System Balancing for Technical Building Systems :

A great opportunity for Energy Savings and Comfort

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EUROPEAN BUILDING AUTOMATION CONTROLS ASSOCIATION
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1. THE IMPORTANCE OF OPTIMISING HEATING AND COOLING SYSTEMS

Heating and cooling our buildings accounts for about 30% of the final energy consumption in the EU, over 70% of which comes from fossil fuels[1]. The optimization of heating, ventilation and air conditioning (HVAC) systems in buildings requires more than simply improving the efficiency of the heating or cooling generation equipment (e.g. heat pumps, boilers, chillers). **It is also vital to look at how heating and cooling is distributed from the central generator to points of end use.**

Hydronic systems operate through the distribution of a warm or cool water, around the buildings. **"Balancing the system" means to ensure that warmth or coolth is distributed around the system to satisfy the building's heating or cooling demand as effectively and efficiently as possible. Non-balanced system do not provide the needed heating or cooling capacity, which in turn leads to insufficient comfort and increased energy consumption.**

Balancing a hydronic system is typically done in one of two ways:

- The more basic **"static balancing"** where the system must be carefully set up by the installer. The static balancing is performed for full load conditions only. A static balanced system might become unbalanced at partial load operation.
- The more advanced **"dynamic balancing"** where special valves are installed to provide automatic balancing, which is much easier to set-up and which, because the valves can continuously react to changing conditions in the system, will result in perfect balance under all operating conditions.

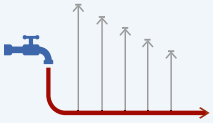
It is estimated that **95% of buildings in Europe lack dynamic hydronic balancing.** In Germany, the majority of heating systems, 80% to 85% are currently installed without even static hydronic balancing[2]. Despite the fact that it is a **capital-light investment with fast pay-back**, balancing is an aspect that today is usually neglected in renovation. In the new-built markets it is not uncommon to find poorly commissioned systems even if balancing valves are installed.

EU legislation, including the Energy Performance of Buildings Directive (EPBD) and Ecodesign, has put forward important provisions to optimize technical building systems but these **have not yet fully addressed market failures** and therefore **the potential of hydronic balancing remains largely unrealized.**

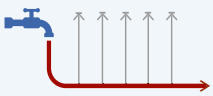
THE TECHNICAL BIT :

Static/manually balanced system – provided by manual balancing valves. It ensures a certain pressure at a given, static operating condition – usually the design (maximum/full) load of the HVAC system. The balance will be set by the installer through measurement and adjustment of the balancing valves taking account of factors such as the building envelope characteristics and climate conditions.

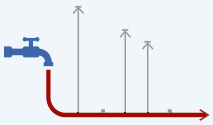
Dynamic balancing – provided by 'automatic balancing valves' or 'pressure-independent control valves', which control the pressure across temperature control valves. The dynamic balancing functionality ensures that the required flow rate is maintained under all operating conditions, including partial load conditions and therefore ensures the correct power output at all system operating conditions. As a result, it provides stable temperature and comfort at all times, and achieves higher and more reliable energy savings than static balancing.



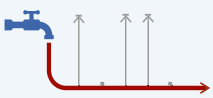
UNBALANCED SYSTEM IN FULL LOAD :
the greater the distance from the source the less hot/cold water reaches the emitters.



STATIC BALANCING SYSTEM IN FULL LOAD :
water is distributed equally.



STATIC BALANCING SYSTEM IN PARTIAL LOAD :
the system does not adapt resulting in unequal distribution and energy waste.



DYNAMIC BALANCING IN PARTIAL LOAD :
the system adapts and ensures stable water distribution under all conditions.

[1] https://ec.europa.eu/energy/topics/energy-efficiency/heating-and-cooling_en?redir=1

[2] Hydraulischer Abgleich: Deutsche verschwenden Energie, Haustec, https://www.haustec.de/heizung/waermeverteilung/hydraulischer-abgleich-deutsche-verschwenden-energie

2. HOW DOES HYDRONIC BALANCING SAVE ENERGY ?

This is most simply explained in relation to a heating system with hot water distribution, but similar effects will also be seen with cooling or air distribution systems.

