of final energy – and it does that in terms of energy (see also 2.3/Figure 1). It can be seen as a means to describe the energy efficiency of complex energy supply chains and combinations thereof. With grid power, major influences are the efficiency of electricity generation and distribution. If, for example in Germany, a certain amount of final energy is required in the form of electricity from the grid, this is assumed to add 80 % overhead in terms of overall energy demand – leading to a primary energy demand of 180 % (hence $PEF_{El}$ = 1,8).

The amount of primary energy required to deliver a certain amount of electricity changes over the course of the day (depending on the momentary energy balance between all the different power plants) and also on a more long-term scale (depending on changes of the mix of power plants). Therefore, primary energy factors – as a pure scientific tool to model energy supply chains or combinations thereof (that, in the case of electricity, can change relatively quickly) – are somewhat volatile. At the same time, the quantity *primary energy factor* is used as a means to cap the allowed energy demand of a building in the context of legal regulations – these legally set primary energy factors to be used in building performance certificates can have significant impact on the way a building can or cannot be built. In order to ensure a certain amount of legal certainty, primary energy factors to be used in building performance certificates are often fixed for longer periods and only updated in larger steps. Thus, these legally set primary energy factors can, by their nature, only approximate real(-time) primary energy factors as average values over a certain period of time. Also, in some cases, political decisions to steer the energy mix in a preferred direction can play a certain role.

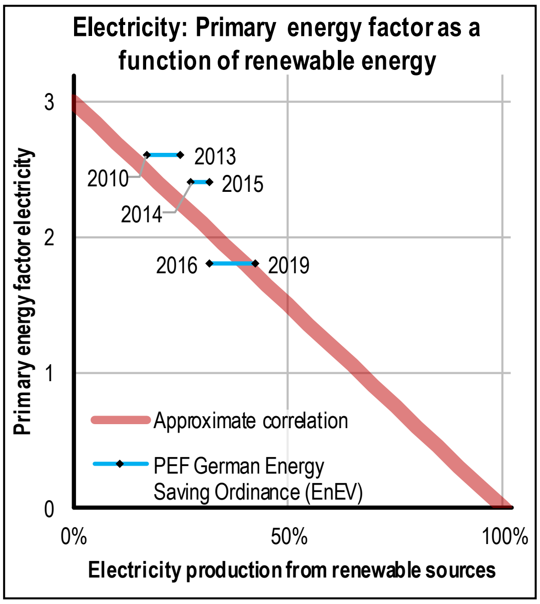


Figure 26 Primary energy factor of electricity as a function of the amount of electricity from renewable sources

When doing primary energy balances, usually only energy from non-renewable sources is counted as effort. For example, the abovementioned $PEF_{el}$ of 1,8 includes that a certain portion of the electricity in Germany is produced from renewable sources (> 40 % in 2019). In fact, the primary energy factor for electricity usually correlates fairly well with the utilised amount of energy from renewable sources: A factor of 0 would mean that 100 % of the electricity is produced from renewables, whereas 0 % of renewables would translate to a factor somewhere in the region of 3[11]. Figure 26 shows the general trend (red thick line) and puts the German primary energy factor as per German Energy Saving Ordinance (EnEV) in that context to provide an example. It should be kept in mind that the factor of 3 for 0 % renewables, albeit commonly accepted, is only an approximate number subject to a variety of influences and also the actual correlation for a certain country is not necessarily a perfectly straight line.

While the primary energy factor for electricity correlates well with the amount of renewables used in its generation, things are more complicated when looking at greenhouse-gas emissions. The greenhouse-gas emissions from energy sources used in electricity generation vary greatly. Also, low emissions in an energy source do not always mean low primary energy demand as well – to provide an example, nuclear electricity generation is commonly rated bad in terms of primary energy, but good in terms of greenhouse-gas emissions[12]. This means that the correlation between primary energy and greenhouse-gas emissions is much more affected by the specific mix of power plants and energy sources in each country. However, it can be said that with decreasing primary energy factors for electricity generation – in large part driven by increased use of renewables substituting coal, oil and gas –, greenhouse-gas emissions will usually be reduced as well.

### 4.2.3 Aggregated Results

Among the included countries, present primary energy factors for electricity range from 1,45 (Netherlands 2021) to 2,6 (Czech Republic). While primary energy factors for natural gas, at this point, are not likely to change significantly[13], recent years show significant changes for electricity in large part due to higher use of renewable energy sources, and this trend will likely continue.

[11] A primary energy factor of 3 is commonly used for nuclear electricity generation by definition – this may vary on a country-to-country basis. A $PEF_{El}$ of 3 also translates to an overall efficiency of electricity generation and distribution of 33 % – this resembles a mix of modern and some older fossil power plants and should, therefore, be representative for average conditions.

[12] Depending on the source, numbers of up to about 110 g/kWh ($CO_2$eq) can be found for Electricity from nuclear power plants. In comparison, natural gas will emit a $CO_2$ equivalent of about 240 g/$kWh_{Heat}$ – if an efficiency of 40 % for electricity generation and distribution is assumed, this becomes 600 g/$kWh_{Electricity}$.

[13] Referring strictly to natural gas (fossil gas), the amount of additional energy put into exploitation, transport and supply is very likely to remain at the present level for the foreseeable future. Therefore, a decrease in primary energy factor is not to be expected. If anything, one could argue that the primary energy factor of 1,0 for natural gas, as used in most countries, usually is a rather optimistic simplification and that, therefore, it should be changed to a slightly higher number.

So far, the term *gas* as grid-delivered energy source refers to fossil gas. Our understanding of that term may change in the future, once gas from renewable sources (e. g. Biogas, Power-to-gas technologies) will be fed to the gas grid in significant quantities. However, judging from past and present development, a similarly rapid development as was seen and still is seen with electricity from renewable sources seems unlikely, at least for now.

The following figures show the overall primary energy demand of the model building – HVAC after PV without bonuses – as a function of the primary energy factor for electricity, averaged over both insulation levels, for these variants:

- 1) Boiler + Hot water tank: Average new building with gas heating and PV
- Average of variants 2 and 3) ASHP: Average new building with heat pump and PV
- Average of variants 4 to 7) EUFH: Average new building with direct-electric heating and PV

The primary energy demand is shown as absolute number in kilowatt hours per year and as percentage in relation to the gas-heating variant.

It is assumed that self-used PV output substituting grid power has the same worth as the substituted grid power.

