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Taxonomy of energy efficiency models

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D2.2: TAXONOMY OF ENERGY EFFICIENCY MODELS

Summary

The main purpose of this report is to gather and systematise existing knowledge about consumer behaviour on the energy market in the context of increasing energy efficiency. At this stage, as a part of the Task 2.2. the authors described and compared taxonomies of existing energy models based on literature review. For the purpose of this report, for further analysis, the authors chose analytical approach dividing the models into three main groups: top-down models; bottom-up models and hybrid models, taking into account two levels of analysis (macro, mezo) in relation to energy end-users. The analysis was complemented with selected consumer behavior models at the micro level. Theise characteristics will be the starting point for further analysis of the factors and criteria necessary to attempt to construct an individual model of energy consumer behaviour.

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List of Acronyms and Abbreviations

ASHRAE – the American Society of Heating, Refrigerating, and Air-Conditioning Engineers

ATUS – the American Time Use Survey

CA: Consortium Agreement

CO: Confidential

DoW: Description of Work, referring to the Annex I of the Grant Agreement

EC: European Commission

GA: Grant Agreement

IPR: Intellectual Property Rights

PPR: Project Progress Reports

PSB: Project Steering Board

PU: Public

QA: Quality Assurance

RECS – the Residential Energy Consumption Survey

SAB: Security Advisory Board

STC: Scientific and Technical Committee

WP: Work Package

Executive summary

A creation of an energy efficiency model review is critical for maximizing energy reduction through user engagement. This is mainly due to the fact that it allowes the design of targeted and highly personalized measures regarding user engagement towards sustainable energy. The creation of a new multi-component taxonomy of energy recipients for creating a behavioural model for ECO - BOT is based on taking into consideration and analysing the results of the empirical research. In economics, scientific taxonomy is associated with a statistical approach, hence the authors of this report decided to describe and compare the already available energy models per various factors, targeting different types of users and covering multi-pillar stakeholders. Initially the authors have chosen an analytical approach dividing the models into three main groups: top-down models; bottom-up models and hybrid models. In addition, when analyzing the energy models, the authors divided selected models taking into account two levels of analysis (macro, meso) in relation to end users of energy. The analysis was supplemented with selected models of consumer behavior at the micro level. Moreover authors in this report have gathered and have systematised existing knowledge about consumer behaviour on the energy market in the context of increasing energy efficiency.

This report is based on a desk study that involved a comprehensive review of scientific and policy literature regarding energy efficiency; behavioural economics; energy consumer behaviour; the political, economic, psychological and behavioural determinants influencing the behaviour of energy consumers and modelling dimensions. An analysis was performed of more than 500 different sources including academic papers, books and technical reports involving online databases of scientific research (such as WoS and ScienceDirect).

After studying both top-down, bottom-up, hybrid and behavioural models, analyzing potential disadvantages as well as the advantages of each approach, the authors have decided to choose the Triandis' Theory of Interpersonal Behaviour decision model as the framework for further analysis in the next stage of research. The energy consumers' behavior model will define the information needed to create an appropriate communication strategy with the energy consumer, provided it is simple but considers a comprehensive approach to the behavior of energy consumers on the market, taking into account both aggregate factors and socio-psychological factors. The Triandis' model analyzes social factors and emotions that play a key role in shaping intentions. In addition, it also analises the role of habits and situational conditions. It is also analyses habits that contribute to sustainable or unbalanced energy consumption, hence omitting these elements could cause a distorted picture of consumption factors.

1. Introduction

Current production and consumption patterns are based on an unbalanced use of materials and energy, affecting the depletion of renewable and non-renewable resources on our Earth. Future development should focus on such ways of delivering products and services that will cause less use of raw materials and will limit the amount of generated waste. To achieve this goal, it is necessary to undertake commitments – by the industrial and commercial sectors, as well as by individual consumers. The potential for economically justified savings in EU Member States is high.

The impact of consumption on the environment can be reducing by decreasing the impact of universal consumer goods and services within the production stages, through the use and disposal of waste and through bringing about fundamental changes in the consumption model by way of shifting demand to categories which use less materials and energy. Achieving this state of affairs requires the determined efforts of all actors, including public authorities, businesses and consumers. Public administration should, therefore, stimulate market demand for environmentally friendly products and encourage sustainable consumption and production. This is why it is so important to promote energy-saving technologies within the market and to raise consumer awareness of the consequences of unnecessary energy consumption. These goals can be achieved by (EAŚ, 2007):

- Legal and regulatory tools (e.g. emission control, product standards, list of banned substances);
- Market instruments (e.g consumption-based fees, tradable permits, differentiated taxes, liquidation of subsidies);
- Support for technological innovations;
- Environmental certification in business (e.g EMAS, ISO 14001) and environmental information standards for consumers (e.g. environmental labelling, labelling of organic food).

Sustainable development as a model solution has been adopted as a priority in many countries of the world, including the European Union. An important part of such a model is the improvement and promotion of energy efficiency through the implementation of modern IT solutions such as ECO - BOT. These solutions should be presented as an element of the entire system, without which they could not function. The idea of implementing the ECO-BOT application is consistent with the priorities of sustainable development such as:

- in economic dimension: it enables improvement of energy efficiency and more optimal use of available energy resources

- In the social dimension - it is based and directed at changing the behaviour of consumers and assumes their active participation in this process
- In the environmental dimension, it allows reducing the pressure on the environment by reducing energy consumption. A very important aspect in this area is shaping proecological attitudes of consumers and raising the level of ecological awareness

An important element in introducing sustainable patterns of production and consumption are actions aimed at improving the state of ecological awareness. Promoting voluntary reporting among entrepreneurs in the field of Corporate Social Responsibility (CSR), as well as popularizing eco-labelling and enabling consumers to make an informed choice of environmentally friendly products and services, is at the forefront of the proposed good practices. In addition, the introduction of a system of cash prizes and other gratuities for organizations selected in contests or as part of the cleaner production program can be treated as an additional result of the conducted innovative activity.

An important problem, in the aspect of actions aimed at increasing the efficiency of energy use, seems to be the emphasis on increasing social awareness aimed at saving energy. Unfortunately, energy consumers, due to the pace and scale of changes taking place in the energy market and being the result of progress, do not have adequate knowledge, both economic and specialist. Hence, ecological education of households is a very important element in the process of greening the society. It is the functioning of households that has an impact on the environment, especially in terms of such key factors as: water and energy consumption, transport and waste management. The key elements in the decision-making process and shaping the relevant behaviors of household members are increasing income, the household's life cycle, consumption patterns prevailing in the society. The latter, especially in recent years, has influenced the general increase in the consumption of goods and services and, consequently, the increase in total energy consumption by households. Therefore, undertaking activities in the field of environmental education and the influence of the state on producers in order to encourage them to conduct environmentally friendly policies, including the use of incentives and instruments supporting especially small and medium enterprises seem to be important enabling instruments shaping sustainable consumption. In addition, in order to include households in the process of sustainable consumption, stricter standards and regulations on the composition and production of products and services should be introduced and campaigns aimed at promoting change in consumption habits should be pursued. In this respect, local governments can engage in activities that ensure a high level of public awareness, as well as understanding and support for energy saving – and that are a good example. In addition, local authorities can do a lot for the promotion of energy efficiency by applying high-performance technical solutions and low-cost installations in the transport sector, in buildings and in lighting systems (Słupik, 2015a; Nycz-Wróbel, 2012).

Researchers have already recognized human behavior as a key and extremely complicated element of energy consumption in households. Conducted experiments aimed at recognizing potential savings in this sector and showing tools that should be used to promote ecological sources of energy and obtain their savings, revealed that the impact of all these instruments is minimal (if there is already a positive, short-lived effect), not at all occurs or brings the opposite effect than expected.

1.1 Aims of the report

This study aims at describing and comparing the taxonomies of already available energy models per various factors, targeting different types of users and covering multi-pillar stakeholders. Initially the authors have chosen an analytical approach to the main groups: top-down models; bottom-up models and hybrid models (which are described more comprehensively) but finally for further analysis authors divided selected models, taking into account two levels of analysis (macro, meso) for end users of energy. The analysis was supplemented with selected consumer behavior models at the micro level

Classification and assessment of energy efficiency models sets a critical framework for maximizing energy reduction through user engagement. This is mainly due to the fact that we are able to design targeted and highly personalized measures regarding user engagement towards sustainable energy. The main problem in energy efficiency is that users often do not follow the suggested advice. Generic recommendations are usually not effective since the degree of adherence is quite low (users do not follow the instructions). On the other hand, by way of utilising the given models, we can now offer targeted and personalized recommendations, thereby potentially increasing the degree of acceptance by the users.

Thus, the main objective in this part of the project was to review and analyze existing literature, statistical data and assumptions of energy policy of EU countries (for comparison, countries from outside the EU were included in some cases). This review will allow the identification of potential fields of promotion and implementation of the ECO-BOT application. Analysis of existing energy efficiency models will allow selection of the most promising model for use in the ECO-BOT application.

1.2 Methodology

This report is based on a desk study that involved a comprehensive review of scientific and policy literature regarding energy efficiency; behavioural economics; energy consumer behaviour; the political, economic, psychological and behavioural determinants influencing the behaviour of energy consumers and modelling dimensions.

As a part of the desk research, we analyzed proven baseline models of energy efficiency that have been delivered within (a) European research activities, (b) international initiatives/projects, (c) international recommendations/guidelines in the field of energy, and (d) outcomes of state of the art papers and research activities carried out worldwide. During the study, over 500 different sources of materials were analyzed – including academic papers, books and technical reports involving online databases of scientific research (such as WoS and ScienceDirect). Moreover, the report is based on statistical data received from following databases: MURE, OECD, IRENA, EIA, Eurostat, and GUS.

The study was carried out in three stages. First, a list of keywords was prepared, based on which the articles were searched for further verification. The following keywords are included: energy models, energy modelling, energy efficiency models, top-down approach, bottom-up approach, hybrid models, top-down models, bottom-up models and hybrid models. Due to the large number of hits with use of mentioned search phrases, the second stage is limited to the verification of keywords and abstracts of papers published in selected magazines about energy. Thus, papers from following scientific journals were considered for verification during the second stage of the desk research: Advanced Energy Conversion, Applied Energy, Biomass and Bioenergy, Building and Energy, Current Opinion in Environmental Sustainability, Energy Conversion and Management, Energy Conversion, Energy Economics, Energy Policy, Energy Procedia, Energy Reports, Energy Research & Social Science, Energy Strategy Reviews, Energy, Environmental Innovation and Societal Transitions, Environmental Modelling & Software, Green Energy & Environment, International Journal of Electrical Power & Energy Systems, Journal of Cleaner Production, Journal of Environmental Psychology, Renewable and Sustainable Energy Reviews, Renewable Energy, Resource and Energy Economics, Sustainable Energy Technologies and Assessments, Sustainable Energy, Grids and Networks and others. Verification during the second stage showed that even if the given keywords returned results, they did not always refer to the topic under consideration (e.g., search using “hybrid model” & ”energy efficiency” may return results with one search phrase in the title and the other in the related abstract – for example, Rusinowski & Stanek (2010): “Hybrid model of steam boiler” – this does not fall within the research theme). After key words and abstract verification, it became apparent that some of the scientific journals do not in reality, carry papers concerning energy modelling (e.g., Green Energy & Environment or Advanced Energy Conversion), even if they focus on the generally understood energy issues. A total amount of 381 papers were qualified for the final stage – the full text verification.

Throughout the years, according to the results of the literature review, issues related to energy modelling theory have been pursued consistently. The considered issues vary greatly, and include some rather general and more mostly theoretical themes. Among these are: proposals of completely new models and solutions; changes and refinements of existing and used models (by way of adding new notions or by changing the existing assumptions); comparison of the assumptions and the results obtained using different types of models. Issues in the field of energy-use modelling may also be considerably more specific and be focused only on certain parts of the energy system (e.g. particular sectors or energy services) or certain subjects and their particular needs (e.g. developing countries or older people). In hindsight, it is difficult to say whether any type of energy model (bottom-up, top-down, hybrid, behavioural/agent) enjoys a greater interest in the course of theoretical consideration than do others. Still, in some of the presented theoretical papers, more attention is given to certain types of models (e.g. bottom-up) or even to a particular model (e.g. TIMES), but other studies take up on more general topics relevant to all types of situations and models (e.g., considerations about the validity of Business-As-Usual assumptions).

