Belarus

Apartment-level Heat Control and Consumption-based Billing in Centrally Heated Multiapartment Buildings

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Energy and Extractives Global Practice

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Preface

The objective of this technical assistance (TA) was to build consensus on broad-scale introduction of apartment-level control of heat consumption and consumption-based billing in multiapartment buildings (MABs) in Belarus. The following specific tasks were undertaken:

- Assessment of the technical and economic feasibility of installing thermostatic radiator valves (TRVs) and using electronic heat cost allocators (HCAs) for consumption-based billing in MABs;
- Review and analysis of institutional and regulatory issues related to apartment-level consumption-based heat billing;
- Consultation with households about their opinions toward apartment-level heat control and the use of HCAs for apartment-level heat billing through focus group discussions;
- Regional knowledge exchange, including review and analysis of relevant experience in European countries where similar transitions have taken place (i.e., introducing apartment-level heat control and consumption-based billing in multiapartment buildings with vertical piping systems); and a study tour to Poland and Hungary for government decision makers, city leaders and DH company executives; and
- Development of a roadmap and recommendations for the rolling out of a national program for supporting large-scale introduction of TRVs and HCA-based heat billing.

The outputs of the TA are summarized in this report, including a Summary Note about the main findings and recommendations, Subreport 1 on the results of technical and economic assessments, Subreport 2 on households' perspectives and legal and regulatory issues, and an Appendix summarizing the findings of the study tour to Poland and Hungary.

The TA was carried out in close collaboration with the Ministry of Housing and Utilities and the Energy Efficiency Department of the State Committee for Standardization, as well as in consultation with the Ministry of Antimonopoly Regulations. The Energy Sector Management Assistance Program (ESMAP) of the World Bank provided generous funding for the TA. The World Bank team included Feng Liu (team leader), Irina Voitekhovitch (Energy Specialist), and Arto Nuorkivi (International Consultant).

Summary Note

Apartment-Level Heat Control and Consumption-Based Billing in Centrally Heated Multiapartment Buildings

Why Do Apartment-Level Heat Control and Consumption-Based Billing Matter?

1. Improving the energy efficiency (EE) of district heating (DH) systems and reducing the wasteful consumption of district heat in multiapartment buildings (MABs) are important to Belarus' energy security. About 80 percent of district heat is produced from imported Russian gas. MABs account for 70 percent of the residential building stock in Belarus and are generally provided with DH service. The government has invested in modernizing DH supply, including new CHP plants, upgraded boiler houses and heat networks. But residential DH remains wasteful due to both technical and behavioral issues:

- *There is little incentive nor technical capability for individual households to actively conserve heat* – heat is generally metered and billed at the building level and the building heat bill is divided into individual household heat bills based on the size of apartments (heated floor area) regardless of actual consumption by individual apartment. The technical and physical infrastructure for heat control and consumption-based billing at apartment level does not exist for most MABs;
- *Residential heat tariff is heavily subsidized* – residential heat tariff for owner-occupied apartments was at about 20 percent of operating cost recovery level in 2018. Households do not have the sense of the full cost of heating and cannot properly rationalize the financial benefit of heat savings; and
- *The heat losses of vintage MABs are high* – about 70 percent of the MABs in Belarus were built between 1950 and 1995 when thermal insulation of building envelope was not required. Application of current thermal insulation requirements would have cut the heat losses of pre-1996 MABs by 50 percent or more.

2. Apartment-level heat control will enable individual households to regulate heat consumption based on needs and preferences. But the active use of heat control is generally associated with behavioral changes triggered by consumption-based billing, which rewards individual households financially for conserving heat energy. Currently, households in overheated apartments open widows to regulate room temperature. For most pre-1996 MABs in Belarus, the technical solution involves installation of thermostatic radiator valves (TRVs) and bypass pipes (for vertically connected radiators) for heat control, and installation of electronic heat cost allocators (HCAs) and data collection (from individual HCAs) and processing equipment for consumption-based billing.

3. The government plans to scale up investment in thermal renovation of pre-1996 MABs. Empirical experience from other countries indicates that actual energy savings from such investments are significantly lower without the active use of TRVs, which in turn is critically dependent on apartment-level consumption-based billing. It is thus important that installation of TRVs are mandatory for MABs undergone thermal renovation, and that HCA-based billing is introduced to induce the necessary behavioral changes. For European Union (EU) countries, apartment-level consumption-based billing is now required for all MABs deemed technical feasible for such arrangements.

The Technical and Economic Viabilities of Apartment-Level Heat Control and Consumption-Based Billing in Belarus

4. TRVs and HCAs are technically reliable. For most of the pre-1996 MABs in Belarus, the use of HCAs is the only viable technical solution for apartment-level consumption-based billing. Individual apartment heat meters can only be applied to apartments with a horizontal piping layout. The cost of changing from vertical piping to horizontal piping cannot be justified for the purpose of heat metering. TRVs and HCAs have been widely used for decades with proven reliability. The widespread use of electronic HCAs with remote reading and monitoring in the last decade or so made consumption-based billing using HCAs significantly more accurate, un-intrusive and tampering-resistant.

5. TRVs and electronic HCAs can be used for both vertical and horizontal piping systems. A mixing loop should be installed to the building basement if there is no existing and functioning building-level temperature control. Occasionally there may be two technical issues to be considered when installing TRVs and HCAs:

- Dilapidated piping inside the building may lead to poor water quality and block the TRVs, requiring selective replacement of piping; and/or
- Hydraulic balance may be difficult to reach in old and corroded piping with sediment layers deposited in the pipes; again, selective replace of old piping may be required.

6. TRVs and HCAs are effective in reducing heat consumption and are financially cost-effective when heat tariff is at operating cost recovery level. Based on the analysis of large datasets from the cities of Minsk, Gomel and Mogilev this study determined that TRVs and HCAs together could reduce heat consumption of MABs in Belarus by roughly 15%. The payback period for installing TRVs and using electronic HVA-based billing is sensitive to heat tariff levels. The payback period at operating cost recovery level for 2018 is less than 4 years, which would be financially attractive since the cycle of replacement for electronic HCAs is 10 years. The effective life span of TRVs is usually 15 years or more.

Households' Opinions on Apartment-Level Heat Control and Consumption-Based Billing

7. Apartment-level heat control and consumption-based billing entails costs and behavioral changes for households, who may be willing to adopt these technologies, if they provide comfort, control, and the ability to save money on heating bills. Under this study 12 focus group (FG) discussions were organized in the cities of Minsk, Gomel, Mogilev, and Brest to learn the views and preferences of MAB households related to the introduction of apartment-level heat control and consumption-based billing. Although the findings from these FGs may not be generalized because of the limited number of participants, they are informative with respect to the potential interests and concerns of the beneficiary households. The main takeaways include:

- MAB tenants value heating comfort and control, and, when informed about the benefits, welcome TRVs and HCAs. FG participants, either with or without experience using TRVs and HCA billing, expressed interest in and support for investing in TRVs and HCAs, usually commensurate with their desire for or satisfaction with improved heating conditions in their homes. Possibility to control heat consumption with the use of TRVs is perceived as important, as it allows to avoid overheating and save heat energy;

- Heating cost allocation based on the measurements provided by HCAs is perceived as more justified than division of heating bill by the size of apartments, since the former is considered more reflective of actual heat consumption;
- The willingness to invest in TRVs and HCA-based billing varies depending on households' priorities. Those who value ability to control heat consumption and maintain comfort tend to tolerate longer financial payback, while still many would consider the investments only with short financial payback period;
- Government support in the form of capital grant to reduce the upfront cost of TRV and HCA investments is desirable. The possibility to pay in installments is also considered as an important supporting measure to ease households' financial burden; and
- There are significant information gaps on usage of TRVs and HCAs to reduce heat consumption and concerns on their technical reliability.

Legal and Regulatory Issues

8. The existing Belarusian regulatory provisions and technical standards for apartment-level heat metering and billing are primarily for new buildings equipped with apartment-level heat meters. Relevant requirements and specific instructions for implementing HCA-based heat billing are lacking, especially in the following areas:

- There are no specific guidance, directions, or procedures on how apartment-level consumption-based billing should be done, for examples, the arrangements between the DH company, billing company and consumers, whether correction coefficients (for locations of apartments) should be used and how, resolution of disputes, penalty for tampering, etc.; and
- Heat is billed 100 percent on the amount of heat consumption at building level, i.e., heating service is priced by the unit of heat energy supplied (one-part tariff). This could lead to significant variation of heating revenue (unfavorable to district heating company) when apartment level consumption-based billing is introduced and households start to control their heat consumption.

Lessons Learned from International Experience

9. The European Union (EU) introduced mandatory apartment-level consumption-based heat billing in 2012 by its Energy Efficiency Directive (2012/27/EU), requiring its member states to achieve full coverage by the end of 2016. But the implementation has been uneven, especially in countries where buildings with the Soviet era vertical internal piping account for the bulk of residential building stock. Many countries across the former Eastern bloc have undergone district heating market reforms (removing heat tariff subsidies and introducing consumption-based billing) in the last two decades. Adoption of apartment-level consumption-based billing has generally been a gradual process, such as in Poland and Hungary, where HCA-based billing has penetrated about 50 of all apartments as of 2016. Croatia tried to implement a sweeping two-year national program for HCA-based heat billing after joining the EU, but the program was later met with a significant backlash when many households did not realize expected heat bill savings,

in part due to insufficient communication and consultation with households. Among the most advanced EU economies, HCA-based billing is mainstream in Germany and Demark. But in Finland and Sweden, penetration of apartment-level heat billing, either using HCAs or heat meters is low in large part due to wide-spread collective efforts by tenants to actively control heat consumption in their own apartments so each member of the community benefits, rendering the investments in HCA-based billing or apartment-level heat metering economically unattractive.

10. The key lessons learned from the experience of introducing HCA-based billing in Poland, Hungary and Croatia is that (i) achieving broad-scale adoption takes time and policy support, including financial incentives, which are useful to spur early adoption; and (ii) a well prepared and orchestrated consumer outreach and consultation is crucial for managing households' expectations and resolve implementation issues.

11. Some of the issues encountered during the implementation of HCA-based billing in Poland and Hungary are useful to note when design a program in Belarus, including:

- Billing formula allocates too much to the variable cost (energy) component and too little on the fixed cost component, which may distort the cost allocation;
- Apartments in different parts of the building have different heating conditions depending on the floor level and area and the orientation of exterior walls. Usually correction factors are used to make heat cost allocation more agreeable among households;
- Residents of apartments located in the central part of the building may close the radiators and enjoy free-of-charge heating from the neighbors. The heating bills of the apartments with connected radiators (above or below) may become overly high;
- Broken/malfunctioning HCAs are not detected quickly: oftentimes billing analysis identifies the problem after several weeks/months; and
- Tampering of HCA readings is a concern.

The Main Challenges for Introducing HCA-based Billing in Belarus

12. The general conclusions of this study are: (i) TRVs and HCAs are technically reliable and economically cost-effective for realizing apartment-level consumption-based billing in multiapartment buildings in Belarus; (ii) households generally appreciate the ability to control heat at apartment level and are inclined to invest in TRVs and HCAs if heat tariffs reach cost-recovery levels; (iii) with the currently subsidized heat tariff significant financial incentives are likely needed to leverage households investments in TRVs and HCAs; and (iv) some regulatory gaps need to be addressed to support broad adoption of HCA-based billing in Belarus.

13. Due to the current state of subsidized residential heat tariff, implementing broad-scale HCA-based billing is likely to face significant challenges, especially in mobilizing households' participation on voluntary basis. The main challenges are:

- The requisite investment in HCA-based billing would not make financial sense to households at the current level of subsidized heat tariff. This means that significant government financial resources may be needed help incentivize early participation and expand the market for HCA-based billing; and

- Need to help households spread investment cost over a period of time. While the total investment for HCA-based billing is not very large, about €240 for a standard 48 m^2 apartment in 2016, focus group discussions indicated that spreading the cost with monthly installments over 2-3 years is generally preferred. This means that government facilitation in setting up a repayment scheme may be needed.

14. There are still doubts among some government officials and technical experts in Belarus on the merits of apartment-level consumption-based billing despite that evidences in Belarus and EU countries generally affirm the economics of such undertaking. The government needs to take a policy decision and amend relevant sector regulations to support the implementation of apartment-level consumption-based billing.

15. Actions could be taken by the government to mitigate the implementation challenges. Some essential actions include

- Continue the effort to gradually remove residential heat tariff subsidies;
- Allocate resources to pilot and demonstrate HCA-based billing at scale;
- Develop a financing scheme to support broad household participation. For example, on-bill financing arrangements through district heating companies may be an efficient way to enable households' investments; and
- Support the development of homeowner associations, or initially relying on local government interventions.

16. All the above actions may be orchestrated through a national program, which is described in more details below.

A Roadmap for Introducing Apartment-Level Heat Control and Consumption-Based Billing

17. The estimated total investment cost for installing TRVs and HCAs in pre-1996 multiapartment buildings in Belarus is about €580 million. Through a multi-year national program, this investment could be funded by a combination of government capital grants (as financial incentives) and households contributions. Such a program could be implemented together with a national thermal renovation program, or as a stand-alone program.

18. A potential national program for broad-scale implementation of HCA-based billing may be carried out in three phases, with the initial phase focusing on policy development and program design and preparation, the second phase focusing on pilot and demonstration activities, and the third phase for long-term support for scaling-up. More specifically,

- *Phase 1 – Policy Development and Program Design and Preparation* – may span 1-2 years and involve the following activities:

a. Develop and affirm policy positions, including potentially mandatory requirements similar to the provisions in EU's Energy Efficiency Directive, and amend regulations to provide a sound regulatory framework for implementing apartment-level consumption-based heat billing, addressing the specific regulatory gaps based on comparison with good international practices;

b. Develop a 5-year plan for supporting the introduction of TRVs and HCA-based billing, including financing and implementation arrangements for pilots and demonstrations, institutional strengthening and capacity building for market participants (e.g., homeowners association, billing companies, and housing and district heating companies), as well as formulation of a long-term scale-up mechanism which would ease funding constraints; and

c. Develop a communications strategy and a program of specific outreach activities for engaging, informing and consultation with households on the implementation of HCA-based billing.

- *Phase 2 – Implementation of Pilots and Demonstrations* – may span 2-3 years and involve the following activities:

a. Implement a national pilot program at scale with government arranged financing (but partially funded by household contributions), potentially involving hundreds of multiapartment buildings in all oblasts and Minsk City, supported by extensive outreach efforts aimed at multiapartment residents in general, as well as intensive consultation efforts targeted at pilot participants;

b. As part of the pilot program, carry out detailed monitoring and evaluation of the results, develop solutions for critical technical and other issues arising during implementation, and revise and refine implementation support policies and approaches; and

c. Develop a long-term support program, focusing on sustainable financing of scale-up efforts and including private sector participation (e.g., vendors of TRVs and HCAs).

- *Phase 3 – Supporting Long-term Scale-up* – would build on the experience and lessons of the pilot phase to achieve broad-scale adoption of apartment-level consumption-based billing.

19. To enhance the design of the national program for rolling out apartment-level consumption-based the following work would be needed:

- *Analysis of affordability at greater depth and detail for developing sensible financing and implementation arrangements which best suit the beneficiary population while addressing social protection needs*. It is recommended that consultations with a large number of diverse (income, age, and gender) heads of district heating households representing all oblast are carried out for developing a concrete and sensible plan for implementing consumption-based billing using heat cost allocators (HCAs).

- *Understanding and resolving potential issues for district heating companies as a result of apartment-level consumption-based billing*. The impact of reduced heat demand on the revenue and cost recovery of district heating companies should be studied and addressed properly. District heating companies in many EU countries have undergone similar transitions and their experience and lessons learned would be useful when contemplating solutions for Belarus.

- *Managing expectations of the beneficiary households is important because the actual heat bill savings for many may be lower than initially expected*. In the short term, district heating companies cannot reduce fixed cost, when less heat is sold, the unit cost of heat will increase. If district heating companies are allowed to recover this incremental unit cost due to reduced heat sales, then heat tariff will need to be increased, thus eating into the potential heat bill savings by households. Another and generally more prominent issue would be the uneven distribution of benefits among apartments in different locations of a building. Experience in other countries indicated that a significant number of the households in a building may end up paying more than what they paid when heating cost was distributed by the area of their apartments. This is particularly true in buildings without good thermal insulation. These issues will need to be analyzed and properly presented to the potential participating households.

20. Belarus is in a good position for introducing apartment-level consumption-based billing since virtually all multiapartment building already have building-level consumption-based billing and underheating is not a common problem. While the subsidized residential heat tariff is a significant barrier to financially-motivated adoption of HCA-based billing by households, financial incentive to early adopters through capital grant is expected to attract households' participation in the pilots, which would help demonstrate the merits of apartment-level consumption-based billing, test potential financing and funding arrangements, and develop solutions to potential technical and behavior issues, thus readying the market for significant scale-up as heat tariff subsidies are removed overtime.

Subreport 1: Technical and Economic Assessments[1]

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[1] Prepared by Arto Nuorkivi, a district heating expert based in Helsinki, Finland, with the support of local consultants Dragun Sergei, Shesteren Igor, and Alla Ozerskaya.

Summary

There is vast experience in using thermostatic radiator valves (TRVs) and heat cost allocators (HCAs) as means to control and indicate heat consumption at the apartment level in most European countries with encouraging results of energy savings.

Significant heat energy savings were also observed in Belarus in apartment buildings where TRVs and HCAs were installed and actively used, even though the heat prices are heavily subsidized. In Minsk, Gomel and Mogilev up to 20% heat energy savings have been achieved in those buildings using HCAs for apartment-level consumption-based billing, compared with similar buildings using traditional billing with building-level heat metering and allocating apartment bills by heated floor area. Over the long term, as heat tariffs continue to increase to cost-recovery level, the incentive for apartment owners to use HCA readings for heat energy savings is likely to strengthen as the monetary benefits would increase significantly.

In Belarus, virtually all multi-apartment buildings are equipped with building-level heat meters already when supplied by district heating. The natural next step would be to extend consumption-based billing from the building level to individual apartments where it is technically feasible and economically justified.

This report provides an overview on the general technical features of installing and operating TRVs and HCAs (Chapters 2 and 3), analytical results of cases of applying TRVs and HCAs in Belarus (Chapters 4 and 5), common issues related to the use of TRVs and HCA (Chapters 6, 7, 8 and 9), two best practice examples from abroad (Chapter 10), and recommendations for Belarus.

List of Abbreviations

Abbreviation	Meaning
DH	District heating
DHC	District heating company
DHS	District heating system
DHW	Domestic hot water
DSM	Demand side management (of heating services)
EC	European Commission
EE	Energy efficiency
EED	Energy Efficiency Directive
EU	European Union
EVVE	E.V.V.E. – European Association for the Consumption-based Billing of Energy Costs
HCA	Heat cost allocator
LHV	Lower heating value of fuel
SH	Space heating of buildings
TRV	Thermostatic radiator valve
WB	The World Bank

Units

a	year
bar	Unit for pressure = 10^5 Pa
°C	Degrees Celsius
d	Day
€	Euro
g	Gram
h	Hour
J	Joule
l	litre
m	meter
m^2	Square meters
m^3	Cubic meters
mth	Month
Pa	Pascal, unit of pressure
t	ton (metric)
W	Watt (=3.6 J)

Multipliers

G = 1000 M
M = 1000 k
k = 1000
m = 0.001

1. Objectives of the Assessment

The paper assesses the technical and economic features as well as some international experiences of apartment-level heat control and consumption-based billing in centrally heated multi-apartment buildings in Belarusian conditions.

For apartment owners to achieve energy savings, they need to have the means to control heat consumption and the incentive to actually act on controlling heat use. Figure 1 below illustrate how these two factors are enabled. TRVs and, for buildings with traditional vertical piping, HCAs, are key installations at apartment-level to achieve such dynamics.

