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Solar Powers Heat 2023

How Solar PV empowers households to turn down fossil gas and save on energy bills

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Foreword

Welcome to SolarPower Europe's Solar Powers Heat Report 2023!

Let me congratulate everyone in the solar PV sector: You are very active in an industry that is booming worldwide, and also in Europe. And that is a very important thing.

We will need much more solar energy to make us independent of fossil energy imports. We need solar energy for our climate as well as for the sovereignty of Europe. Moreover, with the REPowerEU solar installation target, solar power alone will offer over 1 million local jobs in the European Union in 2030.

I have been Austrian Federal Minister of Climate Action since early 2020 – and have set out on an ambitious path for our country.

I initiated a "Million Roof Programme" with the goal to get solar panels on one million roofs in our country. And so far we are not only on track, but are exceeding our interim goals. Since I took office three years ago, we have built as many PV plants as in the entire previous 20 years before 2020. In the last year alone, 1,300 Megawatt of PV capacity was built, lifting Austria for the first time to an annual Gigawatt-scale PV market.

We enabled the creation of decentralised renewable energy communities. More than 200 energy communities have been created so far and we expect a rapid growth in the next years.

I have proposed a renewable heating law. We will ban gas boilers in new buildings – and step by step exchange existing old oil and gas boilers by 2035 and 2040, respectively. We created a simple subsidy system for this: 7,500 euros for all those who want to change to renewable heat – in addition to the financial support by the regions in Austria.

I set up a subsidy scheme in which households in the lowest 20 percent of income are subsidized by up to 100 percent of the cost of a new heat pump or a district heating connection. Its of utmost importance, that we leave nobody behind. Everyone should be able to participate in this energy transition.

In Austria, in total over 400 million Euros were used in 2022 to subsidize the boiler replacement, and a similar amount, almost 400 million Euros for solar PV installations. Because solar thermal and PV in combination with heat pumps can play an important role in decarbonising our building sector.

This is also reflected in this new Solar Powers Heat-Report: Solar energy not only is a sustainable form of energy, it also creates many local well-paid jobs, and helps families to reduce their energy bills and be less effected by the next price hike or global energy crisis.

This is the path we are going: enabling households to invest in solar-powered electrified heat.

The transition is right there – and together we can revolutionise our energy transition.

Because one thing is clear, the gas crisis is not over yet and the climate crisis has just started.

Let's accelerate and fully embrace the potential of solar in this transition, both for decarbonizing electricity and the heating sector.

Enjoy reading the report,

LEONORE GEWESSLER
Federal Minister for Climate Action, Environment, Energy, Mobility, Innovation and Technology of Austria

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SolarPower Europe

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Abstract

This report examines the residential sector, and focuses on three European markets where fossil gas plays a dominant role in home heating: Germany, Spain, and Italy. Specifically, the report assesses the role of solar PV in combination with electricity-based heating solutions in empowering households to reduce gas use, while saving on electricity and heating bills.

The report finds that medium-sized residential solar PV owners have enjoyed substantial savings on their energy bills in 2022 (savings up to 64%), especially in combination with a heat pump (savings up to 84%). These households will continue to benefit from their investment in the coming years in all scenarios, even as gas prices stabilise at lower levels compared to 2022 (even at pre-crisis price levels of 20 EUR/MWh).

However, given the political imperative to rapidly reduce fossil gas demand, the report also finds that policymakers need to take decisive action now if they are to promote the benefits of gas-free homes to the wider population.

The following five policy measures are essential to bring down payback times for new solar PV and heat pumps, from around 20 years today, to around 10 years:

1. **Level the playing field by immediately ending all financing support for residential gas use, and implementing a carbon price floor.** Governments could introduce compensation schemes to offset higher costs for low-income households.

2. **Offer loans at low-interest rates as rising interest rates lead to exponential increases in payback times.** Central banks could issue low-interest rate products specifically for deflationary technologies like solar PV and heat pumps.

3. **Increase CAPEX support for combined investments into solar PV and heat pump installations.** In an inflationary environment with high interest rates and high labor costs, CAPEX support is crucial to reduce payback times, in particular for heat pumps but also for integrated solar PV + heat pump systems.

4. **Promote collective self-consumption,** beginning in the upcoming revision of European Electricity Market Design.

5. **Address the installer and electrician skills shortages** by establishing training and upskilling programs. These shortages are increasing prices for households, and slow down solar PV and heat pump deployment.

The report finds that solar PV is a key component for making gas-free homes affordable to all Europeans. Solar PV and heat pump load profiles match surprisingly well throughout the year, especially in combination with a water buffer tank. This combination reduces households' energy bills, while also benefiting the energy system as a whole; it transfers electricity demand into hours of high renewable energy production. Solar PV substantially improves the business case for heat pump systems, with savings more than tripling compared to a heat pump alone. Looking at the German example, together, the heat pump + solar PV dream team reduces energy bills by around 62% compared to a fossil gas residential heating system.

1 Introduction

Europe is experiencing an unprecedented energy crisis, driven by high fossil gas prices, following Russia's invasion of Ukraine, and the weaponisation of fossil gas supplies to Europe.

Consequently, EU Member States have spent around 657 billion EUR shielding consumers from rising energy costs since the beginning of the energy crisis.[1] Gas prices have decreased recently, because of European action and solidarity. However, gas import prices are still higher than pre-war levels, and may return to higher levels again in 2023, depending on weather patterns and global economic developments, especially in Asia.

In its December 2022 report, the International Energy Agency urged EU leaders to further accelerate the energy transition if it wants to avoid a gas supply crunch by next winter.[2] The IEA also advises Europe to deploy at least 60 GW of new solar in 2023 to compensate for gas shortfalls. In the same month, SolarPower Europe published its annual EU Market Outlook for SolarPower 2022-2026; its most-likely scenario foresees 54 GW of solar installations this year.[3] With the right framework conditions, the EU27 could even go beyond the minimum levels of solar deployment proposed by the IEA.

However, fossil-fuel continues to dominate heating in the residential sector across Europe; latest data shows that in 2020, natural gas is used for 74.6% of space heating, and 19.3% of water heating in the EU. Addressing residential heating is central to rapidly reducing fossil gas demand in the short-term.

This report analyses the electrification of heating in the residential sector, assessing the role of solar PV in empowering households to reduce gas use, while saving on both electricity and heating energy bills, and answering the following questions:

- How much does solar PV save households on energy bills?
- How does the cost of solar PV, combined with electricity-based home heating, compare to gas-based home heating?
- Does the EU policy framework incentivise households to switch off gas, and if not, what should change?

The most important takeaway of this analysis: solar PV is a key component for any affordable gas-free home. Solar PV and heat pump load profiles match well year-round, and in combination, maximise the reduction of consumers' energy bills. Ultimately, this report calls on decision-makers to substantially improve policy frameworks to empower more Europeans to install solar PV and heat pumps, and save on gas consumption and on their energy bills.

1 https://www.bruegel.org/dataset/national-policies-shield-consumers-rising-energy-prices

2 https://www.iea.org/reports/how-to-avoid-gas-shortages-in-the-european-union-in-2023

3 https://www.solarpowereurope.org/insights/market-outlooks/eu-market-outlook-for-solar-power-2022-2026-2

Box 1. Record growth for PV & HP in Europe in 2022

The high prices for gas and electricity in 2022 led to particularly attractive annual savings from solar PV and heat pump technologies. Many homeowners understood this and have invested at record levels in these technologies – in Germany, Italy, and Spain, some of the EU's largest economies and solar PV markets, residential rooftop installations increased by 9%, 240%, and 106% year-on-year, while heat pump installations in these countries increased by 53%, 37%, and 21% (see Fig. 1 and 2). For both technologies, 2022 was a record growth year adding more units than ever before. When looking at the EU as a whole, the annual solar PV market grew by 47% to 41.4 GW of annual installations in 2022, while heat pump installations increased by 42% to reach 2.4 million units in the same period (see Fig. 3 and 4).[4]

As citizens have been seeking ways to reduce their energy bills, as well as increase their feeling of energy security, the numbers could have been much higher if installer shortages had not slowed deployment.

FIGURE 1 ANNUAL RESIDENTIAL SOLAR PV INSTALLATIONS IN GERMANY, ITALY, SPAIN, 2021-2022

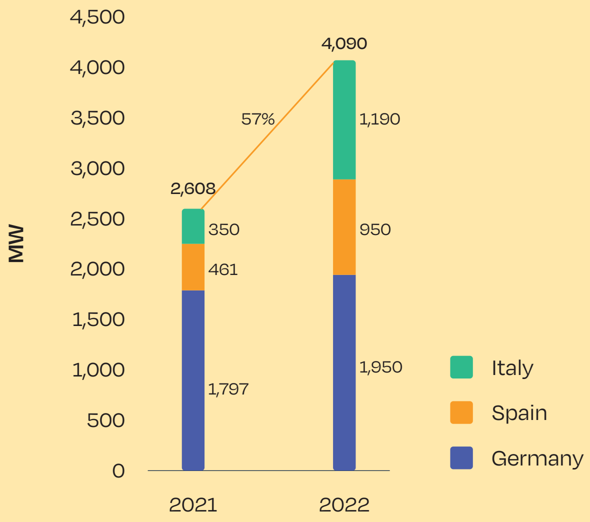


FIGURE 2 ANNUAL HEAT PUMP INSTALLATIONS IN GERMANY, ITALY, SPAIN, 2021-2022

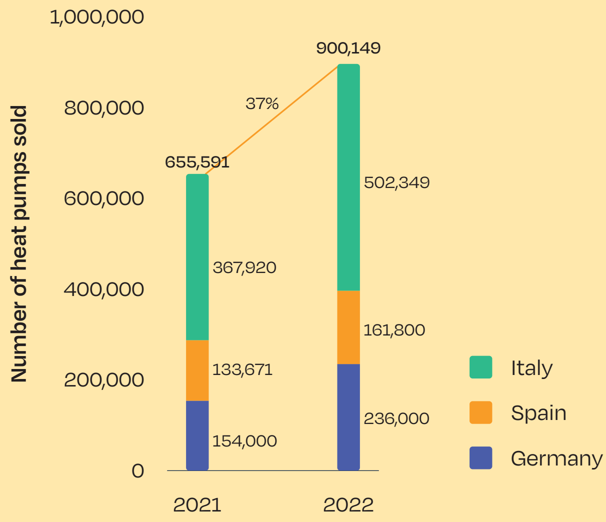


FIGURE 3 ANNUAL SOLAR PV INSTALLATIONS IN EU, 2021-2022

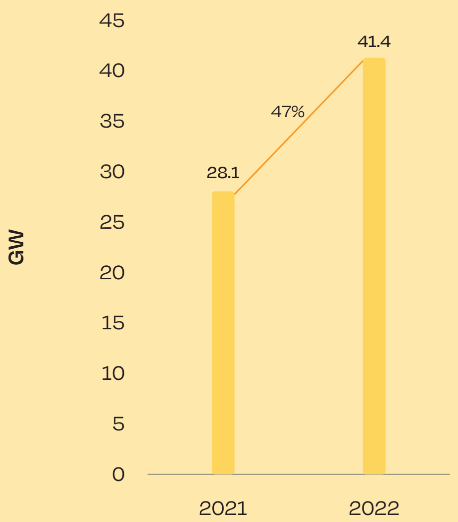
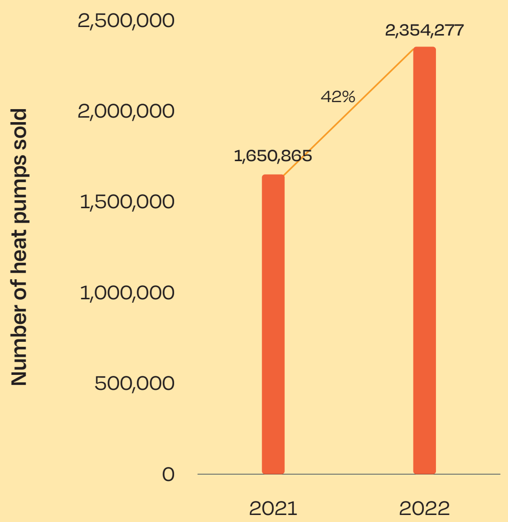


FIGURE 4 ANNUAL HEAT PUMP INSTALLATIONS IN EU, 2021-2022[5]



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4 European Heat Pump Association (2023).

5 Includes the following countries : Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Poland, Portugal, Sweden, Spain.

2 Key results

2.1. Solar PV & HP in 2022: homes with solar PV enjoyed substantial savings on their energy bills, especially in combination with electricity-based heating technologies.

Households saved up to € 3,700 on their energy bills in 2022 with solar PV + heat pumps

The report highlights savings made by German, Spanish, and Italian households using three different technology mixes: solar PV, heat pumps, and solar PV + heat pumps combined. The savings are compared to the price that an average family household would pay by sourcing all of its electricity from the grid, and using a gas boiler for heating. A summary on the savings generated by each technology in Germany, Spain, and Italy in 2022 is provided in Fig. 5 below. While all technologies provide significant savings in all three countries, the combination of solar PV and heat pumps resulted in the highest savings of up to 84%, during the energy crises in 2022 (see Fig. 5).

