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A DECISION SUPPORT TOOL (DST) REFLECTING END-USERS BEHAVIOUR IN ENERGY EFFICIENCY MODELLING

D.3.2

PART OF WORK PACKAGE 3: FORWARD-LOOKING SCENARIO ANALYSIS, FOCUSING ON MACROECONOMIC AND MICROECONOMIC IMPACTS OF ENERGY EFFICIENCY POLICY OPTIONS

REPORT (PART I: METHODOLOGY)

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HERON: Forward – looking socio-economic research on Energy Efficiency in EU countries

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GLOSSARY

Barrier

It is an element that limits the individuals' willingness to implement policies.

For instance, difficulties in trusting new technologies or lack of information about potential energy efficiency benefits are considered barriers (HERON, Deliverable 2.5).

Bounded rationality

A situation under which individuals do not make decisions in the manner assumed in economic models, because of constraints on time, attention, and the ability to process information (Knoblocha F. and Mercure J. - F., 2016).

Therefore, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentives.

Building Energy Management System (BEMS)

A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems (HERON, Deliverable 2.5).

Customs, habits and relevant behavioral aspects

A tradition or a usual way to behave[1]. Furthermore, habit is a particular act or way of acting that a person tends to do regularly[2].

Hassie factor

The required time and effort to find accurate information or appropriate finance so as to move forward to (CBI, 2016; Newfoundland Labrador, 2011).

It is a barrier linked with the end-users since they need time and effort for finding suitable contractors or clearing out a basement for having it insulated (Newfoundland Labrador, 2011). It is also linked with the fact that end-users disrupt the scheduled work for retrofit due to limited time and efforts (HERON Deliverable 2.1).

For overcoming this barrier, a government needs to take a holistic view of the customer journey, design and implement a policy framework that drives and facilitates consumer demand for EE measures (CBI, 2016).

Inertia

The resistance of end-users to change. Individuals are, in part, creatures of habit and established routines, which may make it difficult to create changes to such behaviours and habits (Thollander et al, 2010, p. 56). The more radical the change, the higher the barrier (HERON, Deliverable 3.1).

[1] Source: http://www.yourdictionary.com/custom#e3Fw6Uevh7IEf6Sh.99
[2] Source: http://dictionary.cambridge.org/us/dictionary/english/habit

Light-Emitting Diode (LED)

A light-emitting diode (LED) is a two-lead semiconductor light source. LEDs have many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching.

Rebound effect

The situation which occurs when energy efficiency improvements counter-intuitively lead to higher levels of energy consumption or to the creation of wealth from the energy savings (HERON, 2015 -2.1; UNEP, 2014).

This happens when an energy service becomes cheaper relatively to other goods and services and leads to increased consumption. Rebound effects can therefore have positive social and economic consequences but may lead to a conflict with the goal to reduce energy use and emissions.

Socio-economic status of building users

Set of factors related to the end-user who lives or works in a building/apartment. These factors are: Age, income, economic background, level of education, job - professional category, health conditions, lifestyle, region – climate/geographical zone, level of familiarization with technology, size of family (Omar Jridi, Fethi Zouheir Nouri, 2015; Jacob M., 2007).

Split incentive(s)

The transactions under which the party that covers the expense, does not receive the benefit of this expense/investment. Regarding energy efficiency, the split incentive(s) are caused between the owners and the tenants due to traditional lease structures (City of Boulder, 2016).

The owner wants to minimize the purchase cost of energy related systems and technologies (heating, cooling, hot water, efficient appliances etc), and has no return on this investment, while the tenant wants to minimize his/her energy bill. The owner is not encouraged to make investments in energy efficiency since it is the tenant who receives dividend (Charlier Dorothée, 2014). So, the actors who decide which technologies to use (Agent) are not responsible for paying the energy bills (Principal) (HERON, Deliverable 3.1). Finally, none of these two parties wants to invest in an energy efficient system.

It is also encountered with the alternative term “Agent-Principal” issue.

ACRONYMS

AHP	Analytical Hierarchy Process
BAU	Business-As-Usual
BE	Belgium
BEMS	Building Energy Management System
BEVs	Battery Electric Vehicles
BG	Bulgaria
CI	Consistency Index
CNG	Compressed Natural Gas
CRES	Centre for Renewable Energy Sources and Saving
DE	Germany
DST	Decision Support Tool
EE	Estonia
EE	Energy Efficiency
EPBD	Energy Performance Building Directive
EFTA	European Free Trade Association
ESCO	Energy Services COmpany
EU	European Union
EV	Electric Vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GR	Greece
HEVs	Hybrid Electric Vehicles
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IEE	Intelligent Energy Europe
IN	Implementation Network
IT	Italy
KENAK	Energy Efficiency Regulation for Buildings
LEAP	Long-range Energy Alternatives Planning
LED	Light-Emitting Diode
NSIs	National Statistical Institutes
NZEB	Nearly Zero Energy Buildings
PHEV	Plug in Hybrid Vehicle
RS	Serbia

TI	Total Impact
UK	United Kingdom
UNEP	United Nations Environmental Programme
yoy	Year over Year
YPEKA	Ministry of Energy, Environment and Climate Change

EXECUTIVE SUMMARY

Improving energy efficiency is a priority in all decarbonisation scenarios (European Union, 2012). However, there are important barriers for the implementation of an energy efficient strategy that need to be taken into account and used in energy modelling (SEC(2011) 779 final). These barriers are strongly linked with the consumer behaviour.

The HERON partners identified under "*Work Package 2: Mapping and assessment of social, economic, cultural and educational barriers in buildings and transport within each country*" a set of barriers linked with the behavior of end-users in two sectors: buildings (residential and tertiary) and transport. These barriers were grouped into three main categories: i) Social-Cultural-Educational, ii) Economic and iii) Institutional.

This paper presents the Decision Support Tool (DST) that was developed under the HERON programme for transforming the qualitative information about barriers (WP2) into numerical inputs for the development of EE scenarios (WP4).

With the use of the Analytical Hierarchical Process (AHP), comparative analysis is conducted among barriers created by the end users' behavior towards EE targets. Based on qualitative information for the barriers, the user compares, reveals and quantifies the negative impact of each barrier on the set of the assumed targets, in EE modeling. Mathematical expressions using the calculated impact of barriers provide numerical inputs needed to energy modelling for reflecting the end-user behavior in the assumed EE targets. Once the procedure is completed, the policy maker can modify accordingly the available inputs so as to achieve the set targets.

The paper is prepared for two different target groups, experts interested to understand the methodological approach and those that will use the DST. The first chapter presents analytically the methodology of the developed DST (concept, steps, mathematical expressions). The second chapter concerns the implementation of the DST. The third chapter is the manual of the software.

PREAMBLE

Energy Efficiency (EE) consists one of the main pillars of efforts to mitigate climate change. There is plethora of relevant policy instruments (energy labelling, audits etc) that support the penetration of EE technologies and practices, but different types of barriers affect negatively the achievement of targets set under scenarios. According to the Energy Efficiency Communication of July 2014, the EU is expected to miss the 20% energy savings target of year 2020 by 1%-2% (European Commission, 2014; 2012). The Dutch Government lowered its initial reduction target from 30% to 20% (Vringer K. et al., 2016). Also, Malta's 2020 EE target was lowered in 2015 from 0.825 Mtoe to 0.726 Mtoe expressed in primary energy consumption (European Commission, 2015a).

The EE policies and measures due to barriers do not deliver the expected benefits associated with improvements in EE (such as energy savings, reductions in Greenhouse Gases, employment, poverty alleviation etc) (UNEP, 2014; IEA, 2014). Among these types of barriers, those related to end-users behaviour need to be incorporated also in forward looking energy efficiency modelling after being identified and analysed (McCollum L. David et al., 2016; EC, 2015; EEA, 2013).

Forward-looking models are used for medium-to-long-term scenario analyses, aiming to support relevant policy options; some of these models are designed to consider both technological, economical and socio-behavioral elements in developing their scenarios (McCollum L. David et al., under press; Knoblocha F., Mercure J.-F., 2016). Bridging the gap between these elements has historically been presented as a challenge (McCollum L. David et al., under press). Furthermore, demands of improving the design of models so as to become more 'realistic' by incorporating features observed in the real world are increasing (McCollum L. David et al., under press). One group of such features of the 'real world' relates to human behavior.

The demands are based on the following arguments (McCollum L. David et al., under press): i) Models lacking behavioral realism are restricted in evaluating energy efficiency policies and other influences on end-user demand; ii) Improving the behavioral realism of models consequently affects policy-relevant model analysis of EE as part of the climate change mitigation efforts. However, current modelling of behavioral features in energy-economy and integrated assessment models is relatively limited (McCollum L. David et al., under press). Usually, models and particularly Integrated Assessment Models (IAMs) represent the behavior of consumers or energy end-users through economic relationships: energy demand as a function of price, technology investments to minimize levelized costs, etc (McCollum L. David et al., under press).

End-user behaviour is complex and rarely follows traditional economic theories of decision-making (McCollum L. David et al., under press; Frederiks R. et al., 2015; Knoblocha F., Mercure J.-F., 2016). End-users patterns of energy consumption are influenced by social-cultural-educational (status quo, social interactions etc), economic (risks of investment, financial incentives) and institutional factors (split incentives, hassle factor etc) that are characterized as barriers (Vringer K. et al., 2016; Frederiks R. et al., 2015; UNEP, 2014).

Efforts are focused in overcoming existing barriers and increasing the sophistication of energy and economic modelling (European Commission, 2015b; 2014). Key insights in the outcomes of such efforts can guide the effective design and implementation of end-user-focused strategies and public policy interventions to improve the level of EE interventions (by adopting technologies or practices) (Frederiks R. et al., 2015; UNEP, 2014).

The proposed methodology transforms qualitative research outcomes related to barriers linked to end-users behavior, into quantitative ones allowing their incorporation in the form of numerical inputs in forward looking EE modelling.

THE DECISION SUPPORT TOOL

CONCEPT

Energy consumers exhibit different types of behavior/preferences against the efforts for promoting EE. Each one of these identified barriers that are created by the end-users behavior has a different impact/contribution in limiting the efforts of achieving energy savings.

The question is how to quantify these barriers in numbers with each one expressing correctly these contributions. One of the reasons for seeking an approach that quantifies the barrier impact is the need to have numerical inputs for the forward-looking energy efficiency modelling. Additionally, the policy makers need to understand what the numbers represent and be able to work with the outcomes for designing effective EE policies and measures.

This chapter concerns the methodology for inserting end-users behaviour into forward looking EE modelling. With the use of the Analytical Hierarchical Process (AHP), comparative analysis is conducted among barriers created by the end users' behavior towards EE targets. Based on qualitative information for the barriers, the user compares, reveals and quantifies the negative impact of each barrier on the set of the assumed targets, in EE modelling. Mathematical expressions using the calculated impact of barriers provide numerical inputs needed to energy modelling for reflecting the end-user behavior towards the assumed EE targets. Once the procedure is completed, the policy maker can modify accordingly the available inputs so as to achieve the set targets.

METHODOLOGY

The proposed methodology is developed in nine (9) steps – procedures that facilitate its understanding.

Step 1: Selection of multi-criteria decision analysis method

The Analytical Hierarchy Process (AHP) is used for quantifying the impact of barriers. AHP allows pair-wise comparisons among the objects that need to be assessed (either criteria/sub-criteria, alternatives, options or barriers). It has been preferred in very few similar cases (policies and barriers), but not for barriers related to EE policy issues and end-users behavior (Sunil L. et al., in press; Sara J. et al., 2015). Its use for this set of objects is conducted for the first time.

The AHP method is characterized by a number of advantages and is more preferable than others. The advantages that allow its use for the needs of the concept are the following:

- *AHP is justified mathematically* (specifically, it is mathematical theory of value, reason and judgment, based on ratio scales) (Eakin H., Bojorquez-Tapia L.A., 2008; Kablan M.M., 2004).
- *AHP presents better the problem.* The main advantage of AHP is the decomposition of the problem into elements (Ishizaka A., Labib A., 2011; Berrittella et al., 2008). Due to this advantage AHP has been combined with almost all the other multi-criteria decision analysis methods. Its hierarchical structure of criteria allows users to focus better on specific criteria and sub-criteria when determining the respective weight coefficients through the pairwise comparisons (Ishizaka A., Labib A., 2011).

- Psychologists argue that it is easier and more accurate to express one's opinion only on two alternatives[3] than simultaneously on all (Ishizaka A., Lablb A., 2011).
- *AHP offers guidelines in defining the weight coefficients and has a consistency index for verifying their consistency*. "*The AHP approach employs a consistency test that can screen out inconsistent judgments, which makes the results reliable.*" (Kablan M.M, 2004).
- *AHP is suitable for incorporating the preferences of relevant stakeholders regarding the importance of the criteria/sub-criteria* (Fikret K.T., et al., 2016). The method may be impractical for a survey with a large sample size of as 'cold-called[4]' respondents, because they may have a great tendency to provide arbitrary answers, resulting in a very high degree of inconsistency (Wong K.W.J., Li H., 2008).
- AHP allows qualitative and quantitative approaches for solving a problem (Kilincci O., Onal S.A., 2011; Wong J.K.W., Li H., 2008; Duran O., Aguilo J., 2008). It can handle uncertain, imprecise and subjective data (Srdjevic B., Medeiros Y.D.P., 2008).
- The usage of pairwise comparisons does not require the explicit definition of a measurement scale for each attribute (Bozdura F.T. et al., 2007).
- Comparative analysis of MCDA approaches has indicated AHP to be the most popular compared to other methods due to its simplicity, easiness to use and great flexibility (Kilincci O., Onal S.A., 2011; W. Ho et al., 2010; Srdjevic B., Medeiros Y.D.P., 2008; Duran O., Aguilo J., 2008; Babic Z., Plazibat N., 1998).

  It is an easier technique - with the exception of the eigenvalue calculations used to derive the local priorities of the elements in a cluster of the hierarchy and which remain actually hidden from the end-user - compared to MAUT and SMART and with less required cognitive skills compared to MAUT/MAVT and SMART (Ananda J., Herath G., 2009; Petkov D. et al., 2007).

  The users may directly input judgment data without getting into the mathematical background (Duran O., Aguilo J., 2008).
- AHP has been used only for the determination of the importance of criteria/factors (alone or in combination with other multi-criteria decision analysis methods) (Kuruoglu E. et al., 2015; Kumar S. et al., 2015; Andrejiova M. et al., 2013).

Step 2: Categorization of barriers per groups/sub-groups

All identified barriers linked with the end-users behavior are categorized into main groups. Each group is divided into subgroups. Due to the possible large number of identified barriers per country (or region or municipality), it is necessary to check if barriers are to be grouped into smaller groups under the already identified main ones. Each group or sub-group contains the barriers that have the same basic characteristic. Based on literature research (UNEP, 2014; IEA, 2014; EEA, 2013) three main groups are foreseen for barriers linked with end-users behavior: "Social-Cultural-Educational", "Economic" and "Institutional". The first group can be divide into three sub-groups "Social", "Cultural" and "Educational". This step is applied for any economic sector (buildings, transport etc).

Step 3: Merging the same/similar barriers

Due to the possible large number of identified barriers per country (or region or municipality), it is also necessary to check if some barriers finally have the same content; refer to the same behavior or need to be handled by the same manner. Then they are merged into one barrier with a common title

[3] Since two alternatives form the pairwise comparisons of AHP

[4] A telephone call or visit made to someone who is not known or not expecting contact.

(with all similar ones included under this common title). This action is necessary so that the set of barriers is complete, non-redundant, minimalistic, with non-overlapping barriers, decomposable (Makropoulos C.K. and Butler D., 2006).

Another restriction is that: the preferable maximum number for each AHP matrix, that can be examined for its consistency, is 8x8. So, all identified barriers are either grouped or merged so as to form the respective groups and sub-groups with up to 8 barriers the most for each.

Step 4: Formation of the AHP tree and the AHP matrixes

The previous two steps form the AHP tree, but apart from the groups and sub-groups, the goal (zero level of AHP tree) needs to be determined. The goal reflects the aim of the tree. The goal in this AHP tree is the "limiting efforts for achieving energy savings" due to the impact of each barrier that is part of the AHP tree.

So, the first level of the AHP tree has the following three main groups of barriers: i) "Social-Cultural-Educational"; ii) "Economic" and iii) "Institutional". The first group has three sub-groups: "Social", "Cultural" and "Institutional". The other two groups do not have any sub-groups (Figure 1). Under each group and sub-group the identified and merged barriers are classified.

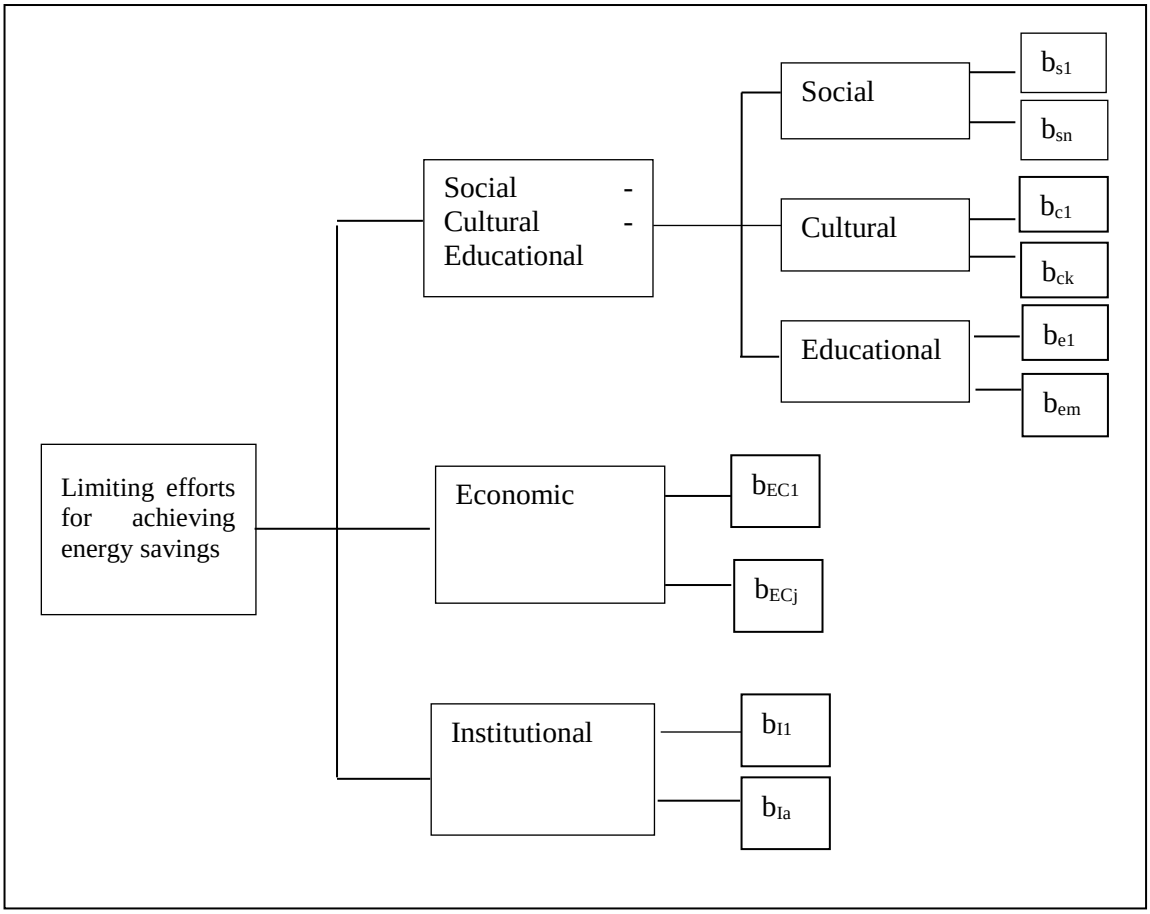

Figure 1: AHP tree of the barriers.

This structure is used to form the AHP matrixes for the comparative analysis. The columns and the rows of these matrixes refer to the compared groups or barriers. The AHP matrixes are filled in their diagonal with "1" due to the pairwise comparison of one group or barrier with itself.

Step 5: Conducting pair-wise comparisons

Step 5.1: First level pair-wise comparisons

First the three groups are compared using the AHP matrix and scale (Tables 1 and 2). Each cell of the AHP matrix is filled after:

i) comparing the object (in this first level, the group of barriers) of each row with the respective object of the column;

ii) assigning the appropriate - according to judgement - intensity from Table 2;

iii) the assignment of the intensity (judgement) is based on the following conditions:

   a. the first object is more important compared to the second one if the number of the identified barriers of the first object is higher compared to those of the second one;

   b. the first object is more important depending compared to the second one on the level of difficulty with which it can be confronted (the more difficult, the more important);

   c. the first object is more important compared to the second one if it is divided in more different sub-groups; and

   d. the first object is more important compared to the second one if the available preferences of experts on EE issues clearly quote this importance.

iv) Depending on how important overally the first group is, compared to the second one, the intensity is assigned. The selected intensity is quoted in the respective cell. If during any comparison the second object is more important than the first one, then the quoted intensity is 1/intensity.

Table 1 shows a filled AHP matrix. The element of the AHP matrix, A_{12}, expresses how more important the "Social-Cultural-Educational" group of barriers is in limiting the efforts of achieving energy savings compared to the group of "Economic" barriers.

Table 1: AHP matrix for pair-wise comparisons.

Barriers linked with end-users behaviour	Social-Cultural-Educational	Economic	Institutional
Social-Cultural-Educational	1	A_{12}	A_{13}
Economic	$A_{21} = 1/A_{12}$	1	A_{23}
Institutional	$A_{31} = 1/A_{13}$	$A_{32} = 1/A_{23}$	1

Table 2: Relative importance between comparisons of AHP method.

Intensity	**Definition**	**Explanation**
1	Equal importance	Two barriers contribute equally to the goal
3	Moderate importance	Experience and judgement slightly favours the one over the other
5	Essential or strong importance	Experience and judgement strongly favours the one over the other
7	Demonstrated importance	Dominance of the demonstrated in practice
9	Extreme importance	Evidence favouring the one over the other of highest possible order of affirmation
2,4,6,8	Intermediate values	When compromise is needed

Step 5.2: Calculation of indexes for the first level of the AHP tree

The necessary calculations of the AHP method are conducted for the determination of the weight coefficients for each group of barriers. Each weight coefficient (or index) expresses the contribution of the category in the limitation of efforts for energy efficiency (Annex 1). The procedure is:

a. Sum of each column (add three numbers in this case-level);
b. Divide each number of the first row with the respective sum of the column it belongs to (a_{11}/sum of column 1, a_{12}/sum of column 2, a_{13}/sum of column 3);
c. Sum up the three outcomes of step b;
d. Divide them with 3 (since there were three outcomes);
e. The outcome is weigh coefficient for group 1 of barriers (row 1, column 4 or a separate column);
f. Repeat for the second row the steps b, c, d, e;
g. Repeat for the third row the steps b, c, d, e;
h. Check if each weight coefficient fulfills the condition 0 < weight coefficient < 1;
i. Check if all together, the three weight coefficients, sum up 1.

Step 5.3: Calculation of the consistency test

Before accepting these values (step 5.2), a consistency test is performed. The approach by Saaty is used for calculating the random ratio of consistency of the respective AHP matrix. Initially, the consistency index is calculated as

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

where
CI is the consistency index,
λ_{max} is the maximum eigenvalue of the matrix and
n is the rank value of the matrix.

The random ratio of consistency is obtained using the equation CR*=CI/CR where CR is the corresponding mean random index of consistency. CR receives the following values; 0 for a 2x2 matrix, 0.58 for 3x3, 0.90 for 4x4, 1.12 for 5x5, 1.24 for 6x6, 1.32 for 7x7, 1.41 for 8x8 and 1.45 for 9x9. A matrix is consistent if CR* < 0.10. Otherwise, the matrix is not consistent and its value should be adjusted.

The calculation procedure is:

a. Multiply the first cell of the first row with the first weight coefficient (step 5.2), the second cell of the first row with the second one, the third cell of the first row with the third weight coefficient);
b. Sum the products and divide by the first weight coefficient. This will be A1;
c. Multiply the first cell of the second row with the first weight coefficient etc;
d. Sum up the products and divide with the second weight coefficient. This will be A2.
e. Repeat the steps a, b for the third row respectively.
f. Add outcomes A1, A2 and A3 and divide the sum with number three.
g. Calculate the fraction (outcome of step f – 3)/(3-1). This will be consistency index CI for the specific AHP matrix.
h. Calculate CR* = CI/0.58
i. If CR* fulfils the condition 0<CR*<0.10, then the results are consistent.

Step 5.4: Calculation of indexes for the second level of the AHP tree

Weight coefficients are defined also for each one of the sub-groups "Social", "Cultural" and "Educational" to which the wider group "Social-Cultural-Educational" is divided to. The previous steps (5.1 – 5.3) are repeated. The conditions of step 5.1 are used for this level also.

Once the weight coefficients of this level are calculated then the contribution of each sub-group of the barriers to goal "limiting the efforts of achieving energy savings" is determined as

"Social barriers" impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{social}$ = W $_{S\text{-}C\text{-}E}$ * W_S

"Cultural barriers" impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{cultural}$ = W $_{S\text{-}C\text{-}E}$ * W_C

"Educational barriers" impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{educational}$ = W $_{S\text{-}C\text{-}E}$ * W_E

"Economic" and "Institutional" barriers are not divided into sub-groups.

Step 5.5: Calculation of indexes for the third level of barriers

The previous steps (5.1 – 5.3) are repeated. Under each sub-group there is a number of identified barriers. For the sub-group of "Social" barriers there are b_{s1}, b_{s2}…b_{sn} barriers. Following the same procedure, the AHP matrix is that of Table 3.

Table 3: AHP matrix for the third level of barriers.

Social barriers	b_{s1}	b_{s2}	b_{s3}	……	b_{sn}	**Weight coefficients**
b_{s1}	1	A_{12}	A_{13}	……	A_{1n}	**W_{s1}**
b_{s2}	$A_{21} = 1/A_{12}$	1	A_{23}	…..	A_{2n}	**W_{s2}**
b_{s3}	$A_{31} = 1/A_{13}$	$A_{32} = 1/A_{23}$	1	…..	A_{3n}	**W_{s3}**
…….	……	…..	……..	1	….	**…..**
b_{sn}	$A_{n1} = 1/ A_{1n}$	$A_{n2} = 1/ A_{12}$	$A_{n3} = 1/ A_{13}$	$A_{n\ n-1} = 1/ A_{n-1\ n}$	1	**W_{sn}**

The AHP matrix is filled with the assignment of the intensities that result from the comparison of the identified barriers (b_{s1}, b_{s2}…b_{sn}) against each other by taking into consideration the following conditions:

- A barrier is more important than the other if the *number of different sources* that refer to it are more than those for the second one;
- A barrier is more important that the other if the *number of sub-sectors* that were linked with it are more than those with the second one;
- A barrier is more important compared to the second one if there are *more difficulties to confront it* (the easier to be confronted the less important it is or if difficulties are encountered in more than one level (local, regional, national) it is more important);
- A barrier is more important compared to the second one if it exists *longer than another* (longer recorded duration of the barrier compared to the other);
- A barrier is more important compared to the second one if the *number of different policy instruments that were linked with it is* higher than those of the other;
- A barrier is more important than the second one if it is identified *as a cross-cutting barrier* (common among two or more different sectors (ie buildings and transport));
- A barrier is more important than another if there are available *expressed preferences of stakeholders for it*.

Calculations are performed for this level as follows:

a. Sum of each column (add six numbers in this case-level);
b. Divide each number of the first row with the respective sum of the column it belongs to (a_{11}/sum of column 1, a_{12}/sum of column 2, a_{13}/sum of column 3 etc);
c. Sum up the "n" outcomes of b;
d. Divide them with n (since there were *n* outcomes) (*n* is the number of columns and rows of this AHP matrix);
e. The outcome is weigh coefficient for barrier 1 (row 1, column n+1 or a separate column);
f. Repeat for the second row the steps b, c, d, e;
g. Repeat for the third row the steps b, c, d, e;
h. Check if each weight coefficient fulfills the condition 0<weight coefficient<1;
i. Check if all together, the six weight coefficients, sum up 1.

Again, the calculated weight coefficients are checked for their consistency (step 5.3).

a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient) etc;
b. Sum the products and divide by the first weight coefficient. This will be A1;
c. Multiply the first cell of the second row with the first weight coefficient etc;
d. Sum up the products and divide with the second weight coefficient. This will be A2;
e. Repeat the steps a, b for the remaining rows.
f. Add outcomes A1, A2, …… An and divide the sum with "n".
g. Calculate the fraction (outcome of f – n)/(n-1). This will be consistency index CI for the specific AHP matrix.
h. Calculate CR* = CI/(number from theory of step 5.3) (for 6x6 matrix this number is 1.24)
i. If CR* fulfils the condition 0<CR*<0.10, then the results are consistent.

The procedure of this step (5.5) is repeated for the "Economic" and the "Institutional" barriers.

Step 6: Calculation of Total Impact per barrier

The Total Impact of each barrier is calculated based on the outcomes (impact/weight coefficient of the barriers) of the previous steps as follows:

b_{1s} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{social}$ * Index $_{social\ 1}$ = W $_{S\text{-}C\text{-}E}$ * W_s *w_{s1}

b_{2s} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{social}$ * Index $_{social\ 2}$ = W $_{S\text{-}C\text{-}E}$ * W_s *w_{s2}

……..

etc and the same procedure and mathematical expression is applied for all barriers of the third level.

Following the same procedure, the impact of each cultural barrier is

b_{c1} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{cultural}$ * w_{c1} = W $_{S\text{-}C\text{-}E}$ * W_c *w_{c1}

b_{c2} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{cultural}$ * w_{c2}

etc

For "Educational barriers" the same rationality is followed.

For the "Economic" barriers, the impact is calculated as

b_{EC1} = Index $_{Economic}$ * w_{EC1}

b_{EC1} = Index $_{Economic}$ * w_{EC2}

etc

For the “Institutional” barriers, the impact is calculated as

b_{I1} = Index $_{Istitutional}$ * w_{I1}

b_{I2} = Index $_{Institutional}$* w_{I2}

etc

All calculated indexes do not have measurement units as they express the contribution of the barrier that is linked with the end-user behavior ie the ratio scale in limiting efforts for energy savings. Table 4 shows these calculated indexes for the building sector. The values of these indexes range from 0 to 1, ie TI$\in$(0,1), where TI means Total Impact.

Table 4: Total Impact of barriers for the building sector.

Type	Name of barrier	Function
Social	Social group interactions and status considerations	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Socio-economic status of building users	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Strong dependency on the neighbors in multi-family housing	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Inertia	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Commitment and motivation of public social support	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Rebound effect	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Cultural	Lack of interest/low priority/Undervaluing energy efficiency	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c1}$
Cultural	Customs, habits and relevant behavioural aspects	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c2}$
Cultural	Bounded rationality/Visibility of energy efficiency	$TI_{c3} = W_{S\text{-}C\text{-}E} * W_c * W_{c3}$
Cultural	Missing credibility/mistrust of technologies and contractors	$TI_{c4} = W_{S\text{-}C\text{-}E} * W_c * W_{c4}$
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	$TI_{E1} = W_{S\text{-}C\text{-}E} * W_E * W_{E1}$
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies	$TI_{E2} = W_{S\text{-}C\text{-}E} * W_E * W_{E2}$
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	$TI_{EC1} = W_{EC} * W_{EC1}$
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	$TI_{EC2} = W_{EC} * W_{EC2}$
Economic	Payback expectations/investment horizons	$TI_{EC3} = W_{EC} * W_{EC3}$
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	$TI_{EC4} = W_{EC} * W_{EC3}$
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	$TI_{EC5} = W_{EC} * W_{EC5}$
Economic	Financial crisis/Economic stagnation	$TI_{EC6} = W_{EC} * W_{EC6}$
Economic	Embryonic markets	$TI_{EC7} = W_{EC} * W_{EC7}$
Institutional	Split Incentive	$TI_{I1} = W_I * w_{I1}$
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	$TI_{I2} = W_I * w_{I2}$
Institutional	Building stock characteristics/aging stock/ Historical preservation	$TI_{I3} = W_I * w_{I3}$
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	$TI_{I4} = W_I * w_{I4}$
Institutional	Lack of data/information-diversion of management	$TI_{I5} = W_I * w_{I5}$
Institutional	Barrier to behavior change due to problematic Implementation Network (IN)/governance framework (Inadequate IN/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities)	$TI_{I6} = W_I * w_{I6}$
Institutional	Disruption/Hassie factor	$TI_{I7} = W_I * w_{I7}$
Institutional	Security of fuel supply	$TI_{I8} = W_I * w_{I8}$

Table 5: Total impact of barriers for the transport sector.

Type	Name of barrier	Function
Social	Low satisfaction with public transport/lack of trust	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Concerns of vehicle reliability/Hesitation to trust new technologies	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Heterogeneity of consumers	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Suburbanisation trends/Low density	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Mobility problems (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social	Inertia	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Cultural	Car as a symbol status and group influence	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c1}$
Cultural	Habit and social norm of driving, car ownership and use	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c2}$
Cultural	Cycling is marginalized	$TI_{c3} = W_{S\text{-}C\text{-}E} * W_c * W_{c3}$
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	$TI_{c4} = W_{S\text{-}C\text{-}E} * W_c * W_{c4}$
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	$TI_{E1} = W_{S\text{-}C\text{-}E} * W_E * W_{E1}$
Educational	Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	$TI_{E2} = W_{S\text{-}C\text{-}E} * W_E * W_{E2}$
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*	$TI_{E2} = W_{S\text{-}C\text{-}E} * W_E * W_{E2}$
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs	$TI_{E2} = W_{S\text{-}C\text{-}E} * W_E * W_{E2}$
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	$TI_{EC1} = W_{EC} * W_{EC1}$
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	$TI_{EC2} = W_{EC} * W_{EC2}$
Economic	Low purchasing power of citizens/Financial crisis	$TI_{EC3} = W_{EC} * W_{EC3}$
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles	$TI_{EC4} = W_{EC} * W_{EC3}$
Economic	Payback period of fuel efficient vehicles	$TI_{EC5} = W_{EC} * W_{EC5}$
Economic	Negative role of Investment schemes/employee benefits encourage transport EE	$TI_{EC6} = W_{EC} * W_{EC6}$
Institutional	Administrative fragmentation and lack of integrated governance	$TI_{I1} = W_I * w_{I1}$
Institutional	Transport EE on the Government Agenda/priorities	$TI_{I2} = W_I * w_{I2}$
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	$TI_{I3} = W_I * w_{I3}$
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics	$TI_{I4} = W_I * w_{I4}$
Institutional	Limited/complex funding in urban public transport	$TI_{I5} = W_I * w_{I5}$
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)	$TI_{I6} = W_I * w_{I6}$
Institutional	Contradicting policy goals (particularly road/car-oriented planning)	$TI_{I7} = W_I * w_{I7}$

Step 7: Repetition of procedure for another sector (ie the transport sector)

The steps 2-6 are followed for any other sector that is to be examined. The **transport sector** was used as the second sector. The total impact of each identified barrier for the transport sector is calculated as presented in Table 5. The groups and the sub-groups of barriers are the same with the previous sector. The barriers themselves differ in their titles and numbers per group or sub-group.

Step 8: Linkage of Barriers Impact and technologies

Each one of the barriers (and consequently their weight coefficients in Tables 4 and 5), is linked with the technologies or practices that are promoted based on national needs and priorities through the implemented policy instruments.

A set of barriers exerts a Total Impact on the penetration of a specific EE technology or practice. This set depends on the examined case (country, region or municipality) and the respective selected EE scenario. This Total Impact is calculated as:

$TI_{technology}$ = sum of Total Impacts of barriers linked with the EE technology

$$= TI_{s1,\ linked\ with\ technology} + \ldots\ldots + TI_{Ia,\ linked\ with\ technology}$$

For a set of technologies, the same rationality is applied, but common barriers are inserted only once in the calculations.

Step 9: Incorporation of barriers impact in forward looking EE modelling

A. Impact of barriers on energy intensity or penetration share of an EE technology

Once the TI of the barriers, that are linked with the specific EE technology or practice, is calculated, the next step is to calculate in terms of energy intensity or penetration share their numerical impact (this step concerns any economic sector included in forward looking EE modelling). Two cases are examined (buildings and transport sectors).

1. Energy intensity per housing type (existing single family housing type 1, etc.) in kWh/m^2 (building sector)

Function

The *Initial Final Energy Consumption with the use of a technology (such as space heating technology) for the reference year (which is denoted as 0) is* expressed as *a function*

$F_o(k,a,c,d,e,h)$

where

k, a, c, d, e are factors from which the final energy consumption depends; such as population (k), income (a), space (c) that is heated or cooled, climatic conditions (d), already existing technology (e) and energy prices (h) (Department of Energy & Climate Change, 2015; Weibin Lin et al., 2014). The selection of more or less factors and their importance for the final energy consumption depends on the scenario assumptions.

A similar function is used for other types of technologies as well.

A new target about energy savings, usually refers to a target year and is a percentage of of the initial final energy consumption of the reference year. This means that the expected/needed energy savings for target year t are

$ES_t = F_o(k,a,c,d,e, h)*(p\%)$ where p% is the assumed expected reduction (the percentage depends on the scenario and whether it concerns a country, region or municipality). It can be for example 5%. This amount, ES_t, is calculated without considering the impact of the barriers.

The expected/needed energy savings for the target year t - ***when barriers are considered*** - are

$ES_{t,\ barriers} = F_o(k,a,c,d,e, h)*(p\%) * (1- TI_{barriers\ linked\ with\ target})$

$TI_{barriers\ linked\ with\ target}$ is defined as explained in previous step (depending on the technology or technologies that are used). The value of $TI_{barriers\ linked\ with\ target}$ depends also on the scenario and on whether it concerns the whole sector or on a specific sub-sector (residential or tertiary for the building sector). The latter defines the barriers that are linked with the technology.

So, the final energy consumption for the target year t will be

$$F_t (k,a,c,d,e, h, TI_{barriers\ linked\ with\ target}) = F_o(k,a,c,d,e, h) – ES_{t,\ barriers}$$
$$= F_o(k,a,c,d,e, h) - Fo(k,a,c,d,e, h)*p\%*(1- TI_{barriers\ linked\ with\ target})$$

Conditions

The following conditions complement the previous discussion and are used as check points for the assumptions of the developed scenarios under the forward-looking EE modelling.

First condition

If all identified barriers are assumed to be linked with an EE technology, then TI is equal to 1. In such a case the energy savings will be

$ES_{t,\ barriers} = F_o(k,a,c,d,e,h)*(p\%) * (1- TI_{barriers\ linked\ with\ target}) = F_o(k,a,c,d,e,h)*(p\%) * (1- 1) = 0$

This means that the assumed penetration of the EE technology or the set of technologies does not contribute in energy savings.

The conclusion is that the assumption needs to be re-examined. This situation is to be avoided. A check is performed so that $TI_{barriers\ linked\ with\ target} <1$.

Second condition

If some of the barriers are overcome sharply due to a new policy package of measures, then the respective $TI_{,barrier\ i}$ will be equal to 0 within the time interval from reference year 0 to target year t. The TI of the rest barriers is calculated, which is denoted as $TI_{barriers\ linked\ with\ target,\ new}$.

The energy savings in such a case will be:

$ES_{t,\ barriers\ -\ new} = F_o(k,a,c,d,e, h)*(p\%)* (1- TI_{barriers\ linked\ with\ target,\ new})$

with $TI_{barriers\ linked\ with\ target,\ new} < TI_{barriers\ linked\ with\ target,\ old} <1$.

Mathematical expressions for forward-looking EE modelling

The following mathematical expressions incorporate the barriers impact in forward-looking energy modelling. These expressions use the calculated impact of barriers and provide numerical inputs needed to energy modelling for reflecting the end-user behavior towards the assumed EE targets.

First approach

One of the tools for the forward-looking energy efficiency modelling, that is used is the software LEAP. In LEAP, the incorporation of the numerical outcomes that express the barriers impact are expressed as

BaselineValue - Interp(reference year; 0; target year; $F_o(k,a,c,d,e,h)*(p\%)*(1- TI_{barriers\ linked\ with\ target}$)

Where $TI_{barriers\ linked\ with\ target}$ is calculated within LEAP, by using all the calculated TIs that will be placed under a branch of the "Key assumptions" of the LEAP tree.

Another option is to have the TI values in an Excel file and link LEAP with that file. Similar mathematical expressions or functions are used.

Second approach

Calculations for $TI_{barriers\ linked\ with\ target}$ are performed in the DST and the final outcome is inserted in LEAP (through an Excel file) or in any other forward looking EE model.

2. Penetration shares for EE technologies or fuels (such as heating oil, natural gas, electric, heat pumps, biomass, LPG, etc.) per housing type (percentages)

Function

The initial share (in %) of a technology (such as heat pumps) is denoted for the reference year, 0, as

$S_o(k,a,c,d,e, h)$

Where

k, a, c, d, e are factors from which the share depends; such as population (k), income (a), space (c) that is heated or cooled, climatic conditions (d), already existing technology (e), energy prices (h). Again, the selection of the factors depends on the scenario assumptions.

The targeted increase of the penetration of the technology (such as heat pumps) is assumed to be A% (or for having a numerical example it can be 20%).

So, the share of the technology (such as heat pumps) for target year t is

$S_t = S_o(k,a,c,d,e,h) + A\%$

This additional percentage is affected by a number of barriers. Therefore, the targeted increase is limited due to these barriers ie

$A\%*(1- TI_{barriers\ related\ with\ the\ penetration\ of\ the\ technology})$

Finally, then

$S_{t,\ barriers} = S_o(k,a,c,d,e,h) + A\%*(1- TI_{barriers\ related\ with\ the\ penetration\ of\ the\ technology})$

Conditions

Same rationality as in the previous case.

Mathematical expressions for forward-looking EE modelling

First approach

In LEAP this is expressed as

BaselineValue - Interp(reference year; S_o(k,a,c,d,e,h) or 0;target year; S_o(k,a,c,d,e,h) + A%(1- $TI_{barriers\ related\ with\ the\ penetration\ of\ the\ technology}$))*

Where $TI_{barriers\ related\ with\ the\ penetration\ of\ the\ technology}$ is calculated within LEAP, by using all the calculated TIs that will be placed under a branch of the "Key assumptions" of the LEAP tree (as in the previous case).

For any other forward-looking energy efficiency model the approach follows the already aforementioned rationality.

Second approach

Calculations for $TI_{barriers\ related\ with\ the\ penetration\ of\ the\ technology}$ are performed in the DST and the outcome is inserted in LEAP or in any other forward-looking EE model.

3. Setting a general target

In some cases, due to the limitation of detailed data, a general target is set for the sub-sector that is studied. So, the following options are adopted.

All available technologies

The achievement of any of these general targets is assumed to be accomplished by the use of the available technologies such as BEMs, LEDS, energy efficient appliances etc.

The concept is that followed in the previously described case. The final energy consumption for the target year will be

$$F_t\ (k,a,c,d,e,\ h,\ TI_{barriers\ linked\ with\ target}) = F_o(k,a,c,d,e,\ h) - ES_{t,\ barriers}$$

$$= F_o(k,a,c,d,e,\ h)\ -\ Fo(k,a,c,d,e,\ h)*p\%*(1-\ TI_{barriers\ for\ available\ technologies})$$

Combination of technologies

This option refers to the intention of exploring which technologies to use and which is the best combination to use.

For the first case, all available technologies are to be used or based on official documents (National Energy Efficiency Action Plans) a specific set of technologies is selected and used in forward looking EE modelling. Then the calculations follow the previous rationality.

For the second case, the possible selection of specific technologies out of a set of available ones is not possible due to the large number of combinations. The exploitation of two technologies out of seven leads to the following possible combinations:

$$\binom{7}{2} = \frac{7!}{2!\,(7-2)!} = 21$$

For combinations of three technologies out of 7, the combinations are even more, ie

$$\binom{7}{3} = \frac{7!}{3!\,(7-3)!} = 35$$

These combinations cannot be examined since out of these 21 or 35 only a few will be more feasible and closer to succeed (accomplish the general target) compared to the others. This is justified by the

fact that: The expected penetration of the available technologies – so as to contribute in the accomplishment of the set target – is restricted due to the existence of barriers. Therefore, the combinations with the potential to overcome their barriers successfully and achieve the set target are those that need to be preferred and explored. For concluding with the more efficient ones the following procedure is followed:

Step 1: Available technologies form possible combinations. The combination with the **maximum number of common barriers** is more preferable than the others, because the efforts for minimizing these barriers will affect the penetration of all involved technologies.

Step 2: Additionally, if there are combinations with the same set of common barriers, the more preferable are those with **the lowest Total Impact**, since the overcoming of the set of their barriers as a group requires less efforts compared to other combinations. The combinations with the lower overall Total Impact are preferable since as a group will be more manageable and will more likely reach easier the set target compared to others.

If the combinations are more than those intended to be examined, then an upper limit for the Total Impact of the combinations is set. By this way only combinations with TI lower that the upper limit are selected. If a limit is set, ie TI<0.50 then the combinations with higher TI are excluded.

The TI of the combination is calculated and used as described in the previous cases.

B. Assumptions about minimizing the impact of barriers

Another set of developed scenarios are those under which barriers are confronted and their impact is reduced so that the set target is achieved. The assumed policy mixture (or package) of the developed scenarios is expected to support the achievement of the set target (general or technology specific one). In such a case the impact of barriers is assumed to be reduced or even eliminated completely.

First approach using the Impact of policy instruments

If a new target is assumed, then it will be supported by a number of existing or newly introduced policy instruments. Some of the barriers linked with the end-users behavior will be overcome due to the impact of specific policy instruments. So,

$ES_{t,\ barriers,\ policy\ instruments} = F_o(k,a,c,d,e,h)*(p\%) * (1- TI_{barriers\ linked\ with\ target} + IP_{policy\ instruments\ linked\ with\ the\ target})$

Where $IP_{policy\ instruments\ linked\ with\ the\ target}$ is the impact/contribution of the set of policy instruments that support the achievement of the expected target.

The $IP_{policy\ instruments\ linked\ with\ the\ target}$ is the sum of the IP contribution of each policy instrument that supports the new target.

$IP_{policy\ instruments\ linked\ with\ the\ target} = IP_{policy\ instrument\ 1} + IP_{policy\ instrument\ 2} +...+ IP_{policy\ instrument\ n}$

Where $\forall\, IP \in (0,1)$.

The calculation of the $IP_{policy\ instruments\ linked\ with\ the\ target}$ needs to be based on another research and collection of data and information, different from the one that led to the barriers impact.

Second approach using linear function

The function that describes the reduction rate of a barrier needs to follow the same rationality with that of the change rate (increase or reduction) of the final energy consumption or of energy savings.

Between the different types of functions, most suitable is the linear function[5], which provides compatible results with the LEAP functionality and the structure of the scenarios.

The Total Impact of barriers is assumed to follow a reduction rate described through the form of a linear function, ie

$Q = Q_o (1 – (0,2/15)*t$

where

Q_o is the Total impact of barrier i in year t=0,

Q is the Total impact of barrier i in year t after the implementation of a policy instrument (or instruments) that addresses the barrier. For any other year than t=0, Q satisfies the mathematical condition $Q < Q_o$.

The initial conditions that defined this final form, starting from the general one $Q = a*t + b$, were the following:

For year t=0, the Total Impact of barrier i, is that already calculated following the steps of the methodology, ie $Q = Q_o$.

For year t = 15 (in 2030), the assumption is that the Total impact of the barrier is reduced by 20%. This reduction means that barrier i, has a lower contribution in preventing energy savings (better situation for achieving energy savings or facilitating better the penetration of a EE technology). The 20% reduction was selected as an indicative value and because the mapping of the barriers showed that the majority of them remain important for several years despite the implementation of policy instruments. Whether the assumed 20% captures sufficiently the reduction of a barrier or not, this requires further research.

The year 2030 was selected due to the fact that the current – under consideration - targets for EE refer to this year. Since the mapping of the barriers occurred in year 2015, this corresponds to a time interval of 15 years.

Based on these initial conditions, the calculations resulted to $a = - 0,2/15$ and $b = Q_o$. This linear function is used for each barrier that is assumed to be reduced.

In the case of the best combination of technologies the minimization of the common barrier impact is divided equally among the involved technologies. The outcomes are inserted in the forward-looking EE model as described previously.

[5] The outcomes from the use of an exponential function are not compatible.

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ANNEX 1: CALCULATIONS FOR AHP

For building sector

1. Formation of first AHP matrix (one 3x3 matrix for the three groups of barriers ie "**Social-Cultural-Educational**" (1st category), "**Economic**" (2nd category), "**Institutional**" (3rd category)
2. User will proceed with the "Conduction of pairwise comparisons for matrix using AHP scale and four conditions"
    a. The diagonal cells (a_{11}, a_{22}, a_{33}) are filled with number 1 automatically.
    b. User compares "Group Barrier 1" with "Group Barrier 2" and fills in the respective cell (a_{ij}) with a number from the AHP scale (1-9) or selects from the scale. For his/her facilitation the four conditions for the compared barriers are displayed in a screen.
    c. The software automatically assigns the number 1/(what the user selected) to the a_{ji} cell.
    d. User continues with next comparison "Group Barrier 1" and "Group Barrier 3" following previous steps b, c.
    e. User continues with the next comparison "Group Barrier 2" and "Group Barrier 3" until the matrix is filled completely
3. Calculation of weight coefficients for the groups of barriers
    a. Sum of each column (add three numbers in this case)
    b. Divide each number of the first row with the respective sum of the column it belongs to (a_{11}/sum of column 1, a_{12}/sum of column 2, a_{13}/sum of column 3)
    c. Sum up the three outcomes of b
    d. Divide them with 3 (since there were three outcomes)
    e. The outcome is weigh coefficient for barrier 1 (row 1, column 4 or a separate column)
    f. Repeat for the second row the steps b, c, d, e
    g. Repeat for the third row the steps b, c, d, e
    h. Check if each weight coefficient fulfills the condition 0<weight coefficient<1
    i. Check if all together, the three weight coefficients, sum up 1.
4. Conduction of consistency test - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell of the first row with the second one, the third cell of the first row with the third weight coefficient)
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps a, b for the third row respectively.
    f. Add outcomes A1, A2 and A3 and divide the sum with number three.
    g. Calculate the fraction (outcome of step f – 3)/(3-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/0.58
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.

5. User accepts results of consistency test or not (it is up to the user to proceed knowing that results are not consistent)
6. If no (user does not accept), user goes to step 2 to re-evaluate/change some of the inputs under pairwise comparisons.

7. If yes, then user proceeds with formation of second AHP matrix for sub-groups of "**Social-Cultural-Educational**" (one 3x3 matrix for sub-group ie for "**Social**" – 1; "**Cultural**" – 2; "**Educational**" - 3) (display on screen)
8. Conduction of pairwise comparisons for matrix using AHP scale and four conditions (same as step 2)
9. Calculation of weight coefficients for the sub-group of barriers (same as step 3)
10. Conduction of consistency test (same as step 4)
11. Accept results or not (same as step 5)
12. If no go to step 8 (same as step 6)

13. If yes, then the user proceeds with formation of third AHP matrix for **social** barriers (one 6x6 matrix for "**Social group interactions and status considerations**" – 1; "**Socio-economic status of building users**" -2; "**Strong dependency on the neighbors in multi-family housing**" - 3; "**Inertia**" – 4; "**Commitment and motivation of public social support**" - 5; "**Rebound effect**"- 6) (display on screen)
14. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 2, but now for the 6x6 matrix)
15. Calculation of weight coefficients for the social barriers
    a. Sum of each column (add six numbers in this case)
    b. Divide each number of the first row with the respective sum of the column it belongs to (a_{11}/sum of column 1, a_{12}/sum of column 2, a_{13}/sum of column 3 etc)
    c. Sum up the six outcomes of b
    d. Divide them with 6 (since there were six outcomes)
    e. The outcome is weigh coefficient for barrier 1 (row 1, column 7 or a separate column)
    f. Repeat for the second row the steps b, c, d, e
    g. Repeat for the third row the steps b, c, d, e
    h. Check if each weight coefficient fulfills the condition 0<weight coefficient<1
    i. Check if all together, the six weight coefficients, sum up 1.
16. Conduction of consistency test - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient) etc
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps i, ii for the remaing rows.
    f. Add outcomes A1, A2, A3, A4, A5 and A6 and divide the sum with six.
    g. Calculate the fraction (outcome of vi – 6)/(6-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/1.24
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.
17. Accept results or not (same as step 6)

18. If no go to step 14

19. If yes formation of fourth AHP matrix for **cultural** barriers (one 4x4 for sub-group, these are: "**Lack of interest/Low priority/Undervaluing energy efficiency**" – 1; "**Customs, habits and relevant behavioural aspects**" – 2; "**Bounded rationality/Visibility of energy efficiency**" – 3; "**Missing credibility/mistrust of technologies and contractors**" – 4)
20. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 4, but now for the 4x4 matrix)
21. Calculation of weight coefficients for the cultural barriers (same procedure as in step 4, but now for the 4x4 matrix)
22. Conduction of consistency test - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient)
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps i, ii for the remaing rows.
    f. Add outcomes A1, A2, A3 and A4 and divide the sum with four.
    g. Calculate the fraction (outcome of f – 4)/(4-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/0.9
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.
23. Accept results or not (same as step 6)
24. If no go to step 20

25. If yes formation of fifth AHP matrix for **educational** barriers (one 2x2 for sub-group, ie "**lack of trained and skilled professionals/trusted information, knowledge and experience**" – 1; "**lack of awareness/knowledge on savings potential/information gap on technologies**"-2)
26. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 2, but know for the 2x2 matrix)
27. Calculation of weight coefficients for the educational barriers (same procedure as in step 5)[6]

28. Formation of sixth AHP matrix for **economic** barriers (one 7x7 for group ie "lack of any type of financial support ("**lack of financial incentive (Public and private sector)/Lack of funds or access to finance**" – 1; "**Expected costs and risks (high capital costs/Financial risk/Uncertainty on investment/ High cost of innovative technologies for end-users**" – 2; "**Payback expectations/Investment horizons**" – 3; "**Energy prices (Relatively cheap energy and fuel prices/misleading tariff system not reflecting correct prices for energy use/EE)**" – 4; "**Unexpected costs (Hidden costs/Costs vary regionally (Fragmented ability))**" - 5; "**Financial crisis/Economic stagnation**" – 6; "**Embryonic markets**" – 7)
29. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 2, but know for the 7x7 matrix)
30. Calculation of weight coefficients for the economic barriers (same procedure as in step 3)
31. Conduction of consistency tests- Calculation by Saaty approach

[6] No calculation of consistency indexes for 2x2 matrixes.

a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient)
b. Sum the products and divide by the first weight coefficient. This will be A1
c. Multiply the first cell of the second row with the first weight coefficient etc
d. Sum up the products and divide with the second weight coefficient. This will be A2.
e. Repeat the steps i, ii for the remaing rows.
f. Add outcomes A1, A2, A3, A4, A5, A6 and A7 and divide the sum with seven.
g. Calculate the fraction (outcome of step f – 7)/(7-1). This will be consistency index CI for the specific AHP matrix.
h. Calculate Cr = CI/1.32
i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.