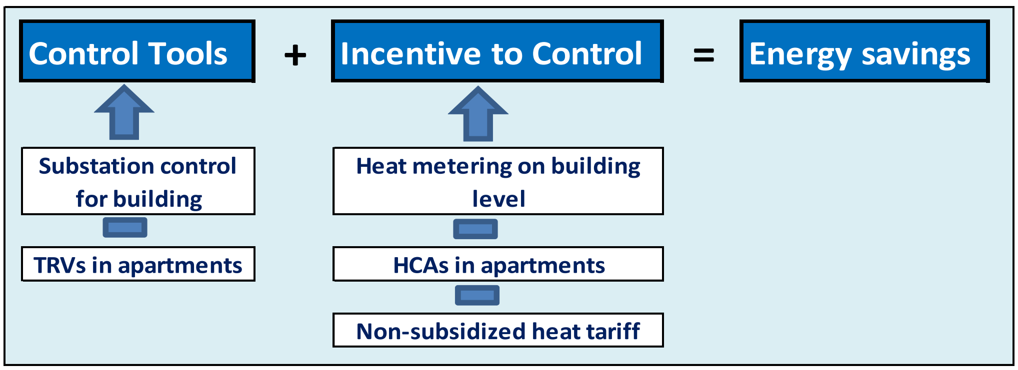


Figure 1: Two-hand approach to enable and incentivize apartment-level heat control

The specific objectives of these technical and economic assessments were to:

- Understand baseline conditions in Belarus
- Identify feasible technical options
- Analyze costs and benefits
- Recommend appropriate technical solutions

2. Equipment for Heat Control and Allocation

2.1 Apartment Level Devices

Technically, small, relatively simple and low cost equipment can be used for heat control and metering/allocation in apartments. Some examples are presented below.

1) Control tool: Thermostatic radiator valve (TRV) senses the actual room temperature, and controls the inflow to radiator either by opening or throttling the water flow.

Figure 2: TRV for vertical 1-pipe

Figure 3: TRV for horizontal 2-pipe

The TRV can be installed in any indoor piping system. However, in the vertical piping with one-pipe only, the TRV requires a by-pass pipe to be installed in front of each radiator.

2) Measuring and billing:

Heat meter can be used only for cost allocation in horizontal piping and is more expensive than HCAs. A heat meter is a combination of water flow sensor, the supply and return water temperature sensors and the calculation unit converting the measurements to heat energy flow.

As an illustration, life cycle analysis for heat metering and heat cost allocator systems for an average apartment of 48 m^2 in Belarus is given below, assuming heat savings being 15% in both cases from the base line of 0.120 Gcal/m^2 that is common in the old buildings in Belarus before thermal renovation and using the estimated average full operating cost recovery heat tariff of €39/m^2 for heat supplied by combined heat and power (CHP) plants in Belarus. The technical lifetime of the equipment is assumed to be 10 years in both cases but the heat meter of the apartment needs to be calibrated (or replaced) every five years.

		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Heat metering												
Heat cost savings	€/a		33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70
Investment cost	€	-336,81					-40,00					
Net cash flow	€	-336,81	33,70	33,70	33,70	33,70	-6,30	33,70	33,70	33,70	33,70	33,70
IRR		-2 %										
Heat cost allocators												
Heat cost savings	€/a		33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70
Investment cost	€	-206,73										
Net cash flow	€	-206,73	33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70	33,70
IRR		10 %										

Table 1: Life-cycle analysis of apartment-level heat metering and heat cost allocation when 15% heat savings are expected.

Using apartment level heat meter, the billing cost is a little lower than that of the HCAs since there is less information flow and processing required in the former, for example, the metered information is already in energy units.

The life cycle analysis indicates that HCAs in general are a cheaper alternative to apartment heat meters because of significantly lower investment costs.

Heat cost allocators (HCAs) can be installed on a radiator in any piping system. The electronic HCAs can be remote read outside the apartment.

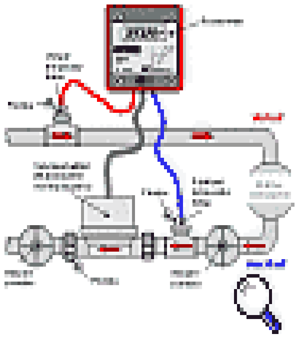


Figure 4: Heat meter with water flow and temperature sensors

Figure 5: HCAs: evaporator type on left and electronic on right.

The HCA should be installed about to the center of the radiator where it reflects the radiator performance in the most accurate way.

Despite of the fact that the standards for HCAs are not harmonized for the time being, the manufacturers or importers of individual HCAs carry out compliance tests based on the requirements of EN 834 and EN 835 on a voluntary basis.

The specifics regarding HCA standards are outlined in Annex 1.

2.2 Building Level Requirements

While using the TRVs, however, the main control should be in the building basement, either in a compact and prefabricated substation (ITP-individualniy teplovoi punkt) or in a mixing loop.

The mixing loop mixes the return water flowing from the radiators with the hot water entering the building to reach the appropriate water temperature to the radiators, appropriate to the prevailing weather conditions and the building specific thermal characteristics.

The mixing loops are illustrated in Figures 6 and 7.

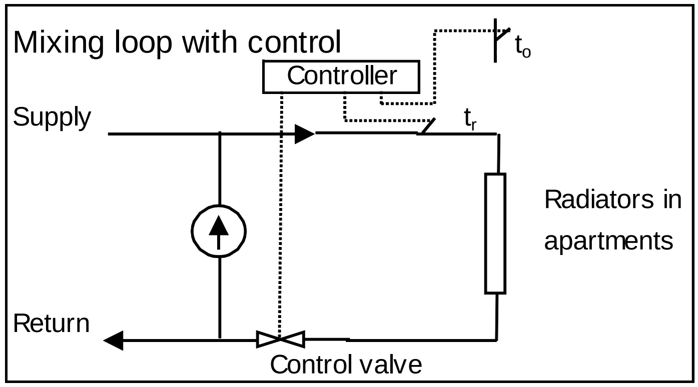


Figure 6: Principle of a mixing loop control and functioning

Figure 7: An existing mixing loop in Minsk with red twin-mixing pump in the center of Figure.

The twin pump in Figure 7 is used to maximize the reliability in case the pump quality is considered poor. Normally, a singly good quality pump would be adequate and economic.

Regardless whether a compact substation (ITP) or a mixing loop is used, there is always a heat meter for the entire building there in Belarus. The heat meter readings would be allocated to the apartments either by means of apartment level heat meters or radiator level HCAs instead of the traditional lump sum payments based on heated square meters of the apartments.

In order for the TRVs to work properly, the riser pipes of the staircases should be balanced in the connection point in the basement of the building, in the outlet of the ITP or the mixing loop.

2.3 Potential Technical Issues

Occasionally there may be two technical issues to be considered when adopting apartment-level heat control and consumption-based billing, as follows.

- Water quality in old piping may be poor and block the TRVs, requiring selective replacement of piping; or,
- Hydraulic balance may be difficult to reach in old and corroded piping with sediment layers here and there inside, again, selective replacement of piping may be needed.

3. In-house Network Systems for Control

3.1 Vertical Piping

Vertical piping means that each radiator is connected to the piping that vertically passes through floors and ceilings of a particular room. Therefore, the radiators of the apartments are connected to separate vertical piping systems which have no common supply connection point for the apartment.

The vertical piping can be further divided to one-and two-pipe systems.

In the one-pipe system the same flow passes through all radiators from the top to the basement floor, thus with the supply temperature reducing on the way. Therefore, as the radiators in the lower floors received supply temperatures lower than the upper floors, the radiators are larger than in the upper floors. The TRV would require a radiator by-pass to function.

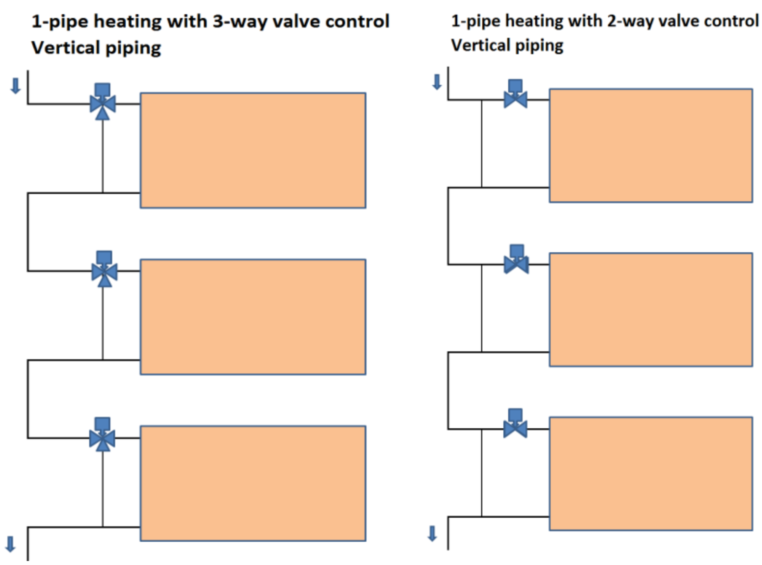


Figure 8: A vertical one-pipe system with an old fashioned 3-way TRV (left) and a modern 2-way TRV (right).

TRVs in one-pipe vertical system is not as effective/accurate as TRVs in horizontal piping due to sensitivity of the flow rates and low pressure differences prevailing between the by-pass and the radiator.

In heat cost allocation, typically, 30-50% of heat consumption is allocated based on HCA readings and the balance based on floor area in one-pipe systems. On the other hand, in two-pipe systems 40-70% are allocated based on HCA readings and the balance on floor areas.

In the two-pipe system the radiators are connected to the riser pipes in parallel, thus each radiator in the vertical line receiving almost the same supply temperature. The TRV would not need a by-pass but can be directly installed to the inlet of the radiator.

2-pipe heating with 2-way valve control
Vertical piping

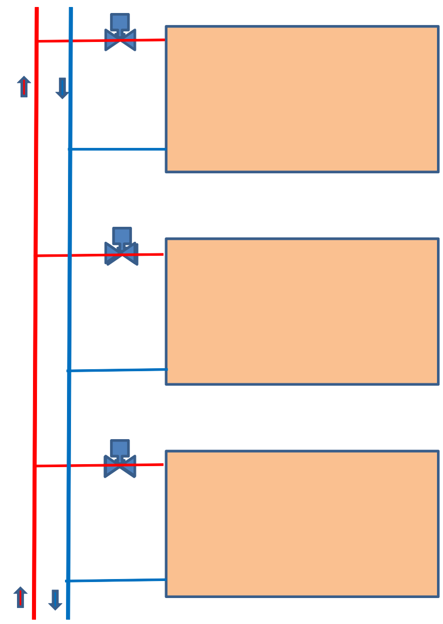


Figure 9: Vertical 2-pipe system with TRVs of same vertically located rooms.

3.2 Horizontal Piping

The horizontal piping means that each apartment is connected to the raiser pipes of the staircase with apartment specific piping connecting all radiators of the apartment to one connection point. Therefore, a heat meter could be installed to measure the heat energy delivered to the apartment if so wished. Again, each radiator can be equipped with TRV and HCA as well.

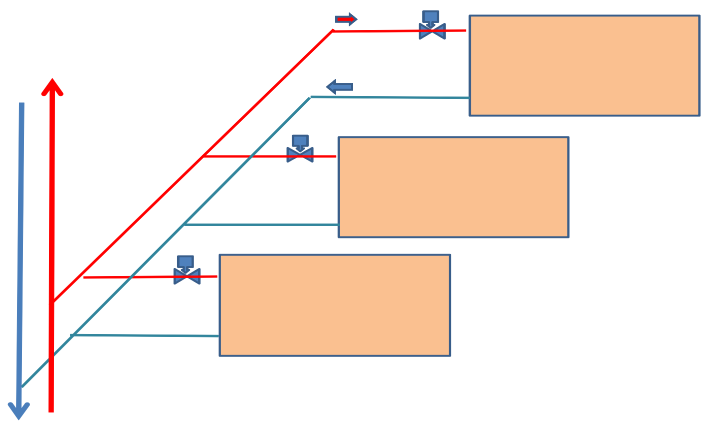


Figure 10: Horizontal piping of an apartment connected to the riser pipes in the staircase.

A two-way valve (TRV) controls the water flow to the radiator by throttling/opening depending on the difference of the actual and set room temperatures.

All modern buildings use horizontal piping, which makes the TRV operation most accurate and allow more accurate consumption-based billing.

While using horizontal piping, typically 50-70% of heat consumption is allocated based on HCA readings.

The horizontal piping is the only piping that allows apartment level heat metering.

4. Belarus Case Studies – Materialized Energy Savings

4.1 Methodology of Belarus Analysis

The analysis is intended for studying the incremental (or the lack of) effect on heat consumption by using TRVs and HCAs for apartment-level heat control and consumption-based billing

All analyzed buildings in Minsk, Mogilev and Gomel have vertical piping with one pipe system.

Heat consumption values from 5 heating seasons were converted to Gcal/m2 specific heat consumption corresponding to a normal year.

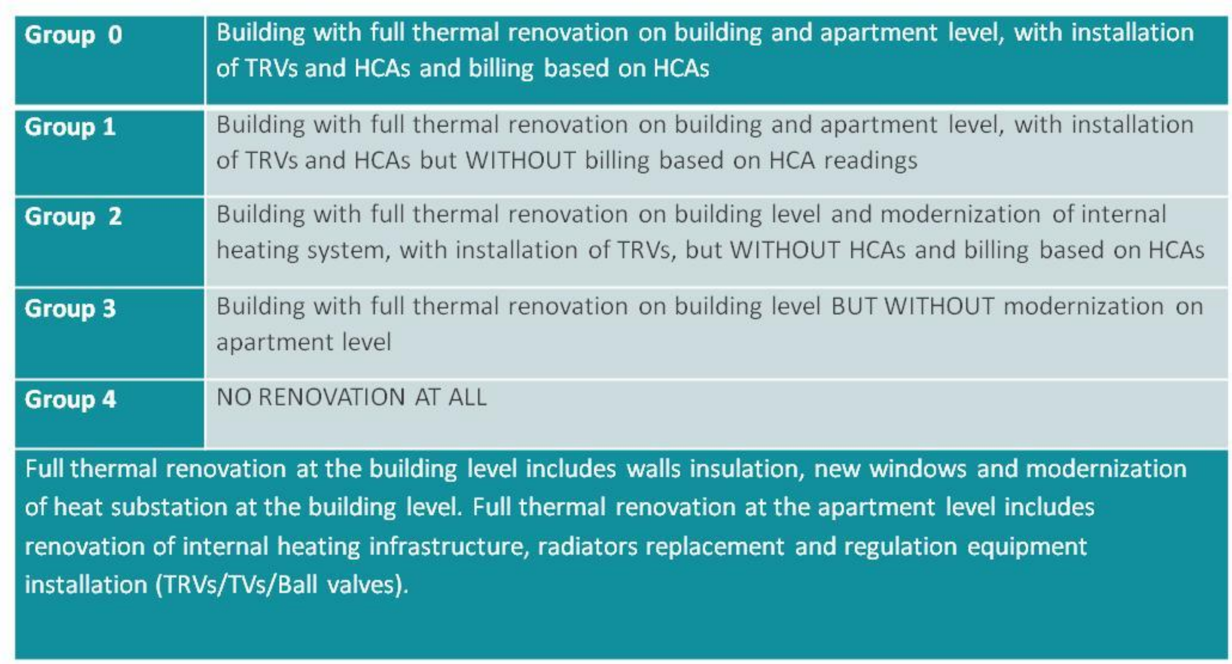
Both the building renovation status as well as the TRV and HCA status in the apartments were recorded.

The investment costs of the various apartment level heat control and cost allocation components were estimated. However, the investment costs of building renovation (windows, building envelope) were not collected, as this is not a concern of this study.

The technical approach of the analysis is presented in Annex 2.

4.2 Overview of Analyzed Buildings

Here only buildings with vertical piping were analyzed. The analyzed buildings were divided into 5 groups according to Table 2 below:



Group 0	Building with full thermal renovation on building and apartment level, with installation of TRVs and HCAs and billing based on HCAs
Group 1	Building with full thermal renovation on building and apartment level, with installation of TRVs and HCAs but WITHOUT billing based on HCA readings
Group 2	Building with full thermal renovation on building level and modernization of internal heating system, with installation of TRVs, but WITHOUT HCAs and billing based on HCAs
Group 3	Building with full thermal renovation on building level BUT WITHOUT modernization on apartment level
Group 4	NO RENOVATION AT ALL

Full thermal renovation at the building level includes walls insulation, new windows and modernization of heat substation at the building level. Full thermal renovation at the apartment level includes renovation of internal heating infrastructure, radiators replacement and regulation equipment installation (TRVs/TVs/Ball valves).

Table 2: Grouping of the buildings in the thermal performance analysis.

Altogether, there were 7,696 apartments covered by this analysis, of which 4,798 were in Minsk, 2,499 in Mogilev and 398 in Gomel. Table 3 provides the sample information in terms of number of buildings and the heated area.

The sample of 351,200 m^2 corresponding to 7,696 apartments results in 46m^2 size apartment on average, which is close to the country average of about 48 m^2.

Code	Heated area				Measures
	Minsk	Gomel	Mogilev	TOTAL	
	th. m2	th. m2	th. m2	th. m2	
Group 0	21 526	3 541	29 864	54 931	RENOV+TRV+HCA+CBB
Group 1	33 892	14 119	87 838	135 848	RENOV+TRV+HCA
Group 2	88 650			88 650	RENOV+TRV
Group 3	38 654			38 654	RENOV only
Group 4	33 117			33 117	Nothing done
	215 839	17 660	117 702	351 200	

Table 3: Heated area of the analyzed buildings per group and city.

4.3 Minsk Buildings

To analyze the impact of TRVs and HCAs on heat consumption the group of similar buildings in Minsk was analyzed. The group consists of 61 buildings, construction period – 1963 – 1972, mainly 4-5 floors, 45-120 apartments.

Minsk was selected as a city with significant amount of renovated building stock and ability to get the statistically significant numbers.

The period of analysis is 5 years, between 2010 and 2015. Starting 2010 there is a good number of residential buildings using apartment-level heat control and billing.

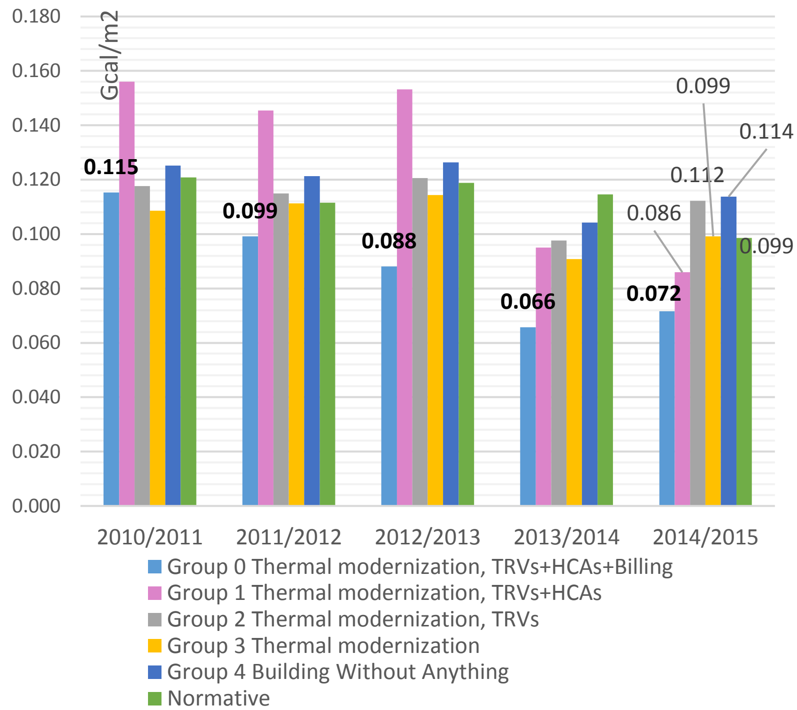


Figure 11: Specific heat consumption of Minsk buildings

The reference buildings of Group “1” were modernized during 2011-2012, and therefore, the heat consumption was high as the thermal insulation, windows, piping and radiators were replaced throughout the year. After the modernization was completed, the Group 1 buildings actually became comparable to Group “0” buildings as the consumption based billing was initiated in year 2012.

Group “2” and Group “4” have insignificant difference of heat consumption within the range of 5-15%. This confirms that after the heat renovation of the building the substation at the building level (the system of automated regulation of heat flow) should be properly readjusted.

Group 1 during 2010/2011 – 2012/2013 seasons was capitally renovated. The increased heat consumption might be a result of increased ventilation and drying of the building because of the increased level of humidity after constriction works.

Buildings without thermal renovation (Group 4) during 2011-2015 consume higher than normative. The normative heat consumption value is set by the building code not to exceed 0.120 Gcal/m^2 in old buildings. Buildings with renovation and TRVs (Group 2) and walls insulation only (Group 3) can be compared with the normative and are not significantly different from the buildings without capital renovation (Group 4).

"Group 0" with thermal renovation +TRVs+HCAs+Billing show the good result subject to household interest to decrease heat consumption. After 2013, Group 1 approaches to Group 0, as consumption based billing has been adopted.

