Deliverable 2.1

Report for examining the economic feasibility and technical suitability for installing individual consumption meters in multi-apartment and multi-purpose buildings

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Acknowledgments & Disclaimer

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EED	Energy Efficiency Directive
MECIT	Ministry of Energy, Commerce, Industry and Tourisms
CBA	Cost Benefit Analysis
DHW	Domestic Hot Water
EU	European Union
HCA	Heat Cost Allocators
HDD	Heating Degree Days
HM	Heat Meters
CA	Consumption-based cost allocations
CA +CI	Consumption-based cost allocations and consumption information services combined

1. Introduction

1.1 Background

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been commissioned by the German Federal Ministry of Economics and Technology (BMWi) with financing provided mainly from the European Commission Structural Reform Support Services under Contract No. SRSS/S2016/S002 to implement the project "Technical assistance for energy efficiency and sustainable transport in Cyprus". As part of this project support is provided to the Ministry of Energy, Commerce, Industry and Tourisms (MECIT) in order to conduct a study for examining the economic feasibility and technical suitability for installing individual consumption meters in multi-apartment and multi-purpose buildings.

The Energy Efficiency Directive (EED, 27/2012/EU) sets up a holistic framework towards the minimization of energy consumption by focusing on multiple target groups. It establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of its 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date.

It lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of indicative national energy efficiency targets for 2020.

Chapter II of the EED sets the provisions for the efficiency in energy use. Among this set of provisions, Articles 9 – 11 cover issues regarding metering and billing of individual consumption of energy.

Specifically paragraph 1 of Article 9 states that Member States shall ensure that all final customers for electricity, natural gas, district heating, district cooling and domestic hot water are provided with competitively priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use with the condition that the installation of these systems is technically possible, financially reasonable and proportionate in relation to the potential energy savings.

Such a competitively priced individual meter shall always be provided when:

a. an existing meter is replaced, unless this is technically impossible or not cost-effective in relation to the estimated potential savings in the long term;
b. a new connection is made in a new building or a building undergoes major renovations, as set out in Directive 2010/31/EU.

Additionally paragraph 3 of the same Article states that:

"Where heating and cooling or hot water are supplied to a building from a district heating network or from a central source servicing multiple buildings, a heat or hot water meter shall be installed at the heating exchanger or point of delivery.

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.

Where multi-apartment buildings are supplied from district heating or cooling, or where own common heating or cooling systems for such buildings are prevalent, Member States may introduce transparent rules on the allocation of the cost of thermal or hot water consumption in such buildings to ensure transparency and accuracy of accounting for individual consumption. Where appropriate, such rules shall include guidelines on the way to allocate costs for heat and/or hot water that is used as follows:

a. hot water for domestic needs;
b. heat radiated from the building installation and for the purpose of heating the common areas (where staircases and corridors are equipped with radiators);
c. for the purpose of heating apartments."

The general philosophy of this set of Articles is to support the role of the behavioral measures towards energy saving. Specifically as the metering systems do not save energy by their own, it is clear that these provisions of the EED will create the appropriate framework in order to raise the awareness and consequently engage the building users in more energy efficient behavior.

The individual metering systems combined with consumption based cost allocation services or even better with consumption information services can effectively trigger building users to act proactively in order reduce their energy consumption.

1.2 Objective

Following the aforementioned legislative framework, the main objective of this report is to determine whether it is technically feasible and cost-efficient to install 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 to measure the consumption of heating or cooling or hot water for each unit in Cyprus. In case of the use of individual meters is not technically feasible or not cost-efficient, the use of heat cost allocators will be examined as an alternative solution of heat consumption measurement.

1.3 Structure of the report

The present report is divided in eight sections. In chapter 2 the methodological approach is presented according to the specific needs of the study. For the determination of the reference scenario in chapter 4, an analysis of the Cypriot building stock is implemented in chapter 3. With the results from chapter 4 the assessment of the technical feasibility of the measures is assessed in chapter 5 and the examination of the economic feasibility is taking place in chapter 6 through a Cost Benefit Analysis (CBA). The results of the CBA are presented in Annex I (excel tool). Furthermore in chapter 7 a sensitivity analysis for the most crucial assumptions is implemented and finally the conclusions of the report are presented in chapter 8.

2. Methodological approach

According to paragraph 3 of Article 9 of EED the technical feasibility and cost-efficiency assessment of the individual consumption meters' installation should be implemented in all multifamily and multipurpose buildings.

The category of multifamily will include all the buildings with more than one household such as block of flats and duplex houses and the category of multipurpose buildings will refer to buildings which include households and other type of uses such as offices, retail etc.

Based on the principle that no one-size-fits-all solutions exists the most crucial step is the determination of the scope and boundaries of the measure. Thus an extensive analysis of the Cypriot building stock should be the starting point. The specific analysis should describe all the different characteristics that may affect the installation of an individual metering system both from technical and financial point of view. This analysis should conclude to the basic geometric characteristics of each reference building and its heating, cooling and domestic hot water (DHW) production systems. Additionally, it should provide information of the energy consumption for each household per system. Variations in the reference buildings derived from different construction periods as well as from different climatic zones are also mandatory to be taken into account.

Additionally to the building stock analysis, the different alternative scenarios for individual metering systems together with the different available level of services have to be determined and matched.

According to the outcomes of the building stock analysis and the determination of the reference buildings, the next step will be the assessment of the technical feasibility of each alternative scenario, according to the specific needs and characteristics of all the reference buildings. In this step technical constraints that minimize the user's degree of freedom upon the different systems will be taken into account.

Finally the cost effectiveness of each scenario will be evaluated through a Cost Benefit Analysis (CBA). The analysis will take place both from the financial and economic point of view in order to take into account the social and the investor perspective and act as policy making tool for the Cypriot ministry. The CBA will be conducted on the household level both for multifamily and multipurpose buildings. Specifically for the multipurpose buildings the analysis will start form the household and if the outcome will be positive than the cost effectiveness of the measure will be examined for the other use of the building.

The final outcome of the study is the allocation of the different reference buildings together with the different types of measures into two distinguished classes. The exempt one will include all the buildings that the installation of any type of individual metering will be either technically impossible or cost inefficient and the viable which will include the buildings for which the implementation of the measure will be both technical feasible and economic feasible. Even for the buildings in viable class issues such as the payback period of the investment or the number and the type of the buildings which are included in this class are extra aspects which should be evaluated by the policy makers before the determination of the obligated parties. The heat cost allocation of the buildings will be implemented through the establishment of transparent allocation rules. The rules for the first class of buildings will referred only in central systems without individual control in apartment level and in the second, if there will be such class, to buildings with individual control.

The following logical diagram presents the methodological approach that will be followed.

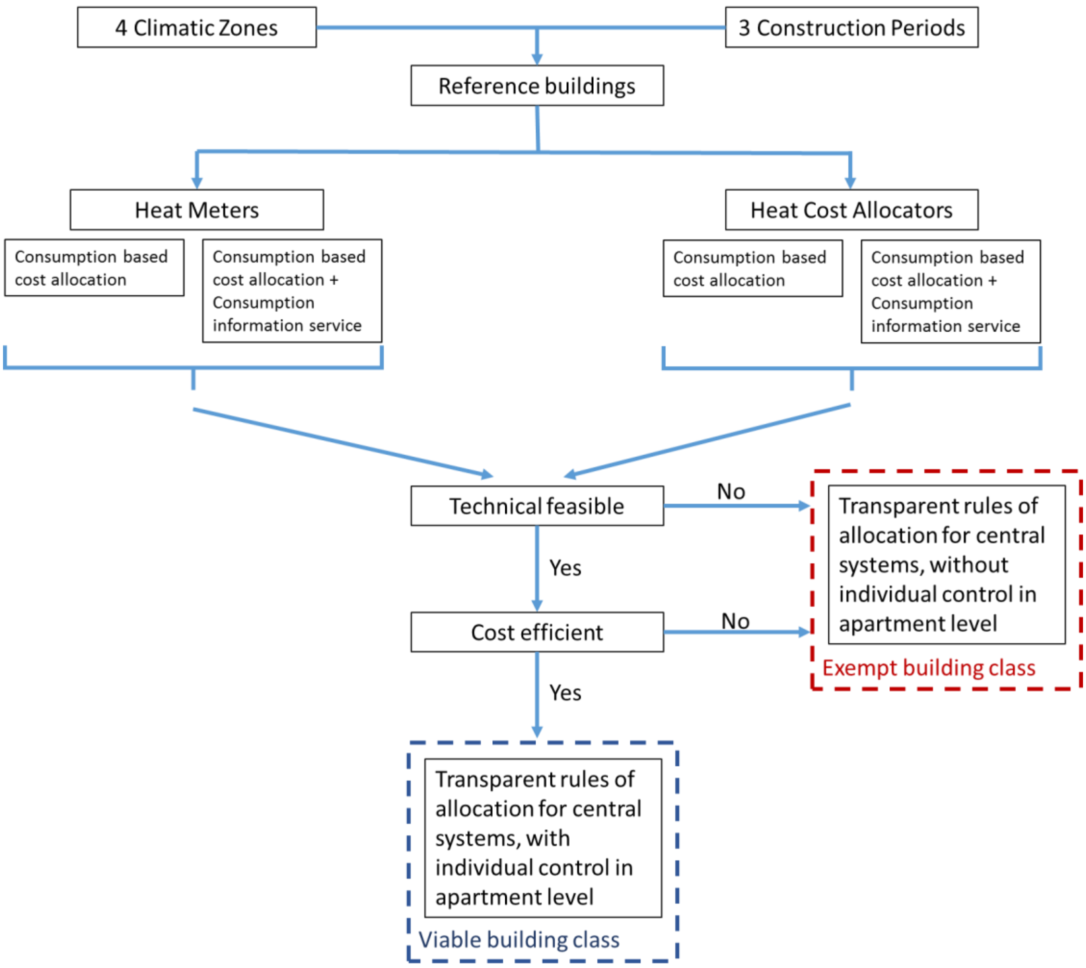


Figure 1: Methodological approach logical diagram

3. Cypriot building stock analysis

The Cypriot building stock can be characterized as quite new as most of the buildings have been constructed after the 80s. The following chart presents the construction period of Cypriot houses.

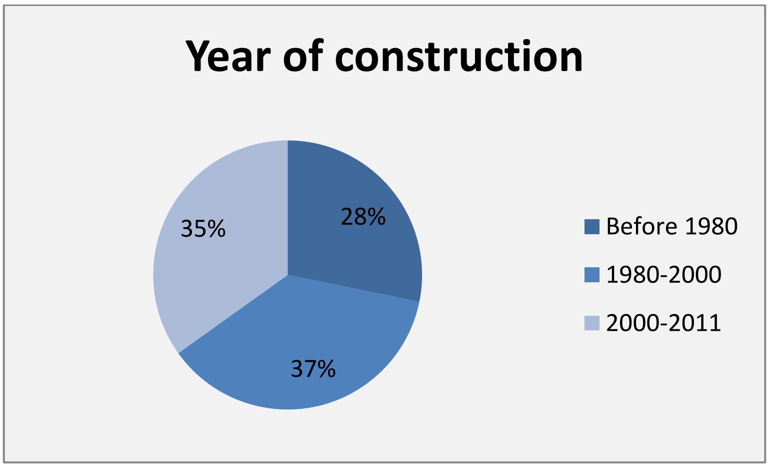


Figure 2: Construction period of Cypriot houses, adapted from Cypriot census of 2011

According to the Cypriot census of 2011 the Cypriot houses are mostly single family houses with the multifamily houses to coming second. The following histogram presents the houses distribution according to their building type. The category of single family houses includes also the row houses and the backyard houses.

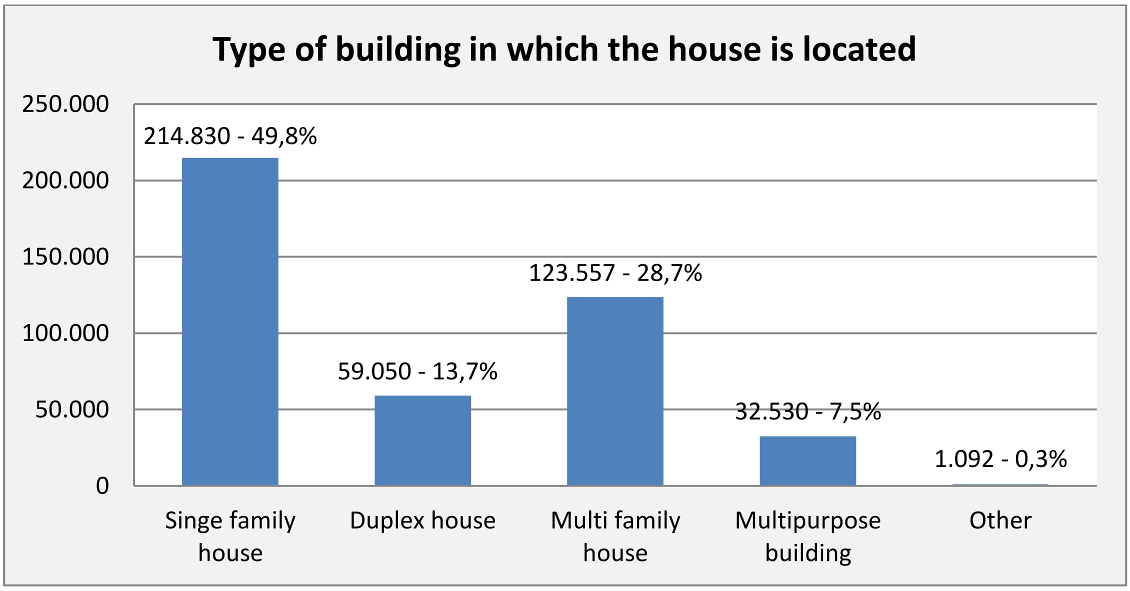


Figure 3: Houses distribution according to building type, adapted from Cypriot census of 2011

The houses which are occupied and used as usual residence by one or more residents vary regarding the different type of building from 33% to 83% for “other” to “duplex house” respectively. The following table presents all the information regarding different occupancy status of each building type.

