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Final energy and CO_2 savings made by replacing aging boilers with condensing boilers

– A detailed study of potential savings, subject to initial conditions

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1 Summary

How much energy and CO2 can be saved if aging boilers are replaced with modern condensing boilers? Public debates claim such changes can generate savings of 30% - but a closer look at the calculations according to norm DIN V 18599 reveals a differentiated view:

- Typical savings gained through replacing a 20-year-old boiler vary between two and 15 %, depending on the substitute boiler.
- Up to 12% savings are possible in the case of skillfully implemented adjustments to the peripherals.
- In most cases, peripheral adjustments (hydraulic adjustment, efficient pumping and control technology) generate higher savings than would be the case if the boilers were replaced.
- Savings on the peripherals are not necessarily linked to boiler exchange –leveraging this potential separately is also a possibility.
- Based on the premise that it is not a majority of constant-temperature boilers but low-temperature boilers that must be replaced (and, in the future, more and more existing condensing boilers), weighted savings made after replacing these with modern condensing boiler are more likely to be around 10%.
- For non-residential buildings, the energy demand, (not counting heating and hot water), is usually much higher than in residential buildings; therefore, savings made by boiler replacement play a more minor role in the context of the building's total energy demand.
- Shifting to renewable energy would have a much greater effect on CO_2 reduction than replacing aging fossil-fuel boilers with new ones.
- The findings satisfy current studies carried out in real operation conditions.

2 Research subjects

The examples cited in this study are six buildings constructed in the 1970s and '80s, in which initial building-age typical renovation had already been carried out. The existing gas boilers are 20 years old, and the peripherals (pipes, pumps, radiators, thermostats, heating circuit temperatures) are typical of the building's age. The boiler also supplies the central hot water system via a circulation pipe. The existing boilers were made in 1998 and include a constant temperature boiler (CT), a low-temperature boiler (LT) and a condensing boiler (CB), which were installed in each building. The distribution pipes were installed during the course of boiler replacement in 1998, and in accordance with the requirements of the time.

The calculations were carried out in the boundary conditions of the current Energy Saving Ordinance [EnEV] featuring [DIN V 18599]. The CO2eq emissions are determined according to GEMIS 4.93

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Existing buildings inspected

Building code	Use	living space/net floor space [m²]	nominal thermal capacity [kW]	primary energy demand – low-temp. boilers [kWh/m²a]	transmission heat loss specs [W/m²K]	specific features
EFH_120	semi-detached single family house	120	19	346.0	1.11	
MFH_216	detached three-family house	216	30	139.8	0.42	partial renovation, shell at EH115 level; heated b
MFH_880	detached apartment building	880	80	168.7	1.08	
MFH_1970	detached apartment building	1,970	186	205.1	1.21	one-pipe heating system
Office	office building, partially air-conditioned	875	188	348.8	1.27	
Discount store	supermarket, air-conditioned	1,525	208	280.5	0.40	

Boiler replacement: The comparative study is based on a system within which an existing 20-year-old boiler is replaced by a gas condensing boiler built in 2018 ("improved condensing boiler" in accordance with DIN V 18599).

Peripherals: Furthermore, in this comparative study the system has been hydraulically balanced and the peripherals improved by installing efficiency class-A pumps, (1/3 of the DIN standard value), as well as installing radiator valves with electronic controllers.

3 Results

According to balanced final energy demands as set out in EnEV, reductions in the final energy demand and CO_2eq emissions are presented separately for both boiler replacement and improvement of the peripherals.