FIGURE 5 ANNUAL ENERGY BILL SAVINGS IN % FOR HOUSEHOLDS WITH DIFFERENT POWER & HEATING TECHNOLOGIES IN GERMANY, SPAIN, ITALY IN 2022

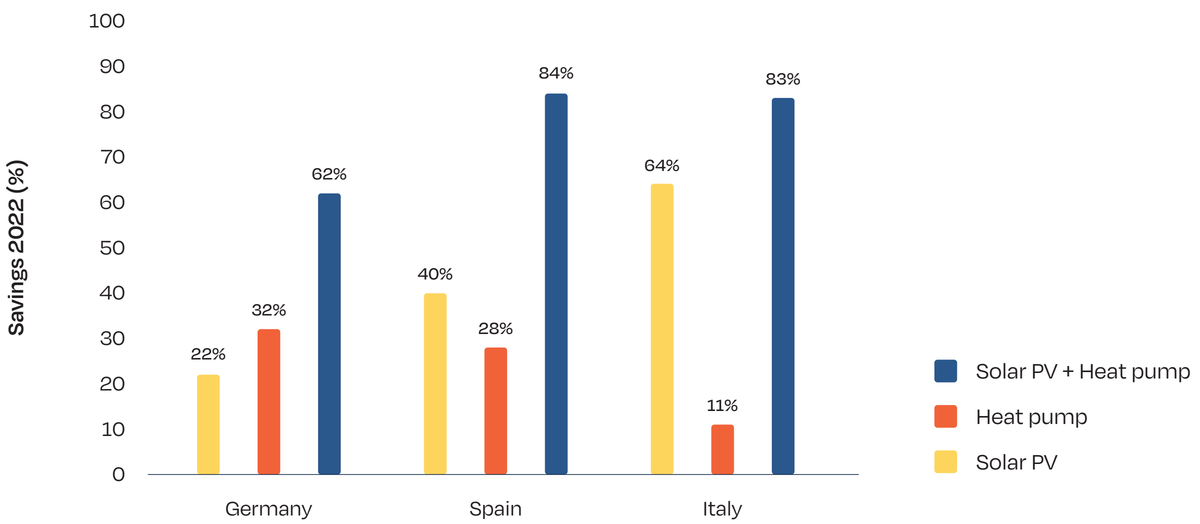

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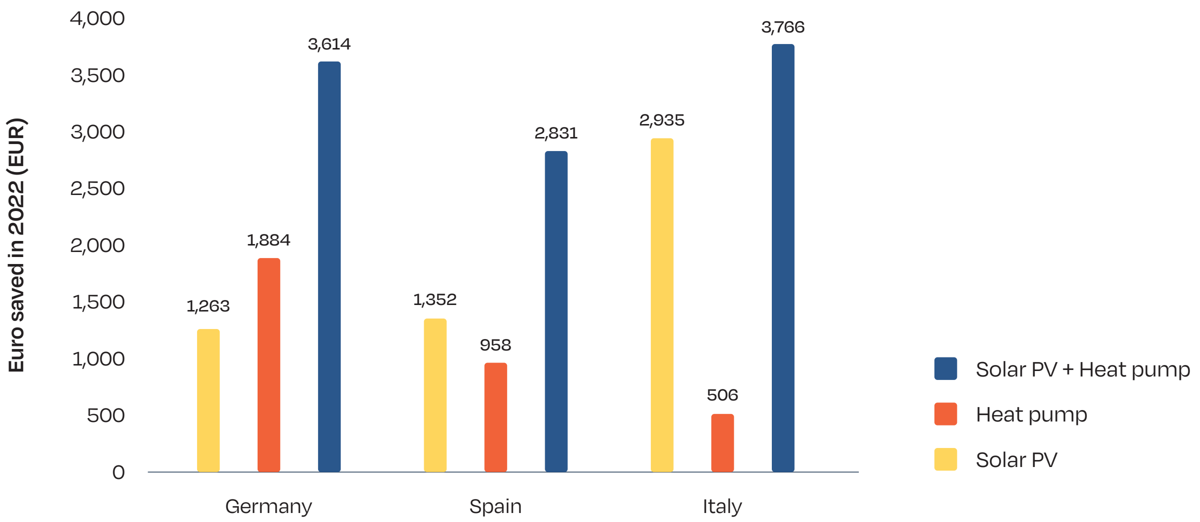
FIGURE 6 ANNUAL SAVINGS IN EURO OF HOUSEHOLDS WITH DIFFERENT POWER & HEATING TECHNOLOGIES IN GERMANY, SPAIN, AND ITALY IN 2022



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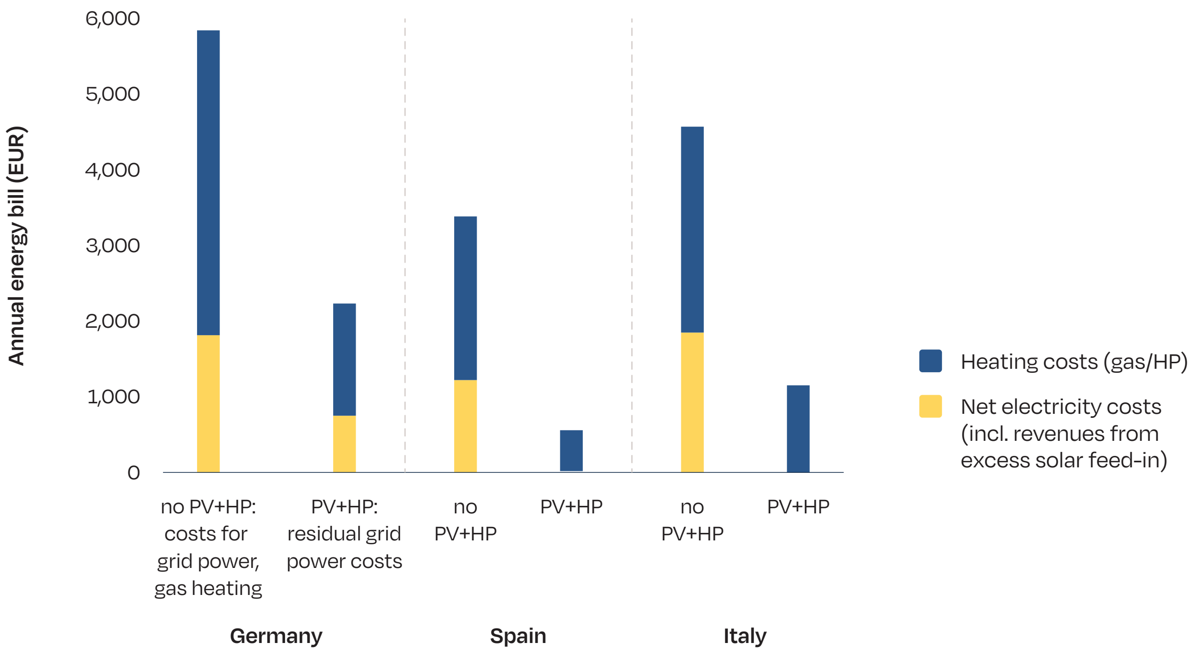
Savings for the model homes were as high as 3,766 EUR in Italy, followed by Germany, and Spain (see Fig. 6).

Box 2. High Energy Prices

For people living in new homes, annual energy expenses shown in the report's results may appear very high, in particular for Germany with nearly 6,000 EUR in 2022 (see Fig. 7). Therefore, it is important to place these figures in context.

This study focuses on the economics of accelerating the energy transition in the existing building stock rather than in new houses. Accordingly, the modelled thermal demand for space and water heating (12,000-20,000 kWh/a) corresponds to an average of existing houses using an average gas boiler with 85% efficiency. Other relevant assumptions include the annual electricity demand of average family homes (4,000-4,500 kWh/a, excl. air conditioning), and average household gas and electricity prices in 2022, which are based on the Household Energy Price Index (Vaasa ETT, 2023). All relevant support measures applying to averages family homes are included (e.g. VAT cuts on gas in all three countries). Energy cost relief measures specifically targeted at low-income families are not included here; the study assumes an average family home that is not eligible for such schemes (e.g. Spanish Bono Social de Electricidad, a government programme to reduce energy poverty). For further background on the report's methodology, see pg. 36 .

FIGURE 7 ELECTRICITY AND HEATING BILL IN 2022 IN GERMANY, SPAIN, AND ITALY



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In all three countries, solar PV and heat pumps dramatically reduced households' energy electricity and heating energy expenses. Households that relied fully on electricity from the grid and used gas for all of their heating, suffered from high energy price crisis. Average family households that used solar PV plus a heat hump were much less exposed to these market price spikes. In Germany, a typical household paid 5,850 EUR without PV + HP and only 2,230 EUR with the domestic clean power duo (see Fig. 7).

On the electricity side, using solar PV reduces the total energy cost by two means: first, it reduces the purchase of grid electricity thanks to PV self-consumption and, second, PV generates income from selling excess production. This resulted in much lower electricity costs in all three countries. The net costs were reduced to almost zero in Spain or non-existent in Italy, where the income from selling excess solar production outweighs the residual cost for grid electricity in times without solar production. This is due to the high solar production output in sunny countries, even though the price received for solar PV power feed-in is much lower than the price of retail grid power. In Italy and Spain, an average PV size of 7 kW was considered. In Germany, an 8 kW system was considered.

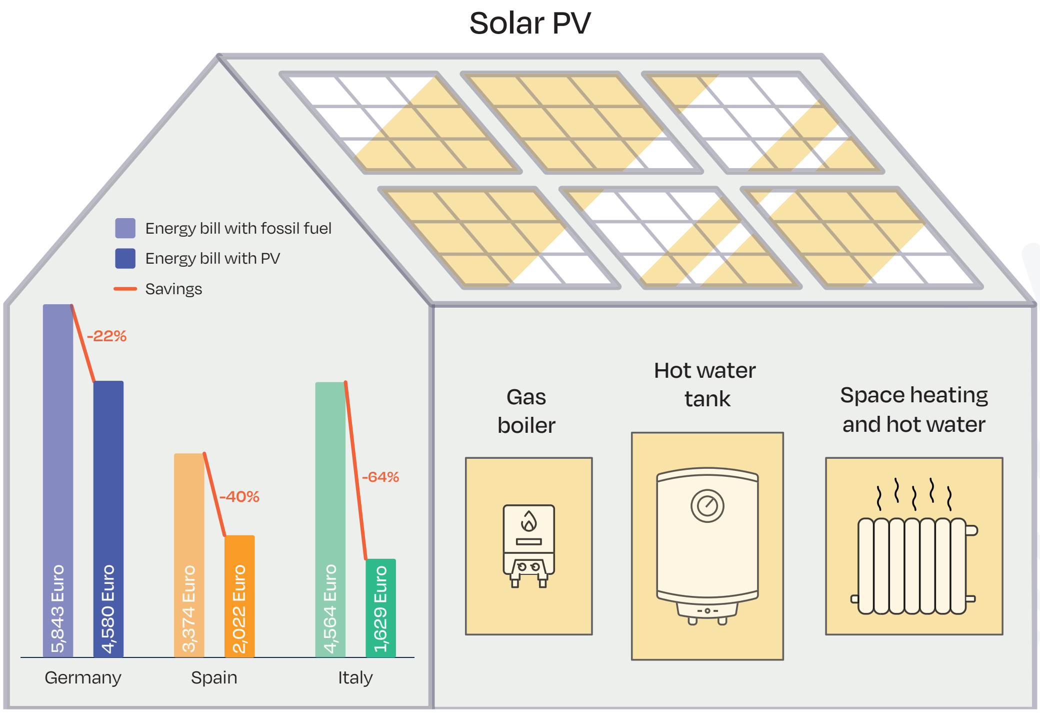
On the heating side, using a heat pump instead of a gas boiler reduces the gas bill to zero, while at the same time, it augments grid electricity needs, and therefore the electricity bill. However, a combination of solar PV + heat pump keeps these total costs lower than the price of using gas heating. Together with an average water buffer tank, on-site solar provides a significant amount of the power needed for the heat pump – 38% in Germany and 62 % in Spain, in an average weather year. The heating cost level is particularly low in Spain, where the solar share in the HP electricity mix is the highest in any case and the residual HP electricity volumes needed from the grid are the lowest.

A detailed look at all three technologies – solar PV, heat pumps, and solar PV and heat pumps – reflected significant financial benefits for households in 2022:

Solar PV: Our first case study is a household that only uses solar PV for generating electricity, and a gas boiler for heating in Germany, Spain, and Italy. In 2022, in all three countries, these households experienced annual savings of over 1,000 EUR, with a 7-8 kW PV system[6] (see Fig. 8). In Germany and Spain, solar households saved on average 1,263 EUR and 1,352 EUR respectively. In Italy, annual savings reached the highest level, up to 2,935 EUR or 64%. Here, electricity prices were higher than in Germany and Spain in 2022, while the feed-in price was remunerated at market price value compared to fixed payments in the other two countries.

Overall, solar-powered households avoided major energy costs (electricity from the grid, and gas for heating) in 2022, while receiving payments for the excess solar PV electricity they produced. For example, this resulted in savings of up to 64% in Italy (see Fig. 8).

FIGURE 8 SAVINGS OF HOUSEHOLDS WITH SOLAR PV IN 2022



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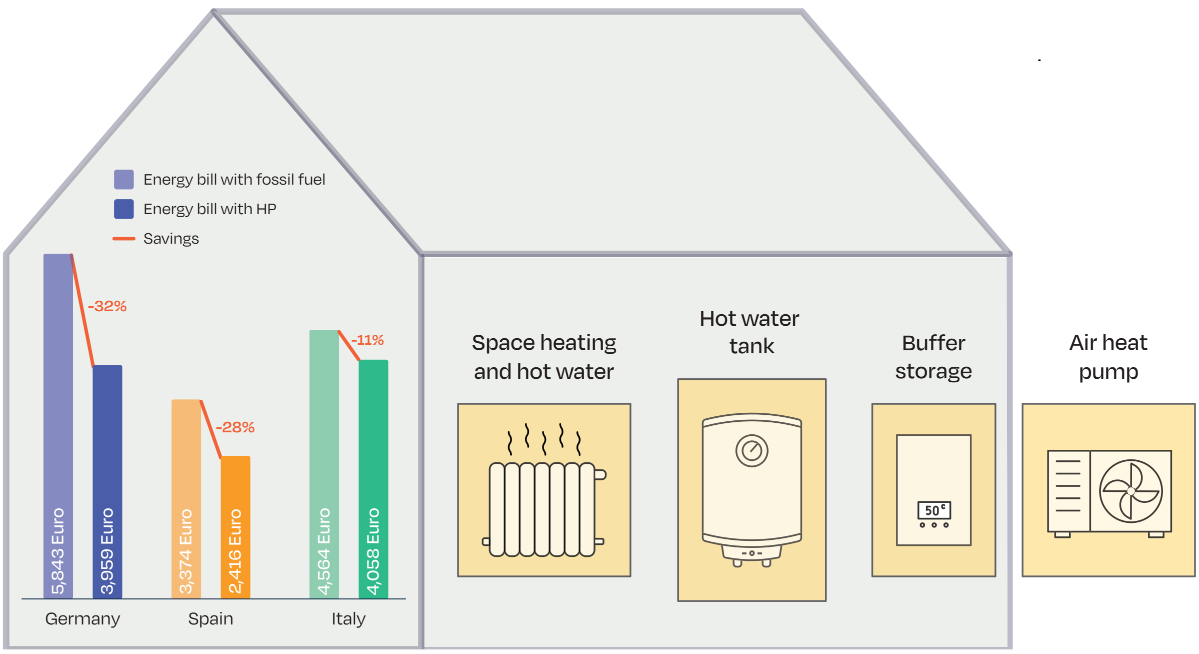
6 For modeling assumptions, see methodology chapter.

Heat pumps: The rapid spike in energy prices that started in 2021 has boosted demand for electricity-based heat. Heat pumps, the key technology used for this purpose, experienced a nearly 38% market growth in Europe in 2022. Around 20 million heat pumps were installed last year.[7] As the EU has been moving quickly to reduce its dependency on Russian gas, several EU Member States now have targets and support programmes for installing heat pumps, independently from solar PV. Therefore, our model is also examining heat pump savings as a separate technology, during times of peak energy prices in 2022 (see Fig. 9).