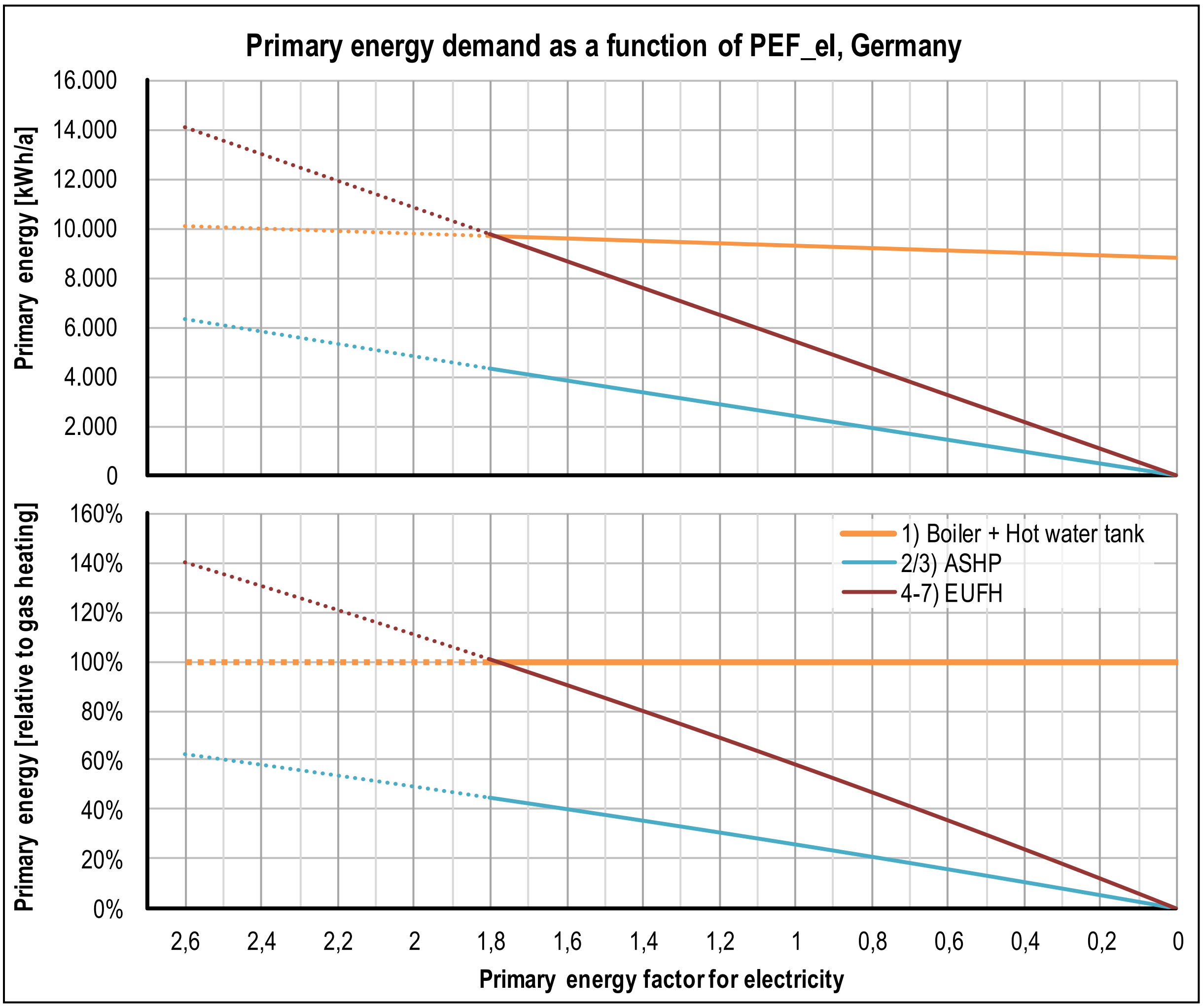


**Figure 27** Primary energy demand HVAC after PV without bonuses, Germany

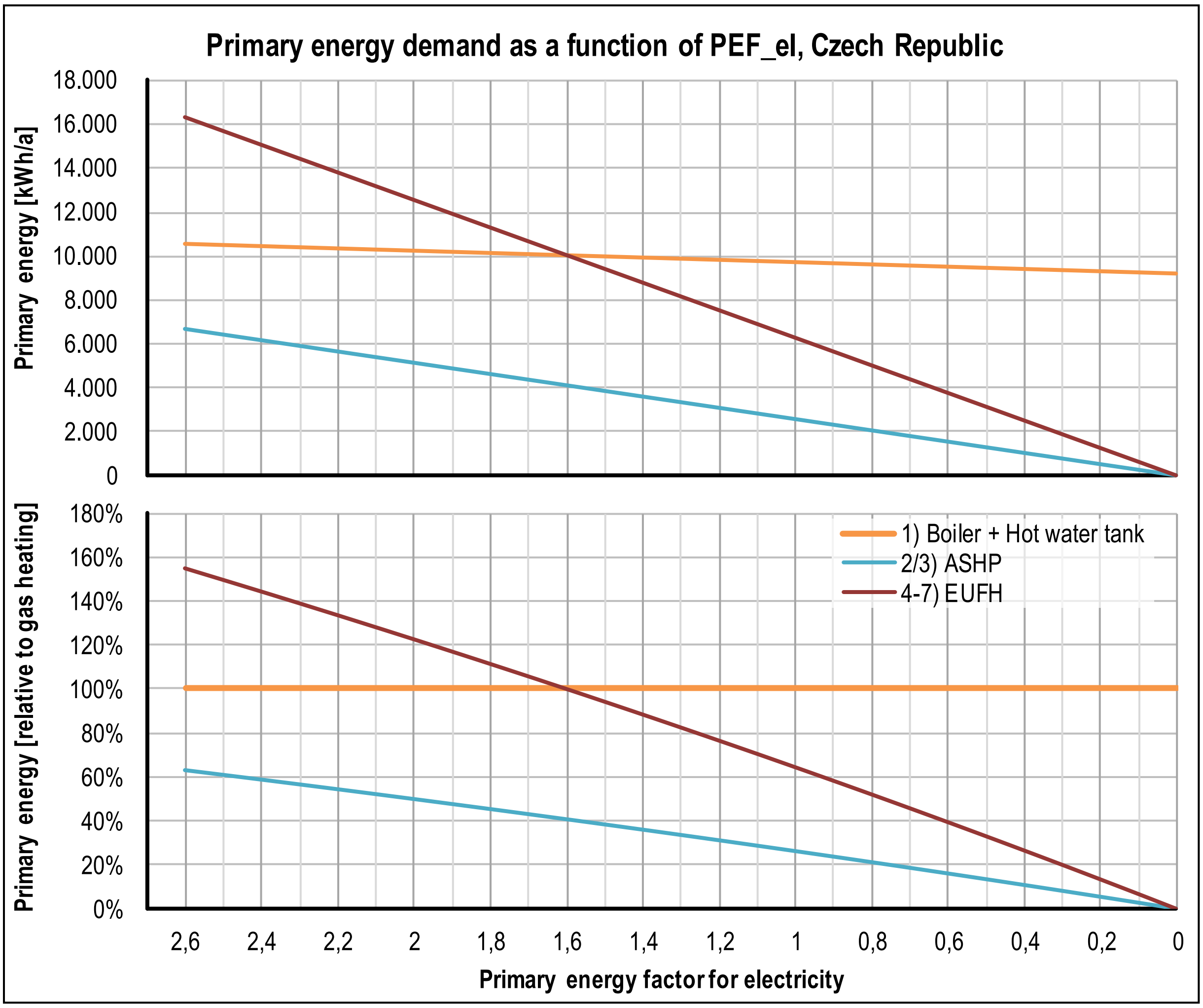


**Figure 28** Primary energy demand HVAC after PV without bonuses, Czech Republic

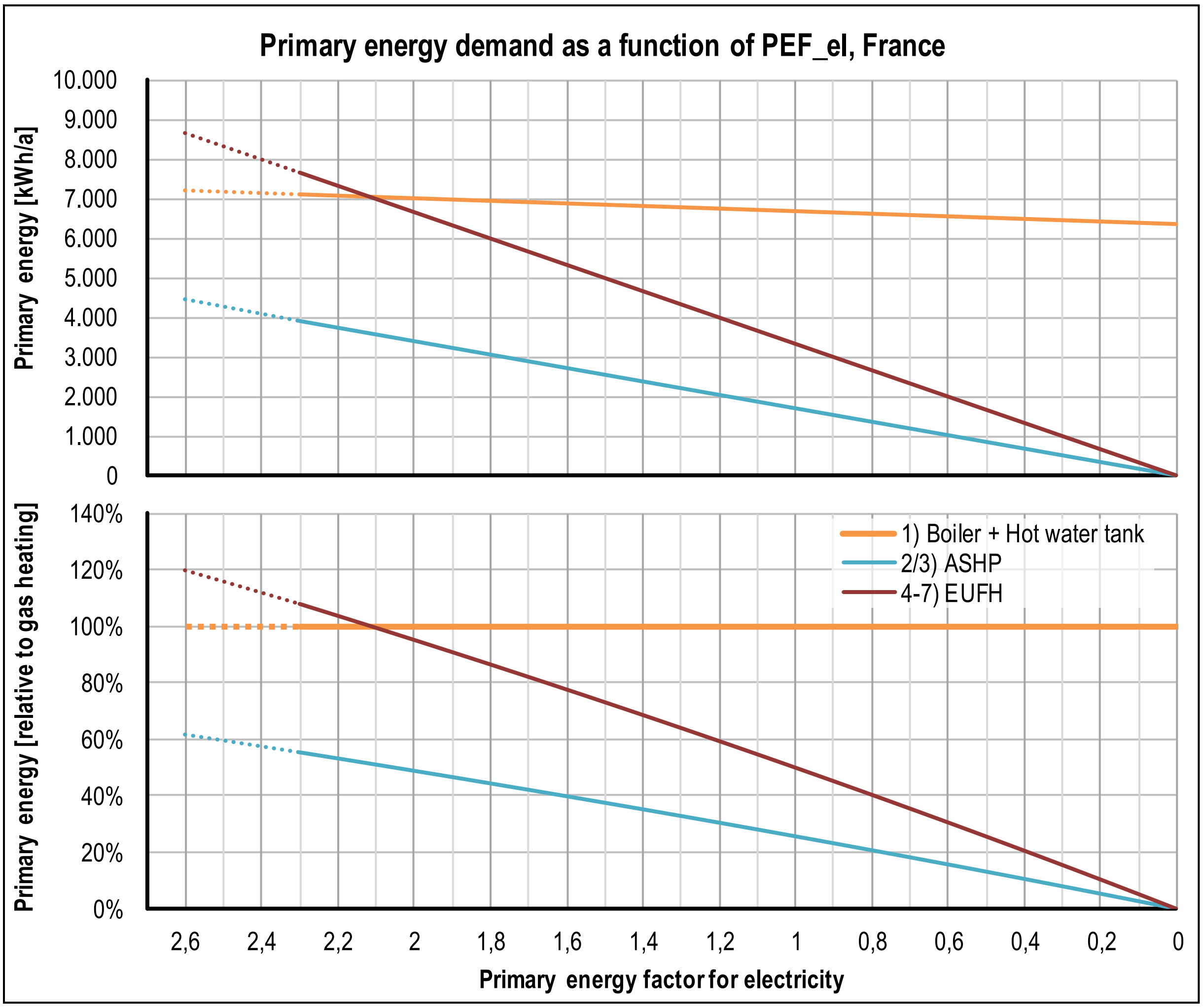


**Figure 29** Primary energy demand HVAC after PV without bonuses, France

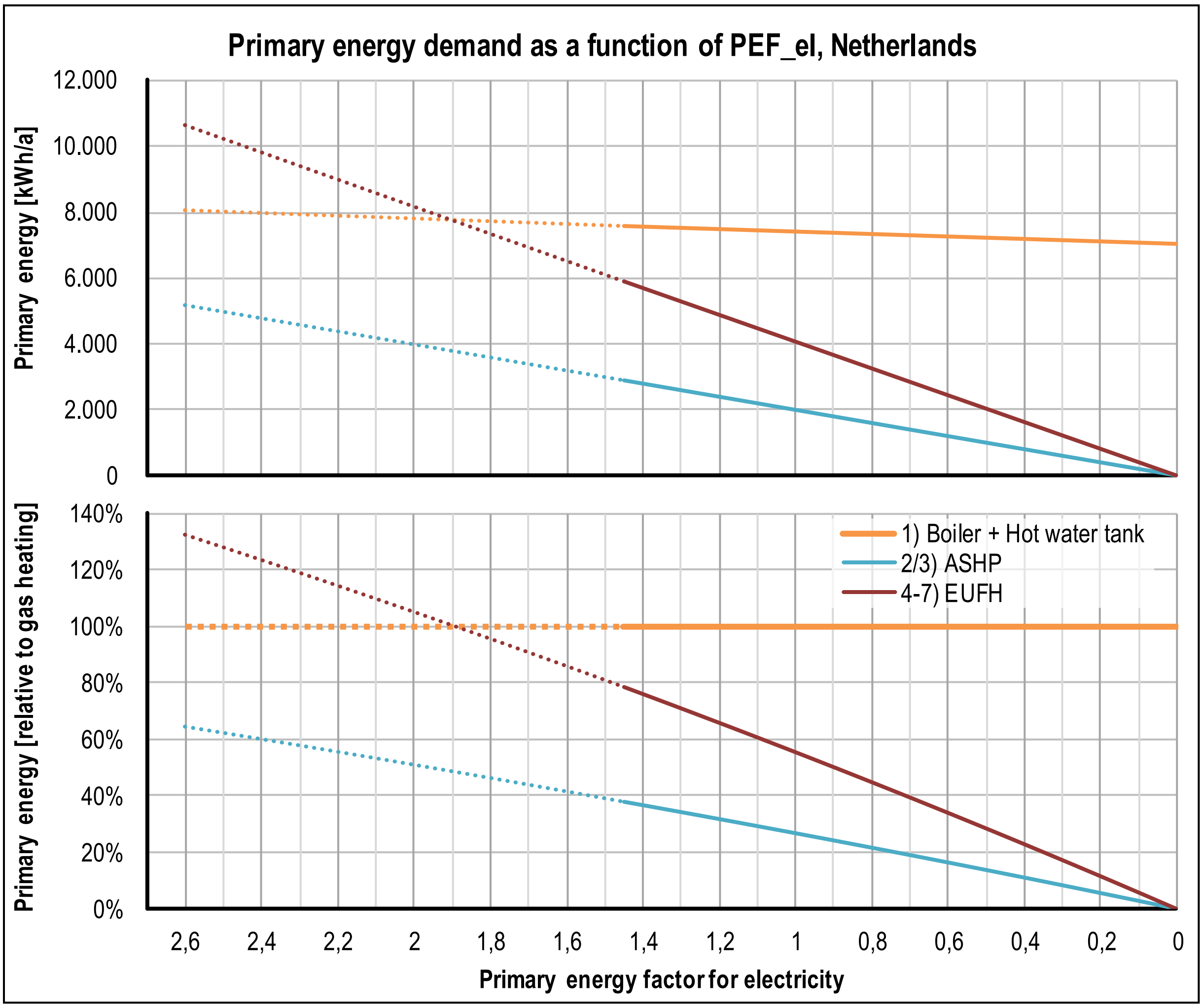


**Figure 30** Primary energy demand HVAC after PV without bonuses, Netherlands

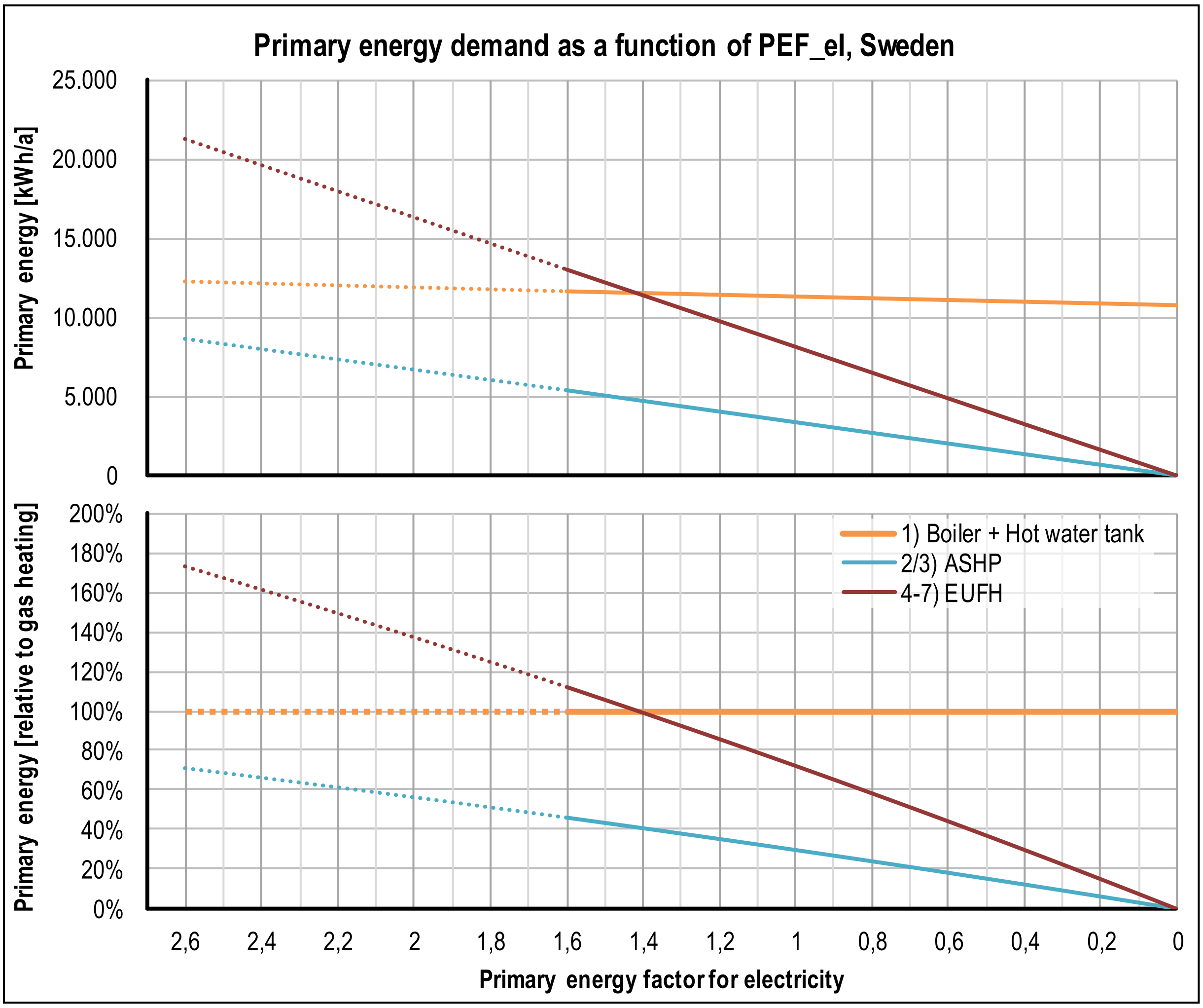


**Figure 31** **Primary energy demand HVAC after PV without bonuses, Sweden**

## Findings

In the comparison of different HVAC variants of the model building looked at here (see 2.4.1), where all variants have the same PV system, the following can be found regarding the influence of the primary energy factor for electricity:

- In Germany, direct-electric heating is, on average, comparable to gas heating (equality at $PEF_{El} \approx 1{,}8$).
- In the Czech Republic, direct-electric heating causes significantly more primary energy demand based on the current primary energy factor for electricity – it will reach equality at $PEF_{El} \approx 1{,}6$.
- In the Netherlands, assuming a primary energy factor for electricity of 1,45 (2021), direct-electric heating causes on average a lower primary energy demand than gas heating.
- In France, direct-electric heating causes slightly more primary energy demand than gas heating, but will reach equality at $PEF_{El} \approx 2{,}1$.

- In Sweden, direct-electric heating causes slightly more primary energy demand than gas or district heating[14], but will reach equality at $PEF_{El} \approx 1,4$.

For the well-insulated model building and taking all 5 countries into account, direct-electric heating in combination with PV would cause more primary energy demand than gas heating with PV right now. However, with ongoing and growing efforts towards electricity production based on renewable energy sources and also extrapolating from the recent past, this is most likely a matter of time only – grid power will become “greener”.

In contrast, there is basically no potential to make natural gas as an energy source and condensing boilers as a technology any better in terms of efficiency, primary energy, greenhouse-gas/pollutant emissions[15] than they are now. Of course the existing gas infrastructure could and should be used for less harmful alternatives as well, if/where/when available.

It has to be noted that a comparison such as is done here highly depends on the assumptions made as well as the reference to compare against. For example, primary-energy-wise, direct-electric heating usually scales better with the building’s heat demand (thermal insulation, air tightness) than gas heating; mainly, it profits more from better thermal insulation. Therefore, different results may show for an even better thermal-insulation level than was assumed here. With direct-electric heating (+ PV) often causing lower total annual costs than gas heating (+ PV), part of the saving could potentially be invested in better thermal insulation.

The comparison shown here assumes that the same type of PV system is used in each variant; that is, also in case of gas heating. If instead direct-electric heating with PV was compared against gas heating without PV, direct-electric heating would fare comparatively better (or gas heating comparatively worse) in terms of primary energy than shown here – but this would also change the annual cost balance in favour of gas heating.

[14] In Sweden, district heating is very common and the same primary energy factor is used for natural gas and district heating. In terms of heat / final energy demand, the difference between heating a building either via gas condensing boiler or via connection to a district heating grid is negligible; therefore, variant 1, while modelling a gas condensing boiler, also approximates district heating very closely.

