Residential PV replacements offer an opportunity that heat pumps should not miss

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Abstract

Incentives, building regulations and energy prices all have a major impact on the heat pump market.
High electricity prices undermine the competitive advantage resulting from a heat pump's efficiency.
Heat pumps are energy-efficient and can only increase their role in reducing heat related CO2 emissions as decarbonisation of the grid progresses.
Unfortunately less CO2 intensive electricity is also linked to rising residential electricity tariffs.
On their pursuit of a decarbonised grid European governments have, to varying degrees, supported sales of distributed energy generation systems, mostly in the form of Photovoltaics (PV).
The vast majority of the PV systems have been installed in the last 5-6 years and will start becoming due for replacement around 2025.
By that time, progress towards decarbonisation of electricity production is likely to push end user electricity prices to ever higher levels.
Governments and utilities will have a strong interest in maintaining the installed decentralised PV generation capacity, as this will account for fair share of the total electricity needs.
The expected push towards the replacement of installed Photovoltaics will represent an opportunity for heat pumps. Offered together with PV as a system they will become attractive to:

- end users – a low cost option for provision of heat and domestic hot water,
- utilities – a good tool to balance the smart grid demand/response system,
- governments – a way to make progress with the decarbonisation of heat within existing dwellings.

A combined PV and heat pump system where smart controls allow real-time communication with the electricity provider has a potential to become a win-win solution for all parties involved.

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Key Words: heat pumps, potential, combined system

1. Introduction

Heat pump markets tend to respond to a few specific drivers. Legislation and purchase incentives feature among the drivers that have been considered most important over the years and, historical sales trends certainly underline their weight.
Nevertheless, changes in the economic environment, in the way energy is produced and in the way consumers relate to their homes have all highlighted the importance of other drivers, notably energy prices, operating costs and the ability to control energy-related spending.

2. Price of electricity, spark and their combined impact on heat pump sales

The price ratio between electricity and gas for the residential end user has not been much noted at the initial

commercialisation stage of heat pumps. While fossil fuel prices were seen as volatile at the beginning of the century, the price of electricity remained stable, offering consumers a sense of "security".
Nevertheless a combination of various events has caused significant changes in the price ratio between electricity and gas, otherwise called the "Spark", resulting in a strong increase in the importance of this factor. The drive towards grid decarbonisation, with renewables increasingly integrated into the energy generation process, has been one of the main factors that has had a strong implications on prices.

In Germany and France, the two main European heat-pump markets, this has resulted in a level of taxation that has been added to the price of electricity in order to cover the cost related to the governments' grid decarbonisation targets.
The value of the German tax called EEG Umlage has increased more than 12-fold within the last ten years and it now accounts for around 22% of the residential end-user electricity price per kWh.
In France the CSPE (called "new CSPE" from 2016) has increased by a factor of 5 in the same timeframe, and now accounts for over 13% of the total average price for French domestic consumers.

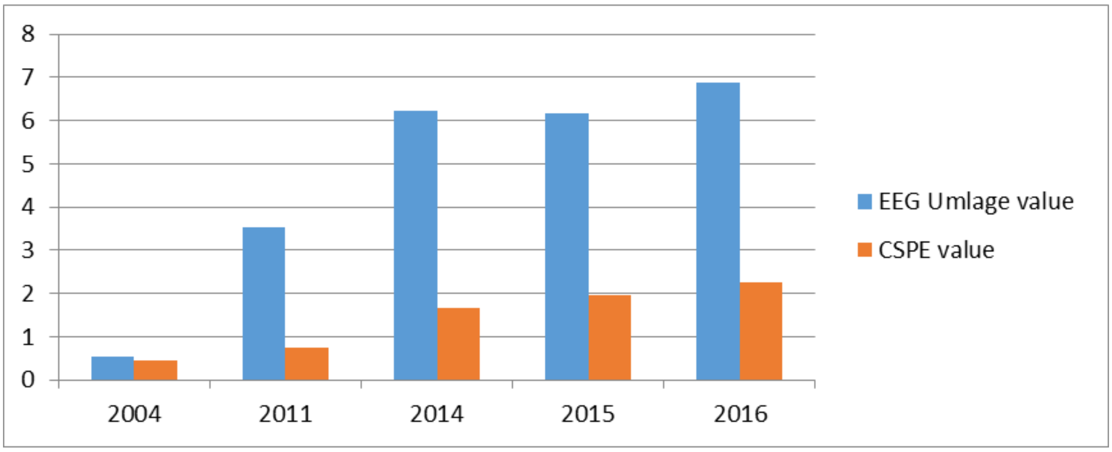

Figure 1: The value of the German and French RES taxation, Eurocent/kWh, 2004 – 2016 (until October 2016) (source: de.statista.com / one.edf.fr)

Continuous increases in taxation were accompanied by the collapse in price of fossil fuels observed at the end of 2014, increasing the gap between the price of gas and electricity that residential end users need to pay.
The impact of the electricity price increases and of the growing Spark can be observed when analysing the historical development of heat pump sales in both the German and French markets.
The two countries have been chosen as they represent two most important heat pump markets in Europe but also because they represent opposing extremes in terms of both electricity prices and the CO_2 factor for electricity production.