The household modelled in Germany showed the highest savings at 1,884 EUR. A typical Spanish household saved approximately 958 EUR, while Italian homes held the lowest savings at 506 EUR. The reasons are clear: heating demand is much higher in Germany than in Italy and Spain, while Italy was burdened with the highest electricity prices amongst the three countries in 2022, which resulted in lower savings. In relative terms, a heat pump alone helped household to save up to 32% on their electricity bills in Germany, 28% in Spain, and 11% in Italy (see Fig. 9). Savings with heat pumps alone, are less than savings with solar PV, as a heat pump reduces gas demand for heating, but leads to an increase in electricity consumption.

FIGURE 9 SAVINGS OF HOUSEHOLDS WITH HEAT PUMPS IN 2022



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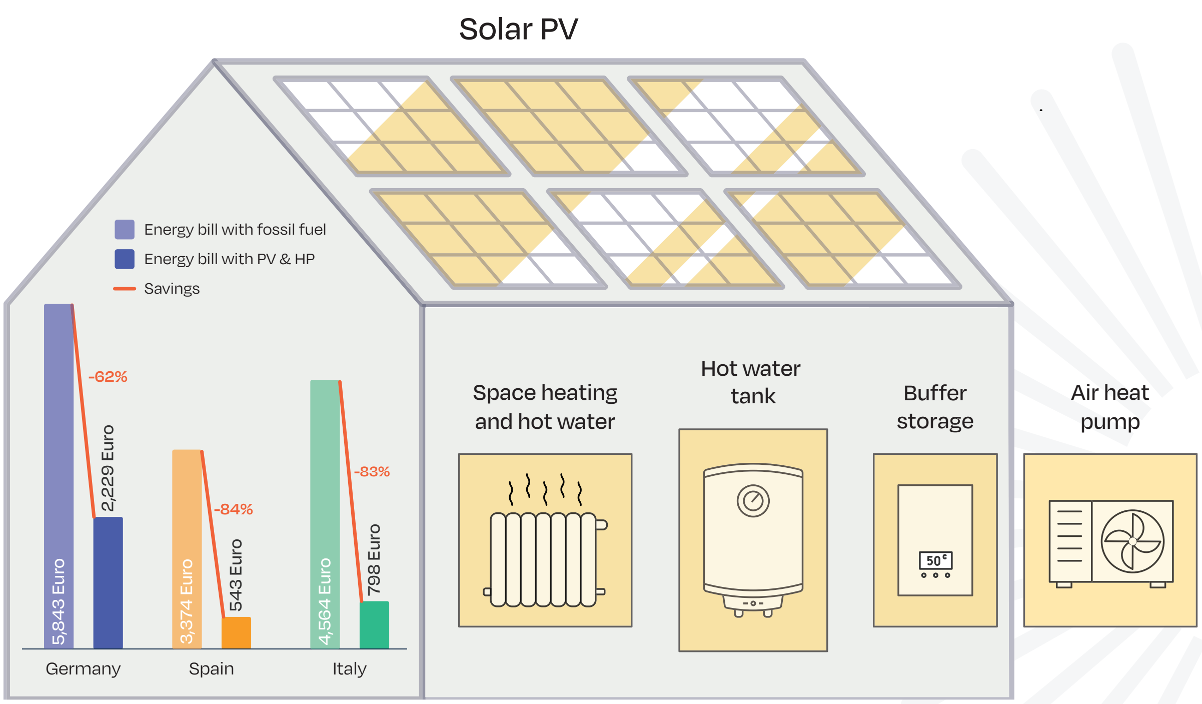
7 https://www.ehpa.org/press_releases/heat-pump-record-3-million-units-sold-in-2022-contributing-to-repowereu-targets/

Solar PV and heat pumps: The combination of both – solar PV and heat pump – yielded the highest annual savings for households in all 3 countries during the energy crises in 2022. Solar PV generates the electricity required by the heat pump, tackling both households' energy bills, and the decarbonisation of their power and heat needs. Crucially, the installation of a buffer storage tank alongside a heat pump is key for the effective combination of solar PV and heat pumps, and to truly leverage the economic potential of these technologies. In the study, we assumed average buffer storage sizes of 400 (Italy & Spain) to 800 litres (Germany). In this way, the warm water can be stored and utilised later, maximising the self-consumption of the house.

However, savings may differ depending on the country's national framework. In 2022, a typical Italian solar PV and heat pump powered household saved the most on their energy bills – 3,766 EUR – due to Italian electricity prices. German household savings follow with 3,614 EUR, then Spanish households with 2,831 EUR. Reduced savings in Spain reflect the measures taken by the Iberian market to lower wholesale electricity prices. In May 2022, Spain adopted a 6.3 billion EUR plan to reduce the generation cost of fossil fuel-fired power stations and, effectively, electricity prices. In addition, Spanish households generally do not have the same heating needs as those in Germany.

In 2022, Solar PV and heat pumps helped to reduce the energy bill of owners by up to 84%, when compared to our medium-sized household case study – sourcing its electricity purely from the grid, and heating from a gas boiler.

FIGURE 10 SAVINGS MADE BY HOUSEHOLDS WITH SOLAR PV AND HEAT PUMPS IN 2022



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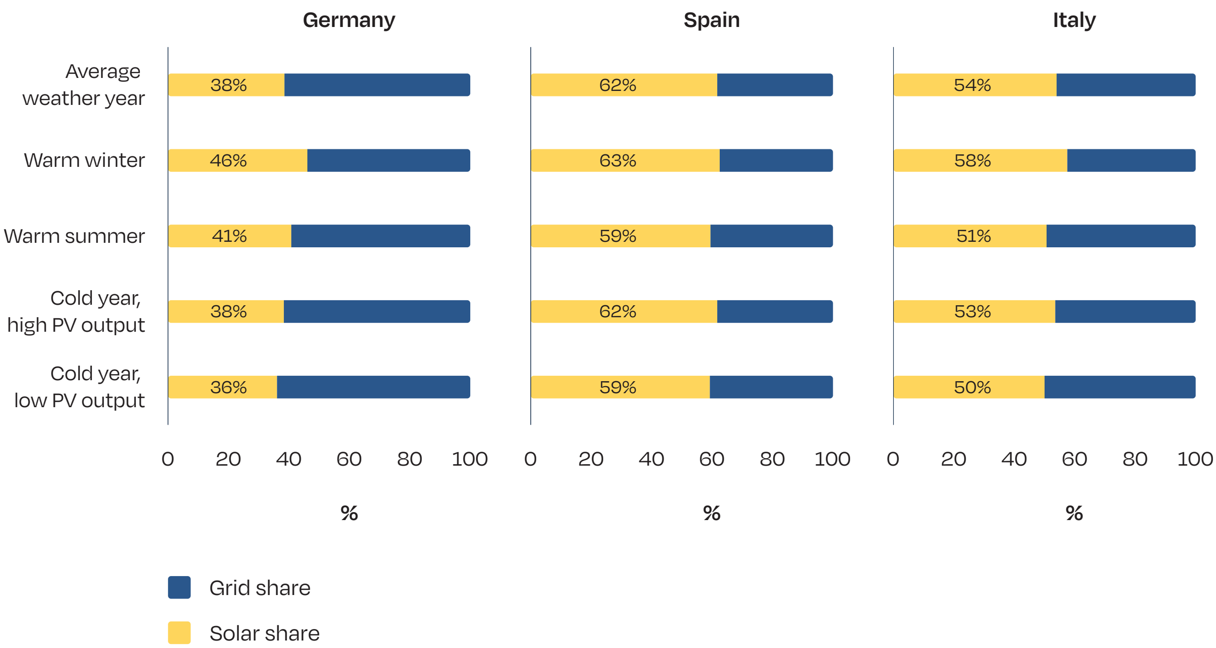
How well do solar and heat pump loads work together?

Switching to heat pumps eliminates the exposure of households to gas price volatility, but it inevitably drives up electricity demand, which increases the risk towards potential electricity price hikes. Combining a solar PV system with a heat pump, protects consumers completely against any gas price volatility and reduces the risk from retail electricity price hikes at the same time.

However, solar PV + heat pumps will only work effectively together if there is a specific overlap between electric heat demand and solar PV production. First, for solar PV and heat pump loads to correlate beyond a 10% range, the usage of a buffer storage tank is fundamental. Buffer storage tanks are ubiquitous today, particularly in cooler countries, like Germany. Secondly, the correlation varies significantly dependent on weather conditions – sunshine and low temperatures. Lastly, the solar PV and heat pumps combination is impacted by consumer behaviour (including load shifting, by showering or using the dishwasher in sunny hours).[8] A 'weather stress-test' was simulated to compare the impact of four extreme weather patterns in one average weather year, each involving different temperature and solar production time series.

The 'weather stress-test' simulation demonstrates the share of the electricity produced by a medium-sized residential solar system for electric heating (see Fig. 11). In Germany, solar power can cover more than a third (36%) of total heat pump electricity demand in a cold year with low solar PV output, and up to 46% in a milder year with a warm and sunny winter.[9] Comparatively, in Italy, on-site solar power supply for the heat pump is much higher – its coverage ranges from 50% to 58%. The best overlap is reached in Spain, where the solar system covers 59% of total heat pump electricity demand in a cold year with low PV output, and close to two thirds (63%) in a year with a warm winter.[10]

FIGURE 11 SHARE OF HEAT PUMP ELECTRICITY DEMAND COVERED BY SOLAR PV GENERATION, IN GERMANY, SPAIN, AND ITALY



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8 These effects were not modelled for this study.

9 DE: Heat pump capacity: 7 kW, Buffer storage: 800 liters, PV capacity: 8 kW.

10 IT/ES: Heat pump capacity: 4/3 kW, Buffer storage: 400 liters, PV capacity: 7 kW.

This overlap is shown in Fig. 12, which illustrates the hourly electric load profiles of solar PV and heat pumps, the electric equivalent of the thermal heating demand of the respective family house, as well as the thermal storage filling level for average Winter and Summer days in Germany, Spain, and Italy.

During an average day of the warm Spring/Summer period (6 months, from April to September) in any of the three countries, the solar system powers the heat pump during daylight hours. The heat pump meets heat demands for hot water usage, in addition to heating up water in the buffer tank during the day. This can be used both for space and water heating, later in the evening and morning hours. This works best in Spring and Autumn, with heating demand and solar production taking place at considerable levels at the same time, and most load shifting and solar-to-heat storage occurring in these months. Very low heat demand in solar-intensive peak summer months (e.g. July), means that it can be fully met by solar PV. Regardless, the demand itself is so low, that thermal water storage hardly depletes at night, and load shifting occurs only very marginally, so that solar energy is mostly fed into the grid.

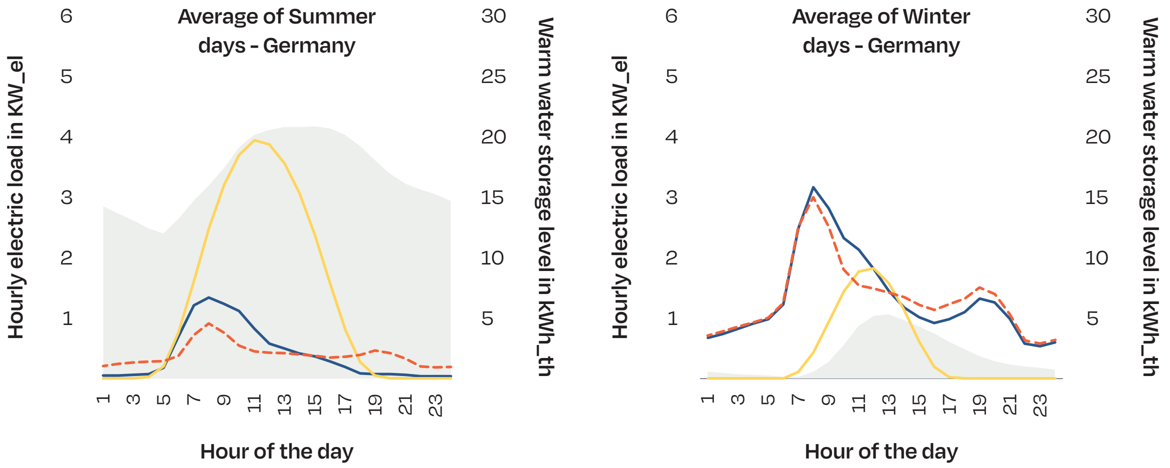
During an average Italian and Spanish 'Winter' day (October to March), solar PV + heat pump powered homes only need to source around 10% of their energy from the grid to complement in-house generation, this number can go higher depending on the specific case. While in peak Winter months (e.g. December), this amount is much higher, it is very low or even zero during the Autumn and Spring months. In comparison, German daily solar PV production in winter is 40-60%[11] lower than in Italy and Spain, while heat demand is 60-80% higher. On a German Winter day, the modelled on-site solar PV and heat pump systems can cover around 20% of the total energy demand during an average day.

Combining solar PV and heat pump systems maximises self-consumption and reduces energy bills for households. In addition, it is important to note that together, these technologies benefit the energy system as a whole, by incentivising electric load shifting into hours of high renewable energy production.

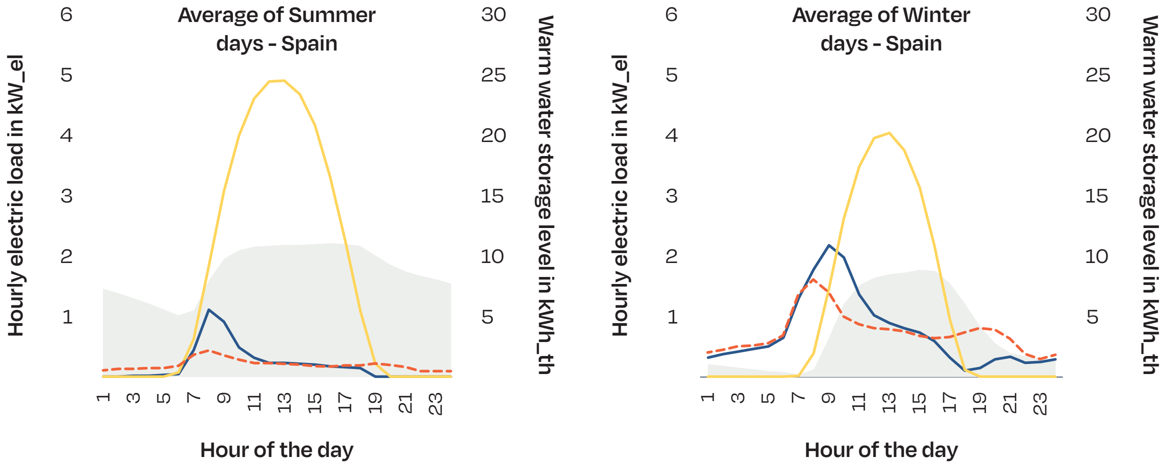
© AFEC

11 Based on MERRA-2 data for the weather year 2008, which is used as average weather year for temperatures and PV production in these three countries.