In the case of the literature review results for the use of energy models, it is also necessary to emphasize the constant interest of researchers in this subject. As in the case of scientific papers dealing with theoretical considerations, there is a noticeable differentiation of issues covered in particular articles. Various energy models are used to verify different types of assumptions regarding the impact that particular decisions (about policies, technology, sources of energy and others) may have on the environment, economy, society, energy security and others. The considerations are conducted at various levels of detail, starting from the local (city level, county) through national (given sector or issue) to international (given region or group of countries) or global. It should be stressed, however, that research is conducted both for developed and for developing countries at various levels of detail. When it comes to the types of models used most frequently, the most of the papers deals with bottom-up or hybrid methodology/approach. MARKAL, TIMES and LEAP models are used the most. Of course in case of some counties, institutions and companies, national/local versions of particular model were developed (e.g. UK MARKAL, SATIM or MEDEE).

The paper is structured as follows. In Section 2, basic political determinants of renewable energy and energy efficiency in the EU are provided. Section 3 presents a short description of basic approaches to behavioural changes in energy consumption, whereas Section 4 reflects the classification of barriers to energy efficiency in relation to the ECO-BOT assumptions. Section 5 then provides a classification of existing energy models and discusses the most important top-down, bottom-up and hybrid models based on a literature review divided into two levels of analysis (macro, meso) for end users of energy. The analysis was supplemented with selected models/theories of consumer behavior at the micro level. Next section, number 6 contains preliminary taxonomy development relevant for ECO-BOT. Finally, Section 7 of this report contains the conclusions.

2. Energy efficiency policies in EU countries. Key findings for ECO-BOT

The EU energy policy concentrates on three main assumptions related to the development of competition, energy security and the protection of the natural environment, which should be implemented, in accordance with the idea of sustainable development. Actual, the most important goals of the European energy and climate policy to be implemented in the 2030 perspective include

1. **Security of energy supply.** Energy security in technical terms is related to the existence of an appropriate transmission infrastructure and all the activities aimed at maintaining it in a good technical condition (Mielczarski, 2012). The EU is increasingly exposed to fluctuations and price increases on the international energy markets, and to the consequences of the increasing concentration of energy resources among a certain few countries in the world. As part of the enhanced security of energy supply, the Union is taking measures to limit vulnerability to external factors resulting from the dependence on imports. Therefore, it promotes the use of its own available energy resources and investments in renewable energy, while on the international market, it takes actions to diversify the directions of energy supply.

2. **Competitiveness and the internal energy market of the EU** - According to the assumptions of European energy policy, a competitive electric energy market will result in a decrease in costs incurred by customers (wholesale and retail), as well as ensuring an adequate level of investment in the sources of production and the facilities of energy transmission (Szczygieł, 2012). In this context, providing economic competitiveness should result in better energy security by ensuring greater security of transmission and distribution networks. An important component in the functioning of the competitive market is also reducing the energy consumption by market processes. Investments for reducing the level of energy consumption are another activity aimed at achieving energy security. These investments can be made by individual recipients (better insulation of buildings, energyefficient household appliances) and wholesale recipients (more modern and more efficient production technologies).

3. **Diversification of energy sources** - is related to the concept of the energy mix, which is a mix of different types of energy.

4. **Increase in energy efficiency** – this means less energy consumption while maintaining the unchanged level of economic activity. Energy 'saving' is a broader concept than 'efficiency', because it also includes reducing consumption by changing behaviour or by limiting business. The main goal of energy efficiency improvement is to achieve zero energy economic growth, for example, the development of the economy

without increase in primary energy demand. Increasing the efficiency of energy use has a large potential for immediate application in the production and distribution of energy. The European Commission underlines the strong link between energy efficiency and environmental protection.

5. Sustainable development - The most mysterious, but probably the most important goal, is the postulate of sustainable development. The energy UE efficiency strategy refers to the postulate of sustainable development (Prandecki, 2011). UE involve sustainable development postulates with the aspect centred upon resource availability (Malko, 2007). Such aspects include:

- the rate of consumption of renewable resources cannot be higher than their regeneration rate,
- the emission of pollutants associated with the use of resources must be smaller than the potential for neutralization,
- non-renewable resources cannot be used at a faster rate than the ability to create their substitutes.

Among the presented elements, special attention should be placed upon the elements that are synergistic components with activities occurring in the sphere of improvement of economic competitiveness and energy security. These elements include, first of all, the issue of reducing energy demand. The reduction of energy consumption, and thus the consumption of energy resources, is an important aspect within the overall concept of sustainable development.

6. Research and development of innovative technologies of energy production and transmission - it is necessary to invest in technological innovations in power engineering that will lower costs and increase energy production efficiency.

7. Solidarity in external policy - the aim is to establish mechanisms supporting solidarity among EU countries. However, the establishment of specific instruments is still at the stage of consultations between Member States. In addition, there is no agreement between EU Member States on how strong and deep a common external energy policy should be. Solidarity in external policy, on the other hand, is the foundation for the implementation of the other objectives of the Union.

8. Energy infrastructure - this is a kind of base, without which it is impossible to achieve the other goals. Integrated and reliable energy networks are the foundation condition for achieving the goals of EU energy and economic policy

To pursue these goals, the EU has formulated targets for 2020, 2030 (presented in the table 1) and 2050.

Table 1: EU targets for 2020 and 2030

Source: own development based on: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2020energystrategy (access: 08.01.2018)

	Energy 2020. A strategy for competitive, sustainable and secure energy	A policy framework for climate and energy in the period from 2020 to 2030
	Targets for 2020	Targets for 2030
Reduction in EU greenhouse gas emissions from 1990 levels (minimum level)	20%	40%
Share of renewable energy consumption (minimum level)	20%	27%
Improvement in the EU's energy efficiency. (minimum level)	20%	27%
	Policies for 2020	Policies for 2030

•	• Making Europe more energy efficient by accelerating investment into efficient buildings, products, and transport. This includes measures such as energy labelling schemes, renovation of public buildings, and ecodesign requirements for energy intensive products • Building a pan-European energy market by constructing the necessary transmission lines, pipelines, LNG terminals, and other infrastructure. Financial schemes may be provided to projects which have trouble obtaining public funding. By 2015, no EU country should be isolated from the internal market • Protecting consumer rights and achieving high safety standards in the energy sector. This includes allowing consumers to easily switch energy suppliers, monitor energy usage, and speedily resolve complaints • Implementing the Strategic Energy Technology Plan – the EU's strategy to accelerate the development and deployment of low carbon technologies such as solar power, smart grids, and carbon capture and storage • Pursuing good relations with the EU's external suppliers of energy and energy transit countries. Through the Energy Community, the EU also works to integrate neighbouring countries into its internal energy market.	A reformed EU emissions trading scheme (ETS) New indicators for the competitiveness and security of the energy system, such as price differences with major trading partners, diversification of supply, and interconnection capacity between EU countries First ideas for a new governance system based on national plans for competitive, secure, and sustainable energy. These plans will follow a common EU approach. They will ensure stronger investor certainty, greater transparency, enhanced policy coherence and improved coordination across the EU.

The Energy Efficiency Directive of 2012 established a set of instruments that will help the EU to achieve energy efficiency target by 2020. The general division of energy policy instruments aimed at supporting energy efficiency improvement and energy saving can be seen in **Error! Reference source not found.**

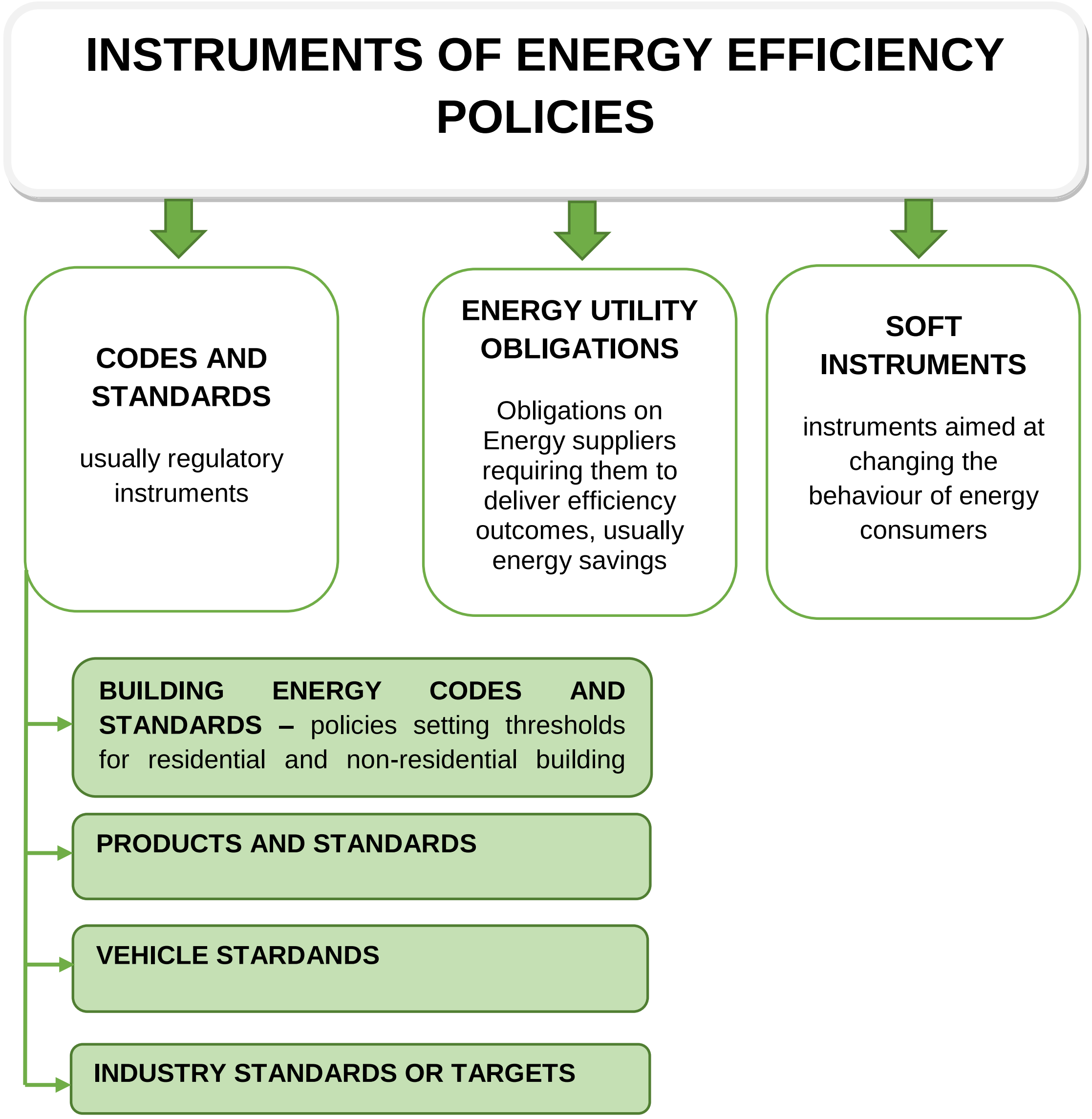

Figure 1 Energy efficiency policy instruments Source: own development

Assessing the strategies of individual countries in terms of potential for ECO-BOT implementation is not easy and unambiguous, considering:

- Methodological problems related to lack of available data for all Member States and the ambiguity of classification of instruments used in individual countries, which makes comparison difficult,
- Information delays and changes in the policy priorities of individual countries, which have their reflection in international statistics and reports with a significant time shift.

Despite the mentioned limitations, the following groups of factors have been chosen as the most favourable for the implementation of ECO-BOT:

I. GROUP - Existence of legal framework and implementation of programs supporting improvement of energy efficiency in buildings.

II. GROUP - Existence of Energy Efficiency Obligation (EEO) schemes;

III. GROUP. High level of use of soft instruments supporting behavioural changes of energy consumers;

IV GROUP. Implementation or planned implementation of smart metering.

As the most important criteria from the point of view of the implementation possibilities of ECO-BOT solutions have been considered instruments aimed at improving energy efficiency and behavioural changes.

