Options for replacing compact heat pump units when renewal is necessary in Passive House buildings

A brief study by the Passive House Institute (PHI) commissioned by the enercity-Fonds proKlima

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Contents

1 Compact heat pump units

Compact heat pump units for Passive House buildings combine the functions of ventilation, heating, hot water generation, and to some extent also cooling, in a single unit. Heat is distributed throughout the home via the supply air, which is required in any case. The exhaust air from the ventilation system serves as the heat source for this purpose.

This concept offers a number of advantages and has therefore been and continues to be used often in Passive House buildings:

- All components are coordinated and controlled by a common control system. This makes it much easier to achieve flawless interaction between all components than if the building services system were to be assembled individually from separate components.
- Thanks to the high level of integration, these devices require little space.
- The installation effort is relatively low. In particular, no specialists for cooling technology are required on site.
- The unit is installed entirely inside the building. It uses the wall penetrations that already exist for the ventilation. It is not necessary to install components on the outside, as is the case with many other types of heat pumps.

The concept of the compact heat pump unit was devised in the late 1990s following the successful experience with the Kranichstein Passive House building and was later implemented by various manufacturers. Units certified by the Passive House Institute (PHI) offer a high level of efficiency that is independently verified. A list of these can be found at [PHI 2025].

However, there are also disadvantages:

If a compact unit fails irreparably, for example because the compressor is defective or spare parts are no longer available, all features of the unit usually have to be replaced. This occurs currently for Passive House buildings that are between 15 and 25 years old. In many cases, the unit cannot be replaced with one of the same dimensions and performance characteristics, since the first-generation units have been further developed in the meantime and are no longer manufactured in the same way – as is the case with other technical devices of a comparable age.

This study will therefore examine various options for replacing the compact unit in such cases. Three criteria play a role here:

- Economic efficiency: A suitable parameter for this is the total costs incurred annually for operation of the building and depreciation of the investment.

- The total electricity consumption of the building. This is an indicator of the operating costs and the impact on expenditure within the supply structure (e.g. backup services).
- The PER demand of the building. PER stands for Primary Energy Renewable. This value describes how much energy must be produced *in a completely renewable energy system* in order to provide a specific energy service. This takes into account the fact that in the future, renewable electricity will rather be abundant in summer, but to some extent electricity consumption in winter (especially for heating) will have to be covered by converting summer surpluses into storable energy sources (hydrogen, methane) and converting them back into electricity in winter, both with considerable losses. Details on the PER system can be found in [Passipedia 2025]. The PER demand is also the current certification criterion for Passive House buildings, which assesses the efficiency of the technical building systems. It is the most suitable measure of the *environmental impact* of energy consumption. Even with a partially renewable energy supply system, as will continue to be the case in the coming years, the PER demand can be used as an indicator of the non-renewable share of electricity generation. The PER demand is therefore an "ecological" parameter. The lower the PER demand, the less of the limited renewable energy available needs to be "expended" for the relevant service.

The most important results are presented below. The study uses data for Germany, with prices dating from 2025. The applied boundary conditions are documented in the Appendix starting from page 17.

2 Comparison of variants

The following variants for replacing the defunct compact unit were examined:

- **Compact:** Installation of a new compact unit, possibly of a different type. All functions of the previous compact unit are undertaken by the new unit. Today's compact units are slightly more efficient than the unit used in the example building from 2006.
- **Dir. el. central:** A new Passive House ventilation unit with heat recovery is installed. Heating then takes place via a central post-heating coil in the supply air duct of the new ventilation system. Hot water is generated by means of a direct electric boiler (storage tank with a heating element).
- **Dir. el. decentral:** New direct electric heaters (including infrared heaters) are installed in each room. Otherwise as in the Dir. elect. central variant: hot water generation by an electric boiler, installation of a new Passive House ventilation unit.

- **Dir. el. & DHW HP:** Installation of a new Passive House ventilation unit, direct electric heating with a central post-heating coil (see Dir. elect. central), hot water generation with a DHW heat pump instead of an electric boiler.
- **Outside air HP:** Installation of a new Passive House ventilation unit, heating and hot water generation via an air source heat pump. The heat pump generates hot water, which heats the supply air via a heating coil and also provides hot water.
- **Split & DHW HP**: Installation of a new Passive House ventilation unit, installation of a new split air conditioning unit for space heating, installation of a new DHW heat pump for hot water generation. Unlike the outside air heat pump variant, the split air conditioning unit, which is also a heat pump, transfers the heat directly to a room on the ground floor via an indoor unit with recirculated air.
- **Split & IWH:** Installation of new Passive House building ventilation unit, new split air conditioning unit for space heating, new instantaneous water heaters for hot water supply.

A semi-detached house with 160 m² of living space, built in Hanover in 2006, was used as an example building. The building has three storeys with a flat monopitch roof inclined north and large south-facing windows.

Figure 1 shows the *total electricity demand* of the variants, for heating, hot water, auxiliary electricity *and household electricity*. The solutions with heat pumps have favourable values; the electricity demand increases significantly as soon as some of the heat demand is covered via direct electricity. Direct electric heating with a central post-heating coil and a directly electrically heated hot water tank comes off particularly poorly.

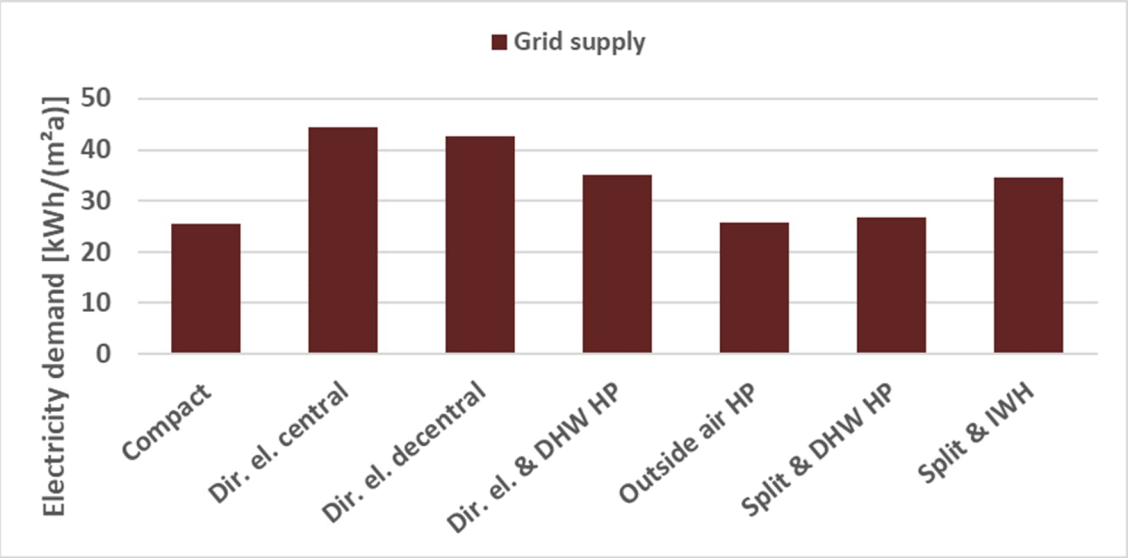


Figure 1 : The electricity demand is significantly higher for direct electric variants than for heat pump solutions.

The differences are even more pronounced when considering the amount of primary electricity that must be generated to provide the building with all energy services (Figure 2). Since a particularly large amount of primary electricity must be generated to cover the demand for heating in winter, direct electric heating has a particularly negative environmental impact.

However, even the worst variant would still be certifiable as a Passive House building.

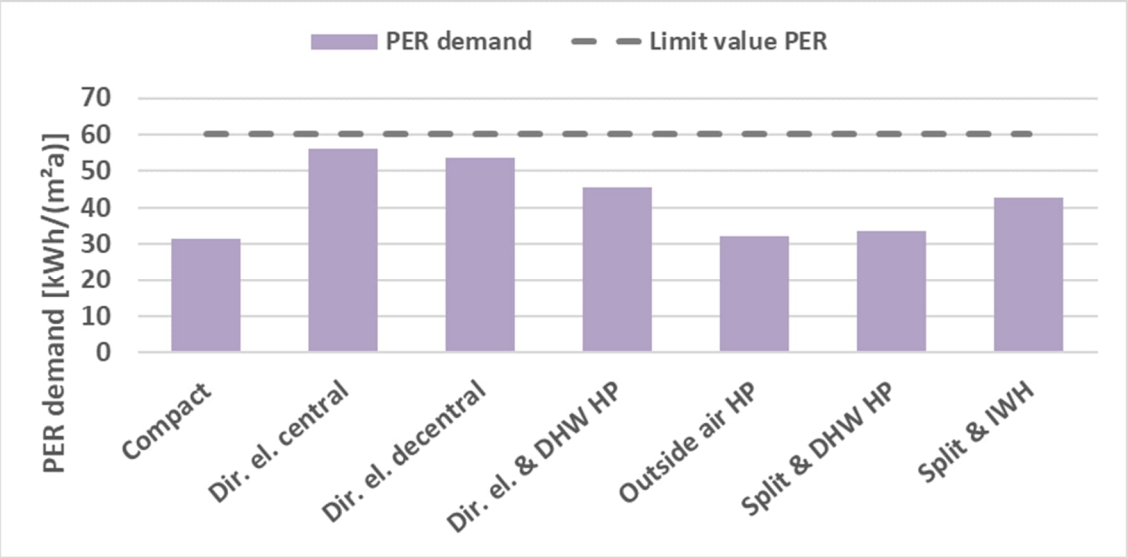


Figure 2 : PER demand comparison: for supplying the worst variant, almost twice as much renewable electricity as for the best variant must be generated; in spite of this, all variants meet the PER criterion.

Naturally, the electricity costs are also highest for the direct electric variants. The picture is more nuanced (Figure 3) if the investment costs are spread over the useful life of the device and the total expenditure is compared. In spite of the replacement costs that appear to be quite high initially, a new compact device is the most cost-effective solution overall. Heating using the split unit in combination with an electric instantaneous water heater for hot water supply is at the same level. The variants completely using direct electricity are slightly more expensive. The least economical variant is the air-to-water heat pump, due to the very high installation costs currently required by the market.

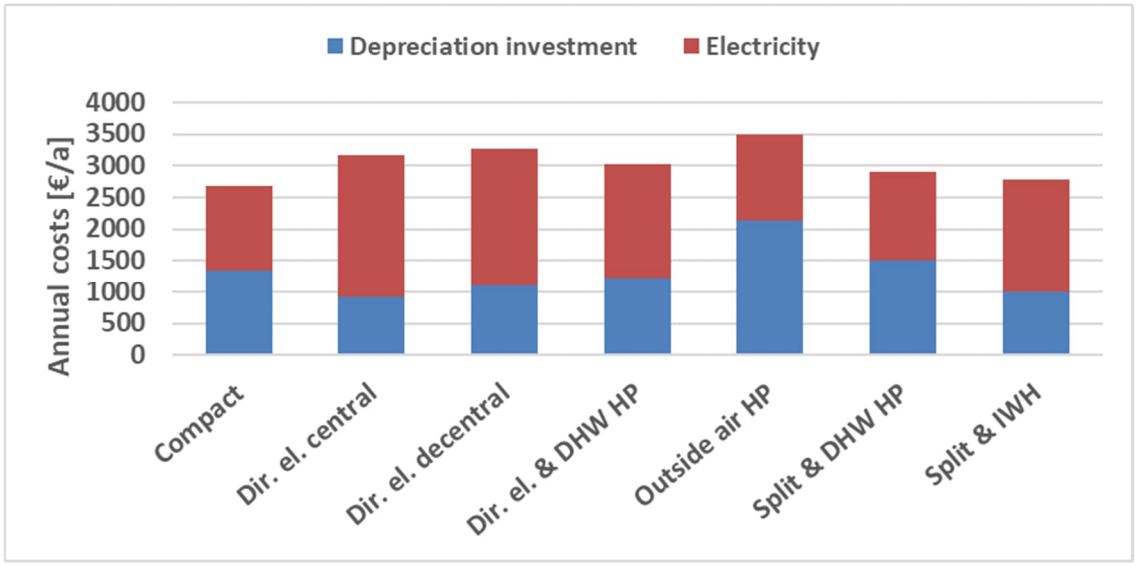


Figure 3 : Comparison of total costs: when investment and electricity costs are taken into account, the differences between the variants are not very big anymore. However, low-cost heat pump solutions still rate better.

Heat pump subsidies have not been taken into account here. These vary greatly from case to case, and the conditions are changing fast. It is clear that heat pump solutions will be even more advantageous if subsidies are available.

A detailed description of each variant can be found in the Appendix in Section 5.3.

3 Further sub-variants

3.1 A PV system is available

If the building has a PV system, electricity is cheaper in the summer months. In this case, high electricity consumption for hot water generation for example has less of an impact on the overall costs. The effects for two different sizes of the PV system are shown in the following graphs.

The investment costs for the PV system are taken into account but shown separately. This allows the costs of the systems to be compared even if a PV system is already in place.