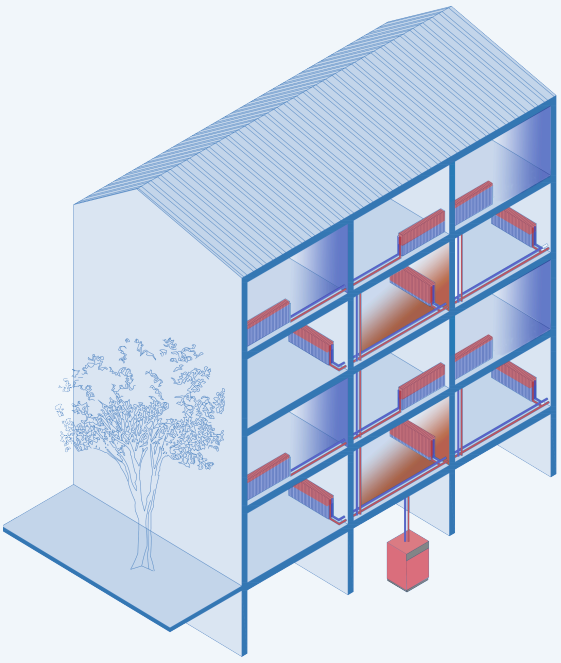
In a heating system a lack of hydronic balancing results in an oversupply of hot water in the system to the emitters located closest to the heat generator, and undersupply to those furthest away. Oversupply means that not all of the heat can be emitted into the space, resulting in high return temperatures to the generator (e.g. a boiler or heat pump), which will then operate with decreased efficiency. It will also increase heat losses in distribution pipes and the power consumption of circulating pumps.

In unbalanced systems comfort will also be noticeably affected. Attempts to resolve complaints often involve increasing water temperatures, 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 deteriorate, because heat transfer and return temperatures are affected by too high flows. Such approaches usually lead to substantially increased energy use.

Hydronic balancing ensures that the right amount of energy is supplied to all emitters/rooms in a building, avoiding oversupply. This will reduce pipework losses and pump power consumption as well as increasing the efficiency of the heat generator.

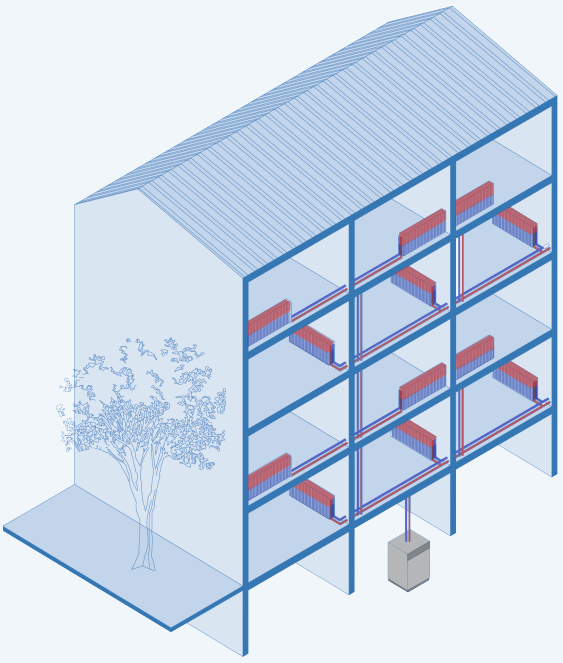
There will be an increasing importance for hydronic balancing with low carbon heating systems, particularly heat pumps where this will ensure a high coefficient of performance.

The illustration below shows a simple example of this with a typical residential heating system:



WITHOUT HYDRONIC BALANCING

- Some rooms are too hot and some too cold.
- Heat appliance is operating inefficiently.



WITH HYDRONIC BALANCING

- Suitable temperatures in all rooms.
- Heat appliance is operating efficiently.

3. HOW MUCH ENERGY CAN HYDRONIC BALANCING SAVE ?

There are a number of studies that have demonstrated the potential for energy savings from hydronic balancing:

For **existing Multi-Family Housing** with radiator heating, **savings of 7-16 kWh/m²** are typically achieved **for thermal energy consumption** (the highest savings with dynamic balancing), and **25% for auxiliary energy consumption** (electricity) with a payback time of 3.5/ 4 years[3].

Studies on a selection of cases suggests a space heating energy consumption reduction from upgrade with automatic balancing equipment in a system where individual room temperature control (e.g. TRVs) is installed **ranges between 11% and 22%**[4].

An ITG study on dynamic balancing in hotels showed that **payback times between 1,6 and 4,4 years are possible** and that implementing dynamic balancing in all hotels in Germany **could save 24,2 m kWh/y, which is equivalent to 7,480 t CO_2.**

4. HOW HYDRONIC BALANCING CAN CONTRIBUTE TO THE EU GREEN TRANSITION

- **Ensuring optimal energy performance at all heat load conditions is essential to provide comfort for occupants with least energy use and operating costs, and no lock-in effects.**
  In a building stock that is increasingly better insulated and in nearly zero energy buildings using the installed heat output capacity in a highly efficient manner becomes ever more important.

