Evaluating Savings from Boiler Replacement

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Abstract

Observed savings of fuel and costs through boiler replacements are important in two ways: They allow the prediction of savings from promoting high efficiency boilers after current average life-times or even after early replacements. And boiler replacements, but only if successful, bring economic benefits to home owners and cut greenhouse gases for all.

Such predictions of the impact of single, rather than of multiple measure refurbishment projects are difficult to come by, covering observed fuel consumption before and after, adjusted for heating degree days.

Out of 2,197 boiler replacements observed through co2online's Energiesparkonto (interactive Energy Savings Account iESA), 80 were single measures and had complete data on natural gas consumption for three years in a row (one year before, one during, one after replacement).

Natural gas consumption changes after replacement ranged from -50% to +10%, and specific consumption cuts per heated floor space, coming from 140 kWh/m2,a „before", ranged between +10 and -40 kWh/m2,a „after", all adjusted for heating degree days. Obviously, home owners who achieve little or no reduction of fuel consumption at all after replacement suffer severe financial and welfare losses.

Two potential causes for such deficiencies are discussed: One reason is malpractice by installers, in particular lack of diligence in adapting the boiler to the individual building, an essential to reap the benefits of modern boiler technology. The second reason for little to no savings may be the good performance of the "old" boiler. In such cases early replacement clearly damages the home owner's wealth.

On average, only 24 kWh/m2 of heating energy consumption were saved and the average return on investment was a disappointing 0 %, which means that all new boilers saving less the 24 kWh/m2 had a negative return on investment, assuming an average price increase of natural gas of 5% for the next 20 years.

For better results, measuring boiler efficiency before deciding about replacement, better installation and hydraulic balancing are suggested. Otherwise net present value losses of 2-3 bn Euro per year may persist in Germany alone, suffered by one in two of all 550,000 boiler replacing home owners.

Introduction

Boiler replacement rates in Germany stagnate at a low 3% per year – despite of subsidized loans from KfW (the German Subsidy Bank) and despite the prospects of rising fuel prices (which make boiler replacement more and more profitable) and despite the urgent needs to raise the efficiency of the German boiler stock as a crucial element of our "Energiewende".

To improve the situation, old and inefficient boilers should to be replaced early, before they are broken and stop functioning. But exactly that does not happen.

A major reason for this reluctance of German home-owners is the high economic uncertainty regarding the decision to replace a boiler. As we show, the average homeowner can hardly foresee whether his/her new boiler will be a cash burner or a cash cow - and as main causes for this we suspect poor planning and faulty installation.

As a result, we will argue that the process of boiler replacement will only speed up and support the German "Energiewende" (energy transition), if this uncertainty can be reduced.

This can be done in two ways:

- Loans and grants with higher subsidy-value could undoubtedly reduce the economic losses caused by a poorly performing new boiler – quasi insuring home owners with tax money against malpractice by installers.[1]
- By reducing the uncertainty itself. This requires better skilled installers and more diligence in their work – or measuring the boiler efficiency before making the decision to replace it. Based on this measurement a reliable forecast of efficiency gains is possible – and thus a reliable prognosis of the economic benefits arising from an early replacement of an old but still functioning boiler. Ex-ante measurements are costly – but they help to avoid damages arising from faulty decisions and from installers doing a poor job.

To illustrate the argument, we first look at the performance of recently replaced boilers in German homes. Our analysis is a statistical one: so far we have not yet been able to do an in depth-analysis of the technical causes for the poor or good performance we observe. [2]

The data source is the interactive Energy Savings Account (iESA), a cost-free monitoring service for heating and electric energy consumption offered by co2online as a free service (thanks to German and EU funding). In total, 78,000 households in Germany and in 8 more EU countries have registered by May 2014.