Table 1: Occupancy status per building type, adapted from Cypriot census of 2011

	Single family house	Duplex house	Multifamily house	Multipurpose building	Other
Occupied and used as usual residence by one or more residents	153 729	48 743	72 072	22 215	363
Vacant house	19 641	4 597	24 254	6 066	93
House reserved for seasonal/secondary use	37 691	5 344	24 729	3 589	589
Used as tourist apartment	2 820	247	2 418	618	43
To be demolished/ Other use	949	119	84	42	4

Furthermore, the following histogram presents the variation of the houses which are occupied and used as usual residence by one or more residents according to the building type.

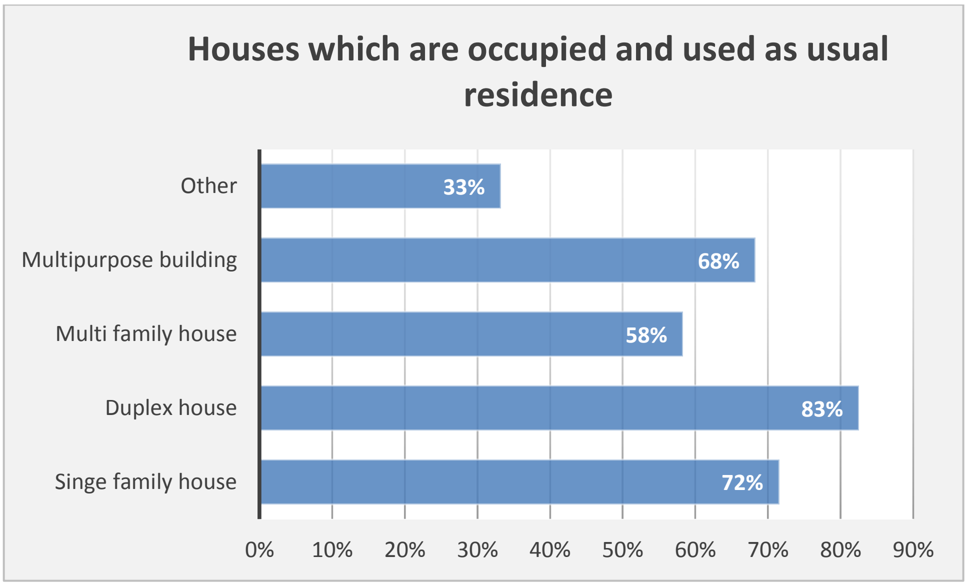


Figure 4: Variation of houses which are occupied and used as usual residence, adapted from Cypriot census of 2011

Cyprus is dived in 4 climatic zones: Coastal area, low land area, semi-mountainous and mountainous, as they are illustrated in the following picture.

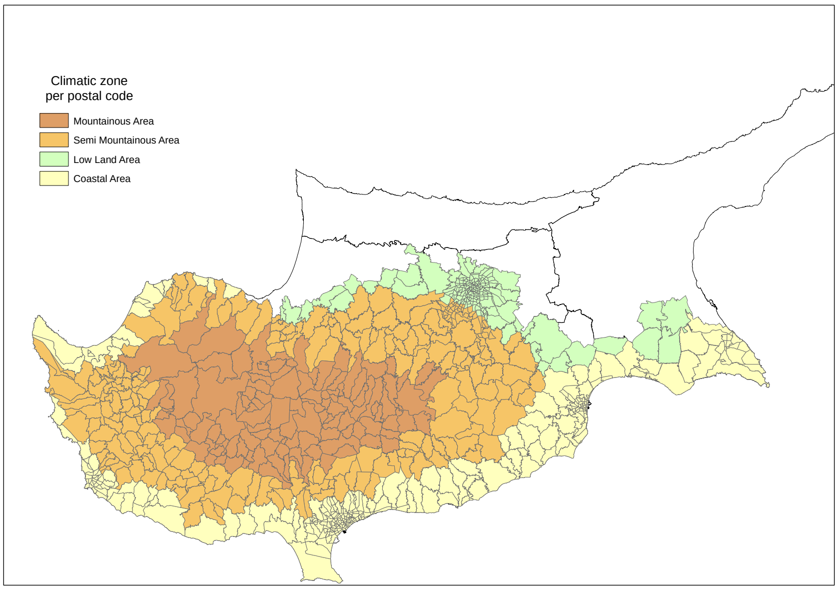


Figure 5: Cypriot climatic zones

The following chart presents the Cypriot building stock allocation in the four different climatic zones.

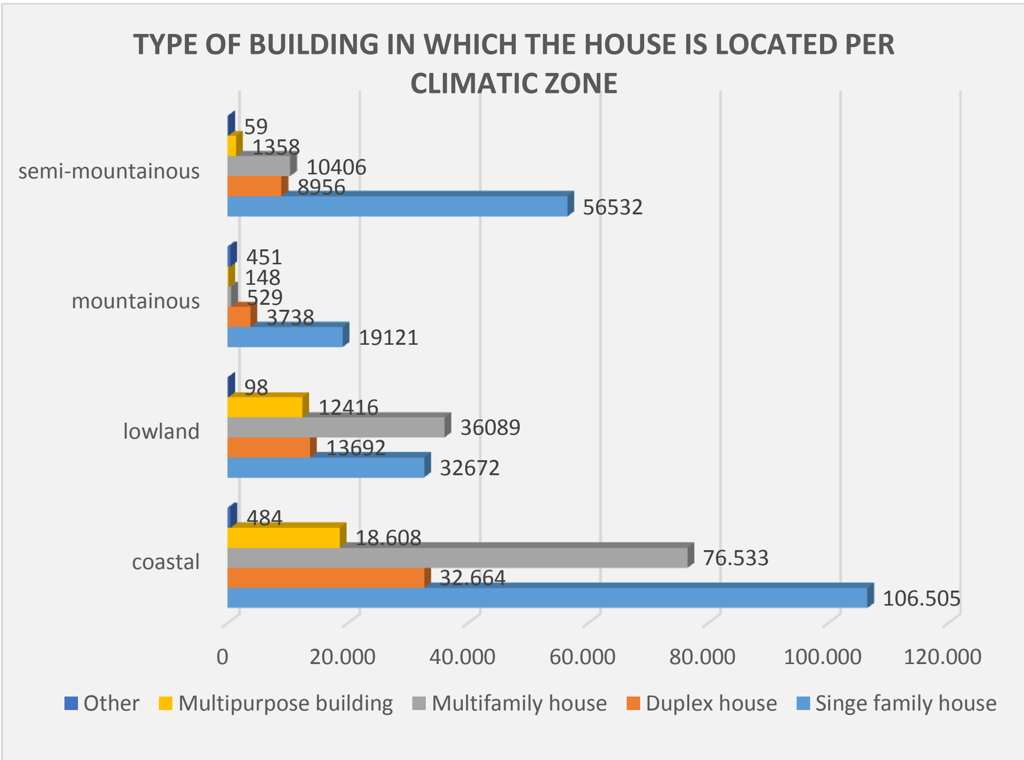


Figure 6: Cypriot building stock allocation in different climatic zones, adapted from Cypriot census of 2011

It is important to notice that in mountainous and semi-mountainous zones the share of multipurpose buildings is quite small, specifically for the mountainous zone is 0.6% and for the semi-mountainous 1.8%.

Furthermore, the following table presents the share of the houses which are empty or used temporarily among the total number of the houses per climatic zone.

Table 2: Share of the empty and temporarily used houses among the total number of the houses per climatic zone

Climatic Zone	Empty and temporarily occupied houses
Coastal	**39.8%**
Lowland	**44.9%**
Semi-mountainous	**41.9%**
Mountainous	**26.9%**

Finally the following table presents the construction period of houses per climatic zone.

Table 3: Construction period of houses per climatic zone

Climatic Zone	Before 1980 (OLD)	1981-2000 (MID)	2001-2011 (NEW)
Coastal	**23.6%**	**38.9%**	**35.6%**
Lowland	**34.1%**	**34.5%**	**28.3%**
Semi-mountainous	**25.5%**	**31.6%**	**40.2%**
Mountainous	**48.0%**	**29.3%**	**22.4%**

According to the Cypriot census of 2009 the majority of the households are using decentralized heating systems such as air heaters or electric heaters and only 29.2% of them are using central systems. Specifically the following table presents the share of multifamily and duplex houses which are using central heating system.

Table 4: Duplex and multifamily households with central heating system

Building type	Households with central heating system
Duplex	**0.38%**
Multifamily	**0.73%**

The following chart summarizes the outcome of the Cypriot census of 2009 in households regarding the main heating systems of the households.

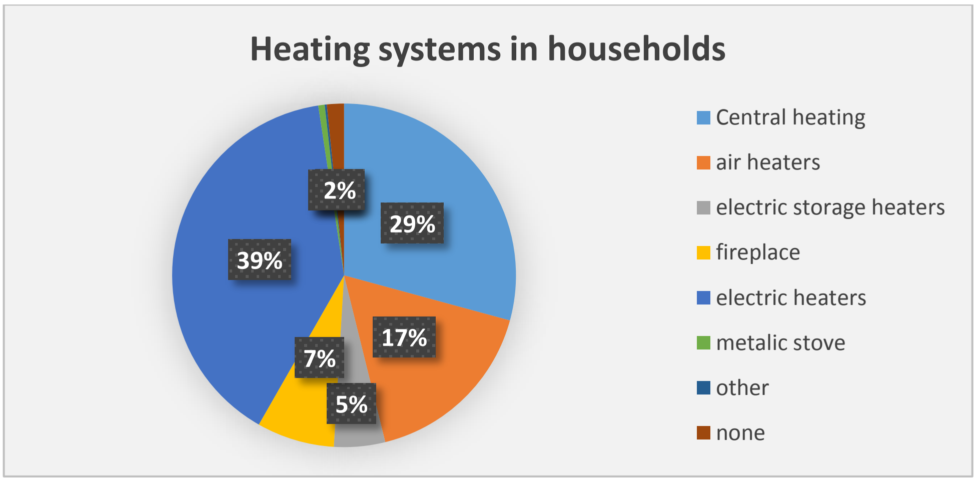


Figure 7: Heating systems in Cypriot households, adapted from Cypriot census in households of 2009

Furthermore the same census reveals that the 80.8% of the Cypriot households are equipped with cooling systems and more specific the absolute majority of them are using as main cooling system air sourced heat pumps (split units).

Finally, the 95.9% of the Cypriot households use solar system with embedded electric resistance as main domestic hot water production system and only 29% of them has also connect it with the central heating. The aforementioned statistics regarding the connected solar systems with the central heating systems can be considered low as the census has been conducted at the household level and not building level (for example one multifamily house can have more than 6 households). Additionally, the energy consumption from the connected central heating systems is very small as the system works as complementary to the solar one.

4. Reference scenario

Following the provisions of EED, the purpose of the study is focused in multifamily, multipurpose and duplex buildings, where the allocation of energy costs per building unit (household, office etc.) can be considered as a crucial parameter for affecting the habits and the final energy consumption of the user.

As has been already described in the methodological approach the assessment of the technical feasibility and the cost efficiency of the alternative individual metering systems should be implemented in unit level as the investment will be undertaken by the owner of each unit. Specifically for the case of multifamily, multipurpose and duplex buildings the assessment will be done at the household level.

Following the methodological approach of chapter 2, one reference building for each type per climatic zone and construction period will be chosen in order to assess the technical feasibility and the cost efficiency of the different individual metering systems for houses. All the reference buildings will be equipped with a central heating system, autonomous cooling units and solar domestic hot water production system. Specifically, it will have a central oil fired boiler as main heating system, air source heat pumps (split units) as main cooling system and a solar system on the roof assisted by an electric resistance.

Thus the assessment of the technical feasibility and the cost efficiency will be focused only in the installation of an individual metering system for heating consumption, excluding the cooling and DHW systems due to their decentralized type.

The efficiency of the heating system (oil fired boiler) will vary according to the construction period. The following table presents the boiler efficiency for each age class.

Table 5: Heating system's efficiency per construction period

Age class	Heating system efficiency
New	0.91
Mid	0.88
Old	0.72

Furthermore, the typical distribution pipe system of the central heating system in Cyprus follow the "two pipes" configuration and the typical emission system consists of high temperature radiators. Thus the chosen reference buildings will also follow the same approach.

According to a preparatory report of the study of "Provision of consulting services for the definition of the Nearly Zero Energy Residential Buildings in Cyprus" which was provided by MECIT, the average floor area as well as the reference useful energy consumption (kWh/m^2a) for each type of dwelling, according to its construction period, are presented in the following table.

