Hydronic balancing and control – how to overcome the global challenge of reducing energy use in multifamily housing

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Abstract

Reducing energy consumption and greenhouse gas emissions in the building stock is one of the key challenges to achieve the climate change mitigation objectives agreed in Paris, and reduce air pollution in cities. This paper provides an analysis of a key ingredient of any solution: getting basic aspects of automatic balancing (meaning the continuous control of flow and pressure in the piping system and radiators leading to the optimal generation, distribution and emission of heat throughout the building) and room temperature control right in multifamily buildings with central, water-based heating systems. These aspects are a key driver for the overall energy performance of buildings, as they have, across different types of heat generators, a significant impact on the efficiency of heat generation, distribution and emission, and for the comfort and health of building occupants. Despite capital-light investment needs with fast pay-back, it is an aspect that today is usually neglected both in renovation and in new-built markets, making it a largely "forgotten" element of the energy transition.

The paper shows that the vast majority of existing and new buildings lack most basic features, provides an overview of key principles and technologies, and discusses some key market barriers. It presents estimates for energy and cost savings, required investments and pay-back from a building owner/tenant perspective. It argues that getting the basics right helps to meet expectations on energy performance after deep renovation and for near-zero energy buildings in actual use. The paper concludes that the on-going revision of buildings energy efficiency legislation should tackle this forgotten dimension, to enable progress towards political long-term decarbonisation objectives.

The paper is organized as follows: first, an overview of latest research on energy saving potentials of individual room temperature control and balancing, and their economics is given. The findings are put into perspective with field test on actual cases, where methodologies and results are presented. The subsequent section provides background on the main physical aspects which impact energy performance. After identifying main market and regulatory barriers for market-uptake of room temperature control and balancing functionalities, the paper closes with conclusions for the current process for new EU energy efficiency legislation.

Introduction

Reducing energy use in multifamily housing is a global challenge. In the EU, heating and hot water alone account for 79 % of total final energy use in residential buildings [1]. The overall annual space heating energy consumption for residential buildings in EU 28 is about 200 Mtoe [2]. Buildings represent the greatest potential to save energy – as 75 % of buildings standing in the EU were built during periods with no, or minimal, energy-related building codes and the energy intensity of heating per floor area is two times higher than any other region of the world (except Russia). Buildings are long-term assets expected to remain in use for 50 or more years and 75–90 % of those standing today are expected to remain in use in 2050 [3]. Efficient space heating of buildings in general is therefore a key to achieve EU and global energy and greenhouse gas reduction objectives.

This paper focuses on functionalities that are indispensable for rationale operation of heating systems:

- hydronic balancing – the adjustment of flows and pressure in the piping system and radiators leading to the optimal generation, distribution and emission of heat throughout the building
- room temperature control – the adjustment of the heat emitted by radiators to achieve the desired comfort level of the occupant depending on the variations of the indoor temperature
- their interaction in hydronic central heating systems. As far as building types are concerned, the scope of the paper focuses on multifamily buildings. 63 % of EU residential buildings are using gas or oil as energy carrier for heating [4], which are mainly water based. Therefore, any policy that tackles the current shortcomings must keep residential buildings including multifamily buildings in focus. To illustrate the magnitude of the problem, we note that majority of heating systems in Germany – 77–84% – are currently without hydronic balancing [5]. Taking climate-protection goals into account, this means that an annual reduction potential of around 10 to 15 million tonnes of CO_2 remains untapped [6].

The paper's focus on multifamily housing is based on the following considerations:

Putting end-users in control of their desired indoor temperature level and energy bill is an important objective of European energy policy, and a key for rational use of energy. Transparent and reliable heat consumption information to occupants of multifamily buildings with central heat supply is a necessary means, but not sufficient. Further necessary conditions are that i) occupant are empowered to react to energy consumption information adequately; ii) heating systems provide desired temperature levels in all parts of the building, at all times. Only the combination of all conditions can deliver cost-effective energy savings and comfortable and healthy indoor temperature levels.

The key functionalities that satisfy conditions i) and ii) are room temperature control and hydronic balancing of "water based" heating systems. Today most buildings fail to provide these functionalities to their residents. They are the forgotten dimension in building renovation and construction, partly due to a lack of understanding and experience of technologies, missing consolidated data and standards, and split incentives for investors and building occupants.

A large part of the analysis is valid for non-residential buildings for both heating and air-conditioning/cooling functionalities, and to some extent for single-family residential buildings.