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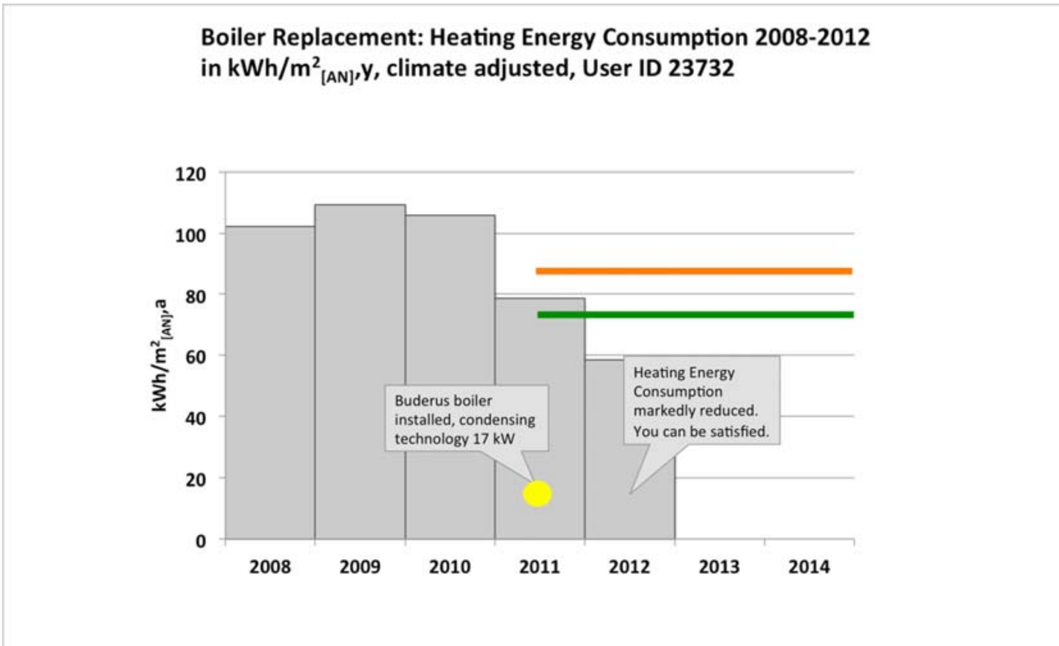
[1] The Green Deal promoted by the UK Government gives financial relief and at the same time reduces the economic risk arising from setbacks in refurbishment: "You can make energy-saving improvements to your home or business without having to pay all the costs in advance. You have to pay back the cost of the improvements over time because the Green Deal is a loan, not a grant. However, the "*savings on your energy bills after you've made the improvements should cover the repayment of the loan*." https://www.gov.uk/green-deal-energy-saving-measures. Likewise: "The amount you pay back will be no more than a typical household will save on heating bills, so you are likely to be better off overall from day one." www.energysavingtrust.org.uk/scotland/Take-action/Find-a-grant/Green-Deal-and-ECO

[2] Such a study we kicked off on June 13th, 2014, first results are expected by November 2014.

The iESA stores data from heating energy bills, meter readings (manual or automated) and displays the development of climate-adjusted heating energy consumption as depicted in the following graph.

Figure 1:

Development of heating energy consumption of a single family building in Germany

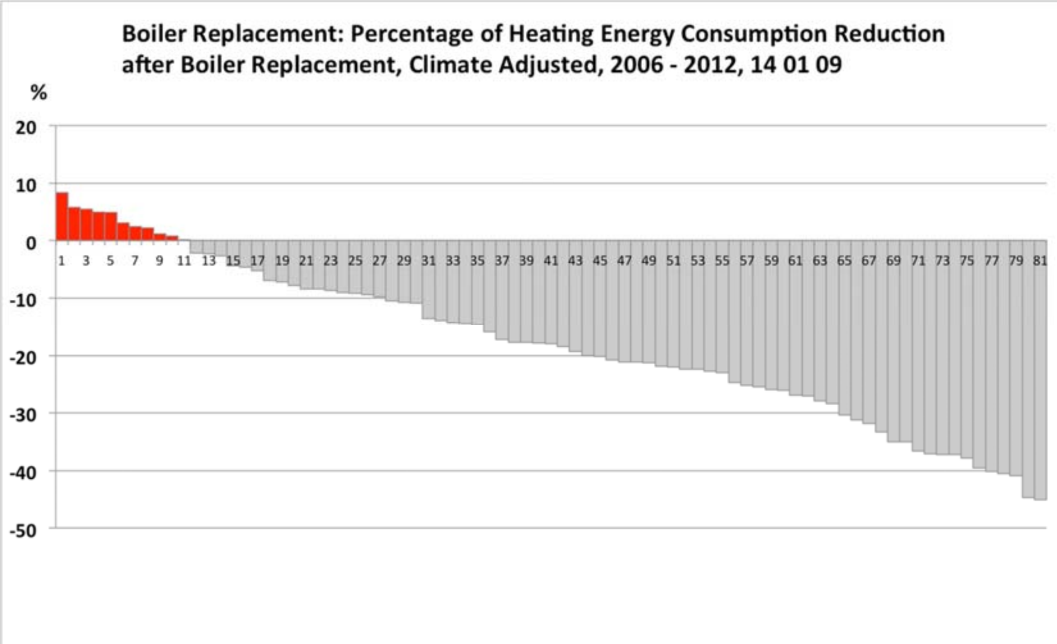


Here a considerable reduction of 52 kWh/m^2,y in heating energy consumption is observed after boiler replacement in the year 2011. (Any consumption after replacement below the green bar is "best practice" compared to the sample, while between orange and green re-checking is justified – and above orange strongly recommended, more on pp. 6-7)