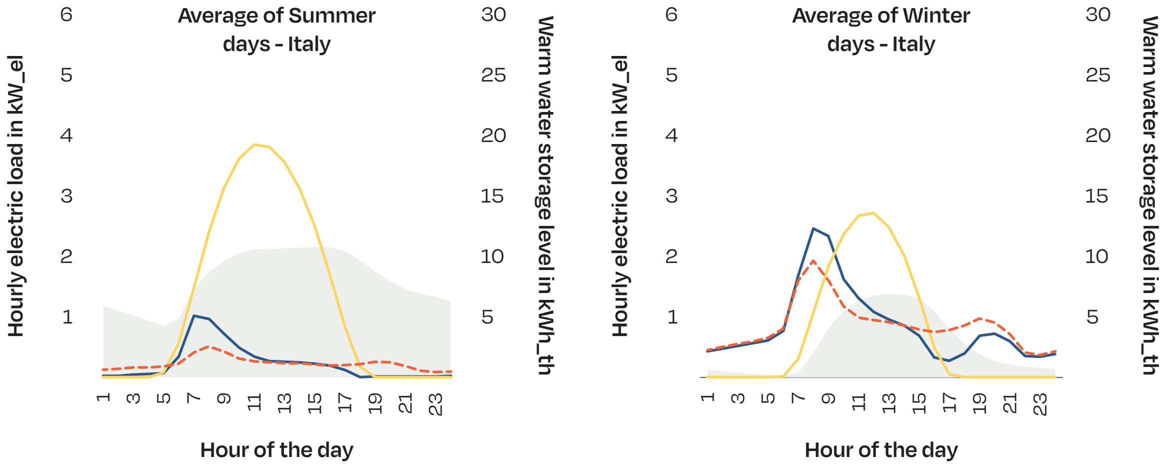
FIGURE 12 WINTER AND SUMMER DAY AVERAGE GERMANY, SPAIN, ITALY - HOURLY ELECTRIC LOAD AND BUFFER STORAGE LEVELS



In summer, Solar PV powers the heat pump during daylight hours, and the heat pump meets heat demands for hot water usage and heats up water in the buffer tank during the day. In Winter, the solar PV and heat pump systems can cover around 20% of the total energy demand during an average day.



In Spain and Italy, on an average 'Winter' day, homes with solar PV + heat pump need to source around 10% of their energy from the grid, this number can increase depending on the specific case, and grows higher in peak Winter months.



On an average summer day in Spain and Italy, the heat demand for water is fully met by the heat pump, and the water storage remains high in the evening.

Warm water storage level (kW_th) — PV production

HP load_el — Heat demand_el

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In conclusion, German, Spanish, and Italian family households equipped with solar PV have been shielded from high energy prices in 2022; they could save up to 22% in Germany (1,263 EUR), 40% in Spain (1,352 EUR), and 64% in Italy (2,935 EUR). Modelled households which used a heat pump for heating purposes, could lower their energy bills even more – by a maximum of 32% or 1,884 EUR in the German case. However, the optimal scenario is the combination of solar PV and heat pumps. A typical residential home using solar PV and heat pumps for heating profited from savings of 62% (3,614 EUR) in Germany, 84% (2,831 EUR) in Spain, and 83% (3,766 EUR) in Italy.

Increased self-consumption rates from integrated PV and heat pump systems are a key driver for these savings. Since typical heat pump systems are equipped with a buffer storage tank today, solar and heat pump load profiles match well. Under average weather conditions , a medium-sized solar system is able to provide nearly two thirds (62%) of electricity needs to heat an average Spanish family household, and more than one third (38%) of a German family household. A historical weather data analysis shows that solar PV + heat pump's performance changes minimally during a cold Winter, with adverse conditions for solar PV, resulting in 59% solar power coverage for Spain, and 36% in Germany. On the contrary, a warm Winter can boost solar's contribution in Germany, reaching close to half of the country's heating needs (46%).

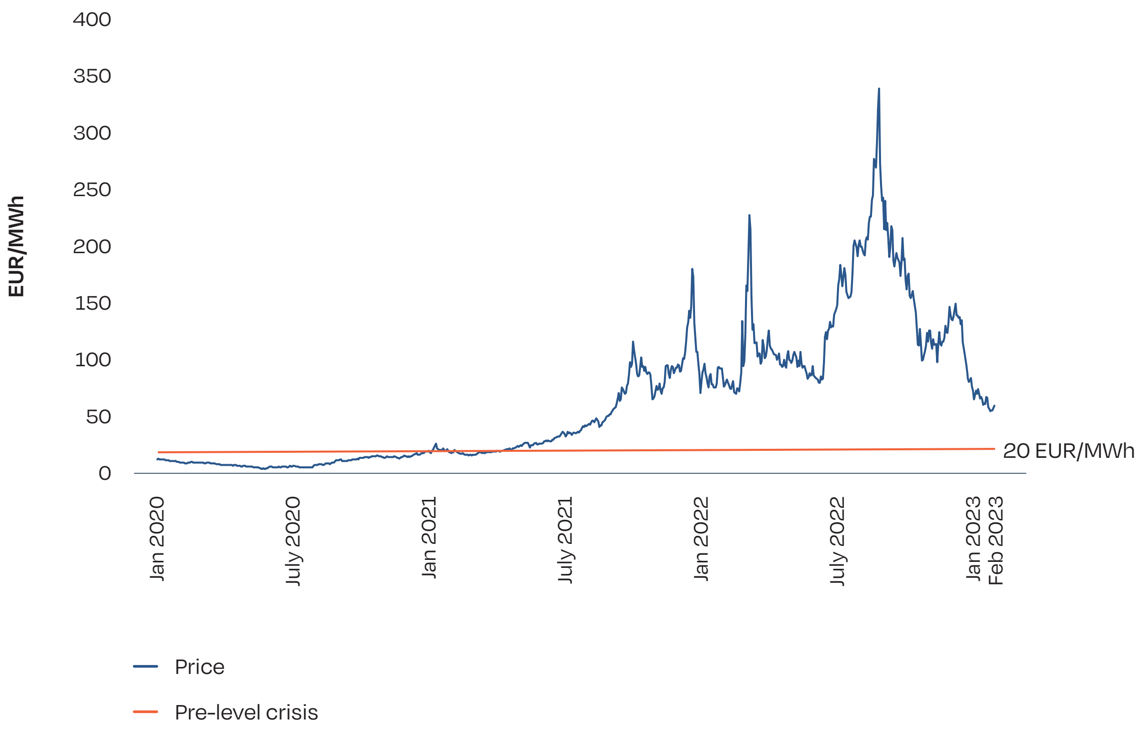
© Pixabay

2.2. Long-term savings for Solar PV & HP: Solar PV will generate large savings for households in the coming years, both alone, and in combination with electrified heating technologies.

Happy heat pump + solar PV owners in all scenarios

For owners of a solar PV, or a combined solar PV and heat pump system, the report finds that the savings continue to be significant in the coming years, even if market-participants widely project long-term gas and power prices to stabilise at lower levels. In the medium scenario used in this study, we assume long-term European fossil gas prices at almost double the pre-crisis level, which at the time of writing (February 2023) appeared to be the New Normal, when taking into account long-term price expectations at international gas trading hubs (Dutch TTF, American Henry-Hub). In Fig. 13 the development of the Dutch TFF future market gas price for front year deliveries is shown, both before and after the start of the energy crisis in autumn 2021. Despite current signs of temporary recovery, gas prices in early 2023 are still very well above pre-crisis levels.

FIGURE 13 DUTCH TTF NATURAL GAS FUTURES



SOURCE: ICE Endex.

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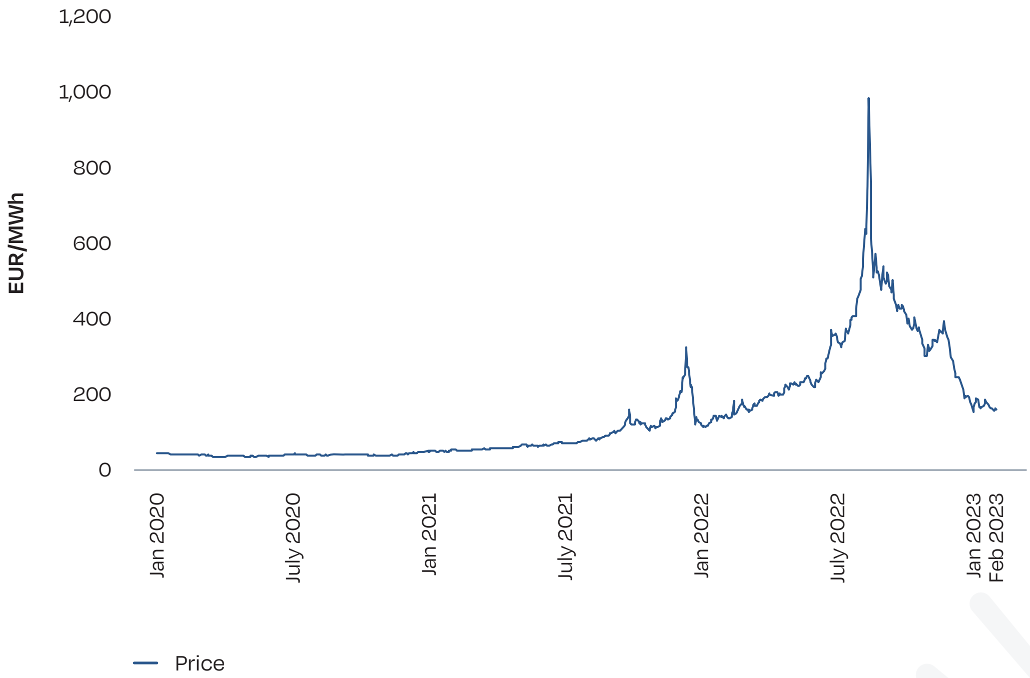
For power prices, the New Normal medium scenario draws on average price expectations of market participants in early 2023 as well. The average EEX settlement prices traded in early February 2023 for baseload deliveries in the coming 10 years are used as a reference (see Fig. 14). Accordingly, German and Italian power prices are expected to reach a New Normal level of around 120 EUR/MWh, average Spanish prices will stabilise at a level of 66 EUR/MWh.

FIGURE 14 EEX HISTORICAL MARKET PRICE, 2020-2022



SOURCE: EEX.

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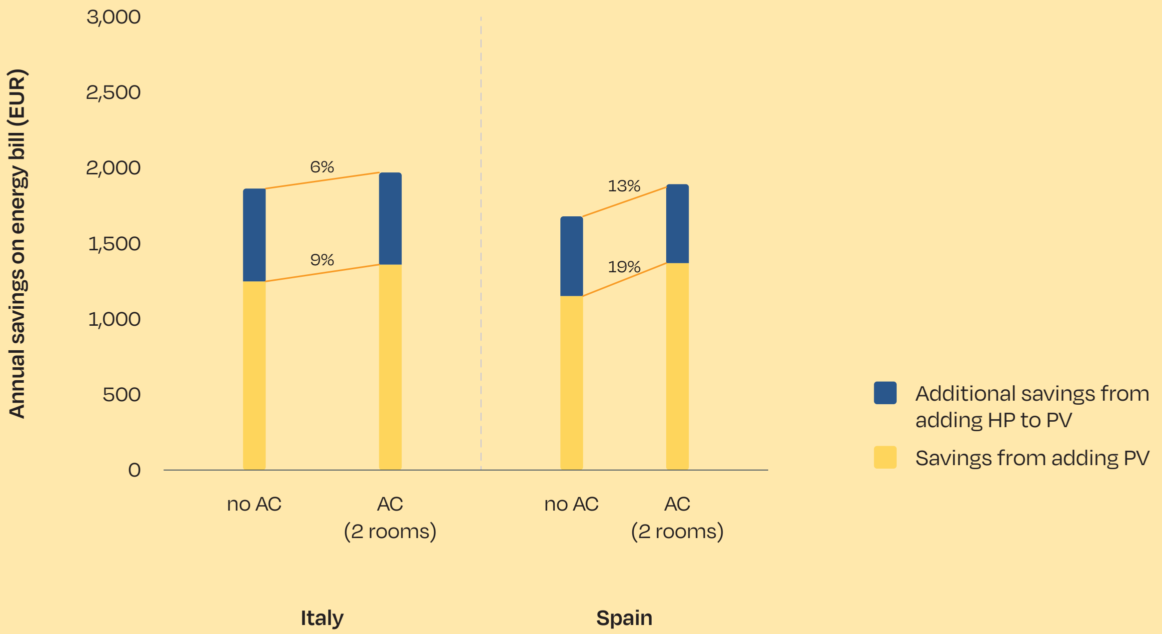
Box 3. AC can significantly increase self-consumption; leading to higher annual savings.

AC + PV + HP: Air Conditioners (AC) are widely used in southern European countries such as Spain and Italy. Our model shows that the use of solar power and heat pumps would lead to extra financial savings.

The annual energy bill savings that an average Italian family home can attain by installing an average size PV system is €113 or +9% higher if a 5 kW AC system is already installed to cool two rooms (living room and bedroom). Due to generally hotter climate and more solar full load hours, this effect is more pronounced in Spain at +€215 or 19%.

The savings from investing in PV+HP are in turn €110 or +6% higher in Italy if an AC system is already installed, and +€212 or 13% in Spain. Since AC and HP use (for hot water during the day, e.g. dishwasher) might slightly cannibalise each other on some days, the numbers are marginally lower than for PV only.

FIGURE 15 ANNUAL SAVINGS FOR PV / PV + HP IF BUILDING ALREADY HAS AC OR NOT, IN THE NEW NORMAL SCENARIO



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Under the New Normal price scenario, for the coming years, annual savings of typical homes equipped with medium-sized solar PV are consistently over 1,000 EUR in Germany, Italy and Spain, and they climb up to over 1,800 EUR when solar PV and heat pumps are combined. The savings of the duo are between 46% and 67% higher, than for a household that operates a solar PV system alone (see Fig. 16).