The worse the system replaced, the greater the savings

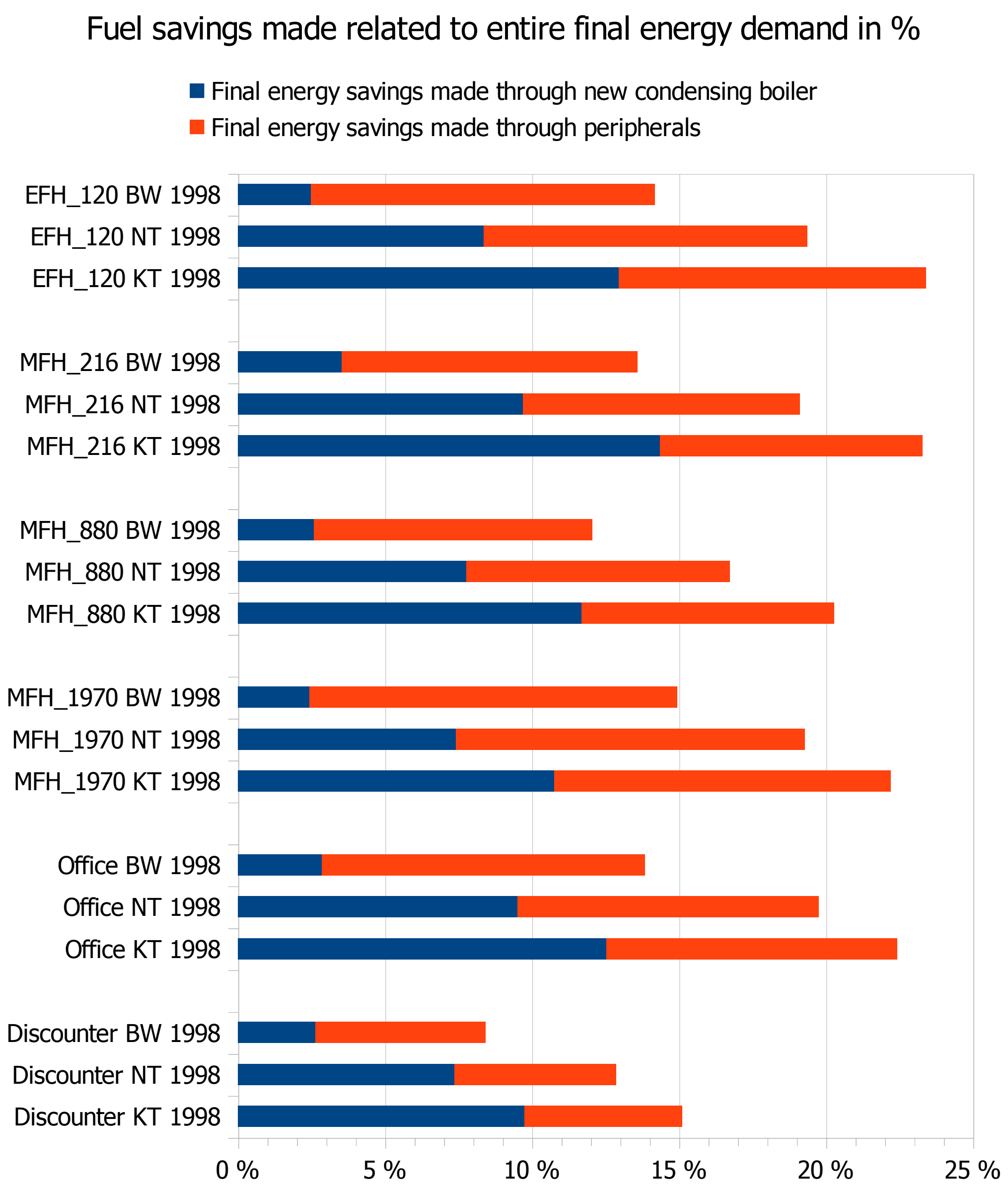

figure 1: fuel savings made in 6 buildings through replacing aging constant-temperature (KT), low-temperature (NT) and condensing boilers (BW) with a new condensing boiler; differentiated according to boiler and peripheral