[15] While specific primary energy demand and greenhouse-gas emissions of an energy source are different things, there is usually a certain correlation between the two, where, if one gets better or worse, the other often does too (e. g. substantial changes to electricity generation such as replacing older plants by newer more efficient ones or increasing use of almost $CO_2$-neutral renewables). This means that the relations between different energy sources (natural gas vs. grid power) shown here may not translate one-to-one to emission numbers, but the general trends for each energy source usually do. However, there are exceptions to this – nuclear power, for instance, is commonly rated with a high primary energy factor of around 3, while it produces comparatively little greenhouse-gas emissions. See also 4.2.2

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# Appendix

## Degree days

**Table 18** Degree days based on monthly mean values for a heating limit temperature of 10 °C, calculated from TMY data [3, 5]

| Country | Σ | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany<br>Potsdam (German reference TMY) | 1.169 | 279 | 227 | 164 | 24 | 0 | 0 | 0 | 0 | 0 | 16 | 177 | 282 |
| Czech Republic<br>Prague: 50°05'N 14°25'E | 1.498 | 313 | 381 | 143 | 24 | 0 | 0 | 0 | 0 | 0 | 68 | 138 | 431 |
| France<br>Paris: 48°51'N 02°21'E | 703 | 143 | 185 | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 81 | 192 |
| Netherlands<br>Amsterdam: 52°22'N 04°54'E | 882 | 267 | 154 | 124 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 226 |
| Sweden<br>Stockholm: 59°20'N 18°03'E | 1.909 | 446 | 370 | 310 | 123 | 0 | 0 | 0 | 0 | 0 | 65 | 198 | 397 |

## Solar insolation

In order to determine PV output, solar insolation is converted into the solar radiation intensity onto the south half of the roof.

**Table 19** Mean solar radiation intensity [W/m²], S 37°; calculated from TMY data [5]

| Country | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany<br>Potsdam (German reference TMY) | 53 | 55 | 122 | 216 | 224 | 233 | 201 | 196 | 158 | 114 | 42 | 27 |
| Czech Republic<br>Prague: 50°05'N 14°25'E | 34 | 99 | 180 | 222 | 156 | 226 | 187 | 189 | 167 | 135 | 62 | 61 |
| France<br>Paris: 48°51'N 02°21'E | 72 | 92 | 166 | 223 | 210 | 241 | 228 | 210 | 192 | 145 | 57 | 62 |
| Netherlands<br>Amsterdam: 52°22'N 04°54'E | 39 | 72 | 167 | 223 | 210 | 216 | 213 | 202 | 153 | 107 | 67 | 50 |
| Sweden<br>Stockholm: 59°20'N 18°03'E | 18 | 54 | 152 | 220 | 224 | 247 | 211 | 186 | 181 | 78 | 43 | 8 |

## Average overall energy demand of the model building

**Table 20** Average overall energy demand of the model building; includes HVAC and household appliances; no PV gains applied

| Country | Average demand [kWh/a] | |
|---|---|---|
| | Natural Gas (HI) | Electricity |
| Germany | 8.000 | 9.100 |
| Czech Republic | 9.200 | 10.000 |
| France | 6.400 | 7.800 |
| Netherlands | 7.000 | 8.300 |
| Sweden | 10.700 | 13.300 |

## Energy balance and energy costs

The following tables show from left to right these results:

- Final energy demand of the whole building before PV
    - Use: Building systems (HVAC), household
    - Energy source: Total gas, total electricity

- Output of the PV system
  - Total
  - Used in building: HVAC, household
  - Fed in to grid
- Energy balance between grid and building
  - Gas consumption
  - Electricity (balance based on momentary values (actual balance) and annual values[16])
    - Consumption: HVAC, household
    - Fed in to grid
- Energy costs
  - Gas consumption
  - Electricity (either based on momentary values or annual values)
    - Consumption: HVAC, household
    - Fed in to grid
  - Total
- Primary energy demand (based on momentary values)
  - Energy drawn for HVAC after PV: Gas, Electricity
  - Additional PV output: Household, fed in to grid
  - Total
    - HVAC only after PV
    - HVAC with bonuses
      - Self-used PV output
      - Fed-in PV output
      - Both

Some sections of these tables may contain both positive and negative values – the sign refers to the quantity described in the topmost header row (e. g. “Energy costs”: Positive values are costs, negative values bonuses).