32. Accept results or not
33. If no go to step 30

34. If yes formation of seventh (last) AHP matrix for **institutional** barriers (one 8x8 for sub-group) (ie "**Split Incentive**" – 1; "**Legislation issues (Lack of relevant legislation/Lack of regulatory provision/ Change of legislation for local/regional administrative division/complex/inadequate procedures)**" – 2; "Building stock characteristics/aging stock/historical preservation" – 3; "Poor compliance with efficiency standards or construction standards/technical problems/performance gap/mismatch" – 4; "Lack of data/information-diversion of management" – 5; "Barrier to behavior change due to problematic implementation network/governance framework (inadequate implementation network/governance framework/inadequate implementation of policy measures/ poor policy coordination across different levels/ cooperation of municipalities"-6; "Disruption/hassie factor" – 7; "Security of supply" – 8)
35. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions ((same procedure as in step 2, but know for the 8x8 matrix)
36. Calculation of weight coefficients for the institutional barriers (same procedure as in step 2)
37. Conduction of consistency tests - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient)
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps i, ii for the remaing rows.
    f. Add outcomes A1, A2, A3, A4, A5, A6, A7 and A8 and divide the sum with number eight.
    g. Calculate the fraction (outcome of vi – 8)/(8-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/1.41
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.

38. Accept results or not
39. If no go to step 35

40. If yes calculation of total weight coefficient for each barrier

a. Multiply Weight coefficient of group*Weight coefficient of sub-group* weight coefficient of barrier ie (for example)
   $WC_{s1} = W_{s\text{-}c\text{-}e} * W_s * W_{s1\ldots\ldots}$
   $WC_{E1} = W_E * W_{e1}$

Prepared by: "*National & Kapodistrian University of Athens-Energy Policy and Development Centre*"

A DECISION SUPPORT TOOL (DST) REFLECTING END-USERS BEHAVIOUR IN ENERGY EFFICIENCY MODELLING

D.3.2

PART OF WORK PACKAGE 3: FORWARD-LOOKING SCENARIO ANALYSIS, FOCUSING ON MACROECONOMIC AND MICROECONOMIC IMPACTS OF ENERGY EFFICIENCY POLICY OPTIONS

REPORT – PART II (IMPLEMENTATION)

DATE: JULY 2017

HERON project

"Forward-looking socio-economic research on Energy Efficiency in EU countries"

Contract no: 649690

Institution: *Energy Policy & Development Centre – National & Kapodistrian University of Athens*

Steering Committee member [(1)]***:*** *Prof. Dimitrios MAVRAKIS*

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[(1)] *The Steering Committee member has the responsibility for ensuring the quality of the report.*

HERON: Forward – looking socio-economic research on Energy Efficiency in EU countries

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GLOSSARY

Barrier

It is an element that limits the individuals' willingness to implement policies.

For instance, difficulties in trusting new technologies or lack of information about potential energy efficiency benefits are considered barriers (HERON, Deliverable 2.5).

Bounded rationality

A situation under which individuals do not make decisions in the manner assumed in economic models, because of constraints on time, attention, and the ability to process information (Knoblocha F. and Mercure J. - F., 2016).

Therefore, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentives.

Building Energy Management System (BEMS)

A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems (HERON, Deliverable 2.5).

Customs, habits and relevant behavioral aspects

A tradition or a usual way to behave[1]. Furthermore, habit is a particular act or way of acting that a person tends to do regularly[2].

Hassie factor

The required time and effort to find accurate information or appropriate finance so as to move forward to (CBI, 2016; Newfoundland Labrador, 2011).

It is a barrier linked with the end-users since they need time and effort for finding suitable contractors or clearing out a basement for having it insulated (Newfoundland Labrador, 2011). It is also linked with the fact that end-users disrupt the scheduled work for retrofit due to limited time and efforts (HERON Deliverable 2.1).

For overcoming this barrier, a government needs to take a holistic view of the customer journey, design and implement a policy framework that drives and facilitates consumer demand for EE measures (CBI, 2016).

Inertia

The resistance of end-users to change. Individuals are, in part, creatures of habit and established routines, which may make it difficult to create changes to such behaviours and habits (Thollander et al, 2010, p. 56). The more radical the change, the higher the barrier (HERON, Deliverable 3.1).

[1] Source: http://www.yourdictionary.com/custom#e3Fw6Uevh7IEf6Sh.99
[2] Source: http://dictionary.cambridge.org/us/dictionary/english/habit

Light-Emitting Diode (LED)

A light-emitting diode (LED) is a two-lead semiconductor light source. LEDs have many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching.

Rebound effect

The situation which occurs when energy efficiency improvements counter-intuitively lead to higher levels of energy consumption or to the creation of wealth from the energy savings (HERON, 2015 -2.1; UNEP, 2014).

This happens when an energy service becomes cheaper relatively to other goods and services and leads to increased consumption. Rebound effects can therefore have positive social and economic consequences but may lead to a conflict with the goal to reduce energy use and emissions.

Socio-economic status of building users

Set of factors related to the end-user who lives or works in a building/apartment. These factors are: Age, income, economic background, level of education, job - professional category, health conditions, lifestyle, region – climate/geographical zone, level of familiarization with technology, size of family (Omar Jridi, Fethi Zouheir Nouri, 2015; Jacob M., 2007).

Split incentive(s)

The transactions under which the party that covers the expense, does not receive the benefit of this expense/investment. Regarding energy efficiency, the split incentive(s) are caused between the owners and the tenants due to traditional lease structures (City of Boulder, 2016).

The owner wants to minimize the purchase cost of energy related systems and technologies (heating, cooling, hot water, efficient appliances etc), and has no return on this investment, while the tenant wants to minimize his/her energy bill. The owner is not encouraged to make investments in energy efficiency since it is the tenant who receives dividend (Charlier Dorothée, 2014). So, the actors who decide which technologies to use (Agent) are not responsible for paying the energy bills (Principal) (HERON, Deliverable 3.1). Finally, none of these two parties wants to invest in an energy efficient system.

It is also encountered with the alternative term “Agent-Principal” issue.

ACRONYMS

AHP	Analytical Hierarchy Process
BAU	Business-As-Usual
BE	Belgium
BEMS	Building Energy Management System
BEVs	Battery Electric Vehicles
BG	Bulgaria
CI	Consistency Index
CNG	Compressed Natural Gas
CRES	Centre for Renewable Energy Sources and Saving
DE	Germany
DST	Decision Support Tool
EE	Estonia
EE	Energy Efficiency
EPBD	Energy Performance Building Directive
EFTA	European Free Trade Association
ESCO	Energy Services COmpany
EU	European Union
EV	Electric Vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GR	Greece
HEVs	Hybrid Electric Vehicles
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IEE	Intelligent Energy Europe
IN	Implementation Network
IT	Italy
KENAK	Energy Efficiency Regulation for Buildings
LEAP	Long-range Energy Alternatives Planning
LED	Light-Emitting Diode
NSIs	National Statistical Institutes
NZEB	Nearly Zero Energy Buildings
PHEV	Plug in Hybrid Vehicle
RS	Serbia

TI	Total Impact
UK	United Kingdom
UNEP	United Nations Environmental Programme
yoy	Year over Year
YPEKA	Ministry of Energy, Environment and Climate Change

EXECUTIVE SUMMARY

Improving energy efficiency is a priority in all decarbonisation scenarios (European Union, 2012). However, there are important barriers for the implementation of an energy efficient strategy that need to be taken into account and used in energy modelling (SEC(2011) 779 final). These barriers are strongly linked with the consumer behaviour.

The HERON partners identified under "*Work Package 2: Mapping and assessment of social, economic, cultural and educational barriers in buildings and transport within each country*" a set of barriers linked with the behavior of end-users in two sectors: buildings (residential and tertiary) and transport. These barriers were grouped into three main categories: i) Social-Cultural-Educational, ii) Economic and iii) Institutional.

This paper presents the Decision Support Tool (DST) that was developed under the HERON programme for transforming the qualitative information about barriers (WP2) into numerical inputs for the development of EE scenarios (WP4).

With the use of the Analytical Hierarchical Process (AHP), comparative analysis is conducted among barriers created by the end users' behavior towards EE targets. Based on qualitative information for the barriers, the user compares, reveals and quantifies the negative impact of each barrier on the set of the assumed targets, in EE modeling. Mathematical expressions using the calculated impact of barriers provide numerical inputs needed to energy modelling for reflecting the end-user behavior in the assumed EE targets. Once the procedure is completed, the policy maker can modify accordingly the available inputs so as to achieve the set targets.

The paper is prepared for two different target groups, experts interested to understand the methodological approach and those that will use the DST. The first chapter presents analytically the methodology of the developed DST (concept, steps, mathematical expressions). The second chapter concerns the implementation of the DST. The third chapter is the manual of the software.

PREAMBLE

Energy Efficiency (EE) consists one of the main pillars of efforts to mitigate climate change. There is plethora of relevant policy instruments (energy labelling, audits etc) that support the penetration of EE technologies and practices, but different types of barriers affect negatively the achievement of targets set under scenarios. According to the Energy Efficiency Communication of July 2014, the EU is expected to miss the 20% energy savings target of year 2020 by 1%-2% (European Commission, 2014; 2012). The Dutch Government lowered its initial reduction target from 30% to 20% (Vringer K. et al., 2016). Also, Malta's 2020 EE target was lowered in 2015 from 0.825 Mtoe to 0.726 Mtoe expressed in primary energy consumption (European Commission, 2015a).

The EE policies and measures due to barriers do not deliver the expected benefits associated with improvements in EE (such as energy savings, reductions in Greenhouse Gases, employment, poverty alleviation etc) (UNEP, 2014; IEA, 2014). Among these types of barriers, those related to end-users behaviour need to be incorporated also in forward looking energy efficiency modelling after being identified and analysed (McCollum L. David et al., 2016; EC, 2015; EEA, 2013).

Forward-looking models are used for medium-to-long-term scenario analyses, aiming to support relevant policy options; some of these models are designed to consider both technological, economical and socio-behavioral elements in developing their scenarios (McCollum L. David et al., under press; Knoblocha F., Mercure J.-F., 2016). Bridging the gap between these elements has historically been presented as a challenge (McCollum L. David et al., under press). Furthermore, demands of improving the design of models so as to become more 'realistic' by incorporating features observed in the real world are increasing (McCollum L. David et al., under press). One group of such features of the 'real world' relates to human behavior.

The demands are based on the following arguments (McCollum L. David et al., under press): i) Models lacking behavioral realism are restricted in evaluating energy efficiency policies and other influences on end-user demand; ii) Improving the behavioral realism of models consequently affects policy-relevant model analysis of EE as part of the climate change mitigation efforts. However, current modeling of behavioral features in energy-economy and integrated assessment models is relatively limited (McCollum L. David et al., under press). Usually, models and particularly Integrated Assessment Models (IAMs) represent the behavior of consumers or energy end-users through economic relationships: energy demand as a function of price, technology investments to minimize levelized costs, etc (McCollum L. David et al., under press).

End-user behaviour is complex and rarely follows traditional economic theories of decision-making (McCollum L. David et al., under press; Frederiks R. et al., 2015; Knoblocha F., Mercure J.-F., 2016). End-users patterns of energy consumption are influenced by social-cultural-educational (status quo, social interactions etc), economic (risks of investment, financial incentives) and institutional factors (split incentives, hassle factor etc) that are characterized as barriers (Vringer K. et al., 2016; Frederiks R. et al., 2015; UNEP, 2014).

Efforts are focused in overcoming existing barriers and increasing the sophistication of energy and economic modelling (European Commission, 2015b; 2014). Key insights in the outcomes of such efforts can guide the effective design and implementation of end-user-focused strategies and public policy interventions to improve the level of EE interventions (by adopting technologies or practices) (Frederiks R. et al., 2015; UNEP, 2014).

The proposed methodology transforms qualitative research outcomes related to barriers linked to end-users behavior, into quantitative ones allowing their incorporation in the form of numerical inputs in forward looking EE modelling.

IMPLEMENTATION

Introduction

The implementation of the developed methodology allows the calculation of the negative impact that barriers created by the end-users behavior have on inputs (concerning technologies and practices) of forward looking energy efficiency scenarios and thus leading to deviation from the expected targets.

The user is provided with the procedure to evaluate the impact of the identified barriers. He/she compares the barriers through pairs and expresses the importance of one barrier over the other using a scale from 1-9. At the end of this procedure the user receives the Total Impact for each of the identified barriers. The Total Impact is a numerical outcome that expresses the contribution of the concerned barrier in preventing the achievement of EE targets.

These numerical outcomes through mathematical expressions are incorporated into the initial inputs of the developed scenarios and the DST provides the diversification of the initially set targets (general or technology oriented) allowing to the user their corrective modification.

The implementation of the DST covers both the initial definition of the negative input that the concerned barriers have on the set EE targets and the capacity of the DST user to examine various combinations allowing the optimization of the scenario analysis inputs.

Implementation for HERON project

In this chapter indicative examples per each step of the methodology described in the previous chapter are presented based on the work of HERON.

Step 1: Selection of multi-criteria decision analysis method

The selection of the AHP fulfills the requirements described in the HERON work. More specifically:

Advantages of AHP	**Use in HERON project** **(Fulfillment of requirements according to GA – Elaboration of the work that has been done)**
AHP is justified mathematically (it is mathematical theory of value, reason and judgment, based on ratio scales) (Eakin H., Bojorquez-Tapia L.A., 2008; Kablan M.M., 2004). ().	Its use allows to define numerically the impact/contribution of each group of barriers and each barrier separately. One group of barriers is compared to the other groups of barriers. Each barrier that belongs in a group/sub-group of barriers is compared with each one of the barriers of the same group/sub-group. Once the impact of each barrier is defined as a number it is easily incorporated in the energy model.

• *AHP presents better the problem.* The main advantage of AHP is the decomposition of the problem into elements (Ishizaka A., Labib A., 2011; Berrittella et al., 2008). Due to this advantage AHP has been combined with almost all the other multi-criteria decision analysis methods. Its hierarchical structure of criteria allows users to focus better on specific criteria and sub-criteria when determining the respective weight coefficients through the pairwise comparisons (Ishizaka A., Labib A., 2011). • Psychologists argue that it is easier and more accurate to express one's opinion only on two alternatives that simultaneously on all (Ishizaka A., Lablb A., 2011).	Its use allows to understand and quantify step by step the contribution of a barrier when this is compared each time with only one other barrier of the same group/sub-group. The pair-wise comparisons allow the calculation of the impact/contribution of the barrier in limiting the efforts for achieving energy savings. Additionally, its use in HERON facilitates the quantification of the contribution of barriers using all the work of WP2 (literature and survey). Its use allows more accurate outcomes so as to overcome the following observed problem. Some of the barriers were characterized by the experts that participated in the survey of *"Task 2.5: Elaboration of a questionnaire for the survey" and in "Task 2.7. Collection and analysis of results",* as having the same high contribution in limiting efforts for achieving energy savings.
AHP offers guidelines in defining the weight coefficients and has a consistency index for verifying their consistency. "*The AHP approach employs a consistency test that can screen out inconsistent judgments, which makes the results reliable.*" (Kablan M.M, 2004).	Its use ensures that the calculated indexes/weight coefficients of the barriers: i) are consistent, reliable and ii) have resulted due to transparent justifications based on given guidelines. These are applied for all national cases in HERON.
• *AHP is suitable for incorporating the preferences of relevant stakeholders regarding the importance of the criteria/sub-criteria* (Fikret K.T., et al., 2016). The method may be impractical for a survey with a large sample size of as 'cold-called[3]' respondents, because they may have a great tendency to provide arbitrary answers, resulting in a very high degree of inconsistency (Wong K.W.J., Li H., 2008).	Its use in HERON is suitable since: i) the material of D.2.1 and D.2.2 can be used for concluding in common barriers for all national cases and for assessing the barriers; ii) all questions of the survey were focusing on the importance of barriers in limiting the efforts of achieving energy savings. Indicatively the following questions are quoted from D.2.5. • Question 1: Please rate the **importance of the following barriers** to the implementation of Energy Efficiency (EE) policies in the building sector of your country • Question 2: According to your expertise, to **what extent** are the following **barriers relevant in limiting interventions** for building fabric upgrade?

[3] A telephone call or visit made to someone who is not known or not expecting contact.

	It is also worth mentioning that the barriers quoted in the questionnaire were referring to the negative aspect of behaviors ie low environmental awareness, low priority, low income, lack of information, low trust to professionals[4]. *So, it was not a matter to characterize environmental awareness as high, low or medium since it was granted that the "low awareness" is a barrier.* The question was how much the barrier of "low awareness" contributes in preventing energy savings. Furthermore, the answers of the questionnaire demonstrate arbitrary (the majority of the experts answered for most of the barriers that they are of high importance) and therefore inconsistency for defining the impact of each barrier. This can be overcome if the answers of the questionnaire are combined with the literature review of D.2.1, the work in D.2.2 and in D.1.4.
• AHP allows qualitative and quantitative approaches for solving a problem (Kilincci O., Onal S.A., 2011; Wong J.K.W., Li H., 2008; Duran O., Aguilo J., 2008). It can handle uncertain, imprecise and subjective data (Srdjevic B., Medeiros Y.D.P., 2008). • The usage of pairwise comparisons does not require the explicit definition of a measurement scale for each attribute (Bozdura F.T. et al., 2007).	Its use in HERON is justified exactly because the available data and information from the questionnaire are characterized as subjective and uncertain (since the experts did not justify the reasons for which they characterized the relevance of a barrier in limiting the efforts for energy savings (either generally in limiting or with the use of a specific technology or approach)). Additionally, no measurement scales were used for awareness or information, but from the beginning it was accepted that awareness is low, information lacks, financial incentives are limited etc. Therefore, AHP is suitable to be used for quantifying the impact of the barriers.
Comparative analysis of MCDA approaches has indicated AHP to be the most popular compared to other methods due to its	Its use in HERON allows the fulfillment of the requirement to develop a DST that will be used also by policy makers. The development

[4] **Educational** aspects mainly referred to the **lack of sufficient communication and information to citizens, as well as the lack of training and competences in professionals involved in EE** (HERON, Deliverable 2.5).

Cultural aspects mainly regarded **low environmental awareness and low priority assigned to EE in investment decisions and low trust in EE professionals**. Finally, **social** aspects mainly referred to the complex decision-making procedures in condominiums and **the low income of old-aged people** (HERON, Deliverable 2.5).

simplicity, easiness to use and great flexibility (Kilincci O., Onal S.A., 2011; W. Ho et al., 2010; Srdjevic B., Medeiros Y.D.P., 2008; Duran O., Aguilo J., 2008; Babic Z., Plazibat N., 1998). It is an easier technique - with the exception of the eigenvalue calculations used to derive the local priorities of the elements in a cluster of the hierarchy and which remain actually hidden from the end-user - compared to MAUT and SMART and with less required cognitive skills compared to MAUT/MAVT and SMART (Ananda J., Herath G., 2009; Petkov D. et al., 2007). The users may directly input judgment data without getting into the mathematical background (Duran O., Aguilo J., 2008).	of the methodology by this manner, allows the users not to get involved with the mathematical background and their involvement is restricted to the minimum efforts from their part ie to express their judgements based on their experience and knowledge. Using the AHP for the DST allows the development of a tool that is aimed to be used by policy and decision makers.
AHP has been used only for the determination of the importance of criteria/factors (alone or in combination with other multi-criteria decision analysis methods) (Kuruoglu E. et al., 2015; Kumar S. et al., 2015; Andrejiova M. et al., 2013).	It is used only to determine the importance/impact of each of the identified barriers in limiting the efforts of achieving energy savings.

Step 2: Categorization of barriers per groups/sub-groups

The initial categorization was done under the work of Deliverable 2.1. The HERON partners identified under "*Work Package 2: Mapping and assessment of social, economic, cultural and educational barriers in buildings and transport within each country*" a set of barriers linked with the behavior of end-users in two sectors: buildings (residential and tertiary) and transport. These barriers were grouped into three main categories: i) Social-Cultural-Educational, ii) Economic and iii) Institutional.

The number of identified barriers per country, type and sector are presented in Table 6 based on the eight reports of "*Task 2.1: Initial mapping of social, economic, cultural and educational barriers to energy efficiency in the building and transport sectors".* The higher number for the case of the UK, is attributed to the fact that the same barriers appeared for different types of EE technologies.

Additionally, for the needs of the methodology, it was ensured that all identified barriers for the seven HERON partners[5] were categorized correctly in groups, sub-groups, with the same rationality (based on the definitions and the provided descriptions of the barriers). So, the same definitions and titles were applied for all national cases.

[5] UA from Belgium terminated its participation in HERON project (13th month).

Table 1: Distribution of number of identified barriers per sector, country and type.

Type of barriers linked with the end-user behaviour	BE	BU	ES	GE	GR	IT	RS	UK
Buildings								
Social	1	7	6	3	15	2	6	22
Cultural	4	2	5	3	3	2	3	4
Educational	5	2	5	1	2	1	4	13
Economic	9	7	10	4	18	3	10	12
Institutional	13	10	6	12	24	6	5	23
Total of barriers for buildings	*32*	*28*	*32*	*23*	*62*	*14*	*13*	*84*
Transport								
Social	1	2	4	4	10	3	3	7
Cultural	2	0	2	8	1	3	1	4
Educational	0	2	1	4	2	0	2	3
Economic	3	4	4	9	5	7	2	8
Institutional	1	6	5	8	6	11	2	20
Total of barriers for transport	*7*	*14*	*16*	*33*	*24*	*24*	*10*	*42*
TOTAL	**39**	**42**	**48**	**56**	**86**	**38**	**23**	**126**

Step 3: Merging the same/similar barriers

For the majority of the identified barriers, each partner used a different title for describing the barrier. Common titles were used for reflecting the same case of an identified barrier. Barriers that referred to the same core issue, were merged into one barrier with a more general title.

Analytically these actions are presented below. Under D.2.1, there is a mapping of barriers in the building sector. In total there are 16+13+16 = 45 commonly presented barriers. For each category, the categorized barriers were examined if finally, they present the same situation.

A. <u>Social-Cultural-Educational</u>

Under the group “Social, Cultural and Educational” there are 16 identified barriers among the eight countries of the HERON project. For comparing them under the AHP, it is needed to create barriers that are independent and do not have interactions or links among them. The initially identified barriers are presented in the following table (Table 2).

Table 2: Identified barriers for the first category "Social-Cultural-Educational".

	Barrier	BE	BG	EE	DE	GR	IT	RS	UK	No.
Social	Social group interactions and status considerations	x			x	x	x	x	x	1
	Socio-economic status of building users	x		x		x	x	x	x	2
	Strong dependency on the neighbors in multi-family housing		x	x		x	x			3
	Inertia		x			x		x	x	4
	Low income of aged people		x	x	x					5
	Commitment and motivation of public					x		x	x	6
	Rebound effect			x					x	7
	Expectations for electricity prices to remain low in the future							x		8
Cultural	Lack of interest/low priority/Undervaluing energy efficiency	x	x	x	x	x	x	x	x	9
	Customs, habits and relevant behavioural aspects	x	x	x		x	x	x	x	10
	Bounded rationality/Visibility of energy efficiency	x		x	x	x		x	x	11
	Missing credibility/mistrust of technologies and contractors				x	x		x	x	12
Educational	Training and skills of professionals	x	x	x		x	x	x	x	13
	Lack of trusted information, knowledge and experience		x	x		x		x	x	14
	Lack of awareness on savings potential			x	x	x		x	x	15
	Lack of knowledge /information gap on technologies	x		x	x	x			x	16

Merging "Social barriers"

Barriers that were identified in three or less countries were examined if they had similarities with others, so as to be merged. Also, the perception that market stakeholders had for the barriers as this was reflected in the survey (Deliverable 2.5) was taken into consideration. The rationality was to cover as much as possible different types of barriers, without repeating the same concept.

The 2nd and the 5th barrier were combined into one, since they are similar. Low income is an economic status, while aged people are a specific social status of building users. The 5th barrier is part of the 2nd one.

The 6th and the 8th barrier were also considered as one type of barrier that is linked with social support. This conclusion was extracted from the descriptions provided in the Hellenic and the Serbian report under Deliverable 2.1. The 8th barrier falls under this broader title because for the Serbian citizens, since the electricity companies are public, their expectation is linked with public social support.

The 15th and 16th barriers of table 2 were merged into one due to their similar content. The same happened for 13th and 14th barrier as well.

Merging "Cultural barriers"

No merging in this sub-group.

Merging "Educational barriers"

The 1st and the 2nd barrier of this sub-group (13th and 14th of table 2) were combined into one concerning the lack of professional assistance towards end-users either through trained and skilled professionals or trusted information, knowledge and experience on energy saving issues. So, the two barriers were combined into one.

The 3rd and the 4th barrier of this sub-group (15th and 16th of table 2) are similar since they concern the low awareness that the end-users have in achieving energy savings. One of the options to do that is to know about the relevant technologies. So, the two barriers were combined into one.

Table 3: Merged barriers (f is used for the frequency under which the barrier is identified among the eight HERON countries, ie 6/8 means that it was identified in 6 of the 8 countries).

	Barrier	BE	BG	EE	DE	GR	IT	RS	UK	f	No.
Social	Social group interactions and status considerations	x			x	x	x	x	x	6/8	1
	Socio-economic status of building users	x	x	x	x	x	x	x	x	8/8	2
	Strong dependency on the neighbors in multi-family housing		x	x		x	x			4/8	3
	Inertia		x			x		x	x	4/8	4
	Commitment and motivation of public social support					x		x	x	3/8	5
	Rebound effect			x					x	2/8	6
Cultural	Lack of interest/low priority/Undervaluing energy efficiency	x	x	x	x	x	x	x	x	8/8	7
	Customs, habits and relevant behavioural aspects	x	x	x		x	x	x	x	7/8	8
	Bounded rationality/Visibility of energy efficiency	x		x	x	x		x	x	6/8	9
	Missing credibility/mistrust of technologies and contractors				x	x		x	x	4/8	10
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	x	x	x	x	x	x	x	x	8/8	11
	Lack of awareness/knowledge on savings potential/information gap on technologies	x		x	x	x		x	x	6/8	12

So, the new titles of the barriers in the revised table 3 were selected so as to be more general and to represent the common characteristic of the identified barriers that were merged. For the 11th barrier in Table 3, Germany was added (absent in table 2) based on information from the description of its institutional barriers.

B. Economic barriers

The same work as in the previous group was performed also.

Table 4: Identified barriers for the category "Economic barriers" for the building sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	No.
Lack of financial incentive (Public and Private sector)		x	x	x	x	x	x	x	1
High capital costs/Financial risk	x	x	x	x	x			x	2
Lack of funds or access to finance	x		x		x	x	x	x	3
Payback expectations/investment horizons				x	x	x	x	x	4
Uncertainty on investment	X	x		x	x			x	5
Economic status of building users	x		x		x		x	x	6
High cost of innovative technologies for end-users			x		x			x	7
Relatively cheap energy and fuel prices		x	x				x		8
Hidden costs	x	x						x	9
Financial crisis/Economic stagnation		x			x	x			10
Embryonic markets					x			x	11
Tariff system not reflecting energy use/EE		x					x		12
Costs vary regionally (Fragmented ability)			x						13

The 1st and the 3rd barrier are similar from the point that end-users (building owners, consumers, hotel owners) cannot receive any type of financial support (either financial incentive, funds for investments etc). This is also understood as one barrier according to the survey outcomes (Deliverable 2.5).

The 2nd and the 5th barrier are similar. Uncertainty in investment is also a risk.

The 7th barrier is also similar from the point that end users do not purchase innovative technologies due to their high costs as in 2nd barrier (reluctance to make any type of investment).

The 6th barrier indeed concerns only "economic status of building users", but since it was already mentioned in the previous category of barriers (Social ones) it was not included here (that is why it is in red color).

The 9th and the 13th barrier were merged in one barrier about costs (hidden and fragmented). These are a category of costs that could not be foreseen. They are unexpected. One would expect that the costs for energy efficiency technologies are almost the same across one country.

The 12th barrier was merged with the 8th, since in the reports that these barriers were quoted (Bulgarian and Serbian) low energy prices are the main reason that prevents end-users from achieving energy savings and not to vary regionally.

The merged barriers and the common titles are presented in Table 5.

Table 5: Merged "Economic" barriers for the building sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	f	No
Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	x	x	x	x	x	x	x	x	8/8	1
High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	x	x	x	x	x			x	6/8	2
Payback expectations/investment horizons				x	x	x	x	x	5/8	3
Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE		x	x				x		3/8	4
Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	x	x	x					x	4/8	5
Financial crisis/Economic stagnation		x			x	x			3/8	6
Embryonic markets					x			x	2/8	7

C. Institutional barriers

Similarly, the identified barriers of table 6 were merged to the barriers of table 7, based on the following justifications.

Table 6: Identified barriers for the category "Institutional barriers" for the building sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	No
Split Incentive	x	x	x	x	x	x	x	x	1
Complex/inadequate regulatory procedures		x	x	x	x	x	x	x	2
Lack of relevant legislation/Lack of regulatory provision		x			x	x	x	x	3
Building stock characteristics/aging stock	x		x		x	x		x	4
Technical problems/ Performance gap			x	x	x			x	5
Missing support chains/Skills and training	x			x		x		x	6
Policy coordination across different levels/cooperation of municipalities	x		x		x	x			7
Lack of data/information-diversion of management		x	x		x			x	8
Inadequate implementation network/governance framework				x	x		x		9
Historical preservation		x			x			x	10
Disruption/Hassie factor				x	x			x	11
Poor compliance with efficiency standards/construction standards	x				x			x	12
Mismatch between policy and occupant reality				x	x			x	13
Inadequate implementation of policy measures				x	x	x			14
Change of legislation for local/regional administrative division		x			x				15
Security of fuel supply			x					x	16

The 9th and 14th barrier are similar and were merged into one.

The 5th and the 12th concern the difference between what was meant to be achieved and was actually achieved. There is also a difference in what the occupants desire and what the policy package/instrument requires. So, generally speaking a difference in what the end user finally achieves or desires to achieve. It is a compliance issue.

The 6th barrier is presented under the first group of barriers as mistrust and lack of professionals (Cultural barrier). It is also covered under inadequate implementation network.

The 4th and the 10th concern the special characteristics of buildings that can create a barrier. This includes also historical preservation issues.

The 3rd and the 15th barrier are about problems generated either by the lack or the change of legislation.

The 7th barrier concerns the functionality of the implementation network. Poor coordination affects its performance and the quality of assistance that it can offer to end-users. So, it was included with 9th and 14th barrier as one.

The 2nd, the 3rd and the 15th concern regulations and legislations. Either there is lack of the appropriate regulatory provisions, or the current ones are complex and time-consuming for end-users.

Table 7: Merged "institutional barriers" for the building sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	f	No.
Split Incentive	x	x	x	x	x	x	x	x	8/8	1
Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)		x	x	x	x	x	x	x	7/8	2
Building stock characteristics/aging stock/ Historical preservation	x	x	x		x	x		x	6/8	3
Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	x		x	x	x			x	5/8	4
Lack of data/information-diversion of management		x	x		x			x	4/8	5
Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities)	x		x	x	x	x	x		6/8	6
Disruption/Hassie factor				x	x			x	3/8	7
Security of fuel supply			x					x	2/8	8

Finally, there are 12+7+8 = 27 barriers now in all three groups.

After the completion of this step a common AHP tree for all national cases under HERON was formed. An additional check was performed so as to secure that all identified barriers for the seven HERON countries fall under the groups, sub-groups and merged barriers.

The same rationality can be applied for any other case (for a country or group of countries, region or municipality).

Step 4: Formation of the AHP tree and the AHP matrixes

For each of the seven national cases of HERON, the AHP tree of barriers is the one presented in Figure 1 of the methodology (Report 3.2 – Part I). The final set of the identified barriers for the building sector is that of Table 4 of the methodology.

Step 5: Pair-wise comparisons

Step 5.1: First level pair-wise comparisons

An indicative example of a filled AHP matrix of the first level for the **building sector** is shown in Table 8. It is a general example and not oriented for one of the seven HERON countries.

The intensities (Table 2 of the methodology) were assigned considering: i) the number of identified barriers in the first group is higher compared to the second one (information quoted under task 2.1), ii) the easiness with which each group can be confronted (information quoted under task 2.1); iii) the different sub-groups to which it can be divided; and iv) the preferences of the experts that filled in the questionnaire in Task 2.5.

Table 8: AHP matrix for pair-wise comparisons.

Barriers linked with end-users behaviour	**Social-Cultural-Educational**	**Economic**	**Institutional**
Social-Cultural-Educational	1	5	3
Economic	1/5 = 0.2	1	0.5
Institutional	1/3 = 0.333	2	1

Step 5.2: Calculation of indexes for the first level of the AHP tree

An indicative example of the calculated weight coefficients is presented in table 9. The outcomes in the right column mean that: The impact/contribution of the "Social-Cultural-Educational" category of barriers limits the efforts for achieving energy savings by 0.648 (or 64.8%). The group of "Economic" barriers prevents the accomplishment of energy savings by 0.122 and the group of "Institutional" barriers by 0.230.

Table 9: AHP matrix for pair-wise comparisons. Values in green color aim to facilitate users of the DST to understand the background calculations.

Barriers linked with end-users behaviour	Social-Cultural-Educational	Economic	Institutional	Sum of outcomes	Weight coefficients
Social-Cultural-Educational	1	5	3	*1.944*	**0.648**
Economic	1/5 = 0.2	1	0.5	*0.367*	**0.122**
Institutional	1/3 = 0.333	2	1	*0.690*	**0.230**
Sum of column	*1.533*	*8*	*4.5*		

Step 5.3: Calculation of the consistency test

For table 9, CR* is equal to 0.003<0.10. Therefore, the calculated weight coefficients are accepted.

Step 5.4: Calculation of indexes for the second level of barriers of the AHP tree

An indicative AHP matrix for this level for the building sector is shown in Table 10. The user is facilitated in this level for assigning the intensities of AHP scale (table 2 of the methodology) by considering: i) if the number of identified barriers in the first group is higher compared to the second one (using the information quoted under D.2.1), ii) the easiness with which each group can be confronted (using the information quoted under D.2.1); iii) the different sub-groups to which it can be divided; and iv) the preferences of the experts that filled in the questionnaire in Task 2.5. Calculations follow the same procedure as in step 5.2

Table 10: AHP tree for barriers that synthesize the group "Social-Cultural-Educational"

Barriers linked with end-users behaviour	**Social**	**Cultural**	**Educational**	**Weight coefficients**
Social	1	3	2	**0.539**
Cultural	1/3 = 0.333	1	0.5	**0.164**
Educational	1/2 = 0.5	2	1	**0.297**

Again, the consistency test is performed and the outcome is CR* = 0.008 <0.10 The indexes can be used since they are consistent.

Using the results of the previous examples, the weight coefficients for the sub-groups of the group "Social-Cultural-Educational" are:

"Social barriers" impact = Index $_{\text{social-cultural-educational}}$ * index $_{\text{social}}$ = 0.648 * 0.539 = 0.350

"Cultural barriers" impact = Index $_{\text{social-cultural-educational}}$ * index $_{\text{cultural}}$ = 0.648 * 0.164 = 0.106

"Educational barriers" impact = Index $_{\text{social-cultural-educational}}$ * index $_{\text{social}}$ = 0.648 *0.297 = 0.192

The figure 0.350 means that the sub-group "Social barriers" is by 35% responsible for preventing the achievement of energy savings. Similarly, "Cultural barriers" are for 10.6% and "Educational barriers" by 19.2%.

Step 5.5: Calculation of indexes for the third level of barriers

For performing the pair-wise comparisons of this level, the user needs to assign the intensities (Table 2 of the methodology) by taking into consideration the following:

- The number of different resources that identified the same barrier (information from D.2.1);
- The number of sub-sectors that were linked with the same barrier (information from D.2.1);
- The easiness with which the barrier can be confronted barrier (information from D.2.1);
- The duration of the barrier (information from D.2.1);
- The number of different policy instruments that were linked with the same type of barrier (information from D.2.1).
- If one of the two compared barriers is identified as a cross-cutting barrier (information from D.2.2)
- The preferences of the stakeholders as these were expressed in the questionnaire barrier (information from D.2.5).

The aforementioned information for the case of Greece is presented in **Annex 1**.

Table 11, shows such an AHP matrix (it is not for a HERON country), but for all eight HERON countries as a total, considering the following conditions:

- The number of countries at which the barrier has been identified;
- The characterization of the barrier as "High", "Medium", "Low";
- The characterization as a cross-cutting barrier (common for buildings and transport sector);
- If it was identified as a main one during the survey under 2.5 and the percentage that it received there (higher or lower) compared to another one.

So, in table 11 intensities were assigned during the pair -wise comparison of the first barrier with the others as following:

i) For "*Social group interactions and status considerations*" and "*Socio-economic status of building users*" the following where considered based on the above aspects: i) the second one is encountered in all eight (8) countries of HERON, while the first in 6 of them; ii) the second is characterized as significant in three countries (Bulgaria, Estonia and UK); iii) the first one is a cross-cutting issue for six of the eight countries, while the second is not; iv) the second one ranked first in the survey with 11.7% of the total grade options while the first 15th with 2.80%. So "Socio-economic status of building users" prevails in three of the six aspects clearly. So, the intensity is 5 for the second barrier.

ii) For "*Social group interactions and status considerations*" and "*Strong dependency on the neighbors in multi-family housing*": i) the first is encountered in 6 countries while the second in 4; the second is "High" in two countries (Bulgaria, Estonia), while the first in one "Belgium"; iii) the second is not a cross – cutting barrier; iv) the second is not identified as a main barrier in the survey, while the first is in the 15th position. So, the intensity is 4, the first is more significant than the second, but not very much.

iii) For "*Social group interactions and status considerations*" and "Inertia", i) the first is encountered in 6 countries while the second in 4; ii) both are characterized as "High" in one country (Belgium the first, UK the second); iii) the first one is a cross-cutting issue for six of the eight countries, while "inertia" is a cross-cutting barrier in two of the eight countries (Serbia and UK); iv) the second is not identified as a main barrier in the survey, while the first is in the 15th position. They are closer compared to the previous comparison, so intensity 3.

iv) For "*Social group interactions and status considerations*" and "*Commitment and motivation of public social support*": i) the first is in 6 out of 8 countries, while the second in 3; ii) the first is "High" in one country the second in none; iii) the first is s cross-cutting barrier, while the second not; iv) the second is not identified as a main barrier in the survey, while the first is in the 15th position. The first is more important than the second one. The intensity is 5.

v) For "*Social group interactions and status considerations*" and "*Rebound effect*": i) the first sis in 6 out of 8 countries, while the second in 2; ii) both are "High" in one, while the first is "Medium" in three and the second in one; iii) iii) the first is s cross-cutting barrier, while the second not; iv) the second is not identified as a main barrier in the survey, while the first is in the 15th position. The first is more important than the second one. The intensity is 5.

Table 11: AHP matrix for the third level of barriers (Social barriers – building sector).

Social barriers	Social group interactions and status considerations	Socio-economic status of building users	Strong dependency on the neighbours in multi-family housing	Inertia	Commitment and motivation of public social support	Rebound effect	Weight coefficients
Social group interactions and status considerations	1,000	0,200	4,000	3,000	5,000	5,000	**0,224**
Socio-economic status of building users	5,000	1,000	7,000	5,000	7,000	7,000	**0,495**
Strong dependency on the neighbours in multi-family housing	0,250	0,143	1,000	1,000	3,000	2,000	**0,090**
Inertia	0,333	0,200	1,000	1,000	3,000	2,000	**0,097**
Commitment and motivation of public social support	0,200	0,143	0,333	0,333	1,000	1,000	**0,045**
Rebound effect	0,200	0,143	0,500	0,500	1,000	1,000	**0,049**

Again, the consistency test is performed and the outcome is CR* = 0.046 <0.10 (Table 11). The indexes can be used since they are consistent.

Similarly, the consistency test was performed for all AHP matrixes. When the consistency test was not fulfilled, adjustments were inserted and calculations were repeated. The presented outcomes in Tables 12, 13, 14 and 15 are fulfilling the condition of the consistency test.

Table 12: AHP matrix for the third level of barriers (Cultural barriers – building sector).

Cultural barriers	Lack of interest/low priority/Undervaluing energy efficiency	Customs, habits and relevant behavioural aspects	Bounded rationality/Visibility of energy efficiency	Missing credibility/mistrust of technologies and contractors	Weight coefficients
Lack of interest/low priority/Undervaluing energy efficiency	1,000	1,000	5,000	7,000	**0,423**
Customs, habits and relevant behavioural aspects	1,000	1,000	7,000	5,000	**0,426**
Bounded rationality/Visibility of energy efficiency	0,200	0,143	1,000	2,000	**0,088**
Missing credibility/mistrust of technologies and contractors	0,143	0,200	0,500	1,000	**0,063**

Table 13: AHP matrix for the third level of barriers (Educational barriers – building sector).

Educational barriers	Lack of trained and skilled professionals/ trusted information, knowledge and experience	Lack of awareness/knowledge on savings potential/information gap on technologies	Weight coefficients
Lack of trained and skilled professionals/ trusted information, knowledge and experience	1,000	3,000	**0,750**
Lack of awareness/knowledge on savings potential/information gap on technologies	0,333	1,000	**0,250**

Table 14: AHP matrix for the third level of barriers (Economic barriers – building sector).

Economic barriers	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	Payback expectations/investment horizons	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	Financial crisis/Economic stagnation	Embryonic markets	Weight coefficients
Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	1,000	2,000	3,000	9,000	9,000	7,000	9,000	**0,409**
High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	0,500	1,000	2,000	6,000	5,000	4,000	7,000	**0,244**
Payback expectations/investment horizons	0,333	0,500	1,000	4,000	4,000	2,000	5,000	**0,150**
Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	0,111	0,167	0,250	1,000	0,500	0,500	1,000	**0,036**
Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability)) Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	0,111	0,200	0,250	2,000	1,000	0,333	2,000	**0,050**
Financial crisis/Economic stagnation	0,143	0,250	0,500	2,000	3,000	1,000	2,000	**0,077**
Embryonic markets	0,111	0,143	0,200	1,000	0,500	0,500	1,000	**0,034**

Table 15: AHP matrix for the third level of barriers (Institutional barriers – building sector).

Institutional barriers	Split Incentive	Legislation issues	Building stock characteristics/aging stock/ Historical preservation	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	Lack of data/information-diversion of management	Problematic implementation network/governance framework	Disruption/Hassie factor	Security of fuel supply	Weight coefficients
Split Incentive	1,000	3,000	3,000	5,000	7,000	5,000	6,000	7,000	**0,331**
Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	0,333	1,000	3,000	5,000	7,000	5,000	5,000	7,000	**0,245**
Building stock characteristics/aging stock/ Historical preservation	0,333	0,333	1,000	2,000	5,000	3,000	7,000	7,000	**0,159**
Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	0,200	0,200	0,500	1,000	2,000	0,500	5,000	5,000	**0,083**
Lack of data/information-diversion of management	0,143	0,143	0,200	0,500	1,000	0,333	1,000	1,000	**0,033**
Problematic implementation network/governance framework	0,200	0,200	0,333	2,000	3,000	1,000	3,000	5,000	**0,089**
Disruption/Hassie factor	0,167	0,200	0,143	0,200	1,000	0,333	1,000	1,000	**0,032**
Security of fuel supply	0,143	0,143	0,143	0,200	1,000	0,200	1,000	1,000	**0,028**

Step 6: Calculation of Total Impact per barrier

The following Total impacts for the identified barriers were calculated as an indicative example based on the calculated numerical outcomes of the previous tables, ie

For "**Social barriers**" the calculations are:

b_{1s} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{social}$ * w_{s1} = 0.648 * 0.539 * 0.224 = 0.350 * 0.224 = 0.078

b_{2s} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{social}$ * w_{s2} = 0.648 * 0.539 * 0.495 = 0.350 * 0.495 = 0.173

etc and the same procedure is followed for all barriers.

Following the same procedure, the impact of the "**Cultural barriers**" is

b_{c1} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{cultural}$ * w_{c1} = 0.648 * 0.164 * w_{c1} = 0.106 * w_{c1}

b_{c2} impact = Index $_{social\text{-}cultural\text{-}educational}$ * index $_{cultural}$ * w_{c2} = 0.648 * 0.164 * w_{c2}= 0.106 * w_{c2}

etc

For "**Educational barriers**" the same.

For the "**Economic**" barriers

b_{EC1} = Index $_{Economic}$ * w_{EC1} = 0.122 * w_{EC1}

b_{EC1} = Index $_{Economic}$ * w_{EC2} = 0.122 * w_{EC2}

etc

For "**Institutional**" barriers

b_{I1} = Index $_{Istitutional}$ * w_{I1} = 0.230 * w_{EC1}

b_{I2} = Index $_{Institutional}$* w_{I2} = 0.230 * w_{EC2}

etc

The Total impact of group "Social-Cultural-Educational" is calculated as

$TI_{S\text{-}C\text{-}E} = TI_s(TI_{s1},TI_{s2}, ...TI_{sn}) + TI_C(TI_{c1},TI_{c2},....TI_{Ck}) + TI_E(TI_{E1},TI_{E2},.....TI_{Em})$

$= TI_{s1} + TI_{s2} + ……TI_{sn} + TI_{c1}+TI_{c2}+…TI_{ck} + TI_{E1}+TI_{E2}+……TI_{Em}$

$= 0.648$

Similarly,

Total impact of "Social", $TI_s = TI_{s1}+ TI_{s2} + ……TI_{sn} = 0.350$

Total impact of "Cultural", $TI_C = TI_{c1}+TI_{c2}+…TI_{ck} = 0.106$

Total impact of "Educational", $TI_E = TI_{E1}+TI_{E2}+……TI_{Em} = 0.193$

Total impact of group "Economic", $TI_{Ec} = TI_{Ec1} + TI_{Ec2} + ……TIc_{Ej} = 0.122$

Total impact of group "Institutional", $TI_I = TI_{I1} + TI_{I2} + ……TI_{In} = 0.230$

So finally, in Tables 16 and 17, the outcomes are presented. All calculations are analytically presented in Annex 2.

Table 16: Presentation of final calculations for the Total impact of each identified barrier.

Group of barrier	Type of barrier	Symbol	Total Impact of barrier	Function of total impact of barrier
Social-Cultural – Educational	Social	b_{s1}	0.350 * w_{s1}	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$
Social-Cultural – Educational	Social	b_{s2}	0.350 * w_{s2}	$TI_{s2} = W_{S\text{-}C\text{-}E} * W_s * W_{s2}$
…..	….	….	….	….
Social-Cultural – Educational	Social	b_{sn}	0.350 * w_{sn}	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{sn}$
Social-Cultural – Educational	Cultural	b_{c1}	0.350 * w_{c1}	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c1}$
Social-Cultural – Educational	Cultural	b_{c2}	0.350 * w_{c2}	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c2}$
…..	….	….	….	…..
Social-Cultural – Educational	Cultural	b_{ck}	0.350 * w_{ck}	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{ck}$
Social-Cultural – Educational	Educational	b_{E1}	0.350 * w_{E1}	$TI_{E1} = W_{S\text{-}C\text{-}E} * W_E * W_{E1}$
Social-Cultural – Educational	Educational	b_{E2}	0.350 * w_{E1}	$TI_{E2} = W_{S\text{-}C\text{-}E} * W_E * W_{E2}$
……..				
Social-Cultural – Educational	Educational	b_{Em}	0.350 * w_{Em}	$TI_{Em} = W_{S\text{-}C\text{-}E} * W_E * W_{Em}$
Economic	Economic	b_{EC1}	0.122 * w_{EC1}	$TI_{EC1} = W_{EC} * W_{EC1}$
Economic	Economic	b_{EC2}	0.122 * w_{EC2}	$TI_{EC2} = W_{EC} * W_{EC2}$
……	….	….	……	……
Economic	Economic	b_{ECj}	0.122 * w_{ECj}	$TI_{ECj} = W_{EC} * W_{ECj}$
Institutional	Institutional	b_{I1}	0.230 * w_{I1}	$TI_{I1} = W_I * w_{I1}$
Institutional	Institutional	b_{I2}	0.230 * w_{I2}	$TI_{I2} = W_I * w_{I2}$
……..	……	….	……	……..
Institutional	Institutional	b_{Ia}	0.230 * w_{Ia}	$TI_{Ij} = W_I * w_{Ia}$

Table 17: Indicative example of calculated indexes that express the contribution of the barrier in limiting efforts for energy savings for the building sector. The names of the barriers resulted after checking which barriers were the same in content and which could be related so as to form one barrier.

Type	Name of barrier	Function	Index/weight coefficient
Social	Social group interactions and status considerations	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$	**0,648*0,539*0,224 = 0,078**
Social	Socio-economic status of building users	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$	**0,648*0,539*0,495 =0,173**
Social	Strong dependency on the neighbors in multi-family housing	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$	**0,648*0,539*0,090 = 0,031**
Social	Inertia	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$	**0,648*0,539*0,097 = 0,034**
Social	Commitment and motivation of public social support	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$	**0,648*0,539*0,045 = 0,016**
Social	Rebound effect	$TI_{s1} = W_{S\text{-}C\text{-}E} * W_s * W_{s1}$	**0,648*0,539*0,049 = 0,017**
Cultural	Lack of interest/low priority/Undervaluing energy efficiency	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c1}$	**0,648*0,164*0,423 = 0,045**
Cultural	Customs, habits and relevant behavioural aspects	$TI_{c1} = W_{S\text{-}C\text{-}E} * W_c * W_{c2}$	**0,648*0,164*0,426 = 0,045**
Cultural	Bounded rationality/Visibility of energy efficiency	$TI_{c3} = W_{S\text{-}C\text{-}E} * W_c * W_{c3}$	**0,648*0,164*0,088 = 0,009**
Cultural	Missing credibility/mistrust of technologies and contractors	$TI_{c4} = W_{S\text{-}C\text{-}E} * W_c * W_{c4}$	**0,648*0,164*0,063 = 0,007**
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	$TI_{E1} = W_{S\text{-}C\text{-}E} * W_E * W_{E1}$	**0,648*0,297*0,750 = 0,144**
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies	$TI_{E2} = W_{S\text{-}C\text{-}E} * W_E * W_{E2}$	**0,648*0,297*0,250 = 0,048**
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	$TI_{EC1} = W_{EC} * W_{EC1}$	**0,122*0,409 = 0,050**
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	$TI_{EC2} = W_{EC} * W_{EC2}$	**0,122* 0,244 = 0,030**
Economic	Payback expectations/investment horizons	$TI_{EC3} = W_{EC} * W_{EC3}$	**0,122*0,150 = 0,018**
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	$TI_{EC4} = W_{EC} * W_{EC3}$	**0,122*0,036 = 0,004**
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	$TI_{EC5} = W_{EC} * W_{EC5}$	**0,122*0,050 = 0,006**
Economic	Financial crisis/Economic stagnation	$TI_{EC6} = W_{EC} * W_{EC6}$	**0,122*0,077 = 0,009**
Economic	Embryonic markets	$TI_{EC7} = W_{EC} * W_{EC7}$	**0,122*0,034 = 0,004**
Institutional	Split Incentive	$TI_{I1} = W_I * w_{I1}$	**0,230*0,331 = 0,076**
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	$TI_{I2} = W_I * w_{I2}$	**0,230*0,245 = 0,056**
Institutional	Building stock characteristics/aging stock/ Historical preservation	$TI_{I3} = W_I * w_{I3}$	**0,230*0,159 = 0,036**
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/	$TI_{I4} = W_I * w_{I4}$	**0,230*0,083 = 0,019**

	Performance gap/mismatch		
Institutional	Lack of data/information-diversion of management	$TI_{I5} = W_I * w_{I5}$	**0,230*0,033 = 0,008**
Institutional	Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities)	$TI_{I6} = W_I * w_{I6}$	**0,230*0,089 = 0,020**
Institutional	Disruption/Hassie factor	$TI_{I7} = W_I * w_{I7}$	**0,230* 0,032 = 0,007**
Institutional	Security of fuel supply	$TI_{I8} = W_I * w_{I8}$	**0,230*0,028 = 0,007**

Step 7: Repeat steps 2-6 for the transport sector

Transport sector - Step 2: Categorization of barriers per groups/sub-groups

This work was performed under Deliverable 2.1, similarly as for the building sector.