Now let's look at a sample of 81 homeowners who did the same and gave us a complete 36 months record of energy consumption figures. These 81 homeowners only replaced the boilers and did not take any further energy saving measures.

Figure 2:

Percentage Change of Heating Energy Consumption after Boiler replacement



As figure 2 shows, there is a wide range from "successful" to "failed" boiler replacements – judging on the percentage change of heating energy consumption. Our first surprise was that 10 per cent of all replacements showed increased heating energy consumption after the replacement had taken place (all data are climate-adjusted using local heating degree days). But we also realized that looking at the percentage is not really fair and clever for judging the success or failure of a replacement – because reducing the heating energy consumption from an already very low level is much more difficult than reducing the excessive consumption of an old building. So we looked at the relationship between the initial heating energy consumption and its changes after the installation of a new boiler.

Figure 3:

Scatter Cloud of Heating Energy Consumption before Boiler Replacement and Reduction of after Replacement

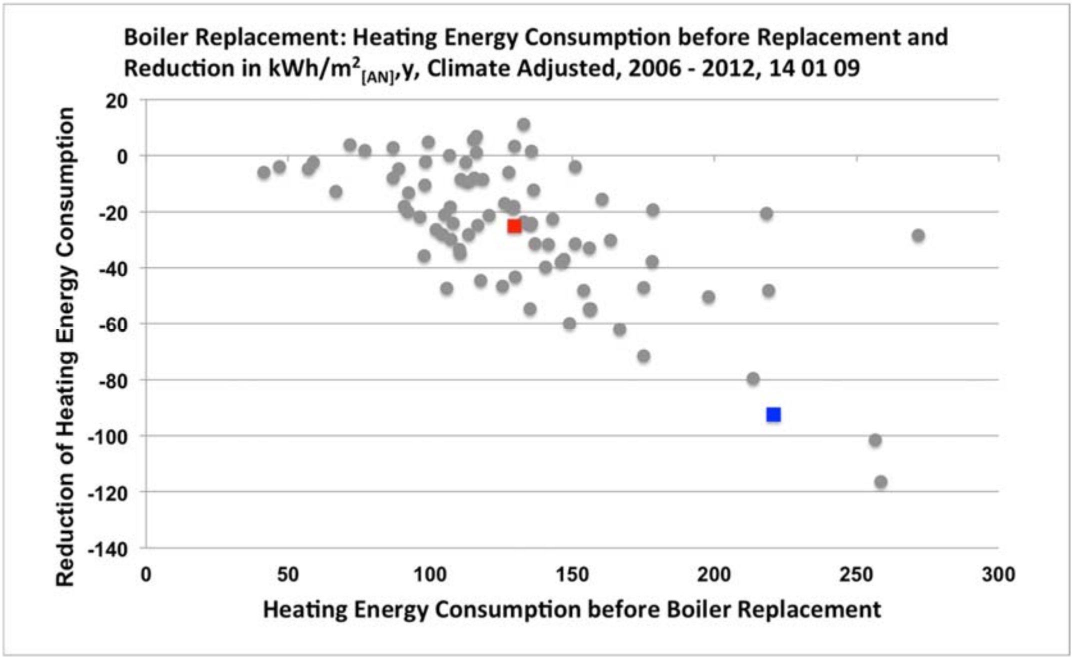


Figure 3 gives a more appropriate picture of the replacement impact. (The red dot marks the sample average, the blue dot marks the average reduction claimed by the boiler manufacturers association (BDH) from the German average consumption before boiler replacement, see footnote 3) Basically, a very rough proportionality between the heating energy consumption before replacement and the change achieved afterwards can be seen. And there is also a virtual diagonal line going from Northwest to Southeast (roughly 40/-5 to 230/-115), a limit, which is not being passed by any replacement. All replacements that come close to this virtual limit apparently exploit the maximum technical potential, which lies between the old (low degree of efficiency) and the new boiler (high degree of efficiency).