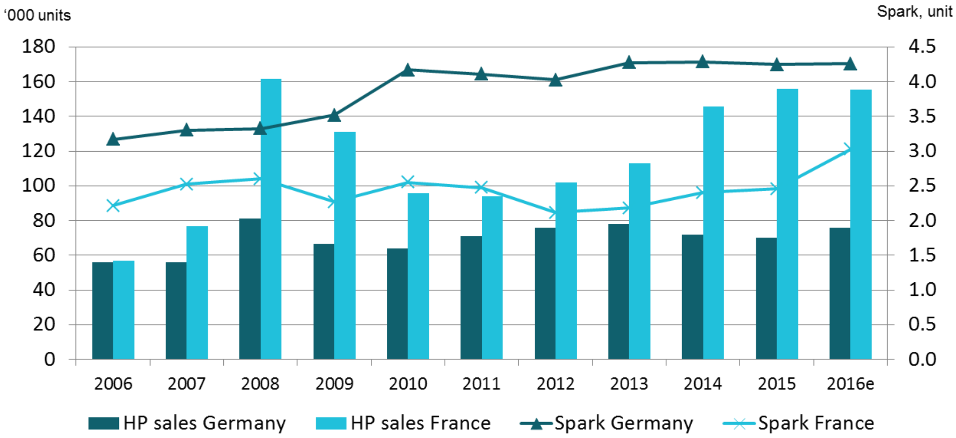

Figure 2: Sales of hydronic heat pumps in Germany and France against the electricity / gas price ratio, units, 2006 – 2016(e)(*Source: BSRIA)*

In Germany, where the price of electricity has been increasing rapidly and where the Spark increased dramatically in 2010 surpassing a factor of 4, the heat pump market has been struggling since then, forcing the government to provide stronger incentive programs. While these incentives are helping the sales of heat pumps, the high Spark is nonetheless undermining their efficiency factor, resulting in higher running cost that is in turn reducing their competitiveness in the market. Increasingly stringent building regulations are also helpful as they are gradually eliminating competition from boilers in the new-build segment. Nevertheless high running cost are damping customers' enthusiasm for heat pumps and encouraging them to look for alternatives.

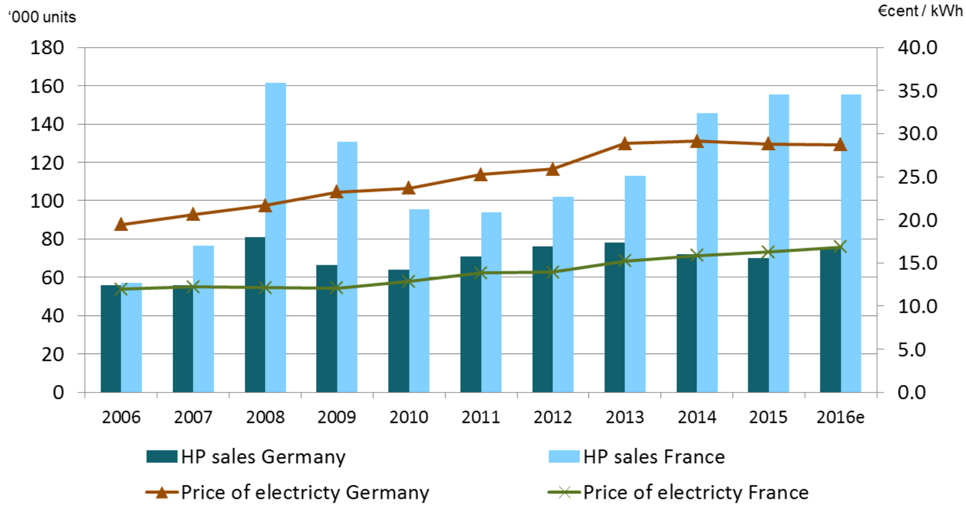

Figure 3: Sales of hydronic heat pumps in Germany and France against the price of electricity to residential end user, units, 2006 – 2016(e) (*Source: BSRIA)*