In comparison to the original energy bill, savings for a household with solar PV only ranges between 33% in Germany and 51% in Spain and Italy, while for the PV + HP combination the reduction is higher, at 55% in Germany and 76% in Italy (see Fig. 17).

This finding is robust against higher and lower commodity price scenarios.

FIGURE 16 ANNUALISED[12] SAVINGS PER TECHNOLOGY IN GERMANY, SPAIN, ITALY, IN THE NEW NORMAL SCENARIO

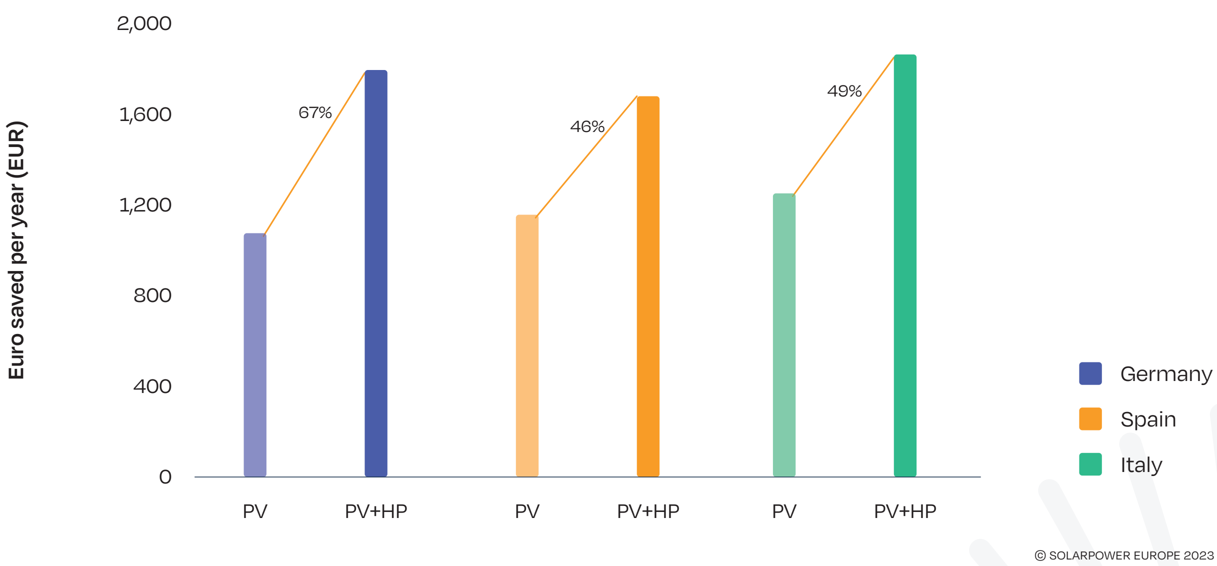
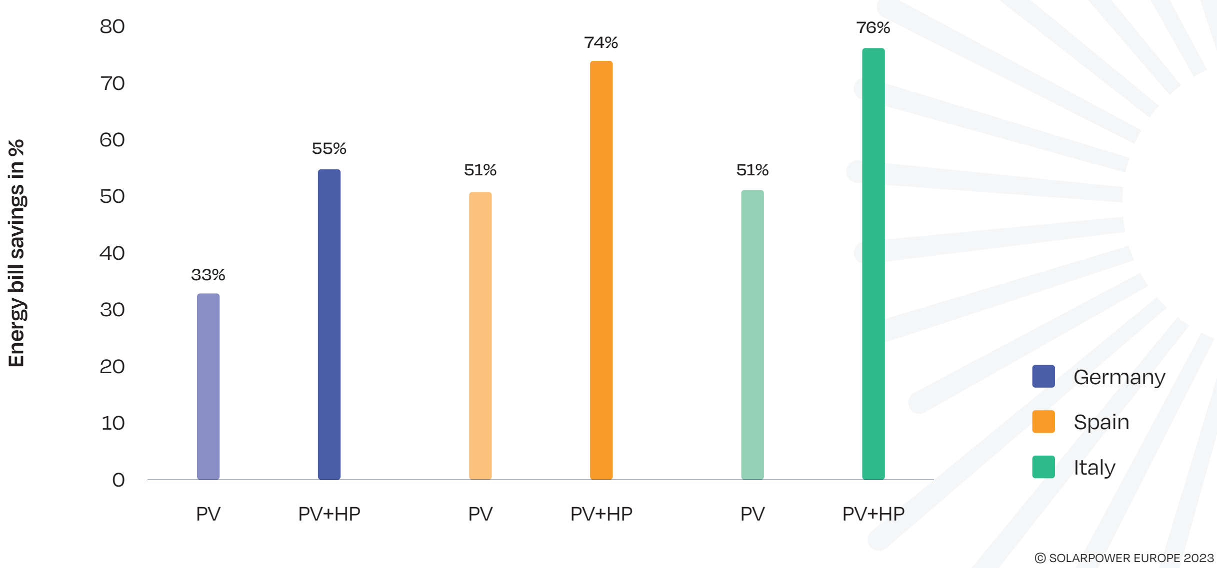


FIGURE 17 ANNUALISED SAVINGS PER TECHNOLOGY IN % IN GERMANY, SPAIN, ITALY, IN THE NEW NORMAL SCENARIO



12 We use 'annual savings' for savings on a specific year, i.e. 2022, and 'annualised savings' for savings that covers several years but are averaged.

Box 4. Looking for a quick and low-cost solution? Check out a heating rod!

The report also evaluates the combination of solar PV with a cheaper, lesser known electric heating technology: the heating rod. Heating rods are easy to find and swift to deploy, with installation costs between €500 and €1,000 in European markets.

It takes the form of an electric immersion heater that sits in a water tank and works somewhat similarly to an electrical kettle. A 'Power-to-Heat' application, it converts electricity generated from solar PV into heat within the water system of the house. The rods are easily fixed to the home heating systems' hot water tank, which today often have pre-installed openings to connect these devices. In combination with solar PV, the heating rod enables increasing the solar self-consumption rate by substituting parts of the household's gas consumption and leading to lower household's energy bill at low upfront investment cost. The impact and contribution from this combination depends on the size of the solar system, the water tank's capacity, and the demand, which is why it makes sense to employ energy management to operate these rods. While rods of around 2 kW are usually used for smaller residential rooftop systems up to 6 kW and water storage tanks up to 250 liters, more powerful rods are applied for larger installations (we used 3 kW for our modelling).

Our model showed a marginal increase on annual savings in Germany with €1,431 (+ €167 or +13%) compared to solar PV alone in 2022; in Spain, the higher solar production leads to an increased heating rod utilisation and thus higher savings of €1,523 (+ €171 or +13%). In Italy, however, the PV and heating rod system savings in 2022 were lower than for the PV only case, at €2,728 (- €207). This result is caused by the very high feed-in electricity prices, which provide better returns than the gains from reduced gas consumption.

In other words, in Italy, in 2022, it was more beneficial to get remunerated for feeding your excess solar electricity into the grid, than to use it with a heating rod in an attempt to reduce the cost of your gas consumption. However, this is different for a heat pump which enabled much higher savings of €3,763. Unlike a heating rod system, which has an efficiency of around 99%, a good heat pump can supply over 3.5 times the heat energy from every electrical energy it consumes, translating into around 350% efficiency.

Fun fact: HP systems often come with pre-installed heating rods as an additional heating element. If the heat pump cannot cover demand, the heating rod steps in. Moreover, this combination allows to switch off the heat pump completely in summer, which increases its service lifetime.

© EnBW

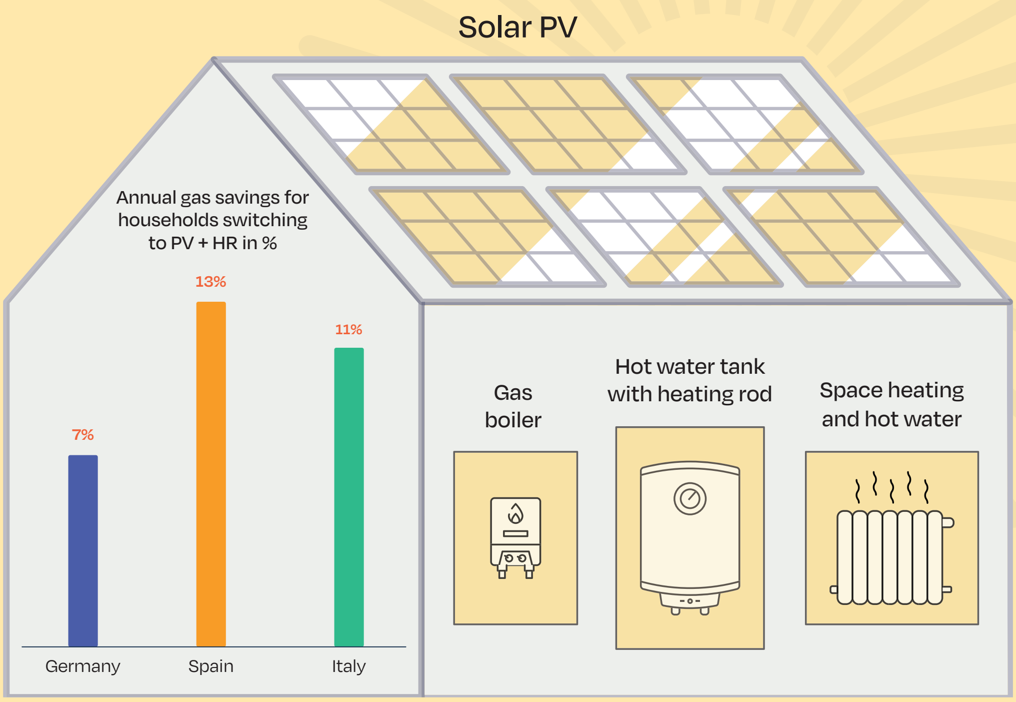
The PV and heating rod case was modelled for annual savings of operating systems over the coming years according to the New Normal scenario.

Savings: In Germany, a typical PV+HR system helps to save €1,088 over a gas boiler, the same range as a solar PV alone which saves €1,076 per year. In Spain, the savings from PV+HR allows for an extra €61 or 5% saved compared to PV alone. The reasons for higher savings in Spain is the higher availability of solar production. In Italy the high feed-in rate makes it more interesting to feed the surplus electricity from the PV system than to use it with a heating rod. The savings from PV alone are €1,251, whereas PV+HR area at little less, reaching only €1,222 per year. However, from a climate perspective it also makes sense – PV+HR reduces gas consumption by up to 13% in Spain, 11% in Italy, and 7% in Germany (see Fig. 25).

Payback time: Adding a heating rod to a solar system in Germany doesn't impact the payback time in the New Normal scenario – it remains at 19 years, since the self-consumption volumes only increase marginally. In contrast, in Spain more solar production is available for the heating rod to significantly improve the self-consumption rate - this leads to 2 years cut in payback time down to 17 years. In Italy, the payback time of PV alone (14 years) is deteriorated by adding a HR (15 years) due to the afore-mentioned economic unattractiveness of substituting gas costs with a HR at an efficiency of 99% instead of feeding in solar surpluses at higher electricity prices.

In summary: Heating rods are a low-cost solution to electrify part of a households heating energy needs. Using a PV system plus a heating rod increases savings on the energy bill by up to 5% in Spain while the needs for gas can be reduced by up to 13%.

FIGURE 18 EXTRA CASE STUDY – HOUSEHOLD WITH PV AND HEATING ROD (PV+HR)



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Alternative scenarios have been modelled to a) address the currently high uncertainty on future commodity price levels, and b) to generally stress-test the results. The high commodity price scenario (Return-to-Crisis) represents a future where the gas crisis re-escalates, for example due to strong global economic recovery in Asia. This in turn would also increase power prices. The low commodity price scenario (Fossil Dumping) represents a future where European and global gas demand falls dramatically, leading to oversupply and fossil dumping on the markets. While this scenario could become a defining trend in the next decades, it is less likely to materialise in the next few years. In any case, it is fair to say that gas markets will remain very volatile and uncertain in the coming years.

The following graphs present the potential annual savings in future years, based on the three aforementioned scenarios for long-term commodity price paths.

In Germany, the absolute savings from a medium size PV system range from €1,041 and €1,180 per year, depending on the commodity price scenario (see Fig. 19). Due to savings on both electricity and gas, combining solar PV and heat pumps can help homeowners to reduce their annual bill much more significantly (€1,427 to €2,323). For example, under the New Normal scenario, savings improve by 67% over a standalone PV system. In the solar PV and heat pump case, savings are also fluctuating much more with the chosen commodity price scenario, since volatility from both power and gas prices directly affects savings. While the biggest savings are recorded in the Return-to-Crisis scenario, even in the Fossil Dumping scenario solar PV only, or solar PV and heat pumps combined, offer notable financial benefits above the mark of €1,000 per year.

When looking at the relative reduction of energy bills by using solar PV, or solar PV and heat pumps, instead of only fossil gas-based heating and grid electricity, the annual energy bill can be reduced by up to 38% (solar PV only) or 55% (solar PV + heat pump) (see Fig. 20). While the *absolute savings in EUR* on the energy bill increases with increasing commodity price levels in both cases in Germany, the *relative savings in %* also increase for solar PV and heat pumps, but not for the case of PV only. The reason is that higher/lower commodity prices increase/decrease the costs for grid consumption proportionally more than the annual savings.