A brief overview of latest research

New, independent research summarizes possible EU aggregated CO_2 emission and primary energy savings by optimizing the *system* performance of technical building systems with certain, given heat supplies. Improvement potentials stemming from heat generator replacement or switch of heat/fuel supply are *not* considered. Energy savings are compared to estimates for the required investments [7].

The research [7] is based on a methodology that defines four residential and four non-residential reference buildings, with typical heating, cooling, hot water, ventilation and lighting systems and specifications. Concrete basic and advanced optimization measures are identified and their individual savings potential is estimated. These measures reflect non-proprietary technologies readily available on the market, addressing the aspects which are govern the optimization technical buildings systems' energy performance beyond heat/cool supply – appropriate dimensioning, proper installation, adjustments, and automation, control and monitoring systems. Associated energy savings are then calculated for each of the eight reference buildings, using existing standards and standard calculation software.

To keep results independent of heat generator characteristics, the saving potential of each improvement measure is calculated per case assuming that the building already has a new high efficient heat generator. The energy demand calculation for each reference case and every measure, like automatic balancing, room temperature control, took into account national climate data and normative reference calculation parameters according to EN 15232 and EN 15316 for the aspects automation, control and monitoring systems, and DIN V 18599 for the aspects appropriate dimensioning, proper installation, and adjustment. The DIN V 18599 ensures the CEN-EPBD conformity. Further details on the methodology are presented in [7].

Table 1 summarizes the key indicators of single improvement measures for the multi-family house reference buildings that are the most relevant for the purposes of this paper: system temperature adjustment, manual and automatic hydronic balancing, night setback, and room temperature control by selfacting thermostatic radiator valve (TRV) or electronic thermostatic radiator valve (eTRV) for the multi-family house.

The calculated estimates for energy savings shown in Table 1 are based on DIN V 18599, which applies a static simulation on a monthly basis. The single measures mentioned and the energy saving figures are linked. In particular dynamic balancing[1] is the fundamental enabler to adjust system temperature. In practice, in case of insufficient heat supply to one or more radiators and building units, it is not necessary to increase the supply temperature, if instead the system is dynamically balanced. Therefore, upgrading the heating system with dynamic balancing functionality facilitates to minimize the system temperature, while ensuring the adequate and comfortable heat supply to all radiators, in all building units. In practice this means that the savings facilitated by dynamic balancing are in the range of the sum of single measure for automatic hydronic balancing, and of the single measures for system temperature adjustment up to about 15 %. This estimate is confirmed in real cases.

With such a significant contribution to the energy consumption it is clear that the heating systems in buildings are an important topic for improvements during retrofit and renovation. Compared to solutions such as building insulation, heat gener-

1. Both terminologies are used e.g. dynamic refers to balancing functionality, while automatic balancing refers to products.

Table 1. Single measure results for the multi-family reference case (considering gas, district heating and heat pump as heat generator) [7].

	Final energy[1] savings [%]	Energy cost savings [EUR]	Investment[2] [EUR]	Payback period [years]
System temperature adjustment (actual set point)[4]	10	5,440	300	0.1
Night setback – adjusted settings (rom 11 pm to 6 am, 2K temperature reduction)	10	5,450	300	0.1
Manual hydronic balancing	7	3,660	5,440	1.5
Automatic hydronic balancing	10	5,760	6,660	1.2
TRV	7[3]	3,850	4,410	1.2
eTRV	11[3]	5,980	5,680	1.0

[1] incl. space heating and domestic hot water; [2] Investment, incl. installation costs; [3] from an old TRV to new TRV/eTRV; [4] supply temperature reduction by 15 K (55 °C required, but set to 70 °C).

ator/supply efficiency and use of renewable energy sources, automatic hydronic balancing and room temperature control are not sufficiently recognized to be a cost effective way to reduce the energy consumption of buildings. We argue in this paper that they are also a prerequisite for successful deep renovation of the building stock.

Confirming research in practice – methodology

This next two sections provide an analysis of expected and measured energy savings based on modernization of technical building system (TBS), reflected by installation of automatic balancing and in two cases also thermostatic radiator valves providing occupants with individual room temperature control functionality. Cost savings together with required investment costs are further provided and used to estimate pay-back time. In the present section we present an overview of methodological aspects that need to be observed for solid results.