France has for a long time enjoyed some of the lowest consumer electricity prices in the EU. The price difference between gas and electricity has therefore been much lower, supporting sales of heat pumps. The market was badly hit by the fall-out from the economic crisis between 2008 and 2010 and only started to recover in 2012 with the Spark has been close to 2.The market saw some positive developments between 2012 and 2015 but despite the constant presence of the tax credit incentive, the only significant sales increase resulted from the growth in sales of domestic hot water heat pumps, while space- and combined heating heat pump sales have stalled. Moreover, in 2016 a small decrease in heat pump sales was expected in France. It is worth noting that in that year the price ratio between electricity and gas reached a factor of 3, resulting from continuous increases in electricity prices combined with a stable, low price for gas.

3. Heat pump and pv installed together reduce energy bills

The price of electricity and its ratio to the price of gas have a direct impact on the competitiveness of heat pumps compared to widely used gas heating technologies.
In Germany, where the price of electricity is among the highest in Europe, an average air-to-water heat pump reaching an SFP of 3.5, installed in an existing dwelling with an average level of insulation is more expensive to run than a high-efficiency gas condensing boiler installed in this same dwelling *(values for the first half of 2016)*.
The same heat pump installed in similar conditions in France, where the price of electricity is still well below the EU average, represents a more economic option in terms of running cost to the end user.
Nevertheless, even in France, constantly rising electricity prices undermine consumer confidence in heat pumps, which is impacting on the drive to install such systems and ultimately depressing sales, as seen in figure 3 above.

Energy bills can change significantly for households that run heat pumps in combination with a photovoltaic system.

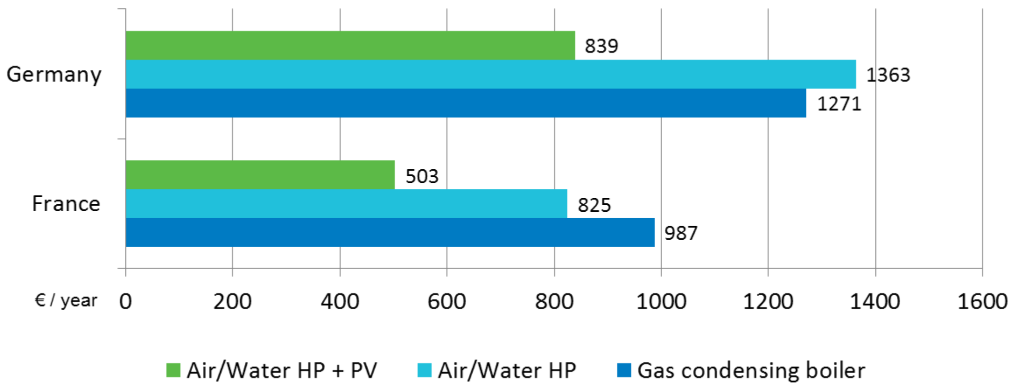

Figure 4: Yearly energy cost in existing dwellings, € / year (*Source: BSRIA)*

A significant reduction in overall household energy costs is achieved thanks to the efficiency of the heat pump combined with the impact of feed-in-tariffs available for residential distributed energy generation systems. The level of own-consumption taken into account for the purpose of this calculation is relatively low (around 35% in both countries).

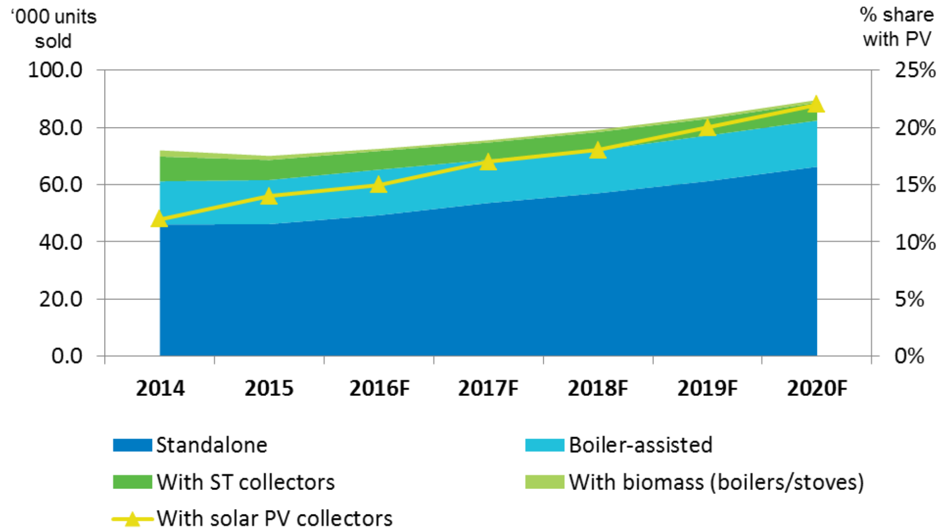

Figure 5: German heat pump market by type of installation, 2014 – 2020f *(Source: BSRIA)*