I GROUP – EXISTENCE OF LEGAL FRAMEWORK AND IMPLEMENTATION OF PROGRAMS SUPPORTING IMPROVEMENT OF ENERGY EFFICIENCY IN BUILDINGS.

In connection with the full transposition of the Energy Efficiency Directive in the Member States (see: REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL 2017 assessment of the progress made by Member States towards the national energy efficiency targets for 2020 and towards the implementation of the Energy Efficiency Directive as required by Article 24(3) of the Energy Efficiency Directive 2012/27/EU COM/2017/0687 final), actions to improve energy efficiency in buildings are taken in all Member States. The most frequently used instruments relate to implementation: buildings renovations programs, establishing standards for new buildings and voluntary agreements (see: ODYSSEE – MURE: Energy Efficiency Country Profiles at: http://www.odyssee-mure.eu/publications/profiles/, access: 01.03.2018; and Energy Policies of IEA Countries series available at: http://www.oecd-ilibrary.org/energy;jsessionid=wawdouqjbo2o.x-oecd-live-03, access: 01.03.2018). Despite the actions taken, the potential for improving energy efficiency remains high in the EU, mainly in the construction, housing, transportation and the energy sector. According to some rough estimates, 75% of housing stock in the EU still has low energy efficiency (issues related to heating) (Communication COM (2014) 520). Therefore, it can be concluded that there is still a great demand in this area for the development and implementation of new instruments to stimulate energy savings and improve energy efficiency.

II GROUP. - EXISTENCE OF ENERGY EFFICIENCY OBLIGATION SCHEMES

One of the most important policy instruments in the area of energy efficiency are Energy Efficiency Obligation schemes (EEOs). The basic concept of the EEO is that the government puts the target of energy saving to energy companies, which must be achieved by the final customer. According to Christian Deconnin, the current ATEE Chairman, EEO have a lot of advantages (ATEE 2017, Snapshot of Energy Efficiency Obligations schemes in Europe: 2017 update, Fourth European Workshop of the White Certificates Club, 30 June 2017, http://atee.fr/sites/default/files/part_6-_2017_snapshot_of_eeos_in_europe.pdf, access: 02.01.2018, p.3):

1. "they are a hybrid system which combines the benefits of energy tax and subsidies,
2. they give the actors of the scheme freedom to choose how they will reach the targets, thereby optimising the costs/benefits of energy efficiency operations implied,
3. they are a quite flexible tool for authorities, which may pursue specific goals through the specification of EEOs parameters,
4. they mobilise the whole Energy Efficiency Supply Chain, from Energy suppliers/distributors, to energy consumers, going through installers, energy service providers, material and equipment manufacturers and distributors,
5. they provide standards and targets for energy efficiency operations".

Currently active EEOs are in Austria, Bulgaria, Croatia, Denmark, France, Ireland, Italy, Latvia, Luxembourg, Slovenia, Spain, Poland, UK, and Greece (see table 2) .

Table 2: Current status of EEOs in EU member states

Source: Fawcett T., Rosenow J., Bertoldi P. (2017), The future of energy efficiency obligation schemes in the EU, ECEEE 2017 SUMMER STUDY – CONSUMPTION, EFFICIENCY & LIMITS, http://www.raponline.org/wp-content/uploads/2017/06/eceee_fawcett_rosenow_bertoldi_future_energy_efficiency_obligation_schemes_eu_2017.pdf (access: 12.12.2017) and ATEE (2017), Snapshot of Energy Efficiency Obligations schemes in Europe: 2017 update, Fourth European Workshop of the White Certificates Club, 30 June 2017, http://atee.fr/sites/default/files/part_6-_2017_snapshot_of_eeos_in_europe.pdf (access: 02.01.2018)

EEOS status	Member States
Active	Austria, Bulgaria, Croatia, Denmark, France, Ireland, Italy, Latvia, Luxembourg, Slovenia, Spain, Poland, UK, Greece
Major revision	Malta
Under consideration	The Netherlands
None planned	Belgium, Cyprus, Czech Republic, Estonia*, Finland, Germany, Hungary*, Lithuania*, Portugal, Romania, Slovakia, Sweden

* EEOs were planned, but these plans have been withdrawn

According to the findings of the authors of the report in the United Kingdom and Denmark, which are successful countries in the implementation of the EEO schemes, there have been concerns about the rising costs of EEO. This has resulted in the reduction of energy saving goals in both systems (Fawcett, Rosenow and Bertoldi, 2017). Other countries like Germany haven't implemented an Energy Efficiency Obligation scheme but intend to meet the energy savings requirement by alternative measures (regulatory, financial, soft).

Table 3 contains results of a survey concerning use of EEO in 14 EU countries prepared by ATEE (2017, Snapshot of Energy Efficiency Obligations schemes in Europe: 2017 update, Fourth European Workshop of the White Certificates Club, 30 June 2017, http://atee.fr/sites/default/files/part_6-_2017_snapshot_of_eeos_in_europe.pdf, access: 02.01.2018)) together with an assessment of the impact on the implementation of ECO-BOT type application.

Table 3: Energy Efficiency Obligations (EEO) schemes in the sample countries of the European Union

Source: ATEE (2017), Snapshot of Energy Efficiency Obligations schemes in Europe: 2017 update, Fourth European Workshop of the White Certificates Club, 30 June 2017, http://atee.fr/sites/default/files/part_6-_2017_snapshot_of_eeos_in_europe.pdf (02.01.2018) and own development of possibilities of eco-bot implementation

	Responsible and managing authorities	Energy savings actions important in context of ECO-BOT implementation	Possibilities of ECO-BOT implementation	
			moderate	high
AUSTRIA	Responsible authority: Federal Ministry of Science, Research and Economy Managing authority: Austrian Energy Agency	The scheme has the largest scope possible (all energy types for the targets, all end-use sectors for the actions). The obligated parties (OPs) are almost all energy suppliers (selling more than 25 GWh/a) (about 600 companies, covering about 85% of Austrian final energy consumption). 42 categories and more than 250 standard methods (formula + deemed savings) are available. An official methodology set guidelines for other types of actions. 52% of energy savings achieved in 2016 came from actions with households, 19% with companies.		●

BULGARIA	Responsible authority: Ministry of Energy Managing authority: SEDA (Sustainable Energy Development Agency)	All types of actions (including behavioural actions) in all sectors, (including energy transformation, distribution and transmission) which can achieve demonstrable energy savings. Obligated parties (OP) are all companies selling energy to final customers. Most of energy savings reported so far have been achieved in the industry therefore; activities in other areas should be intensified.		●
CROATIA	Responsible authority: Ministry of Environmental protection and Energy Managing authority: CEI (NKT) (National Energy Efficiency Authority)	This scheme is currently running. The rules aim at ensuring that the scheme is neutral (regarding the type of actions). Actions will be eligible in all end-use sectors. Obligated Parties are the energy suppliers, and not the energy distributors. The smallest suppliers will not be included in the scheme. Overall, there should be around 40 Obligated Parties.	●	

DENMARK	Responsible authority: Ministry of Climate, Energy and Building Managing authority DEA (Danish Energy Agency)	Obligated Parties are all the energy distributors (65 for electricity, 405 for district heating), covering all end - use sectors (except transports). OPs may establish agreements with affiliated companies or other contractors (consultants, energy traders, installers, craftsmen, retailers, banks, etc.) that will implement programmes towards end -users. All actions saving final energy beyond minimum energy performance criteria (excluding behavioural actions, CFL and appliances after 2009) are eligible. Around 30% of the energy savings are achieved in households.		
FRANCE	Responsible authority: Ministry of Ecology, Sustainable Development and Energy Managing authority: National Pole for White Certificates (also part of the Ministry)	Actions are eligible in all end-use sectors (except consumption covered by the EU ETS), under performance and/or quality requirements. The obligated parties (OP) are the energy suppliers. They can achieve their targets by directly gaining energy savings certificates (CEE) or by buying CEE on the market. Local authorities, national agency for housing and social housing authorities are also eligible to get CEE. 183 standardised operations are currently eligible (90% of CEE issued from Jan. 2015 to March 2017). From Jan. 2015 to March 2017, 49.3% of the CEE was issued for actions in residential buildings.		

GREECE	Responsible authority: Ministry of Environment and Energy Managing authority: CRES (Centre for Renewable Energy Sources and Energy Savings)	This scheme is currently running. The first period (2017-2020) is designed as a learning phase. Actions are eligible in all end-use sectors, considering the guidelines of EED article 7. The obligated parties (OP) for the reference year 2017 consist of electricity, gas and oil products, suppliers or retailers that represent cumulatively at least 95% of the distributed or sold energy for each type of fuel separately. They may implement programmes themselves, as well as through subcontracting or partnerships. They may also use a “buy out” option. The scheme is focused on behavioural or soft measures for its pilot phase e.g. public campaign for energy efficiency.	●	

IRELAND	Responsible authority: DCCAE (Department of Communications, Climate Action & Environment) Managing authority: SEAI (Sustainable Energy Authority of Ireland)	The obligated parties are all energy suppliers (all energy types and sectors) selling more than 600 GWh/a. Suppliers selling between 240 and 600 GWh/a are included on a voluntary basis. They can use partnerships with third parties (e.g. service providers). An online energy savings crediting system has been set for actions in the residential sector. Currently there are about 50 standardised actions for the residential sector (catalogue updated frequently). These actions shall be implemented by qualified contractors. Actions in other sectors are considered on a project-by-project basis, using SEAI assessment tools or other methods. In the period 2014-2016, 1,398 GWh/a (75%) energy savings were achieved in the non-residential sectors, 287 GWh/a (15%) in the residential sector.		
ITALY	Responsible authority: Ministry of Economic Development and Ministry of Environment Managing authority: GSE (Gestore dei servizi energetici)	The obligated parties are the distributors of electricity and natural gas with more than 50 000 customers. They can directly implement projects, have bilateral contracts with operators or buy energy savings via the trading platform. With the new guidelines, published in 2017, actions continue to be eligible in all end-use sectors, under strict additionality criteria.		

LATVIA	Responsible authority: Ministry of Economics Managing authority: Ministry of Economics	Obligated parties will be the electricity suppliers or retailers selling more than 10 GWh/year in the previous year. Obligated parties can fulfil their obligation by implementing programmes or through the payment to an energy efficiency fund. All actions that can demonstrate energy savings for the final customers are eligible (all end-use sectors), including information and consultation.		●
LUXEMBOURG	Responsible and managing authority: Ministry of the Economy	The obligated parties are all the electricity and gas suppliers, based on their sales in the residential, service and industry sectors. Actions are eligible in all end-use sectors to save all types of energy. Behavioural actions may be eligible under conditions. In 2015, in number of measures, most of them were realised in buildings. But in terms of energy savings, half were achieved in the residential/commercial sector and half in the industry sector.		●
POLAND	Responsible authority: Ministry of Energy Managing authority: URE (Energy Regulatory Office)	The obligated parties are the energy suppliers and traders selling electricity, heat, or natural gas to end-users. They can achieve their target through obtaining energy efficiency certificates for actions on their own asset, buying certificates or paying substitution fees to the National Fund of Environment Protection and Water Management. There is no catalogue with deemed savings but an official list of eligible general types of action (covering residential).		●

SLOVENIA	Responsible authority: Ministry of Infrastructure Managing authority: Slovenian Energy Agency	The about 183 obligated parties are the suppliers of electricity, natural gas, heat (district heating), and liquid and solid fuels to final customers in all end-use sectors (with a lower target for transports: 0.25%/a for the whole period). About 30 standardised actions cover all end-use sectors. About 73% of the savings achieved in 2015 came from 3 action types: fuel additives, introduction of energy management systems, and renovation of heating sub-stations.		●
SPAIN	Responsible authority: Ministry of Energy, Tourism and Digital Agenda Managing authority: IDAE (Institute for Diversification and Saving of Energy)	The energy efficiency obligation scheme has started in July 2014. In Spain, the obliged companies can either implement energy efficiency projects themselves or pay to the National Energy Efficiency Fund which will finance energy efficiency projects. The obligated parties are the suppliers of electricity and natural gas, and wholesale retailers of oil products and LPG.		●
UNITED KINGDOM	Responsible authority: BEIS (Department for Business, Energy and Industrial Strategy) Managing authority: Ofgem (Office of Gas and Electricity Markets)	The obligated parties (OP) are the 15 electricity and/or gas suppliers above given thresholds of customers and energy sales, based on energy sales in the residential sector.		●

All countries implementing the Energy Efficiency Obligations (EEO) schemes listed in the table above are potential markets for ECO-BOT, which is why only moderate and high implementation potential was included in the analysis. Countries assessed at moderate level are in the early stages of implementation of EEOs - Greece, Croatia and receive one "+" in summary table 6. In addition, EEOs in Croatia is not addressed to energy distributors who are obvious recipients for the ECO-BOT application. One "+" receive also Malta where EEOs is currently under major revision.