A key element for creating robust outcome and added value for investors and building occupants is a solid methodological approach. Good measurement and verification practice (M&V) [8] is part of the process of identifying, developing, procuring and installing energy savings measures. A standardized state-of-the-art M&V contains several tools and methods for operational verification, where short term performance verification fits closest to methods described below. In case of multifamily residential houses with central heating system, saving potentials for the entire building are identified. This is also the method used in the cases presented in this paper. In practice, energy consumption was measured with central heat meters for the entire building at the point of central heat delivery – the boiler or the district heating building substation. An exception is the case from Italy, where consumption data it the aggregate for the complex of 5 buildings.

The energy consumption values were registered by the building administrator(s). The selection of measuring period is based on operation mode of facility. In case of residential heating the typical measuring period is the heating season. As length of heating season as well as intensity of heat demand throughout the season varies with meteorological conditions across years, normalization of data is a required before results can be evaluated for operational verification. The standard method is the "heating degree-day method" (HDD) which is used to correct measured data for differences in heating demand and season's length.

The energy consumption is compared between data taken a year before TBS modernization, and up to 3 years after the modernization. Where data of more than one year after modernization was used, energy savings are calculated per each year separately and averaged afterwards.

Results

In this section we present 4 cases of modernization of control of energy "generation", distribution and emission of water-based heating systems. The heat supply source – boiler and district heating building station – were unchanged. The cases are distributed geographically to represent different climate conditions, different reference condition of TBS, as well as different modernization measures taken. The data and its interpretation is present in the subsequent section. Described are energy efficiency improvements, cost savings and payback time using the actual investments that were needed for TBS modernization.

Case 1: a complex/condominium of five multi-family buildings in Milano, Italy. A complex was constructed in 1965. Buildings have 9 levels. Heat source is a common single boiler with, as said, a common energy metering station. Reference condition, before TBS modernization: radiator heating system, equipped with simple thermostatic radiator valves without presetting. No balancing valves were present. TBS modernization: five multi-family buildings were retrofitted with automatic balancing valves. The following figures shows the energy data averaged for the heating season 2014/2015 and 2015/2016, compared to 2013/2014, based on heat meter reading, and with consideration of heating degree days.

Case 2: multi-family building in Mjölby, Sweden. Building was constructed in 1955, with original insulation envelope. Partial building modernization took place in 2010, when new windows were installed. There are 10 levels, with total floor space of 1.876 m^2, shared among 25 apartments. Reference TBS condition: radiator heating system equipped with mix of simple and thermostatic radiator valves. No balancing valves were present. TBS modernization: during 2012 a multi-family building was retrofitted with thermostatic radiator valves replacement and automatic balancing valves installation. Over the period of three years, from 2013 to 2015, the energy use has been measured.

Case 3: multi-family building in Szczecin, Poland. Building was constructed in 1982. Building has 11 levels, with total floor space of 9,808 m^2, shared among 66 apartments. In 2004 building envelope was modernized by added insulation of a roof and outer walls. Reference TBS condition: radiator heating system equipped with manual balancing valves and thermostatic radiator valves. TBS modernization: during 2005 heating system was retrofitted with automatic balancing valves, instead of manual ones. Over the period of 3 years, from 2006 to 2008, the energy usage has been measured and recalculated with consideration of heating degree days. [9]

Case 4: multi-family building in Pszczyna, Poland. Reference TBS condition: radiator heating system equipped with thermostatic radiator valves and without any balancing valves. Last heating system season before modernization: 2000/01. TBS modernization: after the heating season 2000/2001, buildings were categorized as 3 pairs of two similar buildings. Within each pair, one building was equipped with manual balancing valves, while another had installed automatic balancing valves. While the previous case for the multi-family building in Milano considers measurements and adjusted calculation (HDD), this project tries to consider a kind of direct comparison, without adjusted calculation. In three areas two similar buildings have been retrofitted. The focus of this project is to benchmark the additional value, changing the heating system from manual to automatic hydronic balancing.

ENERGY SAVINGS

Energy savings are presented in tables 2–5 for each out of 4 cases separately, depending on case specifics.

COST SAVINGS AND PAYBACK TIME

Table 6 summarizes the four case mentioned above. The space heating energy consumption reduction from upgrade with automatic balancing equipment in a system where individual room temperature control is installed ranges between 11 % and 22 %. The achievable savings depend on the characteristics of the building. E.g., the seemingly moderate savings in the Milano case can be explained by the fact that building has poor envelope insulation. This implies larger absolute savings as heat consumption overall is higher than in well insulated buildings.