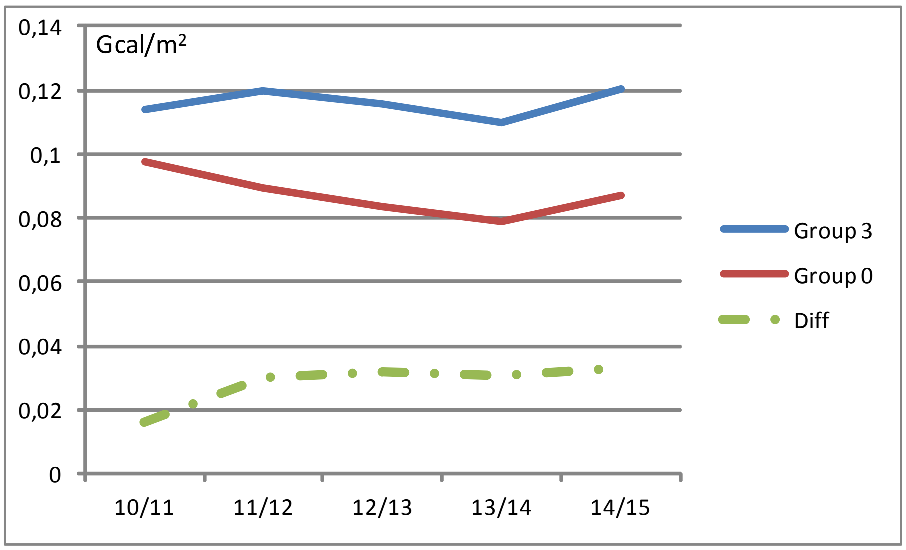


Figure 12: Comparisons of heat consumption of Group "0" and "3" in Minsk.

As both Group "0" and "3"have undergone thermo-renovation already, the 27% lower heat consumption of Group "0" in the latest heating season 2014/15 is a result of the installed TRVs and HCAs, and the latter ones used for individual billing.

The preliminary conclusions from Minsk are as follows:

- TRV and HCA used for apartment-level consumption control and billing achieved up to 27% lower specific heat consumptions relative to those with traditional billing.
- Apartment-level consumption based billing is a distinctive driver for energy savings, significantly increasing the actual energy savings of buildings undergone thermal renovation.

- Small differences between unit heat consumption (Gcal/m2) may be due to inconsistencies in data.

4.4 Gomel and Mogilev Buildings

Both “Group 0” and “Group 1” are similar buildings with thermo-renovation, TRVs and HCAs implemented, but the latter not having used them for billing.

Only “Group 0” uses HCA readings for billing, which have resulted in annual heating savings of10-24% and 19% on average compared to Group 1 since year 2012.

Key findings:

- Thermo-renovation has substantially reduced heat consumption; and
- Apartment-level consumption-based billing provided significant incentive to further reduce heat consumption.

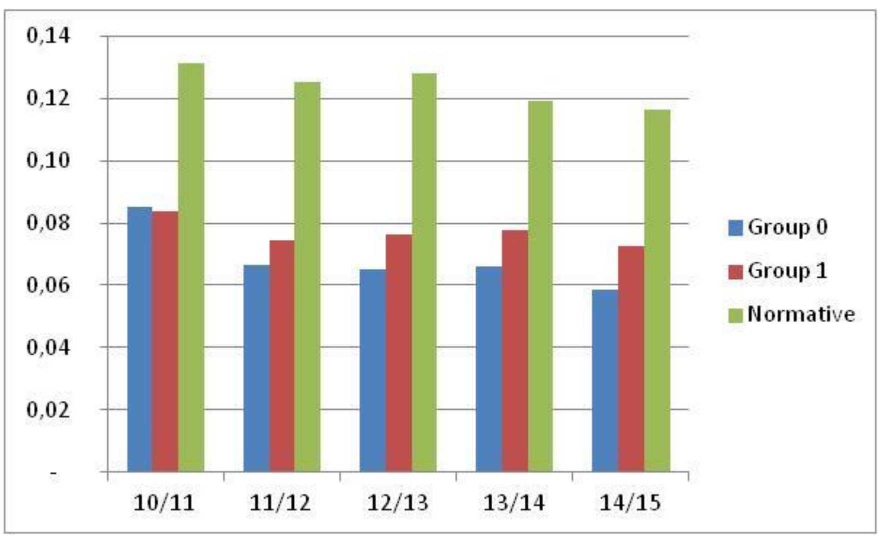


Figure 13: Thermal performance in Gomel with 399 apartments

In Gomel, “Group 0” has started to deviate from “Group 1” due to initiated consumption-based billing. By year 2015, the heat energy savings had reached 19.8% already. In Gomel “Group 0” comprised 80 apartments whereas the balance of 319 were in “Group 1”. A more balanced division might have changed the saving rate.

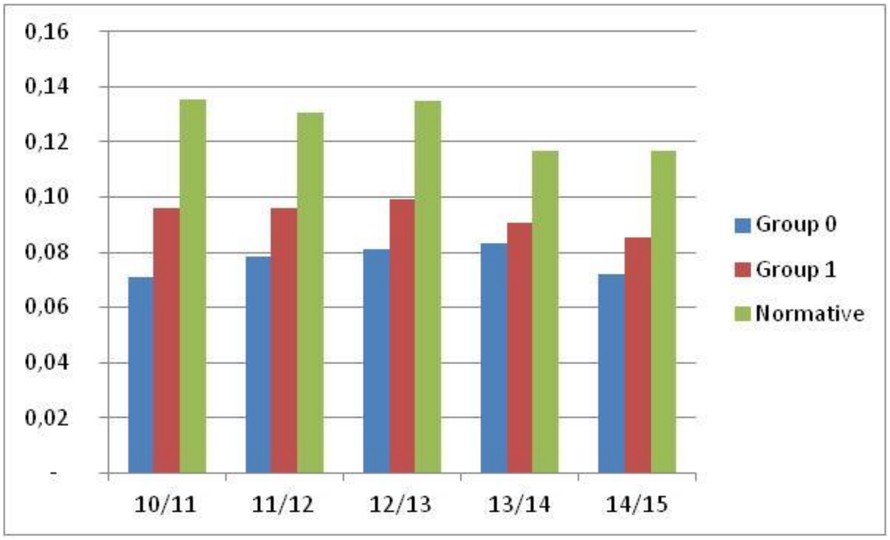


Figure 14: Thermal performance in Mogilev with 2,399 apartments

In Mogilev, about 600 apartments were in "Group 0" and the balance of about "1,800 in "Group 1". In the last year the heat savings in "Group 0" relative to "Group 1" amounted to 16.2% but having reached even larger savings in some preceding years.

5. Belarus - Financial Analysis of Heat Cost Control

5.1 Cost Estimates or Apartment-level Consumption Billing

Here the cost estimates for apartment-level heat control and consumption billing using electronic HCAs are given based on the Belarusian and international experiences.

The typical building size is 4,000 m^2 of which 3,600 m^2 is heated apartments. The investment costs have been converted to heated floor area by using a 46 m^2 floor area and 3 radiators per apartment.

The vertical network with 1-pipe has been used as the base case but to be equipped with a two-way TRV and a by-pass pipe per radiator.

The data collection and heat billing costs range from 0.2 to 0.5 and from 0.05 to 0.1 €/m^2 in annual and monthly billing, respectively.

VAT is excluded in the cost estimates.

In apartment			Goods €/pc	Works €/pc	Total €/pc	Total €/m2
TRV	2-pipe	2-way	25	7	32	2,09
TRV	1- pipe	2-way	38	7	45	**2,92**
TRV	1- pipe	3-way	48	10	58	3,78
Heat meter	Horizontal piping		160	40	200	4,35
HCA			18	5	23	**1,50**
In building entrance						
Mixing loop			2300	200	2500	0,69

Annual billing costs		€/m2,a
Data collection and monthly billing with HCA		**0,07**
Data collection and monthly billing with heat meter		**0,05**
Data collection and annual billing with HCA		0,03
Heat meter calibration every five years	40	0,9

Table 4: Cost estimates of apartment level heat control and consumption based billing.

The incremental investments would include the HCA and the 2-way TRV to each radiator with monthly billing amounting to 4,49 €/m^2 in total, the numbers shown in Table 3 above bold and summarized.

Mixing loop should be added in case there is no temperature control in the basement.

5.2 Pay-back Time Estimates

In this calculation, the financial analysis from the resident's point of view was calculated. In the analysis the TRVs and HCA-based billing is assumed to gain **15% energy savings**. Billing would be on monthly basis.

The estimated full operating cost recover heat tariff for district heat supplied by CHP plants is about $42 per Gcal of heat (about 39 €/Gcal) in 2015/2016 heating season.

In the base case the specific heat consumption would amount to 0.120 Gcal/m^2, which corresponds to old buildings before any thermo-renovation had started. The assumed 15% savings would result in 0.102 Gcal/m^2.

The pay-back time depends strongly on the heat price as presented in Table 4 below. With full operating cost recovery tariffs the simple payback time would be 7 years for heat supplied by CHP plants and 4 years for heat supplied by heat-only boilers.

A 30% investment subsidy for TRVs and HCAs, for instance, would shorten the payback times to 5 and 2 years, respectively. The subsidies would make the investments attractive to the tenants, especially those paying higher heat tariffs.

Heat price	Heat price		Heat energy		Billing	CAPEX	Pay-back
	BLR/Gcal	€/Gcal	Gcal/m2	Gcal/m2	€/m2,a	€/m2	years
CHP networks			Before	After			
Current tariff	133,417	6,1	0,120	0,102	0,07	4,49	114
50% cost covery	427,357	19,5	0,120	0,102	0,07	4,49	16
100% cost covery	854,714	39	0,120	0,102	0,07	4,49	7
Boiler networks	1643,681	75	0,120	0,102	0,07	4,49	4

Table 5: Financial analysis of HCAs with various heat tariff levels and assuming 15% heat savings.

The full operating cost recovery tariff of €39/Gcal for the CHP supplied clients is still substantially lower than the heat prices elsewhere in Europe. For example, in Lithuania, where district heating relies heavily on natural gas, the average heat tariff was about €67/Gcal in 2015.

6. HCA Adjustment to the Current Radiators

Without knowing the actual working conditions of the existing radiators, the HCA system implementation will always be associated with the erratic allocation of heating costs. One of the reasons, which gains erratic alloations, is the oversizing of the radiators. Oversizing is common as there is no or little metered information available on the real heat consumption of the apartments. Oversizing of the radiator increases the need of throttling the heating mass flow, which will change the working conditions of the HCAs mounted on the radiator, because the temperature distribution in the radiator is distorted. Such distorted temperature distribution is illustrated in Figure 15. Distorted temperatures lead to irregularities in allocation of heating costs to individual apartments. Electronic allocator are even more sensitive to the excess mass flow throttling than the liquid/evaporation allocators.

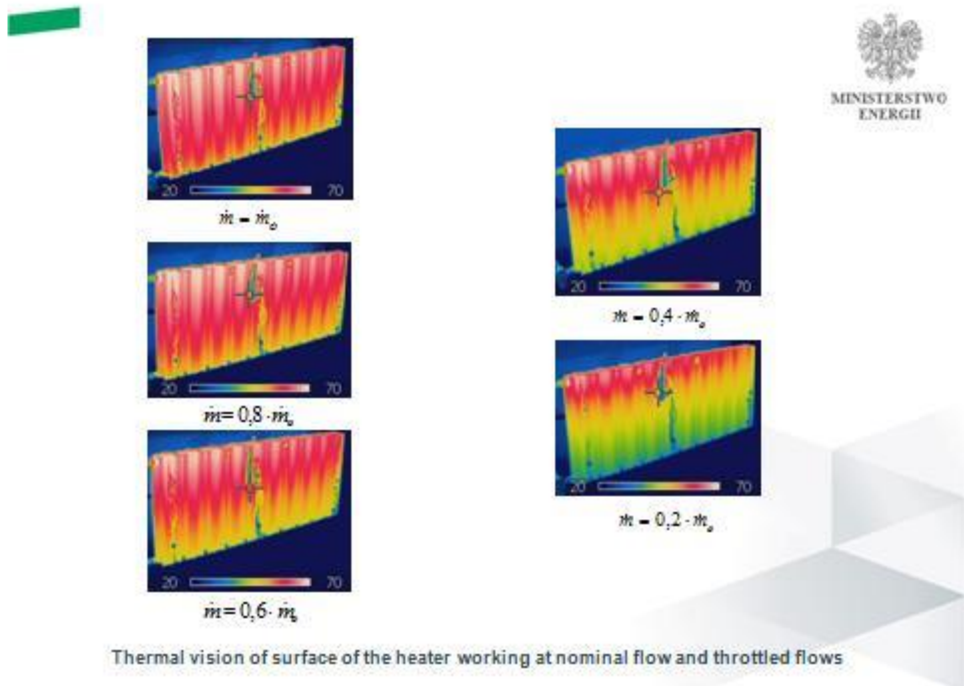


Figure 15: Distorted heat distribution in oversized radiators when TRV throttles the mass flow.

The results of the economic analysis in Poland (Silesian University) indicates that simply installing individual heat cost allocators is not always cost-effective, because it should be preceded by adequate modernization of the central heating system (insulation, a suitable measuring system, weather regulator, thermostatic valves, cleaning of pipes) and adjusting the power of heaters to the design conditions (exchange of radiators).

7 Correction Factors

7.1 Hungary

In general, the correction factors are used to compensate the poor location of the apartments in heating cost allocation. Apartments having large building envelope (corner unit) and located at the outer layer of a building tend to share more of the heating cost of the building than the ones located in the center of the building, especially if the building is poorly insulated.

The correction factors are regulated by Act as presented in Table 6 below.

Description	The amount of correction* in %
*1. Ground-floor corrections**:*	
1.1. ground floor with no room underneath	–15
1.2. ground floor above an unheated room	–10
*2. Top-floor corrections***:*	
2.1. in a flat roof building, directly under the roof	–20
2.2. under an unheated loft that is not built-in	–15
2.3. under a built-in, unheated loft or in the loft	–10
3. Corner-room corrections:	
3.1. each room which has at least two external bounding surfaces (cooling walls)	–10
4. Correction according to the compass point:	
4.1. northern side	–5
5. Other corrections:	
5.1. a room above an unheated passage and doorway	–15
5.2. a room above an unheated ground-floor room	– 10
5.3. a room next to an unheated staircase or walk way	–5

* Corrections shall be calculated for the single rooms of the parts of building. If more than one correction could be applied for a given room, all corrections shall be applied. In case of applying HMs as cost allocators, the corrective factors of the given rooms in the part of the building shall be calculated according to the heated air volume of the room affected by the correction factor per the heated air volume of the whole part of building.

** Ground-floor corrections shall not be applied in the case those rooms that have a vertical down-feed heating system, in the air volume of which a horizontal manifold without thermal insulation goes through.

*** Top-floor corrections shall not be applied in the case of those rooms that have a vertical up-feed heating system, in the air volume of which a horizontal manifold without thermal insulation goes through.

Table 6: Correction factors used in Hungary.

7.2 Denmark

In Denmark, where HCAs were invented, The Executive Order stipulates the correction factors as follows:

§ 9.2: Correction factors may be disregarded if the increased heat loss has been taken into consideration when determining the rent or sale price for the apartments. Apartments having more exterior wall may cost more than those having less. Moreover, correction factors can be disregarded if, after an evaluation of the circumstances prevailing in the building, application of the correction factors would appear unnecessary or turn to be very expensive to individual households, in socially supported housing, for instance.

Executive order on individual metering of electricity, gas, water and heat (1996) – page 2

§ 9.3: Correction factors may be used either in the part of the payment which is dependent on the consumption or in the part which is not dependent on the consumption, or in both parts.

§ 9.4: The correction must be made on the basis of an existing heat loss calculation. If considerable changes in the building have been made since the heat loss calculation, the corrections may be calculated on the basis of the radiator sizes in the flat in question, or on the basis of historical data from previous years or from comparable buildings."

Correction factors in practice can be based on:

- Existing heat loss calculation
- Radiator sizes
- Historical data:
- previous years
- comparable buildings

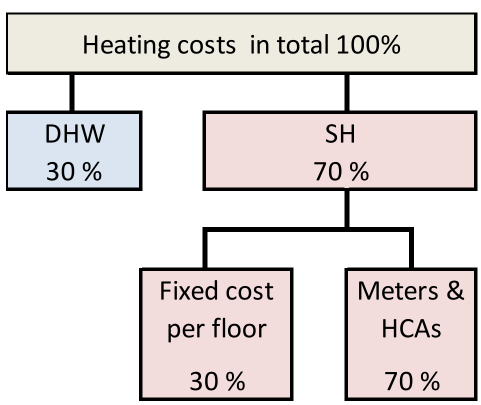


Figure 16: Danish practice for cost allocation[2]

[2] EVVE 2013, K. Forchhammer

Based on Figure 16 above, the HCA readings determine 49% of the total heat costs in Denmark.

Roof								
Top floor	50 %	40 %	40 %	40 %	40 %	40 %	40 %	50 %
	30 %	0	0	0	0	0	0	30 %
	30 %	0	0	0	0	0	0	30 %
	30 %	0	0	0	0	0	0	30 %
Ground floor	40 %	15 %	15 %	0	0	15 %	15 %	40 %
Basement	Cold			Heated		Cold		

Table 7: Danish practice for the fixed component determination of the room space heating part using correction factors[3].

As an example of the correction factors, for example, for the apartments in the top floors, the heating bill will be formed by discounting 40 to 50% of the heat energy indicated by the HCAs as compensation to the location of the apartments being unfavorable in heating terms.

The correction factors of the fixed components may provide a billing-tool to make a fair allocation of the heat costs depending on how the particular apartment is located in the buildings. Those apartments having more building envelope (out wall) will be compensated by those having less while allocating the SH costs. The correction factors are expected to help tenants understand the total energy efficiency of their building, and have the incentive to improve the energy efficiency level equally delegated to the tenants. Without the correction factor, only those customers having more exterior walls would be more motivated than the ones living in the center of the building to improve energy efficiency, and the energy efficiency improvement decision may remain undone if they represent the minority. Whether the particular tenants are in minority or in majority, of course, depends on the type of the building. Those tenants having more exterior walls, usually also have more windows and less disturbance by neighbors, which may improve the living comfort and the sales value of the apartment. Therefore, justification of the correction actor is not that clear.

The domestic hot water (DHW) consumption is allocated to the apartments based on ”Haneandele[4]” which means the allocations is done by means of the shares that are defined as follows:

- Basin = 1 share
- Shower = 2 shares
- Bath = 3 shares
- Kitchen basin = 3 shares
- Per room = 1 share

[3] EVVE 2013, K. Forchhammer

[4] EVVE 2013, Finne

For old residential building, the allocation of 30% for DHW and 70% for SH is used. In modern and highly energy efficient buildings, the DHW takes a share higher than 30%.

8. Some Observed Implementation Issues

The settlement of the cost of the supplied heat to the multi-apartment building on individual premises is a complicated and difficult process due to the physical properties of heat, which passes through the building envelope and internal partitions, and the losses occurring in the heating system in the building.

Currently there is no method that accurately reflects the heat consumption of each of the units in multi-apartment buildings. But the method based on the individual heat cost allocator is sensitive to a number of factors that lead to unfairness in the settlement.

One of the most important disturbances that cause error of the liquid allocators, is the registration of heat consumption by allocators in summer when space heating is not provided. This is usually caused by evaporation of liquid measurement.

Electronic HCAs record temperatures integrated over time and require a power supply. The signals from the temperature sensors are integrated, taking into account the preset constants.

In the electronic allocators the following factors are used:

- KQ - assessment factor of thermal power heater,
- KC - coupling coefficient of thermal and KT - assessment factor for rooms with low temperature design.

These factors, in accordance with Standards, are adopted in settling the heating costs as constant, when in fact they form a non-linear function of the thermal resistance. These factors do not reflect the actual operating conditions of HCAs and radiators, and therefore, are another source of error in heat cost allocation.

Some of the operation related misbehaviour has been identified amongts the residents, billing companies, owners and managers as listed below:

1. Lack of understanding of settling the heating costs;
2. Illegal activities of managers or owners of multi-apartment buildings;
3. Incorrect or unclear billing carried out by the billing company;
4. Lack of energy saving benefits despite the installation and billing using individual HCAs, while worsening the conditions of comfort and living conditions. The HCAs may show high heat consumption even though the apartment suffers for deficit of heating. Such a mismatch can be caused by suboptimal radiators or leaking insulation of the walls and windows, for instance, both being out of the residents influence.
5. Residents try to manipulate the HCA readings in various ways.