III. GROUP - HIGH LEVEL OF USE OF SOFT INSTRUMENTS SUPPORTING BEHAVIOURAL CHANGES OF ENERGY CONSUMERS

When discussing the issue of the friendliness of the types of energy policy instruments to be used for ECO-BOT applications, special attention should be paid to those aspects that assume an impact on energy consumers to change their habits. Since one of the project goals of ECO- BOT is a persuasive impact on the user, it should be stated in this case the most far-reaching degree of coherence between the assumptions of the policy instrument and the assumptions of the application's philosophy.

Soft policy instruments is a group of instruments requiring coordinated educational activities aimed at shaping pro-ecological attitudes among consumers and business entities through providing information, education, promotional campaigns. The use of soft instruments also requires an active attitude from public authorities through confidence building and procedural changes. Public authorities should enable citizens and other stakeholders to access information about plans, engage in the decision-making process and not only inform about decisions already taken.

Examples of soft instruments are the provision of information about energy consumption, political recommendations to switch to more efficient solutions and promotion campaigns. The instruments most frequently mentioned by Member States are:

- campaigns raising the level of social awareness,
- offices, centres, campaigns, portals, etc. providing information on energy efficiency and renewable energy sources;
- trainings and courses;
- advice services;
- exhibitions and demonstration projects;
- good practice guidance.

Countries that in their energy policy assume wide use of such instruments are the most promising markets for ECO-BOT applications. The potential for dissemination of information about the application could be public campaigns on the economical use of energy. During these campaigns, it would be possible to use social media mechanisms to build a positive image of the ECO- BOT application. However, it should be noted that the promising shape of energy policy instruments can be distorted by sociological and economic factors, such as the high level of digital exclusion.

The following analysis includes two groups of soft instruments used in the energy policy of member countries:

1. Soft instruments strictly aimed at meeting the requirements of Article 7 of the Energy Efficiency Directive. Article 7 of Energy Efficiency Directive requires Member States to establish Energy Efficiency Obligations (EEOs) or use other instruments to achieve new savings each year in the period 2014-2020 amounting to 1.5% of the baseline energy sales to final customers. These countries receive three pluses in the summary table 6.
2. Soft instruments used in the promotion of renewable energy sources. These instruments have been included in the analysis because their impact is very often also aimed at achieving energy savings and improving energy efficiency (e.g. using energy-saving equipment, bulbs, etc.). Countries that declare frequent use of soft instruments in this group have two pluses in the summary table 6.

Ad. 1 Soft instruments strictly aimed at meeting the requirements of Article 7 of the Energy Efficiency Directive.

The assessment considered the existence of such instruments. Based on the analysis carried out by Ricardo Energy & Environment (2016), countries using soft instruments for this purpose are: **Germany, Portugal, Greece, Spain, Romania, the Netherlands and Ireland**.

Ad.2. Soft instruments used in the promotion of renewable energy sources

When assessing this group of instruments, the ratio between three groups of instruments: regulatory, economic and soft has been taken into account. The analysis has been carried out based on progress reports in the promotion and use of energy from renewable resources from member countries to European Commission for 2015. On this basis, the EU countries have been divided into two main groups. These are (see Table 4):

- Countries preferring indirect (economic and financial) instruments;
- Countries that prefer regulatory instruments**.**

A separate case is **Malta**, which in the report indicated the largest share and dominance of soft instruments.

By specifying the above classification according the use of soft instruments, two groups can be further distinguished:

- countries preferring regulatory instruments in combination with soft instruments - **Spain and Luxembourg**
- countries preferring financial and economic instruments in combination with soft instruments **The Netherlands, Sweden, Ireland, Denmark, Austria, Belgium, France, Finland and Estonia.**

One important consideration should be made here: a comparison of instruments based on reports prepared in individual countries is very difficult due to the lack of a consistent methodological approach. The instruments as used in various member states, are classified differently. Moreover, member states have diverse approaches to the issue of detail of data: in one group, only very general data are citable (only a few general regulations are provided), for example, the Czech Republic; in the second group, detailed regulations and information about their operation are readily available, for example, in Estonia and Greece. This review, however, gives an idea of the types of instruments used by different countries and their proportions.

Table 4: List of EU countries in terms of their preferred energy policy measures and instruments.

Source: own development based on reports on progress in the promotion and use of energy from renewable resources from member countries to European Commission for 2015, https://ec.europa.eu/energy/en/topics/renewableenergy/progress-reports (08.01.2108)

Countries expressing preferences for regulatory instruments	Countries expressing preferences for Financial/Economic instruments	Countries expressing preferences for soft/ behavioural instruments
Italy	The Netherlands ֍	Malta
Bulgaria	Slovenia	
Poland	Sweden ֍	
Czech Republic	Ireland ֍	
Romania	Denmark ֍	
Spain֍	Hungary	
Luxemburg ֍	Latvia	
Cyprus	Lithuania	
Greece	Austria ֍	
Portugal	Belgium ֍	
Germany	France ֍	
Slovak Republic	Croatia	
	Finland ֍	
	UK	
	Estonia ֍	

֍ - countries that declare frequent use of soft instruments. This countries and Malta receive two pluses in summary table 5 if they haven't already received three pluses in the category of soft instruments strictly aimed at meeting the requirements of Article 7 of the Energy Efficiency Directive.

IV GROUP. IMPLEMENTATION OR PLANNED IMPLEMENTATION OF SMART METERING

Regulations in the framework of EU energy policy require Member States to ensure the implementation of smart metering systems for long-term benefits for consumers. In practice, the state and prospects for implementing these solutions in individual Member States are different. Based on data collected by the European Commission (European Commission: Smart Metering deployment in the European Union, http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union, access: 01.03.2018), we can evaluate the implementation of smart metering in the 2020 perspective in individual countries States. The assessment uses a three-stage division:

1. countries with wide scale of current and planned implementation of smart metering by 2020 (≥ 80%) – **Denmark, Estonia, Ireland, Greece, Spain, France, Italy, Luxembourg, Malta, the Netherlands, Austria, Poland, Romania, Finland, Sweden and Great Britain.**
2. countries with < 80% of smart metering by 2020 – **Portugal, Belgium, Czech Republic, Lithuania.**
3. countries where:
   - no data is available regarding nation -wide roll out **(Slovenia, Hungary, Bulgaria, Cyprus),**
   - there is selective roll-out till 2020 **(Germany, Latvia, Slovakia)**,
   - they are new EU members **(Croatia).**

Based on the above data and considering the presented criteria, the assessment and ranking of energy policies of the member countries has been prepared. The table 5 contains a description of the areas, criteria and scale of the evaluation, table 6 evaluation of Member States' policies in terms of the possibilities / effectiveness of the implementation of the ECO-BOT application.

Table 5: Areas, criteria and scale of evaluation.

Source: own development

Area	Criteria and scale of evaluation
Implementation of programs supporting improvement of energy efficiency in buildings	**"+"**- each country receives one "+" due to the full transposition of the Energy Efficiency Directive in the Member States. All Member States have instruments for improving energy efficiency.
EEO schemes	**"0"** -Countries that do not have an EEO scheme, **"+"** - Countries with an EEO schemes, which possibilities of the ECO-BOT implementation have been evaluated at moderate level

	"++" - Countries with EEO schemes, which possibilities of ECO-BOT implementation have been rated at high level
Soft instruments	**"++"** – high representation of soft instruments in used in the promotion of renewable energy sources **"+++"** - Exsisting of soft instruments strictly aimed at meeting the requirements of Article 7 of the Energy Efficiency Directive.
Roll out of smart metering by 2020 status	**"0"** – countries where: • No data is available regarding nation -wide roll out • There are selective roll-out by 2020 • They are new EU **"+"** - countries with < 80% of smart metering by 2020 **"++"** - countries with wide scale of implementation of smart metering by 2020 (≥ 80%)

Table 6: Evaluation of Member States' policies in terms of the possibilities / effectiveness of the implementation of the ECO-BOT application.

Source: own development

Country	Legal framework and implementation of programs supporting improvement of energy efficiency in buildings	EEO schemes	Soft instruments	Roll out of smart metering by 2020 status	The sum of points
Belgium	**+**	**0**	**++**	**+**	**4**
Bulgaria	**+**	**++**	**0**	**0**	**3**
Czech Republic	**+**	**0**	**0**	**+**	**2**
Denmark	**+**	**++**	**++**	**++**	**7**
Germany	**+**	**0**	**+++**	**0**	**4**
Estonia	**+**	**0**	**++**	**++**	**5**
Ireland	**+**	**++**	**+++**	**++**	**8**
Greece	**+**	**+**	**+++**	**++**	**7**
Spain	**+**	**++**	**+++**	**++**	**8**
France	**+**	**++**	**++**	**++**	**7**
Croatia	**+**	**++**	**0**	**0**	**3**
Italy	**+**	**++**	**0**	**++**	**5**

Cyprus	**+**	**0**	**0**	**0**	**1**
Latvia	**+**	**++**	**0**	**0**	**3**
Lithuania	**+**	**0**	**0**	**+**	**2**
Luxembourg	**+**	**++**	**++**	**++**	**7**
Hungary	**+**	**0**	**0**	**0**	**1**
Malta	**+**	**+**	**++**	**++**	**6**
the Netherlands	**+**	**0**	**+++**	**++**	**6**
Austria	**+**	**++**	**++**	**++**	**7**
Poland	**+**	**++**	**0**	**++**	**5**
Portugal	**+**	**0**	**+++**	**+**	**5**
Romania	**+**	**0**	**+++**	**++**	**6**
Slovenia	**+**	**++**	**0**	**0**	**3**
Slovakia	**+**	**0**	**0**	**0**	**1**
Finland	**+**	**0**	**++**	**++**	**5**
Sweden	**+**	**0**	**++**	**++**	**5**
Great Britain	**+**	**++**	**0**	**++**	**5**

Rating scale:

1-2 points – low level of support

3-4 – moderate support

4-5 points – average level of support

6- 7 points –high level of support

Based on the obtained data, EU countries in terms of political and institutional support for the implementation of the ECO - BOT application can be divided into:

- **I. Group. - countries with low level of support:**
  - Countries with only legal framework – Hungary, Cyprus, Slovakia.
  - Countries with legal framework and< 80% of smart metering by 2020 - Czech Republic, Lithuania.
- **II. Group. - countries with moderate level of support**:
  - Countries with legal framework and implementation of EEO schemes - Bulgaria, Croatia, Latvia, Slovenia;
  - Belgium – has support for soft instruments and there are plans of roll out of smart metering by 2020;
  - Germany – this country has legal framework and strongly support the implementation of soft instruments. Germany doesn't implement EEO schemes and there are plans of selective roll out of smart metering by 2020.

- **III. Group - countries with medium level of support** (all countries in this group have legal framework and they implement or have plans for wide implementation of smart metering):
    - Countries that don't implement EEO schemes but have strong support for soft instruments - Estonia, The Netherlands, Portugal, Romania, Finland, Sweden,
    - Countries in which soft instruments are less used but have active EEO schemes– Italy, Great Britain, Poland;
    - Malta – in this country, a fundamental reconstruction of the EEO scheme takes place.
- **IV. Group - countries with a high level of support -** in this group of countries have been identified support in implementation of ECO-BOT in all analysed areas - Denmark, Ireland, Greece, Spain, France, Luxemburg, Austria.

ECO-BOT will test its product in a country belonging to three groups with moderate, medium, and high level of support, namely: Germany, Great Britain, and Spain. This will allow ECO-BOT and its models to be tested in all the three contexts and compare the effectiveness of ECO-BOT operations under different institutional conditions.