On the other hand, the large savings observed in the Szczecin case can be explained by building modernization that delivered

Table 2. Results for energy savings case 1, Milano, Italy.

Heating season	Heating energy consumption (heat meter reading) [MWh] (date of reading)	Methane consumption [m³]	Heating degree days (HDD)	Specific heating consumption [MWh / HDD]	Difference on specific heating consumption [%]
2013 / 2014	1,205.09 (10.04.2014)	127,064	1,703.3	0.71	
2014 / 2015	1,118.16 (15.04.2015)	115,505	1,764.4	0.63	11.3
2015 / 2016	1,003.04 (08.03.2016)	105,479	1,567.6	0.64	9.9
Average energy savings					10.6

Table 3. Results for energy savings based on case 2, Mjölby, Sweden.

Heating season	Heating energy consumption - adjusted [MWh]	Difference on heating consumption [%]
2012	556	
2013	467	16.0
2014	411	26.1
2015	401	27.9
Average energy savings		23.3

Table 4. Results for energy savings based case 3, Szczecin, Poland.

Heating season	Heating energy consumption (heat meter reading) [GJ]	Heating energy consumption (adjusted) [GJ]	Difference on heating consumption [%]
2005	1,141	1,236	
2006	1,024	868	29.8
2007	851	1,012	18.1
2008	867	1,000	19.1
Average energy savings			22.3

Table 5. Results for energy savings based on case 4, Pszczyna, Poland.

Building after modernisation TRV + dynamic balance	Building after modernisation TRV + manual balance	**Before** modernisation Total energy consumption 2000/2001		**After** modernisation Total energy consumption 2001/2002		% of saving compare to GJ/m² in buildings	Add. Saving in % due to dynamic balancing
		[GJ][1]	[GJ/m²][1]	[GJ][1]	[GJ/m²][1]		
Str. Ziemowita 10–12		903.4	0.64	676.0	0.48	25 %	**+11 %**
	Str. Lokietka 23–25	829.4	0.58	711.0	0.50	14 %	
	difference	+8.2 %		-5.2 %			
Str. Lokietka 13–16		1,197.0	0.63	900.5	0.48	24 %	**+15 %**
	Str. Lokietka 17–20	889.0	0.47	812.0	0.43	9 %	
	difference	+26 %		+10 %			
Str. K. Wielkiego 4		1,857.0	0.58	1,456.0	0.45	22 %	**+8.0 %**
	Str. K. Wielkiego 6	1,624.0	0.49	1,397.0	0.42	14 %	
	difference	+12.6 %		+4 %			

[1] Based on measured, not adjusted calculation.

Table 6. Overview actual cases.

Real cases	Final energy savings [%]	Energy cost savings [EUR]	Investment [EUR]	Payback period [years]
From no balancing to automatic balancing (Milano, Italy)	11	12,595[1]	26,400[2]	2.1
From mix of old TRV/simple radiator valves and no balancing to new TRV and automatic balancing (Mjölby, Sweden)	23	11,352	32,000[2]	2.8
From manual balancing to automatic balancing (Szczecin, Poland)	22	–	–	–
From manual balancing to automatic balancing (Pszczyna, Poland)	8–15	–	–	–

[1] Energy price (methane): 0.76 EUR/m³.

[2] Investment, incl. installation costs.

good envelope insulation leading to high relative savings as explained at the end of section Technical background.

For the case of Mjölby, the combination of replacing older thermostatic radiator valves and installation of automatic balancing reduced space heating energy consumption by about a quarter, consistent with an "average" energy savings from automatic balancing of about 15 %, and additional savings from replacing old by new self-acting TRVs of about 8 % [7, 12].