[16] “Momentary values” refers to the calculation results based on monthly mean values; these give an estimation of what would actually happen under average conditions for standardised use cases. “Annual values” stem from a balance of the aforementioned momentary values over the whole year. In reality, a PV-equipped building will, when monitored over a whole year, almost always both draw electricity from the grid and feed in electricity to the grid. In an annual balance, a PV-equipped building will, when monitored over a whole year, only do either of these (or both could balance out at ±0). An annual balance is only used in the calculation of energy costs the Netherlands.

**Table 21 Energy balance and energy costs, Germany**

| Insulation level | Variant | Final energy demand [kWh/a]: HVAC, Heat generation, R[a] | Final energy demand: HVAC, Heat generation, W[a] | Final energy demand: HVAC, Auxiliaries, R[a] | Final energy demand: HVAC, Auxiliaries, W[a] | Final energy demand: HVAC, Auxiliaries, V[a,b] | Final energy demand: Household | Final energy demand: Σ Gas | Final energy demand: Σ Electricity | PV output [kWh/a]: Total output | PV output: Used in building, HVAC | PV output: Used in building, Household | PV output: Fed in | Grid-building balance [kWh/a]: Gas drawn | Grid-building balance: Electricity, momentary values, Drawn HVAC | Grid-building balance: Electricity, momentary values, Drawn Household | Grid-building balance: Electricity, momentary values, Fed in | Grid-building balance: Electricity, annual balance, Drawn HVAC | Grid-building balance: Electricity, annual balance, Drawn Household | Grid-building balance: Electricity, annual balance, Fed in | Energy costs [€/a]: Gas | Energy costs: Electricity, Drawn HVAC | Energy costs: Electricity, Drawn Household | Energy costs: Electricity, Fed in | Energy costs: Total | Primary energy demand [kWh/a]: Energy drawn (HVAC only), Gas | Primary energy demand: Energy drawn (HVAC only), Electricity | Primary energy demand: Additional PV output, Household | Primary energy demand: Additional PV output, Fed in | Primary energy demand: Total, HVAC only | Primary energy demand: Total, with household bonus | Primary energy demand: Total, with feed-in bonus | Primary energy demand: Total, with household and feed-in bonus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 1 Boiler + Hot water tank | 4.982 | 3.810 | 184 | 123 | 342 | 3.733 | 8.791 | 4.382 | 7.362 | 166 | 1.286 | 5.910 | 8.791 | 484 | 2.447 | 5.910 | 0 | 0 | 2.980 | 661 | 149 | 756 | -558 | 1.008 | 9.670 | 871 | -4.404 | -10.638 | 10.541 | 6.137 | -97 | -4.501 |
| High | 2 ASHP + Hot water tank | 1.479 | 1.702 | 106 | 43 | 342 | 3.733 | 0 | 7.406 | 7.362 | 1.199 | 1.286 | 4.877 | 0 | 2.474 | 2.447 | 4.877 | 22 | 22 | 0 | 0 | 495 | 756 | -460 | 790 | 0 | 4.453 | -4.404 | -8.778 | 4.453 | 49 | -4.325 | -8.729 |
| High | 3 ASHP + Flow heater + Battery | 1.819 | 1.651 | 179 | 0 | 342 | 3.733 | 0 | 7.726 | 7.362 | 1.235 | 2.292 | 3.835 | 0 | 2.758 | 1.441 | 3.835 | 188 | 176 | 0 | 0 | 552 | 445 | -362 | 634 | 0 | 4.964 | -2.593 | -6.903 | 4.964 | 2.371 | -1.939 | -4.533 |
| High | 4 EUFH + HP water heater | 5.061 | 1.493 | 0 | 43 | 342 | 3.733 | 0 | 10.672 | 7.362 | 1.369 | 1.256 | 4.737 | 0 | 5.571 | 2.477 | 4.737 | 2.152 | 1.158 | 0 | 0 | 1.114 | 765 | -447 | 1.432 | 0 | 10.027 | -4.458 | -8.527 | 10.027 | 5.569 | 1.500 | -2.958 |
| High | 5 EUFH + E hot water tank | 5.159 | 3.527 | 0 | 37 | 342 | 3.733 | 0 | 12.797 | 7.362 | 2.403 | 1.239 | 3.721 | 0 | 6.661 | 2.495 | 3.721 | 3.850 | 1.585 | 0 | 0 | 1.332 | 770 | -351 | 1.751 | 0 | 11.990 | -4.490 | -6.697 | 11.990 | 7.500 | 5.293 | 803 |
| High | 6 EUFH + E hot water tank + Battery | 5.159 | 3.527 | 0 | 37 | 342 | 3.733 | 0 | 12.797 | 7.362 | 3.220 | 1.822 | 2.320 | 0 | 5.845 | 1.911 | 2.320 | 3.850 | 1.585 | 0 | 0 | 1.169 | 590 | -219 | 1.540 | 0 | 10.520 | -3.440 | -4.177 | 10.520 | 7.080 | 6.344 | 2.904 |
| High | 7 EUFH + Flow heater + Battery | 6.071 | 1.651 | 0 | 0 | 342 | 3.733 | 0 | 11.798 | 7.362 | 1.495 | 1.892 | 3.975 | 0 | 6.570 | 1.841 | 3.975 | 3.032 | 1.404 | 0 | 0 | 1.314 | 569 | -375 | 1.507 | 0 | 11.826 | -3.314 | -7.155 | 11.826 | 8.512 | 4.671 | 1.356 |
| Very high | 1 Boiler + Hot water tank | 3.465 | 3.839 | 176 | 128 | 342 | 3.733 | 7.303 | 4.380 | 7.362 | 166 | 1.286 | 5.910 | 7.303 | 481 | 2.447 | 5.910 | 0 | 0 | 2.983 | 549 | 148 | 756 | -558 | 895 | 8.033 | 865 | -4.404 | -10.638 | 8.899 | 4.495 | -1.739 | -6.143 |
| Very high | 2 ASHP + Hot water tank | 1.028 | 1.699 | 85 | 43 | 342 | 3.733 | 0 | 6.931 | 7.362 | 1.086 | 1.286 | 4.990 | 0 | 2.112 | 2.447 | 4.990 | 0 | 0 | 431 | 0 | 422 | 756 | -471 | 707 | 0 | 3.801 | -4.404 | -8.982 | 3.801 | -603 | -5.180 | -9.584 |
| Very high | 3 ASHP + Flow heater + Battery | 1.335 | 1.650 | 158 | 0 | 342 | 3.733 | 0 | 7.219 | 7.362 | 1.114 | 2.375 | 3.873 | 0 | 2.372 | 1.358 | 3.873 | 0 | 0 | 143 | 0 | 474 | 419 | -366 | 528 | 0 | 4.270 | -2.444 | -6.972 | 4.270 | 1.826 | -2.701 | -5.146 |
| Very high | 4 EUFH + HP water heater | 3.520 | 1.490 | 0 | 43 | 342 | 3.733 | 0 | 9.129 | 7.362 | 1.183 | 1.276 | 4.904 | 0 | 4.214 | 2.457 | 4.904 | 1.044 | 723 | 0 | 0 | 843 | 759 | -463 | 1.139 | 0 | 7.584 | -4.423 | -8.826 | 7.584 | 3.162 | -1.242 | -5.664 |
| Very high | 5 EUFH + E hot water tank | 3.609 | 3.522 | 0 | 37 | 342 | 3.733 | 0 | 11.243 | 7.362 | 2.244 | 1.258 | 3.860 | 0 | 5.266 | 2.475 | 3.860 | 2.592 | 1.288 | 0 | 0 | 1.053 | 764 | -364 | 1.453 | 0 | 9.478 | -4.455 | -6.949 | 9.478 | 5.023 | 2.530 | -1.925 |
| Very high | 6 EUFH + E hot water tank + Battery | 3.609 | 3.522 | 0 | 37 | 342 | 3.733 | 0 | 11.243 | 7.362 | 3.215 | 1.928 | 2.219 | 0 | 4.294 | 1.805 | 2.219 | 2.592 | 1.288 | 0 | 0 | 859 | 557 | -209 | 1.207 | 0 | 7.730 | -3.250 | -3.995 | 7.730 | 4.480 | 3.735 | 485 |
| Very high | 7 EUFH + Flow heater + Battery | 4.453 | 1.650 | 0 | 0 | 342 | 3.733 | 0 | 10.179 | 7.362 | 1.413 | 2.030 | 3.920 | 0 | 5.033 | 1.703 | 3.920 | 1.784 | 1.033 | 0 | 0 | 1.007 | 526 | -370 | 1.163 | 0 | 9.060 | -3.066 | -7.055 | 9.060 | 5.994 | 2.005 | -1.061 |

[a] R: Room heating, W:Water heating, V: Ventilation

[b] The ventilation system is configured for heating-season-only operation. Therefore, the ventilation energy demand depends on the (calculated) length of the heating season.