Transport sector – Step 3: Merging the same/similar barriers

In total, there are 21+11+16 = 48 commonly presented barriers under Deliverable 2.1. For each category, the categorized barriers will be examined if finally, they present the same situation.

A. Social – cultural – educational barriers

Following the rationality of the work for the building sector, the identified barriers are limited to the merged ones.

Barriers No. 18, No. 20 and No. 21 were merged into one concerning the lack of instructors/professionals/technicians for transport technologies and practices.

The 15th and the 19th barrier can become one regarding low awareness in the transport sector.

The 5th and the 6th barriers were merged in one under the title “Mobility problems”.

The 14th and 16th barrier concern the lack of knowledge/information in the transport sector about all those issues.

The 8th and the 14th barrier concern the attitude of the end-user in making decisions (either the difference of what he/she should do and what he/she decides to do, also the unwillingness to pay more if the car is considered to be energy efficient). The attitude-action is characterized as social/cultural by UK and nothing by Belgium. The merged barrier was categorized under cultural.

Table 18: Identified "Social-Cultural-Educational" barriers for the transport sector.

	Barrier	BE	BG	EE	DE	GR	IT	RS	UK	f	No
Social	Low satisfaction with public transport/lack of trust		x	x		x	x	x		5/8	1
	Concerns of vehicle reliability/Hesitation to trust new technologies	x			x	x			x	4/8	2
	Heterogeneity of consumers	x						x	x	3/8	3
	Suburbanisation trends/Low density			x	x					2/8	4
	Vulnerability of pedestrians / Lack of adequate space for walking				x		x			2/8	5
	Cruising traffic/ Parking problems					x	x			2/8	6
	Inertia							x	x	2/8	7
	Attitude-action gap	x							x	2/8	8
Cultural	Car as a symbol status and group influence	x	x	x	x	x		x	x	7/8	9
	Habit and social norm of driving, car ownership and use			x	x	x	x	x	x	6/8	10
	Environmental concern/Low priority	x			x	x	x	x	x	6/8	11
	Cycling is marginalized			x			x		x	3/8	12
	Bounded rationality/Buyer attitude				x			x	x	3/8	13
Educational	Lack of knowledge/information on green transport/ULEVs/EVs	x	x		x	x		x	x	6/8	14
	Limited awareness of impact of EE in transport		x		x	x		x	x	5/8	15
	Consumer understanding and use of fuel economy information				x			x	x	3/8	16
	Confusion about car and fuel costs (conventional vs ULEVs/Evs)				x				x	2/8	17
	Lack of certified instructors and examiners for eco-driving					x				1/8	18
	Low public awareness towards eco-driving					x				1/8	19
	Lack of integrated transport/mobility and planning professionals			x						1/8	20
	Lack of trained technicians for ULEVs/Evs								x	1/8	21

The 11th barrier is similar with the 15th. So, they were merged.

Table 19: Merged "Social-Cultural-Educational" barriers for the transport sector.

	Barrier	BE	BG	EE	DE	GR	IT	RS	UK		No
Social	Low satisfaction with public transport/lack of trust		x	x		x	x	x		5/8	1
	Concerns of vehicle reliability/Hesitation to trust new technologies	x			x	x			x	4/8	2
	Heterogeneity of consumers	x						x	x	3/8	3
	Suburbanisation trends/Low density			x	x		x			3/8	4
	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)				x	x	x			3/8	5
	Inertia							x	x	2/8	6
Cultural	Car as a symbol status and group influence	x	x	x	x	x		x	x	7/8	7
	Habit and social norm of driving, car ownership and use			x	x	x	x	x	x	6/8	8
	Cycling is marginalized			x			x		x	3/8	9
	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	x			x			x	x	4/8	10
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	x	x		x	x		x	x	6/8	11
	Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	x	x		x	x	x	x	x	7/8	12
	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*				x				x	2/8	13
	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs			x		x			x	1/8	14

B. Economic barriers

The 1st and the 8th barrier are the same.

The 10th and the 11th barrier concern incentives and employee benefits that encourage mobility in roads and prevent EE transport.

The 7th barrier (absence of taxes-Estonia or negative effect of taxes-Germany) was merged with 1st (Tax policies that favour inefficient modes). So, under the 1st barrier, financial measures/policy instruments that do not support EE in transport are included.

The 4th and the 6th barrier were considered the similar since the refer to high costs related with electric cars (their purchase or their battery purchase).

The 9th barrier is similar to the 4th one in the previous category, so it was omitted from this one and considered for Italy in the previous one.

Table 20: Identified "Economic" barriers for the transport sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	No
Lack of finance for new vehicles/ULEVs/public transport	x	x		x	x	x	x		1
Limited infrastructure investment (road/train/cycling)		x	x		x	x		x	2
Low purchasing power of citizens/Financial crisis		x			x	x	x		3
High cost/Low cost competitiveness of electric vehicles				x	x			x	4
Payback period of fuel efficient vehicles				x				x	5
High cost of batteries for electric vehicles						x		x	6
Inefficient or absent fiscal measures			x	x					7
Limited financial incentives for electric vehicles		x					x		8
Low population density/Urban sprawl			x			x			9
Investment schemes do not encourage transport EE			x	x		x			10
Tax free/low tax company car schemes			x						11

Table 21: Merged "Economic" barriers for the transport sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	f	No
Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	x	x	x	x	x	x	x		7/8	1
Limited infrastructure investment (road/train/cycling) – for public transport		x	x		x	x		x	5/8	2
Low purchasing power of citizens/Financial crisis		x			x	x	x		4/8	3
High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles				x	x	x		x	4/8	4
Payback period of fuel efficient vehicles				x				x	2/8	5
Negative role of Investment schemes/employee benefits encourage transport EE			x	x		x			3/8	6

C. Institutional barriers

The 3rd, 4th, 5th and 7th barrier refer to infrastructure either inefficient or undeveloped or limited. So, does the 12th ie infrastructure for biofuels. The 16th also refers to infrastructure about electric cars/planning of charging spots (Greece-UK).

Table 22: Identified "Institutional" barriers for the transport sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	No
Administrative fragmentation and lack of integrated governance			x	x	x	x	x		1
Transport EE on the Government Agenda		x		x	x	x	x		2
Inefficient urban/public transport infrastructure and planning		x	x	x	x	x			3
Undeveloped cycling/walking infrastructure		x	x		x	x		x	4
Lack of support for rail transportation/Limited rail infrastructure		x	x	x		x			5
Lack of national strategy for bike and pedestrian mobility		x	x		x	x			6
Undeveloped infrastructure for recharging of EV	x			x	x	x		x	7
Limited/complex funding in urban public transport				x	x	x			8
Lack of regular transport services in low density areas		x				x		x	9
Immature status of developing technologies for EVs/ULEVs	x					x		x	10
Range of distance travelled between charges for EVs	X			x				x	11
Biofuel distribution and infrastructure	x					x		x	12
Limited policy on freight efficiency/city logistics				x		x		x	13
Lack of improvements/investments in transport infrastructure				x		x			14
Contradicting policy goals car-oriented planning			x	x					15
Unclear urban planning and traffic road regulations for EVs					x			x	16

The 6th and the 13th barrier are grouped into the same category regarding the lack or the limitation of policies for the transport sector.

The 14th barrier concerns the financing of transport infrastructure (Germany-Italy). This was mentioned in the previous category and is also covered now under the 2nd barrier.

The 8th barrier is similar with an economic barrier, but here it refers to the procedures/institutional difficulties.

The 9th barrier deals with the low public transport services in villages/small towns. The frequency of routes etc is low and unattractive (low satisfaction with public transport). This is covered under a barrier of the first category and for this category under "problems with infrastructure".

Table 23: Merged "Institutional" barriers for the transport sector.

Barrier	BE	BG	EE	DE	GR	IT	RS	UK	f	No
Administrative fragmentation and lack of integrated governance			x	x	x	x	x		5/8	1
Transport EE on the Government Agenda/priorities		x		x	x	x	x		5/8	2
Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	x	x	x	x	x	x		x	7/9	3
Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics		x	x	x	x	x		x	6/8	4
Limited/complex funding in urban public transport				x	x	x			3/8	5
Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)	x			x		x		x	4/8	6
Contradicting policy goals (particularly road/car-oriented planning)			x	x					2/8	7

Now, there are 14+6+7 = 27 barriers for the transport sector.

Step 4: Formation of the AHP tree and the AHP matrixes

For each of the seven national cases of HERON, the AHP tree of barriers is the one presented in Figure 1 of the methodology. The final set of the identified barriers for the transport sector is that of Table 5 of the methodology.

Step 5: Pair-wise comparisons

Similarly, as for the building sector, the pair-wise comparisons were performed.

Indicatively the respective AHP matrixes for this sector are:

Table 24: AHP matrix for the groups of barriers in the transport sector.

Barriers linked with end-users behaviour	Social-Cultural-Educational	Economic	Institutional	Weight coefficients
Social-Cultural-Educational	1	4	3	**0,633**
Economic	0,250	1	1	**0,175**
Institutional	0,333	1	1	**0,192**

Saaty consistency test for this AHP matrix: CR* = 0.004 <0.10

Table 25: AHP matrix for the "Social", "Cultural" and Educational" groups of barriers for the transport sector.

Barriers linked with end-users behaviour	Social	Cultural	Educational	Weight coefficients
Social	1	2	5	**0,581**
Cultural	0,500	1	3	**0,309**
Educational	0,200	0,333	1	**0,110**

Saaty consistency test: CR* = 0.002 <0.10

The same procedure is followed for the other AHP matrixes as well.

Table 26: AHP matrix for the third level of barriers (Social barriers for transport sector).

Social barriers	Low satisfaction with public transport/lack of trust	Concerns of vehicle reliability/Hesitation to trust new technologies	Heterogeneity of consumers	Suburbanisation trends/Low density	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)	Inertia	Weight coefficients
Low satisfaction with public transport/lack of trust	1,000	3,000	4,000	4,000	3,000	4,000	**0,401**
Concerns of vehicle reliability/Hesitation to trust new technologies	0,333	1,000	2,000	2,000	2,000	3,000	**0,197**
Heterogeneity of consumers	0,250	0,500	1,000	1,000	1,000	2,000	**0,110**
Suburbanisation trends/Low density	0,250	0,500	1,000	1,000	1,000	2,000	**0,110**
Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)	0,333	0,500	1,000	1,000	1,000	2,000	**0,116**
Inertia	0,250	0,333	0,500	0,500	0,500	1,000	**0,066**

Again the consistency test is performed and the outcome is CR* = 0.046 <0.10 (Table 26). The indexes can be used since they are consistent.

Table 27: AHP matrix for the third level of barriers (Cultural barriers for transport sector).

Cultural barriers	Car as a symbol status and group influence	Habit and social norm of driving, car ownership and use	Cycling is marginalized	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	Weight coefficients
Car as a symbol status and group influence	1,000	1,000	5,000	7,000	**0,423**
Habit and social norm of driving, car ownership and use	1,000	1,000	7,000	5,000	**0,426**
Cycling is marginalized	0,200	0,143	1,000	2,000	**0,088**
Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	0,143	0,200	0,500	1,000	**0,063**

Table 28: AHP matrix for the third level of barriers (Educational barriers for transport sector).

Educational barriers	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – Negative perception	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs	Weight coefficients
Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	1,000	1,000	3,000	5,000	**0,394**
Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	1,000	1,000	3,000	5,000	**0,394**
Confusion about car and fuel costs (conventional vs ULEVs/Evs) – Negative perception	0,333	0,333	1,000	2,000	**0,138**
Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs	0,200	0,200	0,500	1,000	**0,075**

Table 29: AHP matrix for the third level of barriers (Economic barriers for transport sector).

Economic barriers	Lack of finance/Limited financial incentives for new vehicles/ULEVs/ public transport/ - Inefficient or absent fiscal measures for supporting EE	Limited infrastructure investment (road/train/ cycling) – for public transport	Low purchasing power of citizens/Financial crisis	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles	Payback period of fuel efficient vehicles	Negative role of Investment schemes/employee benefits encourage transport EE	Weight coefficients
Lack of finance/Limited financial incentives for new vehicles/ULEVs/ public transport/ - Inefficient or absent fiscal measures for supporting EE	1,000	3,000	4,000	4,000	4,000	5,000	**0,425**
Limited infrastructure investment (road/train/ cycling) – for public transport	0,333	1,000	2,000	2,000	2,000	3,000	**0,191**
Low purchasing power of citizens/Financial crisis	0,250	0,500	1,000	1,000	1,000	2,000	**0,107**
High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles	0,250	0,500	1,000	1,000	1,000	2,000	**0,107**
Payback period of fuel efficient vehicles	0,250	0,500	1,000	1,000	1,000	2,000	**0,107**
Negative role of Investment schemes/employee benefits encourage transport EE	0,200	0,333	0,500	0,500	0,500	1,000	**0,062**

Table 30: AHP matrix for the third level of barriers (Institutional barriers for transport sector).

Institutional barriers	Administrative fragmentation and lack of integrated governance	Transport EE on the Government Agenda/priorities	Barriers to behavior change due to problems with infrastructure/public transport services	Lack or limited policies to support behavior change on specific transport issues	Limited/complex funding in urban public transport	Barriers to behavior change due to no policy support to technological issues/research needs	Contradicting policy goals (particularly road/car-oriented planning)	Weight coefficients
Administrative fragmentation and lack of integrated governance	1,000	1,000	0,500	0,500	4,000	0,333	3,000	**0,103**
Transport EE on the Government Agenda/priorities	1,000	1,000	0,500	0,500	4,000	0,500	3,000	**0,107**
Barriers to behavior change due to problems with infrastructure/public transport services	2,000	2,000	1,000	3,000	7,000	3,000	9,000	**0,334**
Lack or limited policies to support behavior change on specific transport issues	2,000	2,000	0,333	1,000	7,000	2,000	9,000	**0,215**
Limited/complex funding in urban public transport	0,250	0,250	0,143	0,143	1,000	0,111	2,000	**0,035**
Barriers to behavior change due to no policy support to technological issues/research needs	3,000	2,000	0,333	0,500	9,000	1,000	5,000	**0,174**
Contradicting policy goals (particularly road/car-oriented planning)	0,333	0,333	0,111	0,111	0,500	0,200	1,000	**0,032**

Table 31: Total impact of barriers for the transport sector.

Type	Name of barrier	Function
Social	Low satisfaction with public transport/lack of trust	**0,148**
Social	Concerns of vehicle reliability/Hesitation to trust new technologies	**0,072**
Social	Heterogeneity of consumers	**0,040**
Social	Suburbanisation trends/Low density	**0,040**
Social	Mobility problems (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)	**0,043**
Social	Inertia	**0,024**
Cultural	Car as a symbol status and group influence	**0,083**
Cultural	Habit and social norm of driving, car ownership and use	**0,083**
Cultural	Cycling is marginalized	**0,017**
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	**0,012**
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	**0,027**
Educational	Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	**0,027**
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*	**0,010**
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs	**0,005**
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	**0,074**
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	**0,033**
Economic	Low purchasing power of citizens/Financial crisis	**0,019**
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles	**0,019**
Economic	Payback period of fuel efficient vehicles	**0,019**
Economic	Negative role of Investment schemes/employee benefits encourage transport EE	**0,011**
Institutional	Administrative fragmentation and lack of integrated governance	**0,020**
Institutional	Transport EE on the Government Agenda/priorities	**0,021**
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	**0,064**
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics	**0,041**
Institutional	Limited/complex funding in urban public transport	**0,007**
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)	**0,033**
Institutional	Contradicting policy goals (particularly road/car-oriented planning)	**0,006**

Step 8: Linking Barriers Impact and technologies

The technologies and approaches for which the experts were asked in D.2.5 are:

- ✓ For the building sector
  - Building fabric upgrades
  - heat pumps
  - LEDs,
  - BEMs,
  - More efficient appliances

- ✓ For the transport sector
  - Electric and hybrid vehicles
  - More sustainable and efficient modes for individuals
  - More sustainable and efficient modes for freight transport

Based on D.2.1, D.2.2, D.2.5 and D.1.4, the penetration of each one the aforementioned technologies is linked with specific barriers.

The same set of barriers per technology is not encountered between the HERON countries, neither the TI of a barrier for a specific technology is the same.

Indicative examples

Example 1

For the case of UK from respective report of D.2.1, the identified barriers to **uptake an efficient heating system (as part of the Building fabric upgrades)** are those presented in Table 32.

Table 32: Barriers linked with the Building fabric upgrade. The respective values of the indexes for UK will be calculated, but for now the values of table 22 were used for the example.

Type of barrier	Name of barrier	Index for the total impact of the barrier
Social	**Inertia** – Unwillingness to replace systems (Deliverable 2.1)	0.034
Educational	**Lack of awareness/knowledge on savings potential/information gap on technologies, EE** – Lack of awareness of available systems (Deliverable 2.1)	0.048
Economic	**High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users** - Cost of new heating (Deliverable 2.1)	0.030
Institutional	-	0

The function that provides the Total Impact/contribution of **the end-users behavior towards efficient heating systems for the case of the UK** is the following:

$$TI_{\text{efficient heating system, UK}} = 0.034 + 0.048 + 0.030 = 0.112$$

Example 2

For the case of Serbia from the respective report of D.2.1, the identified barriers to **uptake electric boilers for heating water (as part of the Building fabric upgrades)** are those presented in Table 33.

Table 33: Barriers linked with the Building fabric upgrade. The respective values of the indexes for Serbia will be calculated, but for now the values of table 22 were used for the example.

Type of barrier	Name of barrier	Index for the total impact of the barrier
Social	**Socio-economic status of building users –** Households credit capacity (implying renovation) (Deliverable 2.1)	0.173
Economic	**High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users -** High Interest Rates and Numerous Additional Bank Fees and Charges/ Small Size and High Transaction Costs of Energy Efficiency Projects (renovation) (Deliverable 2.1)	0.030
Economic	**Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE –** The belief of citizens that the price of electricity will remain low in the future (from social here)/ low electricity prices (refurbishment, retrofit) (Deliverable 2.1)	0.005
Institutional	**Split incentive -** Split Incentive for Rented Building – Landlord is Responsible for Renovations, but Tenants Pay the Bill (renewal) (Deliverable 2.1)	0.053
Institutional	**Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays) -** Association of homeowners reluctance to make decisions to renovate (renovate)(Deliverable 2.1)	0.048
Institutional	**Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts)** (Deliverable 2.1)	0.028

The function that provides the Total impact/contribution of the end-users behavior towards electric boilers for heating water for the case of Serbia is the following:

$TI_{\text{electric boilers for heating water, Serbia}} = 0.173+0.030+0.005+0.053+0.048+0.028= 0.337$

Example 3

For the case of Estonia from the respective report of D.2.1, the identified barriers to **adopt energy efficient technologies (under energy efficient appliances)** are those presented in Table 34.

Table 34: Barriers linked with the energy efficient appliances. The respective values of the indexes for Estonia will be calculated, but for now the values of table 22 were used for the example.

Type of barrier	Name of barrier	Index for the total impact of the barrier
Social	**Socio-economic status of building users (Social)** - Increasing client/ consumer wellness - Low income of aged people (Deliverable 2.1)	**0.173**
Social	**Inertia (Social)** - Lack of clients' courage and initiative to undertake certain investments to their dwelling (Deliverable 2.1)	**0.034**
Economic	**Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) -** Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support (Deliverables 2.1 and 2.5)	**0.050**
Institutional	-	**0**

The function that provides the Total impact/contribution of the end-users behavior towards energy efficient appliances for the case of Estonia is the following:

$TI_{\text{energy efficient appliances, Estonia}} = 0.173+0.034+0.050 = 0.257$

Step 9: Incorporating barriers impact in forward looking EE modelling

Sector with general target

In the case of HERON, this sub-sector is the tertiary sector. Partners can set a general target such as the following:

- 5% reduction of final energy consumption in year 2020 compared to year 2005
- 27% reduction of final energy consumption compared to the future projections of a BAU scenario in year 2030 using current data
- 18,5TWh of final energy consumption in 2020 etc.

Example 1

The function can be re-written by assuming (for an example) that the barriers that are linked with the target are b_{s1}, b_{s2}, b_{c1}, b_{E2} and b_{I5} and p% = 5%

$ES_{\text{t, barriers}} = F_o(k,a,c,d,e,h)*(5\%)*(1 - TI_{s1} - TI_{S2} - TI_{C1} - TI_{E2} - TI_{I5})$

Where

TI_{s1} is the total impact/contribution of barrier S1 (first social barrier of Table 16) in limiting the efforts for energy savings

TI_{S2} is the total impact/contribution of barrier S2 (second social barrier of Table 16) in limiting the efforts for energy savings

TI_{C1} is the total impact/contribution of barrier C1 (first cultural barrier of Table 16) in limiting the efforts for energy savings

TI_{E2} is the total impact/contribution of barrier E2 (second educational barrier of Table 16) in limiting the efforts for energy savings

TI_{I5} is the total impact/contribution of barrier I5 (fifth institutional barrier of Table 16) in limiting the efforts for energy savings.

So,

$ES_{t, barriers} = F_o(k,a,c,d,e,h)*(5\%)* (1 – TI_{s1} – TI_{S2}- TI_{C1}-TI_{E2} – TI_{I5})$

$= F_o(k,a,c,d,e, h)*(5\%)* (1 –0.078-0.173-0.045-0.144-0.009)$

$= F_o(k,a,c,d,e, h)*(5\%)*(1-0.449)$

$= F_o(k,a,c,d,e, h)*(5\%)*(0.551)$

$= F_o(k,a,c,d,e, h)*(2.775\%)$

The interpretation of this outcome is that the expected energy savings will not reach the expected 5% of the final energy consumption of the reference year, but due to the existence of barriers they will be restricted to a 2.775%. There is a deviation from the 5% target.

Example 2

If energy efficient appliances have a 0% share in the reference year, and the target is to reach 10% in 2030 for Estonia, then the final share of this type of technology type will be:

$S_{t, barriers} = S_o(k,a,c,d,e,h) + A\%*(1- TI_{barriers\ related\ with\ the\ penetration\ of\ the\ technology,\ Estonia})$

$= 0\% +10\%*(1-0.257) = 10\%*0.743 = 7.43\%$

where 0.257 was calculated in example 3. This means that the expected increase will not be accomplished due to the existence of the identified barriers that are linked with the end-users behavior in Estonia. Only 7.43% is estimated to be achieved due to the existing barriers.

- **Setting a general target**

Combination of technologies

Step 1: As an indicative example, table 40 shows the possible barriers for a set of four technologies. The preferable combinations are in green color. So, out of the six combinations of the four technologies by two, there is only one best combination. are two preferable combinations one with two technologies and one with three technologies. Out of four combinations of the four technologies by three each time, only one combination is more preferable.

Step 2: So, if the question was which combination to select between (1+3+4) and (2+3+4) since they have the same set of common barrier, then the following calculation are needed, ie

Total Impact $_{technologies\ 1+3+4}$ = B and

Total Impact $_{technologies\ 2+3+4}$ = C

where $B= TI_{C1}+TI_{C2}+TI_{EC1}+TI_{EC2}+TI_{I3}+TI_{I7}$ and $C = TI_{c1}+TI_{C2}+TI_{E2}+TI_{EC3}+TI_{I4}+TI_{I8}$

If B < C, then the combination of technologies 1, 3 and 4 is the more preferable one. The TI of common barriers is used only once in the sum.

Table 35: Identifying the best combination of technologies from Step 1.

Technology	Barriers of technology	6 combinations of 2 technologies	Combinations of 3
Technology 1	C1, C2, EC1, EC3, I3, I7	**Technologies 1+4 (4 common barriers ie C1, C2, EC1 and EC3)** Technologies 1+2 (3 common barriers ie C1, C2, EC3) Technologies 1+3 (3 common barriers, ie C1, C2 and EC3)	**Technologies 1+3+4 (3 common barriers ie C1, C2 and EC3)** Technologies 1+2+3 (3 common barriers C1, C2 and EC3) Technologies 1+2+4 (C1, C2 and EC3
Technology 2	C1, C2, E2, EC3, I4, I8	Technologies 2 +3 (3 common barriers ie C1, C2 and EC3) Technologies 2+ 4 (3 common barriers, ie C1, C2 and EC3)	Technologies 2+3+4 (3 common barriers) C1, C2 and EC3)
Technology 3	C1, C2, EC3, I6	-	-
Technology 4	C1, C2, EC1, EC3	Technologies 4+3	-

B. Assumptions about minimizing the impact of barriers

Second approach: An indicative example is the following. If the Total Impact of a barrier is 0.368 and the user assumes that the barrier will be confronted by either modifying specific implemented policy instruments or by introducing new ones, then the impact of the barrier is progressively reduced. For a 15-year period the reduction is showed in Table 36 and Figure 2.

Table 36: Minimization of Total Impact of a barrier.

Years	Total Impact of barrier
0	0,368
1	0,363
2	0,358
3	0,353
4	0,348
5	0,343
6	0,339
7	0,334
8	0,329
9	0,324
10	0,319
11	0,314
12	0,309
13	0,304
14	0,299
15	0,294

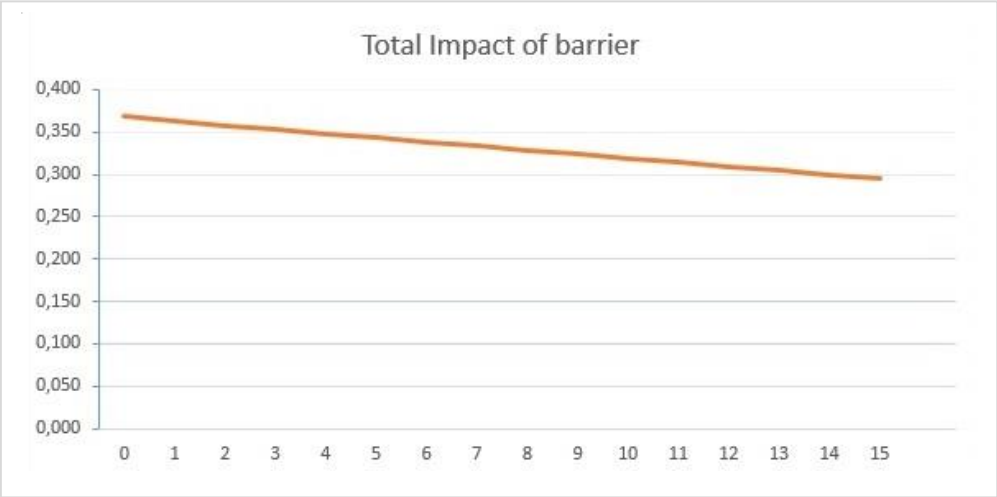

Figure 1: Minimization of the Total impact of a barrier.

Indicative example

If the available data are not detailed so as to reflect the under-study sector analytically, then the respective developed scenario is based on a "General target", ie a target that refers to the "Total energy consumption" for a specific year in the future or to the reduction in percentage of the final energy consumption of the sector in a future year compared to a reference year etc.

This assumed "General target" is assumed to be achieved through the use of all available EE technologies that the country can use.

If this assumed "General target" is affected significantly by the negative impact of the barriers, then the user has the option to decide how to restrict the negative impact of the barriers and which barriers are those to be confronted. Barriers are assumed to be confronted by the use of the proper policy instrument or policy package.

If the user selects which barriers (linked with the available technologies) are to be confronted, then calculations concern these selected ones.

For instance, if the available technologies are: BEMS and LEDS and the user selects $b_{1,\ LEDs}$ and $b_{2,\ BEMs}$ to minimize then using the equation

$$Q = Q_o\ (1- (0,2/15)*t)$$

the results will be the following:

$Q_1 = Q_{o,\ BEMS}\ (1 - (0,2/15)*1) = W\ b_{1,\ BEMS\ -1}$ (figure for the Weight coefficient for barrier 1 for LEDS, during the first year)

$Q_2 = Q_{o,\ BEMS}\ (1 - (0,2/15)*2) = W\ b_{1,\ BEMS\ -2}$

$Q_3 = Q_{o,\ BEMS}\ (1 - (0,2/15)*3) = W\ b_{1,\ BEMS\ -3}$

$Q_4 = Q_{o,\ BEMS}\ (1 - (0,2/15)*4) = W\ b_{1,\ BEMS\ -4}$

$Q_5 = Q_{o,\ BEMS}\ (1 - (0,2/15)*5) = W\ b_{1,\ BEMS\ -5}$

etc

Similarly, for the other barrier

$Q_1 = Q_{o,\ LEDS}\ (1 - (0,2/15)*1) = Wb_{2,\ LEDS\ -1}$ (figure for the Weight coefficient for barrier 1 for LEDS, during the first year)

$Q_2 = Q_{o,\ LEDS}\ (1 - (0,2/15)*2) = W\ b_{2,\ LEDS\ -2}$

$Q_3 = Q_{o,\,LEDS}\,(1 - (0{,}2/15)*3) = W\,b_{2,\,LEDS\,-3}$

$Q_4 = Q_{o,\,LEDS}\,(1 - (0{,}2/15)*4) = W\,b_{2,\,LEDS\,-4}$

$Q_5 = Q_{o,\,LEDS}\,(1 - (0{,}2/15)*5) = W\,b_{2,\,LEDS\,-5}$

etc

The Total impact is then a time series of 15 figures as the sum of the Total impact of the barriers that were not minimized and the Total impact of those minimized as these were calculated above.

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ANNEX 1: QUALITATIVE INFORMATION FOR AHP MATRIX

BULGARIA

Building sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources (D.2.1)	Number of subsectors (D.2.1)	Easiness in confronting barrier (D1.4, D.2.1)	Duration (D.2.1)	Number of policy instruments (D.2.1)	Cross-cutting barrier (D.2.2)	Preferences of stakeholders (D.2.5)
Social	Social group interactions and status considerations						No information		
Social	Socio-economic status of building users						No information		Yes (11.70% for all countries)
Social	Strong dependency on the neighbors in multi-family housing	Strong dependency on the neighbors in multi-family housing		1 (Residential)			No information		
Social	Inertia						No information		
Social	Commitment and motivation of public social support	Mistrust in the institutions and governmental system (here instead of institutional)					No information		
Social	Rebound effect						No information		
Cultural	Lack of interest/low priority/Undervaluing energy efficiency						No information		
Cultural	Customs, habits and relevant behavioural aspects	Neglecting the EE needs					No information	yes	Yes (7.50%)
Cultural	Bounded rationality/Visibility of energy efficiency						No information		
Cultural	Missing credibility/mistrust of technologies and contractors	Lack of trust in ESCOs	1	2 (Residential, Tertiary)			No information		
Educational	Lack of trained and skilled professionals/ trusted information,	Lack of capacity	2	2 (Residential,			No information	yes	

	knowledge and experience			Tertiary)					
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies	Lack of information/ insufficient marketing of EE programmes	2	2 (Residential, Tertiary)			No information		Yes (7.40%)
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	Lack of finance (here, instead of social)/ No incentives for EE projects			moderate		No information	yes	Yes (10% for all countries)
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	Lack of social approval (here, instead of social)/ Financial risk/ High costs					No information		yes
Economic	Payback expectations/investment horizons						No information		Yes (7.00%)
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	Distortion of energy prices/ Low energy prices (here, instead of social) – low level energy prices – Energy tariff system structure does not reflect correctly the cost of energy and carriers					No information		
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	Hidden costs					No information		
Economic	Financial crisis/Economic stagnation						No information		
Economic	Embryonic markets						No information		
Institutional	Split Incentive	Split of incentives in house renting sector (here instead of social)		1 - Residential			No information		

Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	Lack of power for initiation an EE action (characterized as organizational, it fits here) – Long administrative procedures/shortcomings in the legislation with regard to common property/ frequent ungrounded change of regulatory framework					No information		
Institutional	Building stock characteristics/aging stock/ Historical preservation	Historical preservation					No information		
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	Low level of demonstration projects for NZEB					No information		
Institutional	Lack of data/information-diversion of management	Poor regional and municipal energy statistics/Insufficient national statistics/ no sufficient energy data for planning (here instead of cultural)		2 (Residential, Tertiary			No information		
Institutional	Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities)	Mistrust in the institution	1	2 (Residential, Tertiary)			No information	yes	
Institutional	Disruption/Hassie factor						No information		
Institutional	Security of fuel supply		1	1 Residential			No information		

For Bulgarian building sector: Technologies – barriers - policy instruments (sources: D.1.4, D.2.1, D.2.5)

Technologies	Barriers	Policy instruments
Building shell improvement (fabric upgrade)	- **Socio-economic status of building users** (Social)(D.2.5) - **Lack of any type of financial support** *(lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)* (Economic)(D.2.5) - **High costs and risks** (High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users) - *Lack of social approval (here, instead of social)/ Financial risk/ High costs (Deliverables 2.1 +2.5)* - **Strong dependency on the neighbors in multi-family housing** - Strong dependency on the neighbors in multi-family housing (Deliverable 2.1) - **Poor compliance – performance gap/mismatch** - Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch (Institutional) - Low level of demonstration projects for NZEB (Deliverable 2.1) - **Split Incentive** (Institutional) – Split of incentives in house renting sector (D.2.1) - **Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)** (Institutional) - *Lack of power for initiation an EE action (characterized as organizational, it fits here) – Long administrative procedures/shortcomings in the legislation with regard to common property/ frequent ungrounded change of regulatory framework (D.2.1)*	- subsidies, loan guarantees - "Support for energy efficiency in multifamily buildings" under the Operational Programme "Regional Development 2007-2013" - "National energy efficiency program for multifamily residential buildings" (MRDPW 2015a) - "Support for energy efficiency in multifamily buildings" (MRDPW 2011) - Residential Energy Efficiency Credit Line (REECL 2015) - Updated requirements for referent U values, W/m^{2}K of the walls, floors, roofs and windows and building elements - Mandatory annual renovation of 3% of the total area of the central government buildings
Heat pumps	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (2.5) - **Lack of trained and skilled professionals/ trusted information, knowledge and experience** (Educational)(2.5)	
Efficient heating	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (2.5) **Misleading prices (energy/fuel/tariffs) - Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE -** Distortion of energy prices/ Low energy prices (here, instead of social) – low level energy prices – Energy tariff system structure does not reflect correctly the cost of energy and carriers (Deliverable 2.1) - **Lack of trained and skilled professionals/ trusted information, knowledge and experience** (Educational)(2.5)	- Energy Act (EA 2006); - Ordinance on regulating the prices of heat supply (MEE 2008); - Ordinance № 16-334 since 06.04.2007 on district heating (MEE 2015).
Efficient cooling (air conditioning systems A+, A++, A+++)	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)(D.2.5) - **Misleading prices (energy/fuel/tariffs) - Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE -** Distortion of energy prices/ Low energy prices (here, instead of social) – low level energy prices – Energy tariff system structure does not reflect correctly the cost of energy and carriers (Economic)(D.2.1) - **Lack of trained and skilled professionals/ trusted information, knowledge and experience** (Educational)(D.2.5)	
LEDs	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (D.2.5) - **High costs and risks** (High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users) - *Lack of social approval (here, instead of social)/ Financial risk/ High costs (D.2.5)* - **Customs, habits and relevant behavioural aspects** (Cultural)(D.2.5)	"Program for street lightning modernization in the service sector"

Efficient appliances (A+, A++, A+++)	- **Lack of interest/low priority/Undervaluing energy efficiency (Cultural)**(D.2.5) - **Social group interactions and status considerations** (Social)(D.2.5) - **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)(D.2.5) - **High costs and risks** (High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users) - *Lack of social approval (here, instead of social)/ Financial risk/ High costs (D.2.1 + 2.5)* - **Misleading prices (energy/fuel/tariffs) - Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE (Economic)-** Distortion of energy prices/ Low energy prices (here, instead of social) – low level energy prices – Energy tariff system structure does not reflect correctly the cost of energy and carriers (D.2.1)	
BEMS	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance (Economic) (2.5) - **High costs and risks** (High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users) - *Lack of social approval (here, instead of social)/ Financial risk/ High costs (deliverable 2.1 + 2.5)* - **Lack of trained and skilled professionals/ trusted information, knowledge and experience** (Educational)(2.5) - **Lack of interest/low priority/Undervaluing energy efficiency** (Social)(2.5)	

Transport sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources	Number of subsectors	Easiness in confronting barrier	Duration	Number of policy instruments	Cross-cutting barrier	Preferences of stakeholders (2.5)
Social	Low satisfaction with public transport/lack of trust	Avoiding railway transportation							Yes (6.70%)
Social	Concerns of vehicle reliability/Hesitation to trust new technologies								Yes (3.40%)
Social	Heterogeneity of consumers								
Social	Suburbanisation trends/Low density								
Social	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)								
Social	Inertia								
Cultural	Car as a symbol status and	Matter of social status							Yes (4.50%)

	group influence								
Cultural	Habit and social norm of driving, car ownership and use								Yes (5.50%)
Cultural	Cycling is marginalized								
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)								
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	Lack of information on the electric mobility/lack of information on green transportation						yes	Yes (4.60%)
Educational	Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)								
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*								
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs								
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	Lack of finance/ lack of economic stimuli for purchasing electric/hybrid vehicles						yes	Yes (8.20%)
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	Insufficient transport structure							Yes (8.10%)
Economic	Low purchasing power of citizens/Financial crisis								Yes (7.70%)
Economic	High cost/Low cost competitiveness of electric								

	vehicles - High cost of batteries for electric vehicles								
Economic	Payback period of fuel efficient vehicles								
Economic	Negative role of Investment schemes/employee benefits encourage transport EE								
Institutional	Administrative fragmentation and lack of integrated governance								Yes (6.70%-lack of integrated governance)
Institutional	Transport EE on the Government Agenda/priorities	Lack of sustainable Urban Mobility Plans							Yes (7.0%) (lack of a national strategy for sustainable urban mobility) (6.10%- Transport EE on the Government Agenda/priorities) (5.60% - Environmental concern/low priority)
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	Not well developed first class road network (here instead of economic)/Lack of electric mobility infrastructure/ Insufficient transport intercity infrastructure/ Lack of regular transport services in smaller settlements/ insufficient urban transport infrastructure							Yes (7.30 % - insufficient transport infrastructure and planning) (6.70%- insufficient development of cycling/walking infrastructure)(6.60% Lack of support for rail transportation/Limited rail infrastructure) (5.60%- Undeveloped infrastructure for recharging of EV)
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics	Lack of support for rail transportation							
Institutional	Limited/complex funding in								

	urban public transport								
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)								
Institutional	Contradicting policy goals (particularly road/car-oriented planning)								

For Bulgarian transport sector: Technologies – barriers - policy instruments (sources: D.1.4, D.2.1, D.2.5)

Technologies	Barriers	Policy instruments
Electric and hybrid vehicles	- **Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)** (Educational) – *Lack of information on the electric mobility/lack of information on green transportation* (Deliverable 2.5) - **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/** (Economic) - Inefficient or absent fiscal measures for supporting EE (Economic) (Deliverable 2.1) - **Problems with infrastructure/public transport services - Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) -**Not well developed first class road network (here instead of economic)/Lack of electric mobility infrastructure/ Insufficient transport intercity infrastructure/ Lack of regular transport services in smaller settlements/ insufficient urban transport infrastructure (D.2.1)	National action plan to promote production and accelerated entry of environmental vehicles including electrical mobility in Bulgaria 2012 – 2014 (D.1.4)
Efficient and sustainable modes of transport in passenger and freight transport such as		
eco-driving,	- **Lack of knowledge/information on EE transport (Cultural)(2.5)** - **Socio-economic status of users (Social)(2.5)**	
modal shift,	- **Low satisfaction with public transport/lack of trust (Social)** – *Avoiding railway transportation (Deliverable 2.1)* - **Lack of finance/Limited financial incentives for new vehicles/ULEVs/ public transport/**(Economic) - Inefficient or absent fiscal measures for supporting EE– Lack of finance (2.5) - **Problems with infrastructure/public transport services - Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) -**Not well developed first class road network (here instead of economic)/Lack of electric mobility infrastructure/ Insufficient transport intercity infrastructure/ Lack of regular transport services in smaller settlements/ insufficient urban transport infrastructure (Deliverable 2.1)	- Operational Programme "Transport" 2007 - 2013 - Operational Program "Regional Development 2007 – 2013"

	- **Transport EE on the Government Agenda/priorities (Institutional)** – *lack of sustainable urban mobility Plans (D. 2.1)* - **Lack or limited policies to support behavior change on specific transport issues** (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics (Institutional) - Lack of support for rail transportation (Deliverable 2.1) - **Low purchasing power of citizens/Financial crisis (Economic)** (2.5) - **Habit and social norm of driving, car ownership and use (Cultural)** (2.5)	
efficient vehicles	- **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/** (Economic) - Inefficient or absent fiscal measures for supporting EE (Economic) (Deliverable 2.1) - **Problems with infrastructure/public transport services** - Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) - *Not well developed first class road network (here instead of economic)/Lack of electric mobility infrastructure/ Insufficient transport intercity infrastructure/ Lack of regular transport services in smaller settlements (D.2.1)* - **Low purchasing power of citizens/Financial crisis (Economic)(2.5)**	National action plan to promote production and accelerated entry of environmental vehicles including electrical mobility in Bulgaria 2012 - 2014
use of biofuels.	- **Socio-economic status of users** (Social) (2.5) - **Lack of knowledge/information on EE transport** (Cultural) (2.5) - **Concerns on reliability/hesitation to trust new technologies** (Social) (2.5)	

ESTONIA

Building sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources (D.2.1)	Number of subsectors (D.2.1)	Easiness in confronting barrier (D.1.4, D.2.1)	Duration (D.2.1)	Number of policy instruments (D.2.1)	Cross-cutting barrier (D.2.2)	Preferences of stakeholders (D.2.5)
Social	Social group interactions and status considerations								
Social	Socio-economic status of building users	Increasing client/ consumer wellness - Low income of aged people	1	2 (Residential, Tertiary)		9 years (identified since 2007)	2	YES	Yes (11.70% for all countries)
Social	Strong dependency on the neighbors in multi-family housing	Big multistore apartment habitants never find easy way to common ground to undertake the energy efficiency renovation/ Dwellings left empty	2	1 - Residential		3 years	2		
Social	Inertia	Lack of clients' courage and initiative to undertake certain investments to their dwelling				9 years (since 2007)	3 (educational programmes, establishment of Kredex/ establishment of smart energy network)		
Social	Commitment and motivation of public social support								
Social	Rebound effect								
Cultural	Lack of interest/low priority/Undervaluing energy efficiency								
Cultural	Customs, habits and relevant behavioural aspects	Energy usage habits in relation to relatively autonomous national energy Market/ Energy intensity in relation to Estonian cold climate					Total: 2 1 (minimum energy performance /2 (energy label, minimum energy performance)	yes	Yes (7.50%)
Cultural	Bounded rationality/Visibility of energy efficiency								
Cultural	Missing	Technical problems	1	2		No			

	credibility/mistrust of technologies and contractors			(Residential, Tertiary)		information			
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	Not enough high-level trained specialists in energy efficiency matters/ Lack of comprehensive and systematic technical data for research	2	2 (Residential, Tertiary)				yes	
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies	Clients lack appropriate knowledge on economic gains of energy efficiency and technologies thus do not feel like equal partners/ Low awareness. Lack of relevant easily understandable to all tenants information/ Weak national guidance. Lack of knowledge on indoor air quality and health effects	2	2 (Residential, Tertiary)				yes	Yes (7.40%)
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support	3	residential	Moderate (National)	Since 2014	1 policy instrument (Building codes)	yes	Yes (10% for all countries)
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	Dotation to renewable energy generators	1			Since 2014	No information		yes
Economic	Payback expectations/investment horizons								Yes (7.00%)
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	Relatively cheap energy and fuel prices/	1				3 (energy label – minimum energy performance - environmental charges)		
Economic	Unexpected costs (Hidden costs/ Costs	Regionally fragmented	1	Residential	National, regional,	Since 2014	2 policy (energy label,		

	vary regionally (Fragmented ability))	energy saving potential			local		building codes)		
Economic	Financial crisis/Economic stagnation								
Economic	Embryonic markets	Energy services not too well connected with the potential client savings	1	all		Since 2014	No information		
Institutional	Split Incentive	Question of actual tenants when accessing relevant data and actual consumers (instead of having it under cultural) /Prerequisites for energy service undertakings within the commercial and public building sector	1	Tertiary	national	Since 2014	1		
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	Lack of experience in procurement	2	Tertiary (public, government)	National, regional, local	Since 2004	2 policy instruments		
Institutional	Building stock characteristics/aging stock/ Historical preservation	Aging housing stock (instead of economic)	1	residential		Since 2014	No information		
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	Estonia's dependence on district heating – principal agent failure	1	residential	National, regional, local	Since 2013	1 policy instrument (grants)		
Institutional	Lack of data/information-diversion of management								
Institutional	Barrier to behavior change due to problematic	Size of the country (from cultural)/ Finding agreement between	1	2 (Residential,	National, regional,	Since 2014	1 policy instrument	yes	

	implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities)	different parties/Operational overlap and clarity/ Co-operation between localmunicipalities		Tertiary)	local				
Institutional	Disruption/Hassie factor	Development of building sector and the cost of Renovations (instead of being an economic)	1	Residential	national	Since 2014	1 policy instrument		
Institutional	Security of fuel supply	Gas supply security (from cultural)	1	1 Residential					

For Estonian building sector: Technologies – barriers - policy instruments (sources: Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers (Deliverables 2.1 and 2.5)	Policy instruments (Deliverable 1.4)
Building shell improvement (fabric upgrade)	- **Socio-economic status of building users (Social)** - *Increasing client/ consumer wellness - Low income of aged people* (Deliverable 2.1) - **Strong dependency on the neighbors in multi-family housing (Social)** - *Big multistore apartment habitants never find easy way to common ground to undertake the energy efficiency renovation/ Dwellings left empty* (Deliverable 2.1) - **Lack of awareness/knowledge on savings potential/information gap on technologies (Educational)** - *Clients lack appropriate knowledge on economic gains of energy efficiency and technologies thus do not feel like equal partners/ Low awareness. Lack of relevant easily understandable to all tenants information/ Weak national guidance. Lack of knowledge on indoor air quality and health effects* (Deliverable 2.1) - **Inertia (Social)** - Lack of clients' courage and initiative to undertake certain investments to their dwelling (Deliverable 2.1) - **Customs, habits and relevant behavioural aspects (Cultural)** - Energy usage habits in relation to relatively autonomous national energy Market/ Energy intensity in relation to Estonian cold climate (Deliverable 2.1) - **Missing credibility/mistrust of technologies and contractors (Cultural)** – Technical problems (Deliverable 2.1) - **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** - *Not enough high-level trained specialists in energy efficiency matters/ Lack of comprehensive and systematic technical data for research* (Deliverable 2.1) - **Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability)) (Economic)** - Regionally fragmented energy saving potential (Deliverable 2.1) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or**	- subsidies, - loan guarantees - New technology shift measure

	access to finance) (Economic) - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - **Building stock characteristics/aging stock/ Historical preservation (Institutional)** - Aging housing stock (instead of economic) (Deliverable 2.1) - **Disruption/Hassie factor (Institutional)** - Development of building sector and the cost of Renovations (instead of being an economic) (Deliverable 2.1) - **Split Incentive (Institutional)** – *Question of actual tenants when accessing relevant data and actual consumers (instead of having it under cultural) /Prerequisites for energy service undertakings within the commercial and public building sector* (Deliverable 2.1) - **Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities) (Institutional)** – *Size of the country (from cultural)/ Finding agreement between different parties/Operational overlap and clarity/ Co-operation between local municipalities* (Deliverable 2.1) - **High costs and risks (Economic)** - *High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users* (Deliverable 2.5)	
Heat pumps	- **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** - *Not enough high-level trained specialists in energy efficiency matters/ Lack of comprehensive and systematic technical data for research* (Deliverable 2.5) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - High costs and risks (Economic) - *High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users* (2.5)	
Efficient heating	- **Strong dependency on the neighbors in multi-family housing (Social)** - *Big multistore apartment habitants never find easy way to common ground to undertake the energy efficiency renovation/ Dwellings left empty* (Deliverable 2.1) - **Security of fuel supply (Institutional)** - Gas supply security (from cultural) (Deliverable 2.1) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - **Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch (Institutional)** - *Estonia's dependence on district heating – principal agent failure* (Deliverable 2.1)	- subsidies
Efficient cooling (air conditioning systems A+, A++, A+++)	- **Customs, habits and relevant behavioural aspects** (Cultural) (2.5)	
LEDs	- **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.5) - **Customs, habits and relevant behavioural aspects** (Cultural)(2.5) - **High costs and risks (Economic)** - *High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users* (2.5)	
Efficient appliances (A+, A++, A+++)	- **Socio-economic status of building users (Social)** - *Increasing client/ consumer wellness - Low income of aged people* (Deliverable 2.1) - **Inertia (Social)** - Lack of clients' courage and initiative to undertake certain investments to their dwelling (D.2.1)	

	- **Lack of interest/low priority/Undervaluing energy efficiency (Cultural)**(2.5) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5)	
BEMS	- **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - **High costs and risks** (High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users) (Economic)(D.2.5) - **Lack of interest/low priority/Undervaluing energy efficiency (Cultural) (2.5)** - **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** - *Not enough high-level trained specialists in energy efficiency matters/ Lack of comprehensive and systematic technical data for research* (Deliverable 2.5)	

Transport sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources	Number of subsectors	Easiness in confronting barrier	Duration	Number of policy instruments	Cross-cutting barrier	Preferences of stakeholders (D.2.5)
Social	Low satisfaction with public transport/lack of trust	Poor image of public transport	1	all		Since 2013			Yes (6.70%)
Social	Concerns of vehicle reliability/Hesitation to trust new technologies								Yes (3.40%)
Social	Heterogeneity of consumers							yes	
Social	Suburbanisation trends/Low density	Summer houses/Second homes in low density areas - "Own house far from neighbours"	1	Road private	national	Since 2013	1 policy instrument (land tax)	yes	
Social	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)								
Social	Inertia								
Cultural	Car as a symbol status and group influence	Social pressure for SUV-s and Powerful passenger cars	1	passenger	national	Since 2014	3 policy instruments (duty, vat, reporting)		Yes (4.50%)
Cultural	Habit and social norm of driving, car ownership and use	Aggressive/speedy driving style	1	Road transport	national	Since 2014	2 policy instruments	yes	Yes (5.50%)

							(controls, campaigns)		
Cultural	Cycling is marginalized	Image of cycling as sports and leisure activity	2	all	National, local	Since 2012	3 policy instruments (campaigns, bus lanes, free public transport)		
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)								
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)							yes	Yes (4.60%
Educational	Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)								
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*								
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs	Lack of integrated transport/ mobility and planning professionals						yes	
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	Fiscal instruments in transport sector not sufficient for encouraging energy efficiency	2	road	National, local	Since 2010	3 policy instruments (duty, vat, support scheme)	yes	Yes (8.20%)
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	Low population Density/ Lack of investment in public transport and walking/cycling infrastructure (from institutional)	2	all	National, regional, local	Since 2012	1 policy instrument/no policy	yes	Yes (8.10%)
Economic	Low purchasing power of citizens/Financial crisis								Yes (7.70%)
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles								
Economic	Payback period of fuel efficient								

	vehicles								
Economic	Negative role of Investment schemes/employee benefits encourage transport EE	National investment schemes encourage growth in road sector - Perverse incentives by employers/Employee benefits regarding cars	3	road	National, local	Since 2010	4 policy instruments (Duty, new schemes, decreasing vat)		
Institutional	Administrative fragmentation and lack of integrated governance	Transport/mobility sector management is split between several departments, lack of integrated governance – Administrative fragmentation and lack of integrated governance	2	all	National, local/ regional	Since 2013	No policy/2 policy instruments	yes	Yes (6.70%-lack of integrated governance)
Institutional	Transport EE on the Government Agenda/priorities								Yes (7.0%) (lack of a national strategy for sustainable urban mobility) (6.10%-Transport EE on the Government Agenda/priorities) (5.60% - Environmental concern/low priority)
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	Lack of integrated transport and land-use planning	1	All	National, regional, local	Since 2014	1 policy instrument		Yes (7.30 % - insufficient transport infrastructure and planning) (6.70%-insufficient development of cycling/walking infrastructure)(6.60% Lack of support for rail transportation/Limited rail infrastructure)(5.60%-Undeveloped infrastructure for recharging of EV
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national								

	strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics								
Institutional	Limited/complex funding in urban public transport								
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)								
Institutional	Contradicting policy goals (particularly road/car-oriented planning)	Contradicting policy goals and implementation	1	All	National, local	Since 2014	No policy		