Technical background

TWO KEY FUNCTIONALITIES FOR OPTIMIZED SYSTEM PERFORMANCE: INDIVIDUAL ROOM TEMPERATURE CONTROL AND DYNAMIC HYDRONIC BALANCING

The first step in creating an efficient system is to provide room temperature control to all individual rooms. For water-based radiator heating systems, a self-acting thermostatic radiator valve – often also called e.g. radiator thermostat – is the standard solution. Radiator thermostats are designed to feed the radiator automatically with the right quantity of heated water, needed to heat up and maintain a room at the temperature selected by an occupant. Radiator thermostats can be mechanical self-acting, or electronic. For the first, the desired temperature is set on valve by hand[2]. For the second, further functionalities enable individualization of energy consumption e.g. by control via smartphone app, individualized temperature set-point setback scheduling during night-time or working hours, window open detection, and more. Additional energy savings of electronic thermostatic radiator can, depending on the details of the user-behaviour, be very significant. For MFH, Ecofys 2017 estimates that an upgrade from an old to an electronic TRV provides an energy saving of 11 % without taking, into account night set-back savings, which are estimated at 10 %, and without accounting for energy savings from setback during day-

2. By hand means to select the desired room temperature manually. This notion should not be confused with "simple radiator valves", where the flow of water into the radiator solely depends on a given position of the hand-wheel, without any control of flow by a self-acting sensor.

time. Saving figures are relative to a baseline consisting of both space and domestic hot water energy consumption. Hirschberg concludes that replacing an old TRV by an electronic TRV provides savings of 23 %, using night and daytime setback, and using a baseline consisting of space heating energy consumption only. Replacing a simple radiator valve by an electronic TRV saves 46 % space heating energy, according to Hirschberg [12].

For both self-acting and electronic TRVs, the valve should be pre-set to match the design hot water flow into the radiator, which corresponds to the maximum flow needed to keep the designed room temperature comfort at minimum outside temperature. Calculated flow depends on the room/building characteristics, the hot water temperature and the selection of radiators. In systems without pre-setting, flows and pressure losses cannot be neither set nor controlled and can become exceptionally high.

The next step for an efficient system is to keep the pressure drop across the radiator valve, the differential pressure, as constant as possible to prevent deviations in the water flow. This is done by static or dynamic balancing functionality. Static balancing is provided by manual balancing valves. It ensures a certain differential pressure at a given, static operating condition – usually the design load of the heating system, depending e.g. on building envelope characteristics and climate conditions. Dynamic balancing is provided by so called automatic balancing valves or alternative solution, e.g. pressure-independent thermostatic radiator valves, combining individual room temperature control and dynamic balancing functionalities. The dynamic balancing functionality ensures stable differential pressure at all operating conditions of the heating systems. In conjunction with the radiator control valves correct flows and heat delivery are ensured continuously at all full design load and part load conditions.

The final step in creating an efficient system is ensuring the right settings on the balancing valve. The procedure for commissioning heating systems equipped with manual balancing solutions normally requires a lot of work and experience. The commissioning of heating systems that are equipped with dynamic balancing solutions requires less work, less measurement operations and fewer calculations. It therefore ensures that commissioning is done properly and the heating system works at maximum efficiency under actual operating conditions. The benefits of dynamic balancing functionality can be summarized as:

- increased energy efficiency
- more indoor comfort
- less complaints
- time saving due to less work/maintenance and measurement operations
- optimized and secure functionality and performance of the heating system.

NEED FOR DIFFERENTIAL PRESSURE CONTROL EXPLAINED

The challenges for designing, and maintaining well-functioning heating systems presented in the previous section are well known. In practise, however, the major part of heating systems is set-up and operated sub-optimal. Consequences include unsatisfactory indoor temperature or disproportionate heating system noise. All these symptoms can be traced back to the fact that most of Europe's existing building stock have unbalanced or poorly balanced heating systems. Figure 1 illustrates the water distribution in case of unbalanced system.

In the radiators close to the pump (represented in Figure 2 by the water tap) the flow through the connected radiators can be several times higher than necessary for proper functioning. The consequence is that the pressure loss in those pipes increases, which results in too little pressure being available for the 'critical' radiators which are furthest away from the boiler or heat pump room. Occupants of affected building units will at certain parts of the day suffer from completely or partially cold radiators, despite heating need.

Complaints are often attempted to be solved by increasing water temperature, pump head settings, or installing a larger circulation pump. The problem with cold radiators might seem to disappear, but the overall performance and the system hydronics further deteriorates, because heat transfer and return temperatures are affected by too high flows. Such approaches usually lead to increased energy use [10].