6. Residents use the towel dryer that is not used for consumption based billing at maximum to reduce HCA recorded heating elsewhere in the apartment.
7. Broken/malfunctioning HCAs are not detected quickly: too often the billing analysis identifies the problem too late, after several weeks/months
8. The billing formula allocates too much to variable and too little on the fixed component, which may distort the cost allocation
9. Residents shut off the radiators and enjoy free-of charge heating from the neighbors. The heating bill of the apartments with connected radiators may become overly high as they pay for heating of their free riding neighbors as well.
10. The apartments in different parts of the building have different heating conditions depending on the floor level and area and direction of exterior walls. Usually correction factors are used to make heat cost allocation more agreeable among the households.

9. Consumption Based Billing in Old Apartments

In Europe there are numerous apartments equipped with TRVs and HCAs being used in consumption based billing, even though the building itself has not been thermo-renovated yet.

In mid 1990's, in Central Europe in particular, thermo-renovation followed heat metering of buildings and HCAs in apartments. Due to a lack of funds, low-cost measures, such as heat control and heat metering, were introduced first. When consumption-based billing was applied these measures provided heat savings ranging from 15% to 20%.

Heat metering and HCAs together with heat controls required much less financing resources and could be implemented relatively fast without major interruptions of apartment owners' normal lives.

In Poland, for instance, all buildings connected to DH were equipped with heat meters that were used for consumption based billing on the building level by 1998. Simultaneously, the subsidies of more than 90% of the heating costs were phased out by 1998 as well, which substantially increased the heating costs of the tenants. Therefore, due to the strongly increased heating costs and the recently introduced consumption based billing on the building level, the tenants became increasingly interested in their own heating cost and the ways how to reduce the costs.

The HCA based billing of apartments started in 1993 already, and gradually increased to the current 50% of all multi-apartment building stock in Poland.

With old buildings, before the thermo-renovation can be started, the proper task order should be:

1. First to install the TRVs and HCAs to the radiators, and to start consumption based billing after a trial period. The trial period could be a year when information is collected, verified, and possible inconsistencies are fixed.

2. Second, thermo modernization may take place after the enegy audit has been carried out, which is expected to identify the needs of thermo-renovation.

3. Heating system adjustment is necessary after having the points 1 and 2 completed. The heating system must be adjusted, because the heating load curve has changed and the needed heat energy of the particular bill has significantly decreased. This means there is no need to supply the same high level of heat to the beuilding as before the renovation

It is important is to set up proper billing rules – fixed and variable heating costs, and the correction factors if deemed necessary. The bills should be prepared and calculated by an experieiced sub-metering and billing company.

10. Best Practice Examples

10.1 Innovation: Case Smart House in Budapest

FÖTAV, the municipal district heating company of Budapest, launched a pilot program by selecting 4 residential blocks to be equipped with solar panels, advanced TRV and HCA management and building envelope insulation as a model for the public audience to be replicated elsewhere. Public subsidies, tenants' contributions and FÖTAVs own resources were used for financing the Smart House pilot.

As an example of such a smart house in address *Nyirpalota ut 1-12*, the heat consumption has dropped 50% from 18,000 GJ to 8,900 GJ.

All apartments are equipped with two-temperature HCAs, one temperature sensor for the radiator and the other one for the room temperature, and TRVs. The HCAs are remotely read in 15 minute intervals by a receiver station that is installed on the top of the staircase elevator car. As the elevator moves vertically, so does the receiver as well recording the HCA signals from the rooms of the particular staircase. The mobile receiver station made it possible to avoid receiver stations in every one or two floors as one receiver station is able to record readings from 120-150 radiators.

As the data collection is uniquely frequent (15 minute intervals), the faulty measurements can be identified almost immediately and the corrective actions taken. Moreover, the frequent reading can reveal if a tenant has tried to manipulate the HCA reading. A local company *CardWare* has implemented the HCA management system and operates it.

In the beginning, there had been attempts by some tenants to manipulate the HCA readings, for instance, by:

- Replacing the HCA equipped radiator with another radiator that has no HCA.
- Magnetizing the HCAs or heat meters to reduce their reading capability
- Covering the HCA in order to reduce the temperature difference that is used for heat cost determination.

The frequent data collection and verification routines can reveal abused HCA manipulations. The penalty to the abusing tenant is set by the HoA to be 2.5 times the average heating costs of the building during the determined period of time.

Due to the penalty system and the fast detection of possibly abuse, the manipulation problems have become virtually non-existent.

10.2 Consumption Based Billing in Lublin

In this controlled study a single building from Lublin, Poland, was used to demonstrate impacts of consumption-based billing at apartment level. The building was divided to two equal half ends, named as Part A and Part B illustrated in Figure 17.

The two ends of the buildings had a separate heat supply with heat metering, which enabled the heat consumption recorded from Part A and B separately.

The demonstration proceeded in the building in three steps as follows:

1. In year 1999, the TRVs were installed to all apartments of the building but the HCAs only to Part B apartments. In the consecutive years until 2005, Part B consumed less heat, the difference to Part A ranging as a much as from 18.8 to 26.6% per year.
2. In 2005/2006 thermal insulation was added to both building parts equally without adding HCAs to Part A. The Part B apartments consumed now 30% less heat than the apartments of Part A until year 2011.
3. In year 2011, the HCAs were added to the Part A apartments as well, thus resulting in equivalent technical and physical conditions in both parts A and B. During the consecutive 3 years until 2014, the heat consumption difference between the two parts A and B vanished and resulted in equal heat consumptions, about 50-60% lower than in 1998.

The research case of the demonstration impacts was carried out by Technical University of Lublin, Poland[5]

[5] Cholewa, T., Siuta-Olcha, A., Technical University of Lublin Poland, ISBN 978-83-88695-33-9

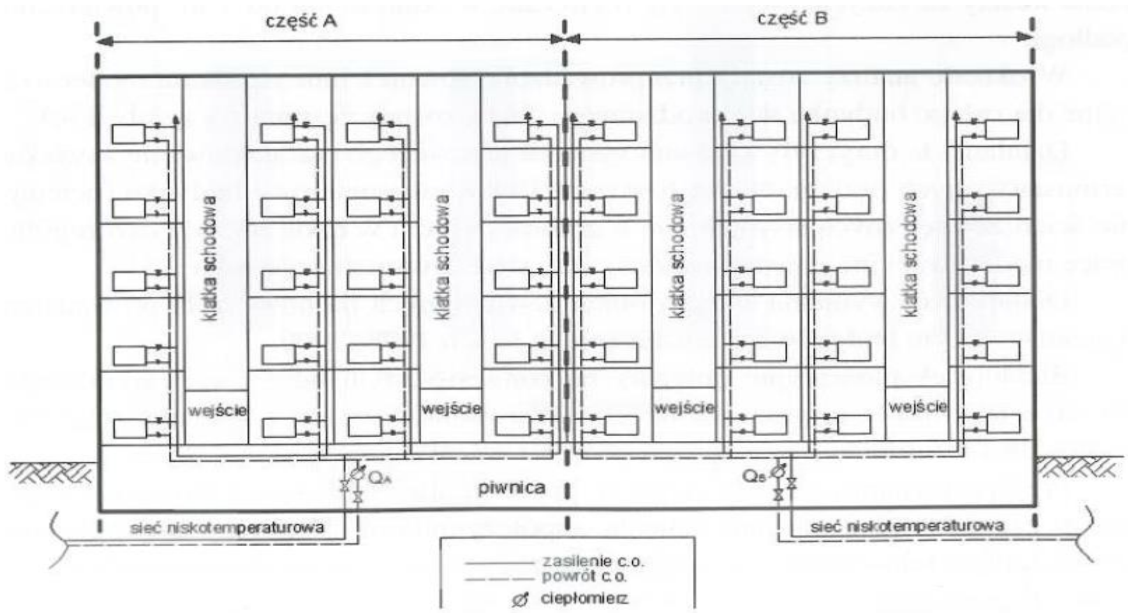


Figure 17: Demonstration of consumption based billing from Lublin, Poland

11. Main Conclusions and Recommendations

HCAs can be used in any network system in the building but heat meters only in horizontal piping systems.

Thermal renovation of the building before or in parallel with TRV and HCA installation will substantially improve the heat cost allocation accuracy and prevent complaints of unjustified allocation. However, the TRVs and HCAs can be installed before thermo- renovation while using a trial period to eliminate malfunctions and inconsistencies in the data collection and billing before the commercial billing commissioned.

Moreover, in Belarus

- Apartment-level heat control and consumption-based billing are effective to enable and incentivize energy savings even under the current heavily subsidized heat tariffs.
- Financial attractiveness of apartment-level heat control and consumption based billing would increase when cost coverage level increases.
- Feasible technologies are available:
    - TRVs and electronic HCAs are applicable to both vertical and horizontal piping
    - Electronic HCAs with remote reading is preferred to the evaporator type which is vanishing on the market

A mixing loop should be installed to the building basement if there is no existing and functioning building specific temperature control.

In order for the benefits of the HCAs and TRVs to materialize, tenant educations is very important. The tenants need to get the information on how to ventilate the flat – shut off the TRVs, open the window for few minutes, then close the window and after few minutes open the TRVs, for instance.

It is also important and helpful to have a system of monitoring daily consumption on remote basis. A web portal would help tenants to monitor their consumption on-line, which would help adjust their consumption behavior.

Annex 1: European Standard EN 834

The standard EN 834 HCAs for the determination of the consumption of room heating radiators - Appliances with electrical energy supply This European standard applies to HCAs which are used to capture the proportionate thermal output of radiators in consumer units. If an account unit comprises consumer units of different types (e.g. technically different types of heating systems or differences due to the consumer behavior, e.g. industrial plants as opposed to private apartments), it could be necessary to divide this account unit into groups of users. HCAs enable the determination of the heat consumption only of each radiator in a consumer unit as a share of the total heat consumption of the account unit or user group. It is therefore necessary to determine this total heat consumption either by measuring the consumed fuel quantity or the amount of heat delivered (the latter by means of a heat meter, for example). For the appropriate use of the heat cost allocators in accordance with this standard, the heating system needs to:

- correspond to the state of the art at the time of installation of the heat cost allocators; and,
- be operated in accordance with the state of the art.

This standard specifies that HCAs shall not be used for heating systems where the temperature of the heating system falls below or exceeds the temperature limits of the HCAs, where the rating factor for the thermal output, KQ, cannot be clearly specified or where the heating surface is inaccessible. This applies usually to the following heating systems:

- floor heating;
- radiant ceiling heating;
- flap controlled radiators;
- radiators with ventilators;
- fan assisted air heaters;
- heating systems with steam operated radiators.

Annex 2: Technical Approach

1. Objective

The objective was to find out what impacts heat control consumption based billing in apartments have had on the heat energy consumption.

2. Selection of Buildings

As selection criteria the following arguments were used:

- The building is either old and renovated but initially built before 1990 or it has been built after 2000 or later as a modern building. The oldest buildings in the analysis were initially built in 1962. Those buildings constructed after year 2000 are all in Mogilev. The 60 buildings in Minsk in total were all built before 1979, but renovated later on.

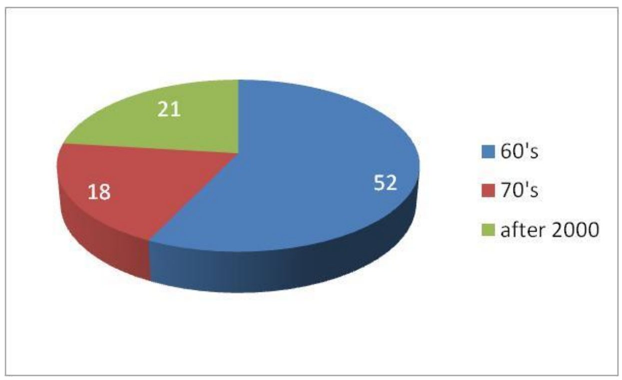
- 

Figure 2.1 In total 90 buildings of the analysis allocated according to initial construction years.

- Most buildings are with vertical one-pipe heating systems in order to represent the majority of the multi-apartment buildings in Belarus.
- Metered heat consumption data is available as time series to allow annual verification of the thermal behavior of the selected buildings
- The energy efficiency measures, TRV and HCA installations and their implementation timing are known and it is reliable.

3. Selection of Period of Time

Five heating years starting from summer 2010 and ending to summer 2015 covered the collected heat consumption data. During the years, some renovation measured ahd been done which could be seen in heat consumptions of those buildings affected.

4. Data Collection and Verification

Data was remote read either to the city data center or the billing company *ista* servers where it was stored.

A few recorded heat consumption numbers were corrected as being ten times higher than would be realistic by dividing them by ten.

Moreover, the following information from the particular buildings was collected:

- The year of initial construction
- The year of thermo-renovation if done
- The number of floors ranging from 5 to 10.
- The number of entrances (staircases) ranging from 1 to 8
- The heated floor area (m2)
- The HCAs and TRVs installed or not
- The HCAs used for billing or not
- The building thermally insulated or not

5. Normative Consumption as Reference

The normative consumption of the old buildings is 0.120 Gcal/m^2 of the heated floor area during a normal year. The normative consumption has been adjusted to various years using Degree-day adjustment.

6. Degree-day Adjustment

A degree day adjustment was made to the normative heat consumption in order to incorporate the different temperatures between the five heating years, thus making the years of remote read data comparative to each others.

In the degree day adjustment the one has to differentiate to two types of heat consumptions, as follows:

- First, room space heating (SH) depends linearly on the outdoor temperature. The lower the temperature, the higher the heat consumption when the outdoor temperature is 17^{o}C or lower. No heating is needed when the outdoor temperature is above 17^{o}C as there are free heat ources in the apartments to keep the room temperatures at around 21^{o}C. Such free heat sources are residents, electric appliances, and solar radiator, for instance.
- Second, domestic hot water (DHW) is considered to be constant during the year, even though hot water is used in winter a little more than in summer.

In order to correctly adjust the annual heat consumption the degree-day adjustment proceeds in the following order:

- The DHW heat consumption will be deducted from the annual total heat consumption. The DHW is assumed to be the average summer consumption extended over the entire year.
- The remaining SH consumption will be multiplied by the ratio of the degree days of the normal year divided by the degree days of the particular year.
- The DHW consumption of the particular year will be added back to the adjusted SH consumption to result in the degree days adjusted heat consumption of the particular year.

7. Input/output analysis

The buildings and the apartment were allocated to five categories depending on whether thermo-renovation had been carried out and what kind of heat control and cost allocators were used, and whether those allocators were used for consumption based billing or not. The categories are presented in table 2.1 below.

Category		Minsk	Gomel	Mogilev	TOTAL
0	Buildings WITH heat renovation and individual regulators and heat cost allocators and Billing	888	319	1907	3114
1	Buildings WITH heat renovation and individual regulators and heat cost allocators but NO Billing	420	80	592	1092
2	Buildings WITH heat renovation and individual regulators but NEITHER heat cost allocators nor Blling	814			814
3	Buildings WITH heat renovation but NEITHER individual regulators nor heat cost allocators nor Billing	1816			1816
4	Buildings WITH NEITHER heat renovation nor individual regulators nor heat cost allocators nor Billing	860			860
TOTAL		4798	399	2499	7696

Table 2.1 Number of apartments per category of heat control and consumption based billing per city.

In the above table the “Billing” means apartment level heat consumption based billing.

From Gomel and Mogilev only buildings equipped with HCAs and TRVs were made available, either the HCAs were used for billing or not. From Minsk, on the other hand, buildings from all categories were made available for the analysis.

The main interest was to find out the difference

- Between Category “0” and “1” to see what were the possible benefits whether the HCAs were used for individual billing or not. For this, samples were available from all three cities comprising 3,114 and 1,082 apartments with and without such billing, respectively. The benefits can be achieved by contracting a billing company to carry out the data collection and billing works as all equipment in the rooms are in place already.

- Between Category “0” and “4” to see the total potential for heat savings when implementing the thermo-renovation and installing TRVs and HCAs to be used for control and billing. Thermo-renovation may cover a mixing loop to be installed in the building basement, replacing the windows and adding thermal insulation to the roof and walls.
- Between Category “0” and combined “2” and “3” to understand how the complementation of HCA and TRV installations together with individual billing introduction would save heat consumption.

When dealing with the categories floor area weighted average has been used to reflect the category specific heat consumption

A category not being included in the analysis at hand is the old building waiting for thermo-renovation but having the TRVs and HCAs in the rooms already used for control and cost allocation. The majority of buildings in Belarus are candidates to this category “5” in case a comprehensive individual consumption based billing program with TRV & HCA would be introduced in Belarus.

Subreport 2: Households' Perspectives and Legal and Regulatory Issues[6]

Table of Contents

[6] Prepared by Irina Voitekhovitch and Yae Jun Kim based on consultant reports.

Summary

The report summarizes the assessments carried out on consumer perspectives as well as legal and regulatory issues for apartment-level heat control and consumption-based billing in centrally heated multi-apartment buildings in Belarus.

Focus group discussions on the attitudes towards introducing the system, willingness to pay for the installation of TRVs and HCAs, financing support for the installations, and billing process were conducted to identify possible obstacles and develop desirable and effective program for the households. Also, the legal and regulatory issues associated with apartment level consumption-based billing are reviewed.

From consumers' perspective, apartment-level heat control and consumption-based billing are regarded as desirable system depending on the situation such as financial incentives and tariff increase. Well-designed approach with financial incentives and public awareness program is required to overcome identified obstacles, including concerns about achieving consensus among households in the buildings, significant upfront cost of investment and maintenance, and the lack of understanding (and trust) on the new heat control and billing system.

The current legal requirements in Belarus are not sufficient for supporting the implementation of apartment-level heat control and consumption-based billing. There is clear requirements to bill heat energy consumption at apartment level. There are no relevant technical standards. More specifically the following gaps need to be addressed:

- Detailed guidance, directions and procedures on how the billing should be done, what is the relation between the DH company, billing company and consumers;
- Mechanism of actual quality control/readiness control of apartment level heat billing system and its further use;
- Introduction of two-part heat tariff so the fix cost of district heating service can be properly reflected in cost recovery when apartment level consumption-based billing is introduced.

List of Abbreviations

Abbreviation	Meaning
DH	District heating
DHC	District heating company
DHS	District heating system
DHW	Domestic hot water
DSM	Demand side management (of heating services)
EC	European Commission
EE	Energy efficiency
EED	Energy Efficiency Directive
EU	European Union
EVVE	E.V.V.E. – European Association for the Consumption-based Billing of Energy Costs
FGD	Focus Group Discussions
HCA	Heat cost allocator
HOA	Homeowner associations
LHV	Lower heating value of fuel
SH	Space heating of buildings
TRV	Thermostatic radiator valve
WB	The World Bank
ZhREOs	State Unitary Enterprises of Housing Repair and Maintenance

1. Consumer Perspectives

Focus group discussions (FGDs) were conducted for apartment building residents to assess homeowners attitudes toward the introduction of TRVs and HCAs. In total, twelve FGDs were carried in four cities (Minsk, Gomel, Mogilev, and Brest). The analysts studied the preferences and views of consumers with respect to numerous issues relevant to the design and adoption of heating reform policy, including preferred home temperatures and payment methods, willingness to pay for installation of TRVs and HCAs, and preferences regarding heating control and billing. The FGDs were conducted among residents of individual buildings to mimic actual discussions among housing collectives and homeowners' associations, and it included both buildings that had already installed TRVs and HCAs, as well as those that had not. The discussions mainly focused on options for a broad-scale introduction of apartment-level heat control and consumption-based billing, including potential actions of the government and individuals, and the sequence of those actions. The FGD guide is provided in Annex 1.

1.1 Attitudes towards Apartment-level Heat Control and Billing

Apartment-level control and consumption-based billing is expected to cause behavioral change such as learning how to use TRVs, less frequent ventilation by using window to regulate heat, and prioritizing conservation measures to reduce heating bills. If consumers can have comfort, control, and the ability to save money on heating bills, they are likely to pay for these technologies.

Participants of FGDs both with and without experience of TRVs and HCAs expressed positive attitudes towards apartment-level heat control and billing with the use of TRVs and HCAs. Also, they consider the possibility to control heat consumption with the use of TRVs is important, since it allows them to avoid overheating during warm weather, results in energy cost saving and comfortable living conditions. Joint use of both TRVs and HCAs is considered as favorable energy saving behavior. Installation of TRVs only without use of apartment level billing is not enough to cause significant behavioral change to save heat. Heat cost allocation based on HCAs is regarded as more justified, since heating bill of household is more reflective of actual heat consumption compared with allocation based on floor area. The comfort level of temperature in household perspective are summarized in Table 1.