In Germany sales of domestic PV systems have been supported by generous feed-in-tariffs in the wake of the decision to close down nuclear power stations and increase the share of renewable energy sources in German electricity production.
The vast majority of systems installed have therefore been feeding electricity into the national grid rather than consuming it on site. Own consumption has also been limited for some time by the lack of appropriate storage. Nevertheless with decreasing feed-in-tariffs and increasing electricity prices customers have appreciated the advantages of consuming self-produced electricity on site. Increasing availability of storage batteries for residential PV systems at competitive prices has extended the potential for own use for consumers.

In 2015 some 14% of heat pumps sold into the German market were installed in households equipped with PV systems. This share is forecast to increase to 22% in 2020.

In France, where until today heat pumps still offers cost advantages over gas boilers, the link between installation of a heat pump and a PV system is not yet fully appreciated by the end user. Only around 2% of heat pumps were installed with solar PV system in 2015 and even though the overall French heat pump market is much larger than the German one, this currently represents a negligible number. Nevertheless, as electricity prices continue to rise and as feed-in tariffs for PV gradually decrease, the number of such installations is forecast to increase fourfold by 2020.

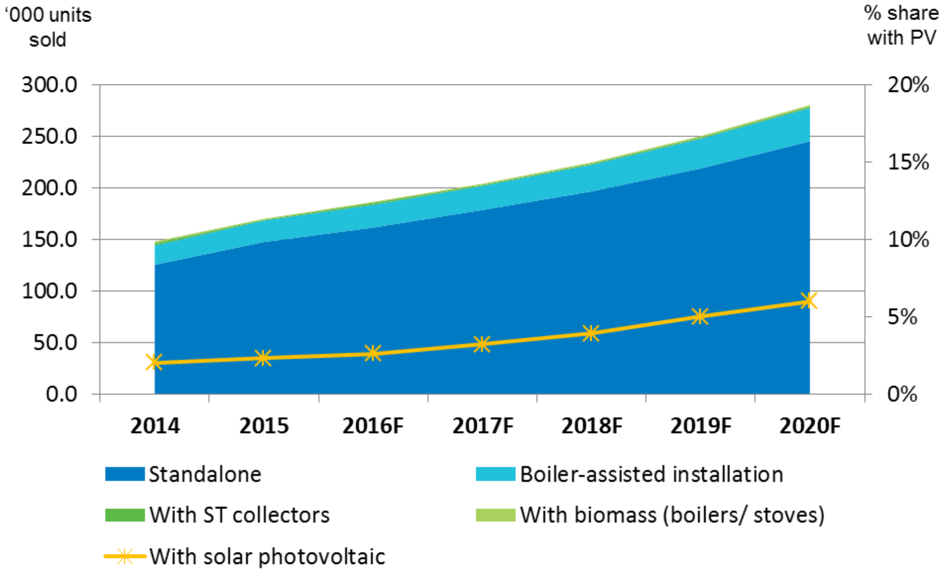

Figure 6: French heat pump market by type of installation, 2014 – 2020f (*Source: BSRIA)*

4. Decarnonised grid and prospects for CO_2 neutral heating

Heat-pumps are energy-efficient and support efforts to reduce the overall use of energy in households. They will also play an increasing role in reducing heat-related CO_2 emissions as decarbonisation of the grid progresses. Both countries have ambitious targets regarding the decarbonisation of the grid. In Germany the share of RES in electricity consumption should reach 35% in 2020, 50% in 2030, 65% in 2040 and 80% in 2050.
With RES accounting for 32.5% in 2015, Germany is well on its way to achieving the first target.