Formally, return temperature relates to water flow according to the equation:

$$Q = \rho * cp * \Delta T * q$$

where
Q heat transfer [W]
ρ water density [kg/m^3]
Cp medium specific heat capacity [J/K]
ΔT (Ti – Tr), temperature difference between ingoing temperature and return temperature [K]
Q water flow [m^3/s]

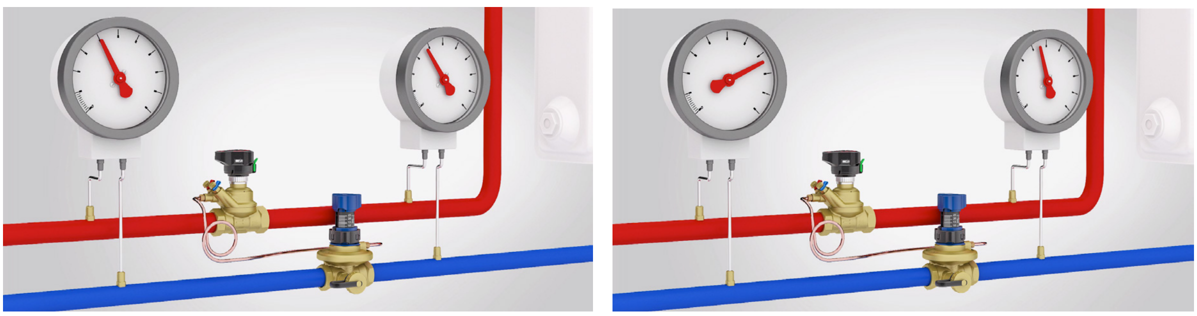

Figure 1. Dynamic balancing functionality provided by automatic balancing valves: stable differential pressure (right meter), at fluctuating available pressure (left meter).

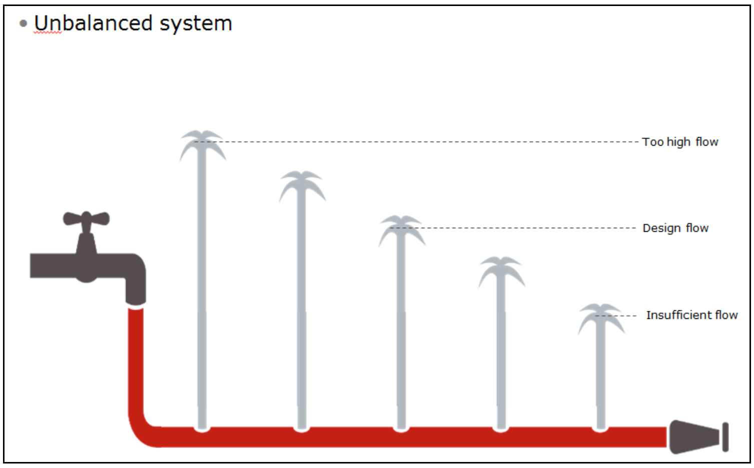

Figure 2. Distribution of hot water in unbalanced heating systems.

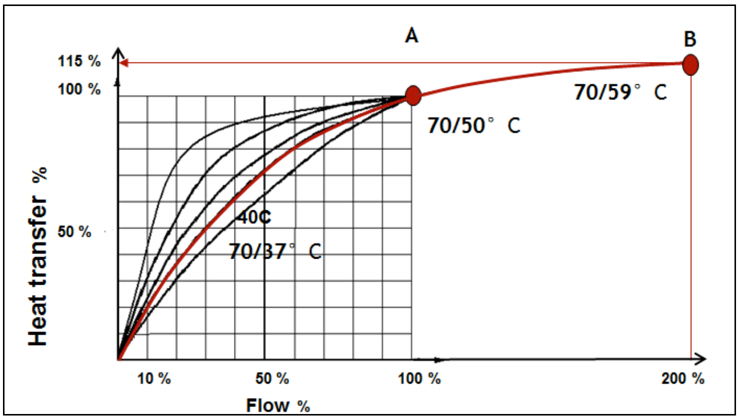

Figure 3. Non-linear heat transfer characteristic of water-air based terminal unit (radiator).

The relation is shown in Figure 3: it shows that if the flow in the radiators close to the pump increases twice (point B), return temperature increases as the heat transfer gain is not linear. The result is overheating in these rooms, also with negative consequences for boiler efficiency. The difference to point A – which would happen in case of balanced system with correct flows – is very large, resulting in 59 °C instead of 50 °C return temperature.

In short, systems without proper hydronic balance are operated with higher water temperatures to achieve the expected comfort level. Then the efficiency of the boilers or heat pump decreases and do not reach its optimal level. In particular the expected efficiency of condensing boilers depends on the condensation of exhaust gas on the heat exchanger. *The colder the return water temperature, the higher the rate of condensation and by that the higher the efficiency of the boiler.* Hence, no or poor hydronic balancing increases heat losses in transportation pipes and the affects the efficiency of condensing boilers and heat pumps.