3. Development of behavioural economics – comments for ECO-BOT

A category of social sciences, economics is an on-going study, which, from its inception, was based on the paradigm of the rationality of people's behaviour. According to this paradigm, people are rational, they are driven by self-interest and strive to maximize their benefits while minimizing costs (Amadae, 2007). In other words, this theory assumes that people are largely selfish, and in encountering incentives or prohibitions, they will react in a rational, thoughtful way, calculating their profits and losses, and considering all "pros and cons". The discussed theory proceeds from the assumption that man is guided in his actions, exclusively by economic motives, has perfect knowledge and knows how to and wants to maximize his satisfaction by choosing the right goods (the homo oeconomicus concept).

The neoclassical economic model explains the behaviour of economic entities as built upon several assumptions about the individual's characteristics (Solek 2010):

- He or she operates on the basis of full and excellent information, and also have unlimited possibilities for information processing,
- The goal of the decision maker is to maximize the expected utility (in the case of consumers) or maximize profit (in the case of companies),
- He or she operates in a narrowly defined self-interest, i.e. without taking into account the usability of other entities, Consistent preferences are held, including that time-based, in line with the model of exponentially discounted usability,
- He or she makes decisions, taking into account the rules of Bayesian inference[1],
- Income and resources are treated interchangeably, i.e. as indeterminate as to the source of origin or destination.

The criteria formulated in such a way make the above theory impossible for use in reality. Research and observations also confirm that the full economic rationality of consumer behaviour cannot be assumed, because people often do things that do not benefit them, do not know all the goods or prices available on the market or are not be able to calculate the benefits for them connected with the selection of individual products. Moreover, in making their everyday decisions, people have limited time for calm reflection or the possibility of a longer focus on individual actions or choices. The relationship between the degree of affluence of society and calculation is also crucial because with the increase in the rate of

[1] Bayesian inference is a method of statistical inference in which Bayes' theorem is used to update the probability for a hypothesis as more evidence or information becomes available.

affluence of the society, psychological factors which influence the consumption behaviour become more and more important - instead of purely economic factors. In fact, as Jones et al. (2013) and Beggs (2014) note, the models of decision-making by people are much closer to Homer Simpson than homo economicus. The behavioural approach thus attempts to realign the assumptions of the theory of choice and bring them closer to the actual decision-making processes and people's behaviour.

Theoretical foundations of behavioural public interventions can be found in the 1950s, in the work of Herbert Simon (1956, 1997) that is devoted to decision-making processes in organizations. In 1956, Herbert Simon proposed a concept of bounded rationality to describe the way people make decisions, recognizing that individuals make decisions with incomplete information and limited processing capabilities. For this reason, they are not able to maximize their purpose function and are sated by minimally satisfying usability levels. A similar concept, according to which companies basically do not reach their full efficiency level, was put forth by Harvey Leibenstein (X inefficiency theory, 1966).

Although Herbert Simon's works have found global recognition (the Nobel Prize in Economics), they have not embraced the mainstream economy dominated by the Chicago School. The combination of psychology and economics begun by Simon, however, was built upon by a team focused in the Carnegie School (Carnegie Institute, Pittsburgh, USA, 1950's-60's). The breakthrough was brought about by the empirical studies of psychologists devoted to the mechanisms of human decision-making in situations of uncertainty. The year 1979 saw the appearance in print of the work of Daniel Kahneman and Amos Tversky: “Prospect Theory: An Analysis of Decisions under Risk”, and a year later, that of Richard Thaler: “Toward and Positive Theory of Consumer Choice”. The aforementioned initiated the rapid development of a new trend called behavioural economics. The aim of these authors was to extend the explanatory power of economic theories, by providing them with the psychological basis of human behaviour. To this end, the behaviourists relaxed the restrictive assumptions of the standard economic model to explain the anomalies that remained inexplicable in the neoclassical trend. It should be noted that behavioural economics is not a homogeneous school. Rather, it is a collection of different theories which include the Michigan school (George Katona), psychological economics (Colin Camerer, Richard Thaler, Ernst Fehr), behavioral macroeconomics (George Akerlof), evolutionary economics (Richard Nelson, Sidney Winter), behavioural finance (Robert Schiller) and experimental economics (Vernon Smith) (see Tomer 2007).

A brief description of the most important theories explaining the behaviour of people within the market (consumers), along with their evolution, is summarized by M. Martiskainen (2007) in the report: “Affecting consumer behavioural energy demand” (see table 7).

Table 7: Overview of Behavioural Theories

Source: Martiskainen M. (2007): Affecting consumer behaviour on energy demand, Final report to EdF Energy, Sussex Energy Group

Behavioural theory/model	Key authors (for full references see Jackson 2005)	Main concept	Limitations
Rational Choice Theory	Elster 1986, Homans 1961	Consumers weigh the expected costs and benefits of different actions and choose those actions that are the most beneficial or the least costly.	The Rational Choice Theory does not take into account habit, emotion, social norms, moral behaviours and cognitive limitations.
Theory of Reasoned Action (TRA)	Ajzen and Fishbein 1980	People expect certain values from the outcomes of their behaviour.	The Theory of Reasoned Action does not address issues such as cognitive deliberation, habits and the influence of affective or moral factors.
Theory of Planned Behaviour	Ajzen 1991	Builds on the TRA model and includes a new dimension of perceived behavioural control (PBC) - person's belief on how difficult or easy a behaviour will be influences his/her decision to conduct that behaviour.	The Theory of Planned Behaviour model has been used more so for measuring the relationships between attitude, intention and perceived behavioural control, rather than the measurement of *actual* behaviour
Ecological Value Theory		Those who mainly hold egoistic and self-interested values are less likely to perform pro-environmental behaviour than those who have pro-social values.	Pro-environmental behaviours can be motivated by self-interest, altruism, and biospheric values. The influence of attitude-behaviour gap.
Value Belief Norm Theory	Stern *et al.* 1999, Stern 2000	Pro-social attitudes and personal moral norms are predictors of proenvironmental behaviour.	All variables have to be analysed to identify the most influential factors.
Symbolic Interactionism and Symbolic Self-Completion Theories	Blumer 1969, Mead 1934, Wicklund and Gollwitzer 1982	People purchase certain goods or symbols not only for their practical value but also to construct their identity, and use those goods for the image they	Evidence suggests that people's responses to goods and symbolic also occur at a sub- or semiconscious level.

		portray of them to the outer world.	
Attitude-BehaviourContext Model	Stern and Oskamp 1987, Stern 2000	Behaviour (B) is an interactive outcome of personal attitudinal variables (A) and contextual (C) factors.	Does not take into account the influence of habits.
Theory of Interpersonal Behaviour	Triandis 1977	Intentions, and habits, influence behaviour, which are also affected by facilitating conditions (external factors).	Has not been as widely used in empirical research as could have been.
Persuasion Theory	Hovland et al. 1953, Petty *et al.* 2002	Persuasion Theory is based on three principles, the credibility of the speaker, persuasiveness of the message and the responsiveness of the audience. The recipients of persuasive enough messages will alter their attitudes and ultimately behaviour accordingly.	A straightforward persuasion theory has its limitations, but versions of it, such as the cognitive dissonance theory which places greater weight on individuals as active recipients of the persuasion process has been shown to provide positive results in experimental research
Social Learning Theory	Bandura 1977	People learn from our experiences (trials, errors) as well as from other social models and observing others around us (family, friends, colleagues and people in the public eye).	

3.1. Heuristics and biases

Based on Simon's (1955) ideas, bounded rationality implies that people do not have unlimited abilities to process all the information needed to make rational choices. Rather, they have inherent behavioural biases and use rules of thumb and shortcuts to make decisions (Mazzotta and Opaluch 1995). Research on decision-making processes has enabled during the last several years to identify dozens of simplifying strategies and rules for inference (heuristics) and resulting cognitive biases. In their works, Kahneman and Tversky, for example, found out that most people are loss averse. Thus, their negative perception of, say, a fine of CHF 1000.00 will be more intense than their positive assessment of an equivalent gain. They also recognized that people make probability assessments on the basis of particular indicators (known as anchors), which are often arbitrary. In his book "Thinking, Fast and Slow" (2011), Kahneman differentiates between two systems of human thinking:

- **System 1** This system is based on simplifying mental shortcuts - heuristics. They allow to save time, energy and attention. However, they are inaccurate and can lead to errors.

- **System 2** slow, reflective thinking, higher-level thinking allows making more conscious decisions. It is based on critical reasoning, but it requires effort and attention.

Each way of thinking has its own advantages and disadvantages: the rational approach of System 2 is accurate and enables making informed decisions. However, this requires time and effort. System 1 has the advantage that it does not require much time and does not require any effort. This system is based on heuristics that are generally useful (if not even necessary) to solve complex daily problems without spending a lot of time. However, in some cases, their use leads to significant systematic deviations. The use of heuristics may cause an incorrect assessment of reality, which leads to incorrect assessments (Mathis and Steffen, 2015). These decision mechanisms that distinguish real people from the idealized homo economics model can be summarized as three main groups of constraints (Jolls et al., 2000):

• bounded rationality - these are simplifying heuristics and errors in estimating probabilities and evaluating values;

• bounded willpower - means that people often take actions that are unfavourable to themselves in the long term;

• bounded self-interest - means that in some situations, people will make decisions not guided by the maximization of their own optimum, but by a sense of justice or cultural norm.

These three limitations have practical implications for the law-making process and the design of public interventions. The first limitation will be important when making decisions in situations of uncertainty (probability assessment) or when estimating the expected effects. The second limitation is important when making decisions that have shifted consequences. The third limitation works in situations where the behaviour of one party deviates from the typically acceptable behaviour for a given situation. Herein, other participants of the interaction are willing to pay the costs to punish dishonest behaviour (Olejniczak and Śliwowski, 2014).

According to Kahneman, heuristics refer to commonly used cognitive abbreviations or rules that simplify and facilitate decision making and represent the process of replacing a difficult question with easier one (Kahneman, 2003). Heuristics can also lead to cognitive biases. There are analyses regarding the relationship between heuristics and prejudices and rationality. In a synthetic approach, the use of heuristics can be called the "ecologically rational" strategy, which makes the best use of limited information available to people (Goldstein and Gigerenzer, 2002). In addition, it can also be stated that there are "universal" heuristics, eg affection, availability and representativeness, while others can be considered more specific to a given field, eg brand heuristics, price and scarcity (Shah and Oppenheimer, 2008).

The following list in table 8 present the basic heuristics that result in our limitations in making decisions and in making judgments. In the table are also presented implications for ECO-BOT.

Table 8: Overview of heuristic and implications for ECO-BOT

Source: own development

Name of heuristic	Mechanism of action	Key authors	Suggestion for ECO-BOT
Affect	The general tendency to make decisions in terms of emotions. Performed activities depend on feelings related to the subject of the decision.	Fischhof et al., 1978; Slovic, Finucane, Peters, MacGregor 2002	ECO-BOT should establish positive associations and emphasize positive aspects of changes in consumer behavior. In this context the visual design of the application is important. It should refer to images and symbols which are well-known to consumers (eg. the respondents of focus group suggested a human form of ECO-BOT)
Availability	Compliance for using easily recalled events in decision-making process.	Tversky, Kahneman, 1974	ECO-BOT may refer to the opinions and experiences of well-known people or public and well-known events, promoting in this way energy saving and protection of the environment.
Scarcity	This is behavioural abbreviation that is commonly used to assess the value of a thing in relation to how easy it is to get it and how easy it can be to	Whitehead et al. 2017; Cialdini 2008; Lee, Seidle, 2012	ECO-BOT should emphasize costs (especially environmental) related to energy production.

	lose it. When an object or resource is less available, we perceive it as more valuable. The simplest manifestation of the scarcity heuristic is the fear of losing access to some resource.		
Representativeness	A tendency based on associative classification of objects based on several characteristic features.	Kahneman, Tversky 1972; Tversky, Kahneman 1974; Payne, Crowley, 2008; Kardes, Posavac, Cronley, 2004; Chen et al., 2007	ECO-BOT should be adopted to national and local conditions. It should use the national language or local dialect and use specific expressions. It should also refer to known symbols and associations.
Anchoring	A tendency based on unreflective acceptance of the suggested values.	Tversky, Kahneman, 1974	ECO-BOT should refer to specific values. An example would be to suggest a specific level of energy savings that can be achieved.