Table 6: Floor area and energy consumptions per household in different building categories, source: MECIT

Age Class	Dwellings in Building type	Average Floor area (m^2)	Space Heating (kWh/m^2a)	Space Cooling (kWh/m^2a)	Water Heating (kWh/m^2a)	Lighting & Devices (kWh/m^2a)	Cooking (kWh/m^2a)
NEW	Single house	140	36	48	15	20	4
	Duplex house	100	36	43	15	21	4
	Row houses	95	46	28	15	19	5
	Back-yard house	15	0	0	0	10	0
	Multifamily houses	70	40	76	15	19	4
	Multipurpose building	90	30	76	15	19	4
	Other type of building	80	0	0	0	10	0
MID	Single house	110	40	54	18	22	4
	Duplex house	100	40	48	18	23	4
	Row houses	82	51	34	18	21	6
	Back-yard house	15	0	0	0	11	0
	Multifamily houses	80	55	84	18	21	4
	Multipurpose building	85	33	84	18	21	4
	Other type of building	80	0	0	0	11	0
OLD	Single house	100	54	72	23	28	6
	Duplex house	100	54	65	23	30	6
	Row houses	75	69	42	23	27	8
	Back-yard house	15	0	0	0	12	0
	Multifamily houses	70	75	105	23	27	6
	Multipurpose building	82	45	105	23	27	6
	Other type	80	0	0	0	12	0

According to a preparatory report of the study of the comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling which was conducted by JRC, MECIT proposed the following multiplying factors for the adjustment of the space heating consumption to the different climatic zones

Table 7: Multiplied factor for space heating per climatic zone, source: MECIT

Climatic Zone	Multiplied factor for space heating
Coastal	1.0
Low Land	1.0
Semi mountainous	1.2
Mountainous	3.0

Applying the above multiplied factors the buildings' characteristics of table 5, the final reference buildings' characteristics for each building type which will be used for this study are presented in the following table.

Table 8: Floor area and useful heating energy consumption of household of multifamily reference buildings per climatic zone

	Age Class	Average Floor area per household (m^2)	Space Heating (kWh/m^2a)
coastal	**new**	70	40
	mid	80	55
	old	70	75
lowland	**new**	70	40
	mid	80	55
	old	70	75
mountainous	**new**	70	120
	mid	80	165
	old	70	225
semi-mountainous	**new**	70	48
	mid	80	66
	old	70	90

Table 9: Floor area and useful heating energy consumption of household of duplex reference buildings per climatic zone

	Age Class	Average Floor area per household (m^2)	Space Heating (kWh/m^2a)
coastal	**new**	100	36
	mid	100	40
	old	100	54
lowland	**new**	100	36
	mid	100	40
	old	100	54
mountainous	**new**	100	108
	mid	100	120
	old	100	162
semi-mountainous	**new**	100	43.2
	mid	100	48
	old	100	64.8

Table 10: Floor area and useful heating energy consumption of household of multipurpose reference buildings per climatic zone

	Age Class	Average Floor area per household (m^2)	Space Heating (kWh/m^2a)
coastal	**new**	90	30
	mid	85	33
	old	82	45
lowland	**new**	90	30
	mid	85	33
	old	82	45
mountainous	**new**	90	90
	mid	85	99
	old	82	135
semi-mountainous	**new**	90	36
	mid	85	39.6
	old	82	54

5. Technical feasibility

The technical feasibility of an installation of any individual metering system affected basically from the type of the system that has to be installed. There are different kinds of individual and sub-metering systems which can be combined with different services levels.

The general philosophy of this set of EED Articles is to support the role of the behavioral measures towards energy saving. Thus we are expecting from any kind of individual metering system to raise the awareness of each user regarding his or her energy consumption aiming to reduce it. The interaction level and the type of the information that will be exchanged between the system and the user can be translated as the service level that assists each system. Systems with higher service levels are expected to affect better the users' habits and consequently produce greater energy savings. Although, if the system does not provide to the user any control level (e.g. thermostatic control per room or per household), even if the meter can be installed form technical point of view, the case has to be considered as non-technically feasible.

Another crucial parameter that can highly affect the technical feasibility of an individual metering system is the type of the distribution pipe system of the central heating system. There are two basic distribution systems' configurations with their variations. The first is the "one pipe" system and the second one the "two pipes" system. The basic difference between these two systems lies in the way of how the radiators are connected to the central distribution pipes of the network. In the case of the "one pipe" system, the radiators are connected in line to each other and in the case of the "two pipes" system, are connected in parallel. In buildings with "one-pipe" system usually there is only one entry of hot water per unit (ownership) and the loops are horizontal. This configuration usually allows the installation both of heat meters and heat cost allocator. In buildings with "tow-pipes" system we can have either one entry per unit, where the situation is the same with the "one pipe" system or multiple distribution columns, with several entry points of hot water per unit (ownership). In this case the installation of heat meters can be considered as non-technically feasible and the only solution is the installation of heat cost allocators combined with thermostatic valves. The picture bellow illustrates a multi apartment building with "two pipes" system and multiple distribution columns.

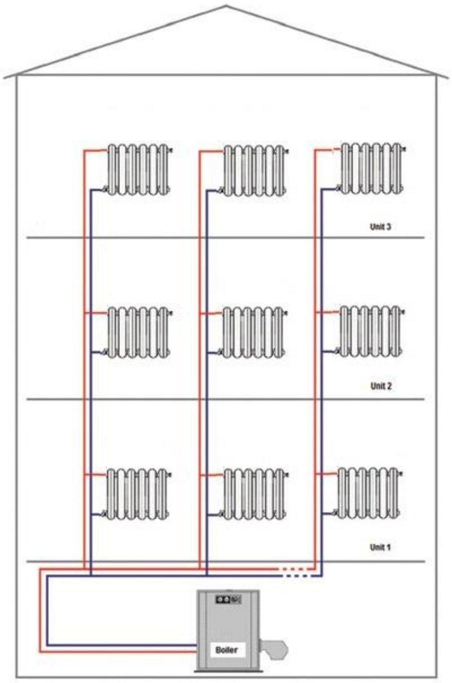


Figure 8: Multi apartment building with "two pipes" system and multiple distribution columns

Additional to the term technical feasible we have also to include the case when an intervention could be feasible but at the same time a very high installation cost is needed. Thus situations where for the installation of an individual metering system, works such demolition of part of a wall or major interventions (e.g. pipe network) are required in order either to create the appropriate space or to separate common pipe networks, should be characterized as too technically complicated to be cost-effective.

According to the characteristics of the reference buildings which was analyzed in the previous chapter, in our case the distribution network follows the "one pipe" configuration and the emission system consists of high temperature radiators.

Additionally, the reference heating system gives no ability to the user to control the system according to his needs neither in radiator level nor in apartment level, as it is a central heating system with one central control of the whole installation.

The central heating system installation of the Cypriot reference building, with multiple ownerships, is illustrated in the following picture.

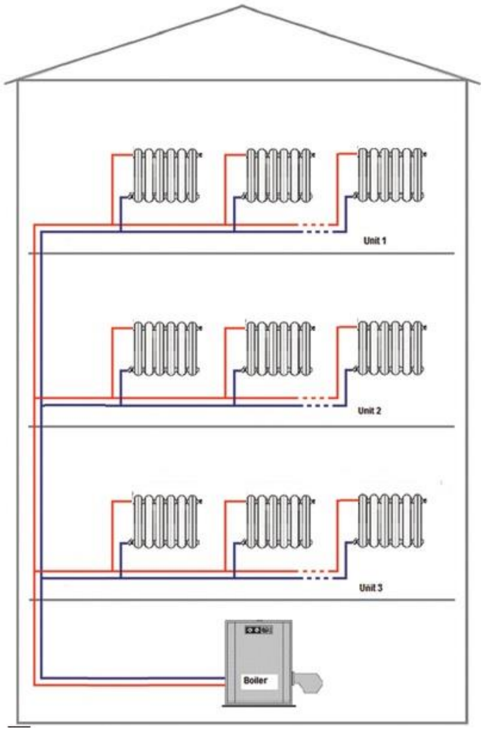


Figure 9: Central heating system installation of reference building with multiple ownerships

The two different individual metering systems that will be examined in this study are the heat meters and the heat cost allocators (HCA). The specific configuration of the installation, without taking into account the technical constrains, theoretically permits the deployment of both solutions. The two pictures below illustrate the two different individual metering systems installed in the reference building's central heating installation.

Figure 10: a) Reference buildings' central heating system with heat meters, b) Reference buildings' central heating system with heat cost allocators

For both cases the installation of thermostatic valves to each radiator together with a differential pressure valve to the main distribution columns is mandatory[1] in order firstly to give the ability to the user to control his heating system and secondly to balance the pressure of the installation.

Following the methodological approach as was described in the logical diagram of chapter 3, for the cases where at least one of the technical constrains exist, the building has to be categorized directly to the exempt building class.

[1] The use of a thermostatic control at apartment level could be also considered as an acceptable alternative but this scenario will not be examined as the potential energy saving of it is very small.

6. Cost efficiency

The cost efficiency of the installation of individual meters in multipurpose and multifamily and duplex houses will be evaluated in terms of a cost benefit analysis of the intervention.

The analysis will be based both in financial and economic perspective in order to provide to the ministry the full picture of the potential benefits of each measure and support the decision making process of the policy makers by providing grants or imposing taxes on the homeowners. The economic approach will reveal the potential benefit from the social point of view and the financial one the potential benefits for the homeowners.

The European standard EN 15459 is explicitly quoted in the EU Guidance note on EED (European Commission, 2013) as an applicable methodology for the economic assessment of the efficiency of individual metering and sub-metering systems in buildings. In fact, the above-mentioned standard can be used, even partially, for the evaluation of the economic feasibility of energy saving choices in buildings and for the comparison of different options of energy saving in buildings.

6.1 Cost categories and benefits

The basic cost categories that will be taken into account in the calculations are:

The **initial investment cost (capital cost)** which includes all the installation and side costs that have to be undertaken in order for the system to be fully operational. Thus this cost category includes the procurement cost and the installation cost.

The **annual cost (energy and operation costs)** will include the energy and the service provider's costs. Specifically this category includes the operation costs for the two different types of services (consumption based cost allocation services and consumption information services) and the energy costs that will be calculated as benefit in terms of avoided cost derived for the energy savings.

Additionally, for the financial perspective the costs which derive from **taxes** will be taken into account as the total costs has to be referred to the real cost that will be paid by the user of the building.

Finally, for the economic perspective the **externalities** or impacts on society welfare will be included in the analysis. These will not be taken into account in the financial analysis as they do not generate a real cash flow for investors. In the context of the cost benefit analysis (CBA), the main externalities to be considered are derived from the environmental and health impact associated with the combustion of fuels. The environmental externalities will be inserted in the calculations as benefits derived from the energy savings.

6.2 Calculation of total global cost

The different types of costs (initial investment costs, annual costs and energy costs) as well as the residual value are converted to global cost by applying the appropriate present value factor or discount rate in order to be referred to year 0 (2017).

The total global cost is determined by summing up the global costs of initial investment costs, operational costs, running costs and energy costs and subtracting global cost of the residual value.

Calculation of global costs may be performed by a component approach, considering the annual costs (referred to the starting year, 2017) for every year i, the disposal costs and the residual value for every component j. Thus the equation for the total global cost for the economic perspective is given below:

$$CG = CO_{INIT} + \sum_{j} \left[\sum_{i=1}^{TC} \left(CO_{a(i)}(j) * \left(1 + RAT_{XX(i)}(j)\right) + CO_{ext(i)}(j) \right) * D_{f(i)} + CO_{finaldisposal(TLS)}(j) - VAL_{fin(TC)}(j) \right]$$

Where:

CG	global costs referred to starting year of 2017
CO_{INIT}	initial investment costs referred to starting year of 2017
$CO_{a(i)}(j)$	annual cost for year i for component j which includes all the aforementioned costs
$RAT_{XX(i)}(j)$	price development for year i for component j
$CO_{ext(i)}(j)$	externalities for measure j during year i;
$D_{f(i)}$	discount factor for year i, which is given by the equation $D_{f(i)} = \left(\frac{1}{1+p}\right)^{i}$, where p is the real discount rate

$CO_{finaldisposal(TLS)}(j)$ final (disposal) cost for decommissioning, deconstruction and disposal in last year of lifecycle TLS of component j (referred to starting year T0)

$VAL_{fin(TC)}(j)$ residual value of component j in year TC at the end of the calculation period (referred to starting year T0)

For the calculation of the total global cost for the financial perspective the same equation will be applied without taking into account the externalities and by considering all the taxes in the different cost categories.

Thus the equation for the calculation of the total global cost for the financial perspective is provided below:

$$CG = CO_{INIT} + \sum_{j} \left[\sum_{i=1}^{TC} \left(CO_{a(i)}(j) * \left(1 + RAT_{XX(i)}(j) \right) \right) * D_{f(i)} + CO_{finaldisposal(TLS)}(j) - VAL_{fin(TC)}(j) \right]$$

Where:

CG global costs referred to starting year of 2017

CO_{INIT} initial investment costs referred to starting year of 2017

$CO_{a(i)}(j)$ annual cost for year i for component j which includes all the aforementioned costs

$RAT_{XX(i)}(j)$ price development for year i for component j

$D_{f(i)}$ discount factor for year i, which is given by the equation $D_{f(i)} = \left(\frac{1}{1+p}\right)^{i}$, where p is the real discount rate

$CO_{finaldisposal(TLS)}(j)$ final (disposal) cost for decommissioning, deconstruction and disposal in last year of lifecycle TLS of component j (referred to starting year T0)

$VAL_{fin(TC)}(j)$ residual value of component j in year TC at the end of the calculation period (referred to starting year T0)

For the calculation of the Present Value Factor (PVF) the following equation will be used:

$$PVF_{f(i)} = \frac{1-(1+p)^{-i}}{p}$$

Where,

p: the real discount rate

i: year

Both in financial and economic perspectives the energy costs will be inserted into the CBA in the side of the benefits as savings that will be achieved from the implementation of the measure. Respectively, the externalities will be also calculated as benefits in the economic perspective.