FIGURE 19 SCENARIOS FOR ANNUALISED SAVINGS FROM PV AND PV+HP IN GERMANY

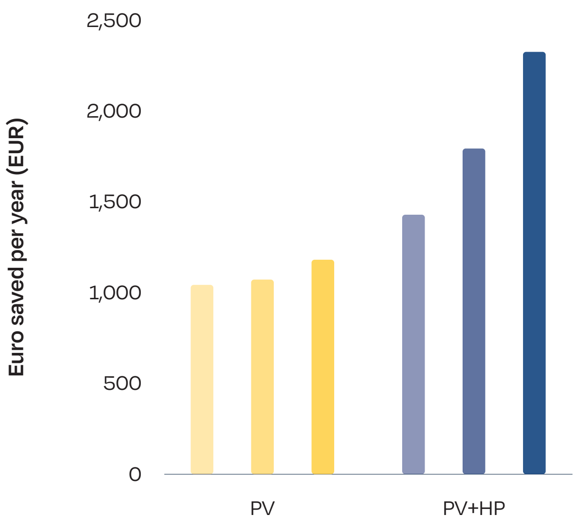
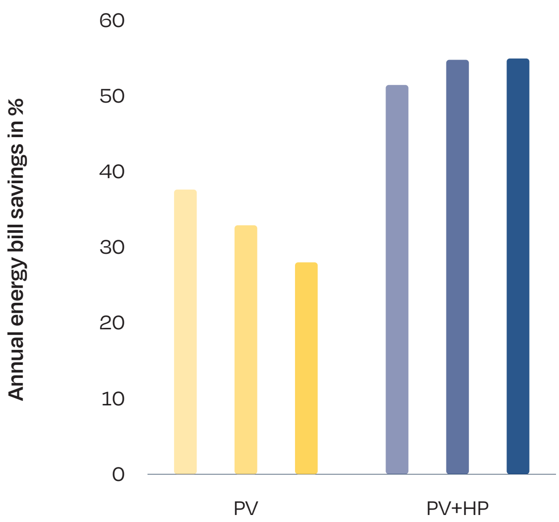


FIGURE 20 SCENARIOS FOR ANNUALISED SAVINGS FROM PV AND PV+HP IN % IN GERMANY



Fossil dumping   New normal   Return-to-crisis

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Indeed, while the grid power price is a parameter both on the cost side (payments for grid power supply) and the savings side (savings from self-consumption), a feed-in tariff completes the picture on the savings side. However, Germany offers a fixed feed-in tariff to residential solar PV owners, which is independent from price developments on the electricity market. Hence, on the savings side, only the savings from self-consumption fluctuate with commodity price levels, while the income from selling excess feed-in remains constant. In contrast, in the self-consumption schemes of other countries, solar excess feed-in is often remunerated at its market value – and therefore fluctuating.

In Spain, homeowners with solar PV can save between €979 and €1,957 and those with solar PV and heat pumps, between €1,296 and €2,401 depending on the scenario (see Fig. 21). By adding heat pumps to solar PV, the annualised savings soar by 46% in the New Normal scenario. This is the lowest increase for the 3 countries modelled. Power price levels in Spain are expected to be much lower than in Germany and in Italy, where the hikes were also much higher in 2022. Lower power prices lead in turn to lower savings from self-consumption.

Compared to Germany, Spanish solar systems generally reach significantly higher full load hours – often over 1.5 times more. Consequently, increased solar power output with higher self-consumption and excess export volumes, creates a more regular fluctuation in Spanish annual savings, especially compared to Germany. The difference is striking in the solar PV only scenario. In the solar PV and heat pump case, Germany's higher heat demand counteracts this trend.

When comparing the solar PV or solar PV and heat pump family household, to the household using only fossil gas heating and grid electricity, the annual energy bill is up to 55% (solar PV only) or 83% (solar PV + heat pump) lower (see Fig. 22). Compared to Germany and Italy, the relative savings in % in Spain increase alongside higher commodity prices, both in the solar PV and heat pump, and the solar PV only scenario (for explanation see section below on Italy).

FIGURE 21 SCENARIOS FOR ANNUALISED SAVINGS FROM PV AND PV+HP IN SPAIN

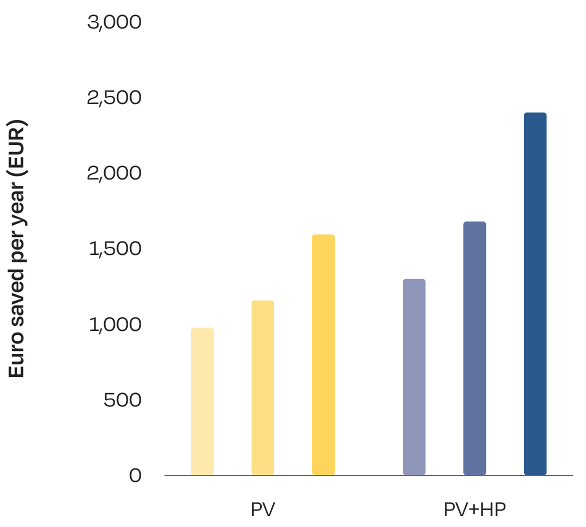
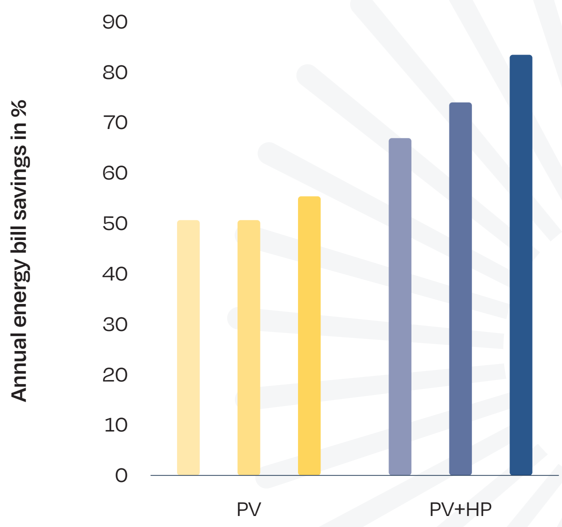


FIGURE 22 SCENARIOS FOR ANNUALISED SAVINGS FROM PV AND PV+HP IN % IN SPAIN



Fossil dumping　New normal　Return-to-crisis

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In Italy, in the next years, the annualised savings are also largely positive – and follow a similar pattern to Germany and Spain, showing increasing savings with increasing energy prices (see Fig. 23). For a solar PV only household, the savings ranges from €1,136 under the Fossil Dumping scenario, to €1,574 under the Return-to-Crisis scenario. If operated together, solar PV and heat pumps allow for significantly higher savings of €1,525 and €2,477, respectively.

Compared to a family house without solar PV or solar PV and heat pumps, the annual savings are up to 54% for solar PV and 80% for solar PV and heat pumps (see Fig. 24).

As in Germany, increasing commodity price levels in Italy cause relative savings in % to rise only for solar PV and heat pumps, but not for solar PV only, while absolute savings in EUR improve for both cases. This means that higher/lower commodity prices increase/decrease the costs for grid consumption proportionally more than the annual savings. In contrast to Germany, however, this effect is much less pronounced and is driven by a slightly different reason. In all three countries, the grid power price is a parameter both on the cost side (costs for grid withdrawal) and the savings side (savings from self-consumption), while the feed-in tariff completes the picture on the savings side. Unlike in Germany, in Italy and Spain the feed-in tariff is not fixed but fluctuates with its market value. However, due to price cannibalisation in midday hours, the solar market value is less sensitive to rising commodity price levels than the average grid power price for a household customer consumption profile.[13] Therefore, the income from excess feed-in grows proportionally slower at higher commodity price levels than the grid power price, resulting in overall savings increasing proportionally slower. This effect is prevalent in both Italy and Spain, but in Spain it is visible to a much lesser extent due to a) the much lower electricity price level and b) generally higher full load hours counteracting this effect.

FIGURE 23 SCENARIOS FOR ANNUALISED SAVINGS FROM PV AND PV+HP IN ITALY

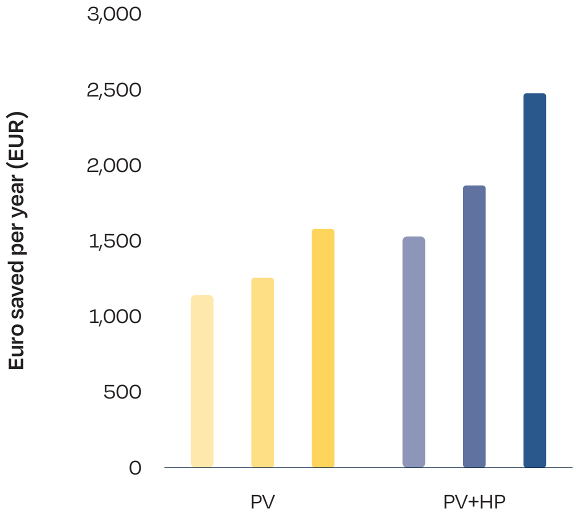
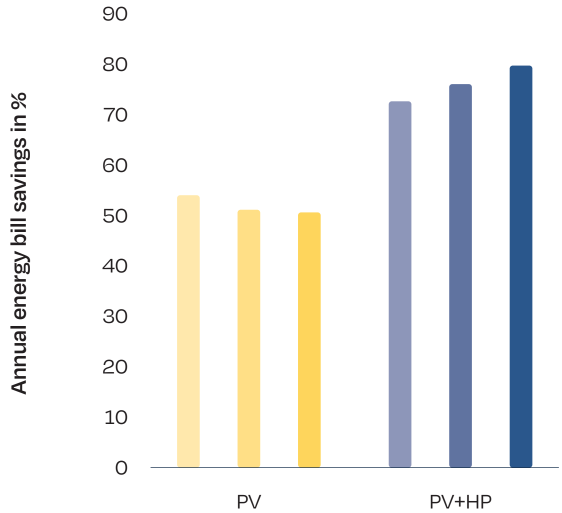


FIGURE 24 SCENARIOS FOR ANNUALISED SAVINGS FROM PV AND PV+HP IN % IN ITALY



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13 To further expand on price cannibalization: the calculation of a) the cost for buying electricity for a household profile or b) the revenue for selling solar surpluses are both based on volume-weighted average hourly power prices. Compared to the average of all hours when households get power from the grid, solar energy in DE, IT and ES tends to be fed into the grid mostly during hours of already high (solar) supply and lower prices. During these hours, less of the expensive (gas) power plants are used to meet electricity demand, as the system can instead use the vastly available cheap solar energy supply. The average of all prices in these sunny hours results in the solar market value. Now, if gas prices rise, power prices in gas-intensive hours rise proportionally stronger than power prices in hours dominated by renewable supply. Since the average price for household consumers contains a greater share of gas-intensive hours, it rises stronger than the solar market value.

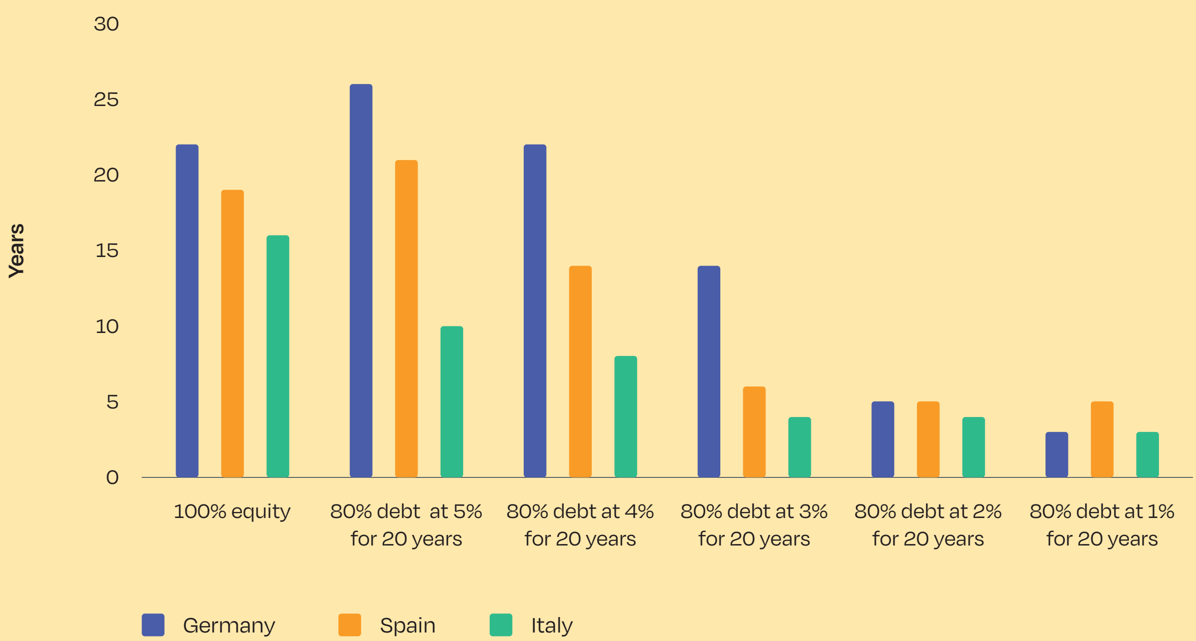
Box 5. Loan-based solutions to spread out investment, lower initial expenses, and get it back sooner.

Paying 100% of a solar PV project upfront might pose an investment hurdle even for middle-class families in today's inflationary environment, and it's getting more challenging for a higher investment when including heat pumps. Recently, more and more solar installation companies have been successfully offering innovative ways to spread costs for households through leasing or renting models for a solar plus heat pump project. What about traditional loans that have been frequently used to finance PV investments in the past? To model the impact of debt on system break-even, we have modelled a 20/80 equity-debt ratio, assuming that 20% of the system is paid by cash, while the 80% remaining is financed via a loan.

It shows that debt significantly impacts the time before break-even. The break-even point is reached when the household has saved as much money as it has initially spent. In other words, it is the number of years it takes for a households to get back the 20% cost of the system it has financed with cash. The rest of the loan is financed by the savings made by the solar PV + heat pump system on the energy bills, which, in our model, are always higher than the monthly loan repayment. The difference between the savings made through the solar PV + heat pump system and the loan repayments influences the time before the 20% initial investment is paid back as well. Figure 23 describes three different interest rate levels and their impact on the break-even time, for the investment in a solar PV system with a heat pump.

A 3% rate allows a German household to reach break-even within the estimated lifetime of a heat pump (about 15 years). Spanish households would financially benefit from a loan if the interest rate is below the 4-5% range. Italian households on the other hand are able to endure high interest rates above 5% if that allows them to spread out the investment. In today's credit market, interest rates are much higher than only 1 year ago. Obtaining 'acceptable' loan levels forms an increasing obstacle, especially for low-income households that would benefit the most from energy savings. Access to government-supported low-interest loans is therefore essential to boost the development of solar PV + heat pump technologies (see policy recommendations, p. 31).