Conditions	Temperature level	Comments
Cold	< 15 °C	Physical discomfort, possibility of getting cold, need to wear warmer clothes
Comfortable	18-20 °C 23-25 °C	Part of the respondents prefer slightly lower temperatures, as they are ready to wear warmer clothes during heating season. Preference of lower temperatures can be connected to heath issues (cardiac problems) Part of the respondents prefer warmer conditions, as they tend to follow the principle: comfort is more important than economy
Hot	> 25-30 °C	Physical discomfort, also connected to low humidity

Table 1: Residents' comfort level with temperature in Belarus

1.2 Willingness to pay for installation of TRVs and HCAs when heat tariff rises

Heat tariff increase is expected to stimulate more mindful attitude towards heat consumption control, since it reduces heat consumption when tenants are absent and provides effective aeration of apartments such as short and intensive ventilation with the radiators turned off. Some of the participants are ready to reduce heating in general and wear warmer clothes.

FGD participants in Minsk mentioned that they have limited ability to control heat consumption, as they use simple ball valves to control the water flow instead of TRVs. In case of tariff increase, they believe that installation of TRVs can be a valuable investment to provide more flexible heat control. The attitude towards different heat saving strategies with use of TRVs and HCAs is summarized in table 2.

Heat saving Strategies	Attitude from respondents
Lowering of heat consumption during business trips	The easiest strategy, positively accepted by all
Lowering of heat consumption in separate rooms	Suitable for small families and single people in big apartments
Lowering of heat consumption during working days	Not suitable for families with small kids and housewives (always stay at home)
Get warmer clothes	Suitable but not for all (especially for people who like high room-temperature)
Constant regulation of heat consumption, switch off TRVs during airing	Possible under significant tariff increase. As of now, the behavioral readiness to such changes is quite low

Table 2: Attitude towards different heat saving strategies with use of TRVs and HCAs

A number of consumers, mainly the elderly, notes that they are ready to install the equipment under the process from a centralized organization due to its "compulsory" nature of the installation similar with the gas or water meters installation.

Two patterns of relations between tariff increase and investments in TRVs and HCAs emerged from the FGDs:

- TRVs and HCAs installation is justified even with the current heat tariff level or with insignificant increase; especially for these households, their priority is to control heat consumption, use of modern technologies, and possibility to save heat energy under the relatively long payback period;

- TRVs and HCAs installation becomes more reasonable with large tariff increase, when such investment is justified with the short payback period.

1.3 A Need for Financial Incentives for Scaling up Installation of TRVs and HCAs

Households believe that government support for TRVs and HCAs investments is highly desirable, and suggest that it can promote the willingness of TRVs and HCAs installation. Up-front costs is a significant barrier to adoption of TRVs and HCAs. For the FGD participants, 30% coverage of equipment and installation costs by government will make the investments more attractive, while 50% coverage of that is the preferred option as shown in figure 1. Many respondents evinced a strong aversion to taking on debt, preferring grants to loans. The possibility of installment pay is also one of the important support measure for households to ease the burden of payment.

Financial incentives are carefully considered for scaling up TRV & HCA installation to households. Many respondents expect high subsidies, and they also expect poor households will receive more government support. Some consumers will face higher costs regardless of the installation due to their consumption patterns and immutable characteristics of their apartments (e.g. corner or top floor apartments).

Possibility of installment payment is also an important support measure for households. Currently, majority of households equipped with TRVs and HCAs are billed for heat according to data from collective heat measurement devices. Information from the HCAs is collected once at the end of heating season, and payments are re-calculated based on the information. However, the modern equipment will allow remote access to data collected by HCAs, and consequently a monthly-basis billing is feasible at apartment-level. Monthly payments based on the HCAs are regarded as preferable option by FGD participants, as they provide regular feedback on the level of consumed heat and could help households to adjust their heat consumption. It will also ease the stress of payment especially to low income households. On the other side, some users of TRVs and HCAs do not consider monthly payments attractive, due to the possibility of increase in billing service costs.

1.4 Information Gaps on the Usage of TRVs and HCAs

With regards to usage of TRVs and HCAs, there are information gaps as an instrument to reduce heat consumption and concerns on its technical reliability. Public awareness campaigns are needed on benefits and energy saving potential of apartment-level heat regulation and control system. Homeowners' understanding of the benefits and advantages of these technologies will foster trust, interest, and a sense of value. Also, Homeowners need to be properly informed on how to manage heat flow, temperature and ventilation in their apartments. Relevant information regarding data collection and billing process need to be provided to tenants for foster trust in the system.

Homeowner education is critical to materialize the benefits of the TRVs and HCAs. For instance, homeowners need to get the information on how to ventilate the flat – shut off the TRVs, open the window for few minutes, then close the window and after few minutes open the TRVs.

It is also important to have a monitoring system of daily consumption on remote basis. A web-portal would help tenants to monitor their consumption.

1.5 Conclusion

In summary, the TRVs and HCAs are generally considered as desirable from consumers' perspective. However, the willingness to pay for their installation varies depends on the situation: it increases if the tariff rises and depends on the financial incentive provided. Well-designed approach is needed with careful consideration to overcome obstacles (Table 3) for adopting TRVs and HCAs.

Obstacle	Description
The need to reach a consensus of the majority households in the building.	Important factor, especially in case when there are many rental apartments in the building.
Costs of installation and long payback period.	Important factor, but its influence is compensated by benefits of apartment-level heat control and billing.
Expectations of possible expenditures regarding repairs of equipment.	Insignificant factor to some participants, as they think the equipment might not be reliable enough.
Uncomfortable temperature conditions in the apartment and dissatisfaction with heating quality.	In case when some apartments in the building are under heated, the households will start compare the temperature conditions of their apartments with the rest of the building. Lower heating bills is not the argument for them.
Lack of trust of the whole heating system, ignorance of heat billing procedures and lack of understanding of equipment work, etc.	Low awareness of the principles of heat consumption and billing procedure contributes to distrust of calculation procedures. Payments conneced with HCAs are considered as 'non-transparent', due to the low awareness.

Table 3: Obstacles to adopt TRVs and HCAs from consumers' perspectives

Financial incentives can play a key role for scaling up TRVs and HCAs installation. Also, public awareness and homeowner education are neeed to fill the information gap on usage of TRVs and HCAs as an instrument to manage heat consumption and concerns on its technical reliability.

2. Legal and Regulatory Review

2.1 Legal and Regulatory Issue

Regulations for apartment-level consumption-based billing for district heating in Belarus are insufficient for implementation of the new system. Currently, there is neither regulatory requirements nor incentives for apartment buildings to install HCAs or other apartment-level heat metering devices. Procedure standard and obligatory requirements to bill heat consumption at apartment level, and supporting regulations are not sufficient.

- There is no detailed guidance, directions and procedures on consumption-based billing and relation between the district heating company (DHC), billing company and consumers;
- No mechanism of actual quality control/readiness control for apartment-level heat billing system and its further use;
- 'Switching off' the heat to avoid heat billing is a possible scenario during heating season, meaning there are no fines for totally 'switched off' radiators;
- The current heat-tariff prices heating service based only on heat supply. Heat bill is totally dependent on heat consumption charge at building level. When apartment-level consumption-based billing is introduced, this could lead to unfavorable condition for district heating company due to large revenue variation from heating.

A full review of these issues related with apartment-level consumption-based billing for district heating in Belarus are listed in Table 4.

Legal norms	Legislation	Gaps or Additional Comments
Installation of Heat meters		
Installation of apartment level meter or HCAs shall follow existing legal and technical norms	√	The requirement is indicated in SNB 4.02.01-03 (in force by Amendment 7 as of August 1, 2016).
Heat meter or HCAs shall be certified	√	This requirement is stated in CM Decree #571 as of June 12, 2014 for heat meters. But, there are no requirements for HCAs to be certified.
Requirements for the households to install the certified meter during: a) new construction; b) capital renovation with thermal modernization	√	However, this requirement is not fully implemented. For new construction, it is implemented by the construction company; and capital renovation is by ZHREO or ZHES.
Hot water service payments should be separate	√	-
Fine in case of refusal to install the heat metering device, breach the metering rules, seal removal		There is no fine. The heat consumption is measured based on area of the flat and in accordance with norms, set by local authorities.

Apartment level heat metering and billing		
Apartment level heat metering and billing		By default, the apartment level billing is done proportionally to apartment area. HoAs or ZHSPK could make the decision (simple majority) on heat distribution between flats based on: a) apartment area, or b) HCA readings.
Rules of HCAs use are set	√	The Methodological recommendations are available (MHU Decree #116), but this is not related to existing standards (TNPA). Billing companies use the coefficients based on design documents.
Obligatory access to the individual heat meters and HCAs to take metering	√	-
TRVs on radiators are obligatory	√	This is prescribed by SNB 4.02.01-03 (in force by Amendment 7 as of August 1, 2016).
Specific coefficients to allocate the heat consumption between space heating and HWS		No. But there are rules regarding a formula allowing to divide the heat consumed between heat and HW upon availability of the joint meter.
There are legal norms to read individual meters, including the situation when the apartment owner does not agree with the readings or deny the access to the meter	√	There are requirements of hot water meters and buildings level meters in HIS. However, no legal norms have been established for individual heat meters in case the apartment owner does not agree with the meter readings In case the flat owner refuses to provide access to the meter (in this case the flat is considered as 'off-the-meter'), it is required to read individual meters.
Allocation of heat energy between households based on fixed and variable parts		The issue needs further work: In methodological recommendations (MHU Decree #116), there is an instruction to consider around 30% of costs as fixed part, but it is only a recommendation rather than a requirement. There is a possibility to switch off the heating by the individual household (flat). There is no responsibility for such actions. Certification of energy performance is not conducted.
Notification of HoA by household about damage of heat meter/HCAs	√	TKP 411-2012, CM Decree #571 as of June 12, 2014 requires notifications of damage of heat meter/HCAs.
Prohibition to use evaporator type HCA for new installations		No
Provision to the household the full report about volume of the building, common areas, share of heat consumption by the apartment, etc	√	-

Special order to document the meter readings from individual heat meters and HCAs	√	For individual heat meters, there is no such requirements if there is no contract with service company. However, if there is a contract that prescribes the process of meter reading and payment for heat energy in accordance with Methodological recommendations (MHU Decree #116), the meter readings is required to be documented. For building level meters, TKP 411-2012 requires to document the meter readings.
Requirements for electronic HCA, including errors	√	STB EN 834-2008 «Devices for heat registering, allocated by indoor radiators, working on the electric power supply» and STB EN 835-2008 «Devices for heat registering, allocated by indoor radiators, based on the principle of evaporation and operating without electric power supply» requires electronic HCA, including errors.
Calculation of payment in case of refusal to provide meter readings for heat provider or unavailability of certified meter		The amount of payment is based on the average norm of heat consumption established by the local executive bodies, with recalculation at the end of heating season (based on actual data).

Table 4. Legal norm and legislation in place

2.2 Conclusion

Legal requirements for apartment level consumption based billing is incomplete, and there is no standard for this procedure or obligatory requirements to bill heat energy consumption at apartment level. For providing the necessary legal and regulatory underpinning of apartment-level heat control and consumption-base billing, the policy should cover guidance, directions and procedures on how the billing should be done, the relationship between the district heating company, billing company and consumers, and rule of billing and heat metering. It is also important to establish measures to prevent cheating and manipulating HCAs and circumventing of heating bills.

Annex 1. Focus Group Discussion Guidance

Qualitative Assessment
Belarus Apartment-level Heat Control and Consumption-based Billing

GUIDE FOR FOCUS GROUP DISCUSSIONS

General instructions

- Try to get as much specific answers as possible.
- Encourage the genuine exchange of views among the participants.
- Explore the issues included in the guide. Depending on the course of discussion, you can combine, replace, skip questions that are proving inadequate and add questions if there are any interesting trends.
- Note any issues that are brought up and may not be specifically covered in the research.
- Start with open-ended questions and then prompt respondents to discuss/elaborate more in the relevant section of the FG (e.g. issues having to do with costs, assistance measures, and responsiveness of the electricity/DH company…)
- If the discussion becomes heated over one particular point explain that these will be covered in more detail during the discussion to follow, and proceed to the next topic.
- After each topic summarize the opinions and estimates of the respondents and seek their agreement with the summary.
- Finally, give an opportunity for further questions and comments on the problems, which have not been discussed in the discussion.

Introduction [recommended time: 15 min]

1. Explain that the purpose of the group is to explore issues to do with introduction of apartment level heat control and consumption-based billing among residential district heating consumers.

Currently in the majority of multi-family buildings constructed before 1996 there is no possibility to adjust heat consumption and regulate room temperature at the apartment level due to vertical piping systems. However, such controls are possible with the installment of thermostatic radiator valve (TRVs) and a bypass on individual radiators. In addition, heating cost for each apartment can be allocated based on heat consumption of the apartment using electronic heat cost allocators (HCAs), instead of using norms based on floor area of the apartment. TRVs are self-regulated valves fitted to hot water heating system radiator to control temperature of a room by changing the flow of hot water to radiator. HCAs are devices attached to individual radiators in apartments that measure the total heat output of the individual radiator. Therefore, with the installation of these devices households can regulate room temperature to avoid overheating and pay heating bills based on heat consumption in the apartment.

2. Remind the time frame (about 2 hours)
3. Introduce the team members, the role of moderator (to lead the discussion, to facilitate the participants to interact, provide similar opportunities to express opinions)
4. Explain that people's anonymity will be respected and audio-record will be used only for elaboration of report
5. Set the rules of discussion:

- To speak openly and freely, but one by one
- To honestly and openly express their opinions as to the study are equally important both negative and positive opinions and assessments
- There are no right or wrong answers, only different points of view; to feel free to say what they think, even if their opinions differ from those of others
- To respect their interlocutors and their views
- To switch off or lower the volume of mobile phones

6. Ask participants to introduce themselves with some basic information (e.g. first name, age, are they employed/what they do, do they live alone or with family, in house/apartment, how long they have lived there, etc.)

PART 1: perception of current quality of heating provision. Consumers' expectations about quality [30-40 min]

Section1.1: Perceptions of quality heating

1. What do you perceive as quality heating? How do you feel yourself in the apartment when the temperature is ok? How do you feel and act when the apartment is underheated, overheated? How would you describe conditions that are not comfortable, but bearable? How would you describe critical conditions (both in terms of extremely low or extremely high temperatures)? [Moderator draws a table with different conditions, fills it with participants' answers].
2. We have outlined different temperature conditions; let's associate them with the approximate temperature figures. [Participants outline what temperature level they perceive as normal, extremely under- or overheated. Moderator draws a table with different temperatures, fills it with participants' answers (temperature and age)].

Participant	Age	Uncomfortable, underheated		Comfortable		Uncomfortable, overheated	
		Description	t, °C	Description	t, °C	Description	t, °C
1							
2							
3							
4							
5							
6							
7							
8							

3. **Reasons for different preferences.** How could you explain existing differences in temperature preferences? Are there any differences in temperature preferences depending on age, health, habits, etc.? Are there any differences in temperature preferences depending on the type of room (for example, bedroom should be warmer or colder than kitchen), time of day (day, night)? [Moderator draws a table with different rooms and temperatures, fills it with participants' answers].

Participant	Age	Bedroom	Kitchen	Living room	Children

4. How would you evaluate your satisfaction with the current quality of heating? (participant evaluate their satisfaction on the scale from 1 to 10, where 1 completely dissatisfied, 10 – completely satisfied)What are the reasons for such evaluation?

Section1.2: Current behaviour practices regarding heating and attitudes toward billing

1. How would you describe your current heating regulations (what are the reasons to change level of heating)? If you control temperature, why do you do it? If you do not, why? What are the main barriers for heat regulations?
2. How has your heat consumption changed after the tariffs increase? If it did not change, why?
3. Let's outline factors influencing the reasons to control temperature (outdoor temperature, different preferences for different types of room, regulations depending on the time of day, tariffs, reducing heating costs, etc.) [moderator writes them down]. Let's outline the most and the least important factor.

Factor	Most important factor (N of participants)	Least important factor (N of participants)

4. Please, describe the way you are billed for heating. Are you satisfied with the billing process? Do you have any problems with/complains about apartment-level consumption-based billing? If yes, what are your problems?
5. How much did you pay for heating this winter? [Moderator compares answers among the group] If the amounts are different, what are the reasons for differences, in your opinion?
6. Do you think it is necessary to allocate heating cost proportional to individual apartment's heat consumption? Or can you think of any other models of heat cost allocation?
7. Are the heating bills different for apartments of different locations (in the middle or at the rear of the building)? Do you have different coefficients for apartments of different locations, as the apartments in the middle tend to get heated by apartments surround them? Are you informed of these correction factors? Do you think it is only fair to use these correction factors?
8. Having TRVs and HCAs usually helps lower bills, but some apartments may have increased heat bill because they indeed consume more heat than what they were paying before the use of HCAs. Is this generally acceptable? How would you deal with the situation if you have a higher bill after HCA-based billing is applied?

PART2: energy efficient Behaviour. investments into energy efficient measures [30-40 min]

Section 2.1: Awareness and attitudes to energy saving measures

1. What do you know of different energy saving measures that could help to save energy (heat, electricity)? What measures do you apply? Which measures you do not apply? Why? Are there any differences in saving strategies with respect to different resources (electricity, heating)?
2. Let's think about different measures that can be used to save heat? Which measures do you use? Which measures do you not? Why? [Moderator starts with the spontaneous answers, then prompts answers if needed].

Measures	**N of People using**	**Advantages**	**Disadvantages**
Shut off heating of some rooms			
Reduce heating in some rooms, especially when going on business trips or related to daily plans when you are out of the flat			
Keep the windows closed			
Reduce overall room temperatures and keep warmer clothing on			
Reduce heating at some time of day			
Other measures			

Section 2.1: Tariffs increase and changes in behaviour

3. The government plans to phase out the heating subsidies by year 2020. How much more would you be willing to pay to keep the current heating quality? At what level of tariffs increase would you try to save more behavior regarding heating would change (you would try to save more heat)?
4. If the heating tariffs continue to increase, how would you change your behavior with respect to heating regulation? Do you think you would be able to reduce your household's heating expenditures? What measures (among those we have discussed) would be more preferable? What other measures you could start using

% of tariff increase	**Cost of 1 Gcal**	**N of people who would significantly change their behavior**	**Type of changes**
January 2016 tariff	133 417 BYR/Gcal		
20%	160 000 BYR/Gcal		

50%	200 000 BYR/Gcal		
100%	266 000 BYR/Gcal		
150%	330 000 BYR/Gcal		
200%	400 000 BYR/Gcal		
300%	530 000 BYR/Gcal		
400%	660 000 BYR/Gcal		
500%	790 000 BYR/Gcal		
≥500%	854 710 BYR/Gcal		

Section 2.2: Investments into energy saving measures

1. Some heating saving measures can be implemented with small monetary investments, and some saving measures need extensive monetary investments. Would you be ready to make such investments if they would help you to save heating cost? How would you describe the biggest obstacles preventing you from making energy efficiency improvements in your house or building?

2. [Moderator reads the following information]:

Currently in the majority of multi-family buildings constructed before 1996 there is no possibility to establish heat consumption control on the apartment level due to vertical piping systems. But this control is possible with the installment of thermostatic radiator valves (TRVs) and electronic heat cost allocators (HCAs). This installation approximately costs 48 USD/radiator or 144 USD/2 room apartment, 192 USD/3 room apartment and 240 USD/4 room apartment

Did you pay for the TRVs and heat meters? If yes, Do you think it's a good investment? Why or why not? If no, in retrospect would you consider paying for the full or a part of the investment cost if you were asked to? Why or why not?

3. Do you consider the investments already done in TRVs and HCAs as affordable? How often do you use them? Is the billing service cost high? Would you have installed them again if you were given now the chance to decide? What if the heat tariff increases as planned by the government?

4. Would you be willing to pay a bit more to have smart heat metering so you'll be able to know your heat consumption in real time and compare with similar apartments? Why and why not?

5. Would you recommend your friends/relatives to install TRVs and HCAs? Do you consider the costs of installing TRVs and possibility to pay based on actual heat consumption as feasible?

6. What should be done (by utility companies, or on government level) to make investments into these energy saving measures more attractive?

PART3: Social assistance benefits to support energy Efficiency investment [20-30 min]

Section 3.1: Prospective support mechanisms to invest in apartment level heat control

1. As the installations of TRVs and HCAs are expensive, how do you think, what social groups would experience difficulties with investing in them? Would your household experience such problems? Your neighbors?
2. How do you think, what are the best measures to mitigate difficulties with energy efficiency investments for vulnerable households? What do you think of different solutions: payments for vulnerable households are shared between their neighbors, grant for energy saving measures for vulnerable households, preferential loan for energy saving measures? For preferential loans, what interest rate you consider as affordable and what loan duration is preferable?
3. In your opinion, how these vulnerable households should be identified and targeted?