6.3 Calculation assumptions

Additionally to the assumptions that have already been described in the above chapter regarding the reference building, information regarding the cost categories, the potential savings of each service as well as additional input regarding the calculation of the total global cost, is presented below.

The determination of the capital and operation costs of the two different types of individual metering systems (heat meters and heat cost allocators) have been based in market analysis in Cyprus and also in Greece, for the products and services which are not available in the Cypriot market, as Greece is the Member State with the most similar market conditions to the Cypriot across EU. Thus the following table presents all the capital and operation costs regarding the heat meters and heat cost allocators combined with the two different type of services a) consumption based cost allocation services and b) consumption based cost allocation services with consumption information services.

Table 11: Capital and operation costs of individual meter systems and services

		Capital costs (euro)			Operation costs (euro)		
System	Service level	per radiator[2]	per meter/ building unit	per building[3]	per radiator	per meter/ building unit	per building
Heat Cost Allocators (HCA)	Consumption-based cost allocation (CA)	65	0	240	0	50	0
Heat Meters (HM)		40	280	240	0	50	0
Heat Cost Allocators (HCA)	Consumption-based cost allocations and consumption information services combined (CA +CI)	80	0	365	0	75	0
Heat Meters (HM)		40	340	365	0	75	0

For the cost allocation in apartment level a typical number of 6 different properties per building will be taken as an assumption.

The benefits from the energy savings will be calculated taking into account the cost of the light fuel oil as well as the development of its price. The following table presents the expected light fuel oil prices development from 2017 to 2026[4].

Table 12: Expected price development for light fuel oil

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Light fuel oil (euro/kWh)	0.080	0.080	0.080	0.081	0.081	0.081	0.081	0.081	0.081	0.082

The source of information used to obtain environmental damage factors per unit of energy produced for different heat and electricity technologies is the report on Cost Benefit Analysis for the potential of high-efficiency cogeneration in Cyprus, which is based on the report on 'Subsidies and costs of EU energy' (Alberici et al., 2014). This report provides environmental damage factors that were estimated considering the Life cycle emission data[5] and considering the following environmental impact categories: Climate change; ozone depletion; terrestrial acidification; freshwater

[2] This cost includes the purchase cost of the HCA, the thermostatic valve and the installation of them for the case of HCA and for the case of Heat meters only the cost of purchase and installation of thermostatic valves

[3] This costs includes also the purchase cost of the differential pressure valve and the installation of it

[4] 2016, Report on Cost Benefit Analysis for the potential of high-efficiency cogeneration in Cyprus.

[5] Life cycle emission data were provided by Ecoinvent database

eutrophication; marine eutrophication; human toxicity; photochemical oxidant formation; particulate matter formation; terrestrial ecotoxicity; freshwater ecotoxicity; marine ecotoxicity; ionising radiation; agricultural land occupation; urban land occupation; natural land transformation; water depletion; metal depletion and depletion of energy resources.

The damage factor that will be used for boiler with light fuel oil is 32euro/MWh.

The interest rate both for the financial and economic perspective provided by MECIT and will be 8% for the financial calculations and 3% for the economic ones.

The accounting period will be equal to the life time of the meters. According to EN 15459-1 the lifespan of the meters is 10 years. Thus as the lifespan of the system is equal to the accounting period no residual value will be included in the calculation.

The residual value of the different metering systems will not be taken into account as the cost can be considered insignificant and it is very difficult to be determined for such small installation's components.

Several studies have been implemented and can provide estimations of energy savings in different building typologies across several European countries from the use of different metering systems and technologies. The table below presents the energy saving potential of a list of international studies[6].

Table 13: Energy saving potential from international studies, source: The association for Energy Cost Allocation

Country	Authors	Title	Savings' potential
Germany	Loga, T.; Großklos, M.; Knissel, J.	Der Einfluss des Gebäudestandards und des Nutzerverhaltens auf die Heizkosten – Konsequenzen für die verbrauchsabhängige Heizkostenabrechnung. IWU Darmstadt, 2003	Existing buildings: 20 %, low energy houses: 30 – 40 %
		Lohnt in Niedrigenergiehäusern die verbrauchsabhängige Heizkostenabrechnung? HLH vol. 56 (2005) No. 7 – July	
	Kuppler, F.; Minol Messtechnik	Erste Heizkostenabrechnung nach Verbrauch in Chemnitz. Sonderausgabe des Heizungsjournals; 3. NT-Sonderausgabe, 1991	On average 20 %
	Schiller, S.	Versuchsergebnisse mit Wärmemessern (Heizkostenverteilern) bei Zentralheizungen. HR, 12/1956	On average 23 %
	Raiß, W.	Einsparung an Heizenergie durch wärmedichtes Bauen und Wärmeverbrauchsmessung. HLH 15, 12/1964	15 %

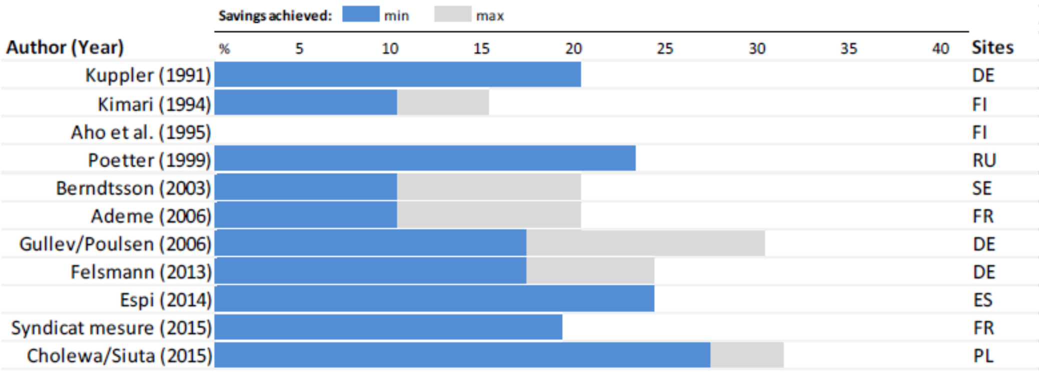
[6] The association for Energy Cost Allocation - Saving potentials energy cost allocation, available international studies

Country	Authors	Title	Savings' potential
	Kolar, J.	Fernwärme und End-Energie in Nürnberg. FWI, Issue 2/1978	15 – 20 %
	Jacobi, E.	Vertretbare und erreichbare Heizungsbetriebskosten im Wohnungsbau. BBauBl, Issue 2/1962	15 – 25 %
	Ackermann, F.; Reckel, G.	Erfahrungen mit einer Verbrauchsvariante der Fernwärmeabrechnung. FWI, Jg. 5, Issue 3/1976	20 %
	Oschatz, B.; Richter, W.	Heizkostenerfassung im Niedrigenergiehaus. On behalf of German Buildings Ministry, Bonn 2004	Simulationen based on 20%, low energy houses: 30 – 36%
	GEWOS	Durchführung der verbrauchsabhängigen Heizkostenabrechnung und ihre Auswirkung auf den Energieverbrauch – Endbericht. Hamburg 4/1986	average 13 %
	Raschper, N.	Energieeinsparpotenziale bei Bestandsgebäuden – Teil 1: Zwischen Bedarfsberechnung und Verbrauchswerten. Die Wohnungswirtschaft, 08/2010	25 – 30 %
		Energieeinsparpotenziale bei Bestandsgebäuden – Teil 2: Warum Verbrauchswerte und Bedarfsberechnungen voneinander abweichen. Die Wohnungswirtschaft, 11/2010	
	Felsmann, C. Schmidt, J.	Auswirkungen der verbrauchsabhängigen Abrechnung in Abhängigkeit von der energetischen Gebäudequalität, TU Dresden 2013	20% in existing buildings < 30% in new buildings
	Stumpf, M.	Verhaltensänderungen und organisatorisch-technische Optimierungen ein starkes Team bei der Energieeinsparung. Erfahrungen und Erkenntnisse aus psychologischen Studien zum Energienutzungsverhalten an Hochschulen. Januar 2014, Universität Freiburg, Doctoral Thesis	9 % heating 36 % electricity (saving because of change in consumer behaviour)
	Peruzzo, G.	Heizkostenabrechnung nach Verbrauch. Kommentar zur Verordnung über die verbrauchsabhängige Abrechnung der Heiz- und Warmwasserkosten. Kommentar und Anleitung für die Praxis. 5., grundlegend überarb. und wesentl. erw. Aufl., Luchterhand Verlag GmbH, Neuwied, Kriftel, Berlin, 09/1996	15 %
Switzerland	Goepfert, J.; Forster, R.	Herstellungs- und Betriebskosten sowie Art der Betriebskostenabrechnung von Zentralheizungen größerer Wohnblöcke und geschlossener Siedlungsgebiete. Sanitäre Technik, No. 2/1962	25 – 40 %
Sweden	Adamson, B.; Reijner, E.	Wärmeverteilungszählung in Wohnhäusern. Gesundheits-Ingenieur, Issue 1/1958	10 – 25 % (heating) 40 – 50 % (hot water)

Country	Authors	Title	Savings' potential
Denmark	Gullev, L.; Poulsen, M.	The installation of meters leads to permanent changes in consumer behavior. News from DBDH, 3/2006	15 – 17 %, Maximum 30 %
France, Italy, Poland, Sweden	Felsmann, C. Schmidt J. Mroz, T.	Effects of Consumption-Based Billing Depending on the Energy Qualities of Buildings in the EU, Potential assessment for member states. TU Dresden, University of Poznan 12/2015	20% in existing buildings
Norway, Finland	Gölz, S.	Energiesparen im Haushalt durch Feedback des eigenen Verbrauchs. Workshop - Folien, Fraunhofer ISE, 12/2009	5 – 10 % (electricity) 13 % (total energy consumption)
Scandinavia, NL, UK, Japan	Darby, S.	The effectiveness of feedback on energy consumption - a review for defra of the literature on metering, billing and direct displays. Environmental Change Institute, University of Oxford, 4/2006	3 – 20 %
France	ADEME: Huze, M.-H.; Cyssau, R.	Maitrise de la demande d'énergie par les services d'individualisation du chauffage. Rapport final, 09/2006	10-20 %
		Maitrise de la demande d'energie par les services d'individualisation du chauffage collectif. Paper	
	Syndicat de la mesure	L'individualisation des frais de chauffage à l'épreuve des faits; Étude de l'impact des systems sur les consommations d'énergie en sésidentiel collectif. Rapport final 12/2015	19,8%
Russia	Poetter, K.; Pahl, M.H.	Wasser- und Wärmeeinsparung in russischen Wohnhäusern. Ergebnisse des Dubna Projekts. 03/1999, Euroheat and Power, Jg. 28, S. 29 - 35	23 % heat 55 % hot water
Austria	H. Juri, F. Adunka	Technische und psychosoziale Einflussfaktoren auf den Wärmeverbrauch von Wohngebäuden	15 – 20 %
	Adunka, F.	Grundlagen der Heizkostenverteilung. Manuskript zu einem Vortrag im Haus der Technik, Essen, 2005	10 – 30 %

Additionally the report "Guidelines on good practice in cost-effective cost allocation and billing of individual consumption of heating, cooling and domestic hot water in multi-apartment and multi-purpose buildings", Empirica GmbH, December 2016, presents a list of recent studies on the behavioral impact of consumption-based cost allocation. The outcomes of the studies are presented below.

Table 14: Recent studies on the behavioral impact of consumption-based cost allocation, source: Empirica GmbH, 2016[7]



According to the above studies it is clear that estimations about the saving potential of metering systems are extremely variable and range from 5% to 40%, due to different experimental contexts, which include different automation levels of temperature control, the usage of home displays, the frequency of consumption readings, the type of user and of building and other specific characterizes of each study. Furthermore, existing studies are in most cases referred to central and North Europe climate, which is very different from the Mediterranean one. In Cyprus, no analyses have been conducted in order to estimate the expected benefits from such measure.

The following table presents the relative heating degree days (HDD) of 32 EU countries of the year 2009 as provided by Eurostat.

