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Costs and benefits of optimizing hydronic performance of water-based heating and cooling systems

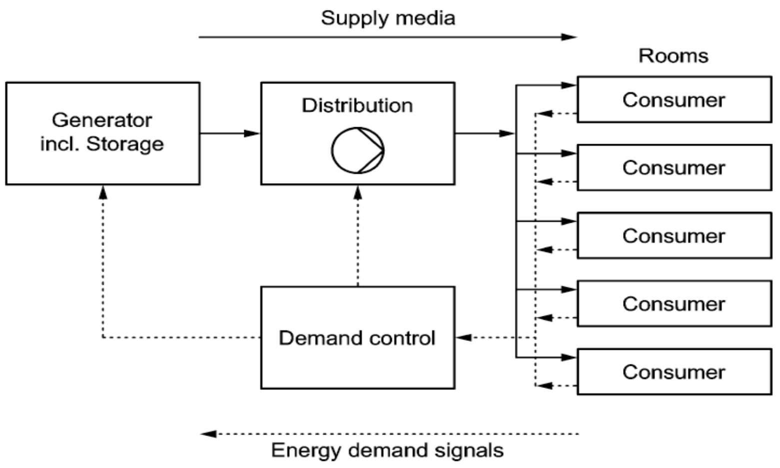
6 June 2019

What is Hydronic Balancing, and why is it important?

- HB is the capability of building automation and controls to ensure the target water flow distribution required to satisfy heating/cooling needs, by calculating and adjusting resistances and pressure losses

→ facilitate that the system delivers the right quantity of heat at the right place at the right time – with minimum input

- HB impacts the entire chain of heat generation, distribution and emission across the building



Appropriate HB facilitates optimal comfort at minimial energy use:

Heat generation	○ **HB facilitates optimized flow/return temperature difference, and hence optimal heat generator performance** ○ **HB facilitates minimizing the flow temperature provided by the heat generator for a given comfort level**
Heat distribution	○ **HB facilitates optimizing energy needs for pumping** ○ **Optimized flow/return temperatures reduce heat losses in pipes**
Heat emission	○ **HB facilitates optimal flow/return temperature in emitters according to actual demand, and hence heat transfer efficiency** ○ **HB facilitates optimal performance of temperature control: minimal deviations actual/set room temperature for minimal setpoint increase (heating) or decrease (cooling)**
Dynamic HB: optimization at all building operating conditions **Static HB: optimization at "design" operating condition, e.g. for space heating lowest outdoor temperature**	

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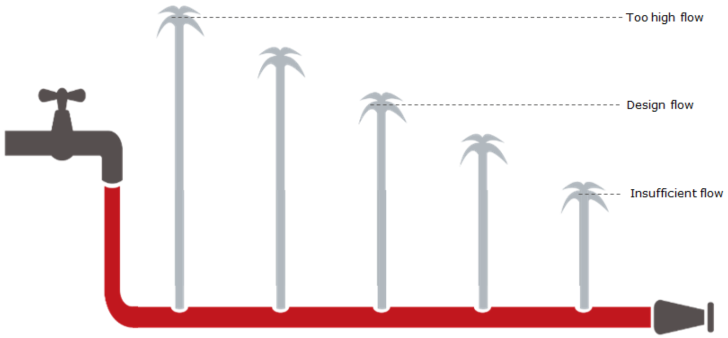
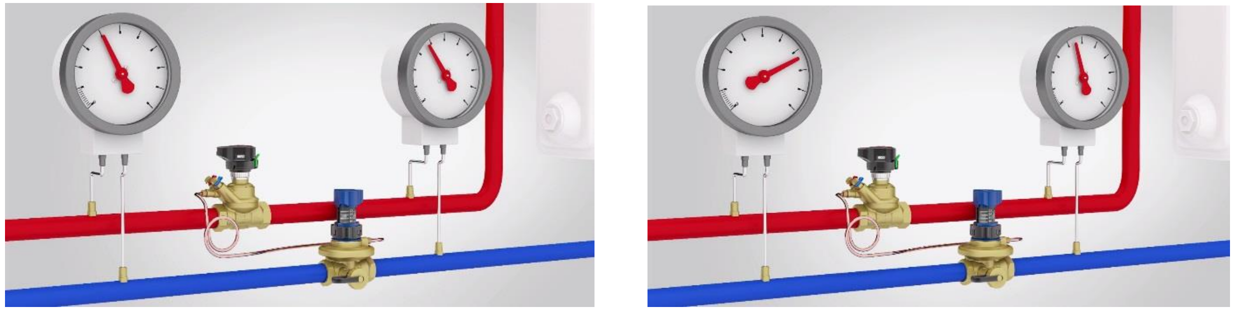
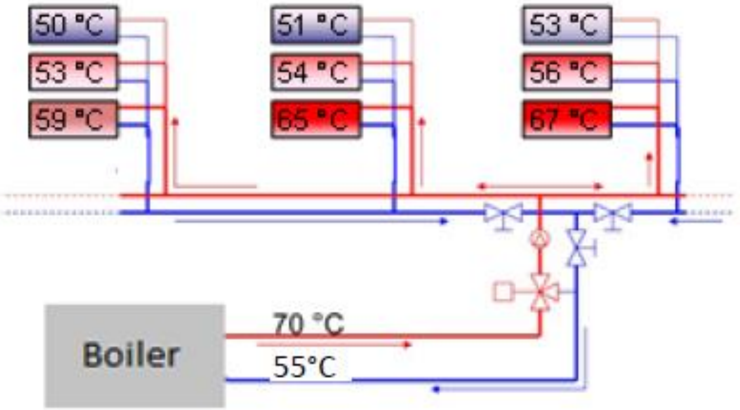
Example: flow temperature optimization of heat generator