	Positive features	Negative features	Conditions
Payments for vulnerable households are shared between their neighbours			
Grant for energy saving measures for vulnerable households			
Preferential loan for energy saving measures			

CONCLUSION [10 min]

1. Finally, we are close to end of our discussion. Summarizing all we have discussed insofar, what do you think is the best argument for installment of TRVs and HCAs? What are the main risk associated with it?
2. Do you have enough information on the EE measures to save heat energy? If yes, what are the sources of information? If no – how would you like this information to be shared with the HH?
3. Is there anything else that we have not discussed, but you think is important regarding energy issues?

Thank you very much for your time and kind cooperation!

Appendix: Findings of Study Tour to Poland and Hungary, April 4-9, 2016

Table of Contents

Summary

The study tour was organized to Poland and Hungary to learn on the experiences on building energy efficiency and the en-user heat control, and the heat cost allocators (HCA) in particular.

Hungary and Poland were chosen because:

Both countries have experienced the economic transition during the past 2+ decades but in different ways:

> Poland was one of the first to start modernizing district heating systems and improving building energy efficiency after year 1990. The considerable public subsidies for district heating were phased out in a few years, and the entire district sector became metered and consumption based billed on the building level. Simultaneously, the heat cost allocators started to spread as a means to arrange consumption based billing on the apartment level.
>
> Hungary started the heating reform later, but is similar to Belarus in terms of size of population and strong dependence on imported natural gas. The district heating sector has been active in supporting heat customers to save heat energy and to improve the comfort level.

Both Poland and Hungary located near to Belarus offer good practices and lessons learned for the authorities to choose the Belarusian model to introduce consumption based billing on the apartment level as a means to improve energy efficiency.

Abbreviations

Abbreviation	Meaning
CHP	Combined heat and power
DH	District heating
DHC	District heating company
DHS	District heating system
DHW	Domestic hot water
DSM	Demand side management (of heating services)
EC	European Commission
EE	Energy efficiency
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
EU	European Union
EVVE	E.V.V.E. – European Association for the Consumption-based Billing of Energy Costs
HCA	Heat cost allocator
HM	Heat meter
HoA	House owner association
RES	Renewable energy sources
SH	Space heating of buildings
TRV	Thermostatic radiator valve
WB	The World Bank

Units

a	year
°C	Degrees Celsius
d	Day
€	Euro
h	Hour
J	Joule
l	litre
m	meter
m^2	Square meters
m^3	Cubic meters
mth	Month
t	ton (metric)
W	Watt (=3.6 J)

Definitions

Correction factor: The sample of number allocating the fixed costs of the heating of the multi apartment building to the apartments depending on their share on the building envelope

Formula: Sharing the heating costs of the apartment to the fixed and the variable consumption based components

Central heating: indoor piping for room space heating with radiators

District heating: urban heating of buildings connected with underground hot water networks to the heat sources

Cost allocator: a device or instrument suitable for the consumption-proportionate allocation of the quantity of heat used in the place of use among the parts of building;

Heat cost allocator: a device or instrument suitable for allocating the quantity of heat used for heating, which can be:

a) an electronic heating cost allocator,

b) an evaporative heating cost allocator,

c) a heat meter applied for the purposes of allocating heating cost, if it has not been qualified to be a settling meter by the decree of the local government (hereinafter referred to as municipality);

W*arm water cost allocator :* a water quantity meter (water meter) installed in the network of the place of use, which measures the quantity of warm water drawing (using) through the bibcock in the part of building, and which has not been qualified as a district heating settling meter under the decree of municipality

1 Characteristics of Heat Cost Allocators

Basically, there are three technical methods to allocate the heating costs amongst the apartments as briefly describe in the following:

1.) *Electronic HCA* determines the heat release of the radiator on the basis of temperature data registered by the sensors of the cost allocator so that the maximum allowed error depends on the temperature differences as below:
a) 5K $\leq$ dt < 10K : 12%,
b) 10K $\leq$ dt < 15K : 8%,
c) 15K $\leq$ dt < 40K : 5%,
d) 40K $\leq$ dt : 3%

where the temperature difference "dt" prevails between the average temperature of the radiator and the room air.

The higher the temperature difference of the radiator and the room, the more accurate is the HCA output.

2. *Evaporative HCA* senses the heat release by evaporating the liquid from the capillary tube; the heat release can be determined on the basis of the quantity of a liquid evaporated from the capillary tube by means of a scale depending on both the details of the radiator and the specific software developed for this purpose.

3. *A HM applied for heat cost allocation* measures the heat consumption on the pipe following its installation place, and shows the quantity of heat provided on its display.

2 EU Directives

There are two directives in the EU that set requirements to the apartment level cost allocation.

Article 9 of Directive 2012/27/EU on Energy Efficiency (EED) states that:

In multi-apartment and multi-purpose buildings with a central heating/cooling source or supplied from a district heating network or from a central source serving multiple buildings, individual consumption meters shall also be installed by 31 December 2016 to measure the consumption of heat or cooling or hot water for each unit where technically feasible and cost-efficient. Where the use of individual meters is not technically feasible or not cost-efficient, to measure heating, individual heat cost allocators shall be used for measuring heat consumption at each radiator, unless it is shown by the Member State in question that the installation of such heat cost allocators would not be cost-efficient. In those cases, alternative cost-efficient methods of heat consumption measurement may be considered.

Article. 9 of Directive 2010/31/EU on the Energy Performance of Buildings (EPBD) requires that the EU Member States shall ensure that *:*

a) by 31 December 2020, all new buildings are nearly zero- energy buildings; and*;*

b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

Member States draw up national plans for increasing the number of nearly zero energy buildings.

Based on the above requirements, the Memeber States need to improve their consumption based billing systems, some more than the others.

3 Poland

3.1 Heating Market

Total number of apartments in Poland amounts to 13.5 million, some 1 million of which is empty. The ownership structure allocates 64.1% to housing cooperatives, 18.3% to municipalities, 8.7% to companies and the balance to others. The average usable floor area per person amounts to 23.8 m^2.

In 2009 coal was still the dominant fuel in buildings, accounting for 26% of final energy consumption, mainly for domestic hot water (DHW) and room space heating (SH). Gas and DH accounted for about 16.5% each, electricity for 20%, oil and renewables (mainly biomass) and waste for 10% each.

Due to the central planning history, a large share of total energy in Poland is used for heating. About 40% of population of 38.5 million and 50% of the building stock are served by DH. Poland has about 20,000 km of DH networks. The installed heat generation capacity was over 58.1 GWth and 105 TWh heat sales in 2012, which makes Poland the largest DH country in the EU. In the capital of Warsaw with the population of about 1.8 million, the DH market share is about 80% as typical with other Polish cities as well.

The other 50% of the Polish buildings are heated individually, mainly by natural gas.

There are still challenges to the DH. The CO_2 emissions from the heating sector are high because of the predominant use of coal. In many municipalities, heat distribution networks are still of poor quality, and heat losses are high. The government plans to achieve emission reductions in the DH sector through a wider use of CHP.

There have been and still are projects going on in the DH network modernization through replacement of group substations with individual ones and concrete pipelines with preinsulated ones. Moreover, to some old substations the new service of DHW has been added.

A possible threat to DH is loss of competitiveness. The rise in heat price may be caused by the necessity of modernizations due to emission standards law and EU policy for CO_2 reductions. Due to weakened competitiveness, set up of small individual heat sources and disconnections from DH networks may materialize. Challenge for the future is to build new heat sources to make generation more efficient and to build new installations on gas and biomass. New installations should be CHPs (in accordance to Energy Policy of Poland: doubling the energy from CHP, replacing heat only boilers with CHP).

The DH customer basis in terms of heated floor area continues expand, but the heat sales have fallen year by year due to thermo-renovation of existing buildings, and the new buildings being highly energy efficient.

3.2 DH Development since 1992

Poland has taken many steps to modernize its DH systems since 1992. This includes installation of heat meters in individual buildings and improvements in customer services. By year 1998 already, all DH sales were based on heat meter readings. The meters were either at group substation (CTP) outlets or in building basements.

Simultaneously, the heat subsidies were phased out from the 97% of the heat price subsidized in year 1993 to zero by 1997. In parallel, the social subsidies were better targeted to the poor, not to everybody anymore. The new subsidies to the poor were not related to heating any more but on household incomes.

In Poland, in particular the TRVs and HCAs were introduced to mitigate the impacts of the rapid price increase of DH, as the subsidies vanished from some 97% to none. Moreover, in Poland there was a harsh competition with the individual gas heating. Many DH companies lost customers to gas heating because gas heating could be metered on apartment level and its use controlled according to the individual need.

There were also serious heating quality problems throughout the year associated with DH that favoured gas heating. Such problems with DH were:

- Excess heating during spring and autumn because too high water temperatures had to be delivered to the network to keep the DHW temperatures acceptable. As the customers did not have any control systems, the only way to reduce room temperatures to a tolerable level was to open the windows and ventilate the excess heat out.
- Deficit in heating in winter because those customers being at the end of the network did not usually have enough pressure difference for their hydroelevators to function properly.
- Shut down heating for a couple of weeks in summer for the overall service break. As the networks were of branch type there were no alternative sources and network loops to serve customers, while maintenance was done in some network sections. Also the network valves were of poor quality, which made the network sectioning to operational and maintainable parts impossible. As a result, the customers had to suffer from cold showers in summer for a couple of weeks as the DH was not in operation.

To make it short, the DH was supply and the gas heating demand driven. In the new conditions of market economy DH had start converting from supply to demand drive to keep the customers.

Conversions to demand driven mode were successful. After a couple of years the customers started to come back from gas heating to DH, because:

- Gas prices rose faster than the DH prices, the latter bound to domestic coal with price changes being moderate compared to gas price hikes.
- The service quality of the DH had substantially improved through heat metering, HCAs and TRVs that allowed consumption based billing as well as the consumption controlled according to the individual needs.
- The worst pipes and valves of the networks were modernized and additional loops installed. Therefore, the summer break could be eliminated and heat supplied to the customers constantly all year round.

- There were also a few gas explosions in old indoor gas piping systems that frightened gas customers. The DH is safer in use as it cannot explode and water temperatures in the indoor pipes are usually below 70^{o}C and the pressures very low. Safe DH was one more reason for the gas customers to switch back to DH.

Even though there were several reasons for the gas customers to switch back to DH, the conversion from the supply to demand driven mode was vital. Without such conversion, the gas would have remained superior in service quality, and who ever could pay for it, would go for it. If that happened, the poorest customers would remain with DH, and the DH system would be used at partial capacity but at almost full costs. Therefore, such partly used DH would collapse without substantial subsidies. Such collapses of DH systems have materialized in large scale in countries such as Romania, Moldova, Ukraine and Armenia, for instance, because DH was not able to respond to the market forces. Often the authorities did not help avoid collapses but even worsened the situation by subsidizing residential gas prices while keeping the gas price of the DHC high.

3.3 HCA Market

Some 54% of the residential buildings in Poland are equipped with HCAs, thus basically most buildings connected to DH[7]. In year 2012, there were 6.5 million flats in multi-apartment buildings, and some 3.5 million flats with HCA or heat meters. Altogether 10 million HCAs are installed in the radiators in Poland being in use.

3.4 HCA Barriers

Costs of DH are low due to regulation, perhaps the lowest in the EU. Low heat prices are counteracting the HCA feasibility.

The use of HCAs is not mandatory in Poland, which hampers the HCA market penetration.

Heat cost allocation according to flat floor area is still possible, thus neither requiring HCAs nor apartment level meters to be commissioned.

No unique method for cost allocation with HCA has been set. Therefore, there are various cost allocation formulas applied in the apartment-buildings.

Poland introduced new, more stringent, building codes in 2008. Since January 2009, new buildings are obliged to fulfil technical requirements whereby installations for DHW heating and SH, cooling and ventilation should be designed and installed in such a manner that the quantity of electricity and heat consumed will be at rationally low levels. However, enforcement of buildings' energy performance standards is often weak.

[7] EVVE 2013, Case study – Poland, Michal Kozak

Moreover, new buildings represent only a small share of the total building stock, so their contribution to the overall energy efficiency (EE) improvement is still limited. By law, the building codes must also be applied when buildings are refurbished but this requirement is not always implemented in practice. According to the Action Plan for the Years 2009-2012 of the *EPP 2030*, minimum standards for EE of buildings were increased in 2010/11.

Furthermore, with the objective of complying with the EU directive, as of January 2009, all buildings that are newly constructed, that undergo major refurbishment, that are sold or rented out must have an energy performance certificate. However, these certificates have not proven yet to be a significant factor in decision making about buying or renting housing. Quality and reliability of information contained in the certificates should be improved, and public awareness about their use should be increased. New public buildings will have to meet this requirement by the end of 2018.

Regulation has been amended in 2013 which partially implement the provisions of Directive 2010/31/EU on the energy performance of buildings, introducing as from 1 January 2014 more stringent requirements for new buildings. The main aim of the changes is reduction of the amount of energy required to cover the energy demand of buildings. Provisions of the new version of the technical conditions requirement regulation came into force from 1 January 2014. At the same time, the Regulation provides that the requirements for the primary energy factor (PEF), demand for non-renewable primary energy and the U coefficient (heat transfer coefficient) will consistently increase with the beginning of years 2017 and 2021.

As regards heat sector, URE (the national regulator) approves DH tariffs according to the “cost-plus” methodology, i.e. the tariff covers all justified costs. According to Polish tariff regulation not only the justified costs but also justified return on capital employed in the heat supply activity may be included into planned revenues of the heat company. In April 2013 URE published the *Model for rules and methods of including the return on capital (costs of capital) in the heat tariffs for the years 2013-2015*. The Model was implemented in 2013 and is monitored on regular basis. In case of any improprieties it will be subject to amendments. Stopping the regulation might raise the DH prices at least in the short term, and this make the HCAs more interesting to install.

The DH companies have not expressed any interest in participating in the end-user control investments, based on the sample survey to Warsaw, Krakow and Gdynia carried out in February 2016. The current regulation by URE does not offer any new business opportunities to the DH companies. Therefore, participating in demand side investments would be such a new business area that would require URE’s approval. Nevertheless, the DH companies may not have incentives to do that, because the end-user heat control would reduce their heat sales without any guarantee to be awarded by URE for improved end-use efficiency.

Drop in demand for heat supplied has been experienced due to low-energy buildings, thermo-modernization and rationalization of heat consumption of existing buildings, and due to lack of marketing attitude within the DH companies. There has been little or no proactive approach in searching for new clients in many DH companies.

3.5 Funding of EE

There are several sources to fund EE improvements of buildings in Poland, but the most important one is based on two laws (acts), namely:

1) Thermomodernization Act of 18 December 1998

The Act has established a subsidized government loan program designed to dramatically increase in the implementation of heating system and building envelope related energy efficiency improvements in residential and public buildings.

2) Act on Support of Thermomodenization and Renovation Investments of 21 November 2008

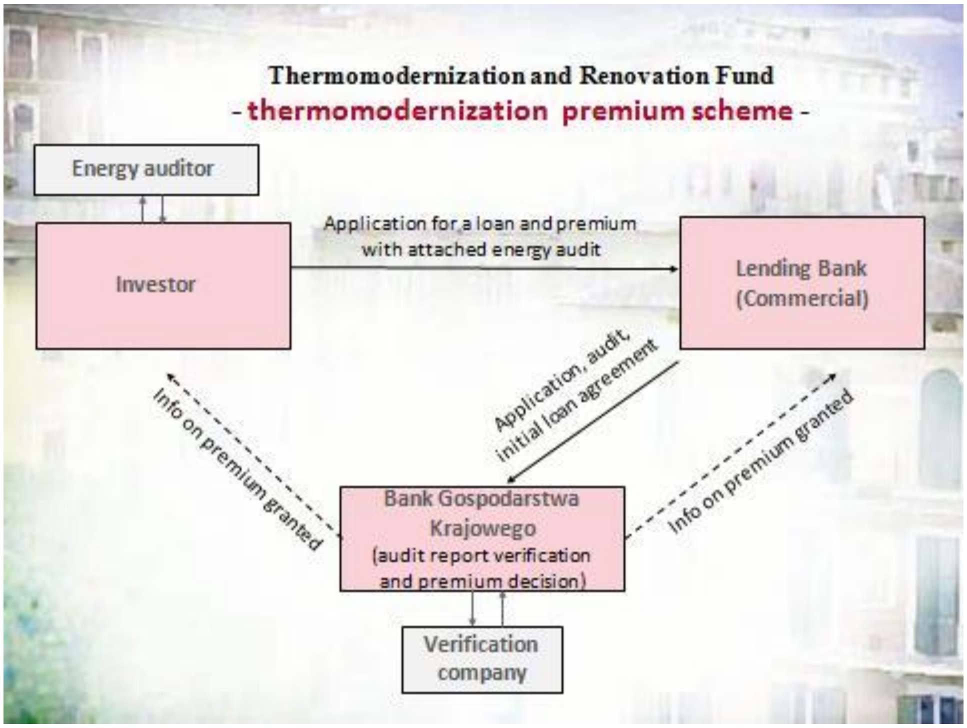
The detailed goals are:

- Improvements dealing with lowering energy consumption for heating purposes and production of domestic hot water,
- Improvements dealing with lowering primal energy loses in local heat distribution networks and supporting local heat sources,
- Replacing local heat sources by connection to centralized heat source, in order to lower heat production costs,
- Completing or partially replacing existing heat sources by renewable energy sources or by high efficiency CHP units.

Thermo-modernization premium constitutes a repayment of part of a loan drawn by an investor for the execution of a thermo-modernization undertaking.

It may be granted to investors that use a commercial loan. Investors who execute thermo-modernization undertakings with their own funds only are not allowed to receive such a premium.

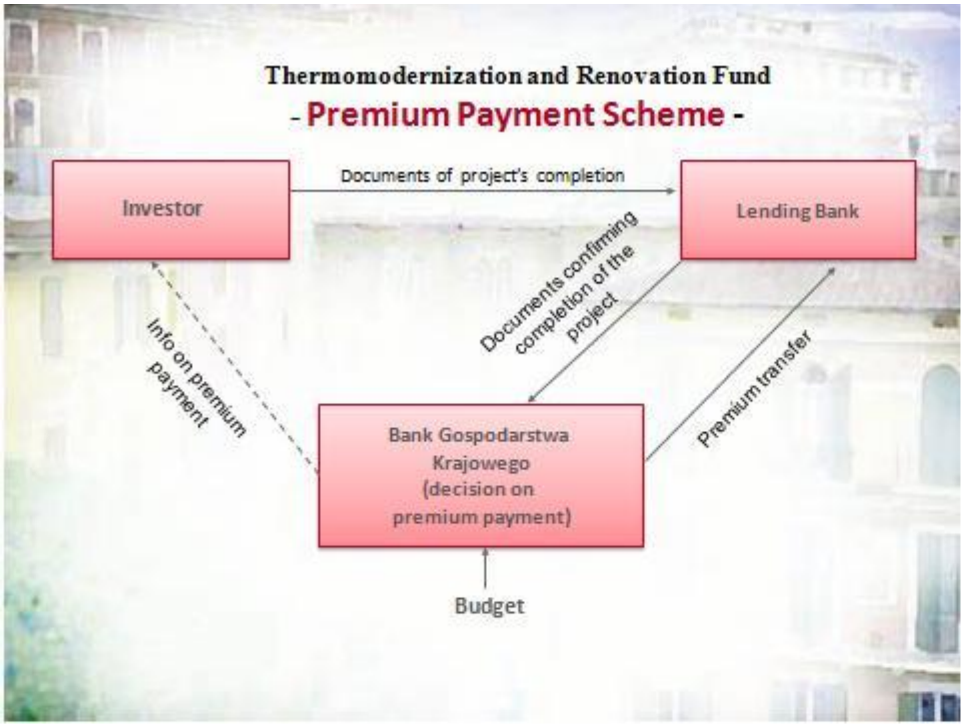
Thermo-modernization premium is equal to 20% of a commercial bank loan used for the execution of thermo-modernization projects, however the percentage cannot exceed16 % of the total cost of the project exceed double amount of the expected annual energy costs savings determined in the energy audit.



The investor orders an energy audit to understand what needs to be done in the particular building to improve the EE performance. If the investment seems attractive with the payback period shorter than 10 years, the investor may submit an application to a commercial bank with requesting a premium (bonus, grant) to be a part of the financing scheme. The commercial lending bank submits the initial loan agreement, the premium request and the energy audit to the national bank (BGK). If the application meets the requirements of BGK, based on the statement of the verification company, BGK submits indicative info back to the bank and the investor to favor the project financing.