The PV system can significantly reduce electricity consumption from the grid and the associated costs. This reduction is slightly greater for the variants with direct electric hot water heating. However, the ranking of the variants remains unchanged.

A detailed characterisation of each variant with a small or large PV system can be found in the Appendix in Section 5.3.

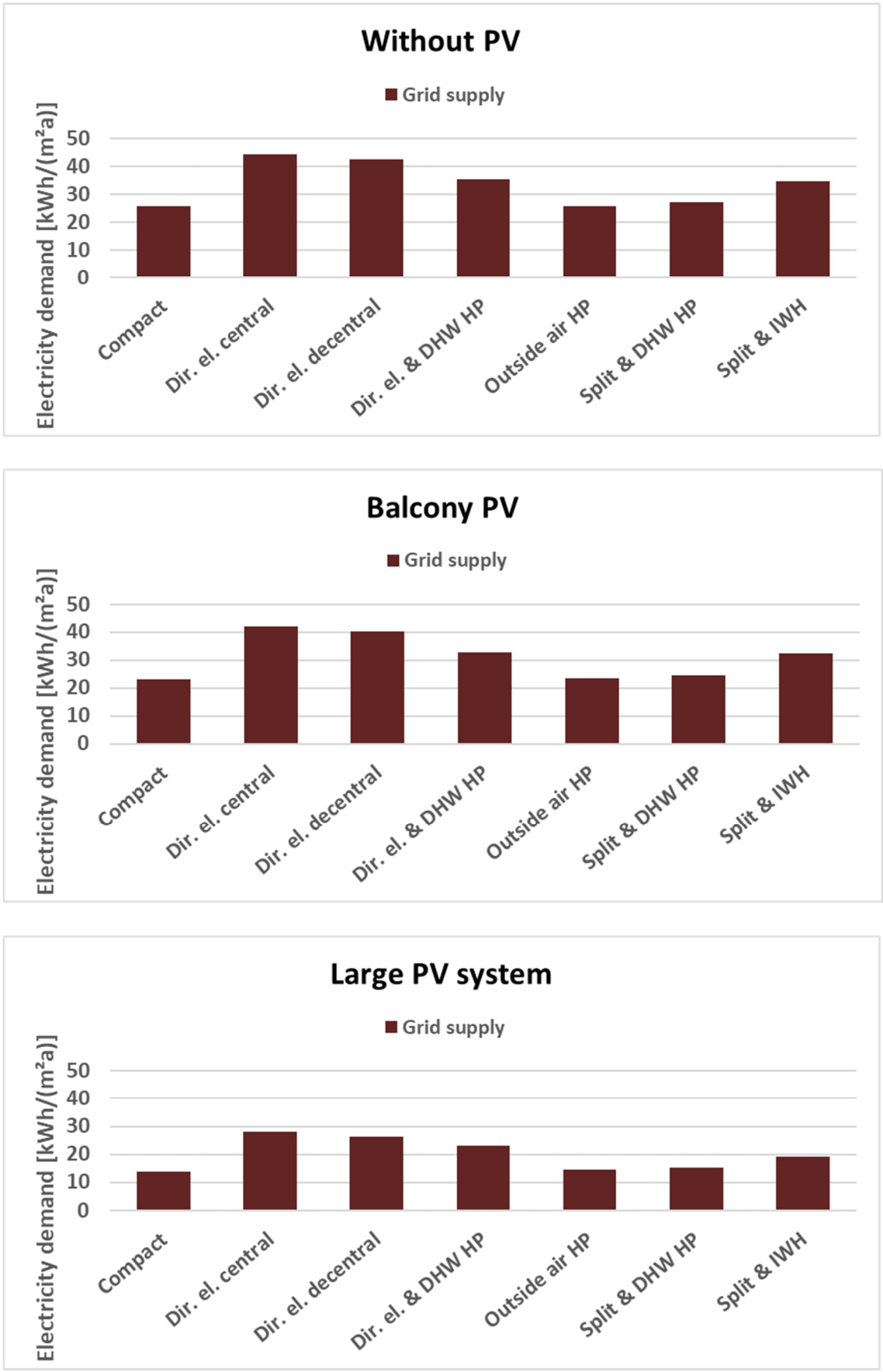


Figure 4: Comparison of electricity consumption: with a PV system, grid electricity consumption decreases primarily in summer.

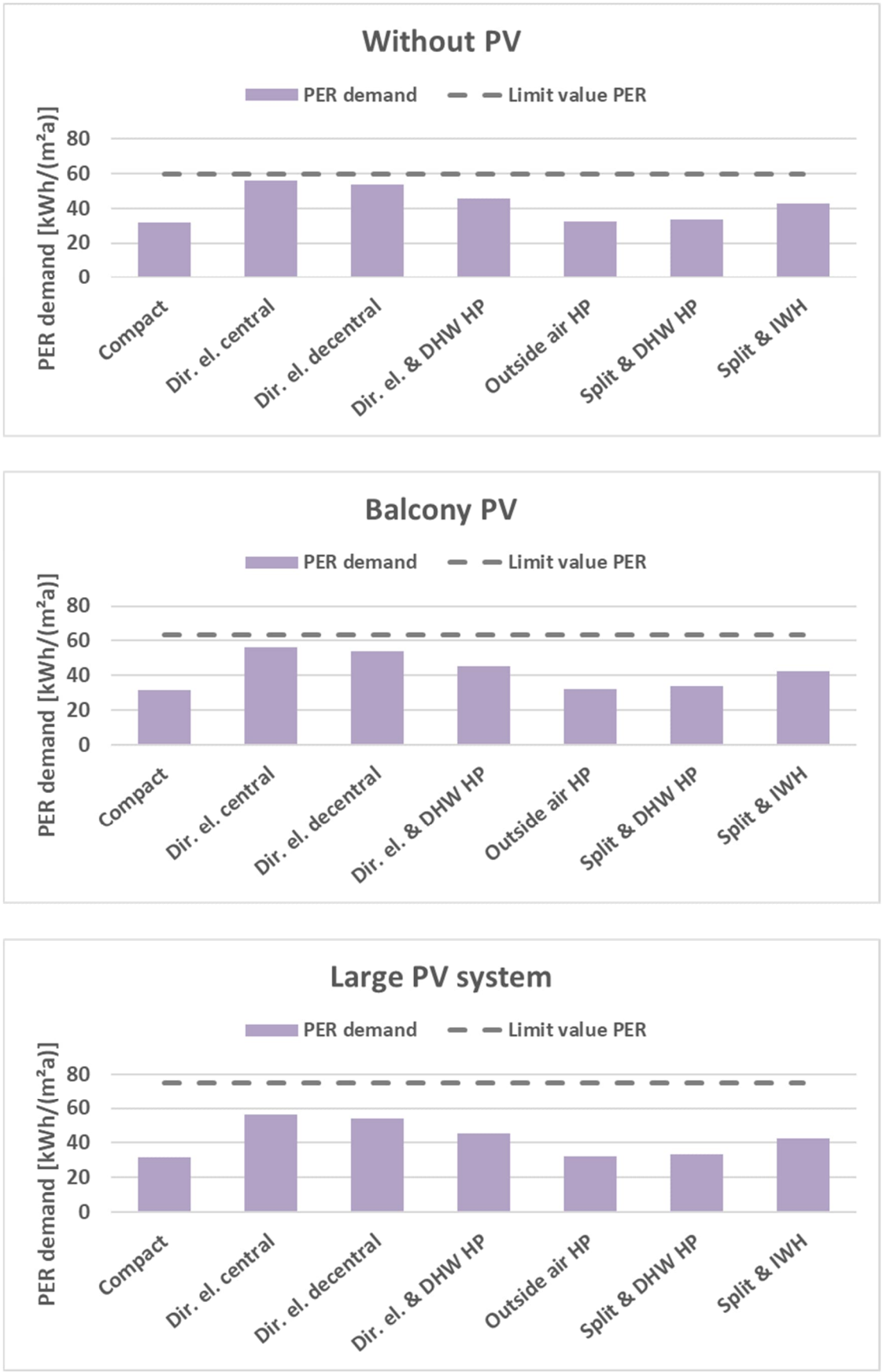


Figure 5: **Comparison of the PER demand: the PV system is not directly offset against the PER demand. However, if a PV system is installed, the PER limit value in the Passive House certificate increases.**

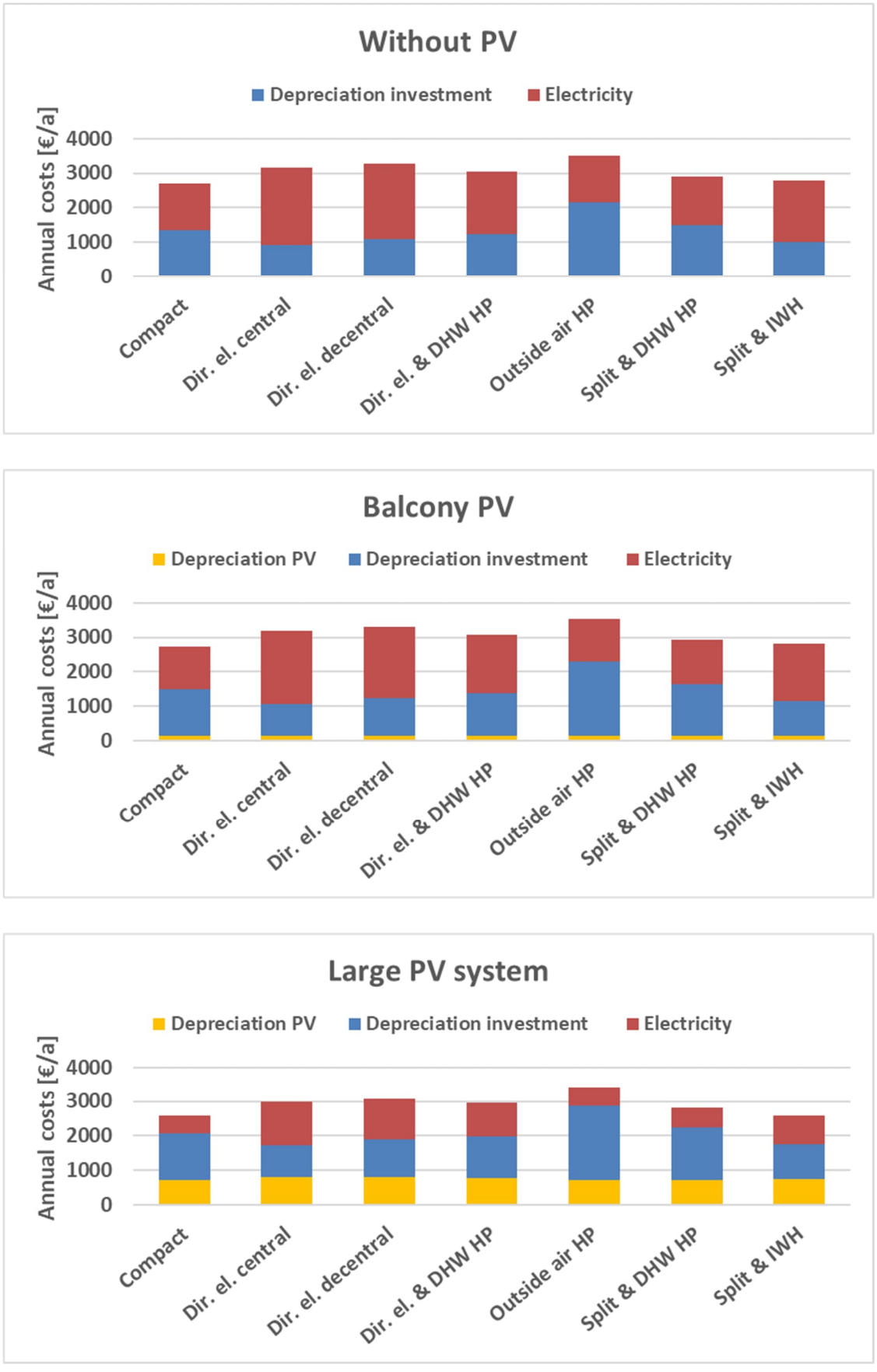
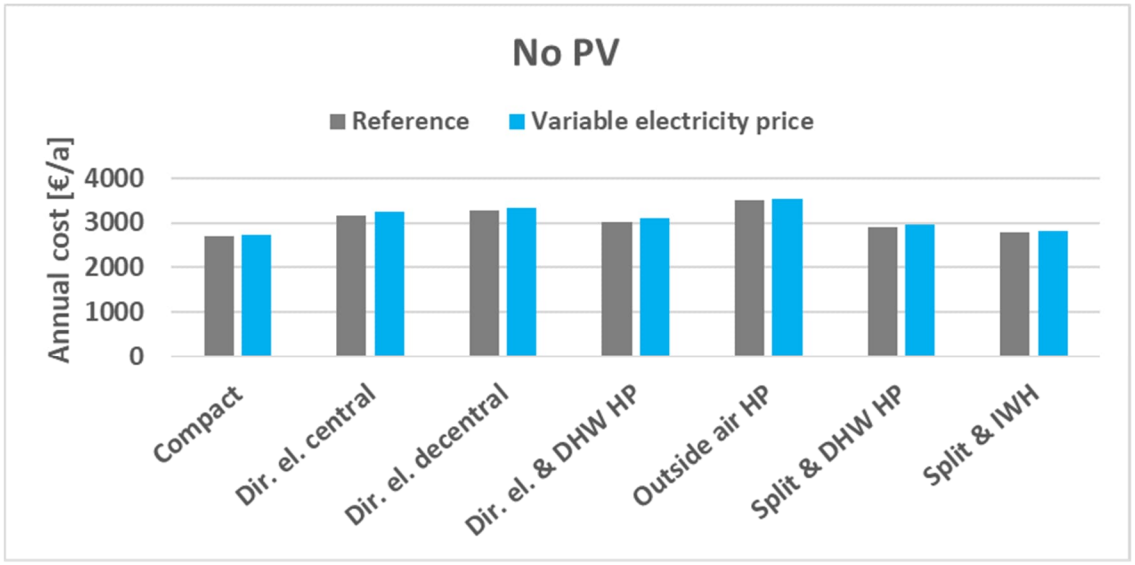