For all replacements more distant from this virtual limit, it would be faulty to conclude that their technological potential was not exploited. It would be faulty, because we just do not know whether those disappointing reductions of the heating energy consumption result from mistakes around the installation process or whether the “old” boiler was still performing so well that replacement could not bring any more improvement. We just don’t know.

Since co2online’s task is to help citizens to save energy and money, we had to derive some practical consequences from theses stunning insights.

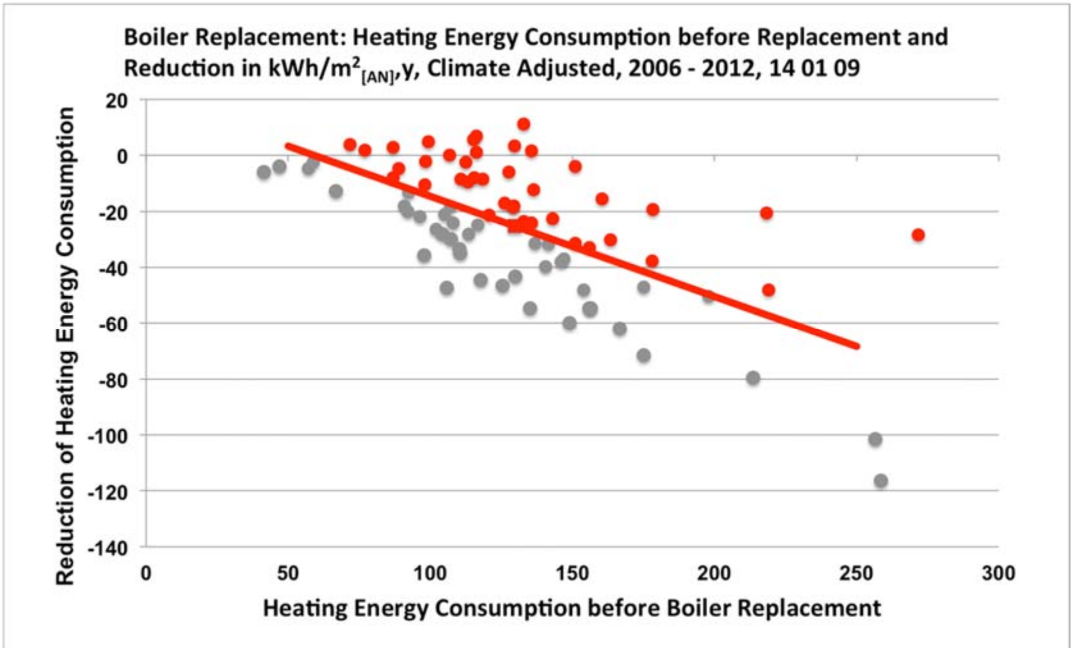
1. Our first practical conclusion from analysing the sample of 81 boiler replacements between 2006 and 2012 that boiler replacement on average leads to a reduction of heating energy consumption by 25 kWh/$m^2_{[AN]}$,y for a building with an average level of prior heating energy consumption of 130 kWh/$m^2_{[AN]}$,y (red dot in figure 3). This finding is trivial and crucial at the same time. It is crucial, since it sharply contradicts an alleged “normal” heating energy reduction of 93 kWh/$m^2_{[AN]}$,y from an “average” heating energy

consumption level of 221 $kWh/m^2_{[AN]},y$ (blue dot in figure 3) as claimed by the German boiler manufacturers in a scientific study published in March 2013[3]. The figure of 25 $kWh/m^2_{[AN]},y$ is also crucial, because it tells the German government, how many boiler replacements are needed to come closer to the goals of a "nearly carbon free economy" in 2050.[4]

2. The second conclusion concerns the advice we give homeowners who use our iESA. For this purpose we divide all installations into two classes: Those with a success above average, and those with a success below average.