For Estonian transport sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers	Policy instruments
Electric and hybrid vehicles	- **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/** - Inefficient or absent fiscal measures for supporting EE (Economic) – Lack of finance (2.5) - **Administrative fragmentation and lack of integrated governance (Institutional)** – *Transport/mobility sector management is split between several departments, lack of integrated governance – Administrative fragmentation and lack of integrated governance* (Deliverable 2.1)	- Grants
Efficient and sustainable modes of transport in passenger and freight transport such as		
eco-driving,	- **Lack of knowledge/information on EE transport (Cultural)(2.5)** - **Socio-economic status of users (Social)(2.5)**	
modal shift,	- **Low satisfaction with public transport/lack of trust (Social)** – Poor image of public transport (Deliverable 2.1) - **Cycling is marginalized (Cultural)** - Image of cycling as sports and leisure activity (Deliverable 2.1) - **Negative role of Investment schemes/employee benefits encourage transport EE (Economic)** – *National investment schemes encourage growth in road sector - Perverse incentives by employers/Employee benefits regarding cars* (Deliverable 2.1) - **Limited infrastructure investment (road/train/cycling) – for public transport (Economic)** – *Low population Density/ Lack of investment in public transport and walking/cycling infrastructure (from institutional)* (Deliverable 2.1) - **Administrative fragmentation and lack of integrated governance (Institutional)** – *Transport/mobility sector management is split between several departments, lack of integrated governance – Administrative fragmentation and lack of integrated governance* (Deliverable 2.1)	

	- **Contradicting policy goals (particularly road/car-oriented planning) (Institutional)** – Contradicting policy goals and implementation (Deliverable 2.1) - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) -** Lack of integrated transport and land-use planning (Deliverable 2.1)	
efficient vehicles	- **Habit/social norm of driving-car ownership & use (Cultural)(2.5)** - **Car as a symbol status and group influence (Cultural)** - Social pressure for SUV-s and powerful passenger cars (Deliverable 2.1) - **Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs (Educational)** - Lack of integrated transport/mobility and planning professionals (Deliverable 2.1) - **Problems with infrastructure/ public transport services (Institutional) (2**.5)	
use of biofuels.	- **Socio-economic status of users** (Social)(2.5) - **Lack of knowledge/information on EE transport** (Cultural)(2.5) - **Concerns on reliability/hesitation to trust new technologies** (Social)(2.5)	

GERMANY

Building sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources (D.2.1)	Number of subsectors (D.2.1)	Easiness in confronting barrier (D.1.4, D.2.1)	Duration (D.2.1)	Number of policy instruments (D.2.1)	Cross-cutting barrier (D.2.2)	Preferences of stakeholders (D.2.5)
Social	Social group interactions and status considerations	Low social recognition	1	2 residential, tertiary	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2005	3	no	Yes (2.80%)
Social	Socio-economic status of building users	Age of building owners	1	1 Residential	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2015	0	no	Yes (11.70% for all countries)
Social	Strong dependency on the neighbors in multi-family housing	Joint ownership of Buildings (from institutional)	1	1 Residential	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2014	0	no	
Social	Inertia								
Social	Commitment and motivation of public social support								
Social	Rebound effect								
Cultural	Lack of interest/low priority/Undervaluing energy efficiency	Disadvantage of energetic quality to other attributes of a housing unit (value)	1	1 Residential	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2006	5	yes	Yes (7.30%)
Cultural	Customs, habits and relevant behavioural aspects								Yes (7.50%)
Cultural	Bounded rationality/Visibility of energy efficiency	Misperception of building condition (bounded rationality)	2	1 Residential	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2005	6	yes	
Cultural	Missing credibility/mistrust of technologies and contractors	Missing credibility and trust concerning technologies/ Missing supply of qualified craft business and energy consultants (from institutional, here)	4	2 residential, tertiary	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2010	Total 6 (5+1)	no	

Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience								Yes (6%- lack of trusted information and experience, 5.40%- training and skills of professionals)
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies	Lack of awareness on non-energy benefits (value)	3	2 (Residential, tertiary)	Moderate – appears in all levels (local/regional /national) (2.1)	Identified since 2007	4	yes	Yes (7.40%-lack of awareness on saving potentials, 4.20% 0 difficulties in using new technologies)
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)								Yes (10% for all countries)
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	High up-front costs, lack of capital and missing profitability/ Uncertainty on investment	7	2 (Residential, tertiary)	Easy – mainly addressed by national level	Since 2005	5	yes	Yes (5.40%
Economic	Payback expectations/investment horizons	Length of payback period/ Investment lock-in in private, commercial and public buildings (here from institutional)	5	2 (Residential, tertiary)	Easy – mainly addressed by national level	Since 2007	11	yes	Yes (7.00%)
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE								
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	Time costs	2	1 tertiary	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2010	6	no	
Economic	Financial crisis/Economic stagnation								

Economic	Embryonic markets								
Institutional	Split Incentive	Split incentives / owner tenant (investor-user) Dilemma/ Difficult real estate markets in somecities/regions	4	1 residential	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2005	5	no	Yes (6.30%)
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	Legal barriers/ Complexity and target conflicts of support programmes	4	2 Residential, tertiary	Moderate – appears in all levels (local/regional /national) (2.1)	Since 2010	2	yes	Yes (6.70% - complex/inadequate regulatory procedures) and 5.5%- lack of relevant information))
Institutional	Building stock characteristics/aging stock/ Historical preservation								Yes (6.60%)
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	Technical/constructional issues	2	2 (Residential, tertiary)	Moderate – appears in all levels (local/regional/national) (2.1)	Since 2010	12	no	
Institutional	Lack of data/information-diversion of management	Missing support chains	0	1 residential	Easy – mostly national level	No information	4	no	
Institutional	Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of	Missing strategic Development/ Adverse long-term effect of municipalities' investments/ Missing incentives by single policies	1	2 (Residential, tertiary)	Moderate – mainly addressed by local/regional level Easy – only at local level	Since 2012	2	yes	

	municipalities)								
Institutional	Disruption/Hassie factor	Preferences for single measures than comprehensive retrofitting	2	2 Residential, tertiary	Not mentioned	Identified since 2010	0	no	
Institutional	Security of fuel supply								

For German building sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers (sources: Deliverables 1.2 + 2.1 + 2.5)	Policy instruments (source: deliverable 1.4)
Building shell improvement (fabric upgrade)	- **Strong dependency on the neighbors in multi-family housing (Social) (legal issues) (Social)(2.1)** Joint ownership of buildings (here instead of institutional) (energetic refurbishment) - **Customs, habits and relevant behavioural aspects** (Cultural) (2.5) - **Lack of experience professionals, trusted information(Educational)(2.5)** - **Lack of awareness/knowledge on savings potential/information gap on technologies (Educational)** *(Lack of awareness on non-energy benefits (value) (about thermal retrofits) (2.1)* - **Bounded rationality/Visibility of energy efficiency (Cultural)** (*Misperception of building conditions (bounded rationality) (about double glazing of windows)) (2.1)* - **Missing credibility/mistrust of technologies and contractors (Cultural)** *(Missing credibility and trust concerning technologies and contractors / Missing supply of qualified craft business and energy consultants (building materials-retrofits) (retrofit measures) (2.1+2.5)* - **Socio-economic status of building users (Social)** *(Age of Building owners (building investments)) (2.1)* - **Disruption/Hassie (Institutional)** *(Preferences for single measures than comprehensive retrofit) (2.1)* - **Payback expectations/investment horizons (Economic)** *(Length of payback period (retrofit)* / Investment lock-in in private, commercial and public buildings (renovation) *(2.1)* - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)** *(High up-front costs, lack of capital and missing profitability / Uncertainty on investment) (retrofits)(2.1)* - **Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability)) (Economic)** *(Time costs (retrofit)(2.1)* - **Split incentive (Institutional)** *(Split incentives / owner tenant (investor-user) Dilemma/ Difficult real estate markets in some cities/regions) (2.1)* - **Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch (Institutional)** *(Technical/constructual issues (building technologies, retrofitting) (2.1)* - **Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures (Institutional)** *(Legal barriers/ Complexity and target conflicts of support programmes) (historic buildings) (2.1)* - **Lack of any type of financial support (Economic)(2.5)** - **Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities) (Institutional)(2.1)** Missing strategic Development/ Adverse long-term effect of municipalities' investments/ Missing incentives by single policies	- Energy performance certificate (energy efficiency enhancement measures) - Seal of quality Efficiency house (building envelope) - On-side energy consultation (building envelope, doors, windows) - Energy checks (walls, windows, doors, roofs) - Energy consultation for SMEs (KfW) (building envelope, building equipment) - KfW construction monitoring (energetic building concepts) - KfW Energy-efficient Construction (energetic building enhancement in line with House Standards) - KfW Energy Efficient Refurbishment (insulation of walls and roofs, windows and exterior doors) - Energy efficiency networks initiative (energy -inefficient buildings, building equipment - Requirement guidelines for energy consultants and list of certified energy consultants (building envelope)- capacity building - Low energy buildings project (dena) and efficient house plus (energy efficient heating and cooling systems, energy-efficient building material) - Research initiative "Zukunft Bau" and Research for energy - optimised construction (energy-efficient heating (and cooling) systems, energy efficient building-material) - Energy research programme (building technologies)

	- **Lack of data/information-diversion of management (Institutional)((2.1)** Missing support chains (energetic refurbishment)	
Heat pumps	- **Social group interactions and status considerations (Social)** *(Low social recognition (renewable energy technologies) (2.1)* - **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** *(Lack of trusted information and experience – 2.5 (higher number of responses)* - **Lack of any type of financial support (Economic)(2.5)** - **High costs and risks (Economic) -** *High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users* **((***High up-front costs, lack of capital and missing profitability / Uncertainty on investment) (retrofits)(2.1)*	- Market incentive programme to promote the use of renewable energies in the heating market (solar thermal collectors, biomass, heat pumps) - BAFA cross-cutting technologies (electrical motors, pumps) - Research initiative "Zukunft Bau" and Research for energy - optimised construction (pumps)
Efficient heating	**Split incentive (Institutional)** *(Split incentives/owner-tenant (investor-user) dilemma (heating, energetic refurbishment) – 2.1*	- Energy Saving Ordinance - Inspections of boilers and heating/cooling installations - Heating cost regulation (boilers) - Energy performance certificate (space and room heating) - Seal of quality Efficiency house (boilers) - On-side energy consultation (space and water heating) - Energy checks (heating and distribution systems; gas- and oil-based heating systems) - KfW construction monitoring (exchange of heating and cooling systems) - KfW Energy Efficient Refurbishment (renewal or optimization of heating and ventilation systems) - Energy tax (exchange of heating and ventilation systems) - BAFA cross-cutting technologies (heat-recovery systems) - Funding for the retraining as an energy consultant (energy efficient technologies) – capacity building - Requirement guidelines for energy consultants and list of certified energy consultants (heating and ventilation systems)- capacity building - Competence centre for public buildings (incl. default guarantees) (energy efficient heating and ventilation systems) - Research initiative "Zukunft Bau" and Research for energy - optimised construction (energy-efficient heating (and cooling) systems, energy efficient building-material) - Low energy buildings project (dena) and efficient house plus (energy efficient heating and cooling systems, energy-efficient building material) - Public procurement guidelines (all technologies)
Efficient cooling (air conditioning systems A+, A++, A+++)	**Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** (Lack of trusted information and experience – 1.2 (lack of inspections – insufficient energy efficient installations)	- Energy Saving Ordinance (EnEV) - Inspections of boilers and heating/cooling installations - Energy performance certificate (cooling system) - KfW construction monitoring (exchange of heating and cooling systems) - KfW Energy Efficient Refurbishment (renewal or optimization of heating and ventilation systems) - Energy tax (exchange of heating and ventilation systems) - Funding for the retraining as an energy consultant (energy efficient technologies) – capacity building

		- Requirement guidelines for energy consultants and list of certified energy consultants (heating and ventilation systems)- capacity building - IPEEC (International partnership for Energy Efficiency Cooperation) (air conditioning, ceiling fans, refrigeration) - Competence centre for public buildings (incl. default guarantees) (energy efficient heating and ventilation systems) - Low energy buildings project (dena) and efficient house plus (energy efficient heating and cooling systems, energy-efficient building material) - Research initiative "Zukunft Bau" and Research for energy - optimised construction (energy-efficient heating (and cooling) systems, energy efficient building-material) - Public procurement guidelines (all technologies)
LEDs	- **Customs, habits and relevant behavioural aspects** – 2.5 (higher number of responses) - **Lack of any type of financial support (Economic)(2.5)** - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)** *(High up-front costs, lack of capital and missing profitability / Uncertainty on investment) (retrofits)(2.1)(2.5)*	- Energy Saving Ordinance (lighting systems) - IPEEC (International partnership for Energy Efficiency Cooperation) (interior lighting, street lighting) - Research initiative "Zukunft Bau" and Research for energy - optimised construction (lighting) - Public procurement guidelines (all technologies)
Efficient appliances (A+, A++, A+++)	- **Lack of interest/low priority/undervaluing energy efficiency (Cultural)** *(Lack of interest and undervaluing energy efficiency benefits – 2.5 (higher number of responses)* - **Lack of any type of financial support (Economic)(2.5)** - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)** *(High up-front costs, lack of capital and missing profitability / Uncertainty on investment) (retrofits)(2.1)*	- Energy checks (Household appliances and ICT equipment) - Energy tax (inefficient appliances) - Funding for the retraining as an energy consultant (energy efficient technologies) - Public procurement guidelines (all technologies)
BEMS	- **Lack of interest/low priority/undervaluing energy efficiency (Cultural)** *(Lack of interest and undervaluing energy efficiency benefits – 2.5 (higher number of responses)* - **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** (Missing credibility and trust concerning technologies and contractors (retrofit measures) (2.5) - Lack of trusted information and experience – 2.5 (higher number of responses) - **Lack of any type of financial support (Economic)(2.5)** - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)** *(High up-front costs, lack of capital and missing profitability / Uncertainty on investment) (retrofits)(2.1)*	- Promotion of energy management systems-capacity building - Funding for the retraining as an energy consultant (energy efficient technologies) – capacity building - Public procurement guidelines (all technologies)

Transport sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources	Number of subsectors	Easiness in confronting barrier	Duration	Number of policy instruments	Cross-cutting barrier	Preferences of stakeholders (2.5)
Social	Low satisfaction with public transport/lack of trust								Yes (6.70%)
Social	Concerns of vehicle reliability/Hesitation to trust new								Yes (3.40%)

	technologies								
Social	Heterogeneity of consumers								
Social	Suburbanisation trends/Low density	Suburbanisation trends	1	All subsectors	No information	Since 2010	No information		
Social	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)	Vulnerability of pedestrians	1	Road sector		Since 2012			
Social	Inertia								
Cultural	Car as a symbol status and group influence	Cars as status symbol/	2	Road passenger sector	Moderate – appears in all levels (local/regional/ national) (2.1)	Since 2005	2		Yes (4.50%)
Cultural	Habit and social norm of driving, car ownership and use	Tradition of car ownership and use/ Opposition against (tighter) speed limits (e.g. on highways)	3	Road passenger sector	Moderate – appears in all levels (local/regional/national) (2.1)	Since 1999	2		Yes (5.50%)
Cultural	Cycling is marginalized								
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	High performance expectations for electric vehicles/ Limited relevance of environmental performance and energy-efficiency in vehicle purchasing decisions/ Criteria for mode choice favour car use	3	1 road	Easy (national level)/ all levels	Since 2011	5	yes	
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	Limited awareness of actual driving behaviour and range requirements/ Lack of awareness of fuel consumption and emission of own vehicles	3	1 road	All levels	Since 2010	1	yes	Yes (4.60%)
Educational	Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts/travel costs of different modes)	Limited awareness of the energy consumption of goods deliveries among private consumers/ Limited awareness about actual travel costs of different	1	1-road	All levels	Since 2013	1	yes	

		modes							
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*								
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs								
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE								Yes (8.20%)
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	Lack of financial resources for high quality public transport	2	all	All levels	Since 2013	1	yes	Yes (8.10%)
Economic	Low purchasing power of citizens/Financial crisis								Yes (7.70%)
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles	Limited willingness to accept high costs for alternative fueled vehicles (e.g. electric vehicles) (here instead of cultural)/ Limited willingness to accept higher purchasing prices for energy-efficient vehicles (here instead of cultural)/ Lacking cost competitiveness of electric vehicles	7	1 (road subsector)	Easy (national level)	Since 2011	4	yes	
Economic	Payback period of fuel efficient vehicles/ revenues for national automobile industry/ Investment lock-in of vehicle owners	Payback period of fuel efficient Vehicles/ High economic importance of the automobile industry in Germany/	2	1 - road	Easy - national	Since 2015	1	yes	
Economic	Negative role of Investment schemes, taxes/employee benefits encourage transport EE	Tax policies that negatively affect road transport energy efficiency/ Tax policies that favour inefficient	3	1 - road	No information	Since 2010	No information	yes	

		modes							
Institutional	Administrative fragmentation, lack of integrated governance, lack of cooperation between levels	Fragmentation of public transport operators/ Segmented planning of transport infrastructure	3	Road, rail/all	All levels	Since 2006	1		Yes (6.70%-lack of integrated governance)
Institutional	(lack) Transport EE on the Government Agenda/priorities (reconsidering, setting)	Priorization of megaprojects, at the expense of more cost-effective sustainable/energy-efficient transport options/ Limited focus on energy efficiency and co-benefits in the public decision making process/ Parallel extension of road networks/ Lack of long-term vision regardingthe improvements of and investments in transport infrastructure	5	All sectors	No information/all levels	Since 2003	No information/1	yes	Yes (7.0%) (lack of a national strategy for sustainable urban mobility) (6.10%- Transport EE on the Government Agenda/priorities) (5.60% - Environmental concern/low priority)
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	(Perceived) lack of charging infrastructure for electric vehicles (here instead of cultural)/ Car-oriented urban planning/ Limited rail infrastructure capacity (from economic here, it is about infrastructure not cost)	3	1 – road/ freight-road	All levels	Since 2012	5		Yes (7.30 % - insufficient transport infrastructure and planning) (6.70%- insufficient development of cycling/walking infrastructure)(6.60% Lack of support for rail transportation/Limited rail infrastructure) (5.60%- Undeveloped infrastructure for recharging of EV)
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics								
Institutional	Limited/complex funding in urban public transport	Complex funding structures in urban public transport	1	Public transport	No information	Since 2010			

Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)								
Institutional	Contradicting policy goals (particularly road/car-oriented planning)	Priorization of megaprojects, at the expense of more cost-effective sustainable/ energy-efficient transport options / Inconsistency in national, regional and local priorities	/ no information	/ no information	/ no information	/ no information	/ no information		

For German transport sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers (2.1, 2.2, 2.5)	Policy instruments
Electric and hybrid vehicles	- **High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles (Economic)** - Limited willingness to accept high costs for alternative fueled vehicles (e.g. electric vehicles) (here instead of cultural)/ Limited willingness to accept higher purchasing prices for an energy-efficient vehicles (here instead of cultural)/ Lacking cost competitiveness of electric vehicles (2.1) - **Attitude (Attitude-action gap /Bounded rationality/Buyer attitude) (Cultural)** - High performance expectations for electric vehicles/ Limited relevance of environmental performance and energy-efficiency in vehicle purchasing decisions/ Criteria for mode choice favour car use - **Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy) -** Limited awareness of actual driving behaviour and range requirements/ Lack of awareness of fuel consumption and emission of own vehicles - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) -** (Perceived) lack of charging infrastructure for electric vehicles (here instead of cultural)/ Car-oriented urban planning/ Limited rail infrastructure capacity (from economic here, it is about infrastructure not cost) - **High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles (Economic)** – Limited willingness to accept high costs for alternative fueled vehicles (e.g. electric vehicles) (here instead of cultural)/ Limited willingness to accept higher purchasing prices for energy-efficient vehicles (here instead of cultural)/ Lacking cost competitiveness of electric vehicles	- CO_2-related motor vehicle taxation - CO_2 emission standards of new vehicles - Passenger car labelling - "Elektromobilitätsgesetz" - Government electro mobility programme (funding for electric mobility in model regions, financial support for R&D) - Funding programme for hybrid electric and plug-in hybrid electric buses for public transport (BMUB, 2014b)
Efficient and sustainable modes of transport in passenger and		

freight transport such as		
eco-driving,	- **Lack of knowledge/information on EE transport (Cultural)(2.5)** - **Socio-economic status of users (Social)(2.5)**	
modal shift,	- **Low satisfaction/lack of trust for public transport** (Social)(2.5) - **Attitude (Attitude-action gap /Bounded rationality/Buyer attitude) (Cultural)** - High performance expectations for electric vehicles/ Limited relevance of environmental performance and energy-efficiency in vehicle purchasing decisions/ Criteria for mode choice favour car use - **Low/Limited awareness (of impact of EE in transport /towards eco-driving/benefits-environmental impacts/travel costs of different modes)** – Limited awareness of the energy consumption of goods deliveries among private consumers/ Limited awareness about actual travel costs of different modes - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)** - (Perceived) lack of charging - infrastructure for electric vehicles (here instead of cultural)/ Car-oriented urban planning/ Limited rail infrastructure capacity (from economic here, it is about infrastructure not cost)(2.5) - **Negative role of Investment schemes, taxes/employee benefits encourage transport EE** - Tax policies that negatively affect road transport energy efficiency/ Tax policies that favour inefficient modes - **(lack) Transport EE on the Government Agenda/priorities (reconsidering, setting)** - Priorization of megaprojects, at the expense of more cost-effective sustainable/energy-efficient transport options/ Limited focus on energy efficiency and co-benefits in the public decision making process/ Parallel extension of road networks/ Lack of long-term vision regarding the improvements of and investments in transport infrastructure (2.5) - **Habit and social norm of driving, car ownership and use (2.5)**	
efficient vehicles	- **Attitude (Attitude-action gap /Bounded rationality/Buyer attitude) -** High performance expectations for electric vehicles/ Limited relevance of environmental performance and energy-efficiency in vehicle purchasing decisions/ Criteria for mode choice favour car use - **Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy) -** Limited awareness of actual driving behaviour and range requirements/ Lack of awareness of fuel consumption and emission of own vehicles - **Payback period of fuel efficient vehicles/ revenues for national automobile industry/ Investment lock-in of vehicle owners** - Payback period of fuel efficient Vehicles/ High economic importance of the automobile industry in Germany/ - **Habit and social norm of driving, car ownership and use (2.5)**	- Tax reduction for natural gas in the transport sector (Natural gas vehicles) - HGV toll (Government plans to introduce staggered charges based on the vehicles' energy consumption) - EU tyre labelling and phase out - Funding programme for low emission engines for navigation (BMVBS 2013a) - Research programme for civil aviation (programme line eco-efficient aviation)
use of biofuels.	- **Socio-economic status of users** (Social)(2.5) - **Lack of knowledge/information on EE transport** (Cultural)(2.5) - **Concerns on reliability/hesitation to trust new technologies** (Social)(2.5)	

GREECE

Building sector									
Type	**Name of barrier**	**Corresponding to (based on D.2.1)**	**Number of different sources (D.2.1)**	**Number of subsectors (D.2.1)**	**Easiness in confronting barrier (D.1.4, 2.1)**	**Duration (D2.1)**	**Number of policy instruments (D.2.1)**	**Cross-cutting barrier (2.2)**	**Preferences of stakeholders (2.5)**
Social	Social group interactions and status considerations	Limitation in selected EE technologies	1	all	national	Since 2014	No policy	No	Yes (2.80%)
Social	Socio-economic status of building users	Diverse socio-economic background in the plenty multifamily buildings in Greece	2	1 - residential	Only national	Since 2014	0	No	Yes (11.70% for all countries)
Social	Strong dependency on the neighbors in multi-family housing	Shared ownership (multilateral ownership)/	2	1-residential	national	Since 2012	1 policy instrument	No	
Social	Inertia	Unwillingness to do more than minimum requirements	1	1 -tertiary	national	2011	1 policy instrument	No	
Social	(Lack of) Commitment and motivation of public social support	Lack of local social support	1	All	local	Since 2013	No policy instrument	No	
Social	Rebound effect	Higher income, higher energy consumption	2	1 -residential				No	
Cultural	Lack of interest/low priority/Undervaluing EE	Market failure to understand financial and social benefits	1	All	Local/national	Since 2013	No policy instrument	No	Yes (7.30%)
Cultural	Customs, habits and relevant behavioural aspects	South European occupant behavior towards shading/working habits	2	1 -residential	national	Since 2010	No policy instrument	yes	Yes (7.50%)
Cultural	Bounded rationality/Visibility of energy efficiency	Established perception (hotels)/confusion and misuse of terms	3	1 -tertiary	national	Since 2011	No policy instrument	yes	
Cultural	Missing credibility/mistrust of technologies and contractors	End-users aloofness due to negative past experience/ Negative public perception	2	all	National	Since 2014/2011	No policy instrument	yes	
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	Lack of expertise – Incomplete training	4	all	Local/national	Since 2010	No policy instrument	yes	Yes (6%- lack of trusted information and experience, 5.40%- training and skills of professionals)
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies, EE	Zero to low availability of information/ Low level of awareness/Lack of environmental consciousness, awareness and culture/Wrong use of information and communication of local scale	12 (2+7+1+1+1)*	all	National/local-4	Since 2010	2+0+0+0+0	yes	Yes (7.40%-lack of awareness on saving potentials, 4.20% 0 difficulties in using new technologies)

		governments/ Information barrier towards emerging innovative technologies							
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support	3	Public buildings of municipalities, hotels	national	Since 2010	No policy instrument	yes	Yes (10% for all countries)
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	Reluctance to pay up front great amount of money for an investment with future returns/Costly innovative technologies for endusers/ Reduced budget for functional expenses due to EE	3	all	national	Since 2012	3 policy instruments	yes	Yes (5.40%
Economic	Payback expectations/investment horizons	Restricted interest of financial institutes towards NZEB/ Ignoring the Cost-Benefit ratio/ Selecting actions with short payback periods/Negative Return of Investment for EE projects	7	tertiary	national	Since 2015	2 policy instruments	No	Yes (7.00%)
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	Cost distribution of central heating systems that favored the occupants of penthouses	2	residential	national	Since 2007	No policy instrument	No	
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability)/not foreseen costs-management costs-JESSICA)	Financial burden for Implementation/ Decommitment of funds	1	tertiary	All three levels	Since 2012	1 policy instrument	No	
Economic	Financial crisis/Economic stagnation	Financial crisis/Status of economic situation	8	all	national	Since 2012	3	yes	
Economic	Embryonic or poorly developed markets	Poorly developed market for energy services	2			Since 2012		No	
Institutional	Split Incentive	Tenure status	1	Residential	National	Since 2012	No policy instrument	No	Yes (6.30%)
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays)	Lack of legislation/ complex and difficult legislation and procedures/ lack of urban and land planning/ Change of legislation for local/regional administrative division/ bureaucracy for publicly funded projects/ lack of legislation for positive policy interactions/ Low prioritization of EE/	7	all	National/ all levels	Since 2010	No policy instrument	yes	Yes (6.70% - complex/inadequate regulatory procedures) and 5.5%- lack of relevant information))

		Administrative burden							
Institutional	Building stock characteristics/aging stock/ Historical preservation	Variable ownership structure, age and condition of the existing building stock (here instead of social)/ Special building cases in the Greek building sector	3	2 residential, tertiary	National	Since 2014/ since 2013	No policy instrument	No	Yes (6.60%)
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	Time delays (second)	1	all	National	Since 2015		No	
Institutional	Lack of data/ /information-diversion of management (at user's level)	Hindering management of funds/ Lack of data/information – diversion of management/ Reluctance for PPP/ interior arrangements in public buildings	9	Tertiary/all	Local/ national	Since 2013/ since 2009	No policy instrument	No	
Institutional	Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts)	Problematic cooperation among parties (instead of educational-social here)/ Higher consumption of oil than gas (habit) (instead of socio-economic due to limited gas grid connections)/Lack of central coordination/ inadequate implementation of policy instruments/ Lack of experience and resources to implement the policy instrument/ Low information and problematic communication among higher and lower levels of administration and communities/ Inadequate implementation network/ governance framework / management of reporting/ unclear procedures for energy service contracts/lack of pertinent authorities for building/ apartment owners	7	all	National/local/all	Since 2010	3 policy instruments (No policy instrument |+1/+2)	yes	
Institutional	Disruption/Hassie factor							No	
Institutional	Security of fuel supply	Higher consumption of oil than gas (habit) (instead of socio-economic, due to infrastructure)						No	

*each of the mentioned barriers in D.2.1 had a number of references. Since they were merged into one barrier, the sum of all references provides the total number of references for the barrier.

For Greek building sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	**Barriers (sources: Deliverables 1.2 + 2.1 + 2.5)**	**Policy instruments (source: deliverable 1.4)**
Building shell improvement (fabric upgrade)	- **Building stock characteristics/aging stock/ Historical preservation (Institutional)** – *Variable ownership structure, age and condition of the existing building stock (here instead of social)/ Special building cases in the Greek building sector (Thermal renovation types) (2.1)* - **Socio-economic status of building users (Social) -** *Diverse socio-economic background in the plenty multifamily buildings in Greece (buildings renovation) (2.1)* - **Missing credibility/mistrust of technologies and contractors (Cultural) -** *End-users aloofness due to negative past experience/Negative public perception (thermal renovation, ventilation) (2.1)* - **Strong dependency on the neighbors in multi-family housing (Social) -** *Shared ownership (multilateral ownership)/ (energy upgrading measures for whole building) (2.1)* - **Lack of awareness/knowledge on savings potential/information gap on technologies, EE (Educational)** – *Low level of awareness (Energy refurbishment policies - renovation)(2.1) - Zero to low availability of information/ Low level of awareness/Lack of environmental consciousness, awareness and culture/Wrong use of information and communication of local scale governments/ Information barrier towards emerging innovative technologies (sustainable buildings) (2.1)* - **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational) -** *Lack of expertise – Incomplete training (bioclimatic architecture – energy renovation) (2.1)* - **Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts) (Institutional) -** *Problematic cooperation among parties (instead of educational-social here)/ Higher consumption of oil than gas (habit) (instead of socio-economic due to limited gas grid connections)/Lack of central coordination/ inadequate implementation of policy instruments/ Lack of experience and resources to implement the policy instrument/ Low information and problematic communication among higher and lower levels of administration and communities/ Inadequate implementation network/governance framework / management of reporting/ unclear procedures for energy service contracts/lack of pertinent authorities for building/apartment owners (bioclimatic building (2.1)* - **Missing credibility/mistrust of technologies and contractors** (Cultural)– *End-users aloofness due to negative past experience/Negative public perception* (Green roofs – refurbishment of buildings)(2.1) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) -** *Reluctance to pay up front great amount of money for an investment with future returns/Costly innovative technologies for end users/Reduced budget for functional expences due to EE (renovation) (2.1)(2.5)* - **Customs, habits and relevant behavioural aspects (Cultural) –** *South European occupant behavior towards shading/working habits (external shadings of buildings) (2.1)* - **Bounded rationality/Visibility of energy efficiency (Cultural) -** Established perception (hotels)/confusion and misuse of terms (energy minimum standards – building codes) (2.1) - **Social group interactions and status considerations (Social) –** *Limitation in selected EE technologies (aluminum frames) (2.1)* - **Financial crisis/Economic stagnation (Economic)** – *Financial crisis/Status of economic situation (Renovation, refurbishment) (2.1)* - **Rebound effect (Social)** – *Higher income, higher energy consumption) (building's envelope) (2.1)* - **Embryonic or poorly developed markets** (Economic) – *Poorly developed market for energy services (refurbishment of buildings towards NZEBs) (Economic-renovation) (2.1)* - **Payback expectations/investment horizons (Economic)** – *Restricted interest of financial institutes towards NZEB/ Ignoring the Cost-Benefit ratio/ Selecting actions with short payback periods/Negative Return of Investment for EE projects (renovation – energy efficiency interventions – double glazing windows) (2.1)* - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or**	- "Energy audits" (Sources: National Laws presented in the national report of D.1.2) - "KENAK – Minimum requirements of energy performance for buildings" (Sources: National Laws presented in the national report of D.1.2, respective EU Directives - Energy inspectors/auditors - Green Fund – subsidies" - "End-use efficiency and energy services (ESCOs)"

	access to finance) (Economic) - *Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support (bioclimatic architecture, building materials - renovations) (2.1)(2.5)* - **Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays) (Institutional) -** Lack of legislation/ complex and difficult legislation and procedures/ lack of urban and land planning/ Change of legislation for local/regional administrative division/ bureaucracy for publicly funded projects/ lack of legislation for positive policy interactions/ Low prioritization of EE/ Administrative burden (insulation- nZEBs – bioclimatic architecture-energy renovation-green roofs)(2.1) - **Split Incentive (institutional)** – *Tenure status (refurbishment) (2.1)(2.5)* - **Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts (Institutional) – bioclimatic** - **Lack of data/ /information-diversion of management (at users level) (institutional)** - Hindering management of funds/ Lack of data/information – diversion of management/ Reluctance for PPP/ interior arrangements in public buildings **(insulation level - renovation) (2.1)** - **Building stock characteristics/aging stock/ Historical preservation (Institutional)** – *Variable ownership structure, age and condition of the existing building stock (here instead of social)/ Special building cases in the Greek building sector (internal and external thermal insulation) (2.1) (2.5)*	
Heat pumps	- **Missing credibility/mistrust of technologies and contractors (Cultural) -** *End-users aloofness due to negative past experience/Negative public perception (groundsource heat pumps) (2.1)* - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) -** *Reluctance to pay up front great amount of money for an investment with future returns/Costly innovative technologies for end users/Reduced budget for functional expences due to EE (renovation) (2.5)* - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic) -** *Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support (bioclimatic architecture, building materials - renovations) (2.5)*	

Efficient heating	- **Lack of awareness/knowledge on savings potential/information gap on technologies, EE (Educational) –** *Zero to low availability of information (2.1) (heating system)* - **Missing credibility/mistrust of technologies and contractors (Cultural) -** *End-users aloofness due to negative past experience/Negative public perception (Solar thermal systems) (2.1)* - **Social group interactions and status considerations (Social) –** *Limitation in selected EE technologies (solar water heating collectors) (2.1)* - **Rebound effect (Social)** – *Higher income, higher energy consumption) (heating systems) (2.1)* - **Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE -** *Cost distribution of central heating systems that favored the occupants of penthouses (heating modes)(2.1)* - **Payback expectations/investment horizons (Economic)** – *Restricted interest of financial institutes towards NZEB/ Ignoring the Cost-Benefit ratio/ Selecting actions with short payback periods/Negative Return of Investment for EE projects (electrical heater – replacement of oil boilers with natural gas ones, thermal insulation of the hot water distribution pipes in older buildings) (2.1)* - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic) -** *Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support (passive energy systems) (2.1)* - **Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays) (Institutional) -** Lack of legislation/ complex and difficult legislation and procedures/ lack of urban and land planning/ Change of legislation for local/regional administrative division/ bureaucracy for publicly funded projects/ lack of legislation for positive policy interactions/ Low prioritization of EE/ Administrative burden (heating)(2.1) - **Lack of data/ /information-diversion of management (at users level) (institutional) -** Hindering management of funds/ Lack of data/information – diversion of management/ Reluctance for PPP/ interior arrangements in public buildings **(heat distribution systems) (2.1)**	- "Energy labeling" (Sources: National Laws presented in the national report of D.1.2, respective EU Directives (European Commission, 2015a; 2015b) - "Energy audits" (Sources: National Laws presented in the national report of D.1.2) - "KENAK – Minimum requirements of energy performance for buildings" (Sources: National Laws presented in the national report of D.1.2, respective EU Directives - Energy inspectors/auditors - supported by "Eco-design requirements" - "Energy Performance Certificate" - Green Fund – subsidies" - "Green Public Procurement" - "End-use efficiency and energy services (ESCOs)"
Efficient cooling (air conditioning systems A+, A++, A+++)	- **Lack of awareness/knowledge on savings potential/information gap on technologies, EE (Educational)** – *Low level of awareness (inverter technology of air-conditioning split units) (2.1)* - **High costs and risks - High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) -** *Reluctance to pay up front great amount of money for an investment with future returns/Costly innovative technologies for end-users/Reduced budget for functional expenses due to EE (solar cooling) (2.1)* - **Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays) (Institutional) -** Lack of legislation/ complex and difficult legislation and procedures/ lack of urban and land planning/ Change of legislation for local/regional administrative division/ bureaucracy for publicly funded projects/ lack of legislation for positive policy interactions/ Low prioritization of EE/ Administrative burden (air-conditioning)(2.1) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic) -** *Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support (renewable cooling systems)(2.1)*	- "Energy labeling" (Sources: National Laws presented in the national report of D.1.2, respective EU Directives Technologies supported by "Energy audits" (Sources: National Laws presented in the national report of D.1.2) - "KENAK – Minimum requirements of energy performance for buildings" Energy inspectors/auditors - "Eco-design requirements" - "Energy management systems" - "Energy Performance Certificate" - Green Fund – subsidies - "Green Public Procurement" - "End-use efficiency and energy services (ESCOs)"
LEDs	- **Financial crisis/Economic stagnation (Economic)** – *Financial crisis/Status of economic situation (lighting regulation)(2.1)* - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) -** *Reluctance to pay up front great amount of money for an investment with future returns/Costly innovative technologies for end users/Reduced budget for functional expences due to EE (renovation) (2.5)* - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic) -** *Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support (bioclimatic architecture, building materials -*	- Technologies supported by "Energy labeling" - Technologies supported by "KENAK – Minimum requirements of energy performance for buildings" - Energy inspectors/auditors - "Energy management systems" - "Energy Performance Certificate"

	renovations)(2.5)	
Efficient appliances (A+, A++, A+++)	- **Lack of awareness/knowledge on savings potential/information gap on technologies, EE** *(Educational) – (devices) – Low level of awareness (technologies)(2.1)- Zero to low availability of information/ Low level of awareness/Lack of environmental consciousness, awareness and culture/Wrong use of information and communication of local scale governments/ Information barrier towards emerging innovative technologies (energy-efficient technologies)(2.1)* - **Customs, habits and relevant behavioural aspects (Cultural) –** *South European occupant behavior towards shading/working habits (office and electronic equipment) (2.1)* - Lack of interest/low priority/Undervaluing EE (Cultural)(2.5) - **Financial crisis/Economic stagnation (Economic)** – *Financial crisis/Status of economic situation (appliances-energy efficient systems)(2.1)* - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)** - *Reluctance to pay up front great amount of money for an investment with future returns/Costly innovative technologies for endusers/Reduced budget for functional expences due to EE (new systems and innovative technologies)(2.1)* - **Lack of data/ /information-diversion of management (at users level) (institutional)** - Hindering management of funds/ Lack of data/information – diversion of management/ Reluctance for PPP/ interior arrangements in public buildings **(energy efficient technologies and practices) (2.1)** - **Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays) (Institutional) -** Lack of legislation/ complex and difficult legislation and procedures/ lack of urban and land planning/ Change of legislation for local/regional administrative division/ bureaucracy for publicly funded projects/ lack of legislation for positive policy interactions/ Low prioritization of EE/ Administrative burden (energy efficient technologies and practices)(2.1) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic) -** *Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support (bioclimatic architecture, building materials - renovations)(2.5)*	- Energy labeling - Technologies supported by "KENAK – Minimum requirements of energy performance for buildings" Energy inspectors/auditors - Eco-design requirements - Energy management systems - Energy Performance Certificate - Green Fund – subsidies
BEMS	- **Lack of interest/low priority/Undervaluing EE** (Cultural)(2.5) - **High costs and risks -** *High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) - Reluctance to pay up front great amount of money for an investment with future returns/Costly innovative technologies for endusers/Reduced budget for functional expenses due to EE (new systems and innovative technologies) (2.5)* - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic) -** *Insufficient budget for integrated energy efficiency plans/Difficult access to finance (hotels)/ Absence of incentive measures for buyers/Low state support (bioclimatic architecture, building materials - renovations) (2.5)* - Lack of experienced professionals, trusted information (Educational)(2.5)	- "Energy management systems" - Green Fund – subsidies" - "Financial incentives"

Transport sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources	Number of subsectors	Easiness in confronting barrier	Duration	Number of policy instruments	Cross-cutting barrier	Preferences of stakeholders (2.5)
Social	Low satisfaction with public transport/lack of trust	Disappointment for new transport systems	1	all	Local/ national	Since 2013	No policy	yes	Yes (6.70%)

Social	Concerns of vehicle reliability/Hesitation to trust new technologies	Low penetration of ICT from elderly people/Negative public perception towards electric vehicles	2	Road (all)	Local/national	Since 2013/since 2012	Some actions from municipality	yes	Yes (3.40%)
Social	Heterogeneity of consumers	Conflict of financial interest among different target groups (from economic here)	1	Road	local	Since 2013	No policy		
Social	Suburbanisation trends/Low density								
Social	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)	Cruising traffic	1	Road private	local	Since 2014	No policy- some actions from municipality of Athens		
Social	Inertia								
Cultural	Car as a symbol status and group influence	Perception that owning and driving a private car shows the status symbol and good lifestyle	1	Road private	National	Since 2012	No policy	yes	Yes (4.50%)
Cultural	Habit and social norm of driving, car ownership and use	Old habits/ wrong perception of people towards their capacity on eco-driving	1	Road private	Local/national	Since 2010	No policy	yes	Yes (5.50%)
Cultural	Cycling is marginalized								
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	Citizens' preference of private cars due toconvenience and affordable running costs	2	all	national	Since 2009	No policy		
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)	Limited knowledge on public transport	1	All	National	Since 2010	No policy	yes	Yes (4.60%
Educational	Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	Low public awareness towards eco-driving/low environmedntal sensitivity/ lack of "green transport bahaviour"	3	road	Local/ national	Since 2010	No policy	yes	
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*								
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs	Lack of certified instructorsand examiners for ecodriving	1	Road	Local/ national	Since 2010	No policy	yes	

Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	Lack of support schemes		Road	national		No policy	yes	Yes (8.20%)
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	Non-renewal of fleet and infrastructure/ Unattractiveness of sector for investments	2	all	national	Since 2006	No policy	yes	Yes (8.10%)
Economic	Low purchasing power of citizens/Financial crisis	Financial crisis	1	road	national	Since 2010	No policy	yes	Yes (7.70%)
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles	Energy efficient solutions more expensive than conventional ones	2	Road	national	Since 2012	Financial policy instruments (grants, tax, exemption for hybrid and electric vehicles)	yes	
Economic	Payback period of fuel efficient vehicles								
Economic	Negative role of Investment schemes/employee benefits encourage transport EE								
Institutional	Administrative fragmentation and lack of integrated governance	Overlap of responsibilities/	1	all	national	Since 2006	No policy	yes	Yes (6.70%- lack of integrated governance)
Institutional	Transport EE on the Government Agenda/priorities	Low prioritization of EE	1	all	national	Since 2006	No policy	yes	Yes (7.0%) (lack of a national strategy for sustainable urban mobility) (6.10%- Transport EE on the Government Agenda/priorities) (5.60% - Environmemtal concern/low priority)
Institutional	Barriers to behavior change due to	Ineffective urban	4+1	all	Local/nation	Since 2006	No policy	yes	Yes (7.30 % -

	problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	transportationPlanning/ Non-integrated energy efficient modal shifts in urban planning			al				insufficient transport infrastructure and planning) (6.70%- insufficient development of cycling/walking infrastructure)(6.60% Lack of support for rail transportation/Limited rail infrastructure)(5.60%- Undeveloped infrastructure for recharging of EV
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics								
Institutional	Limited/complex funding in urban public transport								
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)								
Institutional	Contradicting policy goals (particularly road/car-oriented planning)	Non-integrated policies	2	all	National	Since 2006	No policy	yes	

For Greek transport sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers	Policy instruments
Electric and hybrid vehicles	- **Concerns of vehicle reliability/Hesitation to trust new technologies (Social)** - Low penetration of ICT from elderly people/Negative public perception towards electric vehicles (electric vehicles)(2.1) - **High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles (Economic)** - Energy	- Improvement of infrastructure for electric vehicles - Registration tax exemption for electric and

	efficient solutions more expensive than conventional ones (electric vehicles)(2.1) - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) -** Ineffective urban transportation Planning/ Non-integrated energy efficient modal shifts in urban planning (electric vehicles)(2.1) - **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE (Economic)** – Lack of support schemes (electric vehicles)(2.1) - **Limited Infrastructure investment for public transport (Economic)(2**.5) - **Lack of integrated governance/entities-fragmentation/bureaucracy (Institutional)(2.5)**	hybrid vehicles - Circulation tax exemption for electric and hybrid vehicles
Efficient and sustainable modes of transport in passenger and freight transport such as		
eco-driving,	- **Habit and social norm of driving, car ownership and use (Cultural) -** Old habits/ wrong perception of people towards their capacity on eco-driving (eco-driving) (2.1) - **Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs (Educational)** – (eco-driving) (2.1) - **Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts) -** Low public awareness towards eco-driving/low environmedntal sensitivity/ lack of "green transport bahaviour" (eco-driving)(2.1) - Low purchasing power of citizens/Financial crisis (Economic) – Financial crisis (eco-driving)(2.1)	
modal shift,	- **Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts) -** Low public awareness towards eco-driving/low environmedntal sensitivity/ lack of "green transport bahaviour" (transport mode shift)(2.1) - **Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy)** – Limited knowledge on public transport (sustainable mobility modes)(2.1) - **Attitude (Attitude-action gap /Bounded rationality/Buyer attitude) (Cultural)-** Citizens' preference of private cars due to convenience and affordable running costs (sustainable mobility modes)(2.1) - **Car as a symbol status and group influence (Cultural) -** Perception that owning and driving a private car shows the status symbol and good lifestyle (sustainable mobility modes)(2.1) - **Limited infrastructure investment (road/train/cycling) – for public transport (Economic) -** Non-renewal of fleet and infrastructure/ Unattractiveness of sector for investments (implying modal shift)(2.1) - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) -** Ineffective urban transportation Planning/ Non-integrated energy efficient modal shifts in urban planning (implying modal shift)(2.1) - **Low satisfaction/lack of trust for public transport (Social)(2.5)**	
efficient vehicles	- **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ -** Inefficient or absent fiscal measures for supporting EE (Economic) – Lack of finance (2.5) - **Limited Infrastructure investment for public transport (Economic)(2**.5) - **Low purchasing power of citizens/Financial crisis (Economic)(2.5)** - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) -** Ineffective urban transportation Planning/ Non-integrated energy efficient modal shifts in urban planning (implying modal	**"Emission standards (Euro 5 and Euro 6)"**

	shift)(2.1)	
use of biofuels.	- **Socio-economic status of users** (Social)(2.5) - **Lack of knowledge/information on EE transport** (Cultural)(2.5) - **Concerns on reliability/hesitation to trust new technologies** (Social)(2.5)	

ITALY

Building sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources (2.1)	Number of subsectors (2.1)	Easiness in confronting barrier (1.4, 2.1)	Duration (2.1)	Number of policy instruments (2.1)	Cross-cutting barrier (2.2)	Preferences of stakeholders (2.5)
Social	Social group interactions and status considerations	Group as push factor to energy efficiency investments	0	all	National/regional/local		1 policy (campaigns)		Yes (2.80%)
Social	Socio-economic status of building users	Gender and age differences	0	all	National/regional/local		1 policy (campaigns)		Yes (11.70% for all countries)
Social	Strong dependency on the neighbors in multi-family housing	Fragmentation of home ownership (due to relevant presence of condominiums)	0	residential	National/regional/local		3 policy instruments		
Social	Inertia								
Social	(Lack of) Commitment and motivation of public social support								
Social	Rebound effect								
Cultural	Lack of interest/low priority/Undervaluing energy efficiency								Yes (7.30%)
Cultural	Customs, habits and relevant behavioural aspects								Yes (7.50%)
Cultural	Bounded rationality/Visibility of energy efficiency								
Cultural	Missing credibility/mistrust of technologies and contractors								
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	Lack of technical expertise ofbuilding administrators	0	all	National/local/regional		1 policy (campaigns)		Yes (6%- lack of trusted information and experience, 5.40%- training and skills of

									professionals)
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies, EE	Lack of a "culture of saving"	0	public	National/local/regional		1 policy (campaigns)	yes	Yes (7.40%-lack of awareness on saving potentials, 4.20% 0 difficulties in using new technologies)
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)								Yes (10% for all countries)
Economic	High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users								Yes (5.40%
Economic	Payback expectations/investment horizons								Yes (7.00%)
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	Little incidence of energy costs on companies/families	0	all	National/regional/local		2 policy		
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability)/not foreseen costs-management costs-JESSICA)								
Economic	Financial crisis/Economic stagnation							yes	
Economic	Embryonic or poorly developed markets								
Institutional	Split Incentive	Split incentives and principal-agent problem (instead of economic)	0	Residential - tertiary	National		2 policy		Yes (6.30%)
Institutional	Legislation issues (Lack of relevant legislation/Lack of	Lack of normative schemes	0	all	national		1 policy		Yes (6.70% - complex/inadequate regulatory

	regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays)								procedures) and 5.5%- lack of relevant information))
Institutional	Building stock characteristics/aging stock/ Historical preservation								Yes (6.60%)
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch								
Institutional	Lack of data/ /information-diversion of management (at users level)								
Institutional	Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts)								
Institutional	Disruption/Hassie factor								
Institutional	Security of fuel supply	Higher consumption of oil than gas (habit) (instead of socio-economic, due to infrastructure)							

For Italian building sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers (sources: Deliverables 1.2 + 2.1 + 2.5)	Policy instruments (source: deliverable 1.4)
Building shell improvement (fabric upgrade)	- **Strong dependency on the neighbors in multi-family housing (Social)** - Fragmentation of home ownership (due to relevant presence of condominiums) (energy efficiency technologies – implying also building shell improvement)(2.1) - **Socio-economic status of building users**(Social)(2.5) - **Legislation issues** (Lack of relevant legislation/Lack of regulatory provision / **prioritization/ lack of urban and land Planning/** Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – **bureaucracy-time delays**) (2.5) - **Split incentive(s)**(Institutional)(2.5) - **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (2.5) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (2.5)** - **Payback expectations/investments horizons (Economic)(2.5)** - **Lack of interest/low priority/Undervaluing energy efficiency (Cultural)(2.5)** - **Building stock characteristics and special issues (Institutional)(2.5)**	
Heat pumps	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (2.5) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (2.5)** - **Lack of trained and skilled professionals/ trusted information, knowledge and experience** (Educational)(2.5)	Thermal account, tax deductions, white certificates
Efficient heating	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (2.5) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (2.5)** - **Lack of awareness on savings potential, technologies, EE** - **Lack of trained and skilled professionals/ trusted information, knowledge and experience** (Educational)(2.5)	Thermal account, tax deductions, white certificates, Kyoto fund
Efficient cooling (air conditioning systems A+, A++, A+++)	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (2.5) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (2.5)** - **Lack of awareness on savings potential, technologies, EE (Educational)(2.5)**	-
LEDs	- **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (2.5) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (2.5)** - **Customs-habits-relevant behavioural aspects** (Cultural)(2.5)	White certificates, national Fund for Energy Efficiency (public lighting)
Efficient appliances (A+, A++, A+++)	- **Socio-economic status of building users (Social)** – Gender and age differences (electrical appliances) (2.1) - **Social group interactions and status considerations (Social)** – Group as push factor to energy efficiency investments (electrical appliances)(2.1) - **Strong dependency on the neighbors in multi-family housing (Social)** - Fragmentation of home ownership (due to relevant presence of condominiums) (energy efficiency technologies)(2.1) - **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds	- White certificates, energy labeling of households appliances

	or access to finance) (2.5) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (2.5)** - **Lack of interest/low priority/Undervaluing energy efficiency (Cultural)(2.5)**	
BEMS	- **Social group interactions and status considerations (Social)** – Group as push factor to energy efficiency investments (electrical appliances)(2.5) - Lack of interest/low priority/Undervaluing energy efficiency (Cultural)(2.5) - Customs-habits-relevant behavioural aspects (Cultural)(2.5) - Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)(2.5) - **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)(2.5) - **High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (2.5)**	- White certificates