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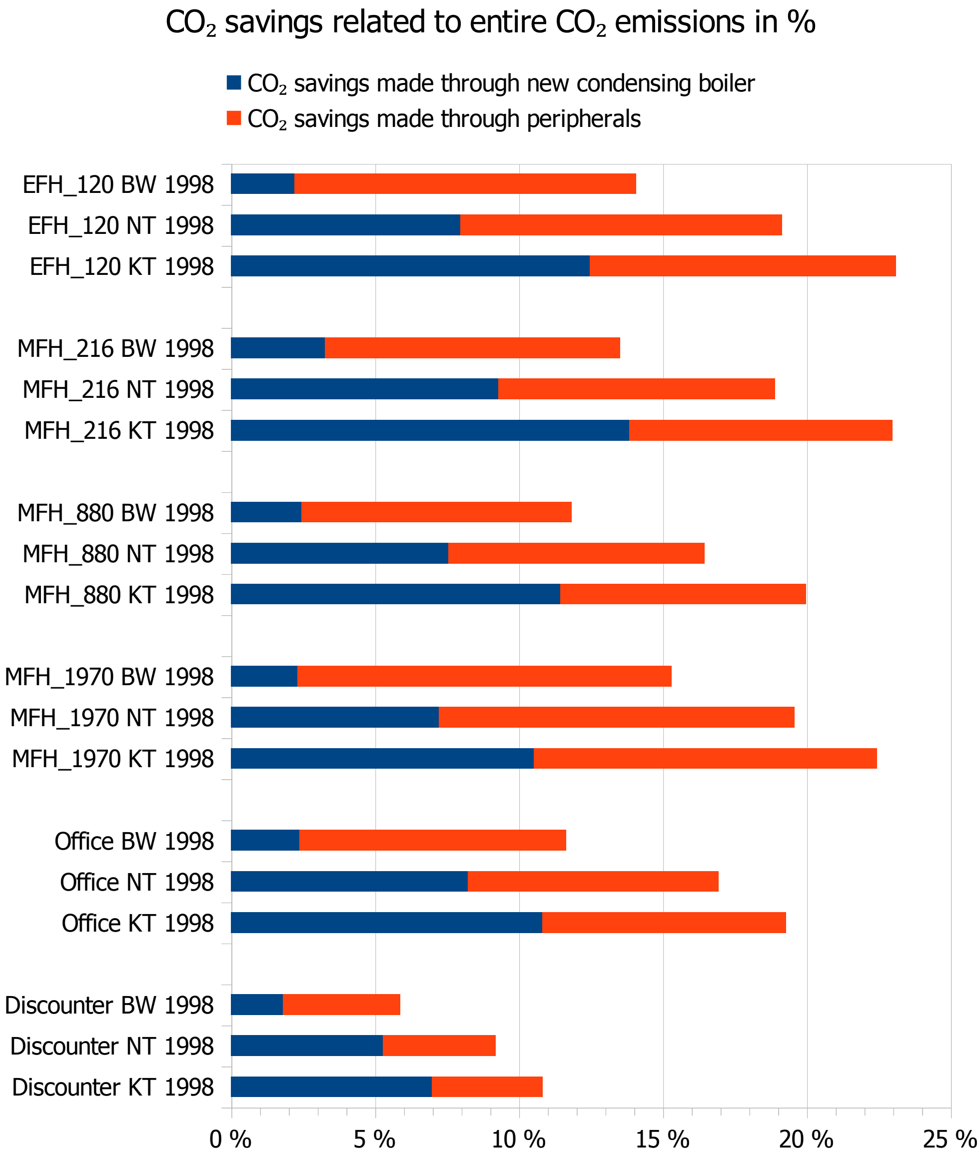

figure 2: CO_2eq savings gained in 6 buildings by replacement of aging constant-temperature (KT), low-temperature (NT) and condensing boilers (BW) with new condensing boilers; differentiated according to boiler and peripherals

4 Comparisons with other studies

In terms of the attainable savings, the calculation models applied are in line with the results of field studies carried out by the Ostfalia University of Applied Sciences in Wolfenbüttel (Ostfalia Hochschule Wolfenbüttel), the German Federal Environmental Foundation (Deutschen Bundesstiftung Umwelt), the Federation of German Consumer Organisations (Verbraucherzentrale Bundesverband) and CO2online.

A viewpoint that resulted from this study was that the information provided by manufacturers concerning the system's efficiency in test conditions and the system's efficiency in real operation was not clear enough. Adjustments to improve the peripherals, such as adjusting the power of the heat generators (modulation), were not usually sufficient; heating curves of controllers were not set; hydraulic balancing was not carried out; and individual radiators were undersupplied.

This would often lead to wrong countermeasures being undertaken, including setting the heating curve and/or pump performance at a higher level. The consequences included increased cycle times of the heat generators, reduced utilisation of condensing technology and increased final energy and electricity consumption, combined with increased CO_2 emissions. This, in turn, would lead to the fact that, in practice, condensing appliances only managed to implement the latent heat of waste gas condensation in an insufficient manner.