Figure 4

Scatter Cloud of Heating Energy Consumption before Boiler Replacement and Reduction of after Replacement – divided into two parts: Winners & Losers



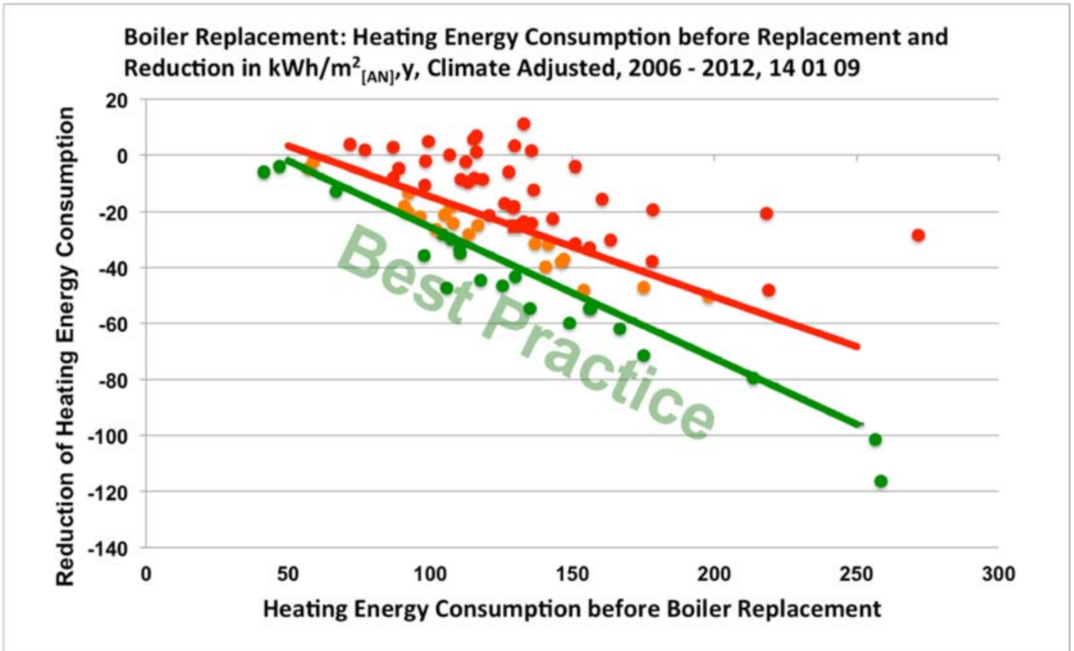
The "red zone" is the alarm zone, where installations appear to be faulty – but may not necessarily be so. To those homeowners we give the – automated – advice to contact the installer (or, for obvious reasons, another local expert, unrelated to the installation) and ask, why the installation has not reached the "virtual border". In order to differentiate even more, we introduce another line – the green line – which separates all successful installations from the rest.

[3] Shell BDH Hauswärme-Studie, Klimaschutz im Wohnungssektor – Wie heizen wir morgen? Fakten, Trends und Perspektiven für Heiztechniken bis 2030, Hamburg, Köln, Mai 2013, p. 45

[4] See below the chapter on "The contribution of boiler replacement to the "Energiewende"

Figure 5

Scatter Cloud of Heating Energy Consumption before Boiler Replacement and the Reduction after Replacement – divided into three parts: Winners & Mainstream & Losers