Transport sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources	Number of subsectors	Easiness in confronting barrier	Duration	Number of policy instruments	Cross-cutting barrier	Preferences of stakeholders (2.5)
Social	Low satisfaction with public transport/lack of trust	Low satisfaction for the public transport (includes several elements, such as the perception of public transport as unsafe and as less flexible/rapid than private means)	5	all	national	Since 2006	7 policy		Yes (6.70%)
Social	Concerns of vehicle reliability/Hesitation to trust new technologies	Technical limitations of electricvehicles (public and private transport)(instead of institutional)	1	all	national	Since 2014	2 policy		Yes (3.40%)
Social	Heterogeneity of consumers								
Social	Suburbanisation trends/Low density	Urban sprawl (private transport)(instead of economic)	1	all	national	Since 2010	no		
Social	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)	Insufficient safety, lack of adequate space for walking (private transport)/ Chaotic parking (private transport)	2		local	Since 2010/since 2007	4 policy		
Social	Inertia								
Cultural	Car as a symbol status and group								Yes (4.50%)

	influence								
Cultural	Habit and social norm of driving, car ownership and use	Car ownership (private transport)/ Several economic operators organize by itself their freights supply (Conto Proprio)/ E-commerce rapid growth	3	Road private	national	Since 2012/since 2008	7 policy instruments		Yes (5.50%)
Cultural	Cycling is marginalized	Bike perceived as dangerous and not compatible with someweather conditions (private transport)	1		national		4 policy		
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)								
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy/energy consumption)								Yes (4.60%
Educational	Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	Low acknowledgement of environmental/social benefits of public transport use	1	public	national	since 2013	4 policy	yes	
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*								
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs / experience	Lack of high level managerial competencies			national		1 policy		
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	Reduction of national public investments in the public transport sector/ High outsourcing level of main logistic operators/ Lack of adequate economic resources for local public administrations	2	public	National/ regional	since 2013	No specific		Yes (8.20%)
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	Few external/international investments in Italian logistic sector	1		national				Yes (8.10%)
Economic	Low purchasing power of citizens/Financial crisis								Yes (7.70%)
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of	High evasion rate of public transport tickets (public transport)/ High cost of batteries for electric	2	public	local	Since 2007	No policy		

	batteries for electric vehicles	vehicles (public/private transport)							
Economic	Payback period of fuel efficient vehicles/low economic viability	Low economic viability of the investment necessary for the realization of high-capacity transport in low-density residential areas (public transport)	0	public	national		6 policy		
Economic	Negative role of Investment schemes/employee benefits encourage transport EE	High importance for logistics operators to show their logo in the last mile delivery and control the quality of delivery (brand identity) (here instead of cultural)							
Institutional	Administrative fragmentation - lack of integrated governance/lack of necessary entities/ bureaucracy	Critical economic condition of several public transport management authorities (public transport) (instead of economic here)/ Fragmentation of public transport operators (public transport)/ Spending review conducted by central government on public transport services (public transport)/ Lack of an Italian Transport Authority for a long time/ High fragmentation of local traffic regulation/ High bureaucracy in the logistic sector (both national and regional level)	1	Public transport	National/ local	Since 2013	6 policy		Yes (6.70%- lack of integrated governance)
Institutional	Transport EE on the Government Agenda/priorities/coordination	Delays in the definition of the strategic national plan/ Scarce attention in the public transport concession of qualitative standards of services/ Lack of a long term vision regarding the future of transport infrastructures/ Low cooperation between logistic operators	2	all	National/ regional	Since 2012	No policy		Yes (7.0%) (lack of a national strategy for sustainable urban mobility) (6.10%- Transport EE on the Government Agenda/priorities) (5.60% - Environmental concern/low priority)
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack	Old Italian public transport Fleets (public transport)/ Few underground lines in Italian cities (public transport)/ Lack of recharge stations for electric vehicles (public and private transport)/ Scarce diffusion	6	public	national	Since 2013/since 2011	2 policy		Yes (7.30 % - insufficient transport infrastructure and planning) (6.70%-

	of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	of Biomethane in Italy (private transport)/ Lack of infrastructures for intermodal logistics (especially in urban areas)/ National logistic infrastructures gap/ Italian southern regions weaknesses in freights infrastructures development							insufficient development of cycling/walking infrastructure)(6.60% Lack of support for rail transportation/Limited rail infrastructure)(5.60%- Undeveloped infrastructure for recharging of EV
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics	Lack of a national strategy for bike and pedestrian mobility	0		national	-	No policy		
Institutional	Limited/complex funding in urban public transport								
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)	Low probability to be sanctioned forirregular parking	1						
Institutional	Contradicting policy goals (particularly road/car-oriented planning)	Strong lobbies block political reforms (here instead of cultural)/ Regulatory aspects limit the growing of green logistic solutions (both national and regional level)	1		National/regional	Since 2013	No policy		

For Italian transport sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers	Policy instruments
Electric and hybrid vehicles	- **High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles (Economic)** - High evasion rate of public transport tickets (public transport)/ High cost of batteries for electric vehicles (public/private transport) (electric vehicles)(2.1) - **Lack or limited finance/incentives (Economic)(2.5)** - **Low purchasing power of citizens/financial crisis (Economic)(2.5)** - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient**	- National infrastructure plan to set up electric vehicle charging points, Road tax, Renewable energy in transport sector (D.lgs 28/2011)

	urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional) - Old Italian public transport Fleets (public transport)/ Few underground lines in Italian cities (public transport)/ Lack of recharge stations for electric vehicles (public and private transport) (electric vehicles)(2.1) - Concerns of vehicle reliability/Hesitation to trust new technologies (Social) - Technical limitations of electric vehicles (public and private transport)(instead of institutional) (electric vehicles)(2.1) - **Lack of integrated governance/entities-fragmentation/bureaucracy (Institutional)(2.5)**	
Efficient and sustainable modes of transport in passenger and freight transport such as		
eco-driving,	- **Lack of knowledge/information on EE transport (Cultural)(2.5)** - **Socio-economic status of users (Social)(2.5)**	Eco-driving Guide
modal shift,	- **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional)** - Old Italian public transportFleets (public transport)/ Few underground lines in Italian cities (public transport)/ Lack of recharge stations for electric vehicles (public and private transport)/ Scarce diffusion of Biomethane in Italy (private transport)/ Lack of infrastructures for intermodal logistics (especially in urban areas) (modal shift implying)(2.1)(2.5) - **Low satisfaction/lack of trust for public transport (Social)(2.5)** - **Lack or limited policies on EE transport issues (Institutional(2.5)**	
efficient vehicles	- **Low purchasing power of citizens/financial crisis (Economic)(2.5)** - **Lack or limited finance/incentives (Economic)(2.5)**	
use of biofuels.	- **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional)** - Old Italian public transport Fleets (public transport)/ Few underground lines in Italian cities (public transport)/ Lack of recharge stations for electric vehicles (public and private transport)/ Scarce diffusion of Biomethane in Italy (private transport) (biofuels)(2.1) - **Socio-economic status of users** (Social)(2.5) - **Lack of knowledge/information on EE transport** (Cultural)(2.5) - **Concerns on reliability/hesitation to trust new technologies** (Social)(2.5)	Incentives for the promotion of biofuels in transport sector, Law n.81/2006

SERBIA

Building sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources (2.1)	Number of subsectors (2.1)	Easiness in confronting barrier (1.4, 2.1)	Duration (2.1)	Number of policy instruments (2.1)	Cross-cutting barrier (2.2)	Preferences of stakeholders (2.5)
Social	Social group interactions and status considerations	Social group interactions and status considerations	1	all	national	Since 2014	3 policy instruments	yes	Yes (2.80%)
Social	Socio-economic status of building users	Heterogeneity of consumers/households credit capacity (from economic here)	2	all	national	Since 2014/since 2012	3 policy instruments	yes	Yes (11.70% for all countries)
Social	Strong dependency on the neighbors in multi-family housing								
Social	Inertia	Inertia	2	all	national	Since 2015	3 policy instruments	yes	
Social	(Lack of) Commitment and motivation of public social support	Commitment and motivation of public	1	all	national	Since 2011	3 policy instruments		
Social	Rebound effect								
Cultural	Lack of interest/low priority/Undervaluing energy efficiency								Yes (7.30%)
Cultural	Customs, habits and relevant behavioural aspects								Yes (7.50%)
Cultural	Bounded rationality/Visibility of energy efficiency	Bounded rationality	1		national	Since 2011	3 policy instruments		
Cultural	Missing credibility/mistrust of technologies and contractors	mistrust of new technologies/ familiarization with technology in general/ willingness to adopt new measures	**1**	all	national	Since 2011	3 policy instruments	yes	
Educational	Lack of trained and skilled professionals/	Lack of information,	**3**	all	National, local	Since 2011	2 policy instruments	yes	Yes (6%- lack of trusted information

	trusted information, knowledge and experience	knowledge and experience/ Lack of experience in cooperation with national and international funds							and experience, 5.40%- training and skills of professionals)
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies, EE	Lack of awareness of the population and local politicians about the potential, economic and social benefits from rational use of energy/ Lack of providing information from the best practice projects	2	all	National, local, regional	Since 2011	3 policy instruments	**yes**	Yes (7.40%-lack of awareness on saving potentials, 4.20% 0 difficulties in using new technologies)
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	Lack of dedicated financing	1	public	Regional, local	Since 2014	5 policy	**yes**	Yes (10% for all countries)
Economic	High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	High Interest Rates and Numerous Additional Bank Fees and Charges/ Small Size and High Transaction Costs of Energy Efficiency Projects/	2	all	National/local	Since 2012	1 financial policy (credit lines, subsidies, loans)/4		Yes (5.40%
Economic	Payback expectations/investment horizons								Yes (7.00%)
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE	The belief of citizens that the price of electricity will remain low in the future (from social here)/ low electricity prices	1	all	National	Since 2015	3 policy instruments		
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability)/not foreseen								

	costs-management costs-JESSICA)								
Economic	Financial crisis/Economic stagnation								
Economic	Embryonic or poorly developed markets								
Institutional	Split Incentive	Split Incentive for Rented Building – Landlord is Responsible for Renovations, but Tenants Pay the Bill	2	Residential/tertiary	national	Since 2003	No policy		Yes (6.30%)
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays)	Association of homeowners' reluctance to make decisions to renovate							Yes (6.70% - complex/inadequate regulatory procedures) and 5.5%- lack of relevant information))
Institutional	Building stock characteristics/aging stock/ Historical preservation								Yes (6.60%)
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch								
Institutional	Lack of data/ /information-diversion of management (at users level)	Distorted District Heating Price and Absence of Metering (from economic here)/ Limitation of Public Sector Entities to Provide Collateral/	7	All	National, local	Since2012/since 2003	2 policy instruments		

		Public sector budgeting does not allow municipalities to keep their baseline budget for a few years after energy efficiency projects/							
Institutional	Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts)	Institutional Capacity of the Government of Serbia/ Institutional Capacity of the local self government/Lack of Specific Home Owner Association (HOA)	4	all	national	Since 2014/since 2003	No policy	yes	
Institutional	Disruption/Hassie factor								
Institutional	Security of fuel supply	Higher consumption of oil than gas (habit) (instead of socio-economic, due to infrastructure)							

For Serbian building sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers (sources: Deliverables 1.2 + 2.1 + 2.5)	Policy instruments (source: deliverable 1.4)
Building shell improvement (fabric upgrade)	- **Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE (Economic)** – *The belief of citizens that the price of electricity will remain low in the future (from social here)/ low electricity prices (refurbishment, retrofit)(2.1)* - **Lack of any type of financial support** (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)(Ecnomic)(2.5) - **High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)** - High Interest Rates and Numerous Additional Bank Fees and Charges/ Small Size and High Transaction Costs of Energy Efficiency Projects (renovation) (2.1)	- **Minimum energy performance requirements for new or reconstructed buildings**

	- **Socio-economic status of building users (Social) –** Households credit capacity (implying renovation)(2.1) - **Split incentive (Institutional) -** Split Incentive for Rented Building – Landlord is Responsible for Renovations, but Tenants Pay the Bill (renewal)(2.1) - **Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts) (Institutional)** (2.1) - **Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays) (Institutional) -** Association of homeowners reluctance to make decisions to renovate (renovate)(2.1) - **Building stock characteristics and special issues (Institutional)(2.**5)	
Heat pumps	- **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** - *Not enough high-level trained specialists in energy efficiency matters/ Lack of comprehensive and systematic technical data for research* (Deliverable 2.5) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)(2.5)	
Efficient heating	- **Missing credibility/mistrust of technologies and contractors - (Cultural) -** *mistrust of new technologies/ familiarization with technology in general/ willingness to adopt new measures (electric boilers for heating water)(2.1*) - **Lack of data/ /information-diversion of management (at users level) (Institutional) -** Distorted District Heating Price and Absence of Metering (from economic here)/ Limitation of Public Sector Entities to Provide Collateral/ Public sector budgeting does not allow municipalities to keep their baseline budget for a few years after energy efficiency projects (district heating companies)(2.1) - **Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use/EE (Economic)** – *The belief of citizens that the price of electricity will remain low in the future (from social here)/ low electricity prices (heat energy)(2.1)*	
Efficient cooling (air conditioning systems A+, A++, A+++)	- **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** - *Not enough high-level trained specialists in energy efficiency matters/ Lack of comprehensive and systematic technical data for research* (Deliverable 2.5) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)(2.5)	-
LEDs	- **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)(2.5) - Customs, habits and relevant behavioural aspects (Institutional) (2.5)	-
Efficient appliances (A+, A++, A+++)	- **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic)** - *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - **High costs and risks** - High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)(2.5) - **Lack of interest/low priority/Undervaluing energy efficiency (Cultural)(2.5)**	- **energy labelling**

BEMS	- **Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts) -** Institutional Capacity of the Government of Serbia/ Institutional Capacity of the local self government/Lack of Specific Home Owner Association (HOA) (system of energy management)(2.1) - **Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance) (Economic) -** *Dependence on private investment only/ Energy service enterprises' capacity to finance EE projects very low/ Availability of government financing support* (Deliverables 2.1 and 2.5) - High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)(2.5) - **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational) -** *Not enough high-level trained specialists in energy efficiency matters/ Lack of comprehensive and systematic technical data for research* (Deliverable 2.5)	-

Transport sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources	Number of subsectors	Easiness in confronting barrier	Duration	Number of policy instruments	Cross-cutting barrier	Preferences of stakeholders (2.5)
Social	Low satisfaction with public transport/lack of trust								Yes (6.70%)
Social	Concerns of vehicle reliability/Hesitation to trust new technologies	Credibility and trust	1	all	national	Since 2007	1 policy	yes	Yes (3.40%)
Social	Heterogeneity of consumers	Heterogeneity of consumers/ Social group interactions and status considerations	2+1	all	national	Since 2008	1 policy	yes	
Social	Suburbanisation trends/Low density								
Social	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems)								
Social	Inertia	Inertia	2	all	national	Since 2014	1 policy	yes	
Cultural	Car as a symbol status and group influence								Yes (4.50%)
Cultural	Habit and social norm of driving, car ownership and use								Yes (5.50%)
Cultural	Cycling is marginalized								

Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)								
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy/energy consumption)	Lack of information, knowledge and experience	1	all	National, local	Since 2011	1 policy	yes	Yes (4.60%
Educational	Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	Lack of awareness of the population and local politicians about the potential, economic and social benefits from rational use of energy	1	all	National/ local	Since 2011	1 policy	yes	
Educational	Confusion about car and fuel costs (conventional vs ULEVs/Evs) – *Negative perception*								
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs / experience								
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	Lack of dedicated funding	1	all	national	Since 2014	2policy	yes	Yes (8.20%)
Economic	Limited infrastructure investment (road/train/cycling) – for public transport								Yes (8.10%)
Economic	Low purchasing power of citizens/Financial crisis	Low purchasing power of citizens	1	road	National, local	Since 2015	2 policy	yes	Yes (7.70%)
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles								
Economic	Payback period of fuel efficient vehicles								
Economic	Negative role of Investment schemes/employee benefits encourage transport EE								
Institutional	Administrative fragmentation and lack of integrated governance								Yes (6.70%-lack of integrated governance)

Institutional	Transport EE on the Government Agenda/priorities/coordination	Institutional Capacity of the Government of Serbia/ Institutional Capacity of the local self government	1	all	Since 2015	national	no	yes	Yes (7.0%) (lack of a national strategy for sustainable urban mobility) (6.10%- Transport EE on the Government Agenda/priorities) (5.60% - Environmemtal concern/low priority)
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)								Yes (7.30 % - insufficient transport infrastructure and planning) (6.70%- insufficient development of cycling/walking infrastructure)(6.60% Lack of support for rail transportation/Limited rail infrastructure)(5.60%- Undeveloped infrastructure for recharging of EV
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics								
Institutional	Limited/complex funding in urban public transport								
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)								

Institutional	Contradicting policy goals (particularly road/car-oriented planning)								

For Serbian transport sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers	Policy instruments
Electric and hybrid vehicles	- Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy/energy consumption) (Educational) - Lack of information, knowledge and experience (vehicles)(2.1) - Low purchasing power of citizens/Financial crisis (Economic) – Low purchasing power of citizens (purchasing cars) (2.1) - **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/** - Inefficient or absent fiscal measures for supporting EE (Economic) – Lack of finance (2.5) - **Administrative fragmentation and lack of integrated governance (Institutional)** – *Transport/mobility sector management is split between several departments, lack of integrated governance – Administrative fragmentation and lack of integrated governance* (Deliverable 2.1) - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional)** - Lack of integrated transport and land-use planning (Deliverable 2.5)	-
Efficient and sustainable modes of transport in passenger and freight transport such as		
eco-driving,	- **Lack of knowledge/information on EE transport (Cultural)(2.5)** - **Socio-economic status of users (Social)(2.5)**	
modal shift,	- **Concerns of vehicle reliability/Hesitation to trust new technologies (Social)** - Credibility and trust (implying modal shift)(2.1) - **Limited infrastructure investment (road/train/cycling) – for public transport** (Economic)(2.5) - **Low satisfaction with public transport/lack of trust** (Social)(2.5) - **Lack of EE in Government Agenda/ priorities/coordination** (Institutional)(2.5)	
efficient vehicles	- Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy/energy consumption) (Educational) - Lack of information, knowledge and experience (vehicles)(2.1) - **Low purchasing power of citizens/Financial crisis** (Economic) – Low purchasing power of citizens (purchasing cars) (2.1) - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional)** - Lack of integrated transport and land-use planning (Deliverable 2.5) - **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/** - Inefficient or absent fiscal measures for supporting EE (Economic) – Lack of finance (2.5)	**Fuel economy standards/vehicle CO_2 - emission standards**
use of biofuels.	- **Socio-economic status of users** (Social)(2.5) - **Lack of knowledge/information on EE transport** (Cultural)(2.5) - **Concerns on reliability/hesitation to trust new technologies** (Social)(2.5)	

UNITED KINGDOM

Building sector

Type	Name of barrier	Corresponding to (based on D.2.1)	Number of different sources (2.1)	Number of subsectors (2.1)	Easiness in confronting barrier (1.4, 2.1)	Duration (2.1)	Number of policy instruments (2.1)	Cross-cutting barrier (2.2)	Preferences of stakeholders (2.5)
Social	Social group interactions and status considerations	Perceived lack by business and industry	1	buildings	national	Since 2007	1 policy instrument		Yes (2.80%)
Social	Socio-economic status of building users	Socio-economic status of household	4	residential	National/regional	Since 2000	2 policy instruments		Yes (11.70% for all countries)
Social	Strong dependency on the neighbors in multi-family housing	Inter-occupant relationships	1	residential	National?	Since 2012	No policy instrument		
Social	Inertia	Inertia/unwillingness to replace systems	5	residential	National/regional	Since 2007	3 policy instruments	**YES**	
Social	(Lack of) Commitment and motivation of public social support	Perceived lack of political action / Lack of time and resources	1	buildings	National?	Since 2007	No policy instrument		
Social	Rebound effect	Rebound effect	5	Residential	national	Since 2000	2 policy instruments		
Cultural	Lack of interest/low priority/Undervaluing energy efficiency	Undervaluing energy efficiency/ low priority/ perception that environmental benefits too small/lack of interest/ competing purchase decisions (here instead of economic)	**7**		National/local	Since 2012/since 2008	4 policy instruments	YES	Yes (7.30%)
Cultural	Customs, habits and relevant behavioural aspects	Social norms and accepted behaviours/Aesthetics/impact on residence (here instead of institutional)	6	residential	National/Regional/local	Since 2000/ Since 2012	2+2 policy instruments	YES	Yes (7.50%)
Cultural	Bounded rationality/Visibility of energy efficiency	Refurbishment seen as low priority/ perceived lack of impact/ visibility of energy efficiency	5	residential	National/ regional/local	/Since 2007	3 policy instruments+1	YES	
Cultural	Missing credibility/mistrust of technologies and contractors	mistrust of technologies/mistrust of energy companies or contractors/ Confidence in	11					**YES**	

		the system/Mistrust - Confidence in technology/ Perceived risk/ lack of trust of utility firms							
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	Access to trusted information/ lack of information on energy use/lack of awareness on savings/ potential /perceived information over-load/ Confidence in contracting and delivery/skills and training/ quality of information/ training and skills/ consumer confusion/ marketing and information+1	14		National/ regional/local	Since 2003	3 policy+2	YES	Yes (6%- lack of trusted information and experience, 5.40%- training and skills of professionals)
Educational	Lack of awareness/knowledge on savings potential/information gap on technologies, EE	Lack of awareness/ interest/ motivation – Externalising responsibility and blame / Understanding of costs versus perceived benefits/ Lack of awareness/ Information gap/ Lack of experience (end users)	6	all	National/regional	Since 2011/since 2007	1 policy+3	yes	Yes (7.40%-lack of awareness on saving potentials, 4.20% 0 difficulties in using new technologies)
Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	Lack of funds or access to finance	1	buildings	National/regional	Since 2011	2 policy instruments	yes	Yes (10% for all countries)
Economic	High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	Capital costs/ risks and uncertainty/ price signal-financial incentive/cost of new heating system/cost of energy tariffs/cost of microgeneration technology/investment risk	12	buildings	National/regional	Since 2007/since 2004	2 policy instruments+1		Yes (5.40%
Economic	Payback expectations/investment horizons	Payback expectations/ investment horizons	3	buildings	regional	Since 2007	1 policy	YES	Yes (7.00%)
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct								

	prices for energy use/EE								
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability)/not foreseen costs-management costs-JESSICA)	Additional costs-hidden costs	3		national	Since 2007	1 policy		
Economic	Financial crisis/Economic stagnation							yes	
Economic	Embryonic or poorly developed markets	Embryonic markets	1			Since 2012		YES	
Institutional	Split Incentive	Misaligned financial incentives/multi-stakeholder issues	4		national	Since 2012	2 policy		Yes (6.30%)
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision / prioritization/ lack of urban and land Planning/ Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures – bureaucracy-time delays)	Lack of regulatory provision/policy framework on refurbishments/regulatory barriers	3			Since 2007	1 policy		Yes (6.70% - complex/inadequate regulatory procedures) and 5.5%- lack of relevant information))
Institutional	Building stock characteristics/aging stock/ Historical preservation	Building stock characteristics/lack of space	3		national	Since 2011	2 policy		Yes (6.60%)
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	construction standards/ Infrastructure and planning barriers (medium sized energy projects and local access to grid connections)/ Poor compliance with building codes/ Performance gap/quality of installation and commissioning/quality of workmanship/Mismatch between policy and occupant reality/Characteristics of	15			Since 2007/since 2001	1 policy		

		technology/fuel/electricity supply capacity/ Difficulty of retrofitting to existing buildings							
Institutional	Lack of data/ /information-diversion of management (at users level)	Lack of data	3		National/regional	Since 2007	1 policy instruments		
Institutional	Barrier to behavior change due to problematic implementation network/governance framework (Inadequate implementation network/governance framework /Inadequate implementation of policy measures / poor Policy coordination – cooperation across different levels - /cooperation of municipalities/ conflicts)	Local oppositions to new energy infrastructure (here instead of social/cultural)	1	all	National/regional/local	Since 2014	3 policy instruments	yes	
Institutional	Disruption/Hassie factor	Disruption/Hassie factor	8			Since 2008/since 2004	No policy instruments		
Institutional	Security of fuel supply	Security of fuel supply, Availability of energy source	1	all	National/regional/local	Since 2008	5 policy instruments		

For UK building sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers (sources: Deliverables 1.2 + 2.1 + 2.5)	Policy instruments (source: deliverable 1.4)
Building shell improvement (fabric upgrade)	- **Rebound effect (Social)** – Retrofit (retrofit)(2.1) - **Lack of awareness/knowledge on savings potential/information gap on technologies, EE (Educational) -** Lack of awareness/ interest/ motivation – Externalising responsibility and blame / Understanding of costs versus perceived benefits/ Lack of awareness/ Information gap/ Lack of experience (end users) (2.1) - **Bounded rationality/Visibility of energy efficiency (Cultural) -** Refurbishment seen as low priority/ perceived lack of impact/ visibility of energy efficiency (2.1) - **Socio-economic status of building users (Social) -** Socio-economic status of household (2.1) - **Missing credibility/mistrust of technologies and contractors (Cultural) -** mistrust of technologies/mistrust of energy companies or contractors/ Confidence in the system/Mistrust - Confidence in technology/ Perceived risk/ lack	-

	of trust of utility firms (2.1) - **Customs, habits and relevant behavioural aspects (Cultural)** - Social norms and accepted behaviours/Aesthetics/impact on residence (here instead of institutional) - **Lack of any type of financial support(Economic)(2.5)** - **High costs and risks** - High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) – cost of new heating system (2.5) - **Split Incentive(s)(Institutional)(2**.5) - **Legislation issues(Institutional)(2**.5) - **Building stock characteristics and special issues (Institutional(2**.5)	
Heat pumps	- **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** (2.5) - **High costs and risks** - *High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic)* – cost of new heating system (2.1) - **Lack of any type of financial support(Economic)(2.5)**	
Efficient heating	- **Inertia (Social)** – Unwillingness to replace systems (2.1) - **Lack of awareness/knowledge on savings potential/information gap on technologies, EE (Educational)** – Lack of awareness of availale systems (2.1) - **High costs and risks** - High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) – cost of new heating system (2.1) - **Lack of interest/low priority/Undervaluing EE (Cultural)(2.5)**	- Energy Company Obligation, - Renewable Heat Incentive (RHI) and its predecessor, - Renewable Heat Premium Payment, - Heat Network Delivery Unit (HNDU), - Community Energy Saving Programme (2009-2012) - Carbon Emissions Reduction Target (2008-2012)and its predecessors, - Energy Efficiency Commitment Scheme (2002-2008), - Energy Efficiency Standards of Performance (1994-2002).
Efficient cooling (air conditioning systems A+, A++, A+++)	- **High costs and risks** - *High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) – cost of new heating system (2.5)* - **Lack of any type of financial support(Economic)(2.5)** - **Lack of interest/low priority/Undervaluing EE (Cultural)(2.5)**	- Energy Company Obligation, - Renewable Heat Incentive and its predecessor, - Renewable Heat Premium Payment, - Heat Network Delivery Unit, - Community Energy Saving Programme (2009-2012) - Carbon Emissions Reduction Target (2008-2012)and its predecessors, - Energy Efficiency Commitment Scheme (2002-2008), - Energy Efficiency Standards of Performance (1994-2002).
LEDs	- **Customs, habits and relevant behavioural aspects (Cultural)** - Social norms and accepted behaviours/Aesthetics/impact on residence (here instead of institutional) (2.5) - **High costs and risks** - High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) – cost of new heating system (2.5) - **Lack of any type of financial support(Economic) (2.5)**	- Climate Change Agreements, - EU-Emissions Trading Scheme, - Ecodesign for energy related Products Directives 2009/125/EC and - Energy Labelling Directive (2010/30/EU).
Efficient appliances (A+, A++, A+++)	- **Bounded rationality/Visibility of energy efficiency (Social)** – (refrigerator) - **Missing credibility/mistrust of technologies and contractors (Cultural)** - mistrust of technologies/mistrust of energy companies or contractors/ Confidence in the system/Mistrust - Confidence in technology/ Perceived risk/ lack of trust of utility firms (high-efficiency devices) (2.1) - **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** – Access to trusted information (2.1) - **Lack of interest/low priority/Undervaluing EE** (Cultural)(2.5)	- Climate Change Agreements, - EU-Emissions Trading Scheme, - Ecodesign for energy related Products Directives 2009/125/EC and - Energy Labelling Directive (2010/30/EU).
BEMS	- **Lack of trained and skilled professionals/ trusted information, knowledge and experience (Educational)** – Access to trusted information (2.5) - **High costs and risks** - High capital costs/high transaction costs/ Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users (Economic) – cost of new heating system (2.5) - **Lack of any type of financial support(Economic)(2.5)**	-

Transport sector									
Type	**Name of barrier**	**Corresponding to (based on D.2.1)**	**Number of different sources**	**Number of subsectors**	**Easiness in confronting barrier**	**Duration**	**Number of policy instruments**	**Cross-cutting barrier**	**Preferences of stakeholders (2.5)**
Social	Low satisfaction with public transport/lack of trust								Yes (6.70%)
Social	Concerns of vehicle reliability/Hesitation to trust new technologies	Hesitation to trust new technologies/ Concerns of vehicle reliability	2	Road private		Since 2013/since 2008	No policy	YES	Yes (3.40%)
Social	Socio-economic status of users /Heterogeneity of consumers								
Social	Suburbanisation trends/Low density								
Social	Mobility problems that prevent the behavior change (Vulnerability of pedestrians / Lack of adequate space for walking/ Cruising traffic/ Parking problems/ range of distance)	Range of distance travelled between charges	3	road	national	Since 2008	1 policy		
Social	Inertia	Inertia	1			Since 2004		YES	
Cultural	Car as a symbol status and group influence	Car as a symbol status	3	Road private	regional	Since 1998	1 policy		Yes (4.50%)
Cultural	Habit and social norm of driving, car ownership and use	Habit and social norm of driving	1	Road private	National/ local	Since 2014	3 policy	YES	Yes (5.50%)
Cultural	Cycling is marginalized	Cycling is marginalized	1	Road private		Since 2014			
Cultural	Attitude (Attitude-action gap /Bounded rationality/Buyer attitude)	Attitude-action gap/ Buyer attitude	1	Road private		Since 2007		YES	
Educational	Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy/energy consumption)	Lack of knowledge/ insufficient information/maintenance difficulties/ consumer understanding and use of fuel economy information	4	Road private		Since 2013/since 2004		YES	Yes (4.60%
Educational	Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts)	Environmental awareness/limited understanding of environmental impact	1	Road private	National/ local	Since 2007	3 policy	YES	
Educational	Confusion about car and fuel costs							YES	

	(conventional vs ULEVs/Evs) – *Negative perception*								
Educational	Lack of certified instructors/examiners/technicians/professionals for eco-driving /integrated transport/mobility/ ULEVs/Evs / experience								
Economic	Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE	Limited financial incentives for freight electric vehicles/ lack of financial support for car clubs/ lack of market and policy certainty for hydrogen innovation	3	Road private	national	Since 2014/since 2007	2 policy instruments	yes	Yes (8.20%)
Economic	Limited infrastructure investment (road/train/cycling) – for public transport	Limited business case for infrastructure investment	2	road	National	Since 2011	1 policy		Yes (8.10%)
Economic	Low purchasing power of citizens/Financial crisis								Yes (7.70%)
Economic	High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles	Battery costs/ running costs/ cost of domestic charging unit/ biofuel distribution and infrastructure (here instead of institutional)/ high costs preventing development of new technologies (here instead of institutional)	6	Road private	national	Since 2008	1 policy+1		
Economic	Payback period of fuel efficient vehicles/low economic viability	High purchase price and long payback	2	road	National	Since 2007	1 policy	YES	
Economic	Negative role of Investment schemes/employee benefits encourage transport EE								
Institutional	Administrative fragmentation - lack of integrated governance/lack of necessary entities/ bureaucracy								Yes (6.70%-lack of integrated governance)
Institutional	Transport EE on the Government Agenda/priorities/coordination								Yes (7.0%) (lack of a national strategy for sustainable urban mobility) (6.10%-Transport EE on the Government Agenda/priorities) (5.60% - Environmental

									concern/low priority)
Institutional	Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV)	Not developed infrastructure for recharging/ inadequate public transport across UK/ undeveloped cycling infrastructure/ Unclear urban planning and traffic road regulations/ no standards for infrastructure investments/extra load on the electricity grid	road	8	Since 2007/since 2000	National/ local	8 policy instruments	yes	Yes (7.30 % - insufficient transport infrastructure and planning) (6.70%- insufficient development of cycling/walking infrastructure)(6.60% Lack of support for rail transportation/Limited rail infrastructure)(5.60%- Undeveloped infrastructure for recharging of EV
Institutional	Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics/lack of legislation-standards	Non-standardisation of connectors/ lack of policy on freight efficiency/ lack of initiatives for fleets/limited car-sharing initiatives	6	road	National/ local	Since 2008/since 2007	4 policy instruments		
Institutional	Limited/complex funding in urban public transport								
Institutional	Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs)	Immature status of developing technologies/ need for R&D in biofuels/ lImited R&D incentives/ concerns about sustainability of biofuels/lack of research in freight efficiency/ range of distance	6	road	national	Since 2013/since 2011/since 2008	3 policy instruments		
Institutional	Contradicting policy goals (particularly road/car-oriented planning)	Biofuel vehicle limitations/confusion about fleet averages for CO_2 emissions	2	road	national	Since 2008	1 policy		

For UK transport sector: Technologies – barriers - policy instruments (Deliverables 1.4, 2.1, 2.5)

Technologies	Barriers	Policy instruments
Electric and hybrid vehicles	- **Concerns of vehicle reliability/Hesitation to trust new technologies (Social)** - Hesitation to trust new technologies/ Concerns of vehicle reliability (2.1) - **Car as a symbol status and group influence (Cultural)** – car as a status symbol (2.1) - **Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts) (Educational)** - Environmental awareness/ limited understanding of environmental impact (2.1) - **Attitude (Attitude-action gap /Bounded rationality/Buyer attitude) (Cultural)** - Attitude-action gap/ Buyer attitude (2.1) - **Inertia (Social)** - Inertia (2.1) - **Lack of knowledge/information (on green transport/ULEVs/EVs - fuel economy/energy consumption) (Educational)** - Lack of knowledge/ insufficient information/maintenance difficulties/ consumer understanding and use of fuel economy information (2.1) maintenance difficulties (2.1+2.5) - **Payback period of fuel efficient vehicles/low economic viability (Economic)** - High purchase price and long payback (2.1) - **High cost/Low cost competitiveness of electric vehicles - High cost of batteries for electric vehicles (Economic)** - Battery costs/ running costs/ cost of domestic charging unit/ biofuel distribution and infrastructure (here instead of institutional)/ high costs preventing development of new technologies (here instead of institutional) - **Limited infrastructure investment (road/train/cycling) – for public transport (Economic)** - Limited business case for infrastructure investment - **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE (Economic)** - Limited financial incentives for freight electric vehicles/ lack of financial support for car clubs/ lack of market and policy certainty for hydrogen innovation (2.1+2.5) - **Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs**) (Institutional) - Immature status of developing technologies/ need for R&D in biofuels/ limited R&D incentives/ concerns about sustainability of biofuels/lack of research in freight efficiency/ range of distance - **Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics/lack of legislation-standards (Institutional)** - Non-standardization of connectors/ lack of policy on freight efficiency/ lack of initiatives for fleets/limited car-sharing initiatives - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional)** - Not developed infrastructure for recharging/ inadequate public transport across UK/ undeveloped cycling infrastructure/ Unclear urban planning and traffic road regulations/ no standards for infrastructure investments/extra load on the electricity grid - **Contradicting policy goals (particularly road/car-oriented planning)** (Institutional)- Biofuel vehicle limitations/confusion about fleet averages for CO2 emissions - **Lack of integrated governance/entities-fragmentation/bureaucracy (Institutional)(2.5)**	- EU new car CO_2 emissions targets: 130 gCO2/km by 2015 and 95 gCO2/km by 2020; and complementary measures), - Plug-in car and van grants (including Electric Vehicle Homecharge Scheme) - (Ultra-)Low Carbon Emissions Zones at local authority/regional level e.g. London). - Freight Transport Association Logistics Carbon Reduction Scheme.
Efficient and sustainable modes of transport in passenger and freight transport such as		

eco-driving,	- **Low/Limited awareness – environmental sensitivity (of impact of EE in transport /towards eco-driving/benefits-environmental impacts) (Educational)** - Environmental awareness/ limited understanding of environmental impact (2.1) - **Lack of knowledge/information on EE transport (Cultural)(2.5)** - **Socio-economic status of users (Social)(2.5)**	
modal shift,	- **Low satisfaction/ lack of trust for public transport (Social)(2.5)** - **Habit and social norm of driving, car ownership and use (Cultural)(2.5)** - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional)** - Not developed infrastructure for recharging/ inadequate public transport across UK/ undeveloped cycling infrastructure/ Unclear urban planning and traffic road regulations/ no standards for infrastructure investments/extra load on the electricity grid (Institutional)(2.5) - Lack or limited policies to support behavior change on specific transport issues (Lack of national strategy for bike and pedestrian mobility/ Limited policy on freight efficiency/city logistics/lack of legislation-standards - Transport EE on the Government Agenda/priorities/**coordination (Institutional) (2.5)** - **Lack of integrated governance/entities-fragmentation/bureaucracy (Institutional)(2.5)**	
efficient vehicles	- **Barriers to behavior change due to no policy support to technological issues/research needs (Immature status of developing technologies for EVs/ULEVs - Range of distance travelled between charges for EVs**) (Institutional) - Immature status of developing technologies/ need for R&D in biofuels/ limited R&D incentives/ concerns about sustainability of biofuels/lack of research in freight efficiency/ range of distance - Low purchasing power of citizens/Financial crisis **(Economic)(2.5)** - **Lack of finance/Limited financial incentives for new vehicles/ULEVs/public transport/ - Inefficient or absent fiscal measures for supporting EE (Economic)** - Limited financial incentives for freight electric vehicles/ lack of financial support for car clubs/ lack of market and policy certainty for hydrogen innovation (2.5) - **Barriers to behavior change due to problems with infrastructure/public transport services (Inefficient urban/public transport infrastructure and planning/ Undeveloped cycling/walking infrastructure/ Lack of support for rail transportation/Limited rail infrastructure/ Undeveloped infrastructure for recharging of EV) (Institutional)** - Not developed infrastructure for recharging/ inadequate public transport across UK/ undeveloped cycling infrastructure/ Unclear urban planning and traffic road regulations/ no standards for infrastructure investments/extra load on the electricity grid (Institutional)(2.5)	- The Low Carbon Vehicles Innovation Platform (LCVIP) - The Low Carbon Vehicle Public Procurement Programme (LCVPP) - The Low Carbon Truck trial - Advanced biofuel demonstration competition
use of biofuels.	- **Contradicting policy goals (particularly road/car-oriented planning) (Institutional)(2.1)** - **Socio-economic status of users** (Social)(2.5) - **Lack of knowledge/information on EE transport** (Cultural)(2.5) - **Concerns on reliability/hesitation to trust new technologies** (Social)(2.5)	

ANNEX 2: CALCULATIONS FOR AHP

For building sector

1. Formation of first AHP matrix (one 3x3 matrix for the three groups of barriers ie "**Social-Cultural-Educational**" (1st category), "**Economic**" (2nd category), "**Institutional**" (3rd category)
2. User will proceed with the "Conduction of pairwise comparisons for matrix using AHP scale and four conditions"
    a. The diagonal cells (a_{11}, a_{22}, a_{33}) are filled with number 1 automatically.
    b. User compares "Group Barrier 1" with "Group Barrier 2" and fills in the respective cell (a_{ij}) with a number from the AHP scale (1-9) or selects from the scale. For his/her facilitation the four conditions for the compared barriers are displayed in a screen.
    c. The software automatically assigns the number 1/(what the user selected) to the a_{ji} cell.
    d. User continues with next comparison "Group Barrier 1" and "Group Barrier 3" following previous steps b, c.
    e. User continues with the next comparison "Group Barrier 2" and "Group Barrier 3" until the matrix is filled completely
3. Calculation of weight coefficients for the groups of barriers
    a. Sum of each column (add three numbers in this case)
    b. Divide each number of the first row with the respective sum of the column it belongs to (a_{11}/sum of column 1, a_{12}/sum of column 2, a_{13}/sum of column 3)
    c. Sum up the three outcomes of b
    d. Divide them with 3 (since there were three outcomes)
    e. The outcome is weigh coefficient for barrier 1 (row 1, column 4 or a separate column)
    f. Repeat for the second row the steps b, c, d, e
    g. Repeat for the third row the steps b, c, d, e
    h. Check if each weight coefficient fulfills the condition 0<weight coefficient<1
    i. Check if all together, the three weight coefficients, sum up 1.
4. Conduction of consistency test - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell of the first row with the second one, the third cell of the first row with the third weight coefficient)
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps a, b for the third row respectively.
    f. Add outcomes A1, A2 and A3 and divide the sum with number three.
    g. Calculate the fraction (outcome of step f – 3)/(3-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/0.58
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.

5. User accepts results of consistency test or not (it is up to the user to proceed knowing that results are not consistent)
6. If no (user does not accept), user goes to step 2 to re-evaluate/change some of the inputs under pairwise comparisons.

7. If yes, then user proceeds with formation of second AHP matrix for sub-groups of "**Social-Cultural-Educational**" (one 3x3 matrix for sub-group ie for "**Social**" – 1; "**Cultural**" – 2; "**Educational**" - 3) (display on screen)
8. Conduction of pairwise comparisons for matrix using AHP scale and four conditions (same as step 2)
9. Calculation of weight coefficients for the sub-group of barriers (same as step 3)
10. Conduction of consistency test (same as step 4)
11. Accept results or not (same as step 5)
12. If no go to step 8 (same as step 6)

13. If yes, then the user proceeds with formation of third AHP matrix for **social** barriers (one 6x6 matrix for "**Social group interactions and status considerations**" – 1; "**Socio-economic status of building users**" -2; "**Strong dependency on the neighbors in multi-family housing**" - 3; "**Inertia**" – 4; "**Commitment and motivation of public social support**" - 5; "**Rebound effect**"- 6) (display on screen)
14. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 2, but now for the 6x6 matrix)
15. Calculation of weight coefficients for the social barriers
    a. Sum of each column (add six numbers in this case)
    b. Divide each number of the first row with the respective sum of the column it belongs to (a_{11}/sum of column 1, a_{12}/sum of column 2, a_{13}/sum of column 3 etc)
    c. Sum up the six outcomes of b
    d. Divide them with 6 (since there were six outcomes)
    e. The outcome is weigh coefficient for barrier 1 (row 1, column 7 or a separate column)
    f. Repeat for the second row the steps b, c, d, e
    g. Repeat for the third row the steps b, c, d, e
    h. Check if each weight coefficient fulfills the condition 0<weight coefficient<1
    i. Check if all together, the six weight coefficients, sum up 1.
16. Conduction of consistency test - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient) etc
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps i, ii for the remaing rows.
    f. Add outcomes A1, A2, A3, A4, A5 and A6 and divide the sum with six.
    g. Calculate the fraction (outcome of vi – 6)/(6-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/1.24
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.
17. Accept results or not (same as step 6)

18. If no go to step 14

19. If yes formation of fourth AHP matrix for **cultural** barriers (one 4x4 for sub-group, these are: "**Lack of interest/Low priority/Undervaluing energy efficiency**" – 1; "**Customs, habits and relevant behavioural aspects**" – 2; "**Bounded rationality/Visibility of energy efficiency**" – 3; "**Missing credibility/mistrust of technologies and contractors**" – 4)
20. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 4, but now for the 4x4 matrix)
21. Calculation of weight coefficients for the cultural barriers (same procedure as in step 4, but now for the 4x4 matrix)
22. Conduction of consistency test - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient)
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps i, ii for the remaing rows.
    f. Add outcomes A1, A2, A3 and A4 and divide the sum with four.
    g. Calculate the fraction (outcome of f – 4)/(4-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/0.9
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.
23. Accept results or not (same as step 6)
24. If no go to step 20

25. If yes formation of fifth AHP matrix for **educational** barriers (one 2x2 for sub-group, ie "**lack of trained and skilled professionals/trusted information, knowledge and experience**" – 1; "**lack of awareness/knowledge on savings potential/information gap on technologies**"-2)
26. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 2, but know for the 2x2 matrix)
27. Calculation of weight coefficients for the educational barriers (same procedure as in step 5)[6]

28. Formation of sixth AHP matrix for **economic** barriers (one 7x7 for group ie "lack of any type of financial support ("**lack of financial incentive (Public and private sector)/Lack of funds or access to finance**" – 1; "**Expected costs and risks (high capital costs/Financial risk/Uncertainty on investment/ High cost of innovative technologies for end-users**" – 2; "**Payback expectations/Investment horizons**" – 3; "**Energy prices (Relatively cheap energy and fuel prices/misleading tariff system not reflecting correct prices for energy use/EE)**" – 4; "**Unexpected costs (Hidden costs/Costs vary regionally (Fragmented ability))**" - 5; "**Financial crisis/Economic stagnation**" – 6; "**Embryonic markets**" – 7)
29. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions (same procedure as in step 2, but know for the 7x7 matrix)
30. Calculation of weight coefficients for the economic barriers (same procedure as in step 3)
31. Conduction of consistency tests- Calculation by Saaty approach

[6] No calculation of consistency indexes for 2x2 matrixes.

a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient)
b. Sum the products and divide by the first weight coefficient. This will be A1
c. Multiply the first cell of the second row with the first weight coefficient etc
d. Sum up the products and divide with the second weight coefficient. This will be A2.
e. Repeat the steps i, ii for the remaing rows.
f. Add outcomes A1, A2, A3, A4, A5, A6 and A7 and divide the sum with seven.
g. Calculate the fraction (outcome of step f – 7)/(7-1). This will be consistency index CI for the specific AHP matrix.
h. Calculate Cr = CI/1.32
i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.

32. Accept results or not
33. If no go to step 30

34. If yes formation of seventh (last) AHP matrix for **institutional** barriers (one 8x8 for sub-group) (ie "**Split Incentive**" – 1; "**Legislation issues (Lack of relevant legislation/Lack of regulatory provision/ Change of legislation for local/regional administrative division/complex/inadequate procedures)**" – 2; "Building stock characteristics/aging stock/historical preservation" – 3; "Poor compliance with efficiency standards or construction standards/technical problems/performance gap/mismatch" – 4; "Lack of data/information-diversion of management" – 5; "Barrier to behavior change due to problematic implementation network/governance framework (inadequate implementation network/governance framework/inadequate implementation of policy measures/ poor policy coordination across different levels/ cooperation of municipalities"-6; "Disruption/hassie factor" – 7; "Security of supply" – 8)
35. Conduction of pairwise comparisons for matrix using AHP scale and seven conditions ((same procedure as in step 2, but know for the 8x8 matrix)
36. Calculation of weight coefficients for the institutional barriers (same procedure as in step 2)
37. Conduction of consistency tests - Calculation by Saaty approach
    a. Multiply the first cell of the first row with the first weight coefficient, the second cell with the second one, the third with the third weight coefficient)
    b. Sum the products and divide by the first weight coefficient. This will be A1
    c. Multiply the first cell of the second row with the first weight coefficient etc
    d. Sum up the products and divide with the second weight coefficient. This will be A2.
    e. Repeat the steps i, ii for the remaing rows.
    f. Add outcomes A1, A2, A3, A4, A5, A6, A7 and A8 and divide the sum with number eight.
    g. Calculate the fraction (outcome of vi – 8)/(8-1). This will be consistency index CI for the specific AHP matrix.
    h. Calculate Cr = CI/1.41
    i. If Cr fulfils the condition 0<Cr<0.10, then the results are consistent.

38. Accept results or not
39. If no go to step 35

40. If yes calculation of total weight coefficient for each barrier

a. Multiply Weight coefficient of group*Weight coefficient of sub-group* weight coefficient of barrier ie (for example)
   $WC_{s1} = W_{s\text{-}c\text{-}e} * W_s * W_{s1\ldots\ldots}$
   $WC_{E1} = W_E * W_{e1}$

Prepared by: "*National & Kapodistrian University of Athens-Energy Policy and Development Centre*"

A DECISION SUPPORT TOOL (DST) REFLECTING END-USERS BEHAVIOUR IN ENERGY EFFICIENCY MODELLING

D.3.2

PART OF WORK PACKAGE 3: FORWARD-LOOKING SCENARIO ANALYSIS, FOCUSING ON MACROECONOMIC AND MICROECONOMIC IMPACTS OF ENERGY EFFICIENCY POLICY OPTIONS

REPORT – PART III (MANUAL)

DATE: JULY 2017

HERON project

"Forward-looking socio-economic research on Energy Efficiency in EU countries"

Contract no: 649690

Institution: *Energy Policy & Development Centre – National & Kapodistrian University of Athens*

Steering Committee member [(1)]***:*** *Prof. Dimitrios MAVRAKIS*

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"Part III: Manual" was prepared by: Prof. Dimitrios Mavrakis, Dr. Popi KONIDARI (Corresponding author), Anna FLESSA

[(1)] *The Steering Committee member has the responsibility for ensuring the quality of the report.*

HERON: Forward – looking socio-economic research on Energy Efficiency in EU countries

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GLOSSARY

Barrier

It is an element that limits the individuals' willingness to implement policies.

For instance, difficulties in trusting new technologies or lack of information about potential energy efficiency benefits are considered barriers (HERON, Deliverable 2.5).

Bounded rationality

A situation under which individuals do not make decisions in the manner assumed in economic models, because of constraints on time, attention, and the ability to process information (Knoblocha F. and Mercure J. - F., 2016).

Therefore, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentives.

Building Energy Management System (BEMS)

A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems (HERON, Deliverable 2.5).

Customs, habits and relevant behavioral aspects

A tradition or a usual way to behave[1]. Furthermore, habit is a particular act or way of acting that a person tends to do regularly[2].

Hassie factor

The required time and effort to find accurate information or appropriate finance so as to move forward to (CBI, 2016; Newfoundland Labrador, 2011).

It is a barrier linked with the end-users since they need time and effort for finding suitable contractors or clearing out a basement for having it insulated (Newfoundland Labrador, 2011). It is also linked with the fact that end-users disrupt the scheduled work for retrofit due to limited time and efforts (HERON Deliverable 2.1).

For overcoming this barrier, a government needs to take a holistic view of the customer journey, design and implement a policy framework that drives and facilitates consumer demand for EE measures (CBI, 2016).

Inertia

The resistance of end-users to change. Individuals are, in part, creatures of habit and established routines, which may make it difficult to create changes to such behaviours and habits (Thollander et al, 2010, p. 56). The more radical the change, the higher the barrier (HERON, Deliverable 3.1).

[1] Source: http://www.yourdictionary.com/custom#e3Fw6Uevh7IEf6Sh.99
[2] Source: http://dictionary.cambridge.org/us/dictionary/english/habit

Light-Emitting Diode (LED)

A light-emitting diode (LED) is a two-lead semiconductor light source. LEDs have many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching.

Rebound effect

The situation which occurs when energy efficiency improvements counter-intuitively lead to higher levels of energy consumption or to the creation of wealth from the energy savings (HERON, 2015 -2.1; UNEP, 2014).

This happens when an energy service becomes cheaper relatively to other goods and services and leads to increased consumption. Rebound effects can therefore have positive social and economic consequences but may lead to a conflict with the goal to reduce energy use and emissions.

Socio-economic status of building users

Set of factors related to the end-user who lives or works in a building/apartment. These factors are: Age, income, economic background, level of education, job - professional category, health conditions, lifestyle, region – climate/geographical zone, level of familiarization with technology, size of family (Omar Jridi, Fethi Zouheir Nouri, 2015; Jacob M., 2007).

Split incentive(s)

The transactions under which the party that covers the expense, does not receive the benefit of this expense/investment. Regarding energy efficiency, the split incentive(s) are caused between the owners and the tenants due to traditional lease structures (City of Boulder, 2016).

The owner wants to minimize the purchase cost of energy related systems and technologies (heating, cooling, hot water, efficient appliances etc), and has no return on this investment, while the tenant wants to minimize his/her energy bill. The owner is not encouraged to make investments in energy efficiency since it is the tenant who receives dividend (Charlier Dorothée, 2014). So, the actors who decide which technologies to use (Agent) are not responsible for paying the energy bills (Principal) (HERON, Deliverable 3.1). Finally, none of these two parties wants to invest in an energy efficient system.

It is also encountered with the alternative term “Agent-Principal” issue.

ACRONYMS

AHP	Analytical Hierarchy Process
BAU	Business-As-Usual
BE	Belgium
BEMS	Building Energy Management System
BEVs	Battery Electric Vehicles
BG	Bulgaria
CI	Consistency Index
CNG	Compressed Natural Gas
CRES	Centre for Renewable Energy Sources and Saving
DE	Germany
DST	Decision Support Tool
EE	Estonia
EE	Energy Efficiency
EPBD	Energy Performance Building Directive
EFTA	European Free Trade Association
ESCO	Energy Services COmpany
EU	European Union
EV	Electric Vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GR	Greece
HEVs	Hybrid Electric Vehicles
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IEE	Intelligent Energy Europe
IN	Implementation Network
IT	Italy
KENAK	Energy Efficiency Regulation for Buildings
LEAP	Long-range Energy Alternatives Planning
LED	Light-Emitting Diode
NSIs	National Statistical Institutes
NZEB	Nearly Zero Energy Buildings
PHEV	Plug in Hybrid Vehicle
RS	Serbia

TI	Total Impact
UK	United Kingdom
UNEP	United Nations Environmental Programme
yoy	Year over Year
YPEKA	Ministry of Energy, Environment and Climate Change

EXECUTIVE SUMMARY

Improving energy efficiency is a priority in all decarbonisation scenarios (European Union, 2012). However, there are important barriers for the implementation of an energy efficient strategy that need to be taken into account and used in energy modelling (SEC(2011) 779 final). These barriers are strongly linked with the consumer behaviour.

The HERON partners identified under "*Work Package 2: Mapping and assessment of social, economic, cultural and educational barriers in buildings and transport within each country*" a set of barriers linked with the behavior of end-users in two sectors: buildings (residential and tertiary) and transport. These barriers were grouped into three main categories: i) Social-Cultural-Educational, ii) Economic and iii) Institutional.

This paper presents the Decision Support Tool (DST) that was developed under the HERON programme for transforming the qualitative information about barriers (WP2) into numerical inputs for the development of EE scenarios (WP4).