Instead of a possible utilization rate of 93 - 95%, many condensing boilers achieved a utilization rate of only 85 - 87% in actual practice [CO2online 2018], [DBU 2004], [DBU 2005], [Ostfalia 2017], [vzbv 2011]. Reference measurements of heat and fuel consumption in real operation within more than 100 power plants showed that the annual utilization rate improved by more than 10% for plants with condensing boilers compared to those with low-temperature boilers [Ostfalia 2017].

5 Conclusion

When aging boilers are replaced by new condensing boilers, 30% energy and CO_2 savings are mooted in public debate. However, on closer look a differentiated picture is revealed: savings that can be made when replacing a 20-year-old boiler are mainly achieved through the adjustments that improve the peripherals (such as hydraulic balancing, efficient pumps and control technology). Only when aging constant temperature boilers are replaced does a boiler contribute up to 15% of the bulk savings.

If a new gas condensing boiler replaces:

- a constant temperature boiler, the resulting savings range from 10 to 15%.
- a low temperature boiler, the resulting savings lie in the range of 5 to 10%.
- an aging condensing boiler, the resulting savings are only in the range of 2 to 3%.
- In addition, further savings of between 5 to 12% can be generated if the peripherals are improved.

In gas heating systems, it is estimated that

- around 10% constant temperature boilers,
- around 80% low-temperature boilers and,
- around 10% aging condensing boilers

are replaced. For oil heating systems, the estimated share of constant temperature boilers is somewhat higher at around 15%, and the proportion of condensing boilers slightly lower at around 5%. According to these estimates, it is mainly low-temperature boilers rather than constant temperature boilers that will be replaced – and, in the future, more and more existing condensing boilers.

As a result, the weighted savings made through replacing aging boilers with new condensing boilers tend to be around 10%, (assuming optimum operation). If, during the course of boiler replacement, the energy carrier is changed from heating oil to natural gas, around 20% of fuel-related savings of CO_2eq emissions can be attained. This of course requires access to a natural gas mains connection. Furthermore, switching to renewable energy and combined heat and power can deliver far greater CO_2eq savings of up to 90% and more.

For non-residential buildings, the energy demand, (excluding that for heating and hot water), is usually much higher than in residential buildings; Therefore, as can be seen in the example of the discount store, the savings percentage attainable by boiler replacement are significantly lower.

The savings of around 10% in the peripherals are not necessarily linked to boiler replacement - this potential could also be bolstered separately. Even if the use of renewable energies covers heating requirements, optimizing the peripherals saves energy. The results are consistent with readings taken from other studies, as listed in the sources.

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6 Sources

[CO2online 2018] Brennwertkessel: Funktion, Einsparpotenzial und Fördermittel, at: https://www.co2online.de/modernisieren-und-bauen/brennwertkessel/

[DBU 2004] Felduntersuchung: Betriebsverhalten von Heizungsanlagen mit Gas-Brennwertkesseln, Fachhochschule Braunschweig Wolfenbüttel, funded by the German Federal Environmental Foundation (Deutschen Bundesstiftung Umwelt) at: http://www.delta-q.de/cms/de/projekte/dbu_brennwertkessel.html

[DBU 2005] Optimus - Heizungsanlagen optimieren, Dr.-Ing. Kati Jagnow und Prof. Dr.-Ing. Dieter Wolf im Auftrag der Optimus-Gruppe, funded by the German Federal Environmental Foundation (Deutschen Bundesstiftung Umwelt) at: http://www.delta-q.de/cms/de/projekte/dbu_optimus.html#bericht

[DINV18599] Energetische Bewertung von Gebäuden – Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung, Trinkwarmwasser und Beleuchtung, December 2011.

[EnEV] Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Energieeinsparverordnung – EnEV), as of 28th October 2015.

[Ostfalia 2017] Kurzgutachten „Effizienz von Brennwertkesseln in der Praxis", Prof. Dr.-Ing. Dieter Wolff, EOS - Institute for Energy Optimized Systems - Ostfalia Wolfenbüttel, 28.11.2017, unpublished for BEE.

[vzbv 2011] Aktion Brennwertcheck der Verbraucherzentrale Energieberatung, funded by the Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Technologie) at: https://www.vzbv.de/sites/default/files/downloads/Brennwertcheck_Studie_Kurzfassung_2011.pdf