- Hydronic imbalances and the lack of individual room temperature controls in buildings are the main causes for energy waste, unnecessary heating/ cooling costs, occupant complaints, and the performance gap between expected and actual energy consumption after renovation.

- A study by the Technological University Dublin showed that **the total potential savings from optimizing hydronic distribution in domestic EU heating systems amount to 22.6 Mtoe.**
  53% of this would come from a reduction in pumping power and the other 47% from a reduction in heat energy consumed by the systems[5].

- Acknowledging the importance of hydronic balancing (and the missed potential with the current uptake), Germany made it a pre-condition for receiving funding in its funding schemes for new heating systems and optimization of heating systems[6].

[3] Potential Energy Savings and Economic Evaluation of Hydronic Balancing in Technical Building Systems, ITG https://files.danfoss.com/download/CorporateCommunication/BuildingEfficiency/Potential-Energy-Savings-and-Economic-Evaluation-of-Hydronic-Balancing-in-Technical-Building-Systems.pdf

[4] Energy savings across EU domestic building stock by optimizing hydraulic distribution in domestic space heating systems, Ahern, Norton https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/5-buildings-and-construction-technologies-and-systems/hydronic-balancing-and-control-8211-how-to-overcome-the-global-challenge-of-reducing-energy-use-in-multifamily-housing/2017/5-235-17_Osojnik.pdf/

[5] Potential Energy Savings and Economic Evaluation of Hydronic Balancing in Technical Building Systems, ITG https://files.danfoss.com/download/CorporateCommunication/BuildingEfficiency/Potential-Energy-Savings-and-Economic-Evaluation-of-Hydronic-Balancing-in-Technical-Building-Systems.pdf

[6] https://www.bafa.de/DE/Energie/Effiziente_Gebaeude/effiziente_gebaeude_node.html

5. MARKET FAILURES AND THE NEED FOR REGULATION

BARRIERS:

Compared to solutions such as building insulation and heat generator replacement, automatic hydronic balancing is not sufficiently recognized as a cost-effective way to reduce the energy consumption of buildings.

There is a cost and time implication to ensure that a system has effective hydronic balancing. Without a level playing field through regulation and enforcement, or the availability of financial incentives, there is little incentive for installers or specifiers to ensure that the work is done.

This work can easily fall foul of "split incentives" in multi-family houses, where the capital costs would be paid by the building owner who would have little motivation when the benefits of energy savings would go to the tenants.

INSUFFICIENT REGULATION:

The amended EU Directive on the energy performance of buildings (EPBD) of 2018 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.

For larger MFH (above thermal rated output 70kW), some incentives are set in the context of inspections.

The inspection shall "where relevant, consider the capabilities of the heating/ cooling system or of the system for combined space heating and ventilation to optimize its performance under typical or average operating conditions."

In principle, this would be an appropriate framework to improve the hydronic properties of HVAC systems.

The optimization of an HVAC system's energy performance under real operating conditions is only possible with hydronic balancing.

However, little progress has been made.

While these provisions acknowledge the importance of reinforced regulatory action on HVAC systems and to some extent the importance of part load conditions, **low levels of appropriate regulatory action are apparent national implementation of the EPBD, which means that the market failure remains largely unaddressed.**

6. SUGGESTED POLICY INTERVENTIONS

1. **EPBD: As mentioned above, the current wording around optimisation of HVAC systems is too vague and, as a consequence, member states don't implement it appropriately. This needs to be improved in the revision of the EPBD.**

2. **The Ecodesign Lot 38 Preparatory Study mentions the significant potential for balancing. This needs to be implemented in conjunction with a strengthened EPBD to drive best automatic balancing technologies where appropriate.**

3. **It is recommended that the addition of dynamic hydronic balancing be made mandatory when heating and cooling systems are subject to retrofit (e.g. when the heat/ cool generator is exchanged) and for new build applications to encourage efficiency gains and the transition to lower carbon heating technologies.**

ABOUT EU.BAC

eu.bac is the European Building Automation and Controls Association. It represents the major European manufacturers of products and systems for home and building automation.
Its vision is a world where everyone lives in buildings that are smart, decarbonised and efficient.
eu.bac has founded the European Association of Energy Services Companies (eu.esco) for promoting Energy Performance Contracting as the economically sustainable solution for improving the energy performance of existing buildings using the guaranteed energy savings to pay for the installation.
For more information, please visit www.eubac.org.

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