7 References:

Kuppler, F. (1991) Erste Heizkostenabrechnung nach Verbrauch in Chemnitz, in: Heizungsjournal, 3.NT-Sonderausgabe1991
Kimari, KTM (1994) Huoneistokohtainen lämmitysenergian mittaus ja laskutus. Kauppa- ja teollisuusministeriö. Energiaosasto. Tutkimuksia D:202. 1994.
Aho, T., Rantamäki, J. & Sormunen, T. (1995) Huoneistokohtaisen mittauksen ja laskutuksen vaikutus energian ja veden kulutukseen. VTT Tiedotteita 1644.
Poetter, K.; Pahl, M.H. (1999) Wasser- und Wärmeeinsparung in russischen Wohnhäusern - Ergebnisse des Dubna Projekts, Euroheat&Power - Fernwärme International
Berndtsson, L. (2003) Individuell Värmemätning i Svenska
Ademe (2006) Maîtrise de la demande d'énergie par les services d'individualisation du chauffage
Gullev, L. & Poulsen, M. (2006) The installation of meters leads to permanent changes in consumer behaviour", News from DBDH 3/2006.
Espí, P. (2014) Estudio de la Implantación de Sistemas Repartidores de Coste de Calefacción en Edificios
Syndicat de la mesure (2015) L'individualisation des frais de chauffage à l'épreuve des faits; Étude de l'impact des systems sur les consommations d'énergie en résidentiel collectif. Rapport final 12/2015
Tomasz Cholewa and Alicja Siuta-Olcha (2015) Long term experimental evaluation of the influence of heat cost allocators on energy consumption in a multifamily building. ENERGY AND BUILDINGS 104 (2015) 122&8211;130

Table 15: Relative Heating Degree Days in EU countries, source: Eurostat

Country	HDD	Country	HDD	Country	HDD	Country	HDD
Austria	3301	Estonia	4302	Iceland	4963	Poland	3439
Belgium	2696	Greece	1449	Italy	1829	Portugal	1166
Bulgaria	2403	Spain	1686	Lithuania	3931	Romania	2773
Switzerland	3320	Finland	5596	Luxembourg	2967	Sweden	5291
Cyprus	**600**	France	2340	Latvia	4161	Slovenia	2774
Czech Republic	3327	Croatia	2316	Malta	499	Slovakia	3160
Germany	3063	Hungary	2594	Netherlands	2727	Turkey	2389
Denmark	3235	Ireland	2841	Norway	5448	Ukraine	2990

Thus the specific report, taking into account the aforementioned analysis and the fact that Cyprus is one of the southern EU Member State with very short and mild winter period (HDD: 600), the assumptions for energy saving potential, agreed with MECIT to be based on a conservative approach. Specifically for the case of heat meters (HM) or hear cost allocators (HCA) combined with consumption based cost allocation services (CA), 10% of energy saving potential will be calculated and for the case of heat meters or hear cost allocators combined with consumption based cost allocation with consumption information (CA+CI) services 15%.

6.4 Cost Benefit Analysis (CBA)

According to the aforementioned methodology the results of the CBA for all the different scenarios are presented below. The cases where the investment can be considered even marginally viable are in blue cells.

Additionally all the analytical calculations for all scenarios are included in Annex I.

*Table 16: CBA results for **multifamily** buildings in coastal climatic zone*

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-719.6	0.21	-638.9	0.30	-457.6	0.50	-651.2	0.24	-564.5	0.34	-369.9	0.57
CA - METERS	-874.3	0.18	-793.6	0.26	-612.3	0.43	-781.2	0.21	-694.5	0.30	-499.9	0.49
CA+CI - HCA	-955.5	0.23	-834.5	0.33	-562.4	0.55	-872.6	0.26	-742.7	0.37	-450.7	0.62
CA+CI - METERS	-1074.7	0.21	-953.7	0.30	-681.6	0.50	-972.8	0.24	-842.8	0.34	-550.9	0.57

*Table 17: CBA results for **multifamily** buildings in lowland climatic zone*

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-719.6	0.21	-638.9	0.30	-457.6	0.50	-651.2	0.24	-564.5	0.34	-369.9	0.57
CA - METERS	-874.3	0.18	-793.6	0.26	-612.3	0.43	-781.2	0.21	-694.5	0.30	-499.9	0.49
CA+CI - HCA	-955.5	0.23	-834.5	0.33	-562.4	0.55	-872.6	0.26	-742.7	0.37	-450.7	0.62
CA+CI - METERS	-1074.7	0.21	-953.7	0.30	-681.6	0.50	-972.8	0.24	-842.8	0.34	-550.9	0.57

*Table 18: CBA results for **multifamily** buildings in semi-mountainous climatic zone*

	Semi-mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-681.4	0.25	-584.5	0.36	-366.9	0.60	-610.1	0.29	-506.2	0.41	-272.6	0.68
CA - METERS	-836.1	0.22	-739.2	0.31	-521.6	0.51	-740.1	0.25	-636.2	0.36	-402.6	0.59
CA+CI - HCA	-898.1	0.28	-752.9	0.39	-426.4	0.66	-811.0	0.31	-655.1	0.45	-304.7	0.74
CA+CI - METERS	-1017.3	0.25	-872.0	0.36	-545.6	0.60	-911.2	0.29	-755.2	0.41	-404.9	0.68

*Table 19: CBA results for **multifamil**y buildings in mountainous climatic zone*

	Mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-337.0	0.63	-94.9	0.90	**449.1**	**1.49**	-240.5	0.72	**19.4**	**1.02**	**603.3**	**1.70**
CA - METERS	-491.7	0.54	-249.6	0.77	**294.4**	**1.28**	-370.5	0.62	-110.6	0.89	**473.3**	**1.48**
CA+CI - HCA	-381.6	0.69	-18.4	0.99	**797.6**	**1.64**	-256.6	0.78	**133.2**	**1.11**	**1009.1**	**1.85**
CA+CI - METERS	-500.8	0.63	-137.6	0.90	**678.4**	**1.50**	-356.8	0.72	**33.1**	**1.03**	**909.0**	**1.71**

*Table 20: CBA results for **duplex** buildings in coastal climatic zone*

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-665.0	0.27	-628.3	0.31	-444.6	0.51	-592.5	0.31	-553.2	0.35	-356.0	0.58
CA - METERS	-819.7	0.23	-783.0	0.27	-599.3	0.44	-722.5	0.27	-683.2	0.31	-486.0	0.51
CA+CI - HCA	-873.5	0.30	-818.6	0.34	-543.0	0.56	-784.6	0.34	-725.6	0.39	-429.8	0.64
CA+CI - METERS	-992.7	0.27	-937.8	0.31	-662.2	0.51	-884.8	0.31	-825.8	0.36	-530.0	0.59

*Table 21: CBA results for **duplex** in lowland climatic zone*

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-665.0	0.27	-628.3	0.31	-444.6	0.51	-592.5	0.31	-553.2	0.35	-356.0	0.58
CA - METERS	-819.7	0.23	-783.0	0.27	-599.3	0.44	-722.5	0.27	-683.2	0.31	-486.0	0.51
CA+CI - HCA	-873.5	0.30	-818.6	0.34	-543.0	0.56	-784.6	0.34	-725.6	0.39	-429.8	0.64
CA+CI - METERS	-992.7	0.27	-937.8	0.31	-662.2	0.51	-884.8	0.31	-825.8	0.36	-530.0	0.59

*Table 22: CBA results for **duplex** in semi-mountainous climatic zone*

	Semi-mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-615.8	0.32	-571.8	0.37	-351.4	0.61	-539.7	0.37	-492.5	0.42	-255.9	0.70
CA - METERS	-770.5	0.28	-726.5	0.32	-506.1	0.53	-669.7	0.32	-622.5	0.37	-385.9	0.61
CA+CI - HCA	-799.7	0.36	-733.8	0.41	-403.1	0.68	-705.4	0.40	-634.6	0.46	-279.7	0.76
CA+CI - METERS	-918.9	0.33	-853.0	0.37	-522.3	0.62	-805.6	0.37	-734.8	0.43	-379.9	0.70

*Table 23: CBA results for **duplex** in mountainous climatic zone*

	Mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-173.1	0.81	-63.1	0.93	**488.0**	**1.54**	-64.5	0.92	**53.5**	**1.06**	**645.0**	**1.75**
CA - METERS	-327.8	0.69	-217.8	0.80	**333.3**	**1.31**	-194.5	0.80	-76.5	0.92	**515.0**	**1.52**
CA+CI - HCA	-135.6	0.89	**29.3**	**1.02**	**855.9**	**1.69**	**7.4**	**1.01**	**184.4**	**1.16**	**1071.7**	**1.91**
CA+CI - METERS	-254.8	0.81	-89.9	0.93	**736.7**	**1.54**	-92.7	0.93	**84.3**	**1.07**	**971.5**	**1.76**

*Table 24: CBA results for **multipurpose** buildings in coastal climatic zone*

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-726.5	0.20	-701.1	0.23	-561.2	0.38	-658.5	0.23	-631.3	0.26	-481.1	0.44
CA - METERS	-881.2	0.17	-855.8	0.20	-715.9	0.33	-788.5	0.20	-761.3	0.23	-611.1	0.38
CA+CI - HCA	-965.8	0.22	-927.7	0.25	-717.9	0.42	-883.6	0.25	-842.8	0.29	-617.5	0.48
CA+CI - METERS	-1085.0	0.20	-1046.9	0.23	-837.1	0.39	-983.8	0.23	-942.9	0.26	-717.7	0.44

*Table 25: CBA results for **multipurpose** in lowland climatic zone*

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-726.5	0.20	-701.1	0.23	-561.2	0.38	-658.5	0.23	-631.3	0.26	-481.1	0.44
CA - METERS	-881.2	0.17	-855.8	0.20	-715.9	0.33	-788.5	0.20	-761.3	0.23	-611.1	0.38
CA+CI - HCA	-965.8	0.22	-927.7	0.25	-717.9	0.42	-883.6	0.25	-842.8	0.29	-617.5	0.48
CA+CI - METERS	-1085.0	0.20	-1046.9	0.23	-837.1	0.39	-983.8	0.23	-942.9	0.26	-717.7	0.44

*Table 26: CBA results for **multipurpose** in semi-mountainous climatic zone*

	Semi-mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-689.6	0.24	-659.1	0.28	-491.3	0.46	-618.9	0.28	-586.2	0.32	-406.1	0.53
CA - METERS	-844.3	0.21	-813.8	0.24	-646.0	0.39	-748.9	0.24	-716.2	0.27	-536.1	0.46
CA+CI - HCA	-910.4	0.27	-864.8	0.30	-613.0	0.51	-824.2	0.30	-775.2	0.34	-504.9	0.57
CA+CI - METERS	-1029.6	0.24	-984.0	0.28	-732.2	0.46	-924.4	0.28	-875.4	0.32	-605.1	0.53

*Table 27: CBA results for **multipurpose** in mountainous climatic zone*

	Mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-357.5	0.61	-281.4	0.69	**138.2**	**1.15**	-262.5	0.69	-180.8	0.79	**269.6**	**1.31**
CA - METERS	-512.2	0.52	-436.1	0.59	-16.5	0.98	-392.5	0.60	-310.8	0.68	**139.6**	**1.14**
CA+CI - HCA	-412.3	0.67	-298.2	0.76	**331.3**	**1.27**	-289.6	0.75	-167.1	0.86	**508.6**	**1.43**
CA+CI - METERS	-531.5	0.61	-417.4	0.69	**212.1**	**1.16**	-389.8	0.70	-267.2	0.79	**408.4**	**1.32**

According to the outcomes of the CBA the absolute majority of the buildings constructed after 2000 regardless the climatic zone which are located, can be included in the exempted class as the Benefit / Cost ratio is below zero both from a financial and economic perspective. Only for new duplex houses which are located in mountainous climatic zone the investment in the installation of HCA combined with consumption based cost allocation with consumption information services can be considered as marginally viable from an economic perspective. The B/C ratio is above one (1,01), the investment will be paid back during the tenth year of operation (depreciated pay back periods, DPBP=10.8) and the IRR is 1.22%.

Buildings that have been constructed between 1980 and 2000 can also be included in the exempted class, except from multifamily and duplex which are located in the mountainous climatic zone. For the these multifamily and duplex buildings the installation of a combination of sub metering system and service levels, except from the meters combined with consumption based cost allocation service, can be considered as marginally viable from an economic perspective.

The situation is clearer for the buildings that have been constructed in the period before 1980 and which are located in the mountainous climatic zone. The results of the CBA analysis both from financial and economic perspective show that these buildings should be included in the viable class as all the investments regardless the systems and service level combination can be considered as viable with B/C ratio to range from 1.15 to 1.69 for the financial approach and 1.14 to 1.91 for the economic one. Though, it has to be considered that multipurpose buildings in the mountainous climatic zone – as presented in chapter 3 - constitute only 0.6% of the total building stock. The amount of the multipurpose buildings which have been constructed before 1980 can thus be characterized as negligible for continuing in a second stage of cost efficiency assessment of the second use of the building.

7. Sensitivity Analysis

7.1 Multiunit reference building

Taking into account the high number of different combinations of building types, climatic zones, metering systems and service levels as well as the very small differences of the results among the different building types, a weight centric approach will be followed in order to merge the different building types and conclude to one reference building (multiunit) for the purpose of the sensitivity analysis.

The characteristics of each household of reference building per climatic zone will be determined following a weighted-centric methodology. Thus the final characteristics of each building will be the results of multiplying the share of each multiunit building type (duplex, multifamily and multipurpose) per climatic zone by the characteristics of each buildings type (Table 6). The table below presets the share of duplex, multifamily and multipurpose buildings among all multiunit buildings (excluding single family houses and "other" categories).

Table 28: Multiunit building type allocation per climatic zone

	Duplex house	Multifamily house	Multipurpose building
coastal	25.6%	59.9%	14.6%
lowland	22.0%	58.0%	20.0%
semi-mountainous	43.2%	50.2%	6.6%
mountainous	84.7%	12.0%	3.4%

Following the calculations, the characteristics of each household of reference building per each climatic zone are presented in the table below.