The decarbonised grid is giving the heat pump a powerful advantage, representing as it does a low CO_2 polluting heating system.
Examples from Germany and France have been taken to make a point, with Germany currently representing a CO_2-heavy generation process for electricity, and France representing a low CO_2 emission process. The calculations supporting the graph below are based on the standard emission factors published for Europe and European countries by Covenant of Mayors based on 2012 values. For both Germany and France the factors have changed since (decreasing from 0.624 in 2012 to 0.535 in 2015 for Germany and climbing slightly from 0.056 in 2012 to 0.092 in 2016 for France) but the difference between the two countries is still significant.
The yearly amount of CO_2 emissions is calculated for heat pumps running in existing households with similar characteristics in both countries and compared to the level of CO_2 emitted by the same household if fitted with a high efficiency gas condensing boiler.
As seen in a French example, a heat pump running on electricity generated with very low CO_2 factor, replacing a high efficiency gas boiler in an existing household can save around 13 times the level of CO_2 emissions.

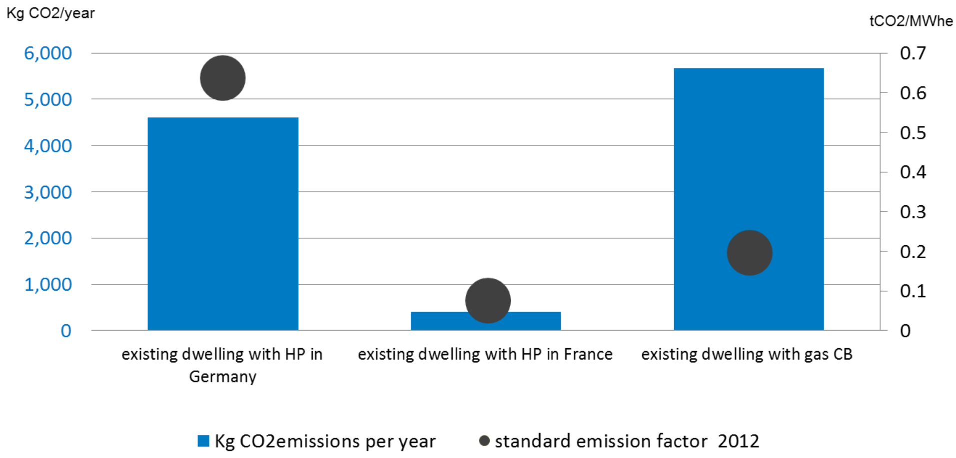

Figure 7: Level of CO_2 emissions for households fitted with either A/W heat pump or gas condensing boiler in Germany and France *(Source: BSRIA)*

As countries increase their share of renewables in electricity generation reducing their electricity CO_2 factor, the potential represented by heat pumps as a future replacement for fossil fuel boilers should not be overlooked.

5. PV an opportunity for heat pumps

In many countries photovoltaics have been identified as an important tool to achieve greener electricity over time. The share of solar production in energy generation will grow in Europe in the years to come, and rooftop systems will account for the majority of the newly added capacity in the short to medium term *(source: New Energy Outlook 2016, Bloomberg New Energy Finance)*.

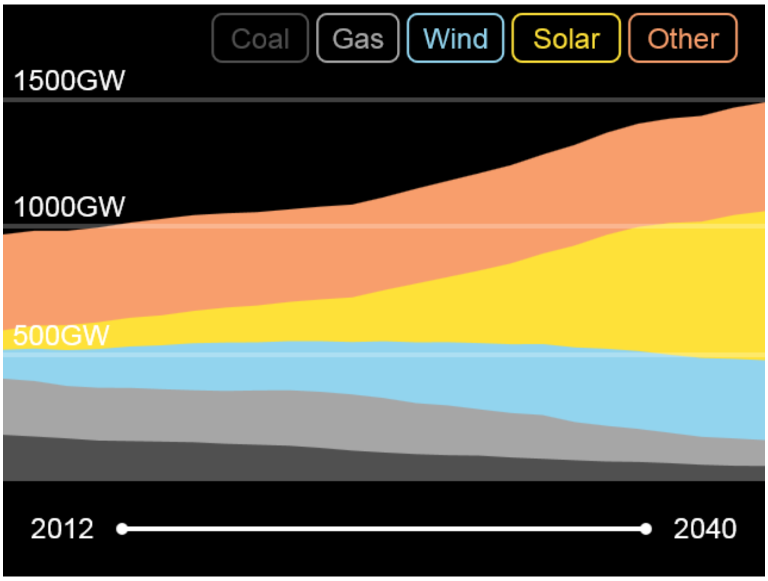

Figure 8: Europe total installed capacity by technology (GW) *Source: bnef.com*

Residential systems installed in the 6 largest European PV markets (Germany, Italy, UK, France, Spain, Belgium) accounted for roughly 13GW of electricity production in 2014, translating into some 4 million systems installed. A large proportion of these have been installed in the last six years but in some countries, particularly in Germany, a fair number of systems were installed well before 2010.
PV panels have a long lifetime of over 20 years and although they usually maintain quite a stable performance for their lifetime (after a small dip in efficiency sometimes recorded in the first year after installation) they often experience a significant amount of physical decay (yellowing, laminate peeling off) in such a long period of operation. It is therefore expected that between 2022 and 2032 an increasing number of residential PV