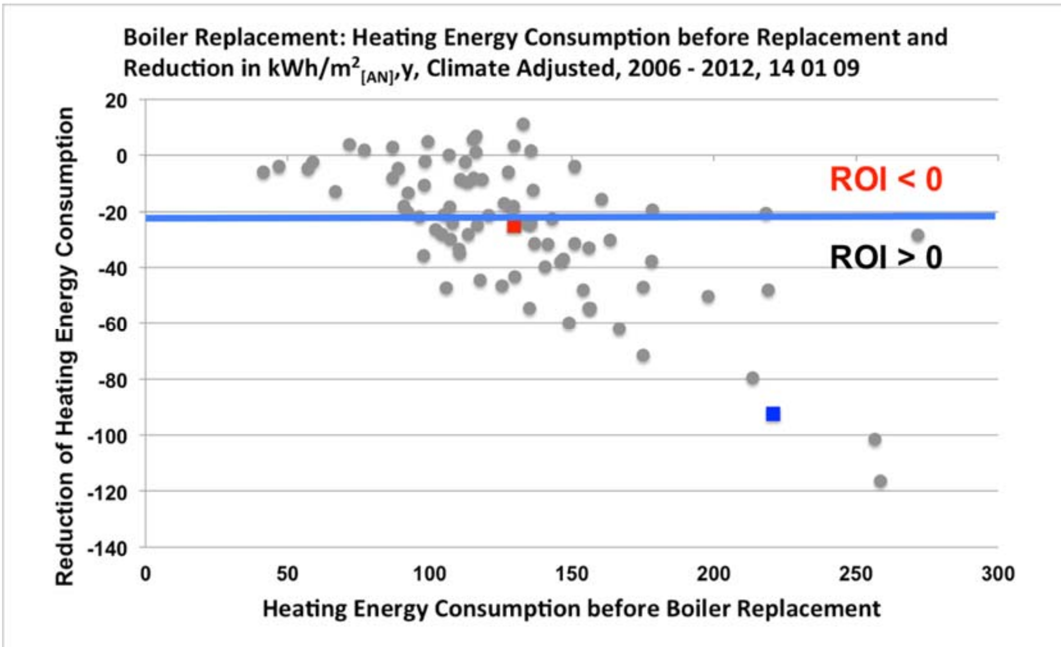


Those building owners whose installations are represented by orange dots should also take a second look a their installation – however, the urgency for that is considerably lower than with the installations that appear in the alarm zone.

The impact on the profitability of boiler replacement

Figure 6

The profitability of boiler replacement



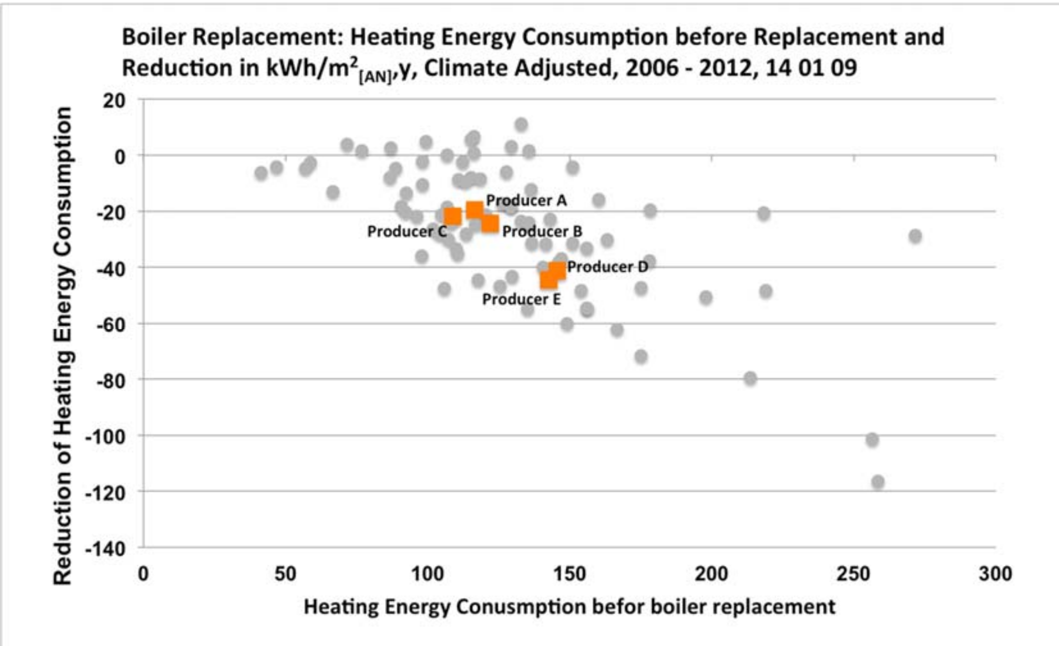
The boiler manufacturers frequently claim that the payback period of the investment in a new boiler is 5 – 10 years on average. Figure 6 shows, that this is a faulty proposition. Assuming a) a current heating energy price of 0.08 €/kWh and b) an annual increase of the fuel price by 5% and c) favourable specific investment costs of 45 €/m^2, a zero return on investment (ROI) is reached at heating energy savings of about 22 kWh/m$^2_{[AN]}$,y, which is only a few kWhs below the average heating energy reduction of 25 kWh/m$^2_{[AN]}$,y (median reduction is 18%, cf figure 2). This implies that 40 – 50% of all boiler replacements do not earn their own write-offs from induced fuel savings which means in turn, that the ROI from boiler replacement is somewhere around 1% p.y

Are there Differences in the Performance of Brands?

One reason for the observed discrepancies in heating energy reduction after replacement might be some "built-in" differences in boiler performance, meaning that some brands yield better results than others. But empirical evidence so far does not show this to be the case. Figure 7 displays the "group performance" of the most frequent brands in the sample. Since the dots representing the different brands are situated on a (virtual) diagonal reaching from Southeast to Northwest, no single brand (with the slight exception of brand C) comes closer to the South-West of the chart, i.e., no brand seems to promise more impact to the buyer for every € invested into the replacement. The horizontal distances between the dots are solely due to the fact that different brands seem to address different target groups in respect to the level of heating energy consumption before boiler replacement. This disproves the idea that technical differences in the performance of the boilers could explain the vast discrepancies observed.