A CLOSER LOOK: DESIGN AND PART LOAD CONDITIONS

This section provides a closer look into importance of dynamic balancing due to partial load conditions. A heating system is calculated for a worst case scenario, called design condition. Calculation is based on minimal expected outside temperature, often referred as design outside temperature.

However, a heating system is a dynamic system. The calculated/designed heat is needed only during approx. 5 % of the heating season; in other words, most of the time heat demand is lower than what system is calculated for due to higher than minimum outdoor temperature, solar gains and internal gains such as heat generated by people or appliances etc.

As such, a typical heating system is running at part load most of the time. This means that 1) hydronic balancing is increasingly important, and 2) systems need dynamic balancing functionality. Manual static balancing commissioned to deliver maximum capacity cannot ensure high efficiency system operation during prevailing actual part load conditions. This effect becomes even more important in well-insulated buildings. Such effect can be observed in case 3 from Szczecin, Poland, where realized dynamic balancing relative savings are highest from all, and higher than expected from study [7]. Well insulated buildings require a dynamically controlled equilibrium between reduced energy losses, internal gains and the remaining energy needs.

Status in existing and new built: market and regulatory barriers

As far as individual room temperature control is concerned, it is estimated that about 500 mln radiators installed in residential buildings lack this functionality [4]. The distribution across geographies varies, as in some countries automatic room temperature control is mandatory since long, while in other coun-

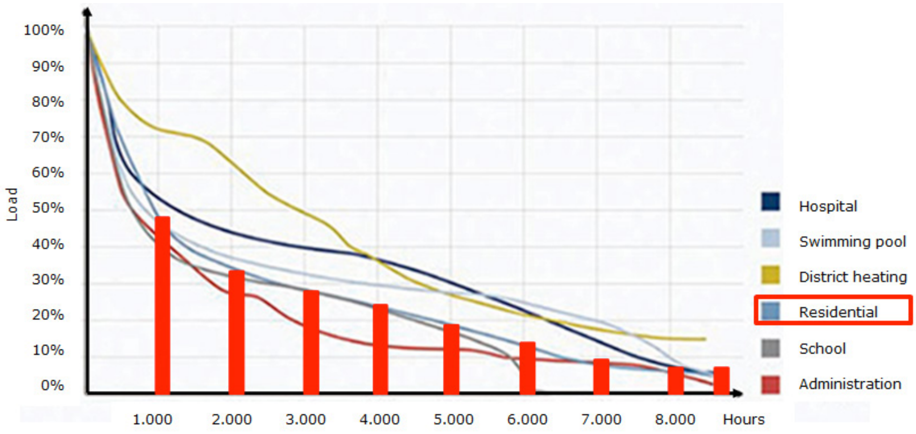

Figure 4. Cumulative heating load distribution for different building types.

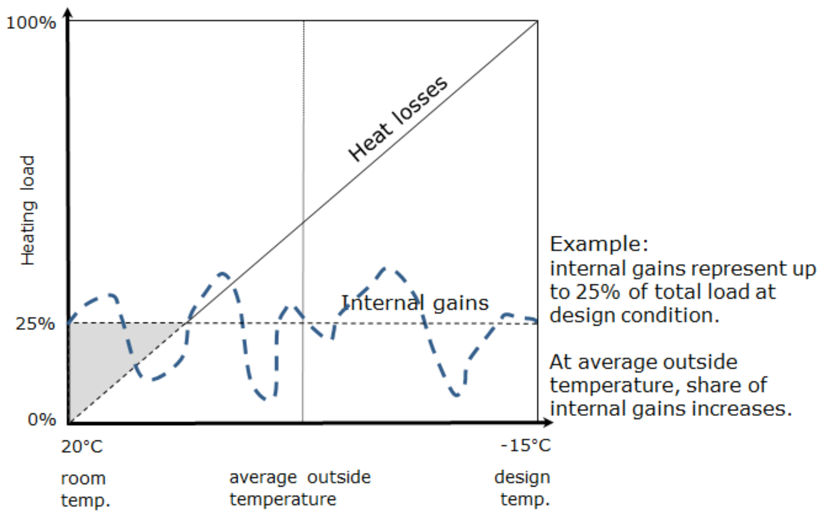

Figure 5. Internal gain increased share at higher than design outside temperature.