Behavioural economists work to categorize and catalogue the ever-expanding list of deviations from rational choice theory. Examples of anomalous behaviour are numerous and are included in the table 9. In the table are also presented possible interactions with ECO-BOT.

Table 9: Overview of chosen cognitive errors heuristic and their interaction with ECO -BOT

Source: own development

Cognitive errors category	Mechanism of action	Key authors	Interaction with ECO -BOT		
			weak	moderate	Strong
Hyperbolic discounting	Difficulty in deferring the moment of gaining benefits. Focus on the earliest consumption of profits.	1 O'Donoghue, Rabin, 1999; Chen et al., 2007			Useful in preparing the ECO - BOT model. ECO-BOT can emphasize the speed of achieving savings under the condition of taking

					energy-saving measures or purchasing new, energy-saving equipment.
Status quo bias	No acceptance for changes. The preference for the present steady state.	Kahneman, Tversky, 1982; Samuelson, Zeckhauser, 1988			One of the main barriers to the effectiveness of ECO-BOT. Energy consumers may be reluctant to change and may delay their adoption.
Sunk cost effect	The tendency to maximize the usage of goods which were gained with costs.	Arkes, Blumer, 1985; Thaler, 1999		Potential barrier. Sunk cost effect may limit consumers' desire to change existing devices to other more energy-efficient ones	
Procrastination	Delaying the necessary decisions.	Johnson et al. 2012			One of the main barriers to the effectiveness of ECO - BOT. Energy consumers may be reluctant to change and may delay their adoption.
Loss aversion bias	The tendency associated with risk aversion and possibility of loss related to	Kahneman, Tversky, 1979; Gächter, Orzen, Renner, Starmer, 2009	Using the ECO-BOT application		

	it.		is not associated with the risk of loss.		
Myopia	The tendency to mitigate the potential negative effects of future decisions.	Olejniczak K., Śliwowski P., 2012			Energy consumers may not appreciate their future energy and environmental costs related to energy consumption.
Over optimism	Attaching too much importance to optimistic assessments of future developments.	Shepperd, Carroll, Grace, Terry, 2002			See above
Crowd effect	The tendency to behave according to the pattern represented by the social group with the strongest influence on the individual.	Nickerson, 1998		ECO - BOT aims to change individual behavior. However, information from the eco-bot application on other people's pro-energy behaviors can stimulate change. ECO- BOT can signal current trends based on respect for the environment.	
Reciprocity	The tendency to take action towards others combined with the expectation of becoming a	Cialdini, Vincent, Lewis, Catalan, Wheeler, Darby, 1975; Cialdini, 1984; Fehr, Gächter, 2000	ECO - BOT is aimed at individual		

	beneficiary of similar activities now or in the future.		impact, directed to a specific person.		
Confirmation bias	The tendency to select facts and opinions by accepting information that confirms the individual's beliefs and rejecting information that contradicts these beliefs.	Nickerson, 1998			Consumer beliefs that do not consider the need to save energy may not consider ECO -BOT'S advice. In this way, the goal of energy saving will not be achieved. On the other hand, consumer decisions on pro-efficiency attitudes will be strengthened.
Framing Effects	The tendency to differently evaluate the same information on the basis on their formulation.	Levin, I. P., Schneider, S. L., and Gaeth, G. J. (1998)			The effectiveness of ECO-BOT's operation may depend on the manner of providing consumers with information necessary to make decisions
Commitments	Willingness to sustain actions that require commitment, if their cessation would involve a loss.	Festinger, 1957; Strecher et al., 1995; Cialdini, 2008; Dolan et al., 2010		ECO -BOT can use incentives to create a positive image of the user by setting savings goals	

				and environmental goals.	
Projection bias	Willingness to accept the assumption of invariability attitudes and preferences despite the time flow and conditions change.	Loewenstein, G., O'Donoghue, Rabin, 2003		★ It can lead to prejudices in planning for the future.	
Endowment effect	The tendency to overestimate the value of owned goods.	Kahneman, Knetsch, Thaler, 1991		★ Potential barrier manifested in the unwillingness to change the equipment.	

The growing popularity of the behavioural approach has resulted in the emergence of different strategies for influencing the most common cognitive errors. Such approaches can also include solutions based on modern information technologies such as ECO-BOT. Undoubtedly the most widely used and commented set of rules is NUDGE developed by Sunstein and Thaler. The word NUDGES is an abbreviation whose development contains the main rules of action (see: Thaler R.H., Sunstein C.R., Balz J.P. 2010):

- Incentives - creating an incentive system;
- Understand choice mapping - understanding the course of the selection process;
- Defaults matter - improving the importance of negligences and unwillingness to act (people tend to minimize the effort, choose the path that is the least onerous, the easiest available, so the "default settings" are crucial;
- Give feedback - it is necessary to help people understand the problem / challenge, it is also necessary to provide feedback - information, warning when failure is approaching, praises for success;
- Expect error - the awareness that people make mistakes - a good system takes this into account and minimizes penalties for these errors;
- Structure complex choices - reducing the complexity of the system - the more choices you can make causes the system become more complicated, and its operation will cause many problems. Opportunities should be simplified rather than multiplying alternatives.

The above general rules / tips can be useful in the ECO -BOT planning process.

4. A classification of barriers to energy efficiency

This section of the report is a systematic classification of barriers to energy efficiency based on a comprehensive review of the literature. The study of energy efficiency barriers is a multi-disciplinary field with contributions from diverse theoretical backgrounds such as neo-classical economics, organizational economics, behavioural theory and organizational theory (Science and Technology Policy Research, 2000).

Despite the fact that the prospects for increasing energy efficiency are huge, they are often ignored. The reason is the existence of inhibitory factors - barriers to the implementation of cost-effective energy efficiency solutions. These factors can be defined as “man-made factors or attributes that operate in between actual and potential development or use” (Verbruggen, *et al*., 2010, p. 852). Furthermore, they may be intentional or accidental, may prevent or inhibit action or inhibit progress in realizing potential (Verbruggen, et al., 2010, p. 852).

The presence of barriers is related to the creation of the so-called "energy efficiency gap", ie a phenomenon where there is a discrepancy between potentially cost-effective measures to increase energy efficiency and the actions actually implemented in reality. Literature also points to institutional or structural barriers that do not directly affect the "gap", even if it affects the overall level of energy efficiency (Thollander, et al. 2010).

The literature contains a great variety of taxonomies. These range from simple lists, to useful and logical categorisations of barriers. The basic division of barriers classifies them into three general groups: economic, behavioural and organisational (Sorrell, et al., 2000; Thollander, et al., 2010; Science and Technology Policy Research, 2000). Sorrell *et al.* (2000) have prepared a taxonomy that allows an understanding of each group via forming perspectives that highlight particular aspects of a complex situation. Still, in practice, this typology is not exclusive (see Table. 10).

The biggest advantages of the study conducted by Sorrell *et al*. is the inclusion of other non-economical perspectives in the taxonomy, i.e. behavioural and organizational theory (Sorrell, *et al.*, 2000) (Katzev & Johnson, 1987). The authors note that as a result of *bounded rationality,* people and companies will rather make satisfactory decisions than look for optimal decisions. Therefore, the behaviour of individuals and organizations is probably significantly different from the expected economic models. Secondly, the restriction on time, attention, resources and information processing capabilities lead to replacement of optimization analyses with imprecise procedures and rules. In the expression of bounded rationality, it seems more obvious that decisions are not made in accordance with economic arrangements, and decision-makers are limited by many attention and resource barriers, being able to peruse and develop only a limited set of information. This phenomenon has not been included in traditional economic models: however, it may be important for the energy services market as these are characterized by complex and significant information costs. This causes attention to be placed almost exclusively to energy production as the basic activity, while ignoring activities considered peripheral, such as energy management (Cagno, *et al.*, 2013).

Table 10: General classification of barriers to energy efficiency

Source: Sorrell, et al., 2000

Perspective	Theory	Examples	Actors
Economic	Neo-classical economics	imperfect information, asymmetric information, hidden costs, risk	Individuals and organisations conceived of as rational and utility maximising
Behavioural	Transaction cost economics, psychology, decision theory	inability to process information, form of information, trust, inertia	Individuals conceived of as boundedly rational with non-financial motives and a variety of social influences
Organisational	Organisational theory	energy manager lacks power and influence; organisational culture lead to neglect of energy/environmental issues	Organisations conceived of as social systems influenced by goals, routines, culture, power structures etc.

In the report "*Promoting the Transition to Green Growth",* the OECD (2012) provided a list and discussion of the typical barriers to energy efficiency. Examples drawn from this are listed in Table 11., but there are other approaches to categorizing barriers. Cagno *et al.* (2013), for example, provide a broader framework in which barriers are broken down by origin, as this is useful in determining the appropriate policy responses. External barriers, as they argue, are the market, government and politics, technology and service suppliers; as well as the designers and manufacturers, energy suppliers and capital providers. Internal barriers are economic, behavioural and organisational, in addition to those related to competences and awareness (Cagno et al. 2013, p. 296).

Table 11: Examples of a typical classification of energy efficiency barriers.

Source: OECD, 2012.

Barriers	Examples
Market	Market organization and price distortions prevent customers from appraising the true value of energy efficiency
	Split incentive problem created when investors cannot capture the benefits of improved efficiency

	Transaction costs – project development costs are high relative to energy savings
Financial factors	Up-front costs and dispersed benefits discourage investors
	Perception of efficiency investments as complicated and risky, with high transaction costs
	Lack of awareness of financial benefits on the part of financial institutions
Information and awareness	Lack of sufficient information and understanding, on the part of consumers, to make rational consumption and investment decisions
	Incomplete information when technology lacks a track record
Institutional regulations	Incentive structure encourages energy providers to sell energy rather than invest in cost effective energy efficiency
	Energy tariffs that discourage efficiency investment, such as declining block rates.
	Institutional bias towards supply side investments
Technical factors	Lack of affordable energy efficiency technologies suitable to local condition
	Insufficient capacities to identify, develop, implement and maintain energy efficiency investments

Extensive insight into existing literature on barriers to greenhouse gas emissions and another classification of energy efficiency barriers is in the "Third Assessment report by the Intergovernmental Panel for Climate Change (IPCC)". The report provides a useful tool to solve the problem from the point of view of policy-makers (Intergovernmental Panel for Climate Change, 2001). In this study, the IPCC presented the sector and technology-specific barriers and opportunities, and categorized barriers according to eight sources. These are as follows: (i) Technological Innovation, (ii) Prices, (iii) Financing, (iv) Trade and Environment, (v) Market Structure and Functioning, (vi) Institutional Frameworks, (vii) Information Provision, and (viii) Social, Cultural, and Behavioural Norms and Aspirations.

Analyzing the available literature of the subject, for the purposes of implementing this project, the energy efficiency barriers have been classified due to three main groups of end users affected by these barriers (see table 12): residential consumers; enterprises and industry, and buildings/facility managers. The table indicates which of the mentioned barriers, according to the authors of the report, have the greatest impact on the design of the ECO-BOT tool (main barriers, strong impact) moreover barriers with weaker impact were also identified.

The division of barriers used in the report results directly from the functional assumptions of the project. In addition, as can be deduced from the literature, the energy end-use sector is next to the energy generation, transmission and distribution the key area that has an impact on achieving energy efficiency improvement in EU countries. The improvement of energy efficiency in this area depends primarily on the awareness of the importance of the problem and the behavior of household representatives, housing communities, public sector entities and small and medium enterprises dictated by this awareness.