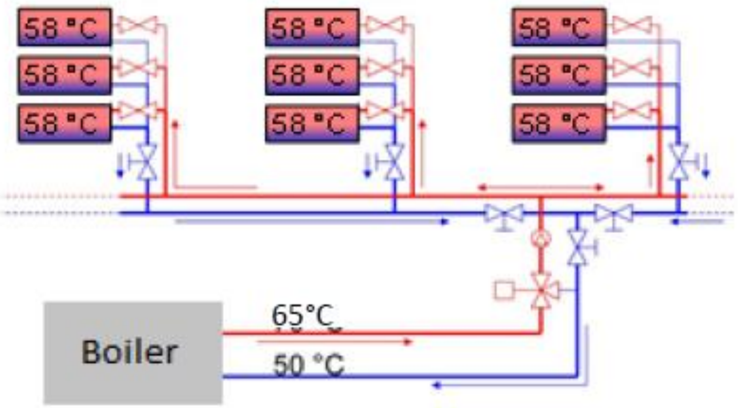
- Unbalanced system







Unbalanced: supply cannot satisfy demand



Balanced:supply satisfies demand

Cost-benefit analysis: iTG Dresden, 2019

Potential Energy Savings and Economic Evaluation of Hydronic Balancing in Technical Building Systems

iTG

Research Report

Potential Energy Savings and Economic Evaluation of Hydronic Balancing in Technical Building Systems

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Dresden, February 4, 2019

- Retrofit HB in existing residential buildings
- Space heating
- Single- and multifamily
- Radiators and floor heating
- Gas boiler, district heating, heat pumps
- Not yet covered: cooling/non-residential → upcoming
- Link: http://files.danfoss.com/download/CorporateCommunication/BuildingEfficiency/Potential-Energy-Savings-and-Economic-Evaluation-of-Hydronic-Balancing-in-Technical-Building-Systems.pdf

Results iTG – amortization period per building

- Positive impact of HB on heating energy and auxiliary electricity use of heating systems
- Relative and absolute energy savings vary with system starting condition
- Typical savings: between 2,5 kWh/m²a…16 kWh/m²a heating energy (end-use) and 25% auxiliary electricty consumption
- Amortization periods for retrofit of HB in existing residential buildings with radiators equipped with pre-settable thermostatic radiator valves
  - About 8-9 years ins single-family houses, and about 3.5-4 years in multifamily houses
  - Calculatory life-time 15 years
  - **Retrofit of HB in an existing heating system is therefore economically feasible pursuant to §5 of the Energy Saving Law**

Results iTG – macroeconomic GHG reduction potential

GHG emissions from heating			190,2	Mt $_{CO2\text{-}equiv}$
GHG reduction potential from HB	Between	5,0%	6,8	Mt $_{CO2\text{-}equiv}$
	And	10,0%	13,5	Mt $_{CO2\text{-}equiv}$
	Average	7,5%	10,1	Mt $_{CO2\text{-}equiv}$