As requirements of GBK, the design documents will be approved after the PEF value of the particular is designed to be lower than required in EED.

The building renovation project shall be implemented and occasionally supervised by a city authority.



After the project is completed, the investor shall deliver the signed documents confirming the project was completed according to the set requirements to the lending bank.

When the building is under commissioning, the construction manager signs a document confirming the building meets the EU requirements.

After approval, the bank submits the documents to BGK. After approved, the BGK transfers the premium to the lending bank that reduces the loan with the amount of the premium. BGK also informs the investor about having had transferred the premium to the lending bank.

The premium is paid from the national budget as long there are funds available in the particular year.

The criteria for approving application require the breakeven being in 10 years or shorter. The loan parameters would be 8 years maturity and with 4.3% interest rate.

3.6 HCA Requirements

According to the current building construction regulation, the new residential buildings to be erected have to be able to adopt HCA or HM, but their application in practice remains on the decision of the building owner.

Energy Law requires HoAs and HCs by stipulating how the heat cost allocation shall be done depending whether the cost allocation will be based on HCA or room heated area.

Formula will be agreed between the billing company, the property manager and the service provider.

Correction factors are used and their values depend on the design of the particular building and the relative locations of the apartment.

3.7 Other HCA support

The Association for Energy Allocation (STOW[8]) works as a "non-profit" organization promoting the HCAs to be installed and used for individual heating cost allocation as a way to rationally manage heat energy.

As the current regulation does not provide incentive to the DH companies to participate in end-user heat control investments, the ESCO approach could be a solution. The DHC of Krakow (MPEC) established an ESCO about 15 years ago, as the first ESCO in the Central European countries, with support of the World Bank, to promote energy efficiency in the regional building stock. The idea was to first focus on municipality owned buildings that have only one owner to negotiate with, and later on to extend the business to private buildings.

The ESCO company, POE, built a team of engineers and construction supervisors focused on energy saving projects. In the first few years it created about 16.7 GWh (60 TJ) of savings. The total value of the work was 31 million PLN (about € 8 million). Substantial comfort improvements were reported by owners of the affected buildings, as well as improvements in the condition of building equipment.

3.8 Lesson Learned

As conclusion, during 1999-2015 about 1.1 million apartments have been included in the EE program altogether, which is 8% of the total amount of apartments being 13.5 million. During the program, the total costs have amounted to PLN 12 billion (€ 3 billion), some 2 billion (€0.5 billion) of which premiums.

Needs of the EE program are supported by three aspects:

- HM and HCA are important incentifiers as "you know what you use"
- EE certification of the buildings shows to the investor what needs to be done
- Legal status of the HoAs need to be stronger than now in Poland.

Based on the Polish experience, in general the EE program has to be designed in a way that it provides incentives to the investors and HoAs. Moreover, for the EE program implementation it is important to:

[8] STOW - Stowarzyszenie ds. Rozliczania Energii

- Use good materials in construction
- Have construction work carried out an finished with good quality
- Have energy prices not subsidized in order to show the real costs and savings to the parties, and to be on an adequate level to provide incentives to save heating costs.

In the beginning of the premium program there was a problem as the commercial bank required a collateral that the building owner did not usually have. Now the system works much better as the commercial bank's decision to lend is based on the credit worthiness of the Investor and the HoA (budget and funds for annual maintenance and repairs)

Moreover, during 1998-2002 the interest rate of the EE loan was as high as 30%. Therefore, only a few cases were implemented then.

Energy Audit has not to be carried out always by a certified body as the audit results will be verified by BGK experts anyway.

In Poland, people are still not fully aware of EE benefits of CBB even though there is almost 20 years of track record with CBB on the market.

Erratic or unclear bills have been sometimes submitted by the billing company, which has raised complaints.

The results of the economic analysis indicates that the installation of individual HCAs is not always cost-effective, because it should be preceded by adequate modernization of the central heating system (insulation, a suitable measuring system, weather regulator, thermostatic valves, cleaning) and adjusting the power of heaters to the design conditions (exchange of radiators).

Sometimes in a poorly insulated and with poorly balanced indoor piping systems the HCA readings have been unrealistic, and therefore, not used in cost allocation. Some apartments may have been underheated both before and after TRV and HCA installation, which makes the tenant question the achieved savings.

The actual working conditions of the radiators in individual rooms have to be known in order to prevent errors in HCA readings. One of the error sources, which strongly influences on the irregularity of validity, is the oversizing of the radiators. The error may be born both during the heating system design and as a result of thermo-renovation of the building. Oversizing of the radiator causes throttling of the mass flow of heating water, thus changing the working conditions of the HCA, due to changes in temperature distribution. This leads to irregularities in allocation of heating costs amongst the apartments.

Electronic allocators appear to be more sensitive to throttling of the heating water mass flow than the evaporator allocators.

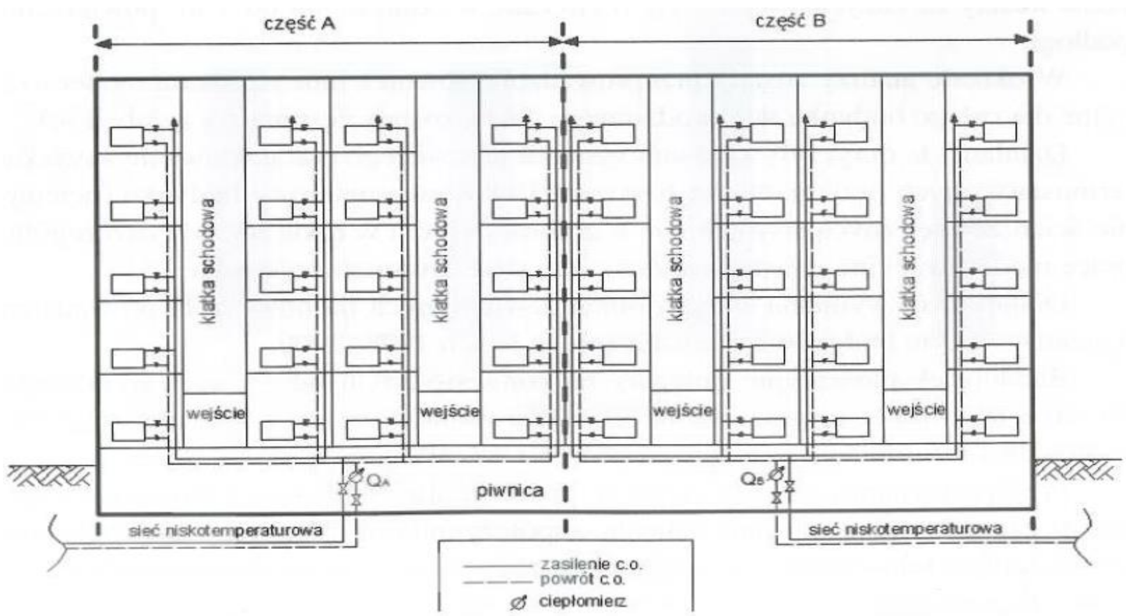
Installation of individual HCAs is less profitable, the smaller is the specific consumption of heat in the building or the lower the heat tariff as there are less costs to allocate relative to the needed investments.

3.9 Best Practice Examples

Here a few best practice cases of HCA use in Poland are presented.

Case Lublin[9]

Back in year 1998 an existing residential building was artificially divided to two equivalent parts, which used to have the same heat consumptions as well.



In year 1999, the TRVs werey installed to all apartments of the building but the HCAs only to Part B apartments . In the consecutive years until 2005, the Part B consumed less heat the difference to Part A ranging from 18.8 to 26.6% per year.

In 2005/2006 thermal insulation was added to both building parts equally without adding HCAs to Part A. The Part B apartments consumed now 30% less heat than the apartments of Part A until year 2011.

[9] Cholewa, T., Siuta-Olcha, A., Technical University of Lublin Poland, ISBN 978-83-88695-33-9

In year 2011, the HCAs were added to the Part A apartments as well, thus resulting in equivalent technical and physical conditions in both parts A and B.

During the consecutive 3 years until 2014, the heat consumption difference between the two parts A and B vanished and resulted in equal heat consumptions, about 50-60% lower than in 1998.

The reserach is based on the Trechnical Univrsity of Lublin, Poland.

Case VEOLIA Lodz

During 2008-2010 the specific heat consumption in terms of kWh/m2/a was recorded to be 136 and 83 without and with HCAs in 11 and 15 buildings on average, respectively. Thus, the buildings with HCAs have consumed 39% heat energy less than those without.

Case Statistical Authority of Poland

In year 2014, the heating costs were PLN 2.45 and 3.36 per m2 in buildings with and without HCAs, respectively. Therefore, the heating costs with HCAs appeared 33% lower than without HCAs.

3.10 HCA Market

TECHEM has been In Poland since 1992 already. In TECHEM business the hot water meters count 90% and the balance of 10% HCAs.

ista has been in Poland a year later in 1993. Today ista has 8,000 customers with PLN 84 million turnover. In Europe ista has local offices allover except Finland, the Balkan countries and Ukraine.

Metrona Polska was established a year later having 15 regional offices today.

In the market the large majority of about 85% of the HCAs are electronic and the balance of 15% evaporator types.

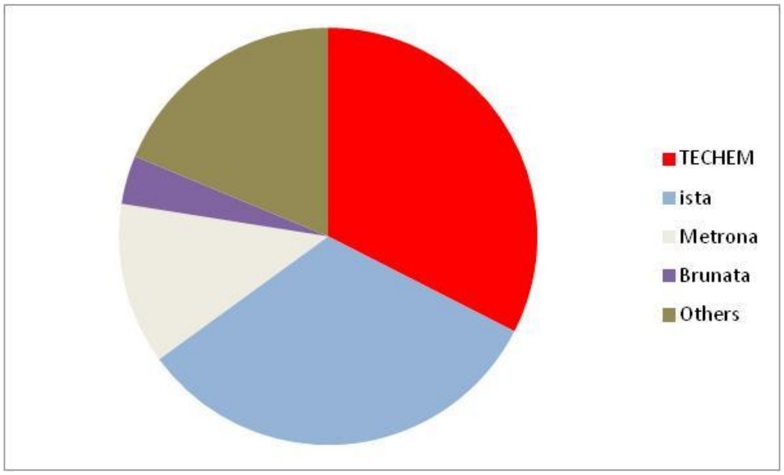


Figure 1. Market shares in Poland in rounded numbers with 15 companies altogether. The 11 "Others" are mainly Polish companies.

Still some 3 million apartments offer a potential to be equipped with HCAs.

4 Hungary

4.1 Heating Market

In general, the heating market is rather similar in structure and size to the one of Belarus except the underdeveloped DH sector in Hungary. Such similarities are summarized in Table below.

	Belarus	Hungary
Population (million)	10.0	9.5
- in capital (million)	2.0	1.7
Land area (th. m2)	208	93
Share of natural gas in all heating	c. 80%	66%
Share of natural gas in DH	c. 80%	78%
Market share of DH	c. 50%	c.20%

Most of the buildings in Hungary are heated individually by natural gas.

Some 30% of the building stock has been thermo-renovated since year 2000.

About one fifth of the total buildings are connected to DH. DH operation exists in 95 cities and is run by 110 licensed companies. Altogether some 650 th. flats (15% of total) are connected inhabiting the population of about 1.6 million. Moreover, about 20% of the non-residential building stock is connected to DH in Hungary.

In year 2012, some 8.9 TWh (32 PJ) of heat was delivered through the DH systems, some 52 % of which produced by CHP plants. From the fuel of DH, as much as 93 % was natural gas.

The total DH sector turnover amounted to € 500 million in 2012.

On average, the heating costs of standard flat of 53 m^2 including room space heating (SH) and domestic hot water (DHW) amounted to some € 600 in 2012, but with a large variation from €100 to € 800 depending on the city.

4.2 HCA Market

The market share of HCAs in the Hungarian residential buildings amounts to about 47% of the building stock.

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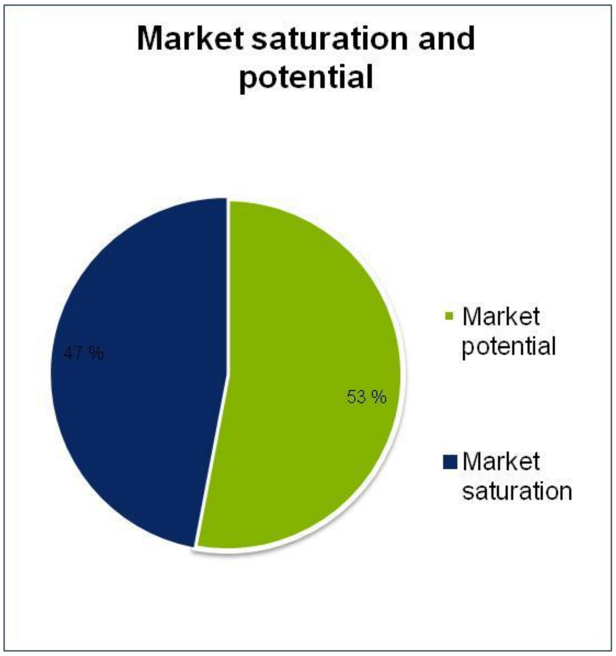

An evaporative type HCA may be applied in case of the replacement of an evaporative type HCA applied prior to the entry into force of the Amended Government Decree.

4.3 Regulation of Heat Cost Allocation

The heat cost allocation regulation is based on the Government Decree No. 157/2005.

The SH fee allocation ratios may be determined by the owners' community in accordance with the organizational and operational code, or the statute of a housing cooperative either on the basis of the heated air volume of the parts of building, or by applying HCAs.

The owners' community shall determine the cost allocation ratios for a certain validity period so that the amount of the cost allocation ratios of heating is 100%. The cost allocation ratios of heating shall not be modified within the validity period.

HCAs may be applied to determine the cost allocation ratios if the heat release of all radiators that are installed in the parts of building being in a separate ownership or separate use in the place of use is determined with a HCA of the same brand and with an unified assessment system, or the heat usage in the parts of building that are in separate ownership or separate use in the place of use can be measured independently with a heat meter providing the function of a HCA.
b) the heat release of radiators may be regulated in all parts of building in the place of use, where it can be solved without breaking the walls,

c) the entity who installs the HCA or the HM for cost allocation certifies the measurement accuracy with a conformity certificate issued by the manufacturer,
d) the installation of the HCA or the HM for cost allocation complies with the relevant legal and technical regulations,
e) the HCAs have been sealed after their installation to prevent intervention or detachment, and
f) the reading of HCAs, and the inspection of their operability and if the seal is undamaged, shall occur until the date determined by the owners' community at the end of the validity period.

The user shall ensure - except in parts of building of common use - the installation of a certified HM or HCA in order to settle the consumed DH and DHW in the parts of building
a) in case of a new connection, if it is made in a new building or
b) if the building has been renovated considerably in accordance with the ministerial order on the determination of the energy characteristics of buildings.
The payer shall notify the representative of the owners' community of the damage of the HCA or its seal forthwith in writing. The costs of replacing the damaged HCA or its seal shall be borne by the payer.

An evaporative type HCA shall not be applied – except for those cases described in Article 23/A (3) – as a heat cost allocator.

(1) In case of using HCAs, the representative of the owners' community or the billing company
a) shall notify the payers in writing 15 days before the meter reading at the latest through a notice posted in a public place well visible by the payer about dates of meter reading and the recommended additional meter reading of the installed HCAs and the appointed date for inspecting if the seal is undamaged and the HCAs operate well, about the legal sanctions due to the failure of meter reading, and the contact details for arranging appointment;
b) shall notify the payers within 3 months following the end of the validity period at the latest through a notice posted in a public place well visible by the payer about
ba) the beginning and the end of the validity period,
bb) the total heated air volume of the place of use,
bc) the heated air volume of the single parts of the building,
bd) the cost allocation ratios of heating and
be) all those data from which the cost allocation ratio of heating can be calculated and checked.
(2) In the notice under point *a)* of paragraph (1) the additional meter reading date of the HCA shall be appointed on a day within 8 days from the meter reading date determined in the notice at the latest.
(3) The payer may initiate the arrangement of an additional meter reading date to be different with 3 days at most from the additional reading date recommended in the notice under point *a)* of paragraph (1).

(4) A record shall be drawn up - including the possible disagreement of the payer- about the meter reading and or additional meter reading carried out on site and about the on-site inspection of the seal's integrity and the cost allocator's operability signed by the inspector and the payer. The inspector shall provide one copy of the record to the payer. If the payer does not enable the inspector do the meter reading, the additional meter reading or the inspection and it does not sign the record, the inspector shall record this fact and provide one copy of the record to the payer and the representative of the owners' community.

If the owners' community has decided on the application of HCAs, then at least 30% but not more than 50% of the quantity of heat used in the validity period shall be allocated between the parts of the building in the proportion of the heated air volume of the parts of the building and the remaining part according the read data of the HCAs modified with the corrective factors. During the calculation of the consumption-based ratio regarding the parts of building, the specific heat consumption taken into account concerning the single parts of the building shall not be larger than 2.5 times the specific heat consumption of the place of use.

(2) If it is not possible to install a HCA on all radiators, then the heat release of those radiators shall be calculated by means of the characteristics of the radiator and the water temperatures on average conditions.

If the payer did not allow the heat cost allocators' installation, reading in a way and at the date specified in the contract, or the payer has detached the heat cost allocator deliberately, or during the reading and inspection of the HCAs it may be have noticed that any HCA of the part of the building or the seals placed on them have been damaged. Then the cost allocation ratio of SH shall be determined by taking into account the quantity of heat calculated as a result of multiplying 2.5 times the specific heating heat consumption of the place of use and the heated air volume of the part of building.

If the HCA fails – then during the recording of data of reading – the heat release of the given heat exchanger shall be taken into account as the average heat release of the radiators installed in the rooms of the place of use with the same location and function. Those calculations shall be applied from the date when the inspector recorded the failure of the HCA in writing until the date when the new or repaired and sealed HCA will be put in operation.

The quantity of heat used during the validity period shall be allocated partly in the ratio of the heated air volume of the parts of the building, and partly based on the consumption according the data of the HCA shall be determined so that their amount expressed in percentage is 100%.

The determination of the allocation ratios of the used quantity of heat for making DHW in the place of use and its fee for the parts of building (hereinafter referred to as the cost allocation ratios of DHW) may occur based on the decision of the owners' community- in tune with the organizational and operational code in case of a condominium or the statute in case of a housing cooperative - as follows:

a) with the application of DHW cost allocators, DHW on the basis of consumption data measured on the DHW cost allocators, DHW as it is specified in paragraph (2), or

b) on the basis of the number of DHW taps installed in the parts of the building.

(2) The cost allocation under point *a)* of paragraph (1) may be applied if:

a) the DHW cost allocators have been installed in the pipe network, preceding the DHW taps of the parts of the buildings participating in the cost allocation,

b) the installation of the DHW cost allocators has been made in compliance with the technical regulations,

c) the DHW cost allocators have been provided with an identification number and have been sealed after their installation to prevent unauthorized intervention or detachment, and

d) the reading of the DHW cost allocators and the inspection of their operability as well as the seal's integrity is performed regularly but at least once a year.

(3) The amount of DHW fee allocation ratios that are determined for the parts of building in the place of use shall be 100%.

(4) The payer shall notify the representative of the owners' community forthwith in writing if the DHW cost allocator or its seal has been damaged. The costs of replacing the damaged heat cost allocator or the seal installed on the cost allocator shall be borne by the payer.

(5) If the determination of the DHW fee allocation ratios is made on the basis of point *a)* of paragraph (1) and

a) the payer did not allow the installation of the DHW cost allocator and its reading in a way and at the date specified in the contract,

b) the payer has detached the DHW cost allocator deliberately, or

c) during the reading and inspection of the DHW cost allocators it may have been noticed that the DHW cost allocator or its seal is damaged, then the owners' community may determine a DHW allocation ratio to be applied for the given part of the building which shall not be larger than 1.5 times the DHW consumption of the part of building with largest use in the place of use and which shall be applied from the date when the installation of the DHW cost allocator or its reading was prevented, or a deliberate detachment or damage was determined.

(6) In the case under point *a)* of paragraph (1), the owners' community or the billing company

a) shall notify the payers in writing 15 days before the reading at the latest through a notice posted in a conspicuous place well visible by the player about the dates of meter reading and the recommended additional dates of meter reading of the installed DHW cost allocators in the parts of buildings as well the recommended dates for inspecting the seal's integrity and the cost allocator's operability about the sanctions due to failure of reading;

b) shall notify the payers within 1 month following the end of the reading period of the DHW cost allocators at the latest through a notice posted in a conspicuous place well visible by the player about the DHW allocation ratio determined for the single parts of the building as the result of the meter reading.