installations will need to be replaced.
A large number of PV systems that will be coming due for replacement, particularly in Germany, Belgium, UK and France, are installed in dwellings that are fitted with either fossil-fuel-based or inefficient direct electric heating systems. So far the efforts to replace existing systems with heat pumps have enjoyed only a modest success across Europe. Proposing a combined PV / heat pump system has a potential to change this.
PV systems play a crucial part in the clean energy transition. Progressive decarbonisation of the grid is giving heat pumps a growing potential to save a substantial amount of CO_2 emissions by replacing existing inefficient fossil-fuel-based systems.
Nevertheless, while this is likely to remain a prime motivation for government action, it will most probably not in itself provide sufficient reason for end users to change their current way of heating their homes.

High electricity prices are a detrimental factor in the heat pump market and with ambitious targets for integration of RES into electricity production they are likely to remain the case for the foreseeable future.
It is likely to keep the Spark (ratio between electricity and gas price) at a high level, putting pressure on the efficiency that heat pump needs to achieve in order to maintain a competitive operating cost compared to a boiler.
In an existing house, this level of efficiency can be achieved given the right operating conditions, but usually it involves additional investment to improve house insulation and heat distribution system.
As shown before, combined PV and heat pump installation currently offers the potential to significantly reduce a household's energy bill, resulting in a reasonable payback for the investment.
The latter becomes an important factor in the end user's decision making process, as clients are learning to consider their choices less in terms of the ' pain' of an immediate outlay and more as an investment for which the 'gains' will be spread over time.

A heat pump installed alongside a PV system can currently provide competitive energy bill to end user. Nevertheless an analysis comparing the advantages over a period of time, taking into account changing both electricity prices and the level of support for FiT, highlights a few concerns that need to be taken into account in future policy making processes.

In Germany, the price of electricity rose by an average of 2.6% per year between 2012 and 2016, while the level of FiT decreased by an average of 7.8% per year. In the same period the price of gas to the residential end user increased by 1.2% a year. Such dynamics resulted in a weakening of the economic impact of combined PV and HP installations on household energy bills when compared to gas condensing boilers from nearly 50% in 2012 to 36% in 2016. If similar trends continue until 2020 the advantage of the impact that a combined PV and HP system has over the gas condensing boiler will shrink to less than 20%.

In France, the increase in electricity prices between 2012 and 2016 was even greater, reaching 4.9% per year on average. The price of gas decreased by an average of 4.1% a year in the same time period and feed-in-tariffs fell by 3.7% per year on average.
All this has had a big impact on the competitiveness of heat pumps as well as that of combined PV and HP installations. While in 2012 the energy bill for a household fitted with PV and a heat pump was 70% lower than the energy bill of a household fitted with a gas condensing boiler, by 2016 this advantage had been reduced to 49% and if the same dynamics in price changes continue, it would fall to 33% by 2020.