FIGURE 25 TIME BEFORE BREAK-EVEN IN THE NEW NORMAL SCENARIO



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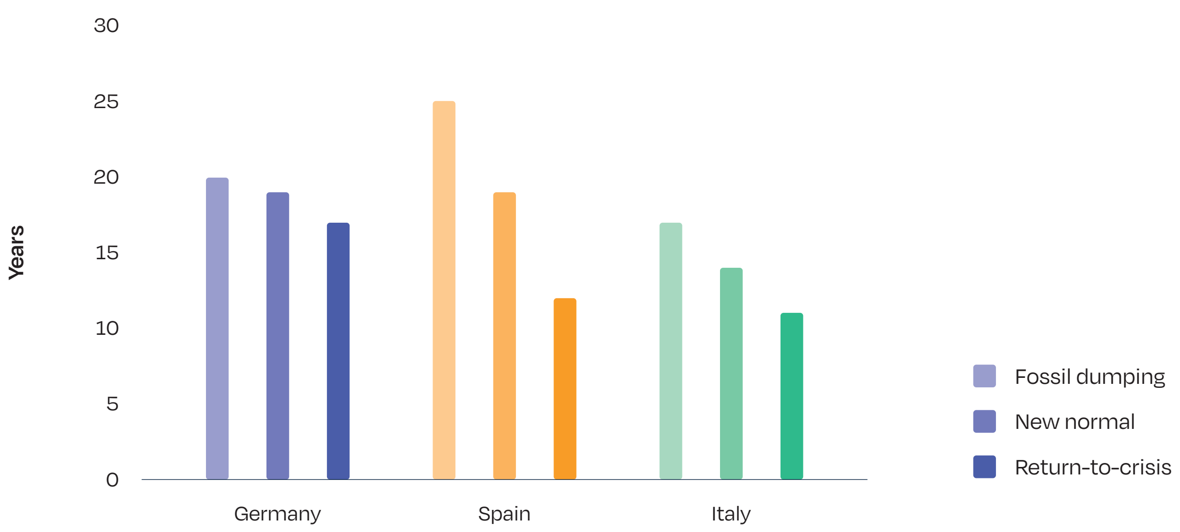
2.3. Returns of new PV + HP investments: Strong policy support is needed to make investment in new solar PV and electricity-based heat technologies attractive to more households.

So far, the report has looked at costs and gas savings in 2022 and following years for households that already invested in solar PV and electrified heat technologies before the energy crisis. The results are striking; households that had the opportunity to decarbonise their heat generation early have been enjoying substantial energy and cost savings while they helped to substantially reduce gas demand. This also explains why the rooftop solar and heat pumps markets soared in 2022.

This success story shouldn't lead to complacency or be taken for granted. There is still severe concern about safe gas supply for winter 2023-24. The inflationary environment in Europe has driven high interest rates and high material costs. All this, alongside a severe lack of installers, augments the prices for both solar systems and heat pump installations. Moreover, energy prices have decreased, which begs the crucial question; will the immediate investment case in these decarbonising and energy secure technologies remain attractive? If not, what needs to be done to bring the benefits of gas-free homes to larger parts of the population?

Looking at solar PV alone, the payback time in Germany varies little between scenarios – from 17 to 20 years. The gap is widest in Spain where the investment is returned between 12 and 25 years. Italy shows a range between 11 to 17 years. While the model household in Germany requires the longest payback of 17 years in the high-gas price Return-to-Crisis scenario, it is not much longer in the low-energy gas price Fossil Dumping scenario. Therefore, the German case shows the lowest sensitivity of payback times to commodity price levels. This is due to the comparatively low solar full-load hours throughout a year. In Italy and particularly in sunny Spain, the sensitivity is, in turn, much higher.

FIGURE 26 PAYBACK TIMES OF PV IN GERMANY, SPAIN AND ITALY



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When looking at both **PV and PV+HP**, their payback times vary enormously depending on the commodity gas price. Assuming 100% equity investment, the difference between high and low gas price assumptions leads payback times to swing between 11 years and over 30 years. When comparing the three countries in the New Normal scenario, Italy shows much shorter payback times of 14 years. The driver for this is a combination of comparatively high full load hours – higher than Germany, lower than Spain – and the highest electricity prices among the three countries.

Because of heat pumps' higher investment cost than for a comparable solar PV system, the payback time is generally longer, and the savings counterbalanced by the higher electricity needs, despite the replacement of the fossil gas boiler.

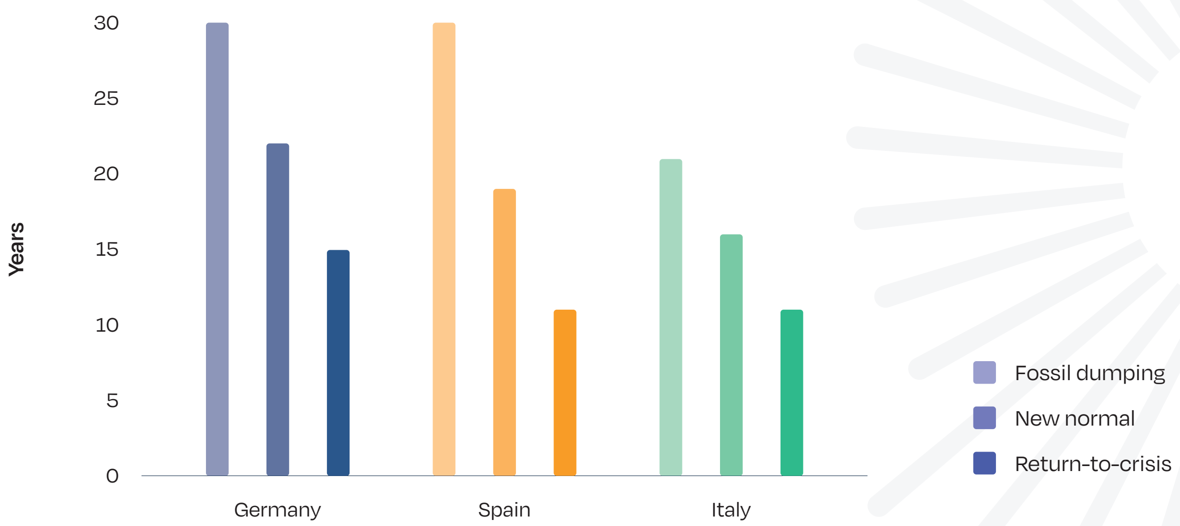
When looking at the payback times for new solar PV and new solar PV + heat pump, they decrease in the New Normal scenario compared to the Fossil Dumping scenario, while it doesn't for HP only. However, the higher the gas price, the better the investment in solar PV and heat pump become compared to PV alone, translating into higher savings and faster payback times.

This difference in payback time between PV alone and PV+HP highlights the importance of deploying the two technologies simultaneously. A solar PV installation complements a household's heat pump and fulfils a significant extent of its electricity needs. The savings for the two technologies together are then higher than for each individual technology.

Looking at solar PV in combination with heat pumps, the impact of diverging gas prices on payback times is even more distinct, as most households in the three countries of the report are heated with gas. In Germany, depending on gas price, the payback time can be as low as 15 years but also twice as high in the Fossil Dumping scenario. The pattern is similar in Spain, but with an even larger difference of 19 years between the Fossil Dumping and the Return-to-Crisis scenario, when the investment would be paid back in 11 years.

This points to the importance of policy. In these times of gas crisis, policy frameworks need to support households in switching off the gas and offer coherent policy packages for solar + electrified heat. Looking at Fig. 27, we see that even in the likelier New Normal medium gas price scenario, payback times are still close to 20 years or more. If policy makers want to bring the benefits and blessings of gas-free homes to larger parts of the population, these payback times should be around 10 years or less.

FIGURE 27 PAYBACK TIMES OF PV+HP IN GERMANY, SPAIN, AND ITALY



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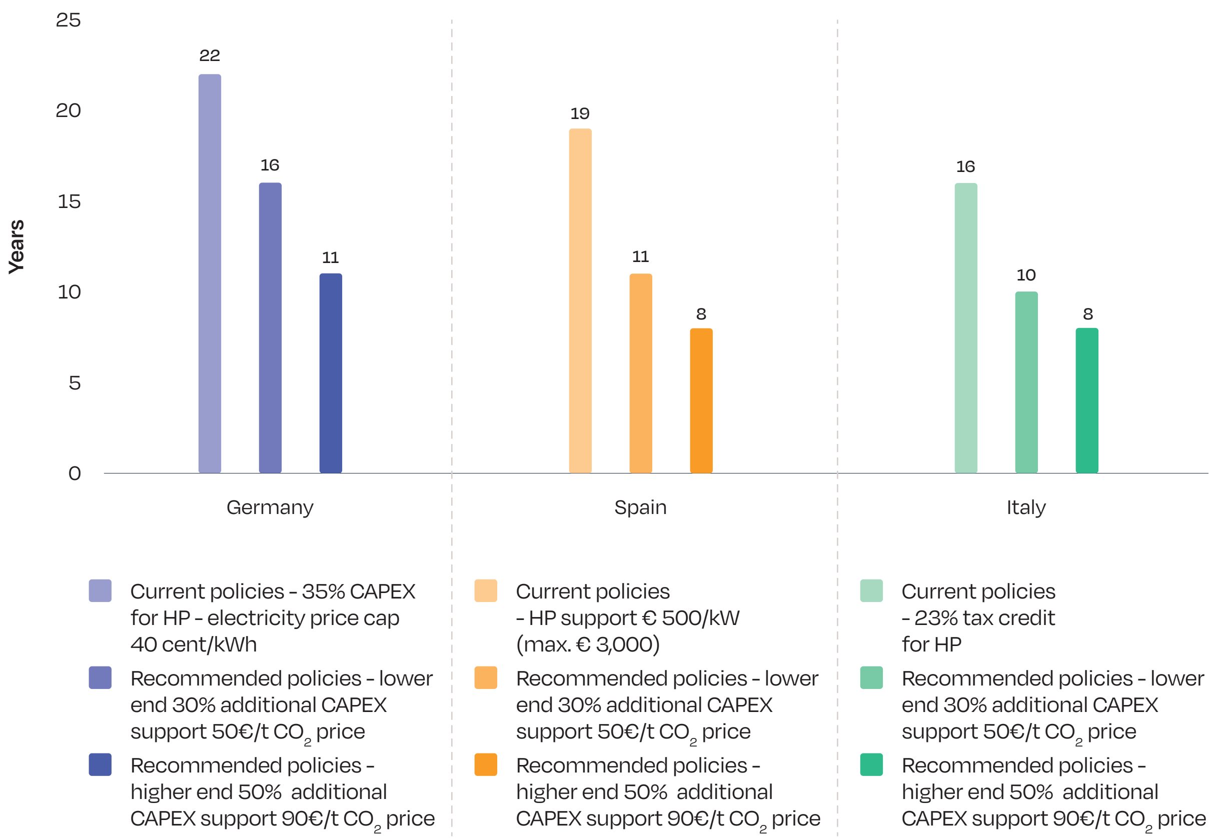
3 Policy Recommendations

Combining a PV system with a heat pump simultaneously protects consumers against any gas price volatility, and reduces the risk from retail electricity price hikes. The report outlines five policy recommendations which, together, can reduce payback times for new solar PV and heat pumps from around 20 years to below 10 years.

FIGURE 28 PAYBACK TIME FOR SOLAR PV AND HEAT PUMP IN GERMANY, SPAIN AND ITALY



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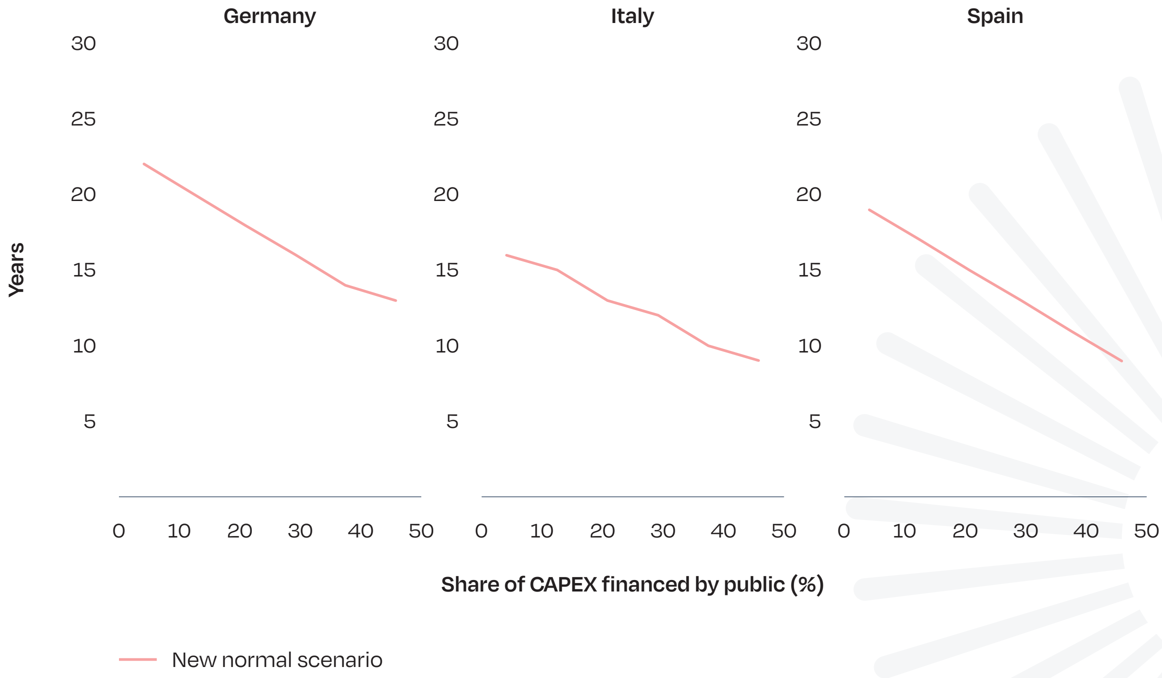
1. Member States should provide CAPEX support. Moderate increases in CAPEX support for solar PV and heat pump installations significantly reduces payback times. The model shows that a 30% increase in CAPEX support reduces payback times by 6-8 years for all three countries. There are several options to provide CAPEX support. Member States could either directly support with a fixed amount (EUR) or an amount relative (%) to the CAPEX investment, and the used technology. Alternatively, they can offer indirect support, for example by cutting VAT (%) or offering tax credits (%). Italy has successfully implemented strong CAPEX support with its 'superbonus' scheme, which allows homeowners to claim a 110 % tax deduction on their solar PV and heat pump installation costs. Germany offers up to 40% financial support for heat pumps. Such measures have to be maintained, and could function as an example to other countries.

2. Member States should offer low-interest rate loans to citizens for solar and heat pumps. This is important because high initial investment is a barrier for low-income households in particular, who profit most from energy savings. On top of this, European prime rates are on the rise (3%), and material shortages and a severe lack of installers have dramatically increased total system prices. This also impacts investment in solar PV plus heat pump and battery storage technology for middle-class families.