**Table 22 Energy balance and energy costs, Czech Republic**

| Insulation level | Variant | Final energy demand [kWh/a] | | | | | | | | PV output [kWh/a] | | | | Grid-building balance [kWh/a] | | | | | | | Energy costs [€/a] | | | | | Primary energy demand [kWh/a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HVAC | | | | | Household | Σ Gas | Σ Electricity | Total output | Used in building | | Fed in | Gas drawn | Electricity based on | | | | | | Gas | Electricity | | | Total | Energy drawn (HVAC only) | | Additional PV output | | Total | | | |
| | | Heat generation | | Auxiliaries | | | | | | | | | | | momentary values | | | annual balance | | | | Drawn | | Fed in | | | | | | HVAC only | with household bonus | with feed-in bonus | with household and feed-in bonus |
| | | R[a] | W[a] | R[a] | W[a] | V[a,b] | | | | | HVAC | Household | | | Drawn HVAC | Drawn Household | Fed in | Drawn HVAC | Drawn Household | Fed in | | HVAC | Household | | | Gas | Electricity | Household | Fed in | | | | |
| High | 1 Boiler + Hot water tank | 6.384 | 3.810 | 236 | 123 | 342 | 3.733 | 10.193 | 4.434 | 7.672 | 202 | 1.353 | 6.116 | 10.193 | 499 | 2.380 | 6.116 | 0 | 0 | 3.237 | 597 | 87 | 416 | -245 | 856 | 10.193 | 1.297 | -6.187 | -15.901 | 11.490 | 5.303 | -4.411 | -10.598 |
| High | 2 ASHP + Hot water tank | 1.896 | 1.702 | 136 | 43 | 342 | 3.733 | 0 | 7.852 | 7.672 | 1.501 | 1.353 | 4.817 | 0 | 2.619 | 2.380 | 4.817 | 95 | 86 | 0 | 0 | 306 | 278 | -193 | 392 | 0 | 6.808 | -6.187 | -12.525 | 6.808 | 621 | -5.717 | -11.904 |
| High | 3 ASHP + Flow heater[c] + Battery | 2.331 | 1.651 | 230 | 0 | 342 | 3.733 | 0 | 8.288 | 7.672 | 1.574 | 2.320 | 3.778 | 0 | 2.981 | 1.413 | 3.778 | 339 | 278 | 0 | | | | | | 0 | 7.751 | -3.674 | -9.822 | 7.751 | 4.077 | -2.071 | -5.745 |
| High | 4 EUFH + HP water heater | 6.485 | 1.493 | 0 | 43 | 342 | 3.733 | 0 | 12.096 | 7.672 | 1.746 | 1.295 | 4.631 | 0 | 6.617 | 2.438 | 4.631 | 3.059 | 1.365 | 0 | 0 | 774 | 285 | -185 | 874 | 0 | 17.205 | -6.340 | -12.040 | 17.205 | 10.865 | 5.164 | -1.176 |
| High | 5 EUFH + E hot water tank | 6.610 | 3.527 | 0 | 37 | 342 | 3.733 | 0 | 14.249 | 7.672 | 2.805 | 1.281 | 3.586 | 0 | 7.712 | 2.452 | 3.586 | 4.854 | 1.723 | 0 | 0 | 902 | 287 | -143 | 1.046 | 0 | 20.050 | -6.375 | -9.324 | 20.050 | 13.675 | 10.726 | 4.351 |
| High | 6 EUFH + E hot water tank + Battery | 6.610 | 3.527 | 0 | 37 | 342 | 3.733 | 0 | 14.249 | 7.672 | 3.790 | 1.874 | 2.007 | 0 | 6.726 | 1.859 | 2.007 | 4.854 | 1.723 | 0 | 0 | 787 | 217 | -80 | 924 | 0 | 17.488 | -4.833 | -5.219 | 17.488 | 12.654 | 12.268 | 7.435 |
| High | 7 EUFH + Flow heater[c] + Battery | 7.780 | 1.651 | 0 | 0 | 342 | 3.733 | 0 | 13.507 | 7.672 | 2.045 | 1.921 | 3.706 | 0 | 7.729 | 1.812 | 3.706 | 4.222 | 1.613 | 0 | | | | | | 0 | 20.094 | -4.712 | -9.636 | 20.094 | 15.382 | 10.458 | 5.746 |
| Very high | 1 Boiler + Hot water tank | 4.440 | 3.839 | 225 | 128 | 342 | 3.733 | 8.278 | 4.429 | 7.672 | 202 | 1.353 | 6.116 | 8.278 | 494 | 2.380 | 6.116 | 0 | 0 | 3.243 | 485 | 86 | 416 | -245 | 743 | 8.278 | 1.284 | -6.187 | -15.902 | 9.562 | 3.376 | -6.339 | -12.526 |
| Very high | 2 ASHP + Hot water tank | 1.317 | 1.699 | 109 | 43 | 342 | 3.733 | 0 | 7.244 | 7.672 | 1.317 | 1.353 | 5.001 | 0 | 2.194 | 2.380 | 5.001 | 0 | 0 | 428 | 0 | 257 | 278 | -200 | 335 | 0 | 5.703 | -6.187 | -13.002 | 5.703 | -484 | -7.299 | -13.486 |
| Very high | 3 ASHP + Flow heater[c] + Battery | 1.711 | 1.650 | 203 | 0 | 342 | 3.733 | 0 | 7.640 | 7.672 | 1.435 | 2.425 | 3.812 | 0 | 2.472 | 1.308 | 3.812 | 0 | 0 | 32 | | | | | | 0 | 6.427 | -3.402 | -9.912 | 6.427 | 3.026 | -3.485 | -6.887 |
| Very high | 4 EUFH + HP water heater | 4.511 | 1.490 | 0 | 43 | 342 | 3.733 | 0 | 10.120 | 7.672 | 1.555 | 1.331 | 4.786 | 0 | 4.832 | 2.402 | 4.786 | 1.545 | 903 | 0 | 0 | 565 | 281 | -191 | 655 | 0 | 12.563 | -6.246 | -12.444 | 12.563 | 6.317 | 119 | -6.127 |
| Very high | 5 EUFH + E hot water tank | 4.624 | 3.522 | 0 | 37 | 342 | 3.733 | 0 | 12.258 | 7.672 | 2.620 | 1.309 | 3.743 | 0 | 5.905 | 2.424 | 3.743 | 3.190 | 1.397 | 0 | 0 | 691 | 284 | -150 | 825 | 0 | 15.354 | -6.304 | -9.732 | 15.354 | 9.050 | 5.621 | -682 |
| Very high | 6 EUFH + E hot water tank + Battery | 4.624 | 3.522 | 0 | 37 | 342 | 3.733 | 0 | 12.258 | 7.672 | 3.700 | 1.988 | 1.984 | 0 | 4.825 | 1.745 | 1.984 | 3.190 | 1.397 | 0 | 0 | 565 | 204 | -79 | 689 | 0 | 12.546 | -4.538 | -5.158 | 12.546 | 8.008 | 7.387 | 2.850 |
| Very high | 7 EUFH + Flow heater[c] + Battery | 5.706 | 1.650 | 0 | 0 | 342 | 3.733 | 0 | 11.432 | 7.672 | 1.844 | 2.046 | 3.781 | 0 | 5.855 | 1.687 | 3.781 | 2.533 | 1.228 | 0 | | | | | | 0 | 15.222 | -4.385 | -9.830 | 15.222 | 10.837 | 5.392 | 1.007 |

[a] R: Room heating, W:Water heating, V: Ventilation

[b] The ventilation system is configured for heating-season-only operation. Therefore, the ventilation energy demand depends on the (calculated) length of the heating season.

[c] Flow-through water heaters are uncommon in CZE due to electricity base prices depending on the amperage requirement of the building. Therefore, no costs/prices are shown for variants with flow water heaters (3, 6).

**Table 23 Energy balance and energy costs, France**

| Insulation level | Variant | Final energy demand [kWh/a] – HVAC – Heat generation – R[a] | Final energy demand – HVAC – Heat generation – W[a] | Final energy demand – HVAC – Auxiliaries – R[a] | Final energy demand – HVAC – Auxiliaries – W[a] | Final energy demand – HVAC – Auxiliaries – V[a,b] | Final energy demand – House-hold | Final energy demand – Σ Gas | Final energy demand – Σ Elec-tricity | PV output [kWh/a] – Total output | PV output – Used in building – HVAC | PV output – Used in building – House hold | PV output – Fed in | Grid-building balance [kWh/a] – Gas drawn | Grid-building balance – Electricity based on momentary values – Drawn – HVAC | Grid-building balance – momentary values – Drawn – House hold | Grid-building balance – momentary values – Fed in | Grid-building balance – annual balance – Drawn – HVAC | Grid-building balance – annual balance – Drawn – House hold | Grid-building balance – annual balance – Fed in | Energy costs [€/a] – Gas | Energy costs – Electricity – Drawn – HVAC | Energy costs – Electricity – Drawn – Hous ehold | Energy costs – Electricity – Fed in | Energy costs – Total | Primary energy demand [kWh/a] – Energy drawn (HVAC only) – Gas | Primary energy demand – Energy drawn (HVAC only) – Elec-tricity | Primary energy demand – Additional PV output – House-hold | Primary energy demand – Additional PV output – Fed in | Primary energy demand – Total – HVAC only | Primary energy demand – Total – with house-hold bonus | Primary energy demand – Total – with feed-in bonus | Primary energy demand – Total – with household and feed-in bonus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 1 Boiler + Hot water tank | 2.996 | 3.810 | 111 | 123 | 244 | 3.733 | 6.806 | 4.211 | 8.496 | 140 | 1.415 | 6.941 | 6.806 | 338 | 2.318 | 6.941 | 0 | 0 | 4.285 | 714 | 59 | 405 | -694 | 484 | 6.806 | 777 | -5.331 | -15.964 | 7.583 | 2.252 | -8.381 | -13.712 |
| High | 2 ASHP + Hot water tank | 890 | 1.702 | 64 | 43 | 244 | 3.733 | 0 | 6.676 | 8.496 | 1.188 | 1.415 | 5.892 | 0 | 1.755 | 2.318 | 5.892 | 0 | 0 | 1.820 | 0 | 205 | 405 | -589 | 21 | 0 | 4.036 | -5.331 | -13.553 | 4.036 | -1.295 | -9.517 | -14.848 |
| High | 3 ASHP + Flow heater + Battery | 1.094 | 1.651 | 108 | 0 | 244 | 3.733 | 0 | 6.830 | 8.496 | 1.257 | 2.722 | 4.516 | 0 | 1.840 | 1.011 | 4.516 | 0 | 0 | 1.665 | 0 | 215 | 177 | -452 | -60 | 0 | 4.233 | -2.324 | -10.387 | 4.233 | 1.909 | -6.154 | -8.479 |
| High | 4 EUFH + HP water heater | 3.044 | 1.493 | 0 | 43 | 244 | 3.733 | 0 | 8.557 | 8.496 | 1.339 | 1.415 | 5.741 | 0 | 3.485 | 2.318 | 5.741 | 34 | 27 | 0 | 0 | 408 | 405 | -574 | 239 | 0 | 8.014 | -5.331 | -13.205 | 8.014 | 2.684 | -5.191 | -10.522 |
| High | 5 EUFH + E hot water tank | 3.103 | 3.527 | 0 | 37 | 244 | 3.733 | 0 | 10.643 | 8.496 | 2.565 | 1.411 | 4.520 | 0 | 4.344 | 2.322 | 4.520 | 1.394 | 753 | 0 | 0 | 508 | 406 | -452 | 462 | 0 | 9.992 | -5.342 | -10.395 | 9.992 | 4.650 | -404 | -5.745 |
| High | 6 EUFH + E hot water tank + Battery | 3.103 | 3.527 | 0 | 37 | 244 | 3.733 | 0 | 10.643 | 8.496 | 3.693 | 2.188 | 2.615 | 0 | 3.217 | 1.545 | 2.615 | 1.394 | 753 | 0 | 0 | 376 | 270 | -261 | 385 | 0 | 7.399 | -3.553 | -6.014 | 7.399 | 3.847 | 1.385 | -2.167 |
| High | 7 EUFH + Flow heater + Battery | 3.651 | 1.651 | 0 | 0 | 244 | 3.733 | 0 | 9.280 | 8.496 | 1.634 | 2.341 | 4.521 | 0 | 3.913 | 1.392 | 4.521 | 469 | 315 | 0 | 0 | 458 | 243 | -452 | 249 | 0 | 9.000 | -3.201 | -10.398 | 9.000 | 5.799 | -1.398 | -4.600 |
| Very high | 1 Boiler + Hot water tank | 2.084 | 3.839 | 106 | 128 | 244 | 3.733 | 5.922 | 4.211 | 8.496 | 141 | 1.415 | 6.940 | 5.922 | 338 | 2.318 | 6.940 | 0 | 0 | 4.285 | 621 | 59 | 405 | -694 | 391 | 5.922 | 776 | -5.331 | -15.962 | 6.699 | 1.368 | -9.263 | -14.594 |
| Very high | 2 ASHP + Hot water tank | 618 | 1.699 | 51 | 43 | 244 | 3.733 | 0 | 6.389 | 8.496 | 1.098 | 1.415 | 5.982 | 0 | 1.558 | 2.318 | 5.982 | 0 | 0 | 2.107 | 0 | 182 | 405 | -598 | -11 | 0 | 3.583 | -5.331 | -13.760 | 3.583 | -1.748 | -10.177 | -15.508 |
| Very high | 3 ASHP + Flow heater + Battery | 803 | 1.650 | 95 | 0 | 244 | 3.733 | 0 | 6.525 | 8.496 | 1.110 | 2.782 | 4.603 | 0 | 1.682 | 951 | 4.603 | 0 | 0 | 1.970 | 0 | 197 | 166 | -460 | -97 | 0 | 3.869 | -2.188 | -10.588 | 3.869 | 1.681 | -6.719 | -8.907 |
| Very high | 4 EUFH + HP water heater | 2.117 | 1.490 | 0 | 43 | 244 | 3.733 | 0 | 7.628 | 8.496 | 1.118 | 1.415 | 5.962 | 0 | 2.776 | 2.318 | 5.962 | 0 | 0 | 868 | 0 | 325 | 405 | -596 | 134 | 0 | 6.385 | -5.331 | -13.713 | 6.385 | 1.055 | -7.328 | -12.658 |
| Very high | 5 EUFH + E hot water tank | 2.170 | 3.522 | 0 | 37 | 244 | 3.733 | 0 | 9.706 | 8.496 | 2.362 | 1.415 | 4.719 | 0 | 3.611 | 2.318 | 4.719 | 745 | 465 | 0 | 0 | 422 | 405 | -472 | 356 | 0 | 8.305 | -5.331 | -10.854 | 8.305 | 2.975 | -2.548 | -7.879 |
| Very high | 6 EUFH + E hot water tank + Battery | 2.170 | 3.522 | 0 | 37 | 244 | 3.733 | 0 | 9.706 | 8.496 | 3.668 | 2.298 | 2.529 | 0 | 2.305 | 1.435 | 2.529 | 745 | 465 | 0 | 0 | 270 | 251 | -253 | 267 | 0 | 5.301 | -3.299 | -5.817 | 5.301 | 2.001 | -517 | -3.816 |
| Very high | 7 EUFH + Flow heater + Battery | 2.678 | 1.650 | 0 | 0 | 244 | 3.733 | 0 | 8.306 | 8.496 | 1.485 | 2.478 | 4.533 | 0 | 3.087 | 1.255 | 4.533 | 0 | 0 | 190 | 0 | 361 | 219 | -453 | 127 | 0 | 7.101 | -2.887 | -10.425 | 7.101 | 4.213 | -3.324 | -6.212 |