- **Annual GHG emission reduction potential of HB retrofit about 10 Mt$_{CO2\text{-}equiv}$**

Basis:

- about 18.9 mln residential buildings in Germany
- Of which 84 % with central heating system (incl. district heating)
- **85 % of residential building have no hydronic balancing**
- dena-Buildings-Repot 2018: 190.2 Mt $_{CO2\text{-}equiv}$ GHG emissions

Approach for energy savings analysis

Literature: validated field tests

Reference	End-use energy savings		Auxiliary electricity savings		Building type
	Older	Newer	Older	Newer	
Schweikhardt et al.	8 … 11 %		-		Church
Optimus-Study: Wolff and Jagnow	8 kWh/m²	18 kWh/m²	13 %		MFH
Irrek	10 … 15 %			50 % (90 %)	MFH
Hirschberg and Felsmann	8 %			25 %	SFH
Guzek	≤ 7 %	(≤ 1,2%)	26%	12 %	SFH
Seifert et al.	0 … 2,8 %	0 … 7,5 %	-		SFH

- Savings related to static HB (exception: Seifert et al.)
- Technical solutions for dynamic HB available
- No scientifically validated field tests available yet

EPB Standard EN 15316-2 (DIN V 18599-5)

Two-pipe system	n ≤ 10 $\Delta\theta_{hydr}$	n > 10 $\Delta\theta_{hydr}$
No hydronic balancing	0.6 K	
Static balancing per radiator/heating surface without group balance	0.3 K	0.4 K
Static balancing per radiator/ heating surface and static group balancing (e.g. with balancing valve)	0.2 K	0.3 K
Static balancing per radiator or heating panel and dynamic group balancing (e.g. with differential pressure controller)	0.1 K	0.2 K
Dynamic balancing per radiator or heating panel (e.g. with flow limiters and/or differential pressure controller)	0.0 K	

$\Delta\theta_{hydr}$ describes the impact of HB on the temperature variation and the efficiency of heat emission – generation and distribution not covered:

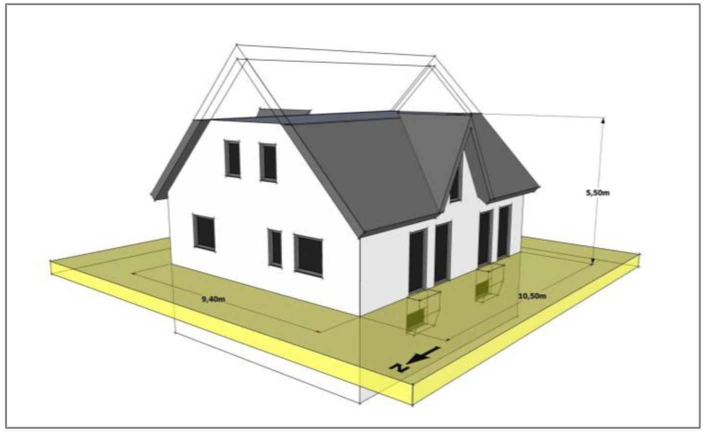
$$\Delta\vartheta_{ce} = \Delta\vartheta_{str} + \Delta\vartheta_{ctr} + \Delta\vartheta_{emb} + \Delta\vartheta_{rad} + \Delta\vartheta_{im} + \Delta\vartheta_{hydr} + \Delta\vartheta_{roomaut}$$