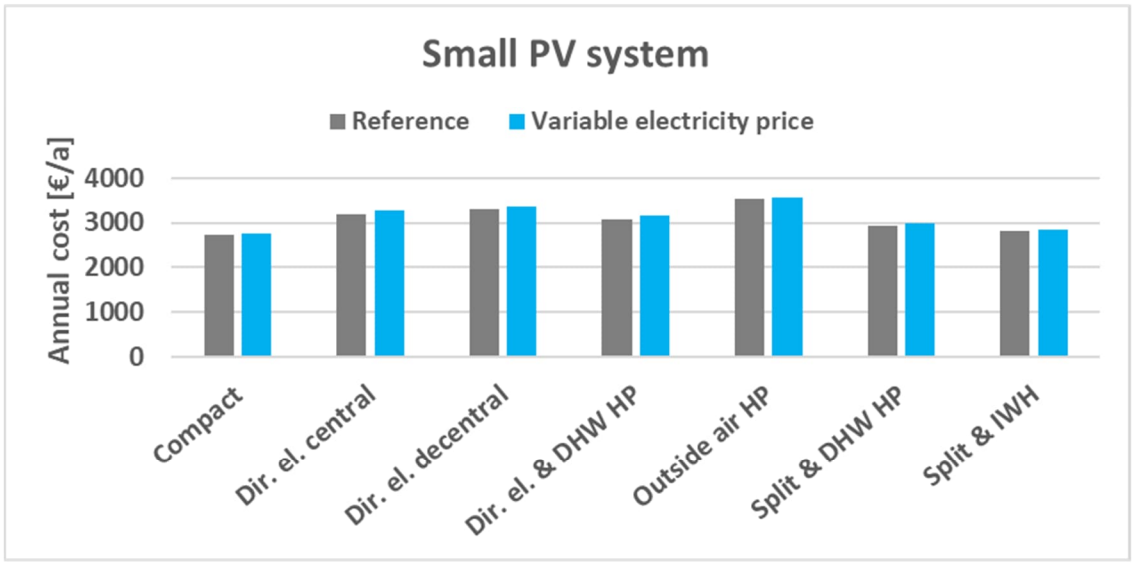
Figure 6: **Comparison of costs: with a PV system, electricity costs are reduced, but even with large PV systems, there is still a base electricity demand in the winter months.**

3.2 Variable electricity prices

Due to the increasing share of PV in the electricity supply and a growing number of heat pumps in the grid, it is expected that electricity prices will be lower in summer and higher in winter in the future. The economic consequences of 10% higher electricity prices in winter and 10% lower prices in summer are shown in Figure 7. The variants with heat pumps for space heating tend to have an advantage in this scenario. However, since the low electricity demand for heating in Passive House buildings only accounts for a limited portion of the total electricity demand in all cases and the investment costs remain unchanged, the impact of variable electricity prices is rather low.

If winter electricity prices rise more sharply in future than assumed here, the advantage of the more efficient systems would be even greater.





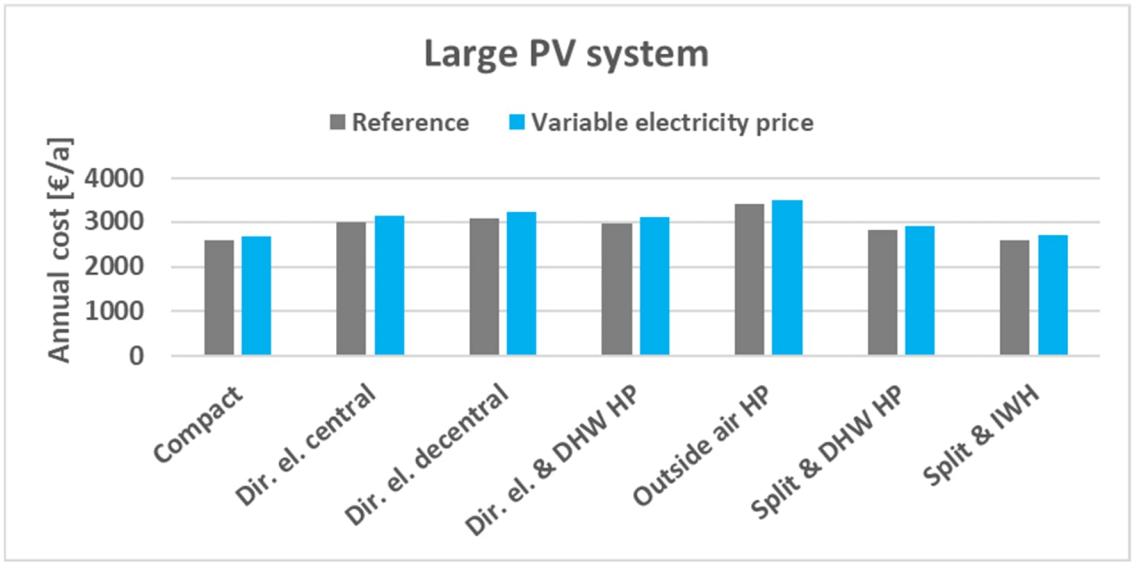


Figure 7: **The expected higher electricity prices in winter further improve the economic advantages of heat pump solutions.**

3.3 Subsidies

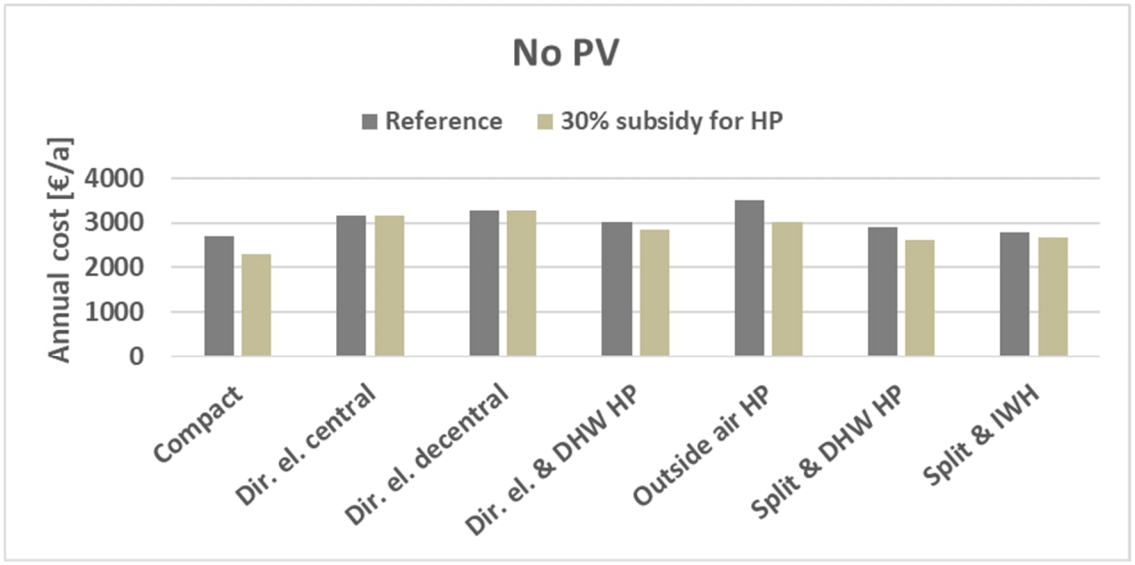
Generous subsidies are available for the installation of heat pumps in some cases. This not only further improves the economic efficiency of heat pump systems, but may also lead to a change in the economic ranking of the solutions.

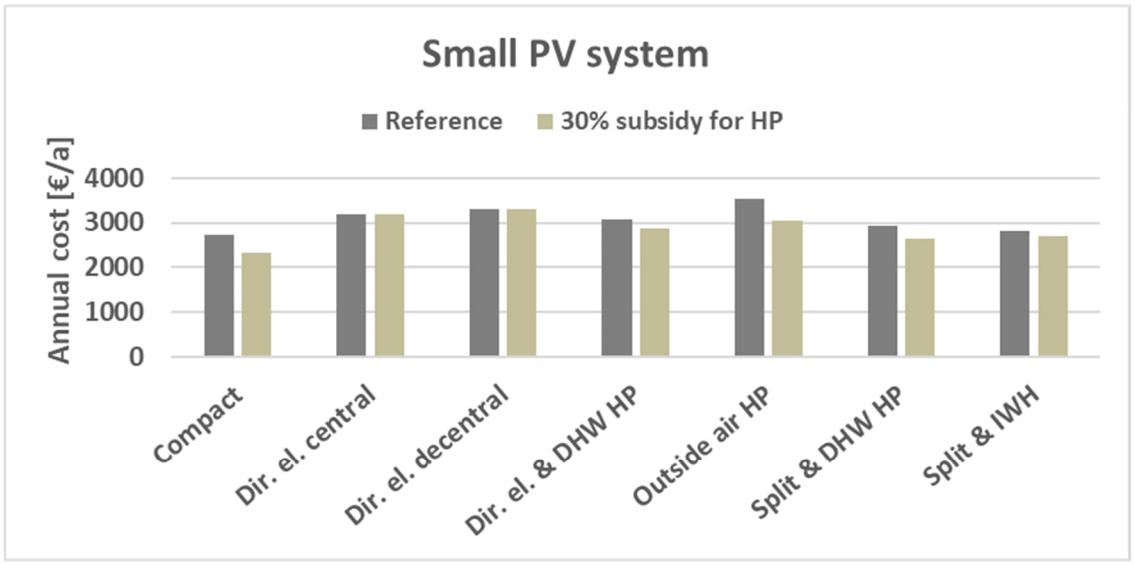
Subsidies across the board also have an impact on prices charged on the market. The investment costs estimated in this study therefore also reflect the current subsidy situation in Germany at the end of 2025.

As subsidy conditions are constantly changing and the subsidies available depend on individual cases, the impact of subsidies in Figure 8 is only shown as an example. The results can serve as a guide as to which variant is worth pursuing in individual cases.

A subsidy rate of 30% for material and installation costs in each case is assumed for

- the compact unit including all components
- the split unit
- the air-to-water heat pump including hot water and buffer storage tank and post-heating coil
- the DHW heat pump.





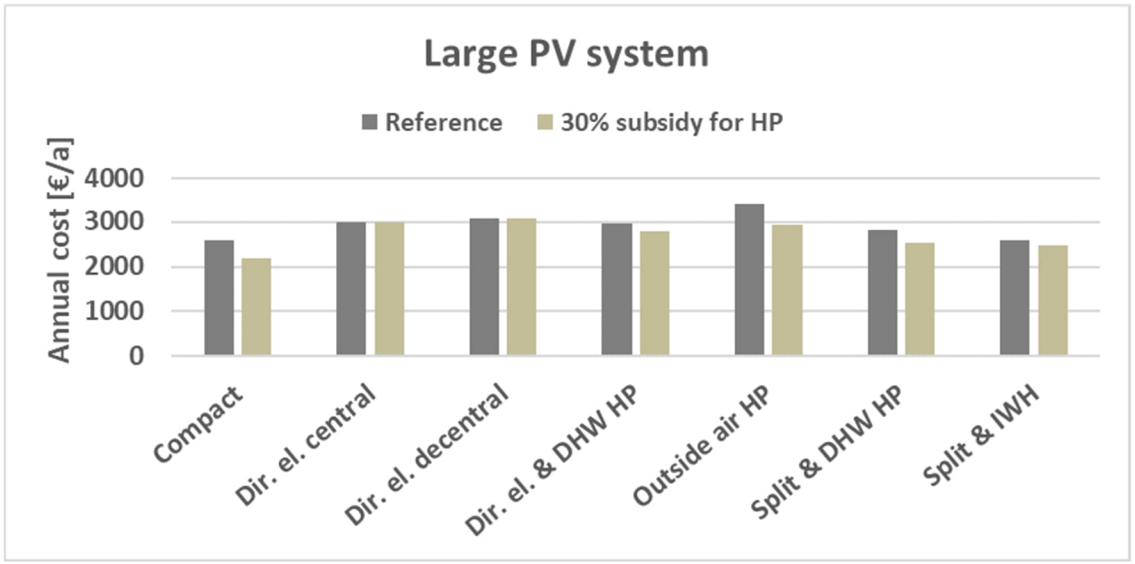


Figure 8: **The ranking may change if subsidies are only available for individual variants.**

4 Conclusion

The best system, both technically and economically, for replacing a compact unit in a Passive House building is to install another compact unit or alternatively, a combination of a split unit (space heating) and an instantaneous water heater (hot water). Both variants offer high efficiency, low operating costs and good eco-balance. In the individual case, this decision may be influenced by personal preferences, structural conditions and available subsidies.