Table 29: Floor area and energy consumptions per household for different climatic zones and construction period

	Age Class	Average Floor area (m^2)	Space Heating (kWh/m^2a)	Space Cooling (kWh/m^2a)	Water Heating (kWh/m^2a)	Lighting & Devices (kWh/m^2a)	Cooking (kWh/m^2a)
coastal	**new**	81	38	68	15	20	4
	mid	86	48	75	18	22	4
	old	79	65	95	23	28	6
lowland	**new**	81	37	69	15	19	4
	mid	85	47	76	18	21	4
	old	79	64	96	23	28	6
s e	**new**	84	38	62	15	20	4

	Age Class	Average Floor area (m^2)	Space Heating (kWh/m^2a)	Space Cooling (kWh/m^2a)	Water Heating (kWh/m^2a)	Lighting & Devices (kWh/m^2a)	Cooking (kWh/m^2a)
	mid	89	47	68	18	22	4
	old	84	64	88	23	28	6
mountainous	new	96	36	48	15	21	4
	mid	97	42	54	18	23	4
	old	96	56	71	23	30	6

Applying the above multiplied factors of Table 7 the buildings' characteristics of Table 29, the final reference buildings' characteristics which will be used for the sensitivity analysis are presented in the following table.

Table 30: Floor area and useful heating energy consumption of household of reference buildings per climatic zone

	Age Class	Average Floor area per household (m^2)	Space Heating (kWh/m^2a)
coastal	new	81	38
	mid	86	48
	old	79	65
lowland	new	81	37
	mid	85	47
	old	79	64
mountainous	new	96	109
	mid	97	125
	old	96	169
semi-mountainous	new	84	45
	mid	89	56
	old	84	77

Applying the cost benefit analysis in the above multiunit reference building proved that this approach is safe as the results are following exactly the same trend with minor changes compared to the results of the chapter 6.4.

The following tables present the outcomes of the CBA which was applied in the new multiunit reference building.

Table 31: CBA results for coastal climatic zone – multiunit reference building

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-700.7	0.23	-636.3	0.30	-456.3	0.50	-630.8	0.26	-561.7	0.34	-368.5	0.57
CA - METERS	-855.4	0.20	-791.0	0.26	-611.0	0.43	-760.8	0.23	-691.7	0.30	-498.5	0.49
CA+CI - HCA	-927.0	0.25	-830.4	0.33	-560.5	0.55	-842.0	0.29	-738.3	0.37	-448.6	0.62
CA+CI - METERS	-1046.0	0.23	-949.4	0.30	-679.5	0.50	-942.0	0.26	-838.3	0.35	-548.6	0.57

Table 32: CBA results for lowland climatic zone– multiunit reference building

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-706.2	0.22	-642.0	0.30	-463.3	0.49	-636.7	0.26	-567.8	0.34	-376.0	0.56
CA - METERS	-860.9	0.19	-796.7	0.25	-618.0	0.42	-766.7	0.22	-697.8	0.29	-506.0	0.49
CA+CI - HCA	-935.3	0.25	-839.0	0.32	-571.0	0.54	-850.9	0.28	-747.5	0.37	-459.9	0.61
CA+CI - METERS	-1054.3	0.23	-958.0	0.30	-690.0	0.49	-950.9	0.26	-847.5	0.34	-559.9	0.56

Table 33: CBA results for semi-mountainous climatic zone– multiunit reference building

	Semi-mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-652.7	0.28	-578.6	0.36	-352.4	0.61	-579.3	0.32	-499.8	0.42	-257.0	0.70
CA - METERS	-807.4	0.24	-733.3	0.31	-507.1	0.52	-709.3	0.28	-629.8	0.36	-387.0	0.61
CA+CI - HCA	-855.1	0.31	-743.9	0.40	-404.7	0.67	-764.8	0.35	-645.5	0.45	-281.4	0.76
CA+CI - METERS	-974.1	0.28	-862.9	0.37	-523.7	0.62	-864.8	0.32	-745.5	0.42	-381.4	0.70

Table 34: CBA results for mountainous climatic zone– multiunit reference building

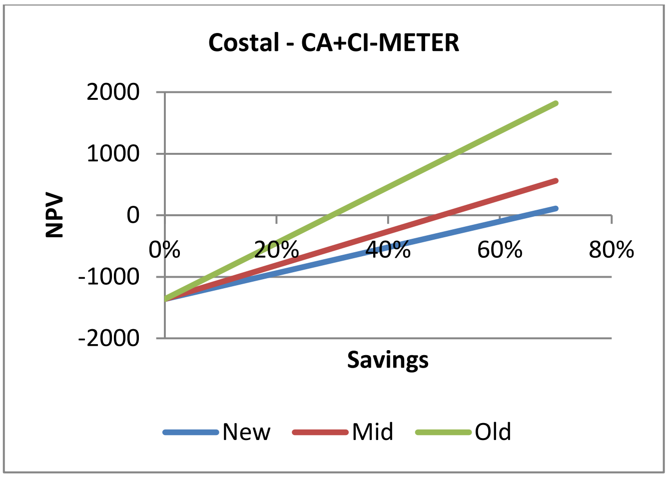
	Mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-196.0	0.78	-63.1	0.93	**490.0**	**1.54**	-89.1	0.90	**53.5**	**1.06**	**647.2**	**1.76**
CA - METERS	-350.7	0.67	-217.8	0.80	**335.3**	**1.31**	-219.1	0.78	-76.5	0.92	**517.2**	**1.52**
CA+CI - HCA	-170.1	0.86	**29.3**	**1.02**	**859.0**	**1.69**	-29.5	0.97	**184.4**	**1.16**	**1075.0**	**1.91**
CA+CI - METERS	-289.1	0.79	-89.7	0.93	**740.0**	**1.54**	-129.5	0.90	**84.4**	**1.07**	**975.0**	**1.76**

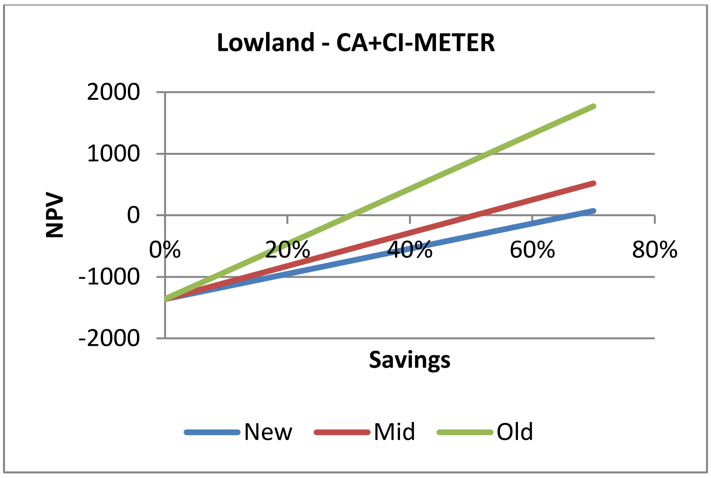
7.2 Sensitivity analysis results

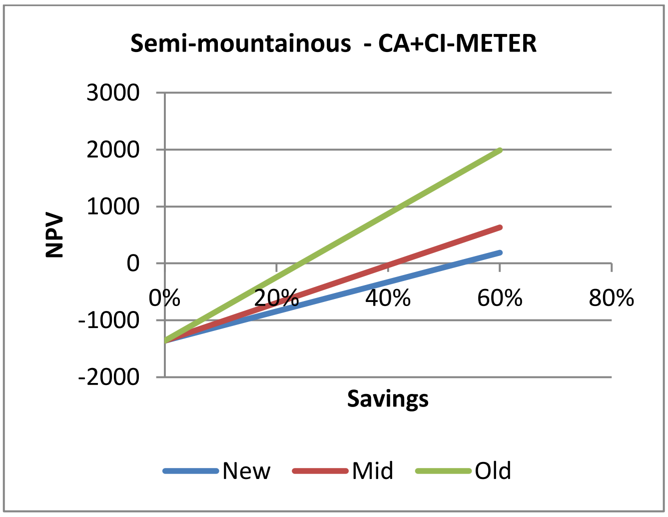
A sensitivity analysis is conducted in order to evaluate the impact of the most critical and uncertain variables to the results. The following four cases have been considered:

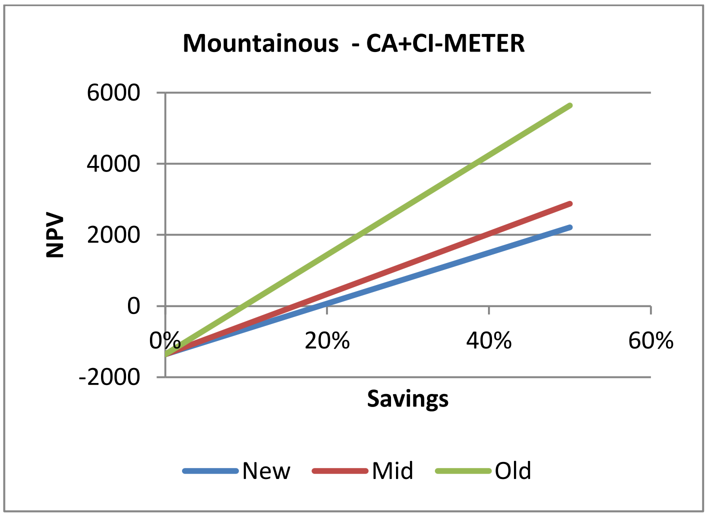
- As the results are very sensitive to the energy saving potential, a sensitivity analysis has been conducted for different levels of energy savings. The analysis conducted only for the financial perspective (user's approach) and for the two metering systems combined with consumption based cost allocation with consumption information services, as between the two available services, this is the one that can achieve the higher energy savings.
- As the capital costs of the different metering systems have been based in market research mostly form other EU countries, a sensitivity analysis has been conducted only for the financial perspective (user's approach), regarding different values of capital costs and keeping the running costs steady for the case of consumption based cost allocation with consumption information services (15% energy savings).
- As the multifamily, the duplex and the multipurpose houses may vary in terms of the total number of different properties (units) that may include; a sensitivity analysis is conducted in order to determine the importance of this parameter in the final class categorization.
- The final case of the sensitivity analysis conducted in order to assess the influence of the interest rate in the final results. Thus two different scenarios have been tested, one with +2% of the interest rate use for the reference scenario both for economic and financial perspective (economic: 5%, financial: 10%) and one for -2% (economic: 1%, financial: 6%)

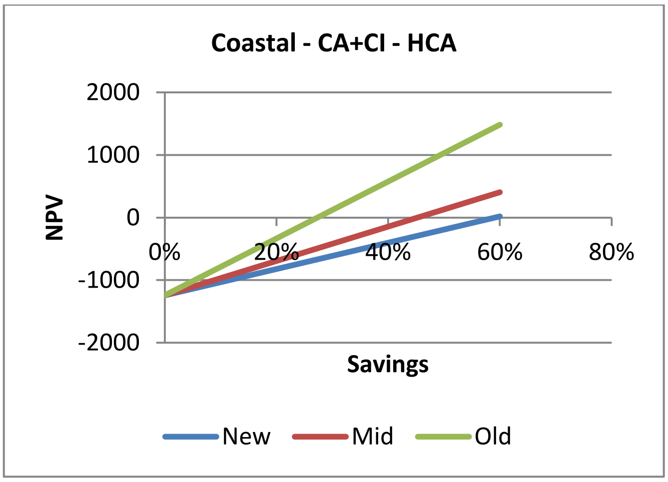
The graphs below present the investment viability limits. Specifically each of one indicates the energy saving potential that is necessary for each measure in order to be viable. The viability threshold is the horizontal axis of the diagram, where the Net Present Value of the cash flow becomes zero.