[a] R: Room heating, W:Water heating, V: Ventilation

[b] The ventilation system is configured for heating-season-only operation. Therefore, the ventilation energy demand depends on the (calculated) length of the heating season.

**Table 24 Energy balance and energy costs, Netherlands**

| Insulation level | | Variant | Final energy demand [kWh/a]: HVAC: Heat generation R[a] | Final energy: HVAC: Heat generation W[a] | Final energy: HVAC: Auxiliaries R[a] | Final energy: HVAC: Auxiliaries W[a] | Final energy: HVAC: Auxiliaries V[a,b] | Final energy: Household | Final energy: Σ Gas | Final energy: Σ Electricity | PV output [kWh/a]: Total output | PV: Used in building HVAC | PV: Used in building Household | PV: Fed in | Grid-building balance [kWh/a]: Gas drawn | Grid: Electricity momentary values: Drawn HVAC | Grid: momentary: Drawn Household | Grid: momentary: Fed in | Grid: Electricity annual balance: Drawn HVAC | Grid: annual: Drawn Household | Grid: annual: Fed in | Energy costs [€/a]: Gas | Costs: Electricity[c] Drawn HVAC | Costs: Electricity Drawn Household | Costs: Electricity Fed in | Costs: Total | Primary energy demand [kWh/a]: Energy drawn (HVAC only) Gas | Primary: Energy drawn (HVAC only) Electricity | Primary: Additional PV output Household | Primary: Additional PV output Fed in | Primary: Total HVAC only | Primary: Total with household bonus | Primary: Total with feed-in bonus | Primary: Total with household and feed-in bonus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 1 | Boiler + Hot water tank | 3.759 | 3.810 | 139 | 123 | 292 | 3.733 | 7.569 | 4.287 | 7.690 | 157 | 1.354 | 6.179 | 7.569 | 398 | 2.379 | 6.179 | 0 | 0 | 3.403 | 697 | 0 | 0 | -170 | 527 | 7.569 | 576 | -3.449 | -8.960 | 8.145 | 4.696 | -815 | -4.264 |
| | 2 | ASHP + Hot water tank | 1.116 | 1.702 | 80 | 43 | 292 | 3.733 | 0 | 6.967 | 7.690 | 1.185 | 1.354 | 5.151 | 0 | 2.049 | 2.379 | 5.151 | 0 | 0 | 723 | 0 | 0 | 0 | -36 | -36 | 0 | 2.970 | -3.449 | -7.468 | 2.970 | -479 | -4.498 | -7.947 |
| | 3 | ASHP + Flow heater + Battery | 1.373 | 1.651 | 135 | 0 | 292 | 3.733 | 0 | 7.185 | 7.690 | 1.277 | 2.543 | 3.871 | 0 | 2.175 | 1.190 | 3.871 | 0 | 0 | 505 | 0 | 0 | 0 | -25 | -25 | 0 | 3.154 | -1.726 | -5.613 | 3.154 | 1.428 | -2.458 | -4.184 |
| | 4 | EUFH + HP water heater | 3.819 | 1.493 | 0 | 43 | 292 | 3.733 | 0 | 9.380 | 7.690 | 1.380 | 1.352 | 4.958 | 0 | 4.267 | 2.381 | 4.958 | 1.017 | 673 | 0 | 0 | 229 | 151 | 0 | 380 | 0 | 6.187 | -3.452 | -7.189 | 6.187 | 2.735 | -1.002 | -4.454 |
| | 5 | EUFH + E hot water tank | 3.893 | 3.527 | 0 | 37 | 292 | 3.733 | 0 | 11.481 | 7.690 | 2.522 | 1.341 | 3.827 | 0 | 5.226 | 2.392 | 3.827 | 2.558 | 1.233 | 0 | 0 | 576 | 277 | 0 | 853 | 0 | 7.578 | -3.468 | -5.549 | 7.578 | 4.110 | 2.029 | -1.440 |
| | 6 | EUFH + E hot water tank + Battery | 3.893 | 3.527 | 0 | 37 | 292 | 3.733 | 0 | 11.481 | 7.690 | 3.659 | 2.068 | 1.963 | 0 | 4.089 | 1.665 | 1.963 | 2.558 | 1.233 | 0 | 0 | 576 | 277 | 0 | 853 | 0 | 5.929 | -2.414 | -2.846 | 5.929 | 3.515 | 3.083 | 669 |
| | 7 | EUFH + Flow heater + Battery | 4.581 | 1.651 | 0 | 0 | 292 | 3.733 | 0 | 10.258 | 7.690 | 1.722 | 2.184 | 3.784 | 0 | 4.803 | 1.549 | 3.784 | 1.633 | 934 | 0 | 0 | 368 | 210 | 0 | 578 | 0 | 6.964 | -2.246 | -5.487 | 6.964 | 4.718 | 1.477 | -769 |
| Very high | 1 | Boiler + Hot water tank | 2.614 | 3.839 | 133 | 128 | 292 | 3.733 | 6.453 | 4.286 | 7.690 | 157 | 1.354 | 6.179 | 6.453 | 396 | 2.379 | 6.179 | 0 | 0 | 3.404 | 594 | 0 | 0 | -170 | 424 | 6.453 | 574 | -3.449 | -8.959 | 7.027 | 3.578 | -1.932 | -5.381 |
| | 2 | ASHP + Hot water tank | 776 | 1.699 | 64 | 43 | 292 | 3.733 | 0 | 6.608 | 7.690 | 1.088 | 1.354 | 5.248 | 0 | 1.787 | 2.379 | 5.248 | 0 | 0 | 1.083 | 0 | 0 | 0 | -54 | -54 | 0 | 2.591 | -3.449 | -7.610 | 2.591 | -858 | -5.019 | -8.468 |
| | 3 | ASHP + Flow heater + Battery | 1.007 | 1.650 | 120 | 0 | 292 | 3.733 | 0 | 6.803 | 7.690 | 1.144 | 2.615 | 3.930 | 0 | 1.925 | 1.118 | 3.930 | 0 | 0 | 887 | 0 | 0 | 0 | -44 | -44 | 0 | 2.792 | -1.620 | -5.699 | 2.792 | 1.171 | -2.907 | -4.528 |
| | 4 | EUFH + HP water heater | 2.656 | 1.490 | 0 | 43 | 292 | 3.733 | 0 | 8.215 | 7.690 | 1.150 | 1.354 | 5.186 | 0 | 3.333 | 2.379 | 5.186 | 286 | 239 | 0 | 0 | 64 | 54 | 0 | 118 | 0 | 4.832 | -3.449 | -7.520 | 4.832 | 1.383 | -2.688 | -6.137 |
| | 5 | EUFH + E hot water tank | 2.723 | 3.522 | 0 | 37 | 292 | 3.733 | 0 | 10.307 | 7.690 | 2.342 | 1.354 | 3.995 | 0 | 4.232 | 2.379 | 3.995 | 1.669 | 948 | 0 | 0 | 376 | 213 | 0 | 589 | 0 | 6.136 | -3.450 | -5.792 | 6.136 | 2.686 | 344 | -3.106 |
| | 6 | EUFH + E hot water tank + Battery | 2.723 | 3.522 | 0 | 37 | 292 | 3.733 | 0 | 10.307 | 7.690 | 3.618 | 2.181 | 1.891 | 0 | 2.956 | 1.552 | 1.891 | 1.669 | 948 | 0 | 0 | 376 | 213 | 0 | 589 | 0 | 4.286 | -2.250 | -2.742 | 4.286 | 2.035 | 1.544 | -706 |
| | 7 | EUFH + Flow heater + Battery | 3.360 | 1.650 | 0 | 0 | 292 | 3.733 | 0 | 9.036 | 7.690 | 1.526 | 2.303 | 3.861 | 0 | 3.777 | 1.430 | 3.861 | 790 | 556 | 0 | 0 | 178 | 125 | 0 | 303 | 0 | 5.476 | -2.074 | -5.598 | 5.476 | 3.402 | -122 | -2.196 |

[a] R: Room heating, W:Water heating, V: Ventilation

[b] The ventilation system is configured for heating-season-only operation. Therefore, the ventilation energy demand depends on the (calculated) length of the heating season.