5 Appendix: Methodology, boundary conditions, details on the variants

The results presented in this study were calculated using the Passive House Planning Package (PHPP) in conjunction with PVEcon. The PHPP has been used successfully for decades in the planning of Passive House buildings and has been validated in numerous inhabited buildings. PVEcon is a tool for determining the self-consumption of PV electricity.

The starting point for the investigations is a semi-detached house built to the Passive House standard in Hanover in 2006. According to the current climate data in the PHPP, the building needs 14.1 kWh/(m²a) of heating energy. It was originally equipped with a compact heat pump unit, which now needs to be replaced after almost 20 years of operation.

The indoor temperature was assumed to be 22 °C when there is only a single heat source per building. In the case of room-by-room control, individual rooms are heated less, but in a Passive House building this only means a slight reduction in temperatures and thus in losses. Here, the average room temperature was set at 21 °C.

The building has a household electricity demand of 15 kWh/(m²a).

5.1 PV system

Two variants of PV systems were considered. In the "large" PV system, the slightly north-facing monopitch roof is covered with PV modules to a large extent. Taking into account the edge areas, this results in 40 m² of PV with a nominal output of 9 kW_p. Due to the unfavourable orientation, only 5300 kWh of electricity can be generated per year.

The second variant is a “small” PV system, which is installed on the roof in the same way. It has an area of 8 m² and a nominal output of 1.8 kW_p.

The systems are each supplemented by a battery with a maximum capacity of 1 kWh per kW_p or per MWh/a electricity demand, whichever is lower.

5.2 Economic efficiency calculation

Simple profitability calculations often use static parameters such as the payback period. These ignore the fact that investment costs must be incurred at the beginning of the period under consideration, while operating costs, especially for energy, are incurred later. Another serious weakness of payback periods is that they must be set in relation to the useful life of the measure.

In the present study, a dynamic profitability calculation is used, with all future costs discounted to the present day. The useful life of 20 years was uniformly applied for the components, which corresponds to the specification in VDI 2067 for electric heat pumps. For ventilation units, for example, this is likely to be more pessimistic; apart

from individual fan malfunctions, a service life of 30 to 40 years is realistic here. The same applies to the ventilation duct network, but this is not included in the calculation here. For reasons of clarity, a useful life of 20 years was also used for the ventilation unit.

The observation period is also 20 years. Replacements or residual values therefore do not have to be taken into account. The real interest rate is 2%; further details on this and the calculation method itself can be found in [AkkP 42].

5.2.1 Investment costs

The investment costs are largely based on information from [Woker 2025]. In addition, two specific offers for different variants were available for the building under examination, which could be used to confirm these costs. For components such as the split unit, experiences gained with other projects were applied.

Table 1: Applied investment costs in € including VAT.

Component	Price material	Installation
Compact unit	18000	4000
Ventilation unit	5000	3500
Split unit	3000	3000
Electric heating coil 2 kW	500	1000
Room-by-room electric heaters	2500	2000
Integrated DHW heat pump 200 l	4000	6000
Electric boiler	3000	2000
Air-to-water heat pump 3 kW	6000	13000
Hot water and buffer storage tank	4000	1000
Hydraulic post-heating coil 2 kW	1500	1000
Instantaneous water heater	400	1400
Small PV system	1400	1400
Large PV system*	7500	7500

* depending on battery size

Compared to prices found online for delivery to the kerbside, the total investment costs for a basic model of the component appear quite high. However, the estimates are likely to be realistic for a turnkey service of a high standard.

5.2.2 Electricity prices

All of the variants examined are powered by electricity and are therefore relatively easy to compare with one another. Nevertheless, the development of electricity prices plays an important role in terms of economic efficiency.

Significant factors influencing future electricity prices include the expansion of renewable energies and the increasing use of heat pumps for space heating and hot water production. The now very cost-effective PV systems lead to lower wholesale prices for electricity in summer, while in winter the electricity demand of heat pumps

results in higher prices. In [vbw 2024], stable wholesale prices averaging around 9 cents/kWh are expected, although the monthly averages will fluctuate between 6 cents/kWh in summer and 12 cents/kWh in winter over the next 20 years. On shorter time scales, even higher fluctuations appear to be realistic.

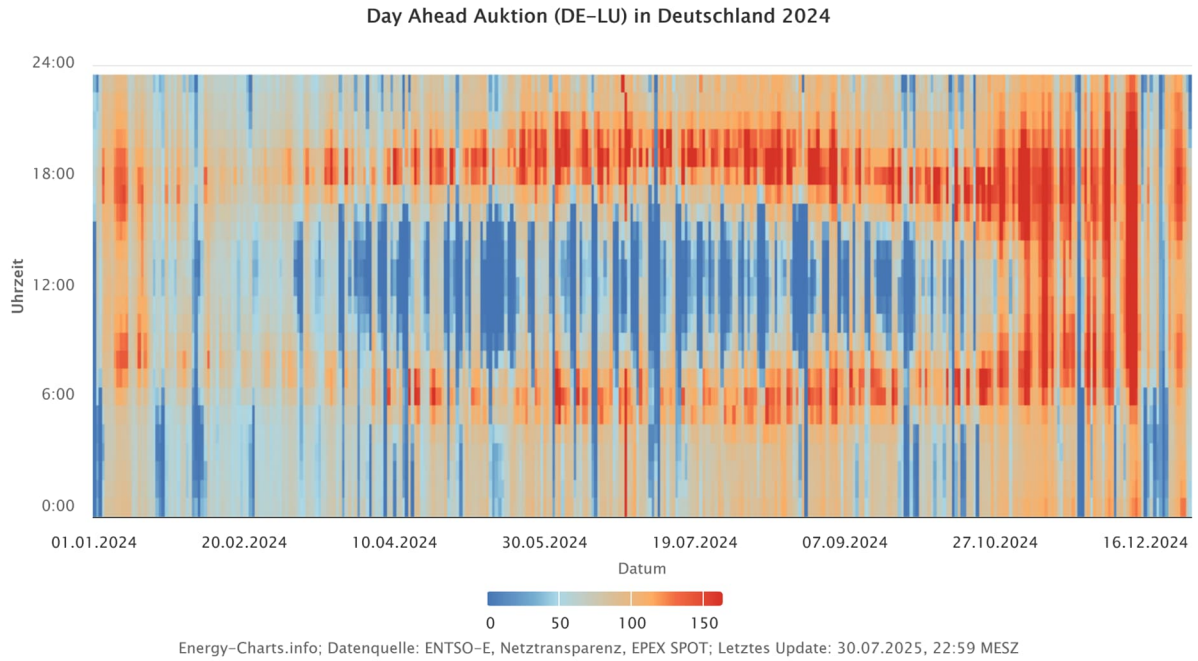


Figure 9 : Heat map of electricity exchange prices in 2024. Source: [Energy-Charts]

The extent to which these fluctuations are passed on to customers is also a political decision. With its high thermal inertia, a Passive House building can in principle bridge short-term price fluctuations of up to several days for heating. With sufficiently large storage capacity, this also applies to hot water production.

Two scenarios were considered for the present study, see Table 2.

Table 2: Estimated end user electricity prices in cents/kWh

	Stable scenario (reference)	Dynamic scenario (variant)
Electricity from grid in winter	30	33
Electricity from grid in summer	30	27
Feed-in tariff for PV electricity	7.5	7.5

Electricity for space heating and the associated auxiliary electricity are charged at the winter price, while electricity for hot water and household electricity are charged at the average of the winter and summer prices. For PV electricity consumed by the owner, the price for electricity from the grid in summer is considered. Although around 20% of

PV electricity is generated in the winter months, periods with high electricity prices stand out by the fact that hardly any renewable electricity is generated.

A feed-in tariff is only considered in the case of "large" PV systems. In this case, the PV electricity generated is divided into electricity consumed by the owner, which reduces the cost of electricity from the grid as described above, and electricity fed into the grid, for which only the feed-in tariff is credited.

5.3 Characterisation of the variants

The following pages provide a detailed description of the characteristics and parameters of the different variants.

Replacement of defective compact heat pump units

System characterisation

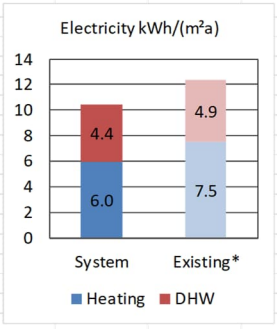
System: New compact unit

A new compact unit is installed in place of the defective compact unit. Due to the usually confined space, it must be checked whether assembly and routing of the ventilation ducts at the previous location is possible. In some circumstances, additional lines or even wall penetrations may be necessary. Many of the current compact units can contribute to cooling in the summer.

Advantages:
- low space requirement, low installation effort
- overall most cost-effective solution with heat pump
- all components compatible with each other ex works
- if neceessary supply air temperature control possible in summer

Disadvantages:
- in case of final failure of a part of the system the complete unit must be be replaced

Energy demand heating and hot water



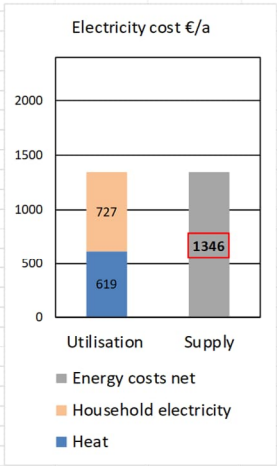
* Existing:compact unit model 2006

Investment costs

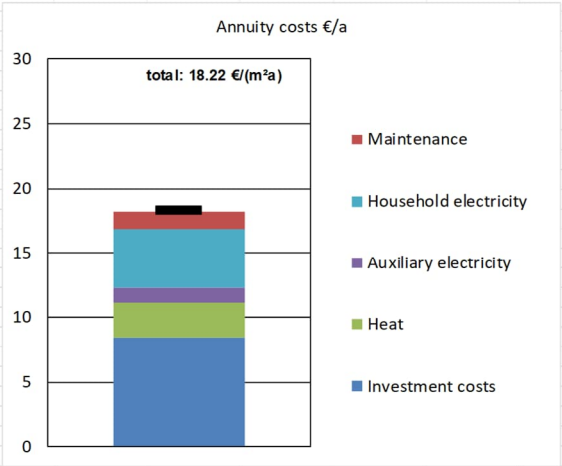
	Unit	Installation	
Compact unit	18000	4000	€
Total		**22000**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	8.42	€/(m²a)
Heat	2.68	€/(m²a)
Auxiliary electricity	1.20	€/(m²a)
Household electricity	4.55	€/(m²a)
Maintenance	1.38	€/(m²a)
Total	**18.22**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 2912 €/a

for investment costs, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

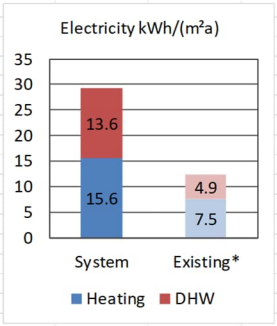
System: Direct electric central

A new ventilation unit with heat recovery is installed. A direct electric heating coil in the supply air duct provides space heating, domestic hot water is produced by an electric boiler. Due to the low heating load in the Passive House building, a three-phase current connection is not necessary. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit.