Figure 7

The performance of different brands



The contribution of boiler replacement to the "Energiewende"

Knowing that the average reduction of heating energy consumption after boiler replacement is 25 kWh/$m^2_{[AN]}$,y and assuming that this figure won't change too much over time, we can estimate the impact of boiler replacement on achieving the "Energiewende" goals.

Contribution of Boiler Replacement to Goals of "Energiewende"

Heated surface area of private homes in Germany		
- total	3.5	Bn. m^2
- provided by district heating	0.4	Bn. m^2
- provided by boilers	**3.1**	Bn. m^2
Heating energy consumption in Germany 2013		
- per m^2	130	kWh/$m^2_{[AN]}$
- total	**455**	TWh
Reduction due to boiler replacement		
- rate of replacement	3.2	% p.y.
- heated surface area with boiler replaced	0.1	Bn. m^2
- heating energy reduction by replacement and m^2	25	kWh/ $m^2_{[AN]}$,y
- total heating energy reduction per year	**2.5**	TWh/y
Percentage reduction due to boiler replacement		
- gross (related to total heated surface area)	**0.54**	% p.y.
- net (related to heated surface area provided with boilers)	**0.61**	% p.y.
Reduction due to boiler replacement from 2013 to 2050		
- gross (related to total heated surface area)	**20**	% p.y.
- net (related to heated surface area provided with boilers)	**23**	% p.y.

As indicated above, the yearly rate of replacement of boilers stagnates at a low rate of 3.2% p.y. As we know from other sources, the heated surface area of all private homes in Germany (not using district heating) is 3.1 Bn. m^2, and the average heating energy consumption per m^2 in 2013 is 130 kWh/$m^2_{[AN]}$,y[5]. This amounts to a total heating energy consumption of private homes of roughly 455 TWh in 2013. Since 3.2% of the heated area of 3.1 Bn. m^2 (0.1 Bn. m^2) benefits every year from boiler replacement, it reduces German heating energy consumption in residential buildings every year by 2.5 TWh. As a share of total heating energy consumed (except for district heating) this corresponds to a reduction of 0.61% p.y. – or a total of 20% over the 36 years remaining between now (2014) and 2050. Again: The contribution of the German boiler industry to the "Energiewende" process can be increased considerably by improving the impact of every single boiler replacement.

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5 www.heizspiegel.de/heizspiegel/bundesweiter-heizspiegel/

Conclusions

The huge vertical spread of heating energy reductions after boiler replacement as represented in our scatter charts, strongly indicate untapped potentials for further savings of heating energy through boiler replacement. But as indicated above, without an in-depth analysis of the efficiency of the old and the new boiler, the size of this untapped potential can only be guessed but not quantified. In an on-going research project co2online will provide this in-depth analysis, which will finally show how much additional energy consumption can be saved by exploiting these potentials by a) avoiding sizing errors in boiler replacement and by b) more thoughtful adaptation of the new boiler to the technical conditions of the particular building (avoiding plug & play “solutions”).

If our in-depth analysis confirms the hypothesis of considerable untapped potentials, the consequence for politics must be to tap into these potentials, since this will certainly be one of the most cost-efficient ways to reach the goals of the “Energiewende”.

Lessons learned

co2online presented the findings about the low reduction levels and the strong disparity of results at several occasions to the senior representatives of the German boiler industry (BDH) and invited them to join in efforts to achieve better results from boiler replacements. Those efforts would comprise to first assess the old boiler’s efficiency in order to create a solid base for estimating the economic and ecologic benefits of an early replacement. Such an assessment would reduce the currently huge uncertainty about the economic benefit of the investment for the homeowner and foster early replacements of old and still functioning boilers. In addition such an assessment would be feasible at very low cost if the manufacturers would decide to make the heat meter an integral part of any boiler produced.

The representatives of the boiler manufacturers strongly decline any such move, because quite obviously they are caught in a dilemma: The possible benefit of an increase in sales of boilers due to reduced uncertainty in the decision making process is more than outweighed by the possible damage arising from installers’ protests, who would be forced by such an arrangement to spend more time adjusting the boiler to the specific conditions of the building. Such a lack of adjustment would lead to poor performance figures on the heat meter display, and to complaints from homeowners, who might demand remedy, without payment, or even take legal action against the installer.