With the use of the Analytical Hierarchical Process (AHP), comparative analysis is conducted among barriers created by the end users' behavior towards EE targets. Based on qualitative information for the barriers, the user compares, reveals and quantifies the negative impact of each barrier on the set of the assumed targets, in EE modeling. Mathematical expressions using the calculated impact of barriers provide numerical inputs needed to energy modelling for reflecting the end-user behavior in the assumed EE targets. Once the procedure is completed, the policy maker can modify accordingly the available inputs so as to achieve the set targets.

The paper is prepared for two different target groups, experts interested to understand the methodological approach and those that will use the DST. The first chapter presents analytically the methodology of the developed DST (concept, steps, mathematical expressions). The second chapter concerns the implementation of the DST. The third chapter is the manual of the software.

PREAMBLE

Energy Efficiency (EE) consists one of the main pillars of efforts to mitigate climate change. There is plethora of relevant policy instruments (energy labelling, audits etc) that support the penetration of EE technologies and practices, but different types of barriers affect negatively the achievement of targets set under scenarios. According to the Energy Efficiency Communication of July 2014, the EU is expected to miss the 20% energy savings target of year 2020 by 1%-2% (European Commission, 2014; 2012). The Dutch Government lowered its initial reduction target from 30% to 20% (Vringer K. et al., 2016). Also, Malta's 2020 EE target was lowered in 2015 from 0.825 Mtoe to 0.726 Mtoe expressed in primary energy consumption (European Commission, 2015a).

The EE policies and measures due to barriers do not deliver the expected benefits associated with improvements in EE (such as energy savings, reductions in Greenhouse Gases, employment, poverty alleviation etc) (UNEP, 2014; IEA, 2014). Among these types of barriers, those related to end-users behaviour need to be incorporated also in forward looking energy efficiency modelling after being identified and analysed (McCollum L. David et al., 2016; EC, 2015; EEA, 2013).

Forward-looking models are used for medium-to-long-term scenario analyses, aiming to support relevant policy options; some of these models are designed to consider both technological, economical and socio-behavioral elements in developing their scenarios (McCollum L. David et al., under press; Knoblocha F., Mercure J.-F., 2016). Bridging the gap between these elements has historically been presented as a challenge (McCollum L. David et al., under press). Furthermore, demands of improving the design of models so as to become more 'realistic' by incorporating features observed in the real world are increasing (McCollum L. David et al., under press). One group of such features of the 'real world' relates to human behavior.

The demands are based on the following arguments (McCollum L. David et al., under press): i) Models lacking behavioral realism are restricted in evaluating energy efficiency policies and other influences on end-user demand; ii) Improving the behavioral realism of models consequently affects policy-relevant model analysis of EE as part of the climate change mitigation efforts. However, current modeling of behavioral features in energy-economy and integrated assessment models is relatively limited (McCollum L. David et al., under press). Usually, models and particularly Integrated Assessment Models (IAMs) represent the behavior of consumers or energy end-users through economic relationships: energy demand as a function of price, technology investments to minimize levelized costs, etc (McCollum L. David et al., under press).

End-user behaviour is complex and rarely follows traditional economic theories of decision-making (McCollum L. David et al., under press; Frederiks R. et al., 2015; Knoblocha F., Mercure J.-F., 2016). End-users patterns of energy consumption are influenced by social-cultural-educational (status quo, social interactions etc), economic (risks of investment, financial incentives) and institutional factors (split incentives, hassle factor etc) that are characterized as barriers (Vringer K. et al., 2016; Frederiks R. et al., 2015; UNEP, 2014).

Efforts are focused in overcoming existing barriers and increasing the sophistication of energy and economic modelling (European Commission, 2015b; 2014). Key insights in the outcomes of such efforts can guide the effective design and implementation of end-user-focused strategies and public policy interventions to improve the level of EE interventions (by adopting technologies or practices) (Frederiks R. et al., 2015; UNEP, 2014).

The proposed methodology transforms qualitative research outcomes related to barriers linked to end-users behavior, into quantitative ones allowing their incorporation in the form of numerical inputs in forward looking EE modelling.

MANUAL

INTRODUCTION TO HERON DST SOFTWARE

DST means Decision Support Tool. It was developed to assist policy and decision makers in quantifying the negative impact of barriers in numbers expressing each one's contribution in preventing energy savings. The numerical inputs of this quantification are used for the forward-looking energy efficiency modelling.

The DST was developed by the Energy Policy and Development Centre (KEPA) of the National and Kapodistrian University of Athens (NKUA). The HERON DST software was developed by App-Art in cooperation with the Energy Policy and Development Centre.

REQUIREMENTS FOR INSTALLATION

The installation of the DST software requires as operational system Windows 7 and newer versions (Windows 8, Windows 10) and Java 7.0. (at least). Installation is also possible on MAC. Free Java downloads are available at: https://www.java.com/en/download/. For WinZip or WinRar http://www.win-rar.com/download.html

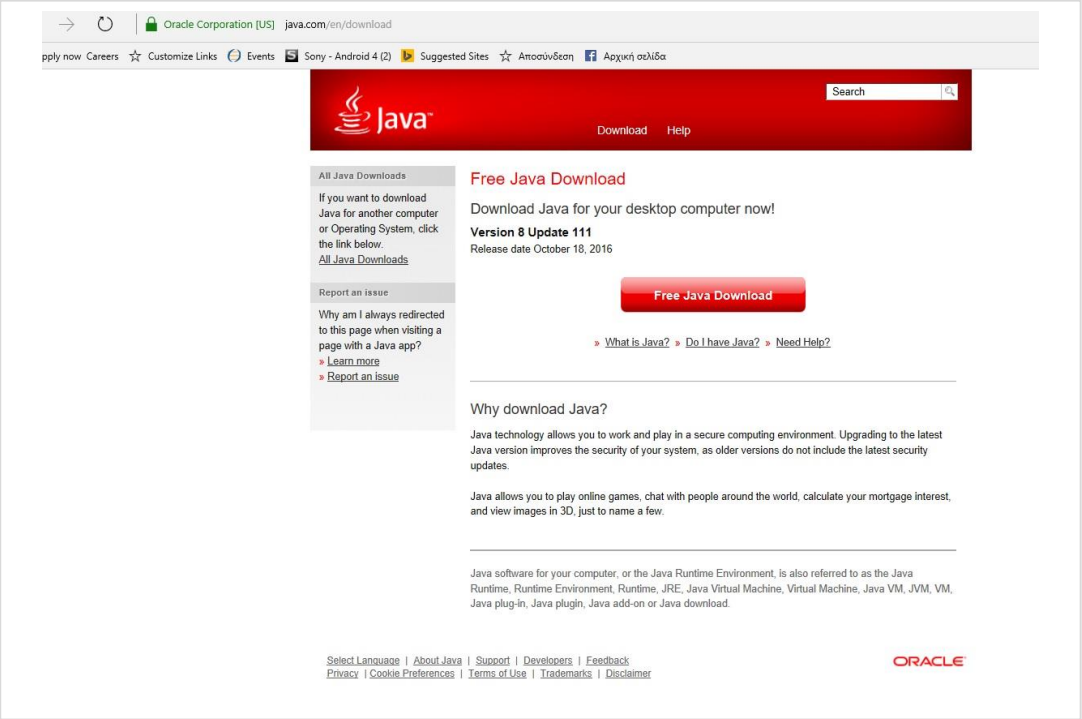

Figure 1: Free download of Java versions.

INSTALLATION

The user receives a zip file that contains the software and its components. The file needs to be expanded using "WinZip" or "Rar" at the location that the user will select (Desktop or a file in the hard disk or the Documents folder).

Then the user double clicks on the Java file with the name Heron_(number of version) and the software opens and works.

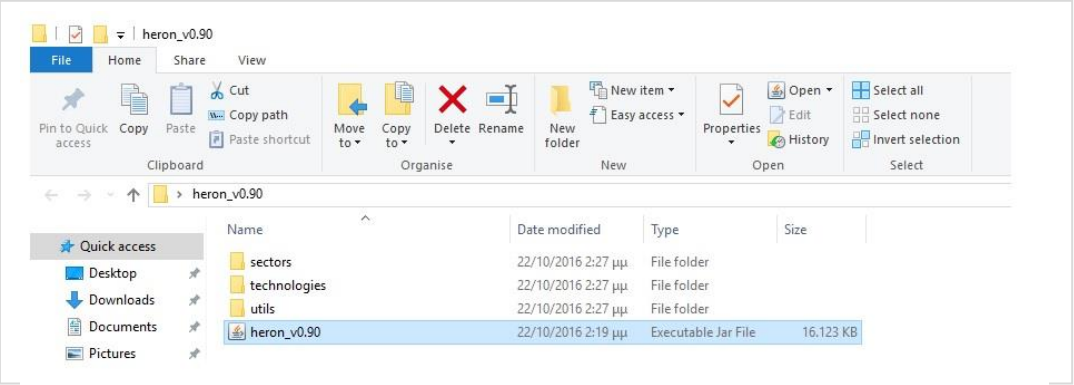

Figure 2: Installation of HERON DST Software.

The HERON DST software runs even if it is within the folder that was created after expansion. It is a portable software meaning that it can be easily mover or carried to another location of the hard disk or another computer.

The user needs to be careful and be sure to use the HERON DST software along with its three folders (sectors, technologies and utils) (Figure 2). These folders are also necessary if the user intends to proceed with modifications.

GETTING STARTED

FIRST SCREEN

Once the HERON DST software is installed the introductory screen opens (Figure 3). For proceeding and working with the HERON DST software the user needs to press the button on the left with the title “Decision Support Tool”.

Figure 3: First screen for HERON DST Software.

The user sees on the right the logo of the project HERON (Grant Agreement No. 649690), the funding authority and the partners. More information about the HERON project is available at: http://heron-project.eu/

SECOND SCREEN

The second screen opens and the user sees on the right the flow diagram of the HERON DST software that reflects briefly the whole concept of the DST.

The developed HERON DST software has two sectors (Buildings and Transport). It is designed in such a manner that the user can include additional sectors as well (see relevant chapter).

The sets of barriers for each sector are the ones presented in the "Methodology" and the "Implementation" part. New barriers or changes in the names of the existing ones are feasible.

As mentioned in the "Methodology" and the "Implementation" part, barriers are linked with the EE technologies. Under this HERON DST Software version, these technologies/actions are seven for the buildings sector and five for the transport sector.

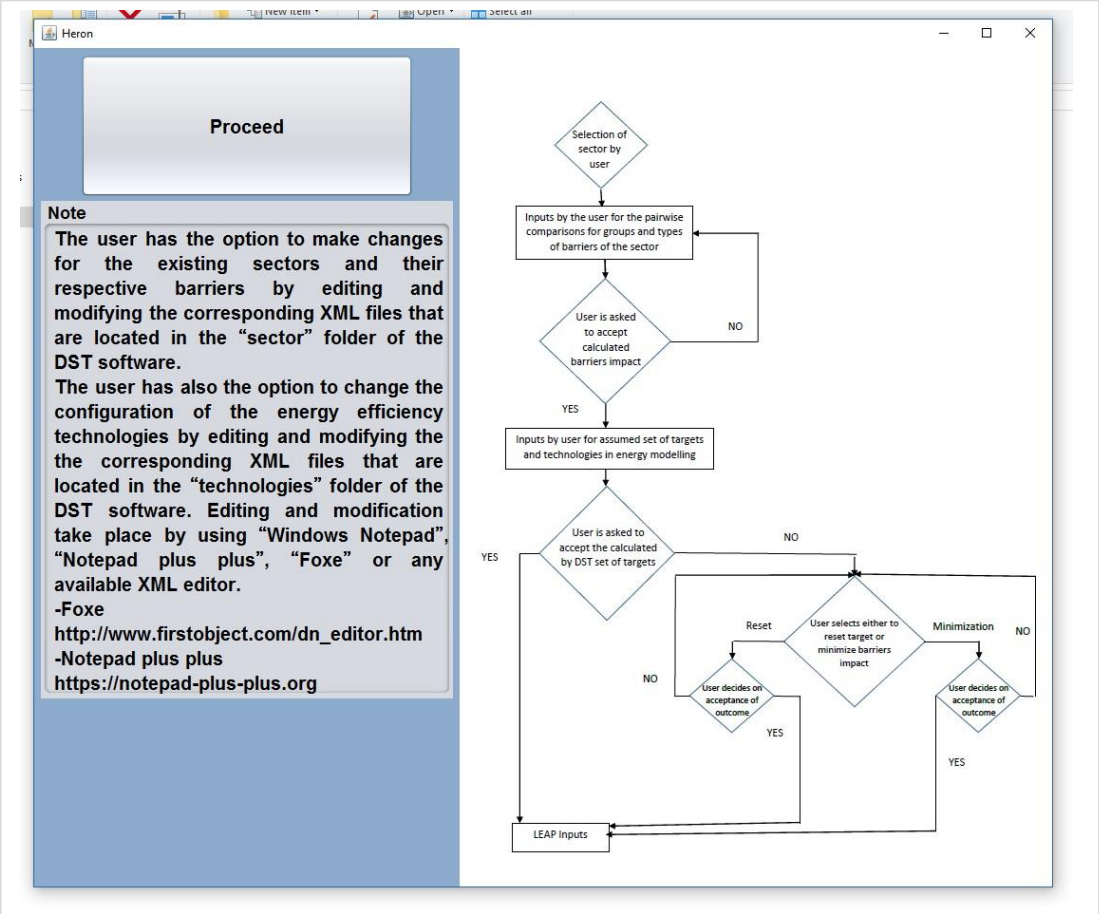

Figure 4: Second screen of the DST software.

If the user intends to make any changes in the existing sectors, the set of the barriers or in the technologies, this is the point to insert those changes. For making the changes, the user can use "Windows Notepad", "Notepad plus plus", "Foxe" or any other available XML editor. For MAC users they will need to use the "Text Edit". Once these changes are done the user can proceed with the use of the HERON DST software.

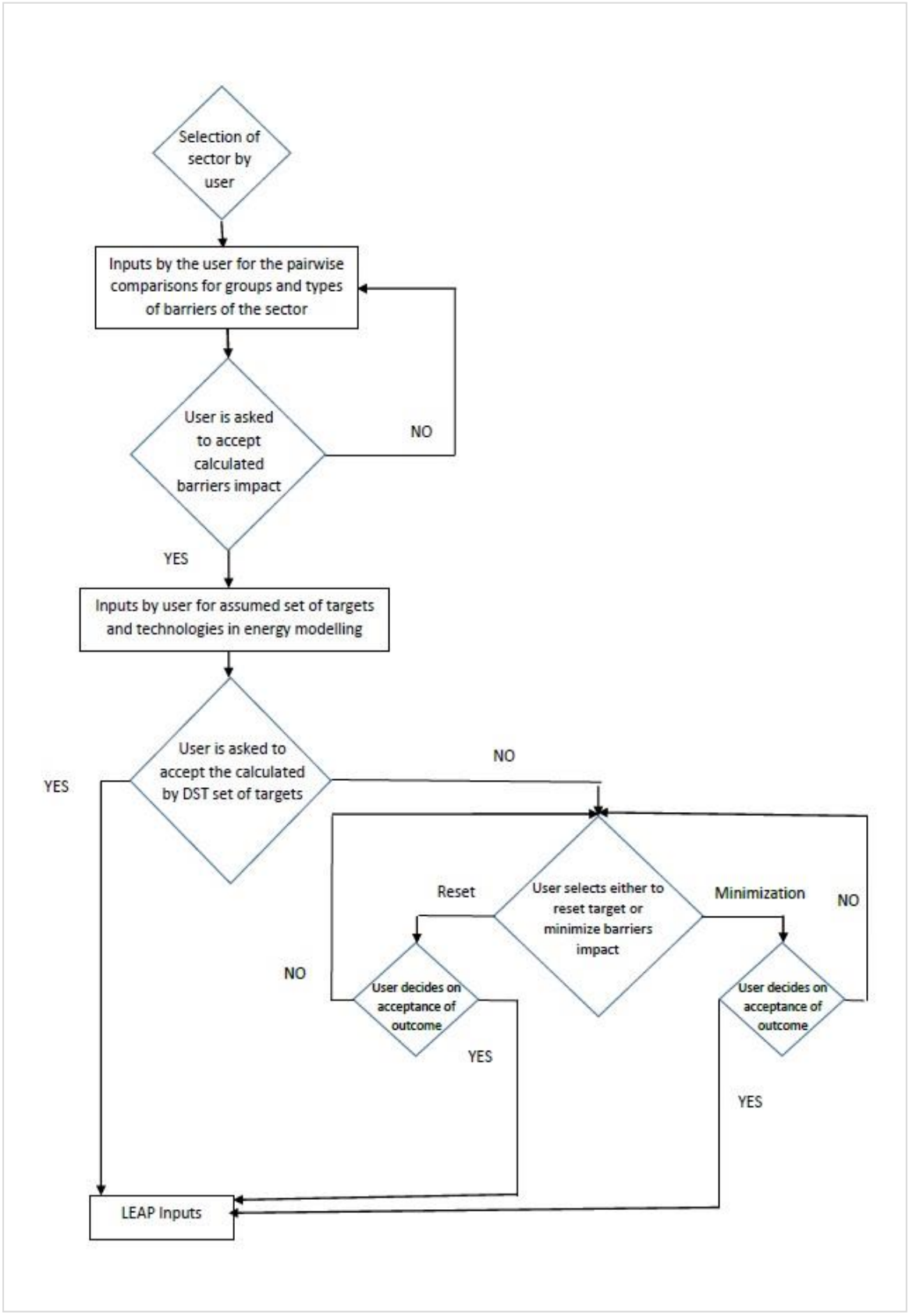

Figure 5: Flow diagram for the HERON DST software.

Windows Notepad

The user checks that the "Windows Notepad" is available by opening the programs of his/her computer. If yes, then the user selects "Windows Notepad" from the available list of programs on his/her computer. Details of how to use it are in the last chapter of this manual.

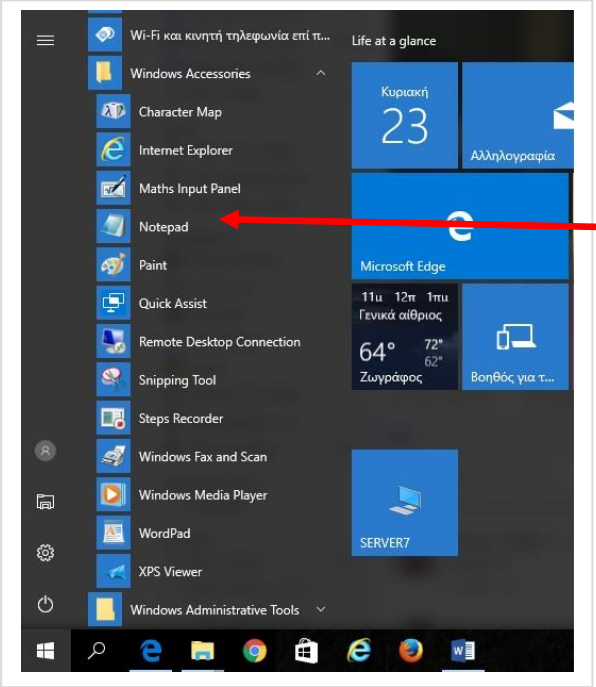

Figure 6: Windows Notepad.

Once the user selects to make changes with the "Windows Notepad", he/she opens the "Windows Notepad", moves the mouse to the Tool bar and selects "File". Then he/she locates the folder of the HERON DST software, opens the folders until he/she reached the xml file that intends to modify.

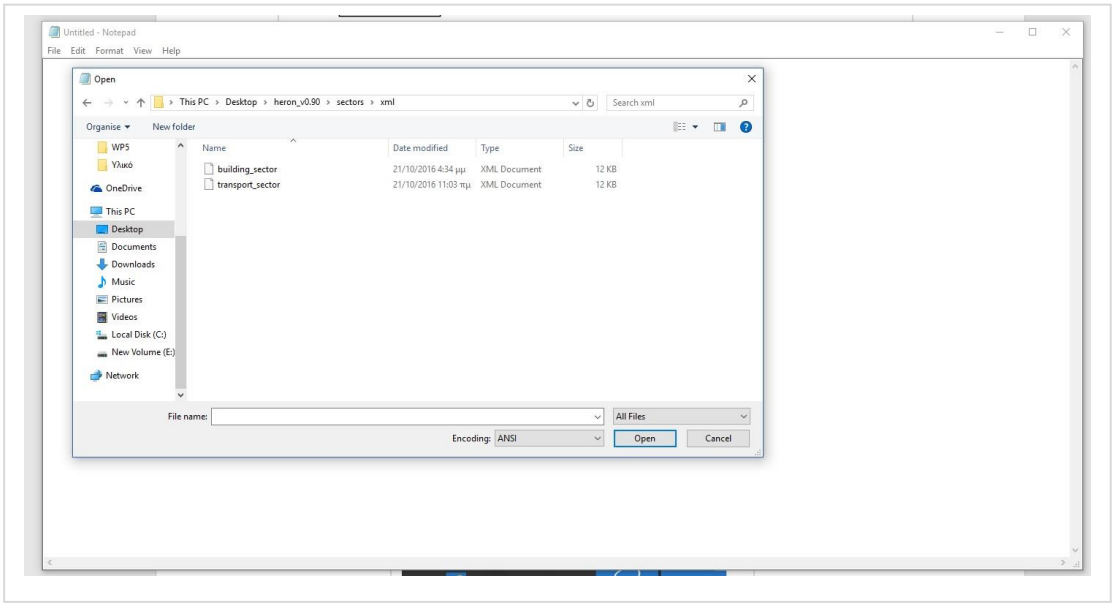

Figure 7: Using "Windows Notepad" to modify xml files.

XML Notepad

If the user does not find the “Windows Notepad” convenient for making the modifications that he/she wants another available software is the XML Notepad, which can be downloaded free from the link: https://xmlnotepad.codeplex.com/

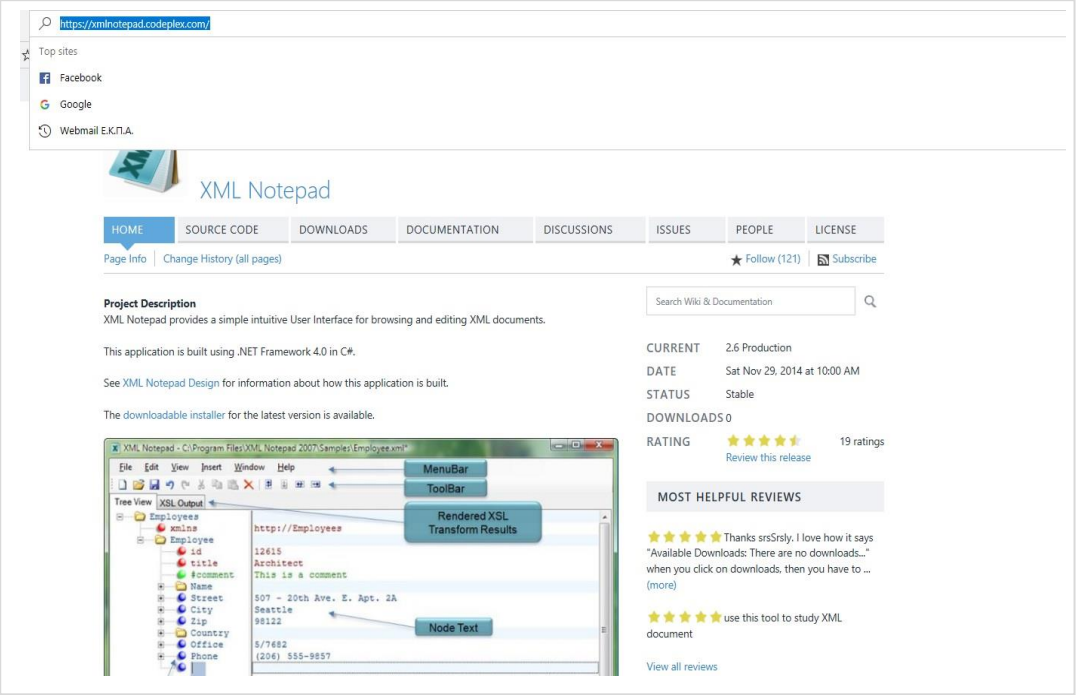

Figure 8: Downloading the XML Notepad.

The user will press on the “downloader installer” and a new window opens that allows to proceed with the downloading. The new window also quotes that for using the “xml Notepad”, “.NET 4.0” is required.

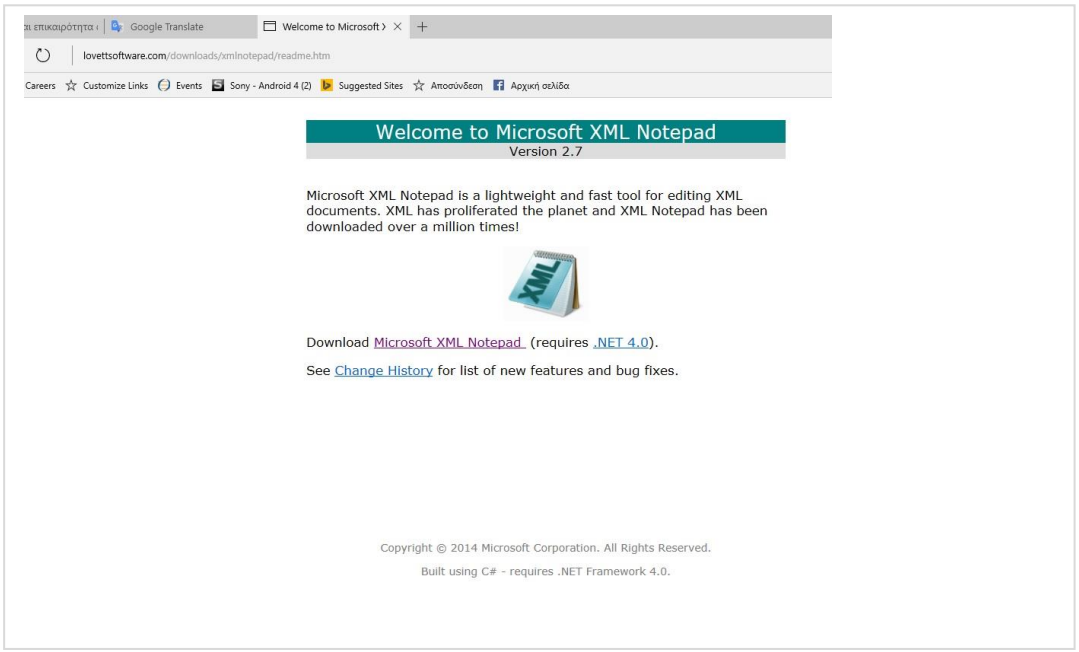

Figure 9: Downloading XML Notepad.

Notepad plus plus

Another software that can be used is the Notepad plus plus that is available at: https://notepad-plus-plus.org/

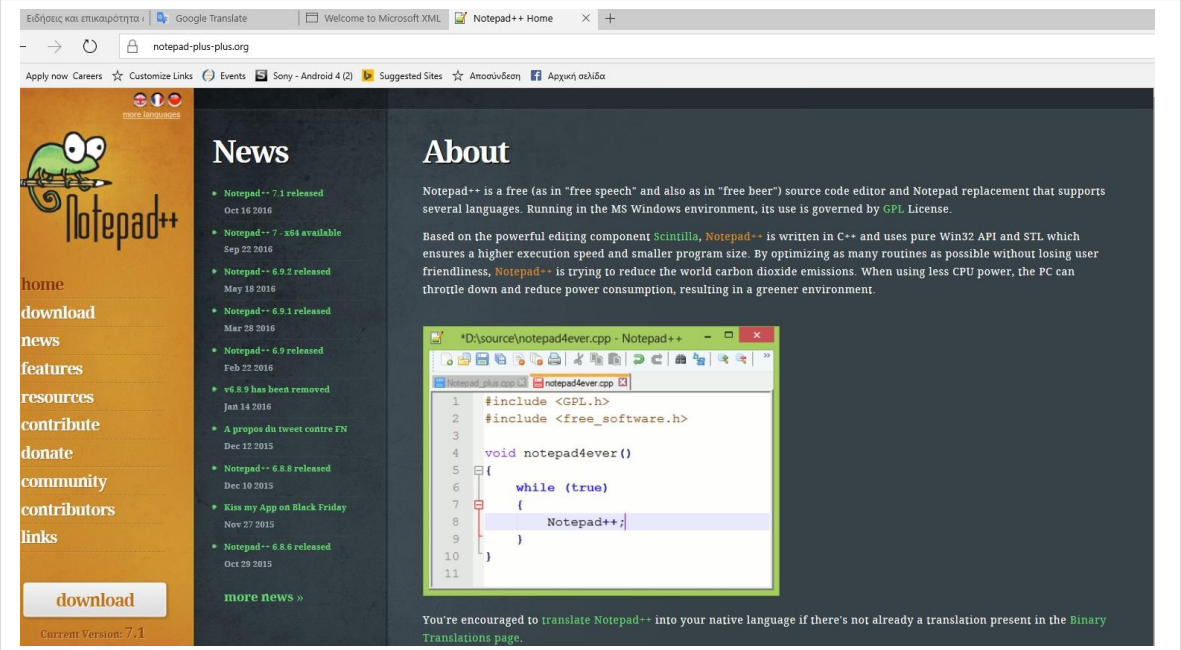

Figure 10: Downloading Notepad plus plus.

EVALUATION OF THE BARRIER IMPACT

A new window opens and the user can start working in quantifying the impact of the barriers. Two sectors are available for this version. The software starts with the building sector. The user has the option to select with which of the two available two sectors (buildings and transport) he/she will work (Point 1 in Figure 11). Depending on the selected sector a different set of barriers appears in the list on the left (Point 2 in Figure 11).

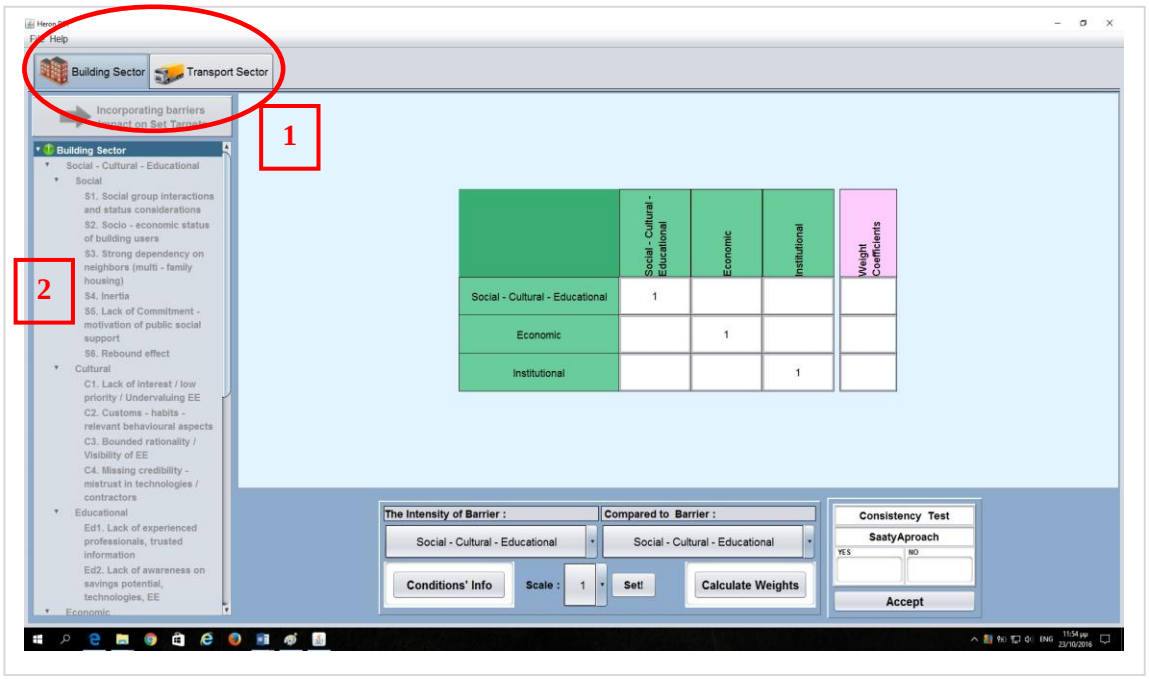

Figure 11: Evaluating the barriers impact.

The evaluation starts with the groups of barriers, ie comparison among “Social-Cultural-Educational”, “Economic” and “Institutional”. The user selects which two groups to compare each time.

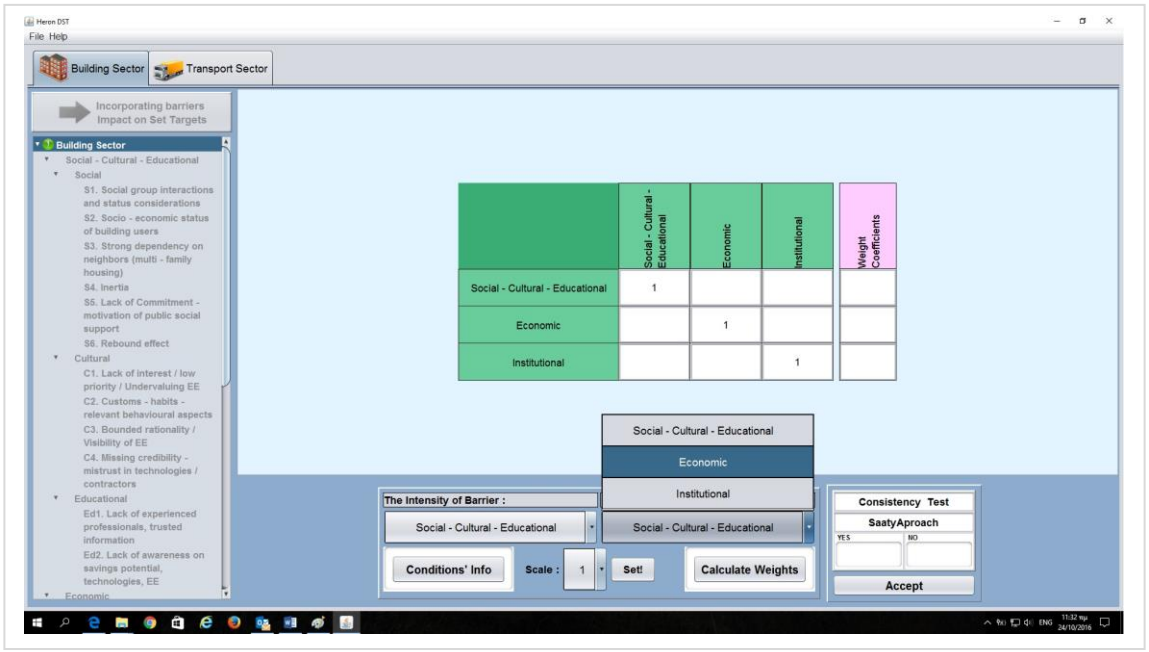

Figure 12: Selecting the groups for pair wise comparison.

The user can select the two groups from the drop boxes under the appearing matrix or by placing the cursor on the cell that he/she wants automatically the pair appears. Once the user has selected the two groups that he/she will compare, he/she can be assisted by:

a. On the top left and under “Help”, the user can find the “Scale Info” and the “Flow chart”. By selecting the “Scale Info” a new window appears with all the information about the AHP scale for assigning intensities.

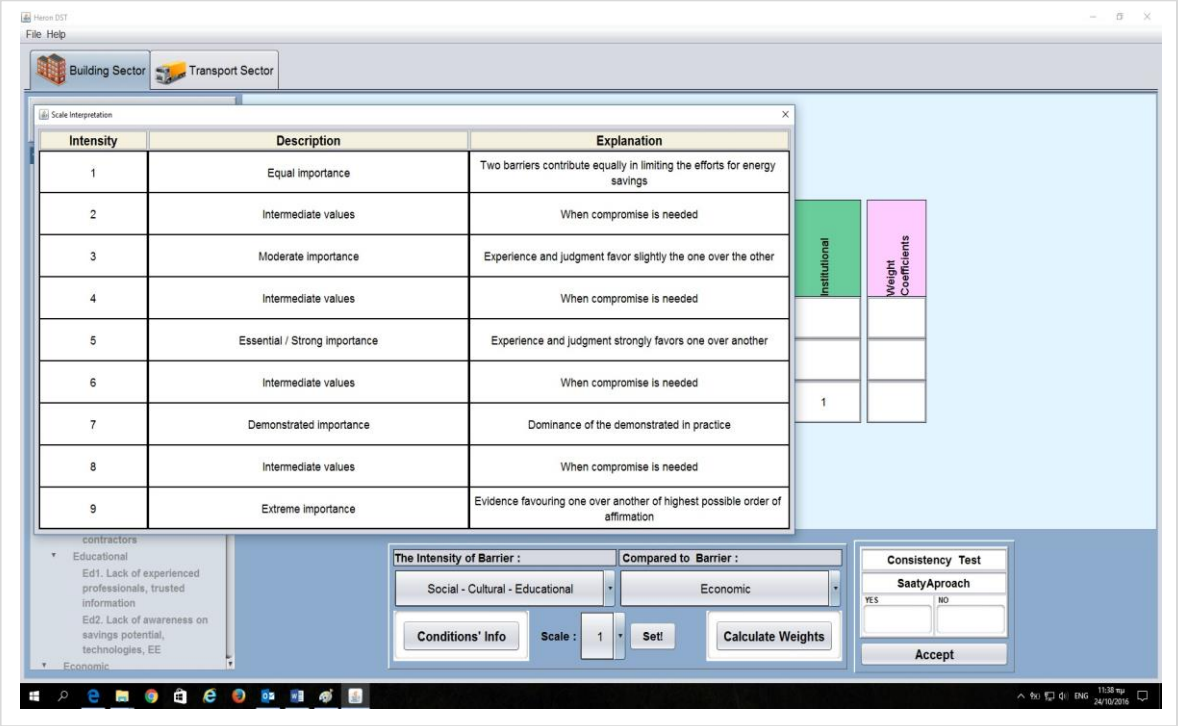

Figure 13: AHP scale.

b. Under the two drop boxes that allow the selection of groups to be compared, there is a button titled “Conditions’ Info”. If the user clicks with the mouse on it, a new window appears with all the information about the conditions that the user needs to take into account for proceeding with the comparison and understanding which group is more important compared to the other one. The conditions serve as guidelines for understanding which intensity (from the AHP scale) is more appropriate in describing the relationship between the two compared groups.

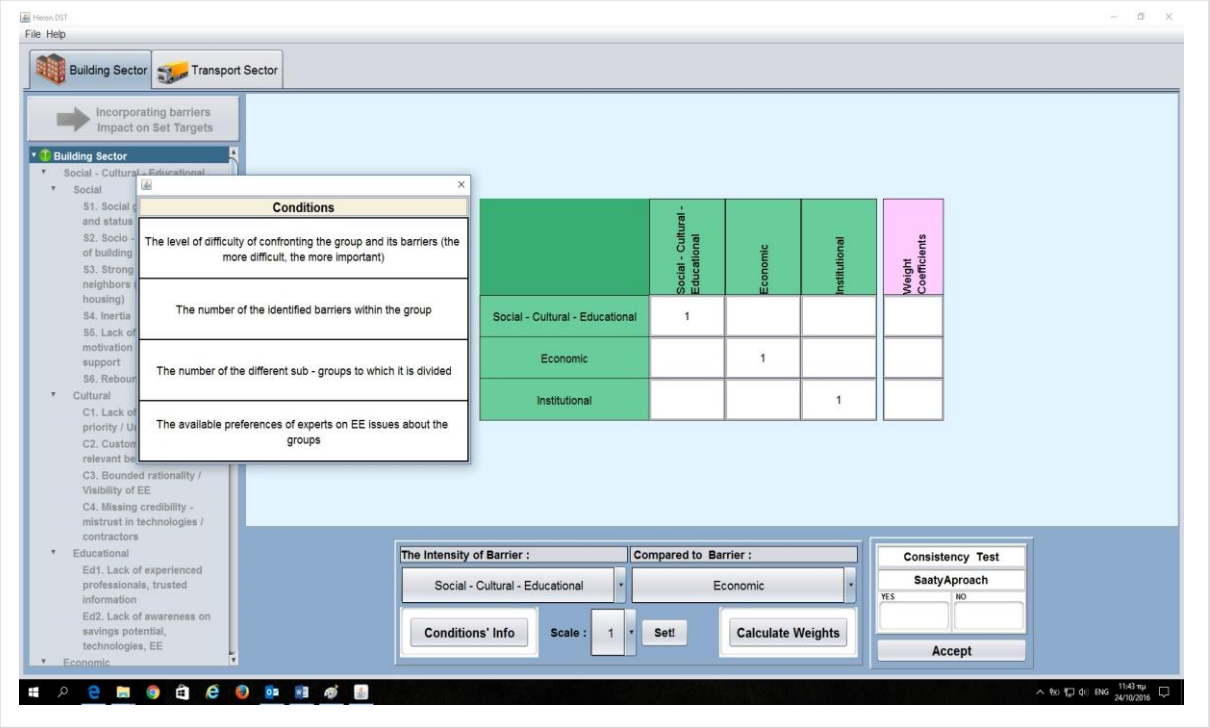

Figure 14: Conditions' info for assisting the user.

Once the user decides which is the most appropriate intensity to assign, he/she moves the mouse to the scale underneath the two drop boxes for selecting the groups and selects the intensity he/she wants.

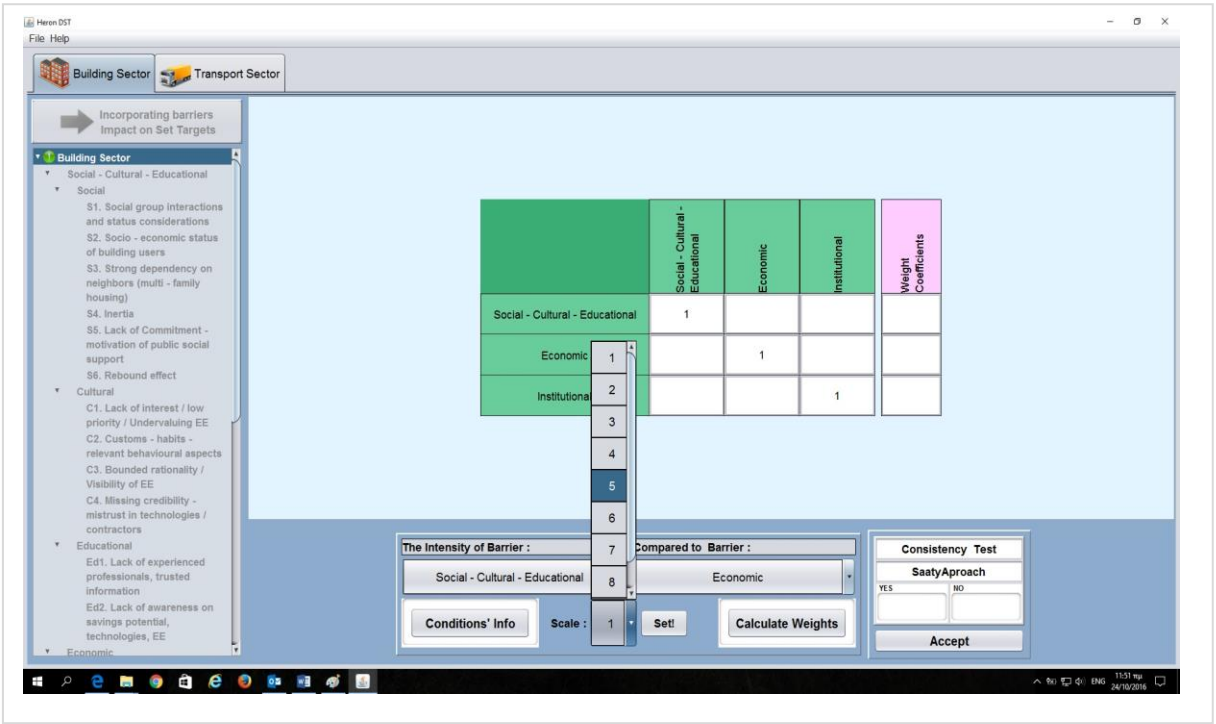

Figure 15: Assigning the appropriate intensity.

If the user is certain for his/her selection, presses the button “Set” and the value is placed in the respective cell of the AHP matrix, while the cell representing the reversal comparison is also filled automatically (see Figure 16).

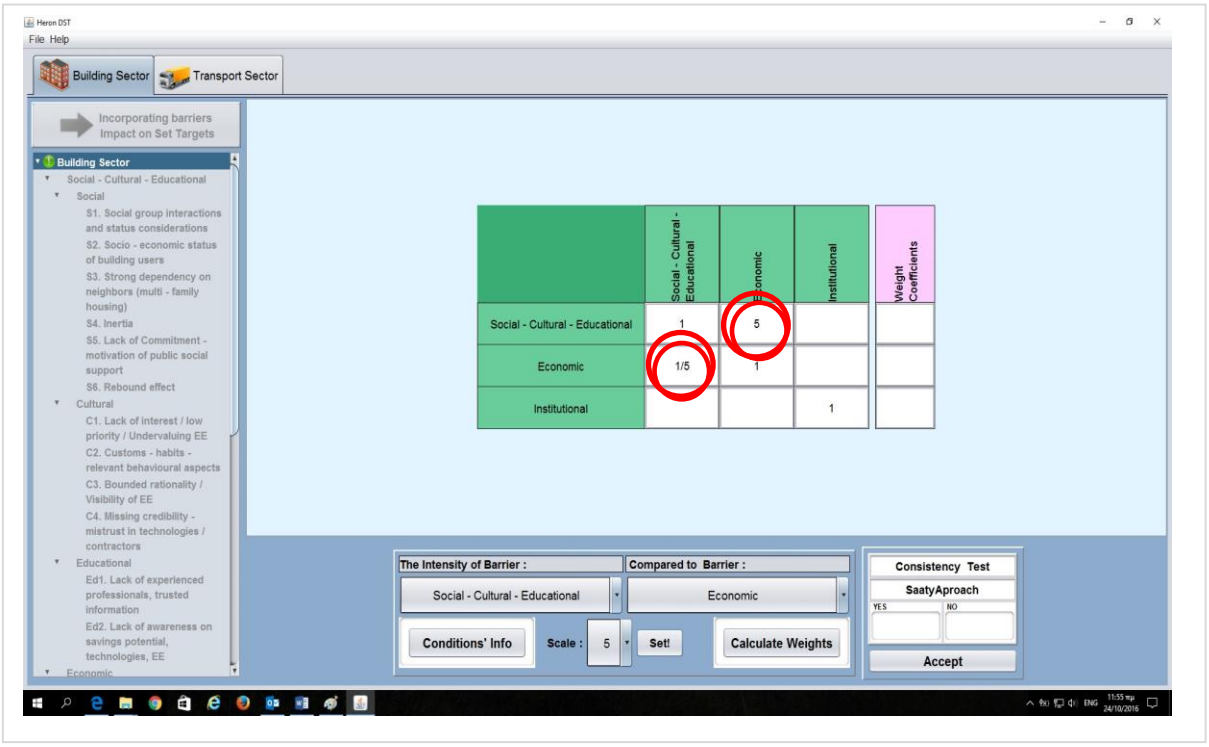

Figure 16: Filling the AHP matrix.

The user continues until the whole AHP matrix is filled (Figure 17). Then the user presses the button “Calculate Weights” and the column “Weight coefficients” is filled with numbers, while simultaneously the user can see on the right if his/her decisions result to consistent outcomes.

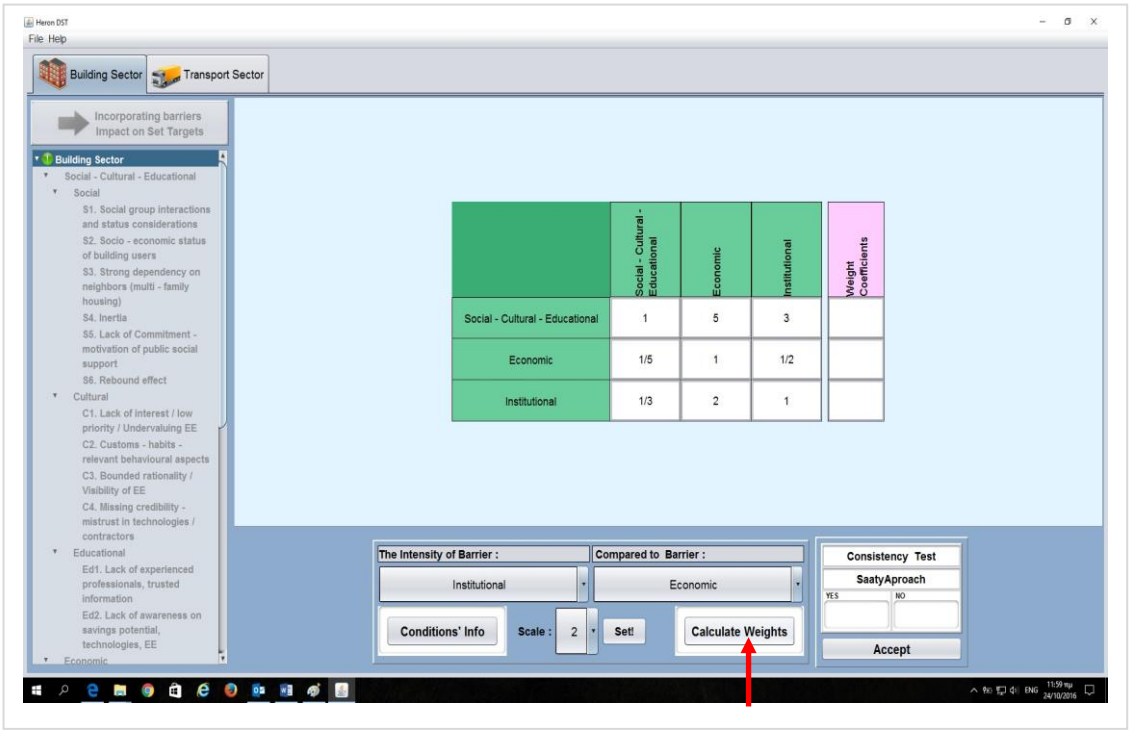

Figure 17: Filled AHP matrix.

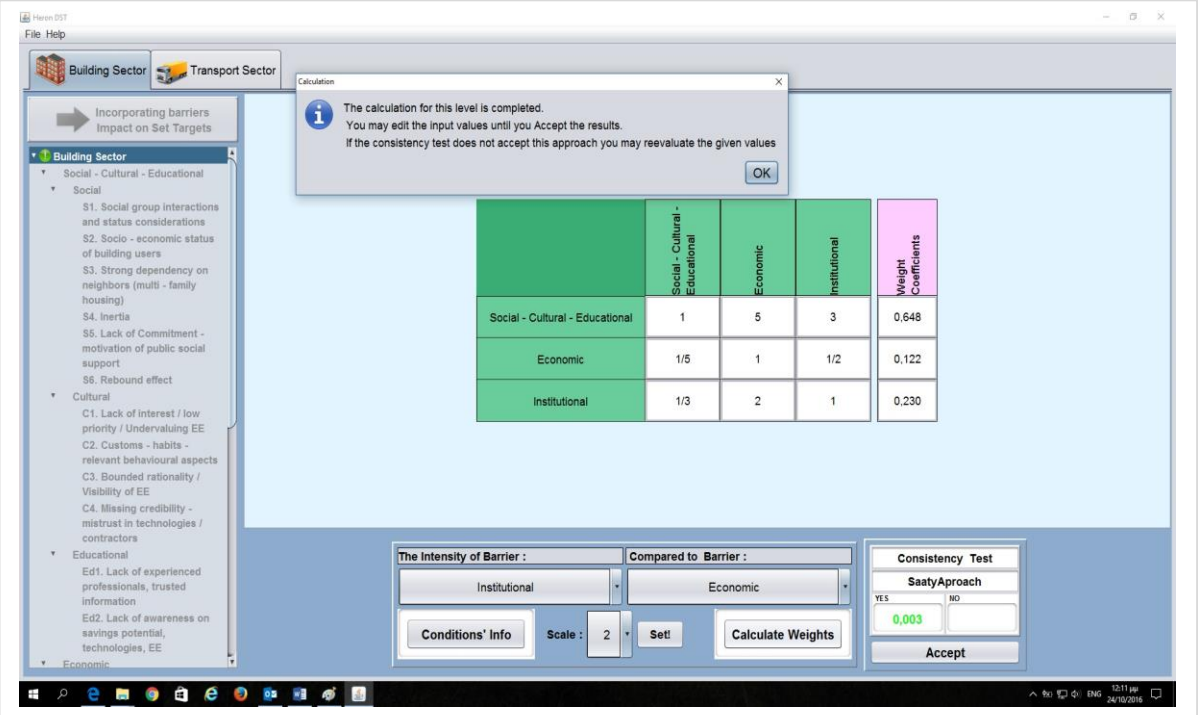

Figure 18: Outcomes for the first pair wise comparison.

If the consistency test shows that the calculated weigh coefficients fulfil the mathematical condition set by the Saaty's approach, the user will see the outcome of these calculations with green color under the "YES" part. Then the user needs to "Accept" the outcomes by clicking the button "Accept". The calculated weight coefficients are saved and the user can proceed to the next level and compare the respective objects with the same manner.

If the consistency test fails to fulfil the required mathematical condition, the user will see the outcome in red color under the "NO" part. Then the user will need to change some of the intensities so as to reflect better the importance among the compared objects. The user can also proceed – even if the consistency test fails – but he/she needs to be aware that the outcomes are not robust.

Once the user accepts the calculated weight coefficients a message appears informing him/her how to proceed. After accepting the calculated weight coefficients, the user cannot make any changes.