Advantages:
- lowest investment costs of all variants
- simple technology
- quiet

Disadvantages:
- highest electricity demand of all variants
- high electricity demand in winter, high PER demand
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

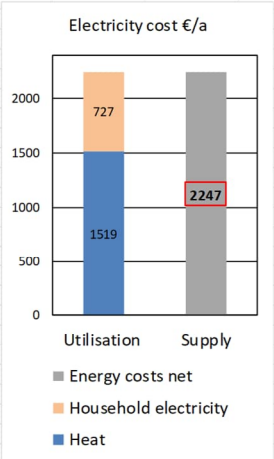
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Electric heating coil 2 kW	500	1000	€
Electric boiler	3000	2000	€
Total		**15000**	**€**

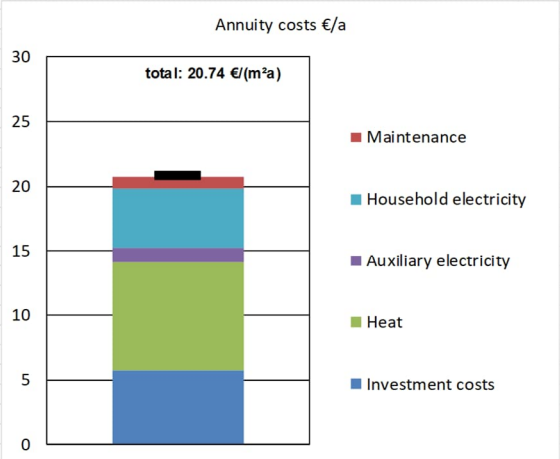
Annuities: costs allocated to each year per m²

Investment costs	5.74	€/(m²a)
Heat	8.37	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
Maintenance	0.94	€/(m²a)
Total	**20.74**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3314 €/a

for investment costs, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

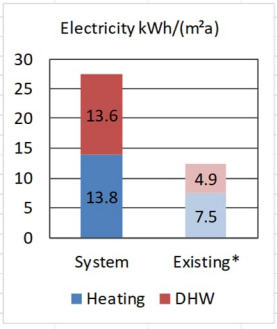
System: Direct electric with radiators in each room

A new ventilation unit with heat recovery is installed. Space heating takes place via electric heaters / infrared heating surfaces in each room; domestic hot water is produced by an electric boiler. Due to the small heating load in Passive House buildings, the radiators can be connected to existing 230 V power sockets. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit.

Advantages:
- low investment costs
- simple technology
- room-by-room temperature control possible
- quiet

Disadvantages:
- relatively high electricity demand
- high electricity demand in winter, high PER demand
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

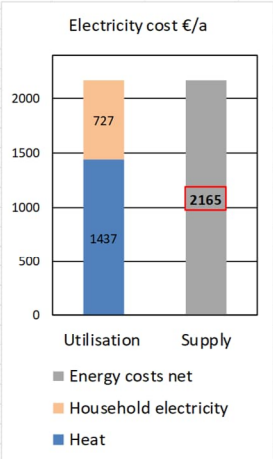
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
El. heater in each room	2500	2000	€
Electric boiler	3000	2000	€
Total		**18000**	**€**

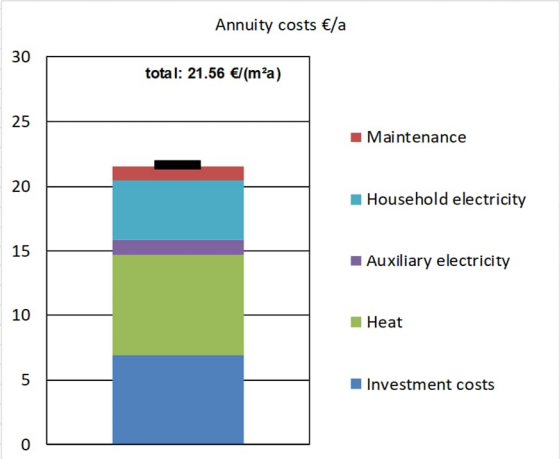
Annuities: costs allocated to each year per m²

Investment costs	6.89	€/(m²a)
Heat	7.86	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
Maintenance	1.13	€/(m²a)
Total	**21.56**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3445 €/a

for investment costs, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

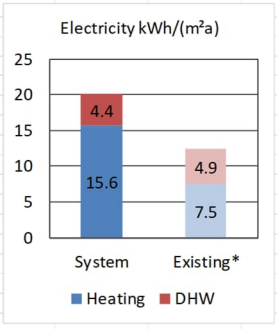
System: Direct electric heating + heat pump water heater

A new ventilation unit with heat recovery is installed. A direct electric heating coil in the supply air duct provides space heating, domestic hot water is provided by a heat pump water heater with an outside air connection. Due to the low heating load in the Passive House building, a three-phase current connection is not necessary. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit.

Advantages:
- efficient hot water generation
- simple heating technology, hardly any space required for heating system

Disadvantages:
- possible additional core hole drilling for air duct of heat pump
- noise exposure from heat pump possible

Energy demand heating and hot water



* Existing:compact unit model 2006

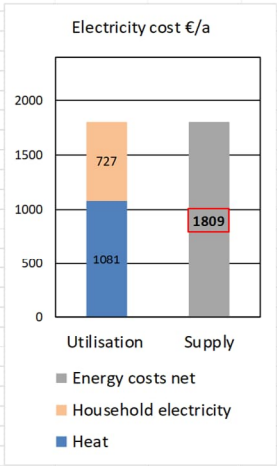
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Electric heating coil 2 kW	500	1000	€
Heat pump water heater	4000	6000	€
Total		**20000**	**€**

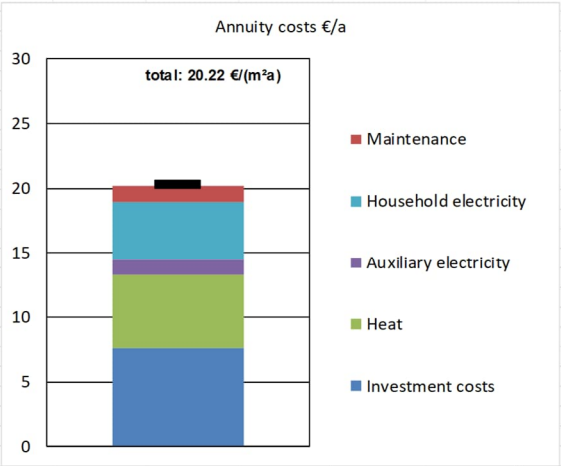
Annuities: costs allocated to each year per m²

Investment costs	7.65	€/(m²a)
Heat	5.63	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
Maintenance	1.25	€/(m²a)
Total	**20.22**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3232 €/a

for investment costs, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

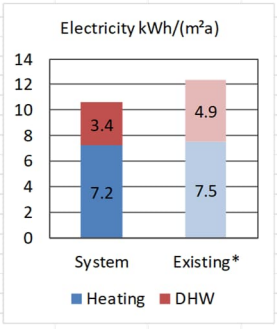
System: Air-to-water heat pump

A new ventilation unit with heat recovery is installed. An air-to-water heat pump for heat generation is installed in the (front) garden or on the roof. A hydronic post-heating coil in the supply air duct provides space heating. The space demand in the plant room is comparable to the other solutions with separate components.

Advantages: - low electricity demand

Disadvantages:
- highest investment costs of all variants
- installation of external unit must be clarified: footing, space demand, clearance spacing, sound impact
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

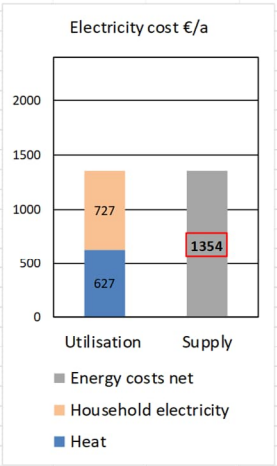
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Air-to-water HP 3 kW	6000	13000	€
DHW and buffer storage	4000	1000	€
Hydronic coil 2 kW	1500	1000	€
Total		**35000**	**€**

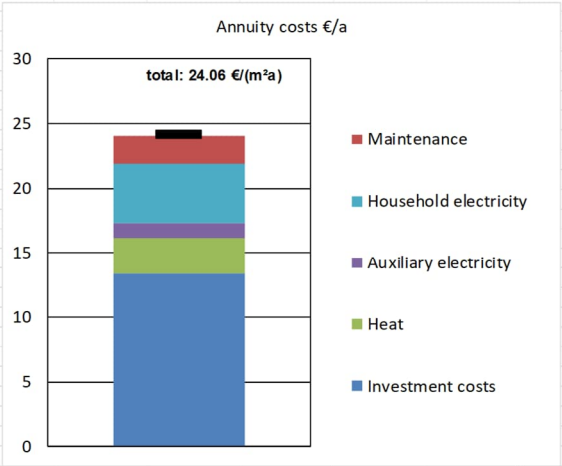
Annuities: costs allocated to each year per m²

Investment costs	13.39	€/(m²a)
Heat	2.79	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
Maintenance	2.19	€/(m²a)
Total	**24.06**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3845 €/a

for investment costs, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

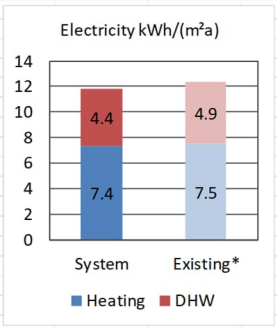
System: Split unit + heat pump water heater

A new ventilation unit with heat recovery is installed. For heating, the indoor unit of a split air conditioning system is installed on the ground floor. Experience shows that this is sufficient to heat a standard semi-detached or terraced house built to the Passive House standard. The outdoor unit is installed in the (front) garden or on the roof. Domestic hot water is provided by a heat pump water heater with an outside air connection. The space required in the utility room is comparable to the other solutions with separate components.

Advantages:
- very cost-effective and energy efficient
- effective cooling of the ground floor in summer is possible

Disadvantages:
- during longer cold periods an interior door must be kept open occasionally
- Installation of external unit must be clarified: space demand, clearance spacing, sound impact
- Drilling necessary for refrigerant lines

Energy demand heating and hot water



* Existing:compact unit model 2006

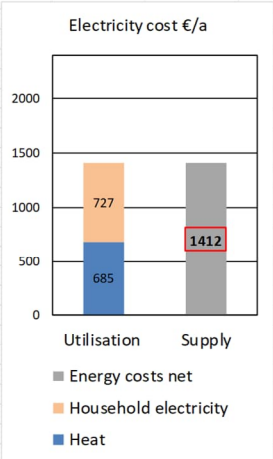
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Split unit	3000	3000	€
Heat pump water heater	4000	6000	€
Total		**24500**	**€**

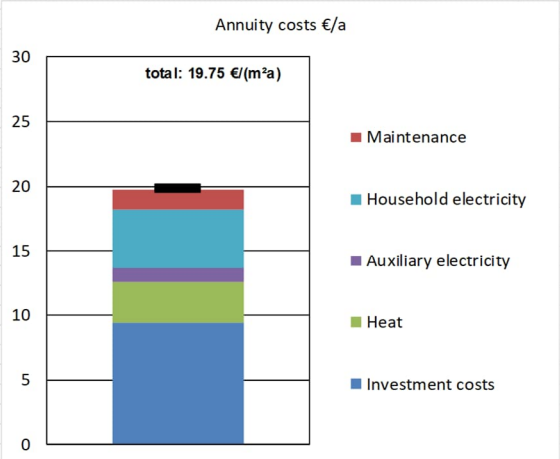
Annuities: costs allocated to each year per m²

Investment costs	9.38	€/(m²a)
Heat	3.15	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
Maintenance	1.53	€/(m²a)
Total	**19.75**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3156 €/a

for investment costs, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

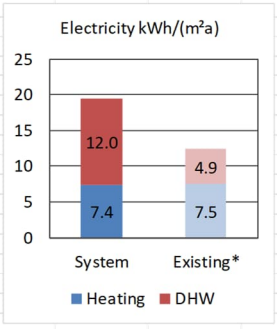
System: Split unit + instantaneous water heater

A new ventilation unit with heat recovery is installed. For heating, the indoor unit of a split air conditioning system is installed on the ground floor. Experience shows that this is sufficient to heat a standard semi-detached or terraced house built to the Passive House standard. The outdoor unit is installed in the (front) garden or on the roof. Domestic hot water is provided by an instantaneous water heater, for which a three-phase current connection is necessary. The hot water storage tank is no longer required, which frees up space in the plant room.

Advantages:
- very little investment costs, acceptable efficiency
- effective cooling of the ground floor in summer is possible
- very little space required

Disadvantages:
- during longer cold periods an interior door must be kept open occasionally
- Installation of external unit must be clarified: space demand, clearance spacing, sound impact
- drilling necessary for refrigerant lines
- high electricity consumption peaks

Energy demand heating and hot water



* Existing:compact unit model 2006

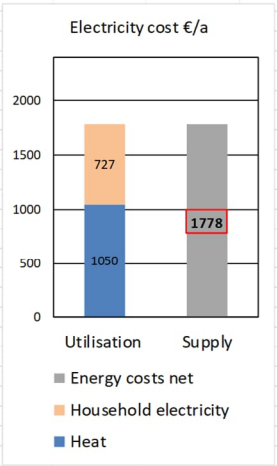
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Split unit	3000	3000	€
Instant. water heater	400	1400	€
Total		**16300**	**€**

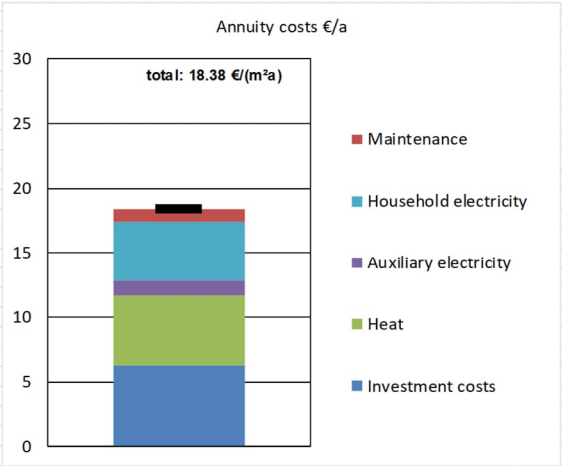
Annuities: costs allocated to each year per m²

Investment costs	6.24	€/(m²a)
Heat	5.44	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
Maintenance	1.02	€/(m²a)
Total	**18.38**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 2938 €/a

for investment costs, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

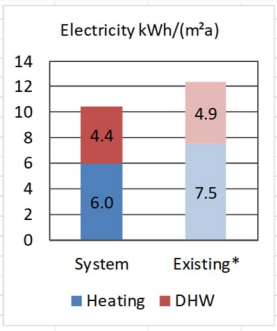
System: New compact unit, small PV system

A new compact unit is installed in place of the defective compact unit. Due to the usually confined space, it must be checked whether assembly and routing of the ventilation ducts at the previous location is possible. In some circumstances, additional lines or even wall penetrations may be necessary. Many of the current compact units can contribute to cooling in the summer. Calculation in combination with a small PV system.