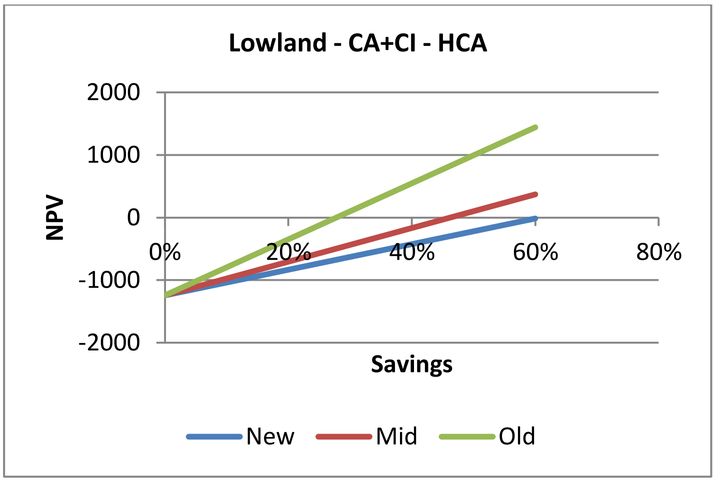

Costal - CA+CI-METER
NPV
2000
1000
0
-1000
-2000
0%
20%
40%
60%
80%
Savings
New
Mid
Old


Lowland - CA+CI-METER
NPV
2000
1000
0
-1000
-2000
0%
20%
40%
60%
80%
Savings
New
Mid
Old


Semi-mountainous - CA+CI-METER
NPV
3000
2000
1000
0
-1000
-2000
0%
20%
40%
60%
80%
Savings
New
Mid
Old


Mountainous - CA+CI-METER
NPV
6000
4000
2000
0
-2000
0%
20%
40%
60%
Savings
New
Mid
Old


Coastal - CA+CI - HCA
NPV
2000
1000
0
-1000
-2000
0%
20%
40%
60%
80%
Savings
New
Mid
Old


Lowland - CA+CI - HCA
NPV
2000
1000
0
-1000
-2000
0%
20%
40%
60%
80%
Savings
New
Mid
Old

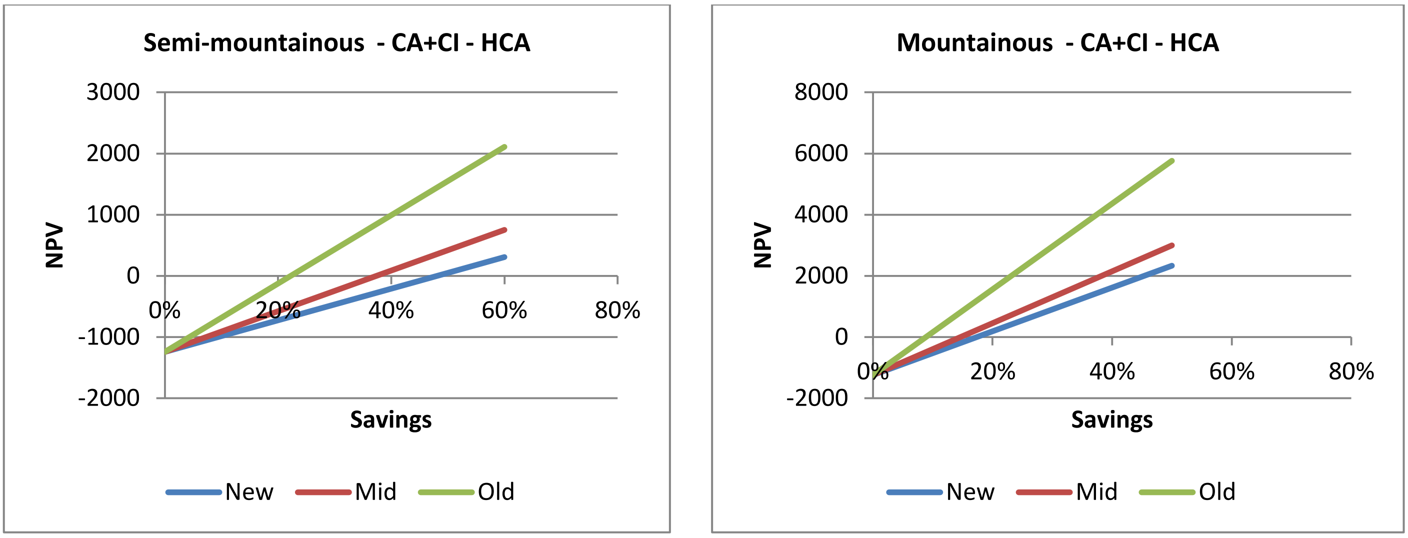


Figure 11: Investment viability limits for different energy saving potentials

The second sensitivity analysis presents the viability limits of the investment among different capital costs. The viability threshold is the horizontal axis of the diagram, where the Net Present Value of the cash flow becomes zero.

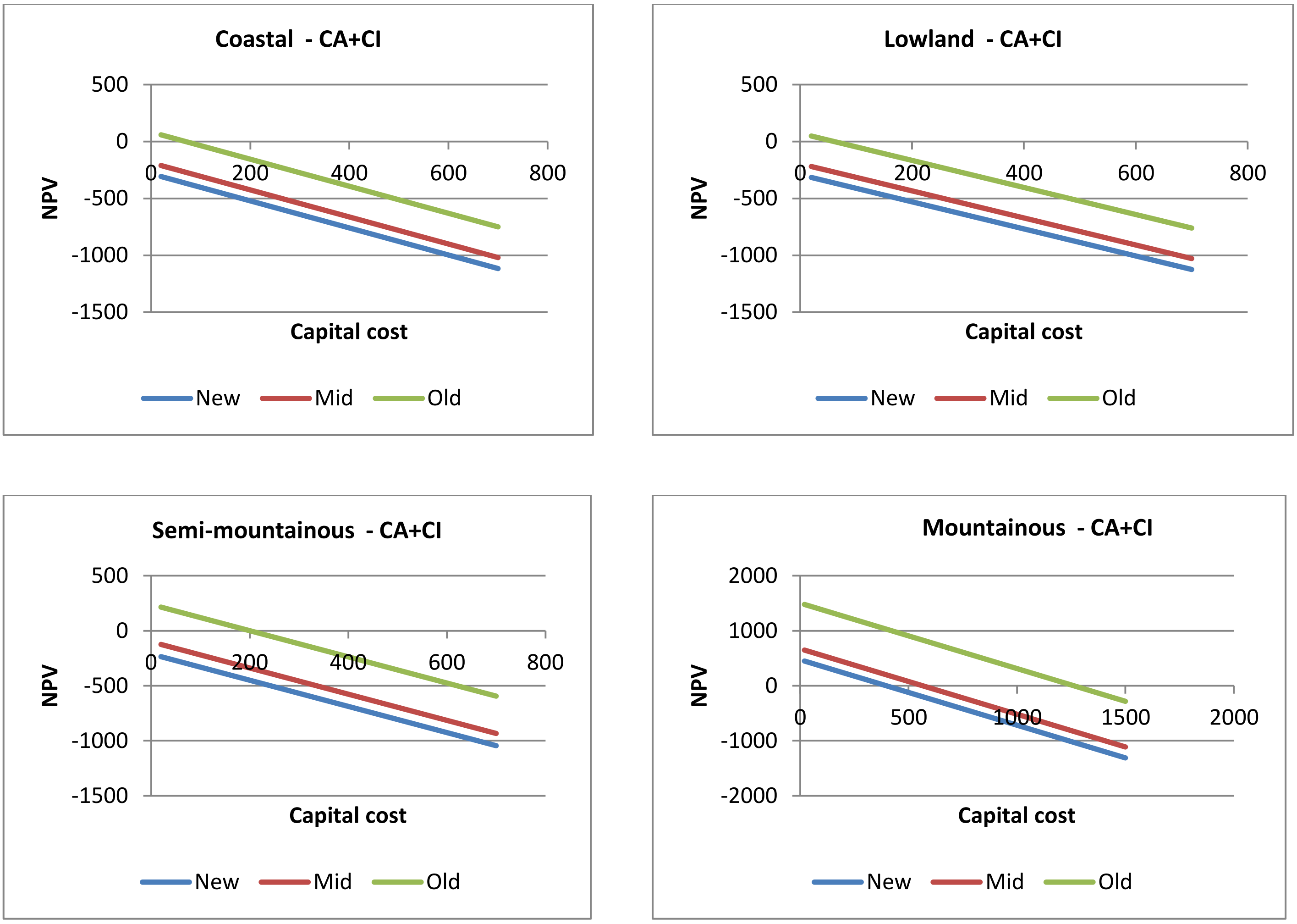


Figure 12: Investment viability limits for different capital costs

The above graphs clearly show that for the buildings which have been constructed after 2000 (new) and between 1980 and 2000 (mid) the capital cost of the investment is not a parameter that may affect the viability of the investment. This fact ensures the result of the CBA that these buildings should be included in the exempted class.

According to the outcomes of the third sensitivity analysis regarding the type of and units in the buildings the results shows that the significance of this parameter can be considered as minor importance. Comparing the results between the reference building which has 6 different properties with one which has 10 properties in total, the categorization of the building stock in viable and exempted classes remains absolutely immutable.

Following the same comparison between the reference building and another one which has 2 different properties this time the results are almost the same in the majority of the building stock. The only difference can be noted for buildings which have been constructed between 1980 and 2000 and are located in the mountainous climatic zone, where some investment scenarios which had been characterized as marginally viable now show a negative NPV and need to be allocated to the exempted class.

The following tables present the results of the two different alternative scenarios with 2 and 10 properties per building, as well as two tables which present the differences between the Benefit/Cost ratio of the reference scenario and the alternative ones.

The cases where the results change the class cauterization due to the different number of building's properties are marked in yellow color in the tables.

Table 35: CBA results for 2 properties' building in coastal climatic zone

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-795.9	0.21	-731.5	0.27	-551.5	0.45	-710.8	0.24	-641.7	0.31	-448.5	0.52
CA - METERS	-950.6	0.18	-886.2	0.24	-706.2	0.39	-840.8	0.21	-771.7	0.28	-578.5	0.46
CA+CI - HCA	-1071.8	0.23	-975.2	0.30	-705.3	0.49	-963.7	0.26	-860.0	0.34	-570.3	0.56
CA+CI - METERS	-1190.8	0.21	-1094.2	0.27	-824.3	0.45	-1063.7	0.24	-960.0	0.32	-670.3	0.52

Table 36: CBA results for 2 properties' building in lowland climatic zone

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-801.4	0.20	-737.2	0.27	-558.5	0.44	-716.7	0.23	-647.8	0.31	-456.0	0.51
CA - METERS	-956.1	0.18	-891.9	0.23	-713.2	0.39	-846.7	0.21	-777.8	0.27	-586.0	0.45
CA+CI - HCA	-1080.1	0.22	-983.8	0.29	-715.8	0.48	-972.6	0.25	-869.2	0.33	-581.5	0.55
CA+CI - METERS	-1199.1	0.20	-1102.8	0.27	-834.8	0.45	-1072.6	0.24	-969.2	0.31	-681.5	0.51

Table 37: CBA results for 2 properties' building in semi-mountainous climatic zone

	Semi-mountainous Climatic Zone											
	Financial Perspective						**Economic Perspective**					
	New		**Mid**		**Old**		**New**		**Mid**		**Old**	
	NPV	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**
CA - HCA	-747.9	0.26	-673.8	0.33	-447.6	0.56	-659.3	0.30	-579.8	0.38	-337.0	0.64
CA - METERS	-902.6	0.22	-828.5	0.29	-602.3	0.48	-789.3	0.26	-709.8	0.33	-467.0	0.56
CA+CI - HCA	-999.9	0.28	-888.7	0.36	-549.5	0.60	-886.5	0.32	-767.2	0.41	-403.0	0.69
CA+CI - METERS	-1118.9	0.26	-1007.7	0.33	-668.5	0.56	-986.5	0.30	-867.2	0.38	-503.0	0.64

Table 38: CBA results for 2 properties' building in mountainous climatic zone

	Mountainous Climatic Zone											
	Financial Perspective						**Economic Perspective**					
	New		**Mid**		**Old**		**New**		**Mid**		**Old**	
	NPV	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**
CA - HCA	-291.22	0.71	-158.33	0.84	**394.82**	**1.39**	-169.14	0.82	**-26.50**	**0.97**	**567.24**	**1.61**
CA - METERS	-445.92	0.62	-313.03	0.73	**240.12**	**1.21**	-299.14	0.72	-156.50	0.85	**437.24**	**1.41**
CA+CI - HCA	-314.86	0.77	**-115.52**	**0.92**	**714.21**	**1.51**	-151.21	0.88	**62.76**	**1.05**	**953.36**	**1.73**
CA+CI - METERS	-433.86	0.71	-234.52	0.84	**595.21**	**1.40**	-251.21	0.82	**-37.24**	**0.97**	**853.36**	**1.61**

Table 39: CBA results for 10 properties' building in coastal climatic zone

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-681.6	0.24	-617.2	0.31	-437.3	0.51	-614.8	0.27	-545.7	0.35	-352.5	0.58
CA - METERS	-836.3	0.20	-771.9	0.26	-592.0	0.43	-744.8	0.23	-675.7	0.30	-482.5	0.50
CA+CI - HCA	-898.1	0.26	-801.5	0.34	-531.5	0.56	-817.7	0.29	-714.0	0.38	-424.3	0.63
CA+CI - METERS	-1017.1	0.24	-920.5	0.31	-650.5	0.51	-917.7	0.27	-814.0	0.35	-524.3	0.58

Table 40: CBA results for ten properties' building in lowland climatic zone

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-687.1	0.23	-622.9	0.30	-444.3	0.50	-620.7	0.26	-551.8	0.34	-360.0	0.57
CA - METERS	-841.8	0.20	-777.6	0.26	-599.0	0.43	-750.7	0.23	-681.8	0.30	-490.0	0.50
CA+CI - HCA	-906.4	0.25	-810.1	0.33	-542.0	0.55	-826.6	0.29	-723.2	0.37	-435.5	0.62
CA+CI - METERS	-1025.4	0.23	-929.1	0.30	-661.0	0.50	-926.6	0.26	-823.2	0.34	-535.5	0.57

Table 41: CBA results for ten properties' building in semi-mountainous climatic zone

	Semi-mountainous Climatic Zone											
	Financial Perspective						**Economic Perspective**					
	New		**Mid**		**Old**		**New**		**Mid**		**Old**	
	NPV	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**
CA - HCA	-633.7	0.29	-559.6	0.37	-333.4	0.63	-563.3	0.33	-483.8	0.42	-241.0	0.71
CA - METERS	-788.4	0.25	-714.3	0.32	-488.1	0.53	-693.3	0.29	-613.8	0.37	-371.0	0.62
CA+CI - HCA	-826.1	0.32	-715.0	0.41	-375.7	0.69	-740.5	0.36	-621.2	0.46	-257.0	0.78
CA+CI - METERS	-945.1	0.29	-834.0	0.37	-494.7	0.63	-840.5	0.33	-721.2	0.43	-357.0	0.72