For matrixes 2x2 the consistency test is not calculated. The user will insert the preferred intensities, press the "Calculate Weights" button, have the results, "Accept" them and proceed.

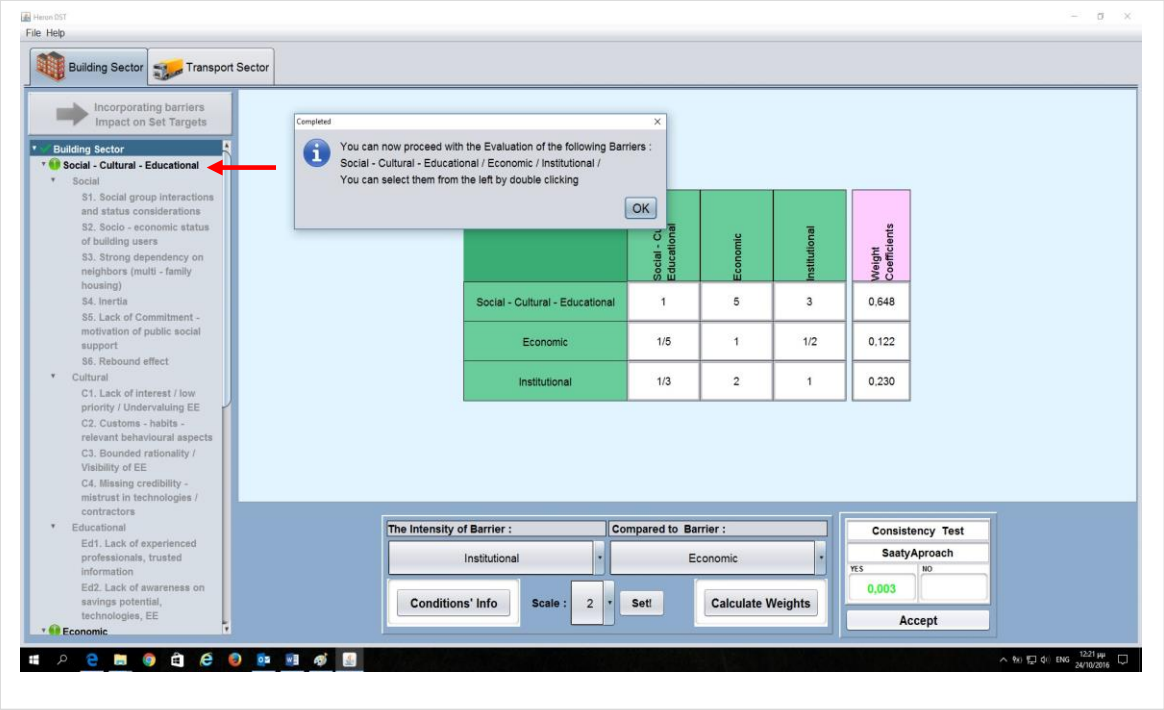

Figure 19: Message for moving to the next level.

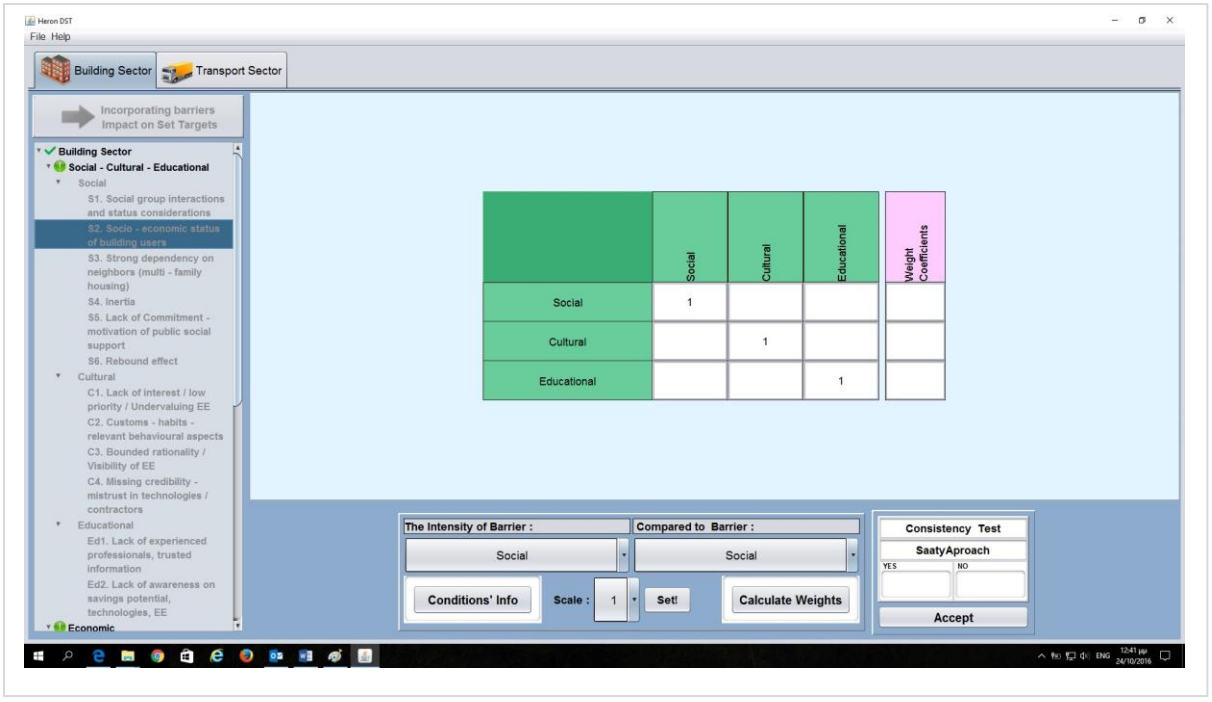

Figure 20: Pair wise comparisons at the next level.

As the user moves from one level to the other he/she will see on the left with Bold letters and with green "√" the levels for which the weight coefficients were calculated (Figures 21 and 22). The barriers for which the weight coefficients are not calculated will remain in grey color. When the user has completed all the necessary pair-wise comparisons he/she will be able to move to the next window.

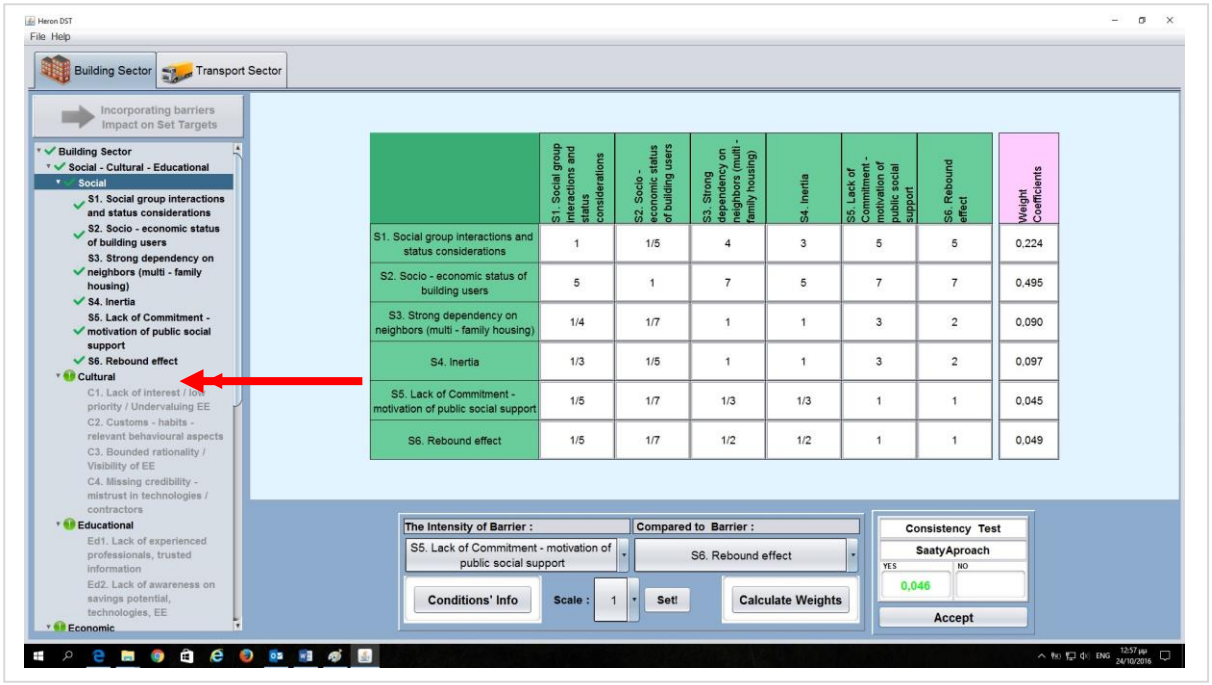

Figure 21: Unlocking levels.

After filling in the last AHP matrix for the group of the "Institutional" barriers and having the weight coefficients calculated the HERON DST software informs the user that the next step is to work with incorporating the barriers impact in the energy efficient modelling (Figures 22 and 23). The user may decide to work with the transport sector before proceeding with the "Incorporation of barriers impact on set targets".

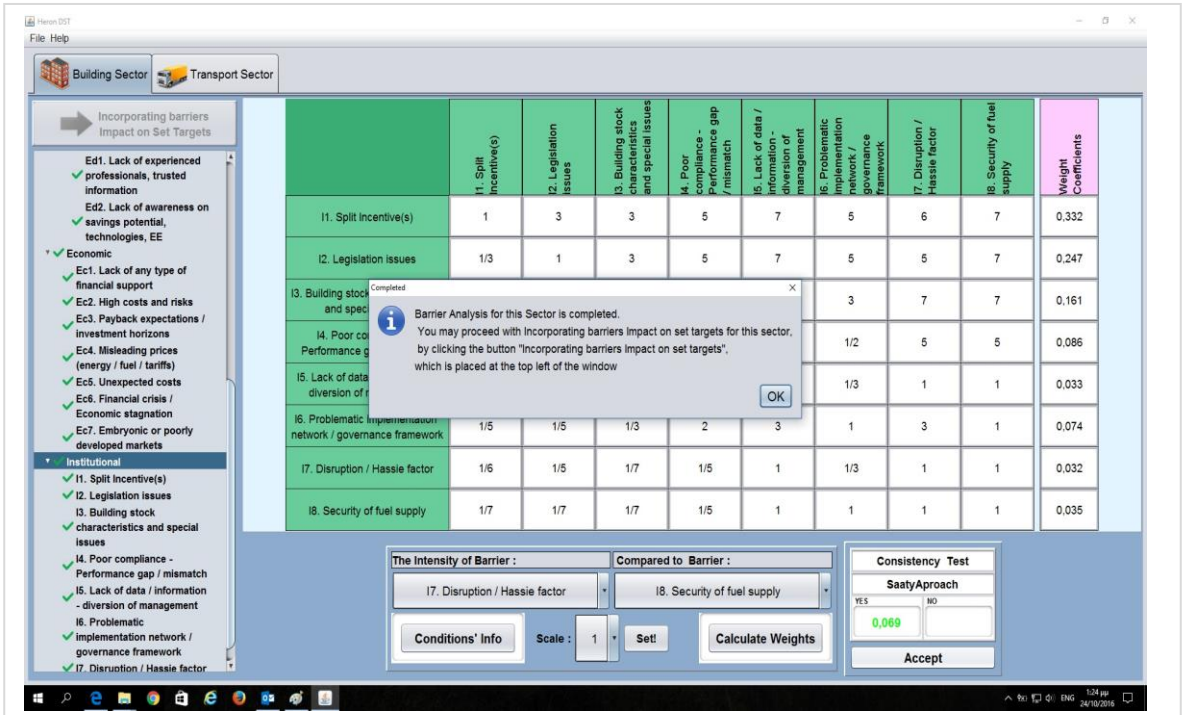

Figure 22: Completion of the evaluation of the barriers impact.

Before moving to the next window the user can save the work that was done for the barriers of the sector. The user opens at the top left the “File” and saves the work in a file with a name that he/she chooses (Figures 22 and 23).

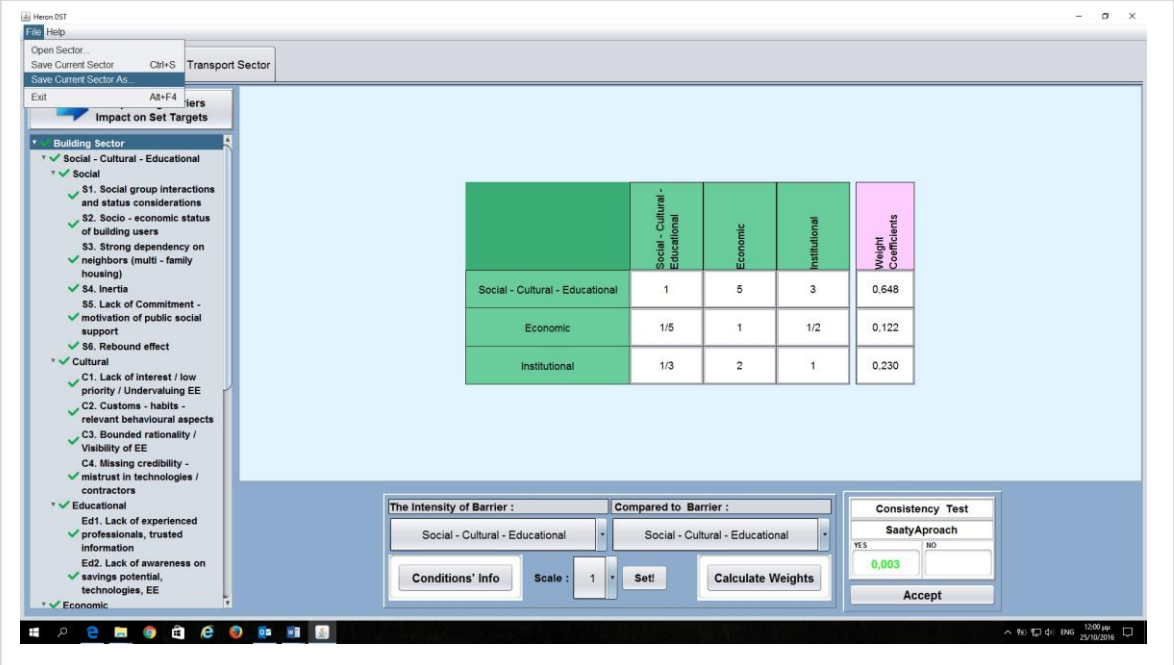

Figure 23: Saving performed work for barriers impact.

INCORPORATION OF THE BARRIER IMPACT IN ENERGY MODELLING

After calculating all the necessary weight coefficients, the HERON DST software unlocks the button that is on the top left of the opened window (Figure 24). The user clicks with the mouse on it and a new window opens (Figures 24 and 25).

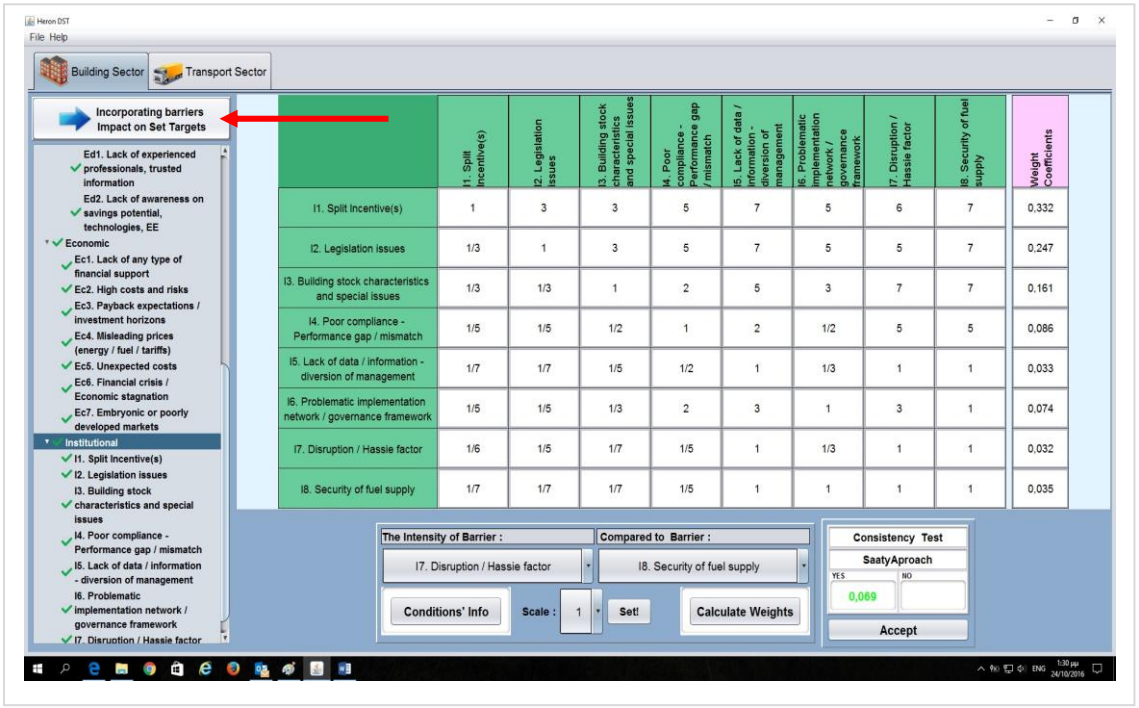

Figure 24: Moving to the next procedure.

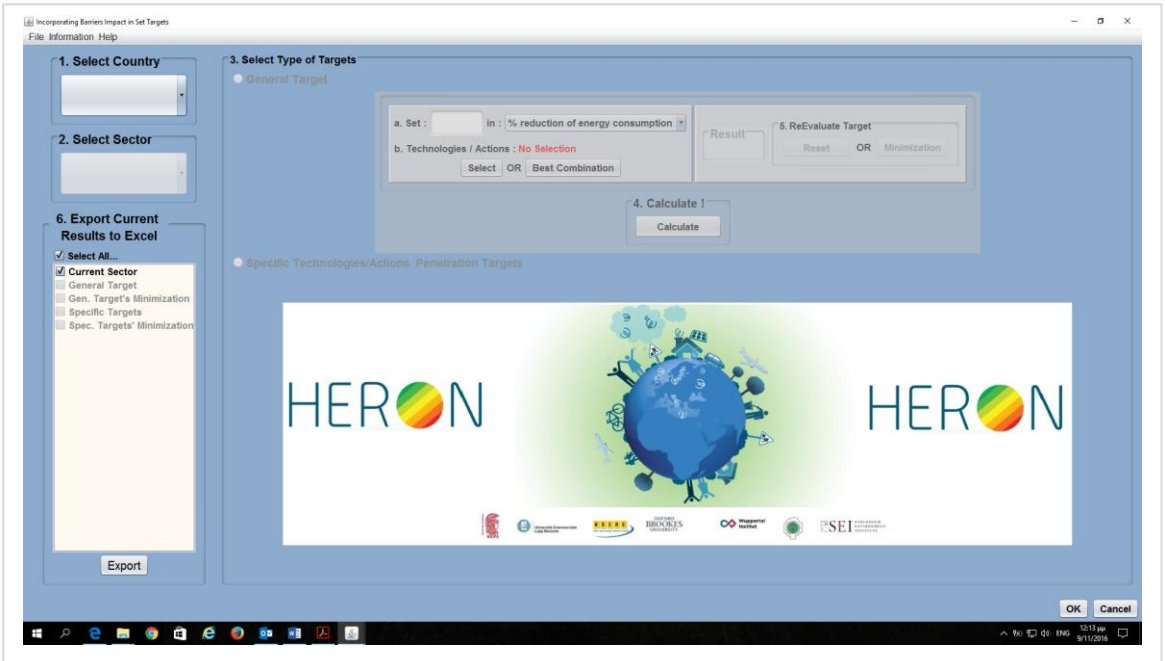

Figure 25: Incorporation of the barriers impact in the assumed targets.

The user needs to define the framework under which he/she will work. So, this requires the specification of:

1. *The country.* The user can select among the seven countries that participate at the HERON project (Figure 26).

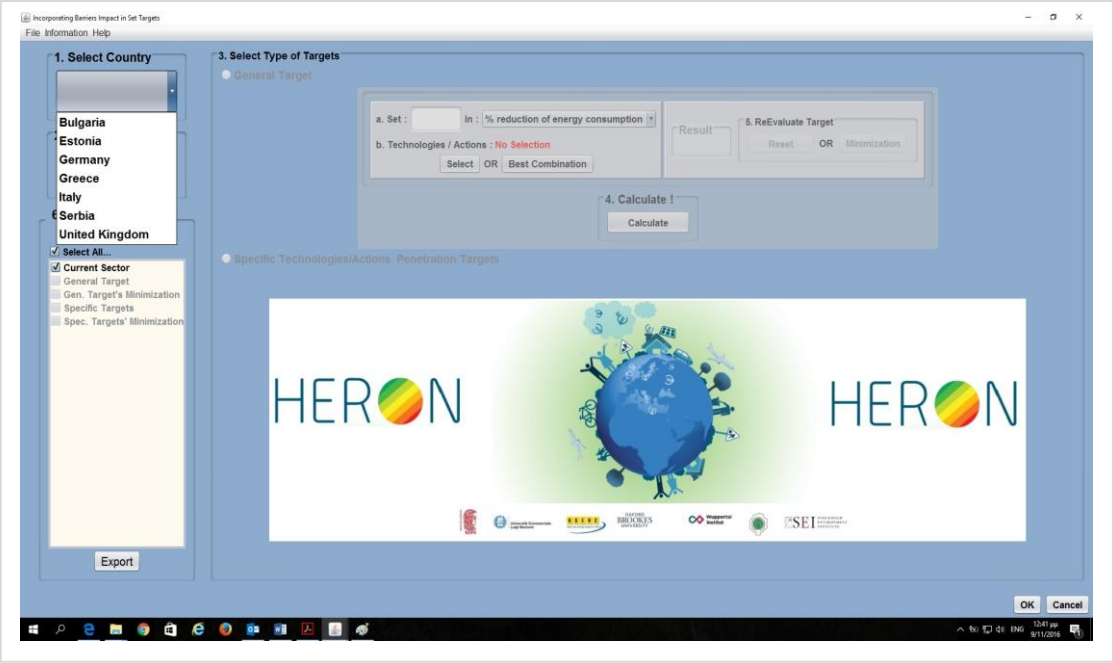

Figure 26: Selection of country.

2. *The sector.* Since the user has been working with the barriers that concern the building sector, this sector appears in No. 2, but if the user intends to work with one of the two sub-sectors he/she can select it respectively (Figure 27).

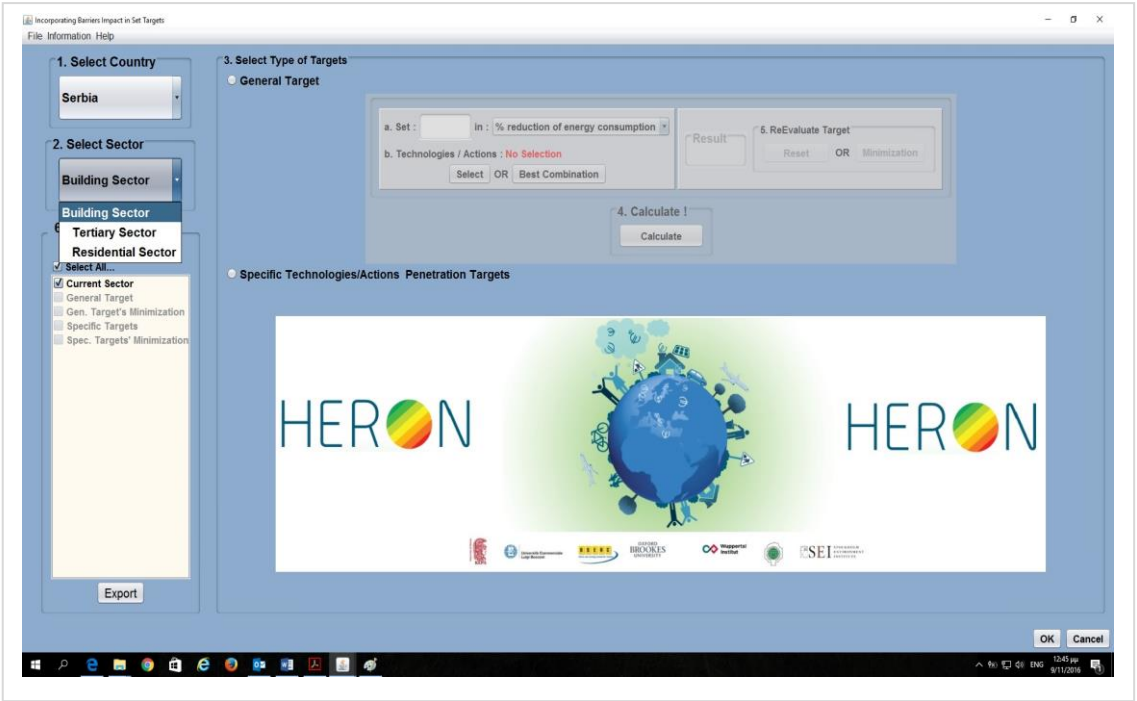

Figure 27: Selecting sector.

3. *The type of the assumed target.* The user has two options:

A. ***to work with an assumed general target.*** This general target concerns the sector as a whole in the case that there are no detailed data per technology or if the user does not work with each technology separately but using the whole set of EE technologies for the development of the scenarios (Figure 28).

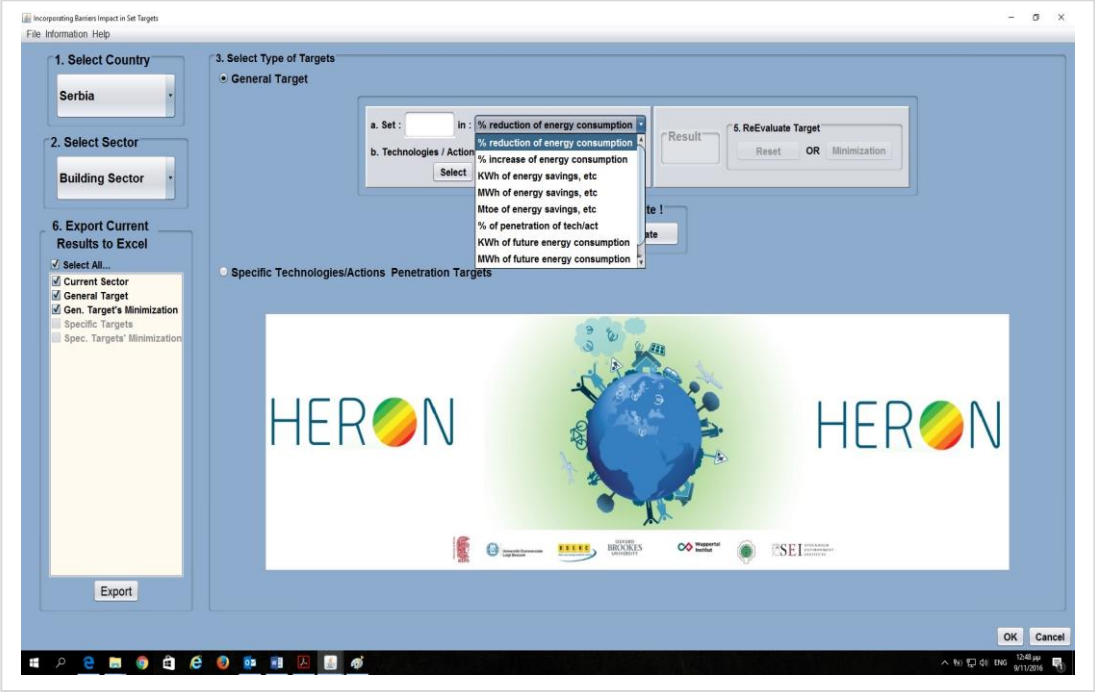

Figure 28: Working with the general target.

The meaning of the term "target" includes for the HERON DST Software *any assumption or expected target about:*

i. *the reduction of final or primary energy consumption in a future year (ie 2020 or 2030) compared to a base (or reference) year (in %);*

ii. *the increase of of final or primary energy consumption in a future year (ie 2020 or 2030) compared to a base (or reference) year (in %);*

iii. *the amount of assumed or expected energy savings in a future year (expressed in KWh, MWh or Mtoe);*

iv. *the assumed or expected penetration of a technology or action that results in energy savings (in %);*

v. *the assumed or expected amount of final or primary energy consumption in a future year (expressed in KWh, MWh or Mtoe).*

After setting the assumed general target, the user needs to specify with which technologies/actions he/she assumes that this target (the target that he/she set in the software) will be achieved. The message in red "**No selection**" refers to the fact that the user has not yet selected any technologies/actions.

The HERON DST offers two options to the user about technologies/actions:

a. to **select** specific technologies/actions out of a set of available technologies/actions (that the country has been promoting or the national market prefers – based on official information) (Figure 29). The user – under this option - can select all available

technologies/actions or only those that concern the scenarios that he/she will develop or

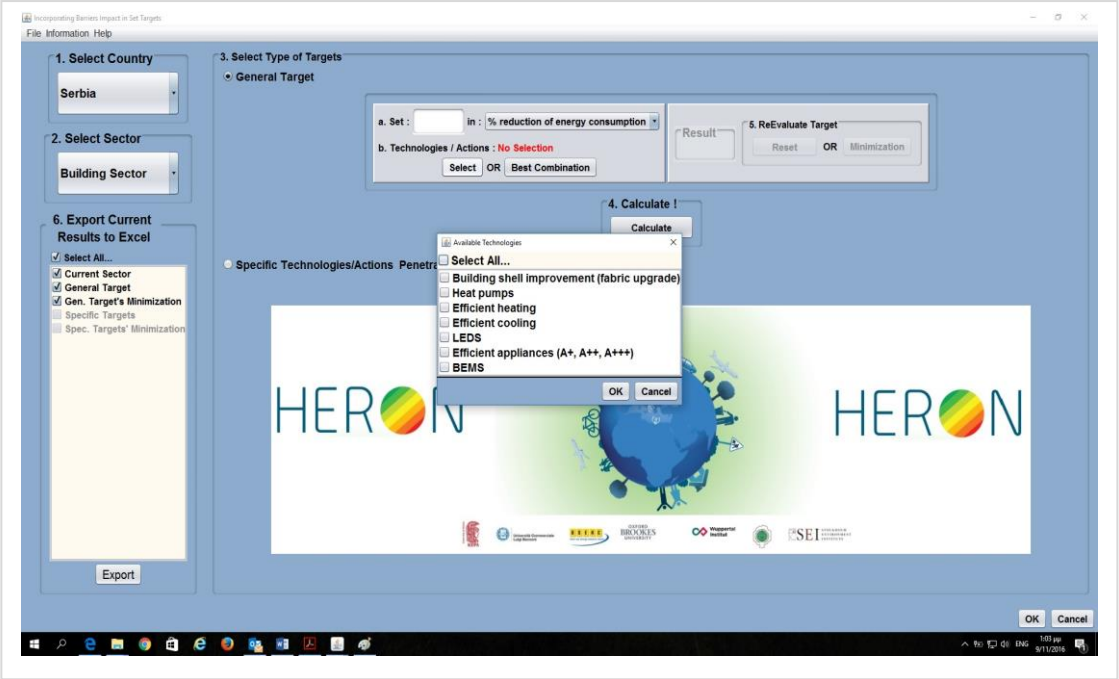

Figure 29: Selection of available technologies/actions for the specific country.

b. to use the "recommended" by the DST **best combination** of technologies/actions that are more likely to deliver the assumed general target (Figure 30). The number of the technologies that can form such combinations are the number of the available technologies minus 1. If the user intends to use all available technologies this option is under the previous option, the "Select".

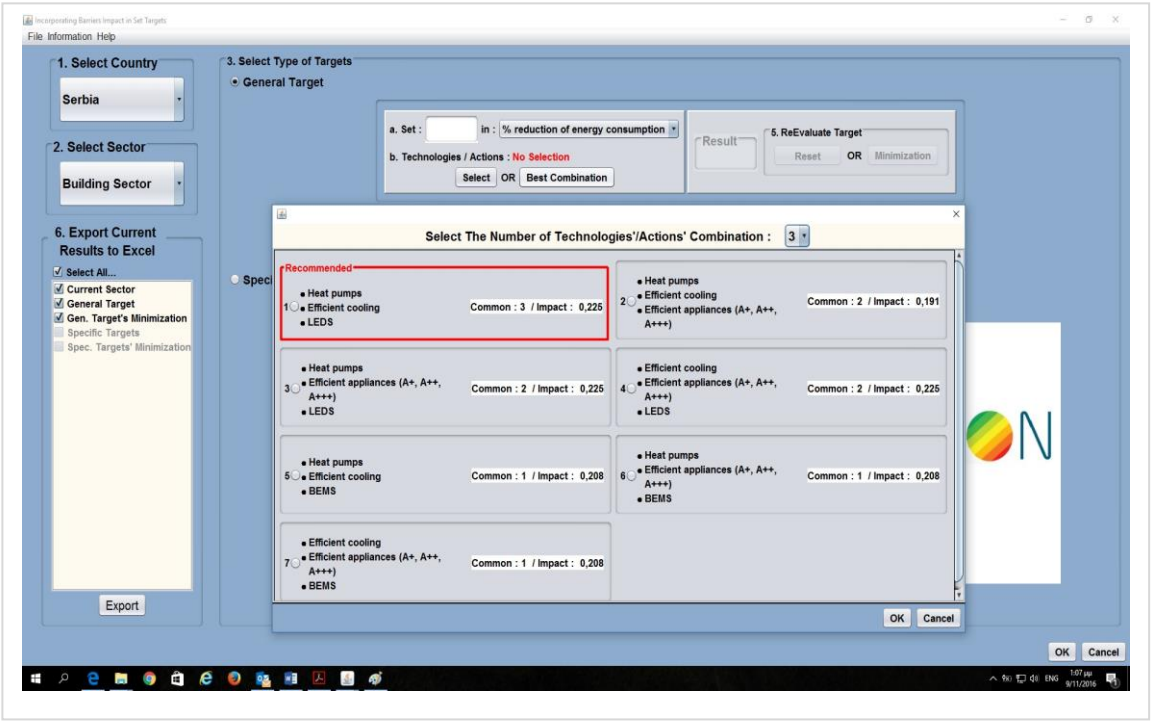

Figure 30: Best combination of technologies/actions.

Under the "Best Combination" the HERON DST provides to the user with the combinations of the national available technologies/actions and recommends the one that has the larger number of common barriers and the lowest total barrier impact (Figure 30). The user can decide to use the combination that he/she prefers by clicking with the mouse on No. 1, 2 or 3. If the technologies/actions do not have any barriers in common, then the HERON DST will not provide any recommendations and it is up to the user to decide what technologies/actions to use.

Now the user can press the "**Calculate**" button. The result shows how the assumed general target is reduced due to the Total impact of the barriers that are linked with the technologies that the user decided to work with (either from the "Select" or the "Best combination" option) (Figure 31).

Figure 31: "Calculate" outcome.

The user has now two options to proceed:

A. To decide to "**Reset**" the target. The HERON DST software calculates and shows to the user the value that he/she needs to insert in the Energy Efficiency modelling (for instance in LEAP) so as to achieve the assumed or expected target (having in this way the desired outcomes ie GHG emissions reduction, achievement of the amount of energy savings etc) under the impact of the existing set of barriers. *The result is higher than the set target due to the need to overcome the total impact of the barriers without introducing any new policy instruments.* If the user does not accept this value, by pressing the "Calculate" button the user sees again the previous result (Figure 32).

Figure 32: "Reset" option.

B. To decide to proceed with "**Minimization**". Under this option the user decides that the assumed general target remains the set one and he/she is exploring possible options to achieve it through the minimization of barriers. So, the user decides which barriers will have a decreasing impact on the assumed general target if they are confronted with new policy instruments or by modifying properly existing ones.

A new window opens and the user will need to specify his/her preferences (Figure 33).

Under the first option "**Select barrier**" the user may choose the barriers that he/she wants out of a list that shows all the barriers due to the "Selected technologies/actions" or the "Best Combination".

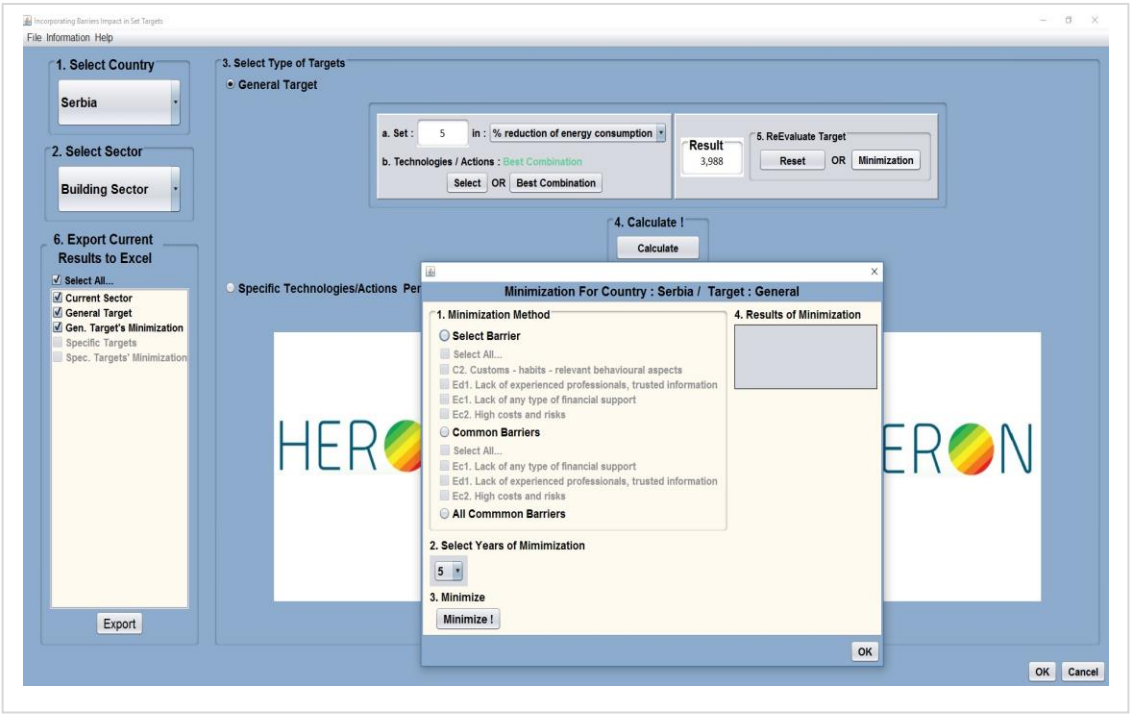

Figure 33: "Minimization" option.

Under the "**Common barriers**" the user may select those barriers that he/she prefers out of a list that shows the common barriers of all the selected technologies/actions.

Under the "**All common barriers**" the user may select immediately the minimization of all the barriers that are common for all the available technologies/actions.

The user needs also to express his/her preferences about the time (in years) within which the impact of the barrier will be reduced.

By pressing the "**Minimize**" button, the user sees on the right under the "Results of Minimization" the Total impact of the barriers on the assumed general target (Figure 37). The results display the time evolution of the assumed general target if the selected by the user barriers are minimized during the set by the user time period.

The same rationality is followed for "Select" and "Best combination" (Figure 34).

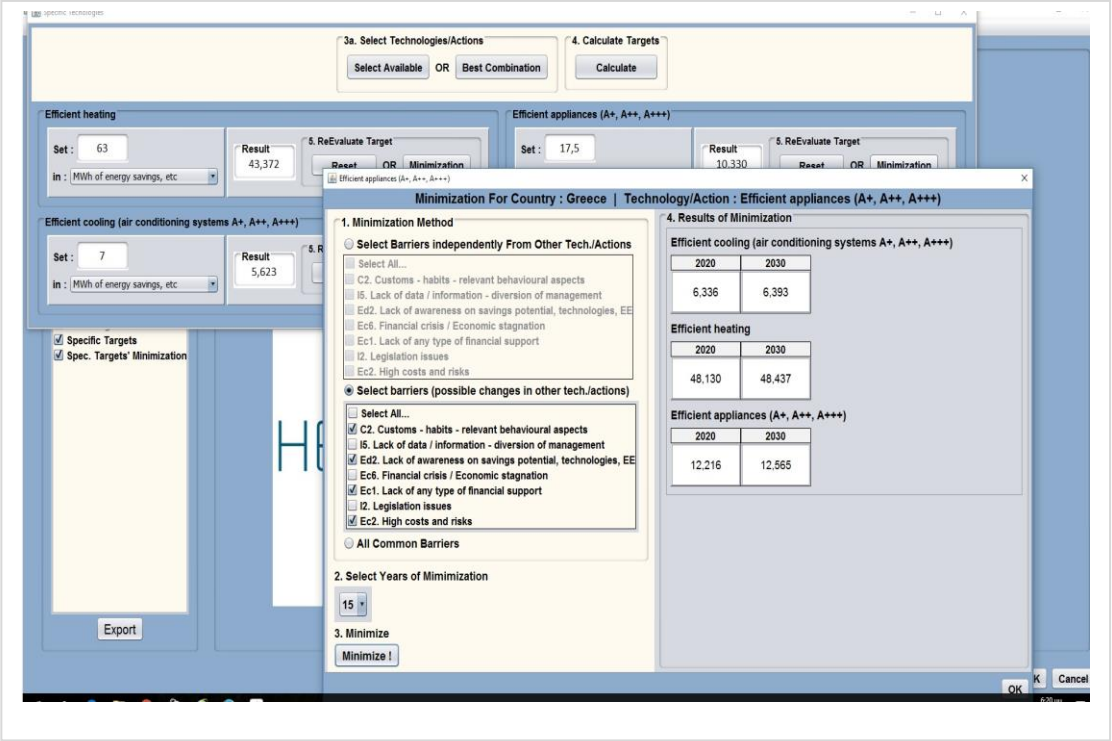

Figure 34: Outcomes for "Minimization" (best combination).

A pop-up window appears after pressing the "Minimize" button to inform the user about the need to save the results if he/she considers them worth to be used (Figure 35).

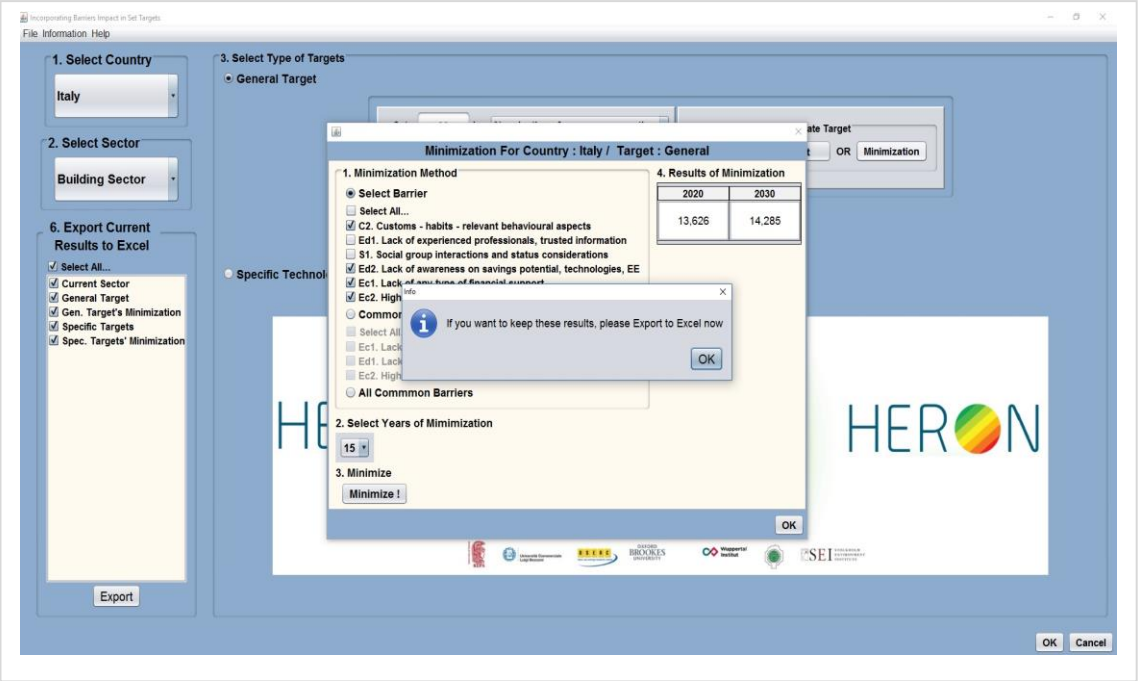

Figure 35: Outcomes for "Minimization" (selected technologies/actions).

B. ***to work with assumed targets per each specified technology.*** This option concerns the targets that the user is able to assume about each of the available technologies/actions that concern the under-study sector. The user has enough data to be able to assume the expected penetration of the available technology/action. The HERON DST software has included in total seven such Energy Efficient technologies[3]/actions for the building sector. For the transport sector, there are five available technologies and practices. The number is restricted each time to the technologies and actions/practices that are available in the examined country.

If the user needs to add a new technology/action the HERON DST Software if flexible on this. The user needs to follow the instructions of another chapter in this manual and make the required modifications.

[3] These can be groups of technologies that concern a specific activity of the sector. For example, efficient heating may concern for the user all available energy efficient technologies that are used for heating and according to the developed scenario or sub-scenario will lead to energy savings.

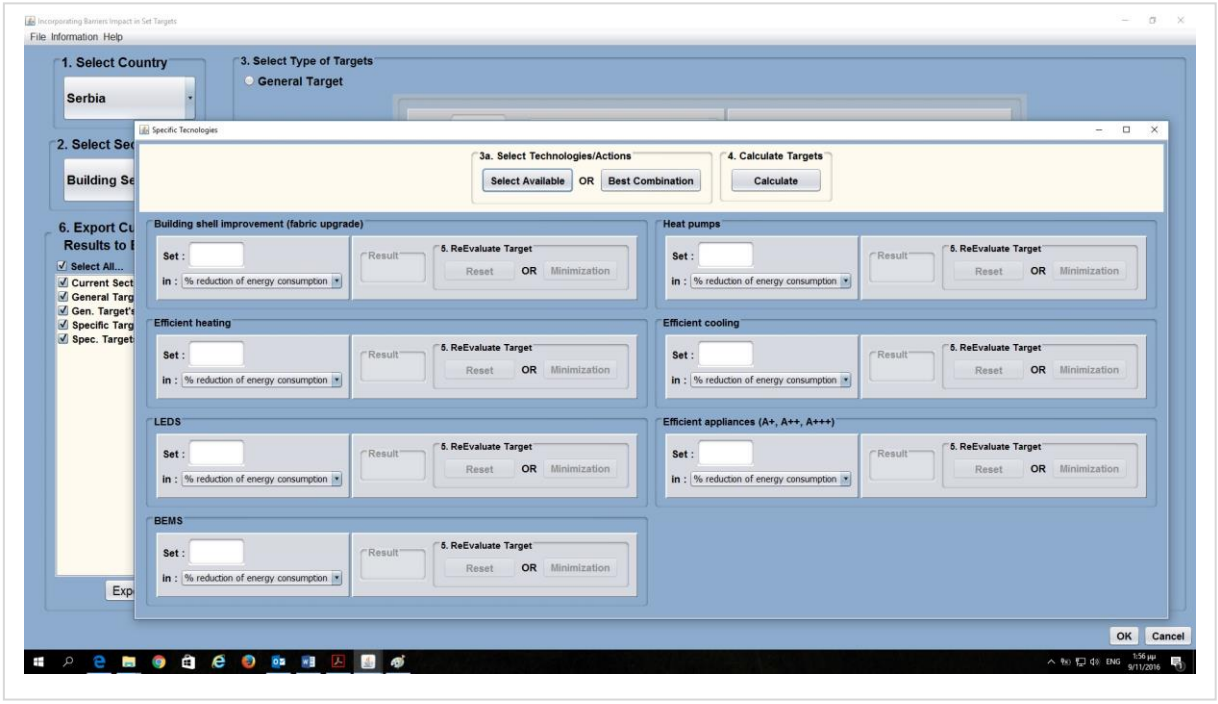

Figure 36: Specific Technologies/Actions Penetration targets.

Once the user selects this option a new window opens with the available technologies for the country. The user may "**Select**" the technologies with which he/she intends to work with (Figure 36).

There is again the option "**Best combination**" under which the user will be informed which combination of these technologies is more promising in delivering the assumed penetrations.

The user sets for each technology/action the targets he/she assumes or expects (again following the same meaning as presented previously).

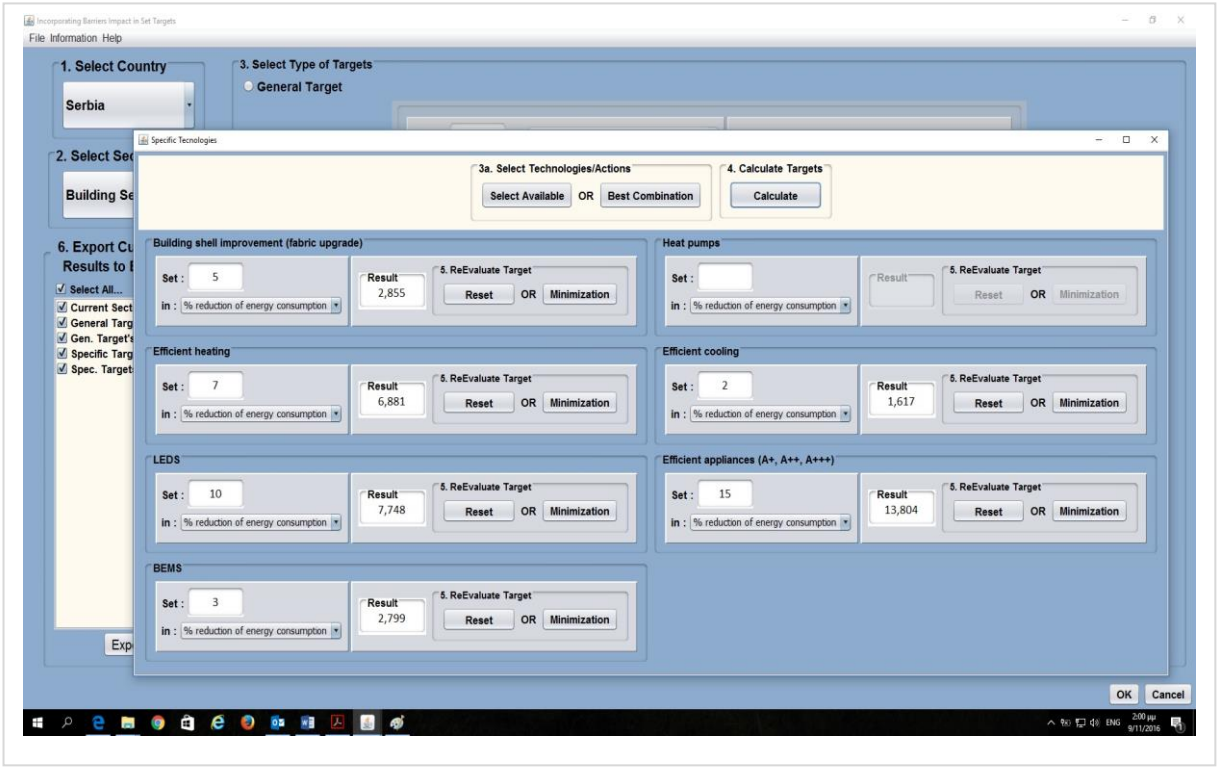

Figure 37: Assumed targets for specified technologies after considering the barriers impact.

Again, the user has two options (Figure 37):

a. to "**Reset**" the assumed target for the specified technology or

b. to proceed with the "**Minimization**" of the barriers that are linked with the specific technology.

Under "Minimization" the user has three options to examine (Figure 37):

a. the minimization of the barriers for the under-study technology/action without considering the barriers impact on the other available technologies/actions that he/she has selected (Figure 38);

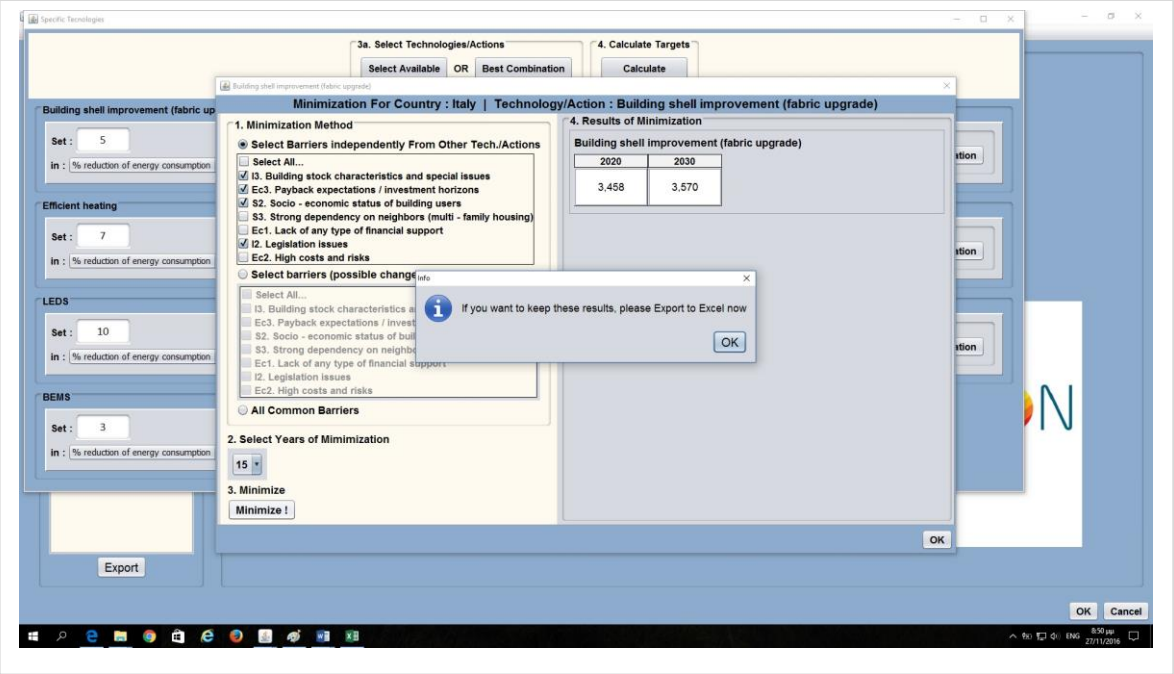

Figure 38: Minimization options for the specified technologies/actions.

b. the minimization of the barriers for the under-study technology/action but also having results of how his/her preferences affect the other technologies/actions as well (Figure 39); The HERON DST Software shows which other technologies/Actions are affected and how. The user can see the impact of his/her preferences on the previously set targets.