FIGURE 29 PV + HP PAYBACK TIME UNDER DIFFERENT CAPEX SUBSIDY LEVELS



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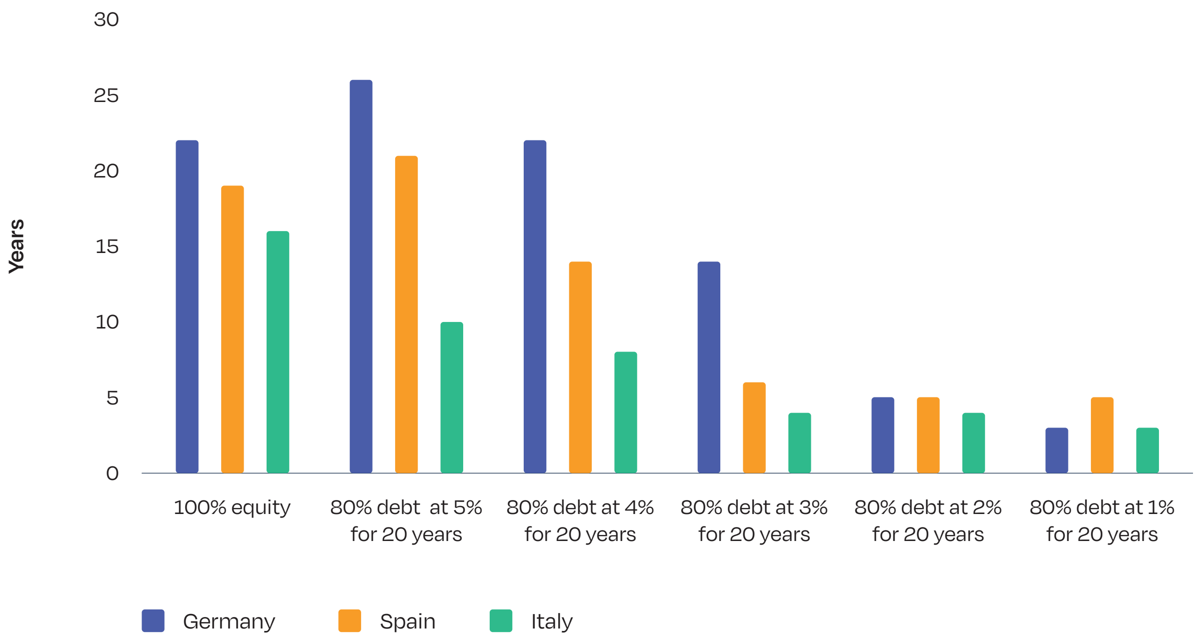
Unquestionably, interest rates impact the repayment time for debt-financed installations. Financing products at a lower interest rate than market rates are vital to accelerate solar PV + heat pump solutions, and quickly decarbonise heat. Governments can generate low interest rates for dedicated technologies through various approaches. Central banks can issue low-interest rate products for dedicated technologies, for example via green loans. Furthermore, they can offer guarantees or insurances, reducing the risks for lenders and accordingly, reducing interest rates for customers. Governments may also lend directly to customers, at interest rates below products on the private market.

Our study shows that Member States should aim towards loans with 2% or less interest rates. With such rates, the initial investment made by households can be repaid within 5 years, while the savings made on energy bills are higher than the reimbursement of the loans. Fig. 30 shows different cashback times depending on distinct debt levels and interest rates. Assuming a 4% cost of equity, interest rates influence the break-even period more than any other policy instruments, ranging from 25 years in Germany for a system financed at 80% with a loan at 5% interest rate, and down to 5 years with a loan at 2%. Payback times in Germany are particularly sensitive to debt financing conditions because of higher total CAPEX (largest heat pump system needed, high labor cost) and higher savings (highest heat demand).

FIGURE 30 TIME BEFORE BREAK-EVEN IN THE NEW NORMAL SCENARIO



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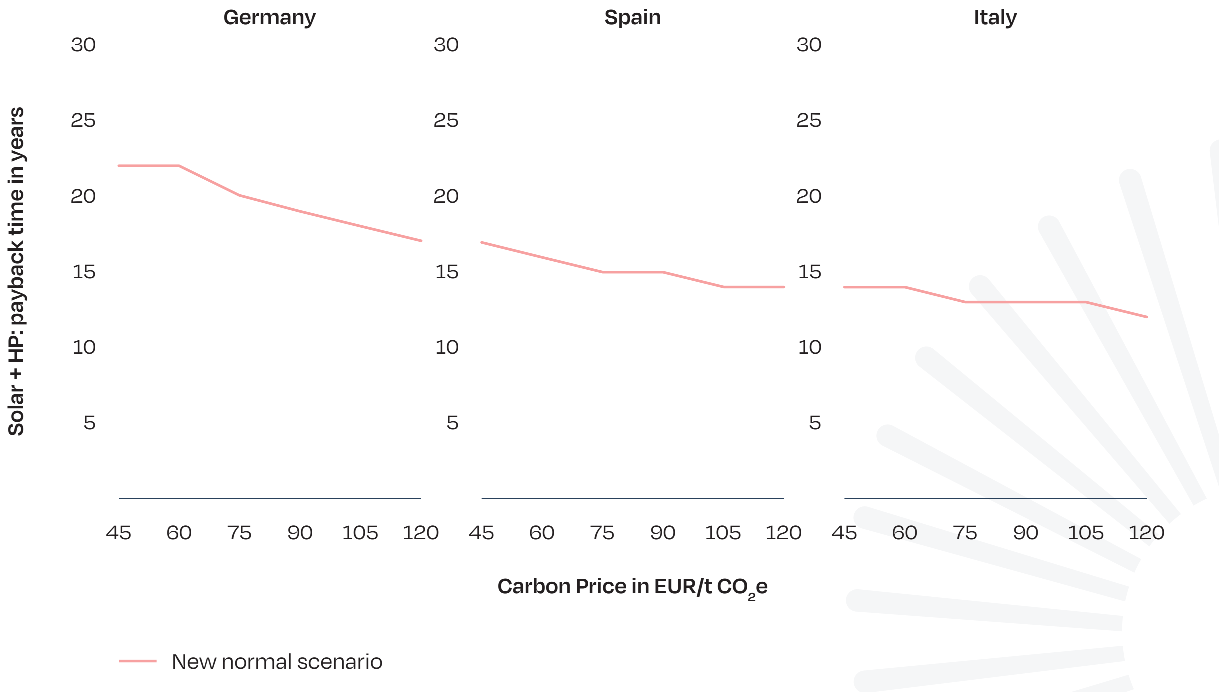
3. Member States should end all CAPEX and OPEX support for residential gas use, and countries with high heating demand should consider a carbon price floor via the EU Emission Trading System for transport and heating (ETS2). Our modelling shows that heating with solar and heat pumps is already competitive in all three markets. Fossil fuel subsidies favour incumbent, inferior technologies, even more so as the environmental costs from fossil fuels are not reflected in prices. Our modelling further suggests that carbon pricing in the residential heat sector will have different impacts across Member States. Fig. 31 shows a significant impact of gas prices on payback times for solar PV and heat pumps in Germany, but a lower impact in Spain and Italy. Germany has a comparably high heating demand; therefore, the carbon price effects monthly heating costs. Conversely, increasing costs from gas heating lower the payback times of solar and heat pump installations. Therefore, the gas price has a stronger influence on payback times in countries with high gas demand. To offset higher costs for low-income households relative to their income, governments should introduce compensation schemes. For example, the Austrian government compensates all citizens from the returns from carbon prices, which can support investment into renewable technologies.

FIGURE 31 PV + HP PAYBACK TIME IN GERMANY, SPAIN, AND ITALY DEPENDING ON CARBON PRICE



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4. Member States should promote collective self-consumption (CSC), beginning with its inclusion in the 2023 revision of the Electricity Market Design. This revision should establish a clear legal framework, including a definition, conditions for its implementation, and the rights and obligations of the parties involved. CSC allows citizens to share and receive self-generated electricity with their neighbours on a contractual basis, in an quick- and accessible manner. CSC incentivises citizens to maximise their rooftop potential as excess energy can be shared at a profit. Simultaneously, it encourages consumers to shift loads as energy rates are below retail electricity prices. While existing EU legislation for renewables self-consumption, peer-to-peer trading, and energy communities provides no guidance for CSC, the necessary framework is already successfully implemented in Portugal and France, and partially implemented in Spain, Belgium, Lithuania, and Slovenia.

Collective self-consumption incentivises households to maximise their rooftop solar installations, in turn allowing them to power a larger share of their electricity demand with self-generated energy, like heat pumps but also electric vehicles.

Matching of demand and generation profiles shows that coupling home electrification with on-site solar PV generation has important system-wide benefits. Solar can deliver 38% to 62% of the heat pump's electricity demand in a year with average weather conditions for the modelled households in Germany, Spain, and Italy. That means solar powered home electrification mitigates grid congestion, and the cannibalisation of solar generation returns. We expect this potential to increase in the future, when additional demand response technologies will bring more system flexibility.

5. Member States, including local authorities, should assess the need for electricians and installers, and set up training and upskilling programs. In addition, they should establish frameworks, both at the individual and company level, comprising of financial incentives for instance through tax reductions. These measures should be included under Member States' National Energy and Climate Plans. Limited availability of electricians was the main bottleneck for solar PV and heat pump deployment in 2022. This lead solar PV installation costs to increase by 20%, and sometimes by more as households look at installing renewable energy technologies. Having a sufficient number of electricians and installers on the market will both accelerate the deployment of renewable energy and reduce payback times.

Annex

Methodology

This report evaluates cost, savings, and payback time of households investing in new clean technologies in 2022. We looked at three cases: Case 1, a residential family house with a new solar PV system; Case 2, a house with new heat pump; and Case 3, a house with new solar PV and heat pump systems. We considered three countries Germany, Spain, and Italy, being three large European economies that have been largely dependent on natural gas for heating. We also evaluated different technologies such as heating rods and air conditioners. Heating rods represent a cheap and easily deployed heating technology, which is quite popular in a few EU countries, like Germany and Austria; AC is very common in sunny countries, like Italy and Spain. The cash flow results are based on hourly simulation of on-site loads for electricity, thermal heating and respective storage technologies as well as their interplay (e.g. to what extent excess power can be transformed to thermal heat and stored for later use). For this matter, country-specific load profiles for each of the three countries were either computed based on weather data (heat, AC, solar) or drawn from public sources (household standard load profiles for electricity). A selected overview of the assumptions made for average family homes in DE, ES and IT is presented in the table below.

The economics of such green investments were compared to our base-case, a house sourcing its entire electricity from the grid and using a standard gas boiler for heating. To assess how the energy transition can be accelerated at large scale in times of energy and climate crises, the following situation was considered: "What if we change incumbent fossil gas boilers immediately" instead of waiting for a natural rollout of gas boilers when reaching end-of-life. For this reason the opportunity cost of replacing an old gas boiler at its end of life was not taking into account for this report. While this consideration would have improved payback, a full transition away from fossil fuels based residential heating would take too long for the strongly gas-dependent countries in this report.

The report first analysed the results for PV+HP system in operation in the energy crisis year 2022 by evaluating various political and technical inputs. The current policy framework affecting energy cost in 2022 was considered for each country (VAT cuts, CAPEX support schemes, tax and subsidies on electricity, carbon pricing, price cap on electricity or gas, etc.).

TABLE 1 OVERVIEW OF TECHNOLOGY CHARACTERISTICS CONSIDERED PER COUNTRY

PARAMETER	UNIT	DE	ES	IT
Power demand excl. heat	kWh_el/year	4,500	4,000	4,000
Thermal heat demand	kWh_th/year	20,000	12,000	14,000
PV capacity (optional)	kWp	8	7	7
HP capacity (optional)	kW_el	7	3	4
AC capacity (optional)	kW_el	-	5	5

To understand the economic performance of these operating system in the future, annualised savings and payback times were evaluated for the next 10 years. In a volatile future electricity and gas price market, the analysis was based on three commodity price scenarios: The Fossil Dumping scenario, New Normal Scenario, and Return-to-Crisis scenario each draw a different pathway for future prices of electricity and gas. The price levels of the scenarios are based to a great extent on future prices observed at energy exchanges (e.g. EEX, TTF) at the time of modelling (beginning of February 2023):

- Fossil Dumping
  - Electricity price: minimum yearly EEX baseload price[14] of the next 10 years
  - Gas price: €20/MWh ('pre-crisis level')
- New Normal
  - Electricity price: average yearly EEX baseload price of the next 10 years
  - Gas price: average price of the next 10 years according to TTF and Henry-Hub futures (for LNG gas imports from US)
- Return-to-Crisis
  - Electricity price: average of the 2024-2025 EEX baseload prices ('crisis level')
  - Gas price: average of the 2024-2025 TTF prices

All prices shown in the Table 2 below represent long-term average price levels for the entire payback period, derived from different long-term scenario trends. Single-year commodity price fluctuations are not considered, albeit they may have significant impact on payback times.

While the Fossil Dumping scenario describes a scenario in which Europe would return to gas prices as low as the pre-crisis level, the Return-to-Crisis scenario assumes long-term average prices to establish at a price level currently observed for the years 2024-2025. These years are widely perceived as 'still-in-crisis years', since the ramp up of LNG import capacities in Europe and export volumes from suppliers on the world market is still marked by uncertainty. However, the assumed price levels are still much lower than price peaks observed in the 'peak crisis year' 2022. Both scenarios provide a stress-test to the results of the New Normal scenario, which represents a 'best guess' based on the current average price expectation of future market traders.

TABLE 2 ELECTRICITY AND GAS PRICE LEVELS IN THE THREE SCENARIOS.

PARAMETER	UNIT	SCENARIO	DE	ES	IT
Wholesale gas price	EUR/MWh	Return-to-Crisis	61	60	59
Wholesale gas price	EUR/MWh	New Normal	35	36	35
Wholesale gas price	EUR/MWh	Fossil Dumping	20	20	20
Wholesale electricity price (baseload)	EUR/MWh	Return-to-Crisis	165	104	161
Wholesale electricity price (baseload)	EUR/MWh	New Normal	121	66	123
Wholesale electricity price (baseload)	EUR/MWh	Fossil Dumping	107	50	109

14 Baseload prices are used to determine the general electricity price level. The wholesale price household pay for their consumption or receive for their solar feed-in depends on the hourly price structure and the hourly load profile. Profile value effects were quantified based on the country-specific hourly day-head price structure in 2022.

For the modelling it was assumed that PV, HP, PV+HP are purchased 100% on equity with 4% cost of equity. As households often buy these systems on debt, in one case study we also have estimated different financing options, notably with the option to finance part of the new system via a loan.

Finally, our Capex assumptions for solar PV, heat pump and heating rod are displayed in the Table 3 below. In the current inflationary context, price evolution can changes quickly and substantially impact the final results.

TABLE 3 CAPEX ASSUMPTION FOR SOLAR PV, HEATING PUMP

	UNIT	CAPEX EXCLUDING VAT
Solar PV	EUR/kWp	1,600
Heat Pump (Germany)	EUR/kW_el	1,975
Heat Pump (Spain)	EUR/kW_el	2,356
Heat Pump (Italy)	EUR/kW_el	2,190

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