Drawing from these considerations, co2online concludes that in the near future the German boiler manufacturers will not provide built-in displays of the boiler’s performance – unless such a display is mandated legally, e.g. by the German Energy Savings Ordinance (EnEV) – or at least by the subsidy regulations of the KfW.

Since heat meters enforced by law will not come about any time soon, co2online recommends homeowners to install heat meters at their own expense before replacing the old boiler so they can make a safer estimate on the efficiency difference between old and new boiler and a safer prediction of the economic benefit of the investment in the new boiler. After the completion of the replacement process the same meter of course allows to check whether the maximum degree of efficiency of – say – 93 to 95% has actually been achieved.

Buying such a heat meter is some sort of “damage insurance”. The cost for this insurance is justified for all those who believe that their chance of incurring a damage is above 1 in 10; because the financial damage caused by a malfunctioning boiler over its 20 year life span can easily exceed the 20-fold cost of installing a heat meter (or of 2 heat meters, if domestic hot water is also involved).[6]

Outlook

The strong divergence of economic success and failure is not a unique feature of boiler replacement. The pattern shown in figures 3-5 is very similar for all refurbishment measures (insulation of walls, roof, and cellar ceiling, window replacement, installation of solar thermal panels - and any combination of those). In all cases there are huge discrepancies between losers and winners of the refurbishment process, which strongly indicates that the technological potential of modern heating and insulation technology is not exploited in the everyday process of building modernization. This raises the challenging question as to what extent those technical potentials are untapped, and how their exploitation can help to speed up the reduction of heating energy consumption and consequently of GHG emissions caused by space heating.

Whatever the answer to this question may be: Just pushing to raise the rate of refurbishment instead of examining at the same time the actual impact of the respective refurbishment measures is economically flawed.

For it is obvious, that an additional investment that considerably increases the impact of the investment already made, but only costs a small fraction of the initial investment, is extremely beneficial both for the environment and for the home owners’ wallet.

Since I presume that the discrepancy between the technological potential of modern boiler, insulation, and window technology, and the results yielded in the practical experience of everyday refurbishment, is not only a German but a general problem, I strongly recommend to the representatives of other member states to pay as much attention to this aspect of the refurbishment process as you usually pay to the increase in the rate of refurbishment.

We are particularly happy that the EU commission has given us the financial support with subsequent tenders[7] for the development of the iESA and its adaptation to the conditions of several member states – so that the state of the art monitoring of the refurbishment process is possible with the same method yielding comparable results in at least 10 member states. So discovering the hidden potentials of an improvement in the refurbishment process can start in all those member states without incurring any major technical or financial barriers.

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[6] The probability of economic damage can be reduced considerably, if the home owner chooses the right installer. But who is the right one? This is easy to find out: Only those installers should be contracted, who do not question the benefit of hydraulic balancing. A positive reaction to this topic is a clear sign that the installer you address is the right one – and hydraulic balancing reduces (for the greater part of all homes) heating energy consumption by 8 – 16 kWh/m^2,a.

[7] Due to the following campaigns, funded by the EU Commission (ECCC (European Citizens Climate Cup), 2010-2012, ePlace (ongoing project), EECC (European Enterprise Climate Cup) started in April 2014) the iESA is now available in Ireland, UK, Latvia, Denmark, Malta, Greece, Spain, Austria, and Italy.

Appendix

Similar conclusions to those drawn in the chapter on *The contribution of boiler replacement to the "Energiewende"* for the German boiler industry can be formulated from the iESA-based impact analysis for all relevant refurbishment measures in buildings.

Yearly Reduction of Heating Energy Consumption due to Refurbishment, last update 2014 01 14						
		Volume		Impact	Success	
	Measure	Heated surface area	Rate of refurbish-ment	Reduction of specific heating energy consumption	Reduction of total heating energy consumption	Reduction related to total heated surface area
		Mrd. m²	% p.y.	kWh/m²,y	TWh/y	kWh/m²,y
1	Boiler replacement	3,1	3,17	-25	-2,5	-0,8
2	Façade insulation	3,5	0,87	-21	-0,6	-0,2
3	Roof insulation	3,5	1,43	-19	-1,0	-0,3
4	Window renewal	3,5	1,56	-18	-1,0	-0,3
5	Insulation of basement ceiling	3,5	0,49	-8	-0,1	-0,0
6	Hydraulic balancing	3,5	4,20	7	1,0	0,3