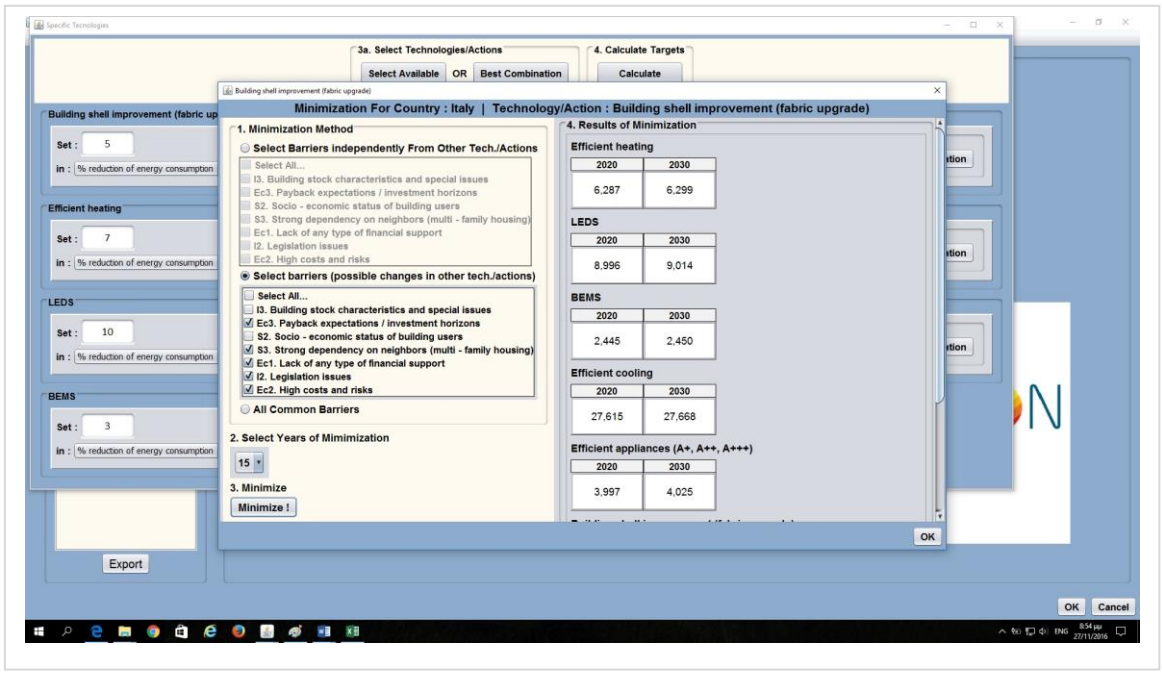

Figure 39: Minimization outcomes for specified technologies that have common minimized barriers.

c. the minimization of all common barriers among all available technologies/actions. If there are no common barriers among all available technologies/actions, no result appears.

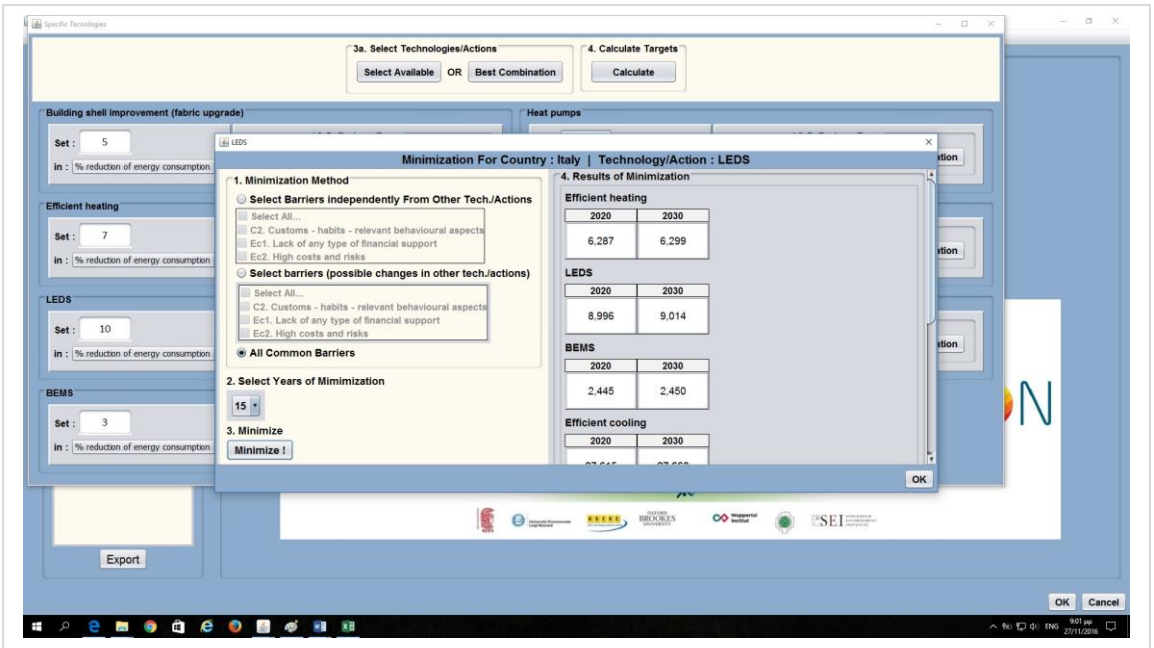

Figure 40: Minimization outcomes for available technologies and their common barriers.

Once the user has finished his/her work, all outcomes can be saved in an Excel file. The content of this file will be used in the Energy Efficiency modelling (Figure 41). The user has also the option to open and see the outcomes (Figure 42).

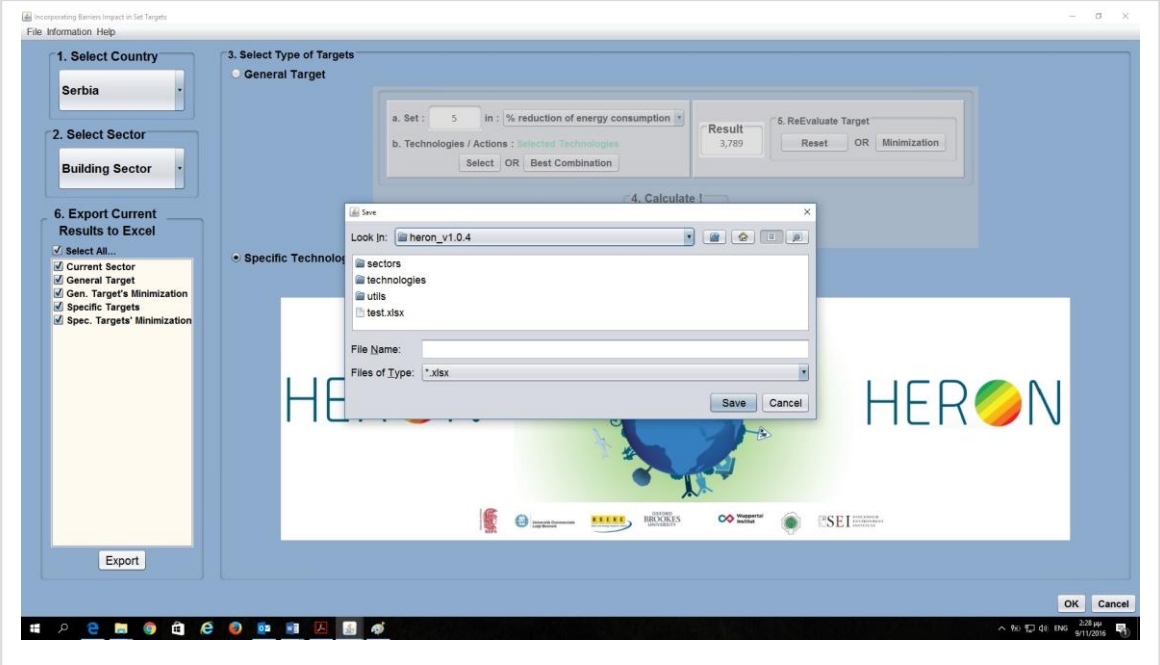

Figure 41: Saving the conducted work for the Energy Efficient Modelling part.

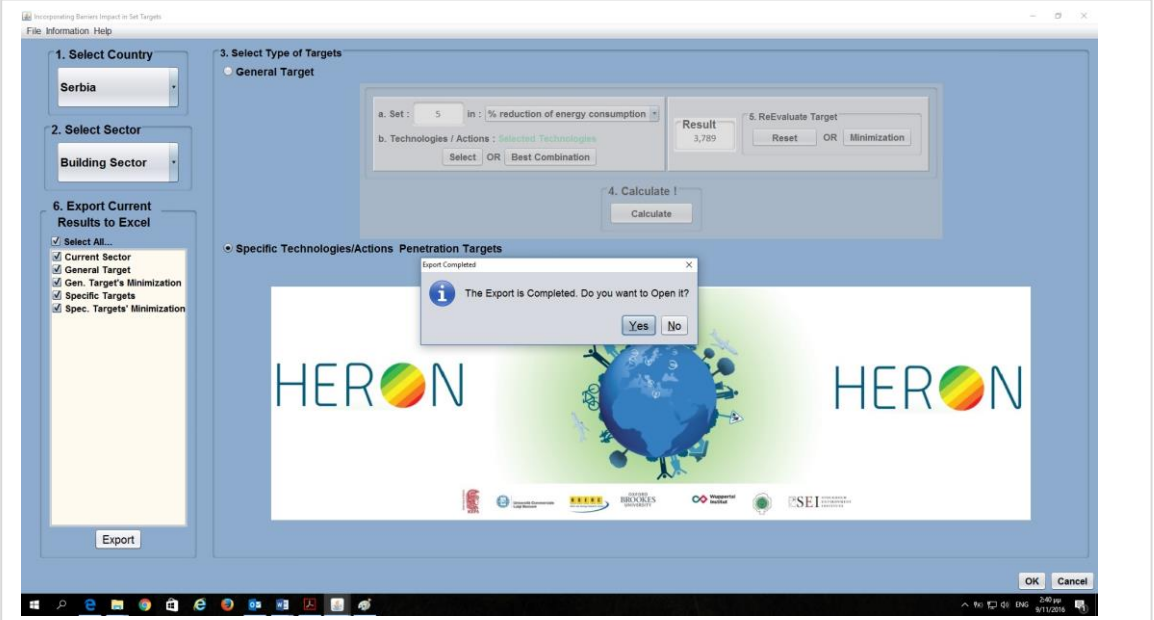

Figure 42: Opening the saved work.

However, the user needs to be careful and remember to save each time the outcomes of the option that he/she has examined. If the user makes changes to the options (ie from barriers that do not affect other technologies to barriers that might affect them), the previous results will not be saved only the ones that are in front of him/her.

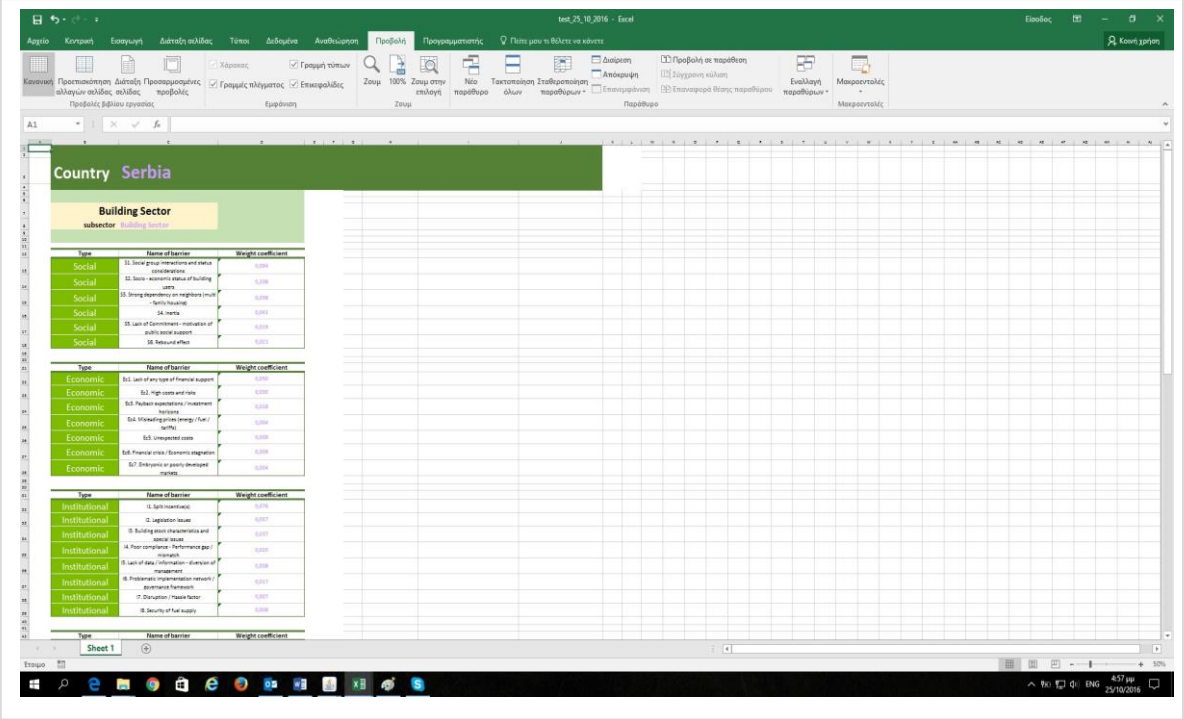

Figure 43: Excel outcomes.

INSERTING NEW SECTOR, BARRIER, TECHNOLOGY

Using Windows Notepad

The user opens the folder that contains the HERON DST software. There are three folders with the names “sectors”, “technologies”, “utils”. If changes are to be made in for the sectors, the user selects the folder “sectors” and double clicks on it. The folder contains two folders with the names “images” and “xml”. The user selects “xml” and double clicks on the respective folder. The folder contains two xml files, one for the building sector and one for the transport sector. The user opens the files he/she wants by selecting the “Windows Notepad”.

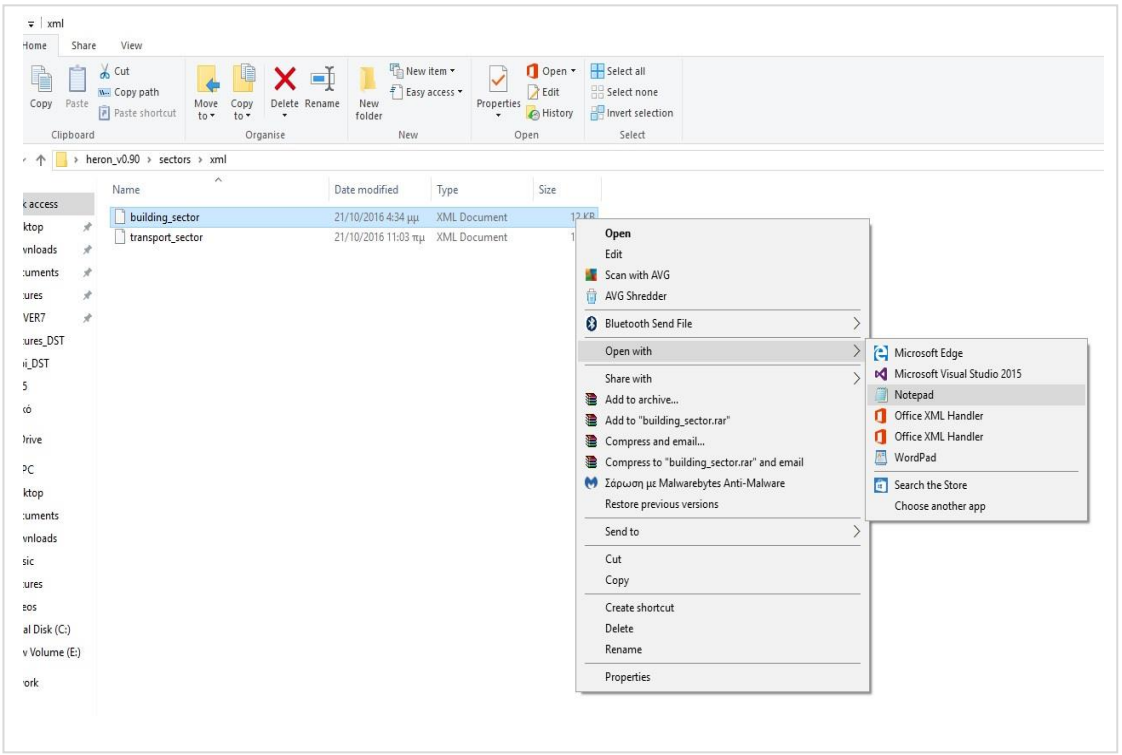

Figure 44: Using “Windows Notepad” to change the sector.

If the user intends to include a new sub-sector, he/she needs to go at the last sub-sector, copy three lines (one that has the name of the sector and one after it). For example

<sector>

<name>Tertiary Sector</name>

</sector>

The copied part is quoted in the xml file for the building sector, right after the least sector. The user needs to remember that the change starts with <sector> and ends with a </sector> (or <barrier> and </barrier>).

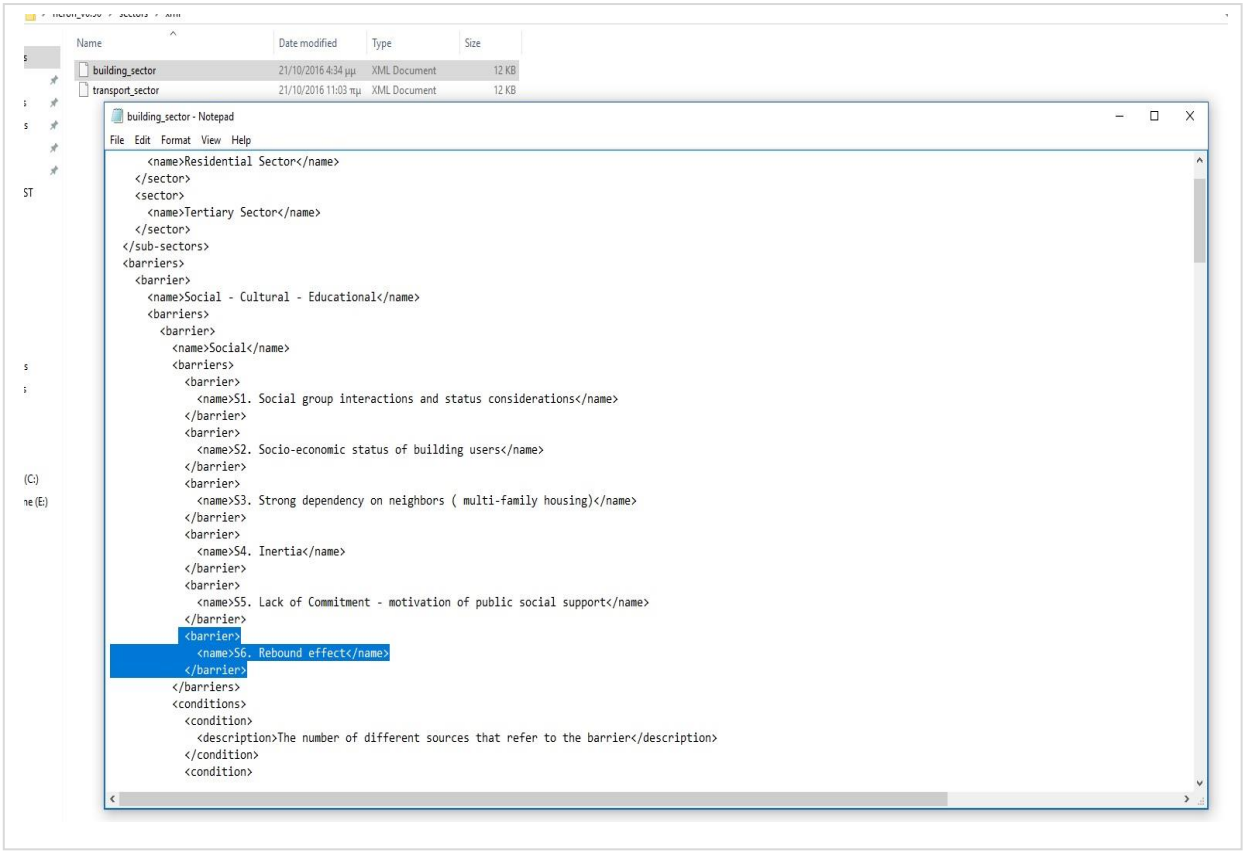

Figure 45: Using "Windows Notepad".

Apart from sectors the same procedure is followed for technologies, countries and units.

Using XML Notepad

The starting procedure is similar to the previous one. The user opens the XML Notepad and locates the file that he/she intends to modify (Figure 46).

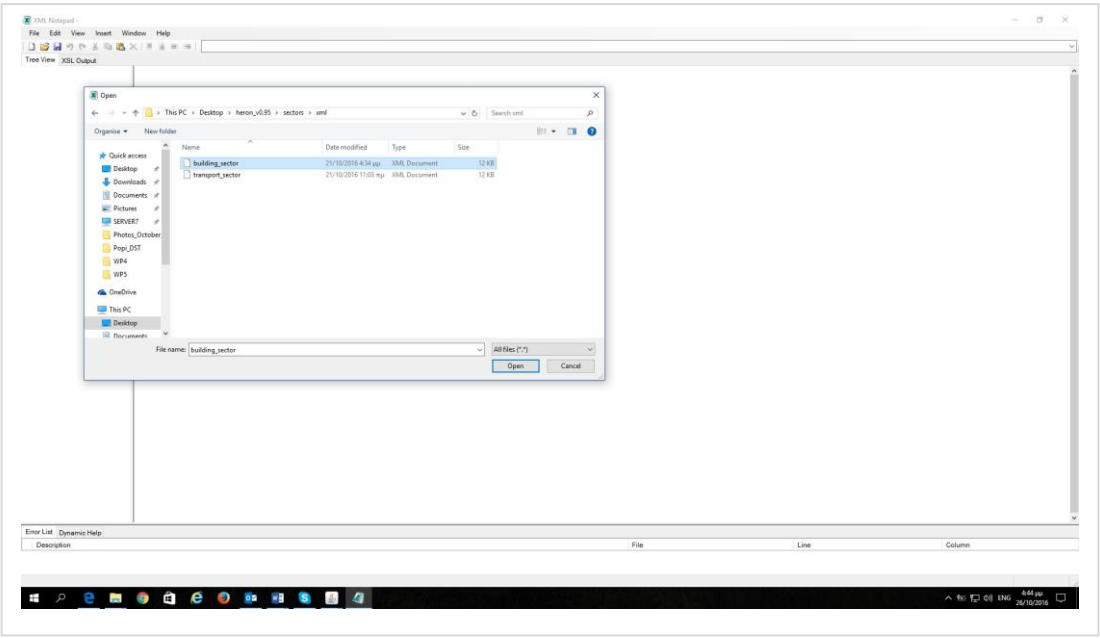

Figure 46: Using "XML Notepad".

This editor might be more convenient since the user can understand better the structure of the AHP tree ie the groups of the barriers, their sub-groups and the barriers under each group or sub-group. The user changes the names on the right or adds the new element (Figure 47).

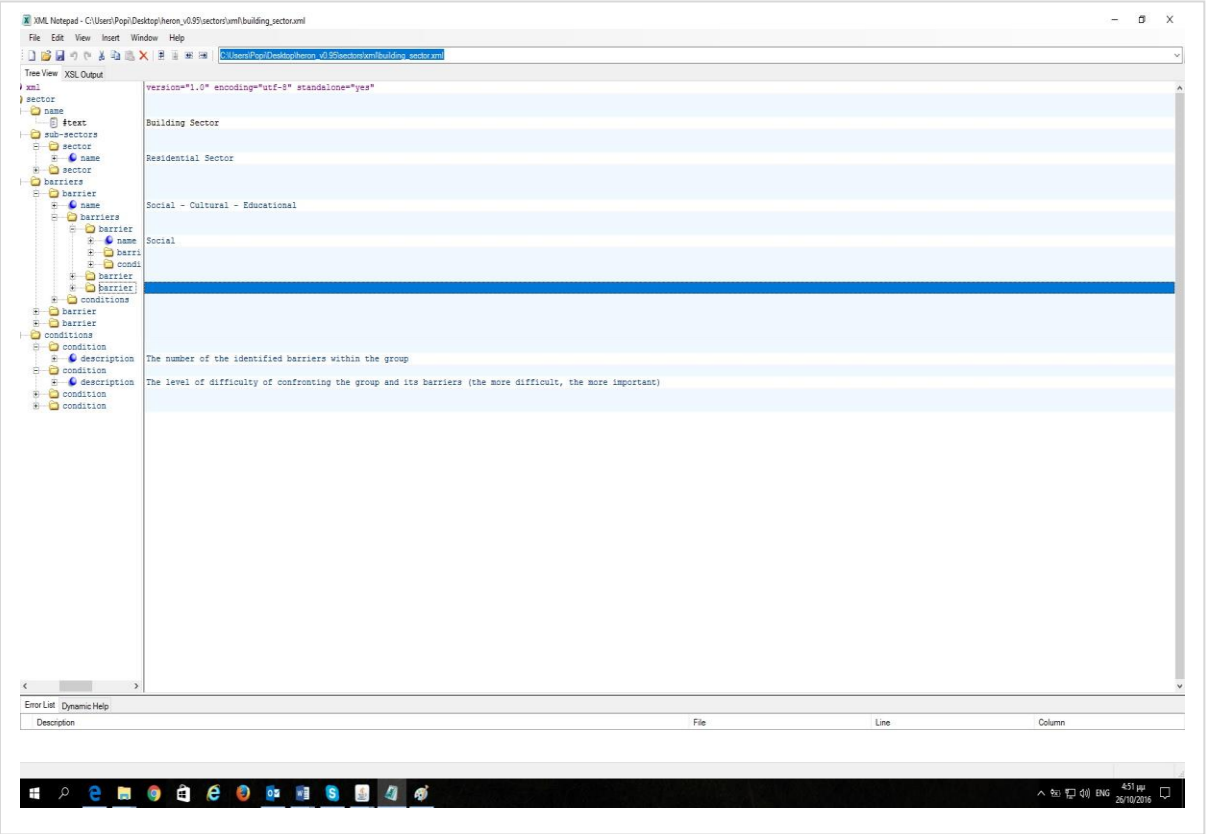

Figure 47: Representation of the xml file with the XML Notepad.

The inclusion of a new element is performed as follows. The user move the mouse on one of the elements he/she intends to create. If it is a barrier, the mouse is placed on one barrier (Figure 48). The user clicks the right button of the mouse and selects from the windows that opens the “Copy” option (Figure 48).

Then he/she places the mouse on the upper level and pastes the element. After that the user can make the necessary modifications and adjust the new element accordingly (Figure 53 and 54). The user works after double clicking on the right part of the screen.

If there is any error in the xml file by opening the XML Notepad the user will be informed where the error is and will be able to correct. If the user opens the HERON DST Software without checking the modified file the software will work with the default files.

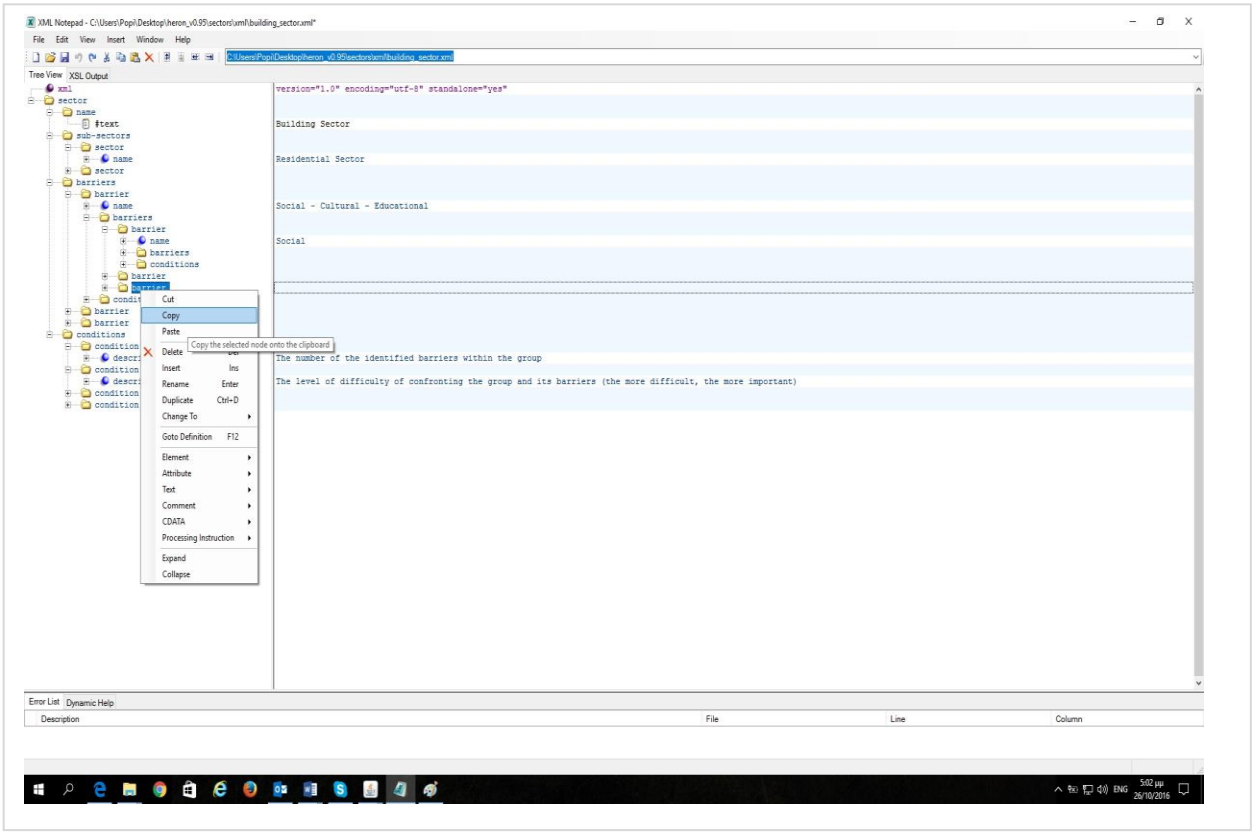

Figure 48: Copying the element.

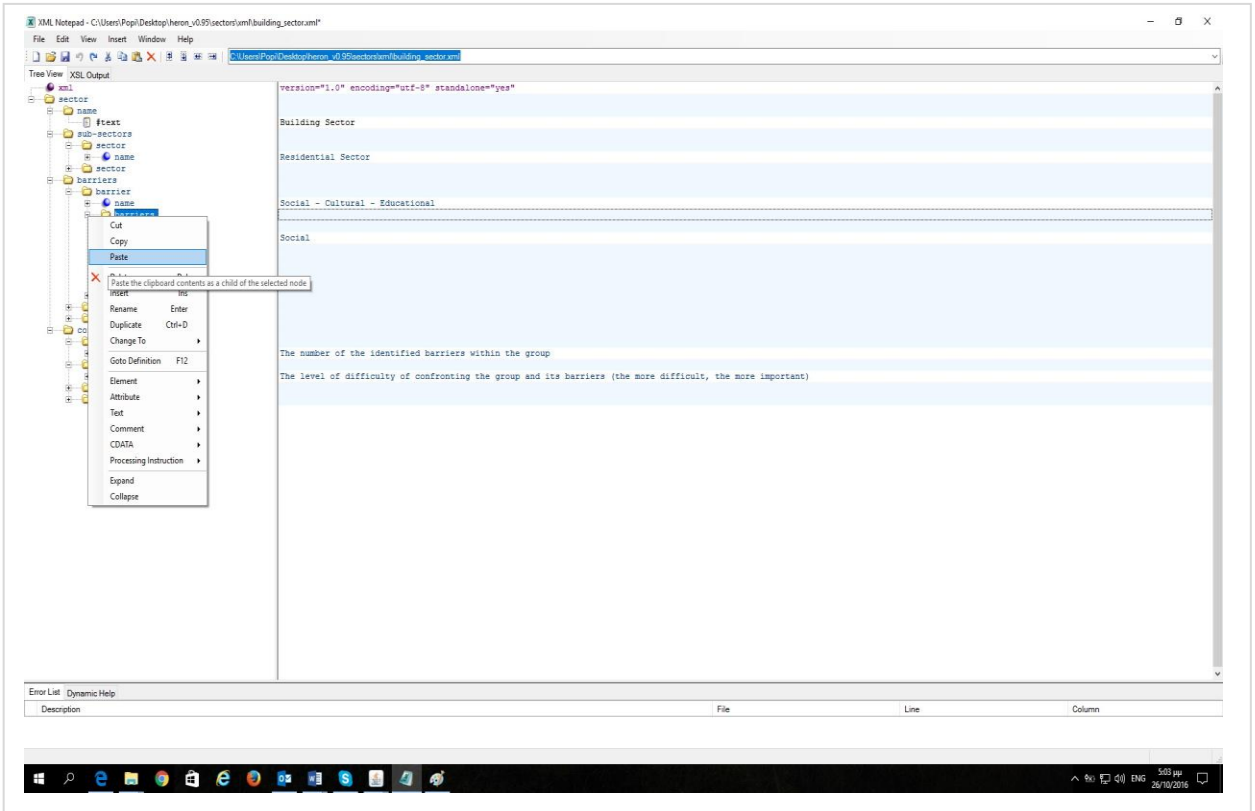

Figure 49: Pasting the element.

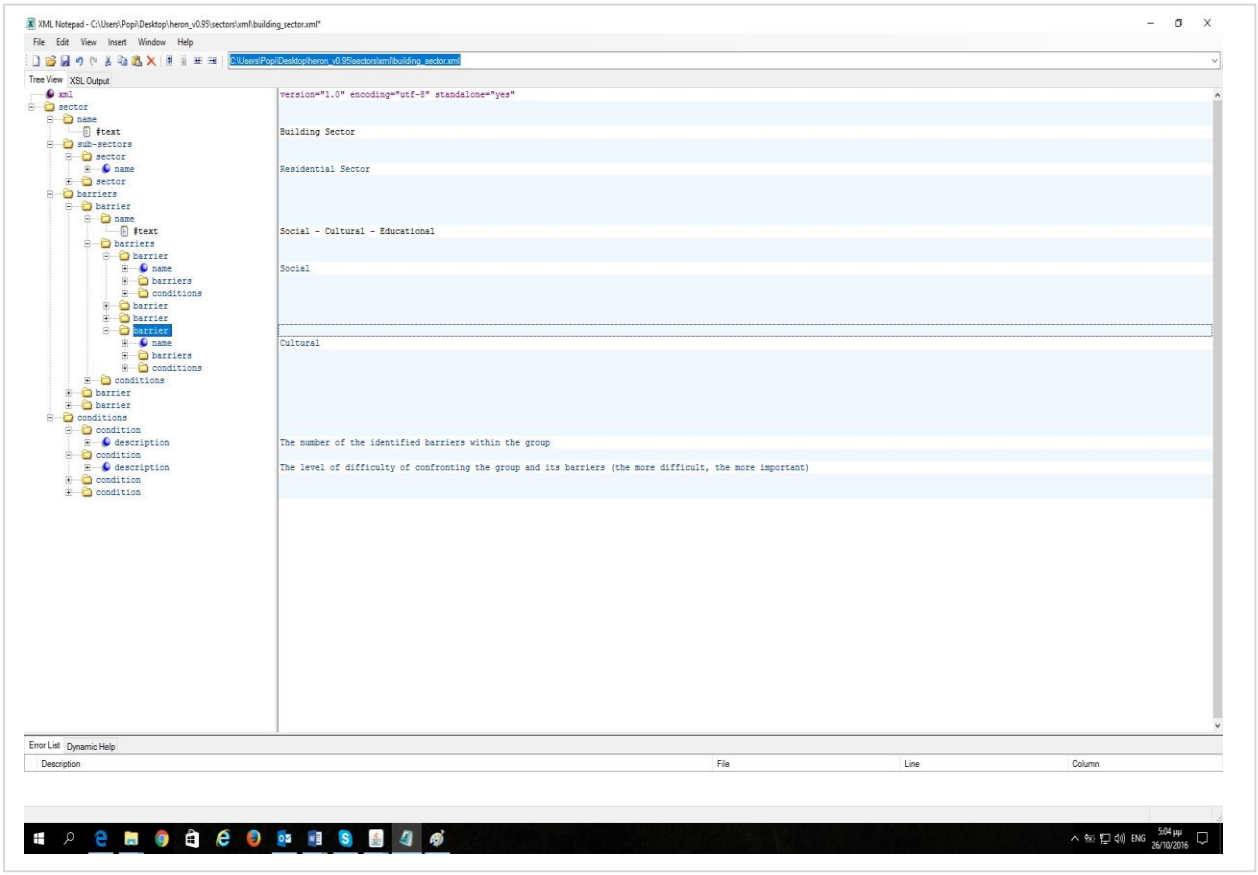

Figure 50: New element created.

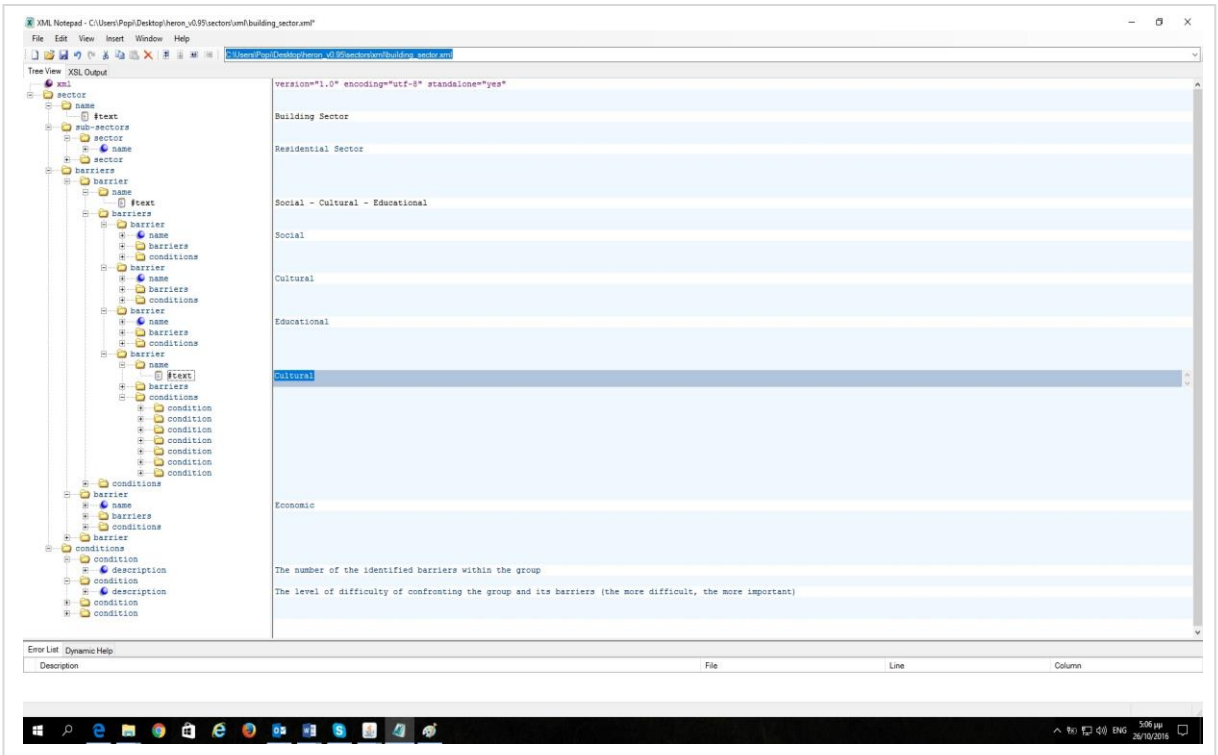

Figure 51: Modifications on the right part.

CONNECTING DST OUTCOMES WITH ENERGY MODELLING

Scenarios

The main assumptions of scenarios, for buildings and transport sectors, concern the penetration of technologies, the adoption of measures and the implementation of the respective policy instruments that support the exploitation of technologies and the achievement of measures.

All EE scenarios reach the horizon of 2030 and all types of assumed targets (concerning shares of specific technologies or general targets (overall reductions of energy consumption, energy savings etc)) are aligned with EU 2030 targets for energy savings and CO_2 emissions.

Six (6) sub-scenarios for buildings (residential and tertiary), can be developed, each of which concerns an assumed specific level of penetration for one technology/measure/action (for instance in LEAP). The sub-scenarios may be the following:

1. Efficient heating: This scenario focuses only on the penetration of heat pumps (such as air-to-air, water source, and geothermal) and on highly energy efficient heating systems (such as new or maintained oil systems with high performance, central heating systems with natural gas etc.) in existing buildings (single-family, multi-family, tertiary).
2. Building shell improvement (building fabric upgrade): This scenario focuses only on the improvement of insulation in existing buildings (single-family, multi-family, tertiary). This scenario decreases the energy intensity of the space-heating for all housing types of the existing building stock.
3. Efficient cooling: This scenario focuses only on the penetration of highly energy efficient air-conditioning (A, A+, A++) in existing buildings (single-family, multi-family, tertiary).
4. Efficient appliances: This scenario focuses only on the penetration of highly energy efficient appliances (A, A+, A++) in existing buildings (single-family, multi-family, tertiary) including cooking devices and water heaters.
5. Efficient lighting: This scenario focuses only on the penetration of LED in existing buildings (single-family, multi-family, tertiary).
6. Application of BEMS: This scenario focuses only on the penetration of BEMS that leads to energy savings in space heating and lighting and ensures better functioning of building installations where applicable (single-family, multi-family, tertiary).

Then the developed scenarios are the following:

1. EE - B0: the combination of all developed sub-scenarios into one (1) EE scenario that should lead to at the maximum potential of energy savings (or reduction of energy consumption) compared to BAU scenario, without using DST,
2. EE - B1: the combination of all developed sub-scenarios into one (1) EE scenario using the actually expected levels of penetration, derived from DST,
3. EE - B2 up to EE – B4: the three (3) best combinations of technologies/measures (ie of the sub-scenarios) with the higher penetration levels after the minimization of barriers.

How to insert from the produced Excel file the DST outcomes into LEAP

Under the LEAP tree, the user selects the Branch at which the DST outcomes need to be inserted. Then the user selects from the "*E-Builder",* the "*f_x function*". A new window opens and the user selects under "Parameter 1", the Excel file from which the DST outcomes will be inserted. The Excel file with the DST outcomes needs to be in the same folder with the Excel file of LEAP (which is in the LEAP Areas folder). The user specifies the Excel range that needs to be used.

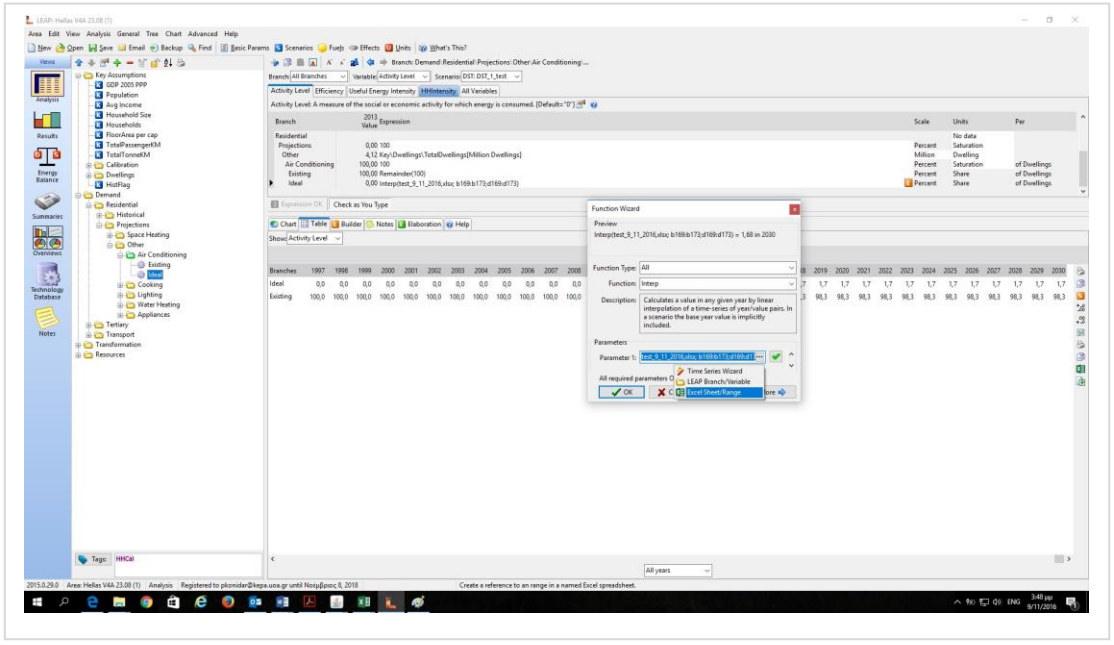

Figure 52: Connecting with the Excel file that has the DST outcomes.

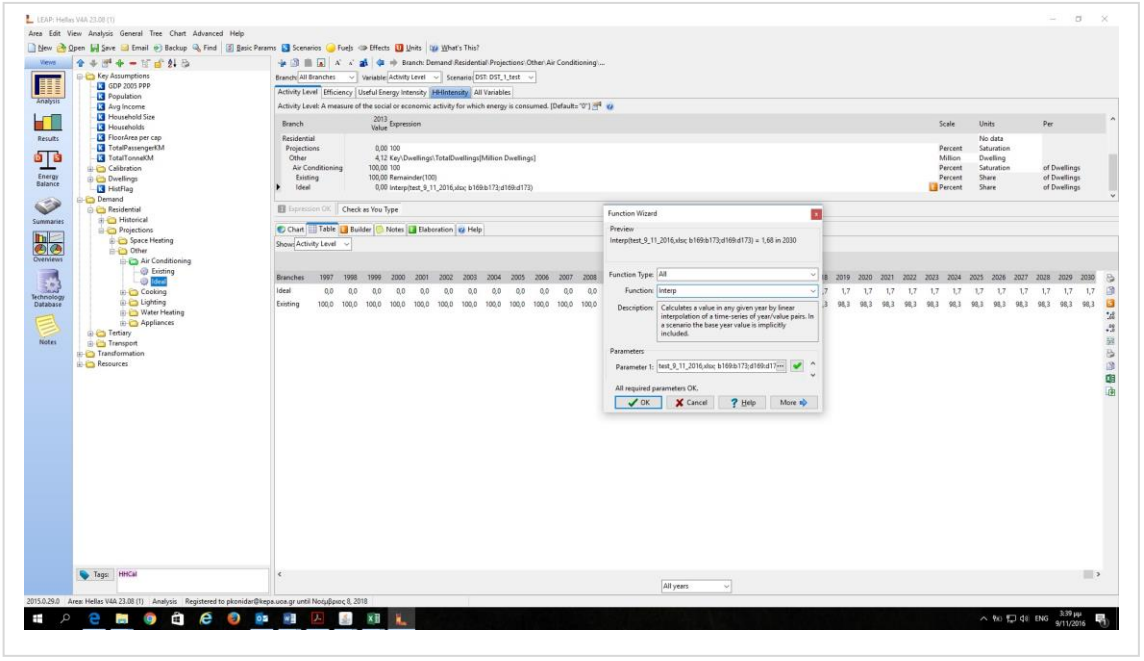

Figure 53: Connecting DST outcomes with LEAP.

FREQUENTLY ASKED QUESTIONS

1. *Question: What is the role of intensities?*

   Answer: Intensities are the numbers of the AHP scale that are used to determine the level of significance of one object (in this case) barrier over the other. For selecting the appropriate intensity, the user needs to have in mind a structured way of comparing the two objects. The conditions that are included for each level of the AHP tree intend to facilitate the users of the DST software.

2. *Question: What to do if consistency test fails?*

   Answer: If the Consistency test fails to fulfil the condition that $0 < CR^* < 0.10$, the user will need to reconsider the inputs at the respective matrix. By making changes and understating better the differences between the objects and being more sure about the assigned intensities, the condition will be fulfilled.

3. *Question: How to add countries?*

   Answer: As the procedure for adding sectors, barriers and technologies. The folder "technologies" contains the xml files that concern countries. The user copies one of these files and modifies accordingly using the recommended xml editors.

4. *Question: Why does the user does not see the results of all of his/her examined options?*

   Answer: The user probably did not save the outcomes of the examined option. The user needs to remember that the HERON DST software saves each time the currently displayed results.

5. *Question: Why CR* is not accepted when it equals to zero?*

   Answer: When CR* is equal to zero, that means that the respective matrix is perfectly consistent. But due to the argument that decision-makers do not normally make "perfect" judgements, the value was not accepted (Alonso J.A., Lamata T., 2006). However, if the user considers his/her inputs reflect perfect consistency, by pressing the "Accept" button, the values are accepted and used for the subsequent steps of the HERON DST Software.

6. *Question: Why minimization is based on the selection of barriers and not of policies?*

   Answer: Barriers are preventing the achievement of energy savings or create difficulties for the penetration of energy efficient technologies/actions. The user minimizes those barriers that according to his/her judgment will allow/facilitate the achievement of the assumed targets (policy assumptions). Once he/she sees the outcomes he/she can then decide which policies are more suitable to be used for minimizing the selected barriers and promote at the same time the energy efficient technologies/actions. In this way, the scenario includes those policies that are expected to be more effective in reaching the assumed targets (policy assumptions).

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ANNEX 1: NAMES OF BARRIERS IN SOFTWARE

Building sector

Type	Name of barrier
Social	**Social group interactions & status considerations**
Social	**Socio-economic status of building users**
Social	**Strong dependency on neighbors (multi-family housing)**
Social	**Inertia**
Social	**Lack of Commitment -motivation of public social support**
Social	**Rebound effect**
Cultural	**Lack of interest/low priority/Undervaluing EE**
Cultural	**Customs-habits-relevant behavioural aspects**
Cultural	**Bounded rationality/Visibility of EE**
Cultural	**Missing credibility-mistrust in technologies/contractors**
Educational	**Lack of experienced professionals, trusted information**
Educational	**Lack of awareness on savings potential, technologies, EE**
Economic	**Lack of any type of financial support**
Economic	**High costs and risks**
Economic	**Payback expectations/investment horizons**
Economic	**Misleading prices (energy /fuel/tariffs)**
Economic	**Unexpected costs**
Economic	**Financial crisis/Economic stagnation**
Economic	**Embryonic or poorly developed markets**
Institutional	**Split Incentive(s)**
Institutional	**Legislation issues**
Institutional	**Building stock characteristics and special issues**
Institutional	**Poor compliance - Performance gap/mismatch**
Institutional	**Lack of data/information-diversion of management**
Institutional	**Problematic implementation network/governance framework**
Institutional	**Disruption/Hassie factor**
Institutional	**Security of fuel supply**

Transport sector

Type	Name of barrier
Social	**Low satisfaction/lack of trust for public transport**
Social	**Concerns on reliability/Hesitation to trust new technologies**
Social	**Socio-economic status of users**
Social	**Suburbanisation trends/Low density**
Social	**Mobility problems**
Social	**Inertia**
Cultural	**Car-symbol status & group influence**
Cultural	**Habit/social norm of driving-car ownership & use**
Cultural	**Cycling is marginalized**
Cultural	**Buyer attitude /Bounded rationality**
Educational	**Lack of knowledge/information on EE transport**
Educational	**Low/Limited awareness – environmental sensitivity on EE**
Educational	**Confusion on car-fuel costs – Negative perception**
Educational	**Lack of certified and experience staff**
Economic	**Lack or limited finance/ incentives**
Economic	**Limited infrastructure investment for public transport**
Economic	**Low purchasing power of citizens/Financial crisis**
Economic	**High costs**
Economic	**Payback period /low economic viability**
Economic	**Negative role of Investment schemes/employee benefits**
Institutional	**lack of integrated governance/entities-fragmentation/bureaucracy**
Institutional	**Lack of EE in Government Agenda/priorities/coordination**
Institutional	**problems with infrastructure/public transport services**
Institutional	**Lack or limited policies on EE transport issues**
Institutional	**Limited/complex funding procedures**
Institutional	**Lack of policy support (technological issues/research needs)**
Institutional	**Contradicting policy goals**