tries market and regulatory praxis prevent their installation. The proportion of "missing" individual room temperature control in MFH is not known. It can be assumed that the on-going implementation of the provisions on individual metering and billing in multi-family houses (MFH) with central heat supply [Directive 2010/30/EU of the European Parliament and the Council of 25 October 2012 on energy efficiency, Article 9] will contribute to the installation of individual room temperature control, along with HCA, to some extent. On the other hand, it can be expected that often MFH will be equipped with HCA only, due to split incentives, missing agreements of proprietors in co-owned properties, and the lack of a regulatory framework. In these cases, occupants will be provided with consumption information, but remain unable to take ownership of their heating bill due to the absence of automatic individual room temperature control functionalities.[3]

3. Guidelines on good practise in cost-effective cost allocation and billing of individual consumption pf of heating, cooling and domestic hot water in multi apartment and multi-purpose buildings https://ec.europa.eu/energy/sites/ener/files/documents/mbic_guidelines20170110.pdf.

The EU Directive on the energy performance of buildings of 2010 mandates that energy performance of "technical building systems" shall be optimized [Article 8 EPBD on Technical Building Systems]. Requirement shall be set i.a. on their overall energy performance, adjustment and control, including heating systems. In principle, this would be an appropriate framework to improve the temperature control and hydronic properties of central heating systems installed in multifamily buildings. However, little progress was achieved. In practice, regulatory action on optimized control of energy generation, distribution and emission is largely absent in national implementation [7], so that the market failure remain largely unaddressed. The European Commission has proposed amendments to the EPBD. They leave the core of the legal requirements on technical buildings systems unaltered, but foresee that their application is facilitated e.g. by documentation of improvement measures taken in individual installations. For larger buildings, some incentives are suggested for larger MFH with installed capacity of 100 kW in the context of inspections. While these provisions acknowledge the importance of reinforced regulatory action on heating systems, it can be expected that the resulting rate of improving buildings will be very low. Furthermore, the proposal does not sufficiently recognize the importance of part-load conditions, and the functionality of automatic hydronic balancing is not reflected. Therefore, it can be expected that the current proposals, were they adopted, would do "too little, too late" in respect of optimized control of energy generation, distribution and emission in existing, renovated and new MFH.

Conclusions

Unsatisfactory performance of central heating systems is a major issue in existing buildings, for renovations, and for buildings towards a decarbonised building stock 2050. Ensuring optimal energy performance at all heat load conditions is a fundamental aspect for providing desired occupant comfort-levels with least energy use and operating costs, and no lock-in effects. In a building stock with increasingly better envelope characteristics and near zero energy buildings, operating conditions using only a small part of the installed heat output capacity become ever more important. Ensuring optimal performance under such conditions is necessary for a successful energy transition in the building sector, and complements the existing policies that target the heat generator/supply and the envelope.

To this end, energy generation, distribution and emission have to be controlled adequately at all times, at all loads and in all rooms/sectors for a building. The basic functionalities are individual room temperature control, and dynamic hydronic balancing. The biggest part of Europe's multifamily buildings is lacking at least one of them. Hydronic imbalances and missing individual room temperature control are main root causes for energy waste, unnecessary heating costs, occupant complaints, and divergence of expected and actual energy consumption after renovation.

Technical solutions that get the basics right are well-proven and offered by multiple suppliers at relatively low cost. Individual room temperature control and dynamic hydronic balancing functionalities delivered by equipment installed at the riser pipes or directly at the radiators secure optimized energy performance of the heating system. This is to the benefit of both building owners and building users or residents. Innovative digitalized solutions deliver additional cost-effective savings potentials and enable the integration of buildings in the wider energy system. They enable occupants to adapt timing and indoor temperature levels to individual behaviour and heat usage patterns, using internet-based, connected technologies that facilitate remote user-interaction with the heating systems settings.

New EU legislation on energy efficiency and energy efficiency in building is being developed. Where market barriers for installation for automatic individual room temperature control and automatic hydronic balancing persist, they should be effectively addressed. The proposals of the European Commission go in the right direction, but will do "too little, too late". The elements on control of energy generation, distribution and emission should be strengthened so as to ensure that basic functionalities for automatic individual room temperature control and automatic balancing are swiftly installed in Europe's MFH.

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