[c] Based on annual balance

**Table 25 Energy balance and energy costs, Sweden**

| Insulation level | | Variant | Final energy demand [kWh/a]: HVAC – Heat generation $R^a$ | HVAC – Heat generation $W^a$ | HVAC – Auxiliaries $R^a$ | HVAC – Auxiliaries $W^a$ | HVAC – Auxiliaries $V^{a,b}$ | Household | Σ Gas | Σ Electricity | PV output [kWh/a]: Total output | Used in building: HVAC | Used in building: Household | Fed in | Grid-building balance [kWh/a]: Gas drawn | Electricity based on momentary values: Drawn HVAC | Drawn Household | Fed in | Electricity based on annual balance: Drawn HVAC | Drawn Household | Fed in |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 1 | Boiler + Hot water tank | 8.137 | 3.810 | 300 | 123 | 342 | 5.925 | 11.946 | 6.691 | 7.256 | 165 | 1.947 | 5.144 | 11.946 | 601 | 3.978 | 5.144 | 0 | 0 | 565 |
| | 2 | ASHP + Hot water tank | 2.416 | 1.702 | 173 | 43 | 342 | 5.925 | 0 | 10.603 | 7.256 | 1.282 | 1.947 | 4.027 | 0 | 3.395 | 3.978 | 4.027 | 1.476 | 1.870 | 0 |
| | 3 | ASHP + Flow heater + Battery | 2.972 | 1.651 | 293 | 0 | 342 | 5.925 | 0 | 11.184 | 7.256 | 1.318 | 3.086 | 2.853 | 0 | 3.941 | 2.840 | 2.853 | 1.847 | 2.081 | 0 |
| | 4 | EUFH + HP water heater | 8.266 | 1.493 | 0 | 43 | 342 | 5.925 | 0 | 16.070 | 7.256 | 1.603 | 1.892 | 3.761 | 0 | 8.541 | 4.033 | 3.761 | 5.564 | 3.250 | 0 |
| | 5 | EUFH + E hot water tank | 8.426 | 3.527 | 0 | 37 | 342 | 5.925 | 0 | 18.257 | 7.256 | 2.568 | 1.865 | 2.823 | 0 | 9.763 | 4.061 | 2.823 | 7.430 | 3.570 | 0 |
| | 6 | EUFH + E hot water tank + Battery | 8.426 | 3.527 | 0 | 37 | 342 | 5.925 | 0 | 18.257 | 7.256 | 3.269 | 2.569 | 1.418 | 0 | 9.062 | 3.356 | 1.418 | 7.430 | 3.570 | 0 |
| | 7 | EUFH + Flow heater + Battery | 9.916 | 1.651 | 0 | 0 | 342 | 5.925 | 0 | 17.836 | 7.256 | 1.773 | 2.617 | 2.867 | 0 | 10.137 | 3.309 | 2.867 | 7.065 | 3.515 | 0 |
| Very high | 1 | Boiler + Hot water tank | 5.659 | 3.839 | 287 | 128 | 342 | 5.925 | 9.497 | 6.683 | 7.256 | 164 | 1.947 | 5.145 | 9.497 | 594 | 3.978 | 5.145 | 0 | 0 | 573 |
| | 2 | ASHP + Hot water tank | 1.679 | 1.699 | 138 | 43 | 342 | 5.925 | 0 | 9.828 | 7.256 | 1.125 | 1.947 | 4.184 | 0 | 2.777 | 3.978 | 4.184 | 1.021 | 1.550 | 0 |
| | 3 | ASHP + Flow heater + Battery | 2.180 | 1.650 | 259 | 0 | 342 | 5.925 | 0 | 10.358 | 7.256 | 1.181 | 3.209 | 2.866 | 0 | 3.251 | 2.716 | 2.866 | 1.327 | 1.774 | 0 |
| | 4 | EUFH + HP water heater | 5.749 | 1.490 | 0 | 43 | 342 | 5.925 | 0 | 13.551 | 7.256 | 1.365 | 1.929 | 3.962 | 0 | 6.260 | 3.996 | 3.962 | 3.542 | 2.752 | 0 |
| | 5 | EUFH + E hot water tank | 5.894 | 3.522 | 0 | 37 | 342 | 5.925 | 0 | 15.721 | 7.256 | 2.395 | 1.911 | 2.951 | 0 | 7.400 | 4.015 | 2.951 | 5.274 | 3.190 | 0 |
| | 6 | EUFH + E hot water tank + Battery | 5.894 | 3.522 | 0 | 37 | 342 | 5.925 | 0 | 15.721 | 7.256 | 3.172 | 2.715 | 1.369 | 0 | 6.623 | 3.210 | 1.369 | 5.274 | 3.190 | 0 |
| | 7 | EUFH + Flow heater + Battery | 7.273 | 1.650 | 0 | 0 | 342 | 5.925 | 0 | 15.192 | 7.256 | 1.582 | 2.764 | 2.910 | 0 | 7.684 | 3.161 | 2.910 | 4.840 | 3.095 | 0 |

| Insulation level | | Variant | Energy costs [€/a]: Gas | Electricity: Drawn HVAC | Electricity: Drawn Household | Electricity: Fed in | Total | Primary energy demand [kWh/a]: Energy drawn (HVAC only): Gas | Energy drawn (HVAC only): Electricity | Additional PV output: Household | Additional PV output: Fed in | Total: HVAC only | Total: with household bonus | Total: with feed-in bonus | Total: with household and feed-in bonus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 1 | Boiler + Hot water tank | 1.039 | 77 | 509 | -26 | 1.600 | 11.946 | 962 | -6.365 | -8.231 | 12.909 | 6.544 | 4.678 | -1.687 |
| | 2 | ASHP + Hot water tank | 0 | 435 | 509 | -20 | 924 | 0 | 5.432 | -6.365 | -6.442 | 5.432 | -933 | -1.011 | -7.376 |
| | 3 | ASHP + Flow heater + Battery | 0 | 504 | 363 | -14 | 854 | 0 | 6.305 | -4.544 | -4.565 | 6.305 | 1.761 | 1.740 | -2.803 |
| | 4 | EUFH + HP water heater | 0 | 1.093 | 516 | -19 | 1.591 | 0 | 13.666 | -6.453 | -6.017 | 13.666 | 7.213 | 7.649 | 1.196 |
| | 5 | EUFH + E hot water tank | 0 | 1.250 | 520 | -14 | 1.755 | 0 | 15.621 | -6.497 | -4.517 | 15.621 | 9.124 | 11.104 | 4.607 |
| | 6 | EUFH + E hot water tank + Battery | 0 | 1.160 | 430 | -7 | 1.582 | 0 | 14.500 | -5.370 | -2.269 | 14.500 | 9.130 | 12.231 | 6.862 |
| | 7 | EUFH + Flow heater + Battery | 0 | 1.298 | 424 | -14 | 1.707 | 0 | 16.220 | -5.294 | -4.587 | 16.220 | 10.926 | 11.633 | 6.339 |
| Very high | 1 | Boiler + Hot water tank | 826 | 76 | 509 | -26 | 1.386 | 9.497 | 950 | -6.365 | -8.232 | 10.448 | 4.083 | 2.216 | -4.149 |
| | 2 | ASHP + Hot water tank | 0 | 355 | 509 | -21 | 844 | 0 | 4.443 | -6.365 | -6.694 | 4.443 | -1.922 | -2.250 | -8.615 |
| | 3 | ASHP + Flow heater + Battery | 0 | 416 | 348 | -14 | 750 | 0 | 5.202 | -4.346 | -4.586 | 5.202 | 856 | 616 | -3.730 |
| | 4 | EUFH + HP water heater | 0 | 801 | 511 | -20 | 1.293 | 0 | 10.017 | -6.394 | -6.339 | 10.017 | 3.623 | 3.678 | -2.716 |
| | 5 | EUFH + E hot water tank | 0 | 947 | 514 | -15 | 1.446 | 0 | 11.840 | -6.424 | -4.721 | 11.840 | 5.416 | 7.119 | 695 |
| | 6 | EUFH + E hot water tank + Battery | 0 | 848 | 411 | -7 | 1.252 | 0 | 10.597 | -5.136 | -2.191 | 10.597 | 5.461 | 8.407 | 3.270 |
| | 7 | EUFH + Flow heater + Battery | 0 | 984 | 405 | -15 | 1.374 | 0 | 12.294 | -5.058 | -4.656 | 12.294 | 7.236 | 7.639 | 2.581 |

[a] R: Room heating, W:Water heating, V: Ventilation

[b] The ventilation system is configured for heating-season-only operation. Therefore, the ventilation energy demand depends on the (calculated) length of the heating season.

## Cost balance

The following tables show from left to right these results:

- HVAC-related investment costs (see 2.8.3)
- Capital costs per year based on 3 % interest rate and common service life spans
- Energy cost per year based on the annual grid-building balance for the Netherlands and on momentary values for all other countries
- Operating costs per year
  - o Regular inspections and maintenance, insurance
  - o Repairs not covered by regular maintenance (averaged over service life)
- Total annual costs

**Table 26 Cost balance, Germany**

| Thermal insulation | Variant | Investment costs | Annual costs | | | | |
|---|---|---|---|---|---|---|---|
| | | | Capital | Energy | Maintenance etc. | Repair | Total |
| High | 1 Boiler + Hot water tank | 47.700 € | 2.574 €/a | 1.008 €/a | 456 €/a | 301 €/a | 4.339 €/a |
| | 2 ASHP + Hot water tank | 50.400 € | 2.939 €/a | 790 €/a | 415 €/a | 310 €/a | 4.454 €/a |
| | 3 ASHP + Flow heater + Battery | 56.350 € | 3.277 €/a | 634 €/a | 405 €/a | 282 €/a | 4.598 €/a |
| | 4 EUFH + HP water heater | 38.850 € | 2.205 €/a | 1.432 €/a | 315 €/a | 149 €/a | 4.101 €/a |
| | 5 EUFH + E hot water tank | 36.850 € | 2.048 €/a | 1.751 €/a | 290 €/a | 129 €/a | 4.218 €/a |
| | 6 EUFH + E hot water tank + Battery | 46.150 € | 2.582 €/a | 1.540 €/a | 290 €/a | 129 €/a | 4.541 €/a |
| | 7 EUFH + Flow heater + Battery | 43.650 € | 2.445 €/a | 1.507 €/a | 280 €/a | 110 €/a | 4.342 €/a |
| Very high | 1 Boiler + Hot water tank | 47.700 € | 2.574 €/a | 895 €/a | 456 €/a | 301 €/a | 4.226 €/a |
| | 2 ASHP + Hot water tank | 49.900 € | 2.903 €/a | 707 €/a | 415 €/a | 305 €/a | 4.329 €/a |
| | 3 ASHP + Flow heater + Battery | 55.850 € | 3.240 €/a | 528 €/a | 405 €/a | 277 €/a | 4.450 €/a |
| | 4 EUFH + HP water heater | 38.850 € | 2.205 €/a | 1.139 €/a | 315 €/a | 149 €/a | 3.808 €/a |
| | 5 EUFH + E hot water tank | 36.850 € | 2.048 €/a | 1.453 €/a | 290 €/a | 129 €/a | 3.920 €/a |
| | 6 EUFH + E hot water tank + Battery | 46.150 € | 2.582 €/a | 1.207 €/a | 290 €/a | 129 €/a | 4.208 €/a |
| | 7 EUFH + Flow heater + Battery | 43.650 € | 2.445 €/a | 1.163 €/a | 280 €/a | 110 €/a | 3.997 €/a |