Advantages:
- low space requirement, low installation effort
- overall most cost-effective solution with heat pump
- all components compatible with each other ex works
- if neceessary supply air temperature control possible in summer

Disadvantages:
- in case of final failure of a part of the system the complete unit must be be replaced

Energy demand heating and hot water



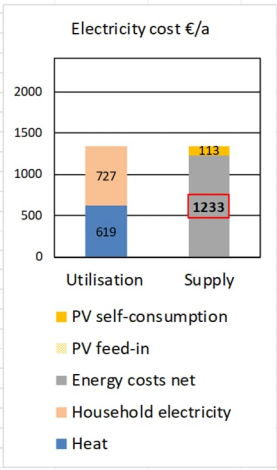
* Existing:compact unit model 2006

Investment costs

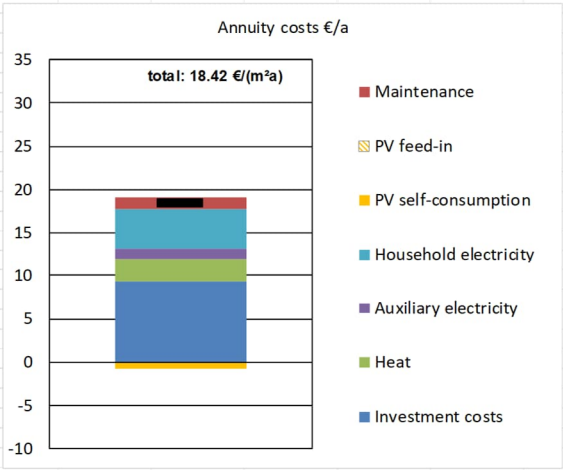
	Unit	Installation	
Compact unit	18000	4000	€
PV system with battery	1400	1400	€
Total		**24800**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	9.33	€/(m²a)
Heat	2.68	€/(m²a)
Auxiliary electricity	1.20	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-0.71	€/(m²a)
PV feed-in	0.00	€/(m²a)
Maintenance	1.38	€/(m²a)
Total	**18.42**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 2944 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

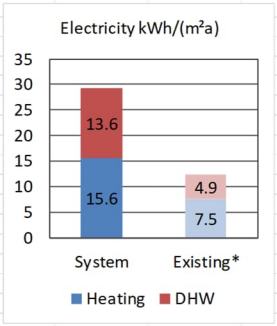
System: Direct electric central, small PV system

A new ventilation unit with heat recovery is installed. A direct electric heating coil in the supply air duct provides space heating, domestic hot water is produced by an electric boiler. Due to the low heating load in the Passive House building, a three-phase current connection is not necessary. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit. Calculation in combination with a small PV system.

Advantages:
- lowest investment costs of all variants
- simple technology
- quiet

Disadvantages:
- highest electricity demand of all variants
- high electricity demand in winter, high PER demand
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

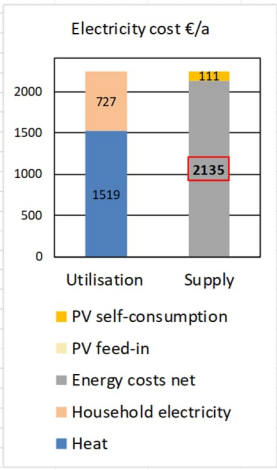
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Electric heating coil 2 kW	500	1000	€
Electric boiler	3000	2000	€
PV system with battery	1400	1400	€
Total		**17800**	**€**

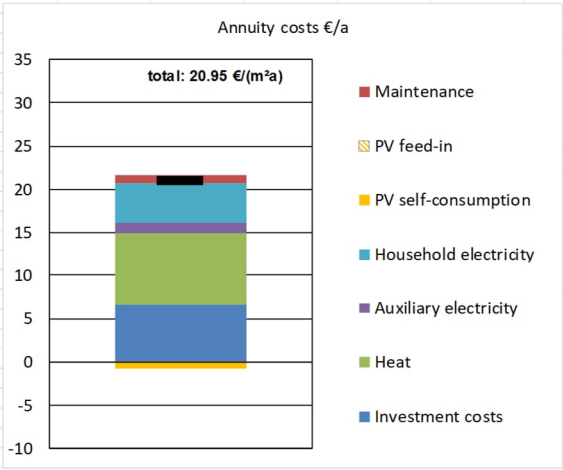
Annuities: costs allocated to each year per m²

Investment costs	6.65	€/(m²a)
Heat	8.37	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-0.70	€/(m²a)
PV feed-in	0.00	€/(m²a)
Maintenance	0.94	€/(m²a)
Total	**20.95**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3348 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

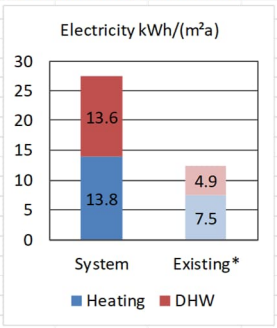
System: Direct electric with radiators in each room, small PV system

A new ventilation unit with heat recovery is installed. Space heating takes place via electric heaters / infrared heating surfaces in each room; domestic hot water is produced by an electric boiler. Due to the small heating load in Passive House buildings, the radiators can be connected to existing 230 V power sockets. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit. Calculation in combination with a small PV system.

Advantages:
- low investment costs
- simple technology
- room-by-room temperature control possible
- quiet

Disadvantages:
- relatively high electricity demand
- high electricity demand in winter, high PER demand
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

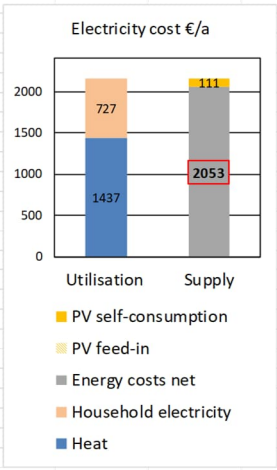
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
El. heater in each room	2500	2000	€
Electric boiler	3000	2000	€
PV system with battery	1400	1400	€
Total		**20800**	**€**

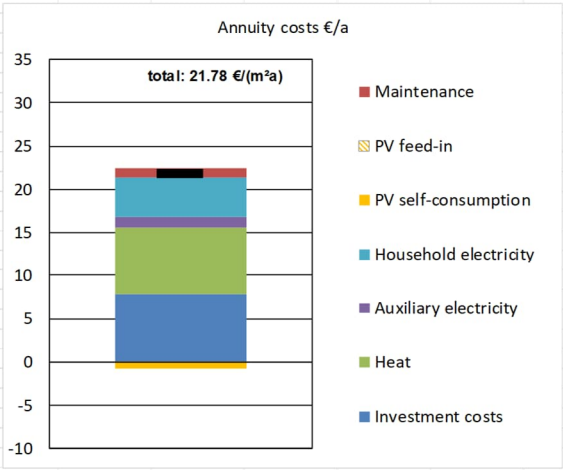
Annuities: costs allocated to each year per m²

Investment costs	7.80	€/(m²a)
Heat	7.86	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-0.70	€/(m²a)
PV feed-in	0.00	€/(m²a)
Maintenance	1.13	€/(m²a)
Total	**21.78**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3480 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

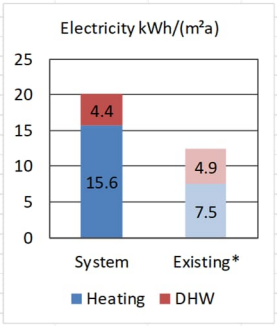
System: Direct electric heating + heat pump water heater, small PV system

A new ventilation unit with heat recovery is installed. A direct electric heating coil in the supply air duct provides space heating, domestic hot water is provided by a heat pump water heater with an outside air connection. Due to the low heating load in the Passive House building, a three-phase current connection is not necessary. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit. Calculation in combination with a small PV system.

Advantages:
- efficient hot water generation
- simple heating technology, hardly any space required for heating system

Disadvantages:
- possible additional core hole drilling for air duct of heat pump
- noise exposure from heat pump possible

Energy demand heating and hot water



* Existing:compact unit model 2006

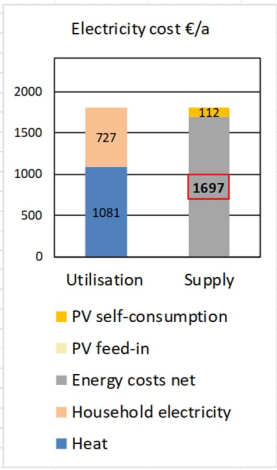
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Electric heating coil 2 kW	500	1000	€
Heat pump water heater	4000	6000	€
PV system with battery	1400	1400	€
Total		**22800**	**€**

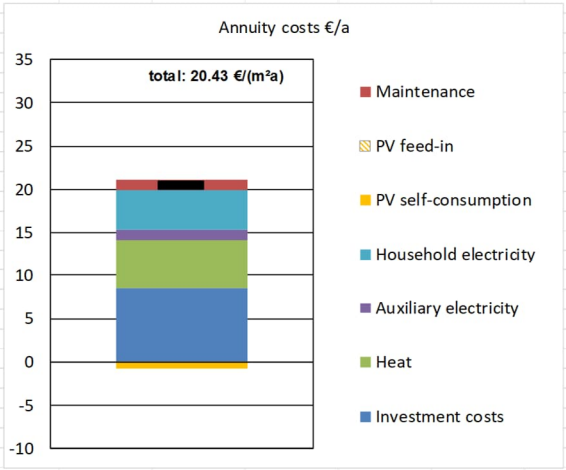
Annuities: costs allocated to each year per m²

Investment costs	8.56	€/(m²a)
Heat	5.63	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-0.70	€/(m²a)
PV feed-in	0.00	€/(m²a)
Maintenance	1.25	€/(m²a)
Total	**20.43**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3266 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

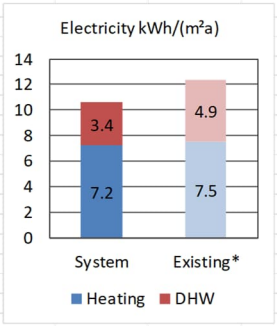
System: Air-to-water heat pump, small PV system

A new ventilation unit with heat recovery is installed. An air-to-water heat pump for heat generation is installed in the (front) garden or on the roof. A hydronic post-heating coil in the supply air duct provides space heating. The space demand in the plant room is comparable to the other solutions with separate components. Calculation in combination with a small PV system.

Advantages: - low electricity demand

Disadvantages:
- highest investment costs of all variants
- installation of external unit must be clarified: footing, space demand, clearance spacing, sound impact
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

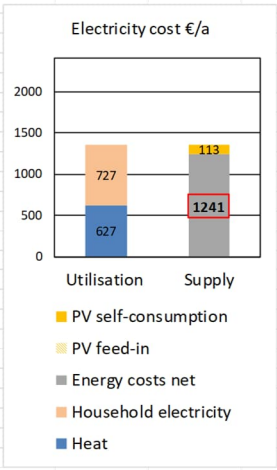
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Air-to-water HP 3 kW	6000	13000	€
DHW and buffer storage	4000	1000	€
Hydronic coil 2 kW	1500	1000	€
PV system with battery	1400	1400	€
Total		**37800**	**€**

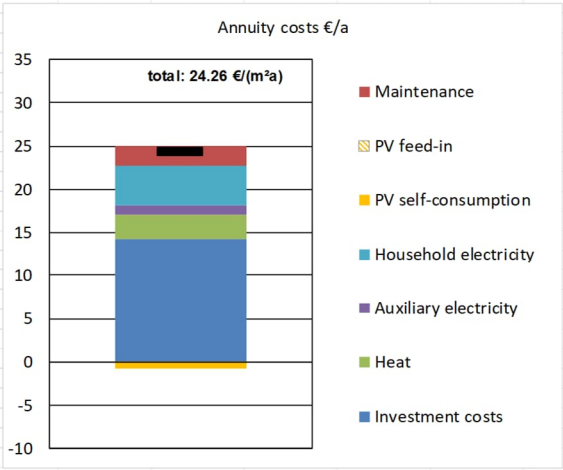
Annuities: costs allocated to each year per m²

Investment costs	14.30	€/(m²a)
Heat	2.79	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-0.71	€/(m²a)
PV feed-in	0.00	€/(m²a)
Maintenance	2.19	€/(m²a)
Total	**24.26**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3877 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

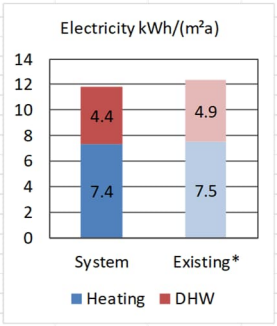
System: Split unit + heat pump water heater, small PV system

A new ventilation unit with heat recovery is installed. For heating, the indoor unit of a split air conditioning system is installed on the ground floor. Experience shows that this is sufficient to heat a standard semi-detached or terraced house built to the Passive House standard. The outdoor unit is installed in the (front) garden or on the roof. Domestic hot water is provided by a heat pump water heater with an outside air connection. The space required in the utility room is comparable to the other solutions with separate components. Calculation in combination with a small PV system.