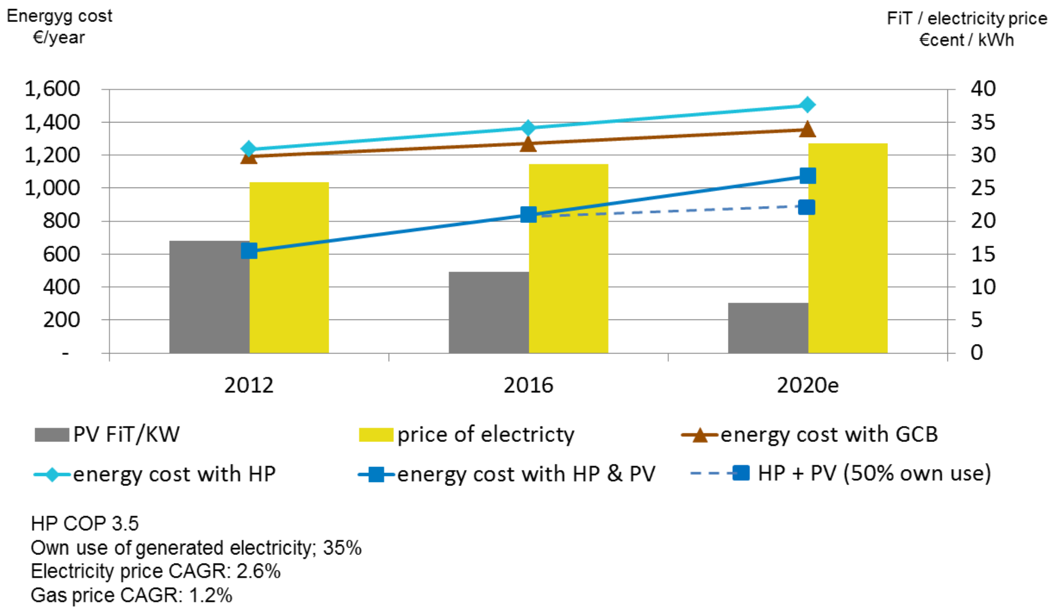

Figure: 9 Germany, existing dwelling, household energy cost in relation to the changing FiT and electricity price *Source: BSRIA*

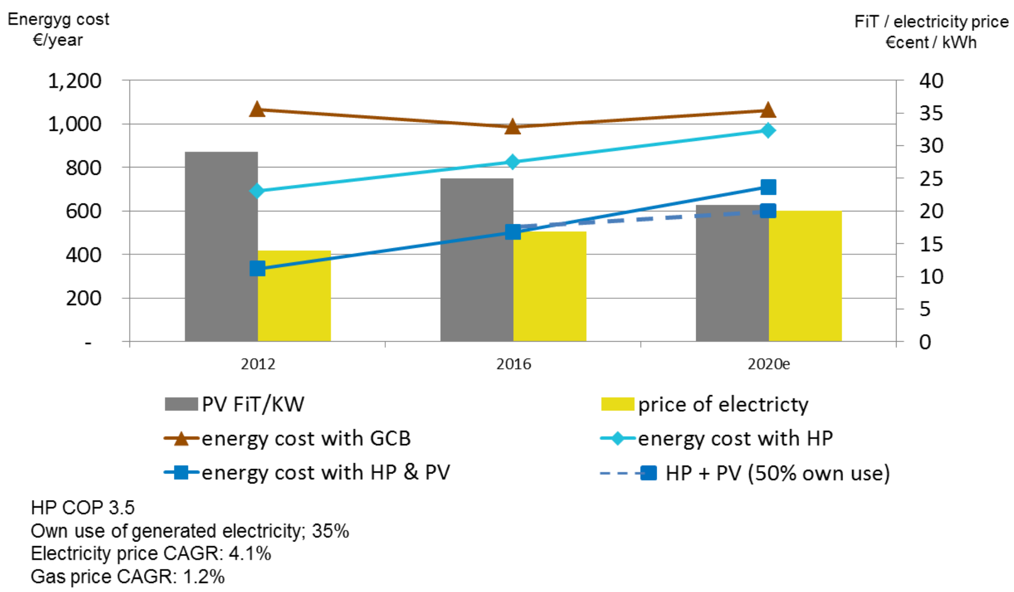

Figure 10: France, existing dwelling, household energy cost in relation to the changing FiT and electricity price *Source: BSRIA*

It is important to bear this development in mind since if the dynamics in electricity prices, gas prices and the level of feed-in-tariffs continues in its current direction we might be heading for a future where countries will produce CO_2 lean, green, electricity but the vast majority of their existing heating systems will still be running on much more CO_2 heavy gas devices because this will make more economic sense for the end user.

The advantage of combined PV and HP system can be protected against the decrease of feed-in-tariffs and increase of Spark if end users have the opportunity to consume more of the generated electricity on-site. With 50% of own generated electricity consumed on-site, instead of the current 35%, the household's energy cost would be reduced by some 11%.
Similar effects can be achieved by offering a reduced electricity price for the operation of the heat pump – an idea that has already been successfully explored in Germany during early years of the dynamic heat pump

growth in the country.

6. The potential impact of domestic energy storage

More extensive consumption of the on-site generated electricity has been prevented by the perceived absence of on-site battery storage that is cost effective for residential and light commercial applications.

In Germany there is a small but rapidly growing market for domestic battery storage. However, in 2016, of an estimated 13 million plus single family homes in Germany, only some 1.6 million deployed solar PV, and of these, some 34,000 had installed some kind of battery storage, according to research by EuPD Research published on the financial advice site www.finanztip.de. This represents only around 0.3% of potential households.