**Table 27 Cost balance, Czech Republic**

| Thermal insulation | Variant | Investment costs | Annual costs: Capital | Energy | Maintenance etc. | Repair | Total |
|---|---|---|---|---|---|---|---|
| High | 1 Boiler + Hot water tank | 39.140 € | 2.093 €/a | 856 €/a | 359 €/a | 247 €/a | 3.555 €/a |
| | 2 ASHP + Hot water tank | 41.680 € | 2.413 €/a | 392 €/a | 337 €/a | 260 €/a | 3.402 €/a |
| | 3 ASHP + Flow heater[a] + Battery | | | | | | |
| | 4 EUFH + HP water heater | 30.420 € | 1.721 €/a | 874 €/a | 251 €/a | 112 €/a | 2.959 €/a |
| | 5 EUFH + E hot water tank | 28.160 € | 1.555 €/a | 1.046 €/a | 231 €/a | 90 €/a | 2.921 €/a |
| | 6 EUFH + E hot water tank + Battery | 35.600 € | 1.982 €/a | 924 €/a | 231 €/a | 90 €/a | 3.227 €/a |
| | 7 EUFH + Flow heater[a] + Battery | | | | | | |
| Very high | 1 Boiler + Hot water tank | 39.140 € | 2.093 €/a | 743 €/a | 359 €/a | 247 €/a | 3.442 €/a |
| | 2 ASHP + Hot water tank | 41.280 € | 2.384 €/a | 335 €/a | 337 €/a | 256 €/a | 3.312 €/a |
| | 3 ASHP + Flow heater[a] + Battery | | | | | | |
| | 4 EUFH + HP water heater | 30.420 € | 1.721 €/a | 655 €/a | 251 €/a | 112 €/a | 2.739 €/a |
| | 5 EUFH + E hot water tank | 28.160 € | 1.555 €/a | 825 €/a | 231 €/a | 90 €/a | 2.700 €/a |
| | 6 EUFH + E hot water tank + Battery | 35.600 € | 1.982 €/a | 689 €/a | 231 €/a | 90 €/a | 2.992 €/a |
| | 7 EUFH + Flow heater[a] + Battery | | | | | | |

a Flow-through water heaters are uncommon in CZE due to electricity base prices depending on the amperage requirement of the building. Therefore, no costs/prices are shown for variants with flow water heaters (3, 6).

**Table 28 Cost balance, France**

| Thermal insulation | Variant | Investment costs | Annual costs: Capital | Energy | Maintenance etc. | Repair | Total |
|---|---|---|---|---|---|---|---|
| High | 1 Boiler + Hot water tank | 45.270 € | 2.472 €/a | 484 €/a | 378 €/a | 215 €/a | 3.549 €/a |
| | 2 ASHP + Hot water tank | 54.680 € | 3.167 €/a | 21 €/a | 410 €/a | 288 €/a | 3.886 €/a |
| | 3 ASHP + Flow heater + Battery | 60.680 € | 3.482 €/a | -60 €/a | 385 €/a | 249 €/a | 4.056 €/a |
| | 4 EUFH + HP water heater | 39.600 € | 2.162 €/a | 239 €/a | 265 €/a | 92 €/a | 2.758 €/a |
| | 5 EUFH + E hot water tank | 37.200 € | 1.983 €/a | 462 €/a | 242 €/a | 68 €/a | 2.755 €/a |
| | 6 EUFH + E hot water tank + Battery | 47.200 € | 2.557 €/a | 385 €/a | 242 €/a | 68 €/a | 3.252 €/a |
| | 7 EUFH + Flow heater + Battery | 46.750 € | 2.544 €/a | 249 €/a | 239 €/a | 65 €/a | 3.097 €/a |
| Very high | 1 Boiler + Hot water tank | 45.270 € | 2.472 €/a | 391 €/a | 378 €/a | 215 €/a | 3.456 €/a |
| | 2 ASHP + Hot water tank | 54.680 € | 3.167 €/a | -11 €/a | 419 €/a | 288 €/a | 3.863 €/a |
| | 3 ASHP + Flow heater + Battery | 60.680 € | 3.482 €/a | -97 €/a | 393 €/a | 249 €/a | 4.026 €/a |
| | 4 EUFH + HP water heater | 39.600 € | 2.162 €/a | 134 €/a | 265 €/a | 92 €/a | 2.653 €/a |
| | 5 EUFH + E hot water tank | 37.200 € | 1.983 €/a | 356 €/a | 242 €/a | 68 €/a | 2.649 €/a |
| | 6 EUFH + E hot water tank + Battery | 47.200 € | 2.557 €/a | 267 €/a | 242 €/a | 68 €/a | 3.135 €/a |
| | 7 EUFH + Flow heater + Battery | 46.750 € | 2.544 €/a | 127 €/a | 239 €/a | 65 €/a | 2.975 €/a |

**Table 29 Cost balance, Netherlands**

| Thermal insulation | Variant | Investment costs | Annual costs | | | | |
|---|---|---|---|---|---|---|---|
| | | | Capital | Energy | Maintenance etc. | Repair | Total |
| High | 1 Boiler + Hot water tank | 43.750 € | 2.347 €/a | 527 €/a | 422 €/a | 301 €/a | 3.597 €/a |
| | 2 ASHP + Hot water tank | 46.450 € | 2.712 €/a | -36 €/a | 381 €/a | 310 €/a | 3.367 €/a |
| | 3 ASHP + Flow heater + Battery | 52.400 € | 3.050 €/a | -25 €/a | 371 €/a | 282 €/a | 3.677 €/a |
| | 4 EUFH + HP water heater | 34.900 € | 1.978 €/a | 380 €/a | 281 €/a | 149 €/a | 2.789 €/a |
| | 5 EUFH + E hot water tank | 32.900 € | 1.821 €/a | 853 €/a | 256 €/a | 129 €/a | 3.059 €/a |
| | 6 EUFH + E hot water tank + Battery | 42.200 € | 2.355 €/a | 853 €/a | 256 €/a | 129 €/a | 3.593 €/a |
| | 7 EUFH + Flow heater + Battery | 39.700 € | 2.218 €/a | 578 €/a | 246 €/a | 110 €/a | 3.151 €/a |
| Very high | 1 Boiler + Hot water tank | 43.750 € | 2.347 €/a | 424 €/a | 422 €/a | 301 €/a | 3.494 €/a |
| | 2 ASHP + Hot water tank | 45.950 € | 2.676 €/a | -54 €/a | 381 €/a | 305 €/a | 3.308 €/a |
| | 3 ASHP + Flow heater + Battery | 51.900 € | 3.014 €/a | -44 €/a | 371 €/a | 277 €/a | 3.617 €/a |
| | 4 EUFH + HP water heater | 34.900 € | 1.978 €/a | 118 €/a | 281 €/a | 149 €/a | 2.527 €/a |
| | 5 EUFH + E hot water tank | 32.900 € | 1.821 €/a | 589 €/a | 256 €/a | 129 €/a | 2.795 €/a |
| | 6 EUFH + E hot water tank + Battery | 42.200 € | 2.355 €/a | 589 €/a | 256 €/a | 129 €/a | 3.329 €/a |
| | 7 EUFH + Flow heater + Battery | 39.700 € | 2.218 €/a | 303 €/a | 246 €/a | 110 €/a | 2.876 €/a |

**Table 30 Cost balance, Sweden**

| Thermal insulation | Variant | Investment costs | Annual costs | | | | |
|---|---|---|---|---|---|---|---|
| | | | Capital | Energy | Maintenance etc. | Repair | Total |
| High | 1 Boiler + Hot water tank | 47.700 € | 2.574 €/a | 1.600 €/a | 456 €/a | 301 €/a | 4.930 €/a |
| | 2 ASHP + Hot water tank | 50.400 € | 2.939 €/a | 924 €/a | 415 €/a | 310 €/a | 4.587 €/a |
| | 3 ASHP + Flow heater + Battery | 56.350 € | 3.277 €/a | 854 €/a | 405 €/a | 282 €/a | 4.817 €/a |
| | 4 EUFH + HP water heater | 38.850 € | 2.205 €/a | 1.591 €/a | 315 €/a | 149 €/a | 4.260 €/a |
| | 5 EUFH + E hot water tank | 36.850 € | 2.048 €/a | 1.755 €/a | 290 €/a | 129 €/a | 4.222 €/a |
| | 6 EUFH + E hot water tank + Battery | 46.150 € | 2.582 €/a | 1.582 €/a | 290 €/a | 129 €/a | 4.583 €/a |
| | 7 EUFH + Flow heater + Battery | 43.650 € | 2.445 €/a | 1.707 €/a | 280 €/a | 110 €/a | 4.541 €/a |
| Very high | 1 Boiler + Hot water tank | 47.700 € | 2.574 €/a | 1.386 €/a | 456 €/a | 301 €/a | 4.716 €/a |
| | 2 ASHP + Hot water tank | 49.900 € | 2.903 €/a | 844 €/a | 415 €/a | 305 €/a | 4.466 €/a |
| | 3 ASHP + Flow heater + Battery | 55.850 € | 3.240 €/a | 750 €/a | 405 €/a | 277 €/a | 4.671 €/a |
| | 4 EUFH + HP water heater | 38.850 € | 2.205 €/a | 1.293 €/a | 315 €/a | 149 €/a | 3.962 €/a |
| | 5 EUFH + E hot water tank | 36.850 € | 2.048 €/a | 1.446 €/a | 290 €/a | 129 €/a | 3.913 €/a |
| | 6 EUFH + E hot water tank + Battery | 46.150 € | 2.582 €/a | 1.252 €/a | 290 €/a | 129 €/a | 4.253 €/a |
| | 7 EUFH + Flow heater + Battery | 43.650 € | 2.445 €/a | 1.374 €/a | 280 €/a | 110 €/a | 4.208 €/a |