Advantages:
- very cost-effective and energy efficient
- effective cooling of the ground floor in summer is possible

Disadvantages:
- during longer cold periods an interior door must be kept open occasionally
- Installation of external unit must be clarified: space demand, clearance spacing, sound impact
- Drilling necessary for refrigerant lines

Energy demand heating and hot water



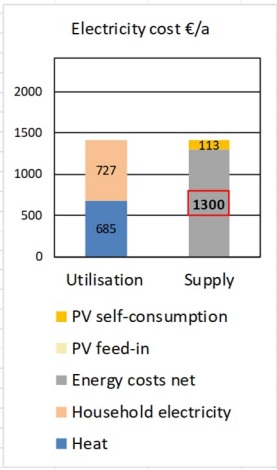
* Existing:compact unit model 2006

Investment costs

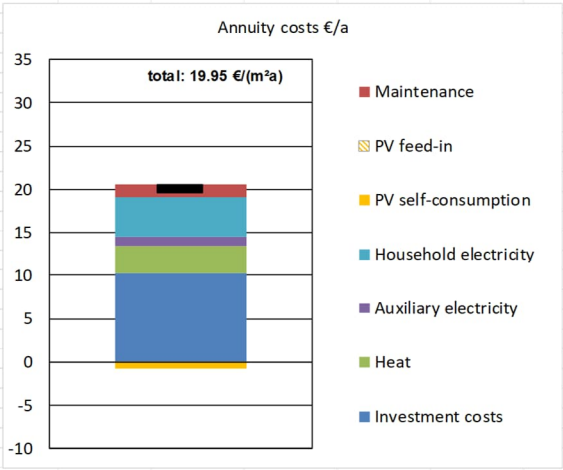
	Unit	Installation	
Ventilation unit	5000	3500	€
Split unit	3000	3000	€
Heat pump water heater	4000	6000	€
PV system with battery	1400	1400	€
Total		**27300**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	10.29	€/(m²a)
Heat	3.15	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-0.70	€/(m²a)
PV feed-in	0.00	€/(m²a)
Maintenance	1.53	€/(m²a)
Total	**19.95**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3189 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

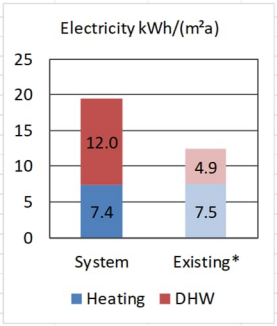
System: Split unit + instantaneous water heater, small PV system

A new ventilation unit with heat recovery is installed. For heating, the indoor unit of a split air conditioning system is installed on the ground floor. Experience shows that this is sufficient to heat a standard semi-detached or terraced house built to the Passive House standard. The outdoor unit is installed in the (front) garden or on the roof. Domestic hot water is provided by an instantaneous water heater, for which a three-phase current connection is necessary. The hot water storage tank is no longer required, which frees up space in the plant room. Calculation in combination with a small PV system.

Advantages:
- very little investment costs, acceptable efficiency
- effective cooling of the ground floor in summer is possible
- very little space required

Disadvantages:
- during longer cold periods an interior door must be kept open occasionally
- Installation of external unit must be clarified: space demand, clearance spacing, sound impact
- drilling necessary for refrigerant lines

Energy demand heating and hot water



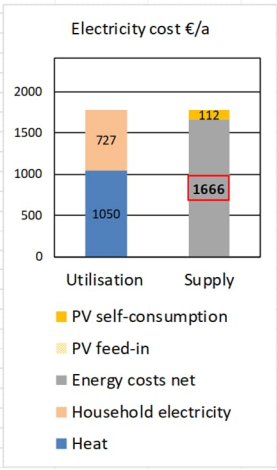
* Existing:compact unit model 2006

Investment costs

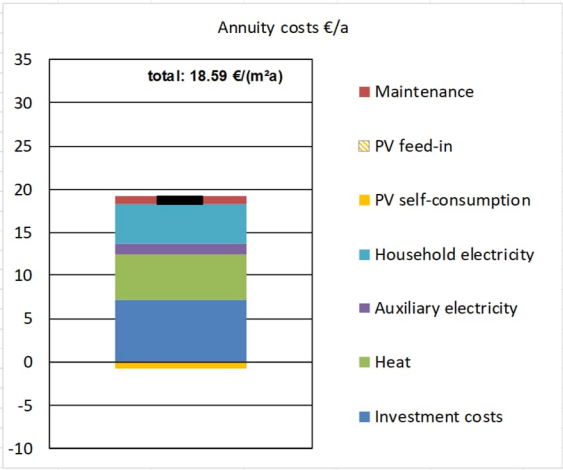
	Unit	Installation	
Ventilation unit	5000	3500	€
Split unit	3000	3000	€
Instant. water heater	400	1400	€
PV system with battery	1400	1400	€
Total		**19100**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	7.15	€/(m²a)
Heat	5.44	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-0.70	€/(m²a)
PV feed-in	0.00	€/(m²a)
Maintenance	1.02	€/(m²a)
Total	**18.59**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 2971 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

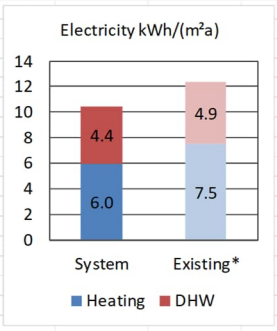
System: New compact unit, large PV system

A new compact unit is installed in place of the defective compact unit. Due to the usually confined space, it must be checked whether assembly and routing of the ventilation ducts at the previous location is possible. In some circumstances, additional lines or even wall penetrations may be necessary. Many of the current compact units can contribute to cooling in the summer. Calculation in combination with a small PV system. Calculation in combination with a small PV system.

Advantages:
- low space requirement, low installation effort
- overall most cost-effective solution with heat pump
- all components compatible with each other ex works
- if neceessary supply air temperature control possible in summer

Disadvantages:
- in case of final failure of a part of the system the complete unit must be be replaced

Energy demand heating and hot water



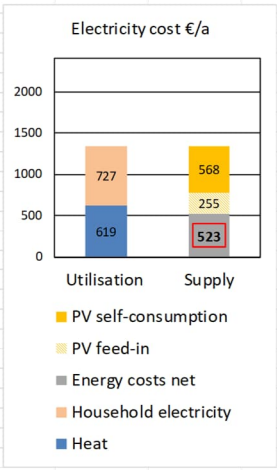
* Existing:compact unit model 2006

Investment costs

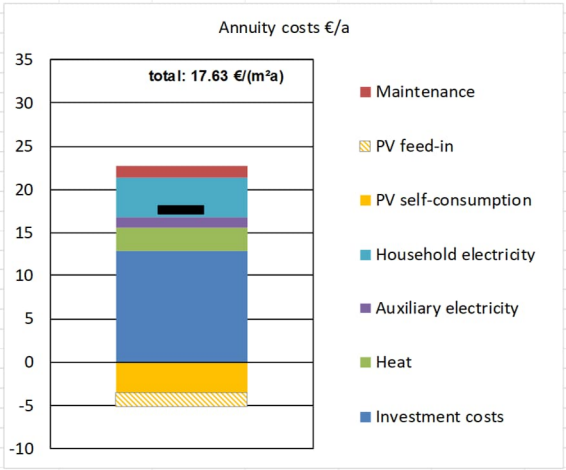
	Unit	Installation	
Compact unit	18000	4000	€
PV system with battery	7500	7500	€
Total		**37000**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	12.98	€/(m²a)
Heat	2.68	€/(m²a)
Auxiliary electricity	1.20	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-3.56	€/(m²a)
PV feed-in	-1.59	€/(m²a)
Maintenance	1.38	€/(m²a)
Total	**17.63**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 2817 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

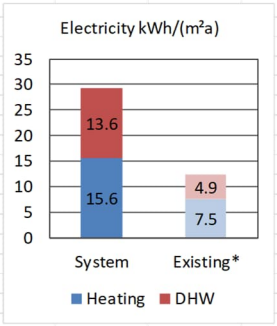
System: Direct electric central, large PV system

A new ventilation unit with heat recovery is installed. A direct electric heating coil in the supply air duct provides space heating, domestic hot water is produced by an electric boiler. Due to the low heating load in the Passive House building, a three-phase current connection is not necessary. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit. Calculation in combination with a small PV system. Calculation in combination with a small PV system.

Advantages:
- lowest investment costs of all variants
- simple technology
- quiet

Disadvantages:
- highest electricity demand of all variants
- high electricity demand in winter, high PER demand
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

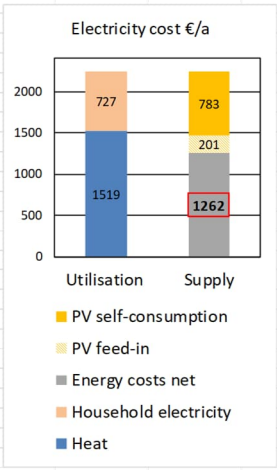
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Electric heating coil 2 kW	500	1000	€
Electric boiler	3000	2000	€
PV system with battery	8000	8000	€
Total		**31000**	**€**

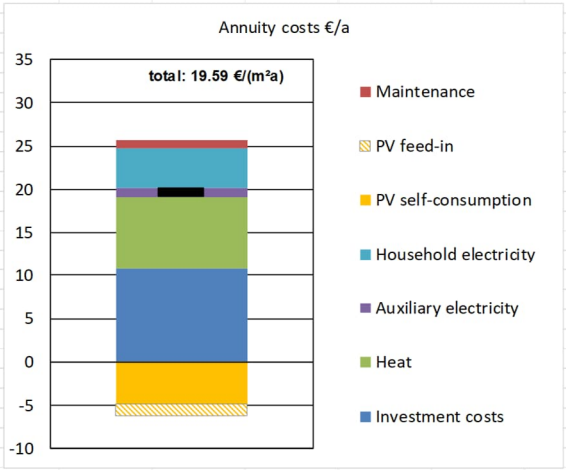
Annuities: costs allocated to each year per m²

Investment costs	10.76	€/(m²a)
Heat	8.37	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-4.90	€/(m²a)
PV feed-in	-1.26	€/(m²a)
Maintenance	0.94	€/(m²a)
Total	**19.59**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3131 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

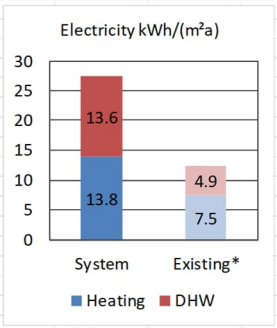
System: Direct electric with radiators in each room, large PV system

A new ventilation unit with heat recovery is installed. Space heating takes place via electric heaters / infrared heating surfaces in each room; domestic hot water is produced by an electric boiler. Due to the small heating load in Passive House buildings, the radiators can be connected to existing 230 V power sockets. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit. Calculation in combination with a small PV system. Calculation in combination with a small PV system.