Table 42: CBA results for ten properties' building in mountainous climatic zone

	Mountainous Climatic Zone											
	Financial Perspective						**Economic Perspective**					
	New		**Mid**		**Old**		**New**		**Mid**		**Old**	
	NPV	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**	**NPV**	**B/C ratio**
CA - HCA	-177.0	0.80	-44.1	0.95	**509.1**	**1.57**	-73.1	0.91	**69.5**	**1.08**	**663.2**	**1.79**
CA - METERS	-331.7	0.68	-198.8	0.81	**354.4**	**1.34**	-203.1	0.79	-60.5	0.94	**533.2**	**1.55**
CA+CI - HCA	-141.1	0.88	**58.2**	**1.05**	**888.0**	**1.73**	-5.2	1.00	**208.8**	**1.18**	**1099.4**	**1.95**
CA+CI - METERS	-260.1	0.80	-60.8	0.95	**769.0**	**1.58**	-105.2	0.92	**108.8**	**1.09**	**999.4**	**1.80**

Table 43: Benefit / Cost ration differences between 10 properties and reference buildings in costal climatic zone

	Coastal Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	2.51%	2.66%	1.95%	3.29%	3.17%	1.86%
CA - METERS	0.47%	0.95%	1.02%	1.12%	1.27%	2.62%
CA+CI - HCA	3.98%	2.89%	2.18%	0.97%	3.38%	2.11%
CA+CI - METERS	2.93%	3.07%	2.36%	3.66%	0.59%	2.22%

Table 44: Benefit / Cost ration differences between 10 properties and reference buildings in lowland climatic zone

	Lowland Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	4.35%	0.52%	2.43%	0.57%	1.02%	2.08%
CA - METERS	2.97%	2.80%	1.84%	2.94%	2.58%	1.04%
CA+CI - HCA	1.24%	3.90%	2.47%	1.83%	1.22%	2.18%
CA+CI - METERS	0.22%	0.93%	2.84%	0.93%	1.39%	2.45%

Table 45: Benefit / Cost ration differences between 10 properties and reference buildings in semi-mountainous climatic zone

	Semi-mountainous Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	3.41%	3.51%	2.66%	3.06%	1.05%	1.89%
CA - METERS	2.82%	2.43%	2.63%	2.01%	2.10%	1.26%
CA+CI - HCA	2.98%	2.70%	3.04%	2.75%	2.84%	2.33%
CA+CI - METERS	3.83%	1.11%	1.41%	3.43%	1.41%	2.26%

Table 46: Benefit / Cost ration differences between 10 properties and reference buildings in mountainous climatic zone

	Mountainous Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	2.77%	2.21%	2.00%	1.44%	2.14%	1.65%
CA - METERS	1.95%	1.26%	2.18%	1.37%	1.92%	1.94%
CA+CI - HCA	2.76%	2.74%	2.47%	2.63%	1.77%	2.14%
CA+CI - METERS	1.87%	2.62%	2.41%	1.81%	1.55%	2.02%

Table 47: Benefit / Cost ration differences between reference and 2 properties buildings in costal climatic zone

	Coastal Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	9.13%	9.00%	9.63%	7.30%	7.40%	8.58%
CA - METERS	9.42%	8.99%	8.92%	7.98%	7.85%	6.62%
CA+CI - HCA	9.04%	9.99%	10.62%	10.35%	8.21%	9.34%
CA+CI - METERS	8.95%	8.82%	9.45%	7.13%	9.89%	8.42%

Table 48: Benefit / Cost ration differences between reference and 2 properties buildings in lowland climatic zone

	Lowland Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	7.50%	10.89%	9.20%	9.74%	9.33%	8.38%
CA - METERS	7.16%	7.32%	8.19%	6.33%	6.66%	8.06%
CA+CI - HCA	11.44%	9.12%	10.36%	9.59%	10.12%	9.27%
CA+CI - METERS	11.34%	10.72%	9.02%	9.58%	9.17%	8.22%

Table 49: Benefit / Cost ration differences between reference and 2 properties buildings in semi-mountainous climatic zone

	Semi-mountainous Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	8.33%	8.25%	9.00%	7.50%	9.31%	8.55%
CA - METERS	7.30%	7.65%	7.47%	7.17%	7.09%	7.85%
CA+CI - HCA	9.92%	10.16%	9.86%	8.77%	8.69%	9.14%
CA+CI - METERS	8.15%	10.55%	10.29%	7.34%	9.15%	8.39%

Table 50: : Benefit / Cost ration differences between reference and 10 properties buildings in mountainous climatic zone

	Mountainous Climatic Zone					
	Financial Perspective			Economic Perspective		
	New	Mid	Old	New	Mid	Old
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
CA - HCA	8.90%	9.39%	9.58%	8.96%	8.33%	8.77%
CA - METERS	8.08%	8.71%	7.87%	7.75%	7.25%	7.24%
CA+CI - HCA	10.11%	10.12%	10.36%	8.88%	9.64%	9.32%
CA+CI - METERS	9.88%	9.21%	9.41%	8.79%	9.02%	8.60%

Finally the third sensitivity analyses regarding the deviation of the interest rate shows that the results of the CBA are not sensitive at all in this parameter. The following tables present the results of the CBA for the different interest rates and the cases where the investment change form viable to unviable or the opposite is marked with yellow color.

Table 51: CBA results for 5% interest rate for economic calculations and 10% for financial in coastal climatic zone

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-682.5	0.22	-622.9	0.29	-456.2	0.48	-609.6	0.25	-546.4	0.33	-369.7	0.55
CA - METERS	-837.2	0.19	-777.6	0.25	-610.9	0.41	-739.6	0.22	-676.4	0.29	-499.7	0.47
CA+CI - HCA	-899.8	0.25	-810.4	0.32	-560.4	0.53	-810.3	0.28	-715.4	0.36	-450.4	0.60
CA+CI - METERS	-1018.8	0.22	-929.4	0.29	-679.4	0.48	-910.3	0.25	-815.4	0.33	-550.4	0.55

Table 52: CBA results for 5% interest rate for economic calculations and 10% for financial in lowland climatic zone

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-687.7	0.22	-628.2	0.28	-462.7	0.47	-615.1	0.25	-552.0	0.32	-376.6	0.54
CA - METERS	-842.4	0.18	-782.9	0.24	-617.4	0.40	-745.1	0.21	-682.0	0.28	-506.6	0.46
CA+CI - HCA	-907.5	0.24	-818.3	0.31	-570.1	0.52	-818.4	0.27	-723.9	0.35	-460.7	0.59
CA+CI - METERS	-1026.5	0.22	-937.3	0.29	-689.1	0.47	-918.4	0.25	-823.9	0.32	-560.7	0.54

Table 53: CBA results for 5% interest rate for economic calculations and 10% for financial in semi-mountainous climatic zone

	Semi-mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-638.10	0.27	-569.49	0.35	-360.00	0.59	-562.53	0.31	-489.80	0.40	-267.74	0.67
CA - METERS	-792.8	0.23	-724.2	0.30	-514.7	0.50	-692.5	0.27	-619.8	0.34	-397.7	0.58
CA+CI - HCA	-833.2	0.30	-730.3	0.39	-416.0	0.65	-739.6	0.34	-630.5	0.44	-297.4	0.73
CA+CI - METERS	-952.2	0.27	-849.3	0.35	-535.0	0.59	-839.6	0.31	-730.5	0.40	-397.4	0.67

Table 54: CBA results for 5% interest rate for economic calculations and 10% for financial in mountainous climatic zone

	Mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-215.1	0.75	-92.1	0.90	**420.3**	**1.48**	-114.2	0.86	**16.3**	**1.02**	**559.4**	**1.69**
CA - METERS	-369.8	0.64	-246.8	0.76	**265.6**	**1.26**	-244.2	0.74	-113.7	0.88	**429.4**	**1.45**
CA+CI - HCA	-198.8	0.83	**-14.1**	**0.99**	**754.4**	**1.63**	-67.1	0.94	**128.6**	**1.11**	**943.2**	**1.84**
CA+CI - METERS	-317.8	0.76	-133.1	0.90	**635.4**	**1.48**	-167.1	0.86	**28.6**	**1.02**	**843.2**	**1.69**

Table 55: CBA results for 1% interest rate for economic calculations and 6% for financial in coastal climatic zone

	Coastal Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-721.5	0.24	-651.6	0.31	-456.4	0.52	-655.4	0.27	-579.4	0.36	-367.1	0.59
CA - METERS	-876.2	0.21	-806.3	0.27	-611.1	0.45	-785.4	0.24	-709.4	0.31	-497.1	0.52
CA+CI - HCA	-958.3	0.26	-853.5	0.34	-560.6	0.57	-879.0	0.30	-765.0	0.39	-446.5	0.64
CA+CI - METERS	-1077.3	0.24	-972.5	0.31	-679.6	0.52	-979.0	0.28	-865.0	0.36	-546.5	0.60

Table 56: CBA results for 1% interest rate for economic calculations and 6% for financial in lowland climatic zone

	Lowland Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-727.5	0.23	-657.8	0.31	-464.0	0.51	-661.9	0.27	-586.2	0.35	-375.3	0.58
CA - METERS	-882.2	0.20	-812.5	0.26	-618.7	0.44	-791.9	0.23	-716.2	0.31	-505.3	0.51
CA+CI - HCA	-967.3	0.26	-862.8	0.34	-572.0	0.56	-888.8	0.29	-775.1	0.38	-458.8	0.63
CA+CI - METERS	-1086.3	0.23	-981.8	0.31	-691.0	0.51	-988.8	0.27	-875.1	0.35	-558.8	0.59

Table 57: CBA results for 1% interest rate for economic calculations and 6% for financial in semi-mountainous climatic zone

	Semi-mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-669.5	0.30	-589.1	0.38	-343.7	0.64	-598.8	0.34	-511.4	0.43	-244.5	0.73
CA - METERS	-824.2	0.25	-743.8	0.33	-498.4	0.55	-728.8	0.29	-641.4	0.38	-374.5	0.64
CA+CI - HCA	-880.2	0.32	-759.7	0.42	-391.6	0.70	-794.1	0.37	-662.9	0.47	-262.6	0.79
CA+CI - METERS	-999.2	0.30	-878.7	0.38	-510.6	0.64	-894.1	0.34	-762.9	0.44	-362.6	0.73

Table 58: CBA results for 1% interest rate for economic calculations and 6% for financial in mountainous climatic zone

	Mountainous Climatic Zone											
	Financial Perspective						Economic Perspective					
	New		Mid		Old		New		Mid		Old	
	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio	NPV	B/C ratio
CA - HCA	-174.0	0.82	-29.9	0.97	**570.2**	**1.60**	-60.0	0.93	**96.9**	**1.11**	**749.6**	**1.83**
CA - METERS	-328.7	0.70	-184.6	0.83	**415.5**	**1.38**	-190.0	0.82	-33.1	0.97	**619.6**	**1.60**
CA+CI - HCA	-137.1	0.89	**79.2**	**1.06**	**979.3**	**1.75**	14.2	1.01	**249.5**	**1.20**	**1228.5**	**1.98**
CA+CI - METERS	-256.1	0.82	-39.8	0.97	**860.3**	**1.61**	-85.8	0.94	**149.5**	**1.11**	**1128.5**	**1.84**

8. Conclusions and recommendations

According to the outcomes of the cost benefit analysis and the sensitivity analysis for all the different scenarios we can conclude the following:

Firstly, the number of the total units per building as well as the interest rates used in the calculations can be characterized as non-crucial parameters as their deviation has only minor influence to the final categorization of the buildings.

Furthermore, all the buildings in coastal and lowland climatic zone can be safely included in the exempted class regardless of their building type and construction period. Additionally, for the buildings which have been built after 2000 and between 1980 and 2000 in the semi-mountainous climatic zone can also be safely included in the exempted class. Although, old buildings constructed before 1980 in semi-mountainous zone can also be included in the exempted class except for those cases where the required capital of the investment is less than 200 euro or the energy saving potential proved that is higher than 20%.

The buildings in the mountainous zone are at the border between the viable and exempted classes. New buildings can be marginally included in the viable class only in those cases when the required capital for the investment drops below 500 euro. As to those buildings built between 1980 and 2000, according to the outcomes of the CBA, the duplex and multifamily buildings can be included in the viable class only from an economic perspective. Though, the viability limits regarding the potential energy saving and the capital cost of the investment reveals that the results can change with very small deviation of these two parameters. The clearest case is for old buildings constructed before 1980 in this climatic zone, which can safely be included in the viable class.

Taking into account that the total number of multifamily, multipurpose and duplex buildings in the mountainous zone is 4,415, from which 1,192 are temporary occupied (27%), 1,033 are new (22.4%) and that only 0.38% of the total Cypriot households in duplex houses and 0.73% in multifamily are using central heating systems, we can conclude that the energy saving potential from this kind of policy measure is expected to be very low for the case of Cyprus. Additionally, the aforementioned statistical data shows that the final number of buildings in the viable class will represent less than 1% of the total Cypriot building stock. Thus, is recommended not take legislative action addressing such a small amount of obligated parties and which is expected to generate very few energy savings.

9. References

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10. Annex I

Attached excel file “Cypriot CBA calculations”.