Energy savings and full investment costs work + material

HB option matching typical system status			End-use energy saving in kWh/m²a *Investment in EUR per building / amortization period in years*			
			Single family		Multifamily	
			Older	More recent	Older	More recent
			until 2001	2002 – 2008	until 2001	2002 – 2008
(1)	Static HB at each radiator and static HB at group level, existing pre-settable TRV (and static group level valves in MFH) are adjusted only	Condensing boiler + radiators	5,0 *290 / 8.8*	6,0 *250 / 6.4*	8,0 *4900 / 4.0*	9,0 *4000 / 2.9*
		District heating + radiators			7,0 *4900 / 3.5*	8,0 *4000 / 2.5*
(2)	Static HB at each radiator and static HB at group level, with installation of new valves/TRVs (and new static group level valves in MFH)	Condensing boiler + radiators	9,0 *900 / 15.7*	10,0 *700 / 11.0*	11,0 *16900 / 10.0*	12,0 *13900 / 7.6*
		District heating + radiators			10,0 *16900 / 8.6*	11,0 *13900 / 6.4*
(3)	Static HB at each radiator and static HB at group level, existing pre-settable TRV and dynamic HB by installation of new group level valves in MFH)	Condensing boiler + radiators			11,0 *6700 / 4.0*	12,0 *6000 / 3.3*
		District heating + radiators			10,0 *6700 / 3.4*	11,0 *6000 / 2.8*
(4)	Dynamic HB at each radiator with installation of new dynamic radiator valves and new sensor heads	Condensing boilers + radiators	13,0 *1000 / 12.2*	14,0 *800 / 9.1*	15,0 *18700 / 8.2*	16,0 *15100 / 6.2*
		District heating + radiators			14,0 *18700 / 6.8*	15,0 *15100 / 5.1*

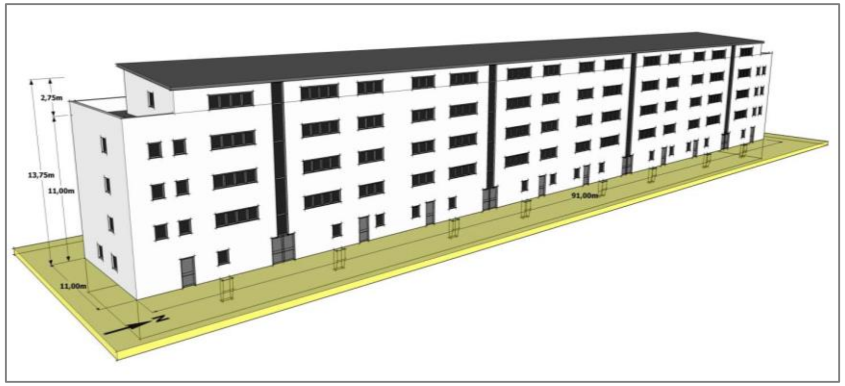
Reference Single Family House

110 m² living area (150 m² overall)



Reference Multi Family House

2850 m² living area (3800 m² overall)



Conclusion: HB in building policies – Germany

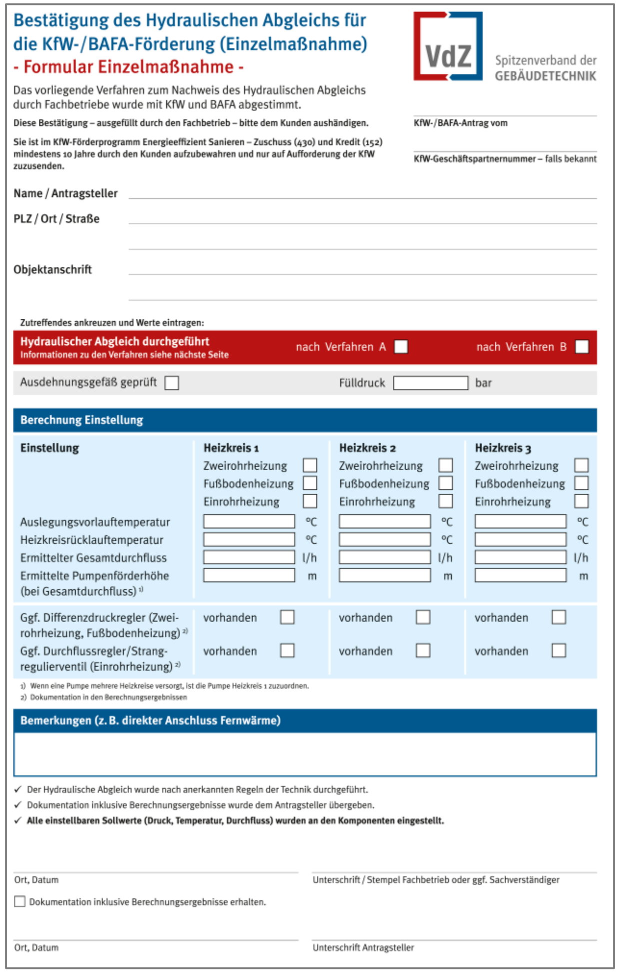
Status:

- HB mandatory for new-built under "Vergabe- und Vertragsordnung für Bauleistungen" (VOB)
- Covered in standards for planning of heating systems
- Covered under KfW and BAFA subsidies
- But at this stage not part of Energieeinsparverordnung
- Yet: 85% of buildings not balanced

Suggestion iTG:

- HB should covered by "GEG"
- Strengthening and clarification of requirements for new-built
- Requirement for HB retrofit in stock

Tools are available, e.g.:



Bestätigung des Hydraulischen Abgleichs für die KfW-/BAFA-Förderung (Einzelmaßnahme)
- Formular Einzelmaßnahme -

VdZ Spitzenverband der GEBÄUDETECHNIK

Das vorliegende Verfahren zum Nachweis des Hydraulischen Abgleichs durch Fachbetriebe wurde mit KfW und BAFA abgestimmt.

Diese Bestätigung – ausgefüllt durch den Fachbetrieb – bitte dem Kunden aushändigen.

Sie ist im KfW-Förderprogramm Energieeffizient Sanieren – Zuschuss (430) und Kredit (152) mindestens 10 Jahre durch den Kunden aufzubewahren und nur auf Aufforderung der KfW zuzusenden.

KfW-/BAFA-Antrag vom

KfW-Geschäftspartnernummer – falls bekannt

Name / Antragsteller

PLZ / Ort / Straße

Objektanschrift

Zutreffendes ankreuzen und Werte eintragen:

Hydraulischer Abgleich durchgeführt — nach Verfahren A ☐ — nach Verfahren B ☐
Informationen zu den Verfahren siehe nächste Seite

Ausdehnungsgefäß geprüft ☐ — Fülldruck ___ bar

Berechnung Einstellung

Einstellung	Heizkreis 1	Heizkreis 2	Heizkreis 3
	Zweirohrheizung ☐	Zweirohrheizung ☐	Zweirohrheizung ☐
	Fußbodenheizung ☐	Fußbodenheizung ☐	Fußbodenheizung ☐
	Einrohrheizung ☐	Einrohrheizung ☐	Einrohrheizung ☐
Auslegungsvorlauftemperatur	°C	°C	°C
Heizkreisrücklauftemperatur	°C	°C	°C
Ermittelter Gesamtdurchfluss	l/h	l/h	l/h
Ermittelte Pumpenförderhöhe (bei Gesamtdurchfluss) 1)	m	m	m
Ggf. Differenzdruckregler (Zweirohrheizung, Fußbodenheizung) 2)	vorhanden ☐	vorhanden ☐	vorhanden ☐
Ggf. Durchflussregler/Strangregulierventil (Einrohrheizung) 2)	vorhanden ☐	vorhanden ☐	vorhanden ☐

1) Wenn eine Pumpe mehrere Heizkreise versorgt, ist die Pumpe Heizkreis 1 zuzuordnen.
2) Dokumentation in den Berechnungsergebnissen

Bemerkungen (z. B. direkter Anschluss Fernwärme)

✓ Der Hydraulische Abgleich wurde nach anerkannten Regeln der Technik durchgeführt.
✓ Dokumentation inklusive Berechnungsergebnisse wurde dem Antragsteller übergeben.
✓ **Alle einstellbaren Sollwerte (Druck, Temperatur, Durchfluss) wurden an den Komponenten eingestellt.**

Ort, Datum — Unterschrift / Stempel Fachbetrieb oder ggf. Sachverständiger

☐ Dokumentation inklusive Berechnungsergebnisse erhalten.

Ort, Datum — Unterschrift Antragsteller

Conclusion: HB in building policies – EPBD implementation

Article 8(1): TBS

Optimize overall energy use of **technical buildings systems** by requirements on overall energy performance, proper installation, appropriate dimensioning, adjustment and control

Article Article 14/15: Inspections

Installation of **building automation and control systems** in larger non-residential buildings, and continuous electronic energy monitoring and installation of **effective control functionalities** in larger residential buildings

Tackle HB in EPBD transposition and implementation:

- ✓ TBS optimization
- ✓ Installation of BACS in non-residential buildings
- ✓ Alternative to inspections in residential buildings
- ✓ Target actual performance under typical building operating conditions – avoid performance gaps
- ✓ Synergies between envelope, equipment and controls in LTRS

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