Advantages:
- low investment costs
- simple technology
- room-by-room temperature control possible
- quiet

Disadvantages:
- relatively high electricity demand
- high electricity demand in winter, high PER demand
- high overall costs

Energy demand heating and hot water



* Existing:compact unit model 2006

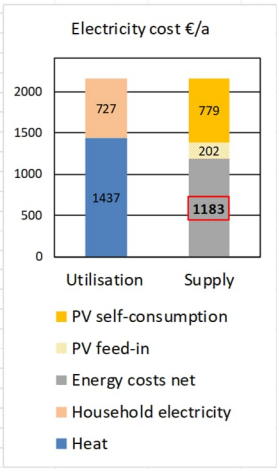
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
El. heater in each room	2500	2000	€
Electric boiler	3000	2000	€
PV system with battery	7900	7900	€
Total		**33800**	**€**

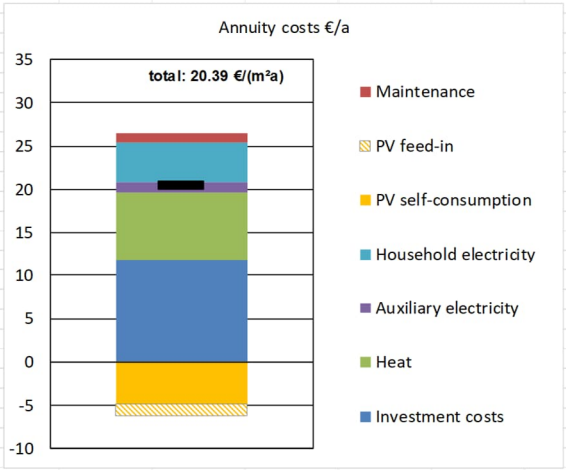
Annuities: costs allocated to each year per m²

Investment costs	11.86	€/(m²a)
Heat	7.86	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-4.87	€/(m²a)
PV feed-in	-1.27	€/(m²a)
Maintenance	1.13	€/(m²a)
Total	**20.39**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3259 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

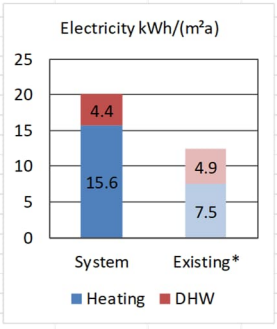
System: Direct electric heating + heat pump water heater, large PV system

A new ventilation unit with heat recovery is installed. A direct electric heating coil in the supply air duct provides space heating, domestic hot water is provided by a heat pump water heater with an outside air connection. Due to the low heating load in the Passive House building, a three-phase current connection is not necessary. The separate units are often relatively easy to accommodate, although they require more space in total compared to the previous compact unit. Calculation in combination with a small PV system. Calculation in combination with a small PV system.

Advantages:
- efficient hot water generation
- simple heating technology, hardly any space required for heating system

Disadvantages:
- possible additional core hole drilling for air duct of heat pump
- noise exposure from heat pump possible

Energy demand heating and hot water



* Existing:compact unit model 2006

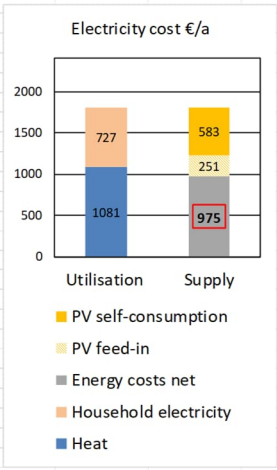
Investment costs

	Unit	Installation	
Ventilation unit	5000	3500	€
Electric heating coil 2 kW	500	1000	€
Heat pump water heater	4000	6000	€
PV system with battery	7800	7800	€
Total		**35600**	**€**

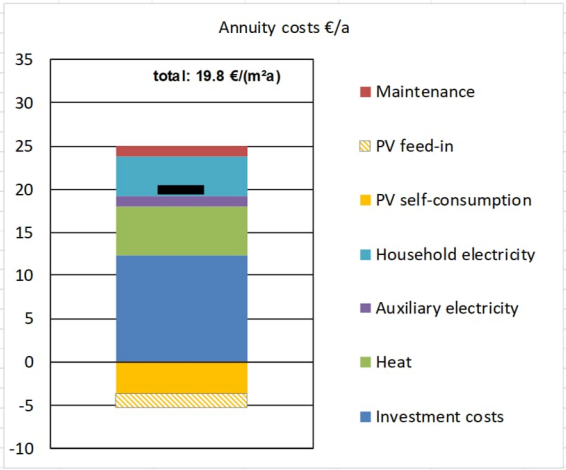
Annuities: costs allocated to each year per m²

Investment costs	12.45	€/(m²a)
Heat	5.63	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-3.65	€/(m²a)
PV feed-in	-1.57	€/(m²a)
Maintenance	1.25	€/(m²a)
Total	**19.80**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3164 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

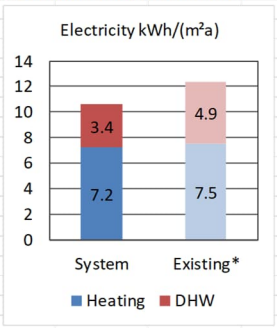
System: Air-to-water heat pump, large PV system

A new ventilation unit with heat recovery is installed. An air-to-water heat pump for heat generation is installed in the (front) garden or on the roof. A hydronic post-heating coil in the supply air duct provides space heating. The space demand in the plant room is comparable to the other solutions with separate components. Calculation in combination with a small PV system. Calculation in combination with a small PV system.

Advantages: - low electricity demand

Disadvantages: - highest investment costs of all variants
- installation of external unit must be clarified: footing, space demand, clearance spacing, sound impact
- high overall costs

Energy demand heating and hot water



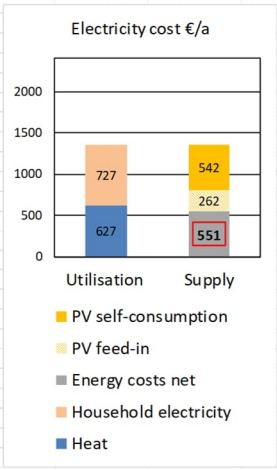
* Existing:compact unit model 2006

Investment costs

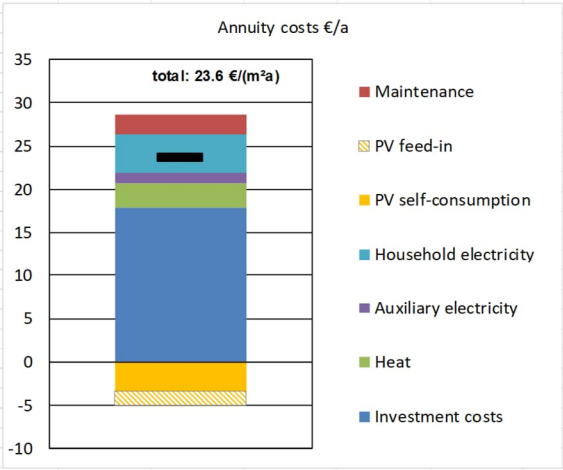
	Unit	Installation	
Ventilation unit	5000	3500	€
Air-to-water HP 3 kW	6000	13000	€
DHW and buffer storage	4000	1000	€
Hydronic coil 2 kW	1500	1000	€
PV system with battery	7500	7500	€
Total		**50000**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	17.96	€/(m²a)
Heat	2.79	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-3.39	€/(m²a)
PV feed-in	-1.64	€/(m²a)
Maintenance	2.19	€/(m²a)
Total	**23.60**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3771 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

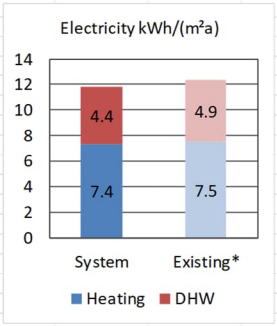
System: Split unit + heat pump water heater, large PV system

A new ventilation unit with heat recovery is installed. For heating, the indoor unit of a split air conditioning system is installed on the ground floor. Experience shows that this is sufficient to heat a standard semi-detached or terraced house built to the Passive House standard. The outdoor unit is installed in the (front) garden or on the roof. Domestic hot water is provided by a heat pump water heater with an outside air connection. The space required in the utility room is comparable to the other solutions with separate components. Calculation in combination with a small PV system. Calculation in combination with a small PV system.

Advantages:
- very cost-effective and energy efficient
- effective cooling of the ground floor in summer is possible

Disadvantages:
- during longer cold periods an interior door must be kept open occasionally
- Installation of external unit must be clarified: space demand, clearance spacing, sound impact
- Drilling necessary for refrigerant lines

Energy demand heating and hot water



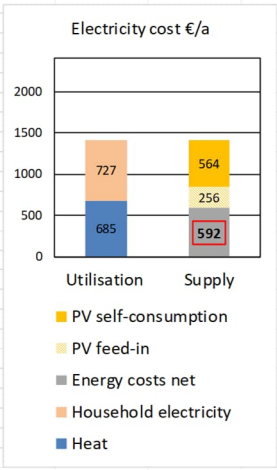
* Existing:compact unit model 2006

Investment costs

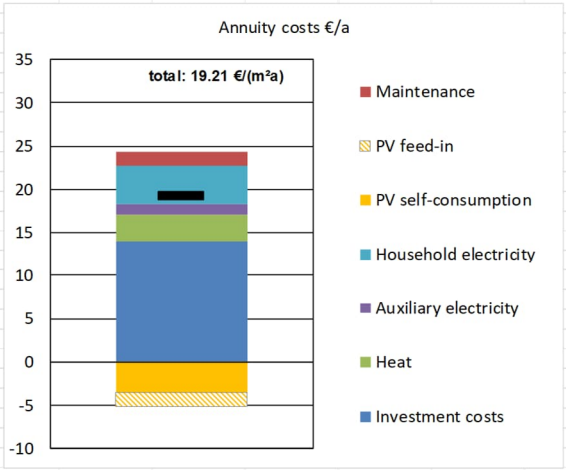
	Unit	Installation	
Ventilation unit	5000	3500	€
Split unit	3000	3000	€
Heat pump water heater	4000	6000	€
PV system with battery	7600	7600	€
Total		**39700**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	13.97	€/(m²a)
Heat	3.15	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-3.53	€/(m²a)
PV feed-in	-1.60	€/(m²a)
Maintenance	1.53	€/(m²a)
Total	**19.21**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 3070 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

Replacement of defective compact heat pump units

System characterisation

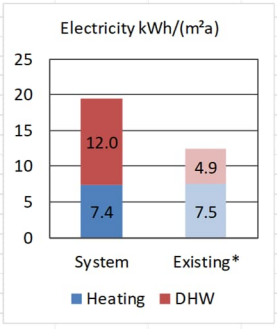
System: Split unit + instantaneous water heater, large PV system

A new ventilation unit with heat recovery is installed. For heating, the indoor unit of a split air conditioning system is installed on the ground floor. Experience shows that this is sufficient to heat a standard semi-detached or terraced house built to the Passive House standard. The outdoor unit is installed in the (front) garden or on the roof. Domestic hot water is provided by an instantaneous water heater, for which a three-phase current connection is necessary. The hot water storage tank is no longer required, which frees up space in the plant room. Calculation in combination with a small PV system. Calculation in combination with a small PV system.

Advantages:
- very little investment costs, acceptable efficiency
- effective cooling of the ground floor in summer is possible
- very little space required

Disadvantages:
- during longer cold periods an interior door must be kept open occasionally
- Installation of external unit must be clarified: space demand, clearance spacing, sound impact
- drilling necessary for refrigerant lines

Energy demand heating and hot water



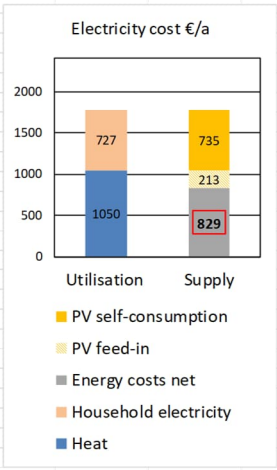
* Existing:compact unit model 2006

Investment costs

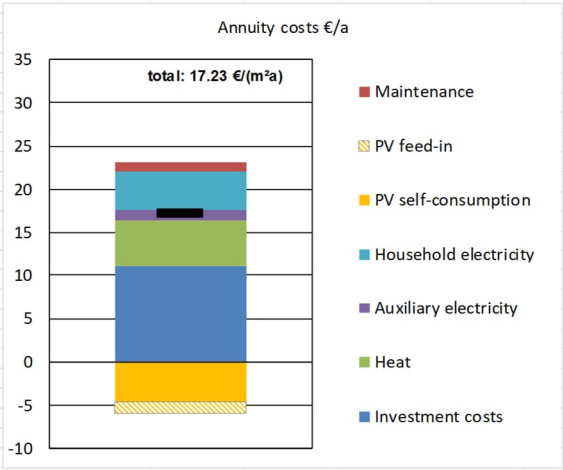
	Unit	Installation	
Ventilation unit	5000	3500	€
Split unit	3000	3000	€
Instant. water heater	400	1400	€
PV system with battery	7700	7700	€
Total		**31700**	**€**

Annuities: costs allocated to each year per m²		
Investment costs	11.02	€/(m²a)
Heat	5.44	€/(m²a)
Auxiliary electricity	1.13	€/(m²a)
Household electricity	4.55	€/(m²a)
PV self-consumption	-4.60	€/(m²a)
PV feed-in	-1.33	€/(m²a)
Maintenance	1.02	€/(m²a)
Total	**17.23**	**€/(m²a)**

Electricity costs



Annuity costs



Annuity total costs: 2753 €/a

for investment costs building services & PV system, heating, domestic hot water, household electricity and auxiliary electricity

6 References

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[Woker 2025] Woker Planungsbüro GmbH: Passivhäuser Niebüller Weg 19-29, 30159 Hannover, Entwicklung von Wärmeversorgungs- u. Lüftungskonzepten als Ersatz für die vorhandenen Vitotres 343 Kompaktgeräte in den Passivhäusern. Hannover, August 2025.