Table12. Classification of barriers to energy efficiency – literature review

Source: Sorell et al. (2000), Thollander et al. (2010), IEA (2012), Fraunhofer ISE et al. (2012); ITRE (2016); Cagno, *et al*., 2013; Vogel et al. (2015); ESMAP, 2014; Fleiter, Schleich and Ravivanpong (2012), BMG Research (2009)

End-users that refer to	Categories		Barriers	References	Meaning for ECO-BOT	
					Key Barriers	Weak influence
Residential Consumers	Behavioural	Priorities	Lack or low awareness of the benefits associated with the use of measures to improve energy efficiency	(Sorell, et al., 2000; Thollander, et al., 2010; Science and Technology Policy Research, 2000); Directorate General for Internal Policies. Policy Department A: Economic and Scientific Policy, ITRE, 2016 IEA (2012), Fraunhofer ISE et al. (2012); Perman et al.	X	
			Consumers choose other visible improvements in the household		X	
		Comfort	Behavioural inertia and bounded rationality		X	
			Loss of comfort and dissatisfaction during the renovation phase (noise, dirt, etc.)			X
			Concerns regarding a dispute with a tenant / property owner (behavioral dimension of split incentive)		X	
	Informational	Dwelling information	Lack of knowledge about energy consumption in the apartment		X	
			Misperception about known consumption /lack of knowledge about saving potentials		X	
			Lack of understanding the difference between overall maintenance costs (eg of boiler) and energetic improvements resulting from new investments		X	
		External information	No general information on energy consumption, energy saving options, economic and environmental benefits, etc.		X	
			Lack of reliable information		X	

End-users that refer to	Categories		Barriers	References	Meaning for ECO-BOT	
					Key Barriers	Weak influence
			Lack of comprehensible information (complexity of information, form of information)	(2003),	X	
			Lack of personal data due to the heterogeneity of individual services		X	
			No specific information on loan/ grant support programs			X
			Lack of information about consultancy and advisory services		X	
	Economic	Financial	No access to internal capital (due to low savings or prioritization of other investments)		X	
			No access to external capital			X
		Incentives	Split incentives		X	
			Subsidies on energy prices			X
		Risk aversion	Due to hidden costs (costs related to making decisions, costs related to information, new costs of technology adaptation, etc.)		X	
			Due to long amortisation time			X
			Due to the uncertainty regarding their own future economic situation		X	
			Due to overall economic situation			X
			Due to the uncertainty about energy prices			X
			Due to general preference for equity over debt		X	
			Due to technological risk		X	
	Regulatory/Administrative		Regultions regarding the transfer of costs		X	

End-users that refer to	Categories		Barriers	References	Meaning for ECO-BOT: Key Barriers	Meaning for ECO-BOT: Weak influence
			of modernization to tenants			
			Complex ownership structures in multi-family housing		X	
Enterprises and industry	External	Market	Distortion of energy prices	OECD (2012); Thollander and Ottosson (2008); (Cagno, *et al.*, 2013). BMG Research (2009) and Fleiter, Schleich and Ravivanpong (2012),		X
			Low diffusion of technology			X
			Low diffusion of information			X
			Market risk			X
			Difficulties in collecting external skills			X
		Government/Politics	Lack of proper regulation			X
			Distortion in fiscal policies			X
		Technology/Services Suppliers	Lack of interest in energy efficiency		X	X
			Little communication skills		X	
		Designers and Manufacturers	Technical Characteristics not adequate			X
			High initial costs		X	
		Energy Suppliers	Little communication skills		X	
			Distortion in energy policy			X
			Lack of interest in energy efficiency		X	
		Capital Suppliers	The cost of investing the availability of capital		X	
			Difficulties in determining the quality of investments			X
	Internal	Economic	Low availability of capital		X	
			Hidden costs		X	
			Risks related to intervention			X
		Behavioral	No interest in interventions in the field of energy efficiency		X	
			Other priorities		X	
			Inertia		X	

End-users that refer to	Categories		Barriers	References	Meaning for ECO-BOT: Key Barriers	Meaning for ECO-BOT: Weak influence
			Imperfect assessment criteria			X
			No sharing of goals		X	
		Organisational	Low status of energy efficiency		X	
			Divergent interests			X
			Complex decision chain			X
			Lack of time		X	
			Lack of internal control		X	
		Barriers related to competences	Identification of inefficiencies			X
			Implementation of interventions			X
		Awareness	Lack of awareness or ignorance		X	
Buildings (facility managers)	Lack of knowledge and know-how		Lack of reliable and credible information about energy performance and the costs and benefits of efficiency improvements	(ESMAP, 2014); (Schipper, et al. 1992); Vogel et al. (2015)	X	
			Lack of implementation capacity: shortage of relevant technical skills in local markets to ensure compliance of building EE codes			X
			Risk aversion to unfamiliar materials, methods and equipment, or uncertain outcomes			X
			Lacking knowledge about investment horizons, risks, and life spans		X	
			Resistance to change		X	
			Lacking knowledge of and interest in energy related topics		X	
	Institutional and regulatory deficiencies		Lack of national and/or local commitment to energy efficiency (EE) in general, and to EE in buildings in particular		X	
			Government internal procedures and lines		X	

End-users that refer to	Categories	Barriers	References	Meaning for ECO-BOT	
				Key Barriers	Weak influence
		of responsibility that discourage EE in public buildings (e.g., budgetary and procurement policies not conducive to contracting EE services)			
		Poorly designed social protection policies that undermine price signals for efficient use of energy (e.g., generally subsidized energy prices)		X	
	Financing challenges	Local government budget constraints			X
		Lack of long-term financing at a moderate cost		X	
		High transaction costs due to small individual investments		X	
		Unattractive financial returns		X	
		Unreliable repayments		X	
		Weak or non-existing incentives for using latest technology		X	
		Low transparency of energy pricing models		X	
	Market failures and inefficiencies	Split incentives: EE investment decisions are made by actors that do not receive direct financial benefit		X	
		Suboptimal decisions or choices due to insufficient information		X	
		Fragmented building trades: multiple professions involved in different stages or decision processes			X
		Unclear incentives for the market to reach energy targets		X	

4.1 Barriers to energy efficiency in small and medium-sized enterprises

Taking into consideration the analyzed literature (Goldberg et al., (2012); Reinaud and Goldberg, (2011); OECD (2012); Thollander and Ottosson (2008); Cagno, *et al*., (2013). BMG Research (2009) and Fleiter, Schleich and Ravivanpong (2012); Węglarz, et al., (; 2016); Leszczyńska & Ki-Hoon, (2016); Rogosz, et al. (2016) in the sector of small and medium-sized enterprises the following barriers have been identified and classified:

1. Financial:

- In some sectors the high cost of capital when making investments in new and effective equipment and facilities is a serious limitation of the rate of improvement of energy efficiency, companies indicate that it is a relatively small advantage for them with a long payback period

- Companies do not have sufficient access to capital (lack of support from state authorities through the creation of access to financial instruments, incentives, grants and loans to support projects related to energy efficiency, development of financial support instruments);

- Investing in energy saving generates too high a threat due to the lack of knowledge of the principles of preparation and implementation of such projects in contrast to typical business projects and the difficulty in predicting future energy prices;

- Entrepreneurs willingly use capital and other resources to develop their business; when it comes to reducing costs, it is usually done with the least possible expenses; companies often undertake projects whose payback period is limited to only 18, maximum 24 months, unless there is a clear increase in productivity or results;

- Improvement of energy efficiency is perceived in terms of reduction of operating costs, and for such measures the budgets of companies are limited.

2. Market, information and organizational as well as behavior related:

- Energy prices and taxes are subsidized in some countries in the industrial sector; therefore, companies do not bear the full costs of energy consumption, and therefore have less incentive to reduce this consumption;

- Some effort and expenses have to be paid to recognize issues related to costs, benefits and energy saving opportunities; these costs may discourage changes and investments in this area;

- Companies have limited knowledge and access to information about existing and new energy-saving technologies as well as their impact on the company's economic results in the long-term perspective,

- Companies can exaggerate the technical and operational risks of projects that improve energy efficiency due to ignorance of technologies that reduce energy consumption and lack of practice compared to typical business projects;

- Improving energy efficiency is not the main driving force for most companies; instead, companies focus on their core business, such as production development or modernization;

- Professional and functional boundaries in the organization limit the cooperation needed to recognize and support energy efficiency (Paton, 2001, p. 169). For example, employees who make energy payments do not take part in the ordering of energy consuming devices, and these in turn are not related to the team that is responsible for maintaining the equipment,

- Personnel barriers (for example, lack of experienced and qualified staff, lack of adequate managerial skills and technical knowledge, reluctance to change, inability to manage tasks related to improving energy efficiency). Most companies, regardless of size and industry, consider the use of energy as an important problem, but it is not possible to entrust it to a dedicated person - generally no one is responsible for it. Few companies conduct an energy audit and even less consider the introduction of an energy management system. In addition, management boards focus on core business activities and ignore secondary energy management issues. There is a lack of information and education - lack of awareness that relatively simple measures can provide significant savings.

3. External:

- Uncertainty caused by the development of future technologies and legal regulations as well as other political events (uncertainty as to the optimal moment of launching new technologies);

- Lack of knowledge and skills of external energy auditors and other energy service providers, which may prevent enterprises from maximizing energy efficiency. There is an insufficient number of consultants and experts in terms of efficiency energy.

4.2 Barriers to energy efficiency of individual consumers

The individual energy consumer is very important user for the ECO-BOT application. An increasing role of the consumer in the energy market is observed, and the increasing access to smart metering increases the pressure on improving the transparency of information on the functioning of the market and current energy consumption. As results from the analysis of the literature (Sorrell, et al., (2000); Thollander, et al., (2010); Science and Technology Policy Research, (2000); Directorate General for Internal Policies. Policy Department A: Economic and Scientific Policy, ITRE, (2016); IEA (2012), Fraunhofer ISE et al. (2012); Perman et al. (2003); Węglarz, et al., (2016); Rączka & Bayer, (2016); Throne-Holst, et al. (2008); Rogosz, et al. (2016); Słupik, (2015); IEA, (2007); the basic barriers to saving energy by individual consumers are:

- information issues: low awareness of people in the field of energy saving activities. Decisions of households regarding investments in energy saving and energy production must be based on detailed hourly data showing the individual profile of energy consumption. Without this knowledge, there is a high risk of missed decisions and loss of funds. There is still a lack of access to information in many countries, consumers are not informed about individual consumption and possible savings. The quality of information consumers receive about electricity consumption can also be considered to be insufficient. Reliable knowledge about when and how much energy the consumers consumes is a key information for them. The barrier is the lack of the availability of measurement data from smart meters and the lack of use of dynamic retail tariffs that allow the price signal to be transferred from the wholesale market to end consumers. The lack of energy consumption control by consumers simply leads to a lack of proper energy management at home.

- economic issues. One of the most important reasons why energy users do not invest in energy efficiency is the lack of awareness of the problem of high energy waste and related financial losses. In addition, prices for households in some countries are regulated or remain low, so it is difficult to construct a competitive price offer, and for many households the share of electricity costs in expenses is low and the benefits of changing the way of energy management are also low so consumers simply do not want to devote time to this matter. Moreover, some measures to reduce the energy consumption of households require investment. Over time, these investments give payback, but it must still be assumed that households will have additional funds for their implementation, which may be difficult or impossible for low-income households. For a family that tries to overcome financial difficulties, upgrades that require large financial outlays are eliminated in advance, even if it would mean saving money in the long run. This lack of short-term cash flow is the first major obstacle to adopting energy-efficient improvements in low-income communities. Lack of financial support for measures to improve energy efficiency reduces the incentive to save energy. Energy efficiency is not appreciated then.

- behavioral issues: energy consumers' habits based on their own experience, upbringing or culture are very important for ECO-BOT applications. Also the way how consumers understand the information they receive (whether the information is well understood or misunderstood) is significant. Ecological behavior requires additional effort for consumers, especially if it is decided to use energy more efficiently. Some consumers believe that changing their behavior can be a complex task and require a lot of time and effort. Such a belief blocks the pro-energetic attitude and is most often the result of a lack of knowledge and information about energy saving. The reason may also be the lack of previous experience in the purchase of energy-saving technologies or negative experiences in the past. Another problem is routine behavior where old patterns prevent the adoption of new habits in the field of energy saving. Consumers are getting used to previous activities, although the change would be quick and easy.

- educational issues: lack of consumer education towards the possibility of rational energy management in households. Many consumers indicate lack of knowledge as a key barrier to achieving energy efficiency. Very often, consumers point out as a barrier the lack of sufficient promotion of national initiatives or programs to improve energy efficiency or a small scope of promoting and raising awareness of the importance of even small measures that bring tangible results.