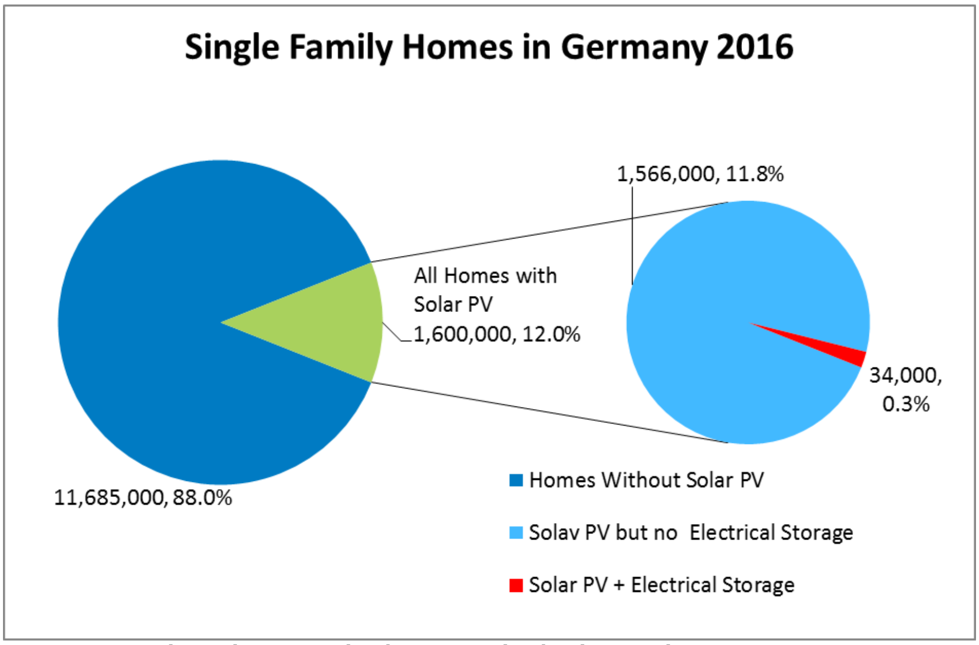

Figure 11: German Single Family Homes and Light commercial with Solar PV and On-Site Energy Storage – January 2016
Sources: Statistiches Bundesamt, EuPD Research, BSRIA

The same source forecasts that the implementation of electrical storage for residential and light commercial buildings will more than double, to reach 75,000 by 2020, representing compound growth of more than 55% annually, but this will still represent only a very small fraction of all Solar PV installations, let alone of all single family homes in Germany.

Even if this high rate of compound growth continues for the next 25 years, the proportion of single family homes with solar PV and local electricity storage would still not have reached even 3% by 2050. It follows that either major incentives or a major breakthrough in technology and in public perception will be needed if energy storage is to support the uptake of combined PV and heat pump systems in the medium term, even in a relatively advanced market like Germany.

7. Combined pv and heat pump installations can support smart grid in the future

The increased share of RES in energy generation results in high levels of fluctuation in energy availability and developments aimed at introducing a smart energy distributing grid that can match availability to demand are already well into the trial phase. Findings from the Customer Led Network Revolution trial completed in 2014 by Northern Powergrid and partners in the UK has proved that customers who have their own PV systems fitted were successful at adjusting their electricity usage to take advantage of their own generation and were the most engaged customers of all *(source: Customer-Led Network Revolution – Conclusions).*
As utilities often voiced concerns about the increased load with higher numbers of heat pumps installed, a

combined PV- heat pump – energy storage system can provide the potential to improve management of the grid's electrical load.

Although this is still an area for further research and trials, a combined PV / HP & storage systems where smart meters and controls allow a real time communication with electricity provider has potential to become a win – win solution for all parties involved, paving the way towards a stronger level of market uptake.

8. Conclusions

As a long term replacement of fossil fuel boilers, heat pumps have the potential to save an increasing amount of CO_2 emissions in the future but their uptake depends heavily on their competitiveness in terms of providing an operating cost advantage to the end user.

The installation of a heat pump along with a PV system gives the end user potential to benefit from just such an economically advantageous system.

Installed PV systems will become due for replacement at a gradually increasing rate hence combined PV and heat pump systems can be offered to maximise the economic benefits for households and accelerate the pace of replacement of existing fossil fuel systems.

PV owners are engaged and can play an important part in mitigating the load or by adjusting energy availability to demand, a process that can be reinforced if a combined PV, heat pump and storage system is installed.

Local energy storage in homes or light commercial premises has the potential to provide a further boost to the cost-effectiveness of heat pumps when combined with solar PV. However the current uptake needs to rise very rapidly over a long period in order to make a serious impact.

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