(7) In the notice under point *a)* of paragraph (6) the additional meter reading date of the DHW cost allocator shall be appointed on a date within 8 days at the latest from the meter reading date determined in the notice.

(8) The payer may initiate the arrangement of an additional meter reading date to be different with 3 days at most from the additional reading date recommended in the notice under point *a)* of paragraph 6.

(9) A record shall be drawn up - including the possible disagreement of the payer - about the meter reading and additional reading executed on site and about the on-site inspection of the seal's integrity and the cost allocator's operability, signed by the inspector and the payer. The inspector shall provide one copy of the record to the payer. If the payer does not allow the reading, the additional reading or the inspection and it does not sign the record, the inspector shall record this fact and provide one copy of the record to the payer and the representative of the owners' association.

If the owners' community decides to use cost allocators, then it shall ensure their installation, operation, maintenance, temporary inspection, reading of its data, assessment and the calculation of heating and warm water fee allocation ratios, and it bears the related costs.

(2) The owners' community can perform its obligation concerning the tasks included in paragraph (1) through a billing company.

(3) If the owners' community concludes a contract of services according to paragraph (2), then the contract between the billing company shall include at least:

a) the address and lot number of the place of use,

b) the position of the single parts of the building (staircase, floor, door) and their heated air volume,

c) type of cost allocators to be applied in the place of use,

d) the frequency and dates of meter reading and additional meter reading of cost allocators,

e) the method of meter reading notices,

f) the documentary tasks relating to the meter reading data of cost allocators, the way in which documents will be transferred to the representative of the owners' community and its frequency, the retention period of data and the determination of the right of access,

g) the way in which the consumer applications (complaints) will be handled,

h) the obligations and rights of the owners' community and those of the agent, especially in connection with the inspection, reading, assessment of the cost allocators, the determination of the fee allocation ratios, and payer information,

i) the fee of the billing company, the way in which the fee is settled,

j) the applied corrective factors.

(4) The conditions of applying cost allocators installed in the part of the building shall be provided by the payer. The payer shall cooperate with the representative of the owners' community and the billing company.

(6) The representative of the owners' community shall provide the payer – at an agreed time and place - insight into the calculation of fee allocation ratios to be used in the part of the building.
(7) The cost allocation ratios shall only be modified subsequently in case of a false calculation, at the written notification of the representative of the owners' community to the DH supplier. The representative of the owners' community shall inform the payers about the notification of the subsequent modification regarding the fee allocation ratios, about and the modification, the reason of the modification, its content and impacts.
(8) In case of applying a heat meter qualified in a decree of the municipality as a settling meter, the part invoice shall only be based on the energy quantity determined by the DH supplier through statistics analysis (estimate) if during the given period either the HM has not been read, or the HM reading data has not been reported to the DH supplier.

The district office may order the access of the DH supplier to the place of use if the user or the payer does not make it possible to read or inspect the DH measurement instruments or heat cost allocator devices.

4.5 Correction Factors

The correction factors are used to compensate the poor location of the apartments in heating cost allocation. Those apartments having building envelope more than the others located in the center of the building would suffer for unfairly high heating costs if no correction factors would be used. The correction factors are regulated by the Act as presented in Table below.

Description	The amount of correction* in %
*1. Ground-floor corrections**:*	
1.1. ground floor with no room underneath	–15
1.2. ground floor above an unheated room	–10
*2. Top-floor corrections***:*	
2.1. in a flat roof building, directly under the roof	–20
2.2. under an unheated loft that is not built-in	–15
2.3. under a built-in, unheated loft or in the loft	–10
3. Corner-room corrections:	
3.1. each room which has at least two external bounding surfaces (cooling walls)	–10
4. Correction according to the compass point:	

Description	The amount of correction* in %
4.1. northern side	–5
5. Other corrections:	
5.1. a room above an unheated passage and doorway	–15
5.2. a room above an unheated ground-floor room	–10
5.3. a room next to an unheated staircase or walkway	–5

* Corrections shall be calculated for the single rooms of the parts of building. If more than one correction could be applied for a given room, all corrections shall be applied. In case of applying HMs as cost allocators, the corrective factors of the given rooms in the part of the building shall be calculated according to the heated air volume of the room affected by the correction factor per the heated air volume of the whole part of building.

** Ground-floor corrections shall not be applied in the case those rooms that have a vertical down-feed heating system, in the air volume of which a horizontal manifold without thermal insulation goes through.

*** Top-floor corrections shall not be applied in the case of those rooms that have a vertical up-feed heating system, in the air volume of which a horizontal manifold without thermal insulation goes through.

The correction factors shall be used to adjust the recorded HCA readings when setting the heat bills of the apartments.

4.6 Energy between Heating and Hot Water

DHW flow meters are installed to all apartments in Hungary to measure the DHW energy. Moreover, their readings are used to determine the SH consumption of the buildings in the following steps:

- The DHW flow meter measures the water volume that was used by the DHW.
- The temperature difference of supply and return prevailing in the summer time, when there is is only DHW consumption, will be recorded.
- The water volume and the temperature difference will be used to result in the DHW energy consumption of the selected period of time.
- The DHW energy consumption will be deducted from the total heat consumption of the building to obtain the SH energy consumption.
- The SH energy consumption will be allocated to the apartments by means of the formula being a mixture of HCA readings (x%) and the heated floor area (100%-x%).Conclusions

Best Practice Examples

Apart to Poland, in Hungary some DH companies have been active in end-use heat control. According to the information obtained from MaTáSzSz, the DH Association of Hungary:

- The DHC of Nyíregyháza called NYÍRTÁVHŐ uses HCAs for all residential customers on its service area.
- On the HCA market, there are two member companies of MaTáSzSz who install and operate HCA systems, namely TECHEM Ltd. and ista Hungary Ltd.
- The DHC of Budapest, *FÖTAV*, used to run an end-use heat efficiency program titled ÖKO Plusz a few years back, but the program was finished because of lack of subsidy concerning the demand side. It means that in Budapest only in one third of 240,000 district heated flats there are HCAs on the radiators. More on the ÖKO Plusz program is given in the following subchapter .

The approach of the DHC of Budapest, FŐTÁV, offers two interesting examples to Belarusian authorities to consider. In past eight years FÖTAV has organized two programs, the "ÖKO Plusz" and the "Smart House" pilot program to help customer buildings to improve their energy efficiency and technical heating performance. Here the short introduction to the programs and the results is given[10].

Case ÖKO Plusz Program

In year 2008 already, FŐTÁV launched the ÖKO Plusz Program in Budapest, because a significant part of many residential communities did not have any technical and financial resources to modernize the heating systems of their residential buildings.

In the ÖKO Plusz program the FŐTÁV's contribution was to:

- Assist in preparing applications to obtain state subsidy;
- Provide 10% discount from the base fee (as of 1 January 2008 retrospectively) for consumers contracting with the company to join the ÖKO Plusz Program;
- Organizing thermal insulation of buildings, replacing windows with state aid of 33%;
- Retrofitting of heating systems (thermostatic radiator valves, HCAs and hydraulic balancing valves) with state aid of 50%; and,
- Organizing thermal insulation of buildings and replacing windows with state aid of 33%.

The average investment cost was about €500 € per flat, some 50% of which covered by the customer and the other 50% by the state subsidy and FŐTÁV together.

In order to commission the ÖKO program, FÖTAV organized two rounds of tendering.

The first tender period covered February 1, 2008 – June 30, 2009

- Number of offers: for 1246 buildings
- Number of applications submitted: for 512 buildings (44 906 flats)
- Number of winner applications: 512

[10] EVVE 2013, Csaba Fekete, CEO, FŐTÁV, 11 November 2013

- Awarded subsidy amounted to 2.6 Billion HUF (equivalent to about € 0.8 million)

The second tender period covered December 1, 2009 – September 30, 2010

- Number of offers: for 716 buildings
- Number of applications submitted: for 154 buildings (10 843 flats)
- Number of winner applications: 143
- Awarded subsidy amounted to 600 Million HUF (equivalent to about € 2 million)

In total the heat efficiency improvement of 489 buildings was compledted in two phases:

- ÖKO 1: Modernization of 425 buildings completed
- ÖKO 2: Modernization of 64 buildings completed

The energy savings achieved from the ÖKO Plusz amounted to 18.4 % on average but ranging widely from -13% up to 50%. The value „-13%" imlies that in some buildings a deficit in heating services had prevailed before the program, and after the program completed, the net heat consumption increased up to 13% as acombination of the deficit coverage and energy savings together.

During the years 2012 and 2013 FÖTAV launched a pilot program titled „Smart house" with the goal to promptly improving energy efficiency, obtain energy savings and enhancing the amount of renewable energy utilized in the buildings connected to DH. In the pilot program the activities of FŐTÁV were in the selected buildings:

- Modernization of the DHW system
- Establishment of a renewable solar power generation system
- Establishment of a smart metering system for SH and DHW supply

A motivation to launch the pilot program was that DH service suffered for poor indoor installations of buildings, for instance, as:

- The DHW systems are in a worse technical conditions than the SH systems;
- Pipes are exposed to more aggressive corrosion; and,
- The insulation of the riser circulation pipe is very poor in most cases;

As the consequence the energy effectiveness of the heating substations was worsening. Therefore, FŐTÁV had to maintain significant additional water circulation in the DH system due to poor quality of the customer heat control systems.

The accrued benefits of the „Smart house" Pilot program where twofold:

- The DHW savings in two of the pilot buildings having been completed amounted to 27% and 39% a year, equal to 75 and 91 MWh heat savings, respectively.
- The installed solar panels generated about 7 kWh/day electricity on average.

Case Smart House in Budapest

FÖTAV, the DHC of Budapest, launched a pilot program by selecting 4 residential blocks to be equipped with solar panels, advanced TRV and HCA management and building envelope insulation as a model for the public audience to be replicated elsewhere. Public subsidies, tenants' contributions and FÖTAVs own resources were used for financing the Smart House pilot.

As an example of such a smart house in address *Nyirpalota ut 1-12*, the heat consumption has dropped 50% from 18,000 GJ to 8,900 GJ.

All apartments are with two-temperature HCAs and TRVs. The HCAS are remote metered in 15 minute intervals by a receiver station that is installed on the top of the elevator car. As the elevator moves vertically, so does the receiver as well recording the HCA signals. The mobile receiver station made it possible to avoid receiver stations in every one or two floors.

As the data collection is uniquely frequent (15 minute intervals), the faulty measurements can be indentified almost immediately and the corrective actions taken. Moreover, the frequent reading reveals if a tenant has tried to manipulate the HCA reading. A local company *CardWare* has implemented the HCA management system and operates it.

There have been many attempts by the tenants to manipulate the HCA readings, for instance, by:

- replacing the HCA equipped radiator with another radiator that has no HCA. The removed HCA equipped radiator has been put under the bed or elsewhere without connection to the heating system.
- magnetizing the HCAs or heat meters to reduce their reading capability
- covering the HCA in order to reduce the temperature difference that is used for heat cost determination.

The frequent data collection and verification routines reveal abused HCA manipulations. The penalty to the abusing tenant is set by the HoA to be 2.5 times the average heating costs of the building during the determined period of time.

Due to the penalty system and the fast detection of possibly abuse, the manipulation problems have become virtually non-existent.

Solar electricity with 33 kW peak production capacity is used for common lighting in the corridors and elevators of the building. The excess power is sold to the national grid. The power generation is measured in 2-3minute intervals.

Frequent reading of the HCAs as carried out in the Smart House@ pilot is important to monitor the accuracy of CBB and to provide services to the customers to maintain the creditability of heating services. This is only possible with radio type electronic HCAs.

Usually, the evaporator type HCAs are read in Budapest on monthly basis but elsewhere in Hungary on annual basis, which may yield problems in accuracy and manipulation that can be too late to address.

Case HCAs mandatory in Nyiregyhaza town (Nyirtavhö DHC)

The population of Nyiregyhaza amounts to 120,000. The DHC id the 8th largest in Hungary with 50% market share in the town heating.

Most multi-apartment buildings are equipped with HCAs and TRVs as strongly supported by the DHC. Financing of the equipment has been shared between the DHC (86%), the government subsidies (10%) and the tenants by themselves (4%) during 1996-2011. Altogether € 3.9 million was spent to have 14,300 households equipped with 55,900 HCAs and TRVs, and those 309 blocks in which the HHs exist with balancing valves.

The DHC plans to continue the HCA and TRV program with another € 0,25 million contribution to finalize the HCA and TRV program.

The ownership of the HCAs and TRVs has exceptionally remained with the DHC even though the devices are in the apartments. Elsewhere in Hungary, all indoor heating facilities beyond the substation are owned by the customers.

The annual costs of maintaining the HCAs and TRVs amount to €40-45 per apartment, which adds some 10% to the heat tariff.

Based on the high awareness of building energy efficiency, some 55% of residential and 70% of public buildings have been thermo-renovated already. Neither have disconnections of the DH customers been faced in Nyiregyhaza as having been typical elsewhere in Hungary. Moreover, in year 2014 the receivables from those customers equipped with HCAs were 60% less (HUF 0.8 million) compared to those without HCAs (HUF 2.0 million). Also the specific heat consumption of SH in Nyiregyhaza is the lowest in Hungary, about 96 kWh/m2 and 35 kWh/m3 equivalent to 18 GJ/HH a year and 52 m2 on average a year. All those benefits can be considered be achieved by the active role of the DHC when promoting HCAs and TRVs as a means to improve heating efficiency in the customer premises.

DH Action Plan

DH is still underdeveloped in Hungary due to tough competition with individual gas heating. The competition is hampered by the DH sector being heavily dependent on natural gas as well. In Budapest, for instance, even though having the largest DH systems of Hungary, about 40% of the total, the densely built city center is not connected to DH yet. Moreover, the DH networks are separate network islands requiring interconnections.

DH has a poor reputation in the heating market, which also hampers the attractiveness in the eyes of the potential customers.

The DH development requires alternative and renewable heat sources to be introduced such as geothermal, biomass and waste incineration. DH networks should be integrated and the density (MWh of heat sold /meter of network length) increased.

Before year 2010 some 60% of DH was produced by CHP plants, but the share has now dropped to some 30%. the reason to downsizing CHP has been the power market unbundling: CHP generated electricity has to be sold to the power market at too low a price, which makes CHP uneconomic. Before 2011, the high electricity price of CHP was used to cross-subsidize the price of DH, but this is not possible anymore.

In year 2010, the VAT for DH was dropped to as low as 5%.

4.7 Lessons Learned

The lessons learned from the two programs desicribed above were:

- Too high expectations adopted in the beginning did not fully materialize as some 70 th. flats were modified only out of 240 th. in total heated by FÖTAV;
- There was no interest among the customers if the calculated economy indicated longer than 5 years pay back;
- Basically the state subsidization was good, but too autocratic and slow to process. Moreover, it required pre-financing from the other two parties;
- Fair cost allocation is a critical success factor. Therefore, correction factors shall be applied;
- Transparent and continuous information about consumption is needed as a kind of „smart cost allocation”; and,
- Communication is important directly with the customers and the audience to raise public awareness.

4.8 HCA Barriers

Otherwise, end-users are not really motivated to change as long as the EED is not implemented properly in Hungary with strict deadline and sanctions attached.

Therefore, roughly 60% of the market is still not covered with HCA in Hungary.

4.9 HCA Support

The use and the general rules of the heat cost allocators are regulated in the 157/2015. (VIII. 15.) Government decree from the section 17/A. to the section 17/H. and the 189/1998. (XI. 23.) Government decree.

Since September 2011, only electronic HCAs have be allowed to be installed as the new installations of evaporators was forbidden

A couple of years ago there had been subsidy programs (non refundable financial support) for heat reconstruction and HCA installation for dwellings connected to district heating. Recently, at the end of 2015, another HUF 11.5 billion non-refundable support had been allocated to about 440 buildings covering about 30-50% of the overall investment costs of het end-use control.

MaTáSzSz has a strategic agreement with the Ministry of National Development, which is responsible for the regulation of the HCAs.

4.10 Future

Most probably that was the last such non-refundable funds, since the government is planning to introduce a different support scheme, some subsidized credit line with very low interest rates.

In future, there remains potential for heat savings as presented in Table below.

Table 1: Heat saving potential in Hungarian apartments[11]

Measure	Savings potential from total heat consumption
SH system without regulation	15-20%
DHW system in poor technical shape	5-10%
Poor building insulation	25-30%
Low customer consciousness	c. 5%

Insulation of the building should be implemented only after renovation the building heating systems.

[11] EVVE 2013, Csaba Fekete, CEO, FŐTÁV, 11 November 2013

FÖTAV has prepared a Proposal to introduce a new subsidy for rehabilitation of the building heating systems, as follows:

State subsidy 50% of the investment with annual cost of ranging from HUF 3.9 to 5.4 billion HUF with the cumulative subsidy value of HUF 23.1 to 32,4 billion during 6 consecutive years.

The new subsidy system would complete renovation of heating systems in 180,000 flats and implement smart HCA systems in 60,000 flats in Budapest.

The expected energy savings would amount to 14 % equivalent to HUF 24 thousand per flat with the customer pay-back time 5 years or shorter. This would equal to 160,000 tons of CO_2 emissions avoided per year.

Moreover, the subsidy system would contribute to overall economic recovery and job creations.

By the date, however, no approval from the state is available to initiate the subsidized heating system rehabilitation.

5 Conclusions

5.1 Lessons

As conclusion,

1) TRVs and HCAs were introduced to mitigate the tariff increase and improve acceptability of tariff increase;
2) Adopting the demand driven mode offered the possibility to DH companies not to lose many of their consumers or to even attract those who left because of possibility to regulate the heat ;
3) People are not willing to pay for the higher than needed temperatures in their rooms if they cannot regulate it, so they got disconnected or switched to alternative heating
4) Also vertical indoor piping can be used for HCAs and TRVs but not for apartment level heat metering, that would have been more expensive and with little or if any added value;
5) Heat control at the CTP and not even in the building is not enough to comply with the temperature comfort level of all HHs;
6) There are heat savings after TRVs introduction to the amount of 10-20% due to change in human behavior, so people do not regulate the heat with windows, but with TRVs, and
7) HCAs and TRVs are not tremendously expensive and have the payback period of a couple of years only.

5.2 Costs

As indicative costs, the HCA is about €10-15, and typically 3 HCAs in a room of 52 m2 would amount to investment costs of €30-45. On the other hand a HM on apartment level would cost about €100-160, but would be more accurate.

The lifetime of the HCAs is 10 years as with HM as well. The latter however, has to be legalized after the first 5 years which costs about €30-40.

The maintenance costs of the HCA systems amount to about 3% of the heating costs. The maintenance works are carried out either by the billing company or the housing maintenance company depending on the agreement.

In case the tenant wishes to replace the radiator, the billing company will replace the HCA to meet the requirements of the new radiator.

HCA cannot be installed in bathrooms if the radiator towel dryer radiator is not equipped with a TRV. Such an unregulated dryer provides inaccuracy to heat cost allocation as the tenant may use the dryer as the main heat source of his dwelling and keep the TRVs closed most of time. One way is to reduce the total ordered heat load of the building. Therefore, as the capacity of the towel drier is not adequate to heat up more than the towels, the TRV have to open at higher outdoor temperatures already. Another way is to install a TRV to the towel dryer as well.

The common areas are allocated to the apartments relative to the sizes of the apartments by using the fixed factors in the allocation formula. The property manager usually decides how the common areas a dealed with in the heat cost allocation.

Type of cost allocation	Fixed	Variable	
HM in horizontal piping	10%	90%	
HCA in horizontal piping	30-50%	50-70%	
HCA in vertical piping	60-70%	40-30%	

First, thermal balancing of the riser pipes should be carried out and the thermorenovation of the building envelope if planned already

Each HCA has to be adjusted according to the size and type of the radiator. The radiators are tested in a certified laboratory which set the UF value of the particular radiator type. The uF value will be used in HCA reading interpretation.

Thereafter, the HM or HCA should be introduced.

Data collection and verification

Today, more and more HCAs are operated in radio mode. In such a case, almost every floor has a HCA data receiver as the distance between the received and the individual HCA should be short, not longer than 20 m. The receivers save and send the data to the master collectors, that save the collected data and send by GPRS to the billing company's computer centre. Thus, the invoicing can be carried out without visiting the apartment and even the building at all.

In the computer centers there is data verification, and based on that, the suspicious data will be indicated for checking. The data will be verified based on the historical and similar other apartments.