Other barriers that affect individual decisions regarding energy consumption are, for example: administrative barriers, difficulties in terminating a contract with one supplier and entering into another, which causes unwillingness to change suppliers; no impact on the individualization of the energy-related product that consumers purchase as opposed to consumers purchasing other consumer goods and services, as well as regulatory and legal barriers to making pro-ecological decisions. According to the analysis of the literature on consumer research, it can be noticed that energy consumers do not constitute a homogeneous group in terms of their level of awareness. They can be divided into three basic groups (see: Pluskwa-Dąbrowski, 2016, p. 3 https://www.documents.clientearth.org/wp-content/uploads/library/2016-12-07-konsument-w-energetyce-rzut-oka-w-przyszlosc-ext-pl.pdf.):

1. Prosumers are a group that is interested in an active, participatory model in the electricity market. If they have space and technical options, they are considering to run their own micro-installation. They are more likely than others to use energy-saving household appliances, and they would be willing switch tariff to more effective. They could engage in a demand side response system if the energy consumption shifted out of rush hour it would also give them economic benefits.

2. Conscious consumers are a group that is not active and involved but has (at least the general) awareness of its rights and is ready to seek knowledge when needed. The conscious consumer is usually guided by a pragmatic approach - he knows that there are specific options for action, but he joins them if he sees certain benefits - mainly, but not only, financial.

3. Passive consumer is a recipient who is not interested in their rights, possibilities of action (eg energy saving, choice of supplier, change of tariff). However, such consumers have certain expectations. The basic one is a fair price for energy. The passive consumer also has its "tolerance threshold" for the harmful behavior of energy companies. Long power outages, prolonged connection procedures and hastily charged penalties for interfering with the measuring system (eg a slightly outlined meter housing) - these are matters that can mobilize even the most passive consumer. The group also does not like the system of forecasts in settlements and complains about illegible and incomprehensible invoices for energy.

To raise consumer awareness, it is necessary to implement a number of instruments addressed to the household sector, such as (Kott, 2015; Popczyk, 2014):

- frequent information campaigns, whose main objective should be to increase awareness of the rational use of electricity,
- placing information on websites describing lighting equipment, household appliances and electronics on the energy efficiency side and characterizing available energy-saving technologies used in households. This information will help consumers in the conscious and rational selection and purchase of energy-efficient electricity receivers,
- widespread and widely available information on the labeling of home appliances and consumer electronics, as well as the development and implementation of a system for enforcing the labeling of equipment and devices at the points of sale,
- inclusion of a labeling system for information and education of energy users,
- a universal education system consisting of trainings that increase awareness and rational use of energy in the household sector
- a system of vocational training raising the qualifications and skills of applying standards as well as consulting in the use of energy-saving technologies for individual recipients,
- introduction of a number of legal regulations aimed at promoting the effective use of energy by end users, including households.
- creation of a comprehensive system of co-financing of projects regarding the potential of effective energy use and the use of renewable energy sources in multi-family and single-family buildings with public funds.

The ECO-BOT application can become an effective tool for raising energy consumers' awareness. It should focus on both passive and conscious consumers. Through its action it can educate and cause changes in the behavior of energy consumers. It should also help in the process of transitioning consumers from passive to conscious to possibly prosumers.

4.3 Barriers to energy efficiency of buildings/facility managers

The last group of end users separated due to the scope of the project are buildings/ facility managers. The barriers to energy efficiency identified for this group also include those barriers characteristic for individual and some of SMEs consumers as well as followed (Szczepaniak, 2014; ESMAP, (2014); Schipper, et al. (1992); Vogel et al. (2015); Węglarz, et al., (2016); Paiho & Ahvenniemi, (2017); Rogosz, et al. (2016); Palm & Reindl, (2018); Marquez, McGregor, & Syme, 2012); Koshman & Ulyanova, (2014):

- historical maintenance of old buildings may be a limitation for energy-saving renovation because using thermal insulation measures can be difficult,
- low quality of buildings, age and technical condition of the building, as well as the type and efficiency of the heating system - no renewal possible without stronger incentive systems, active promotion and technological innovations,
- no common application of the integrated design practice, involving close cooperation of specialists from various industries, from the conceptual phase of the building (investment) to its implementation,
- inconsistent, split and fragmented legal regulations concerning various aspects of sustainable construction,
- lack of an effective system of financial support for investments using energy-saving solutions in enterprises and housing construction,
- lack of knowledge, awareness or motivation leading to the use of modern technologies, allowing for the acquisition of renewable energy, reduction of heat losses, automation of energy processes in buildings (related to the production and use of energy);
- lack of support from state authorities for cheap energy audits, access to qualifications systems for energy service providers and energy audits, for energy managers and for entities installing building elements related to the use of energy, information and training development, support of the energy services market, contracts for energy services,
- split incentives for families who rent their homes. In particular, building owners do not invest in efficiency because tenants pay energy bills. And vice versa, tenants probably do not invest in real estate that they do not have. In addition, even if tenants wanted to incur costs themselves, they are at a disadvantage when it comes to obtaining financing for large capital projects. Reason: they usually do not have equity, such as having a home,
- division of expenditures and benefits in the construction of new buildings - there is no incentive to improve energy efficiency of building constructors who first of

all want to reduce costs. Deciding on the basic characteristics of the building, its external coating and the equipment of heating devices, the builder very often chooses the cheapest available solutions, not paying attention to the impact of these solutions on the amount of energy bills. Very often chosen solutions lower the void costs at the price of suboptimal solutions for households. In the long run, it is not profitable.

5. Energy system models – in search of a unified scheme

5.1 Introduction to energy system models – general classification

There are several common approaches to categorizing models. The predominant strategy adopted in the literature on model classification is to determine the analytical approach of a model (e.g. "Top-down" or "Bottom-up"), the methodology (e.g. simulation or optimisation) and the mathematical approach (type of programming techniques used). Hourcade et al. (1996, pp. 283-286), differentiated energy models according to three main categories: the purpose of models, their structure and with reference to their external or input assumptions. The general purpose of an energy model may be to explore interactions in the energy system or to discern possible paths towards decarbonisation or to predict or attribute costs associated with certain energy scenarios. Moreover, the general purpose may be one of (a) forecasting, (b) exploring and (c) backcasting. The specific purpose field is to be descriptive and consider the aspects on which the model itself focuses, such as energy demand, energy supply, impact or appraisal (van Beeck, 1999). Hourcade *et al.* (1996) lists some external assumptions that may be made such as population growth, economic growth, energy demand, energy supply, price and income elasticities of energy demand, existing tax system and tax recycling. Grubb *et al.* (1993, pp. 432-446) used six dimensions to classify energy models. These are: top-down/bottom-up; time horizon; sectoral coverage; optimization/simulation techniques; aggregation level, and geographic coverage, trade and leakage. Hall and Buckley (2016) proposed an interesting, unified and complex classification scheme for energy modelling. It is comprised of 14 categories that take into account purpose, structure, approach, mathematical and technological detail (see Table 13). Such a scheme is based on a review of both the academic literature and UK-origin policy papers since 2008 that cover the topic of energy systems modelling. In building upon this background, they aimed at making the landscape of models more transparent while still covering the wide range of factors relevant to energy modelling.

Table 13: Classification of energy system models by purpose, structure, technical and mathematical details.

Source: Hall & Buckley, 2016.

Model Category		Type of model
1. Purpose of the model	**General**	Forecasting Exploring Backcasting
	Specific	Energy demand Energy supply Impacts Environmental Appraisal Integrated approach Modular
2. Structure of the model: internal assumptions & external assumptions		Degree of endogenization Description of non energy sectors Description of end-uses Description of supply Technologies Supply or Demand analysis tool
3. Geographical coverage		Global Regional National Local/community Single-project
4. Sectoral coverage		Energy sectors Other specific sectors Overall economy
5. The time horizon		Short Medium Long Term
6. The time step		Minutely Hourly Monthly Yearly Five-yearly User-defined
7. Renewable Technology Inclusion		Hydro Solar (PV and thermal) Geothermal Wind Wave Biomass Tidal
8. Storage Technology Inclusion		Pumped-hydro energy storage Battery energy storage Compressed-air energy storage Hydrogen production/storage/consumption

9. Demand Characteristic Inclusion	Transport Demand	Internal-combustion vehicles Battery-electric vehicles Vehicle-to-grid electric vehicles Hydrogen vehicles Hybrid vehicles Rail Aviation
	Residential Demand	Heating Lighting Cooking Appliance usage Smart Appliances & Smart metres
	Commercial Demand	Offices Warehousing Retail
10. Cost Inclusion		Fuel prices Fuel handling Investment Fixed Operation & Maintenance (O&M) Variable Operation & Maintenance (O&M) CO2 costs
11. The Analytical Approach		Top-Down Bottom-Up Hybrid Other
12. The Underlying Methodology		Econometric Macro-Economic Micro-Economic Economic Equilibrium Optimization Simulation Stochastic/Monte-Carlo Spatial (GIS) Spreadsheet/Toolbox Backcasting Multi-Criteria Accounting
13. The Mathematical Approach		Linear programming Mixed-integer programming Dynamic programming Fuzzy logic Agent based programming
14. Data Requirements		Qualitative Quantitative Monetary Aggregated Disaggregated

For the purpose of this report, for further analysis, the authors chose analytical approach dividing the models into three main groups: top-down models; bottom-up models and hybrid models, taking into account two levels of analysis (macro, mezo) in relation to energy end-users. The analysis was complemented with selected consumer behavior models at the micro level. The authors believe that such a classification will be a clear starting point for an attempt to analyze and structure the model that takes into account behavioral factors.

The bottom-up models usually focus exclusively on the energy sector and use highly disaggregated data to describe in detail end uses of energy and technology options. They consider both the supply side, that is, the acquisition of energy carriers and conversion technologies, as well as the demand side, which is characterized by the demand for particular types of final energy. These models are able to capture competition among technologies, and to monitor or allow technological progress. They create a good mapping of the energy system, but the tight sectoral scope of these models makes them blind to macro-economic feedbacks. For example, depending on the construction of the model, a macro-economic carbon cap will change the technology mix, induce fuel switching, perhaps influence vehicle choice or energy consumption; but a bottom-up model will not provide information about how the carbon cap affects economic growth, or how the cost of the cap is distributed across parties. The feature of these models is the lack of system connections with the rest of the economy, while the decision criterion is the minimization of direct costs (Mai, *et al*., 2013).

The alternative top-down approach focuses on building a model of the entire economy. Herein, the energy sector is only one of the elements affecting the environment and experiencing feedback effects. The top-down approach allows wide coverage of interactions across sectors and regions, and it models economic interactions, including aspects of market distortions, through calibration to historical behaviour in real economies. Top-down models, or general equilibrium models, cover the supply and demand side. They are based on the assumptions of the ideal market and the balance between production and demand. These models assume the necessity of taking into account external costs in decisions of energy producers, e.g. emission costs. The shortcoming of such models is the need to simplify the model of the energy sector itself and omit technical details that may be significant, especially in a shorter period. The historical approach gives top-down models the possibility of implying certain uneconomical decision-making processes (e.g. the limits of social acceptance for a given location). However, it also implies that the technologies, preferences, and behavioural patterns wrapped up in the model coefficients are fixed, or at least exogenously defined, so technological advancement, public policy changes, and shifts in attitudes or behaviour have limited ability to change the discerned market dynamics (Mai, *et al.*, 2013).

5.2 Macro level models

5.2.1.Bottom-up models

In the first stage, following models from a group of macro scale models of bottom-up were examined for suitability to the ECO-BOT:

- RESGEN
- MARKAL
- EFOM
- EFOM-ENV
- TIMES
- ETSAP-TIAM
- BUENAS
- RAINS-EU
- RAINS-ASIA
- PRIMES
- PRIMES-TREMOVE
- PRIMES Biomass Supply
- MESSAGE
- MEDEE
- MAED

In a significant majority of these models do not find application in the ECO-BOT due to their specificity. These are the models covering the entire energy chains, from extraction to end -use at the level of the economy or the country. They often cover the entire regions of the world (like the MESSAGE and others). It seems that only model PRIMES Biomass Supply, in fact their modules, could be taking into consideration for ECO-BOT purposes.

PRIMES Biomass Supply

The PRIMES Biomass Supply is one of the PRIMES family models, and was developed within E3Mlab at the National Technical University of Athens (NTUA) (Capros, 2012). It usually works together with the PRIMES Energy System Model as closed loop system, but it can work as a standalone model provided that the demand for bio-energy commodities is given exogenously.

From the year 2000, to the year 2050, all EU27 Member States are covered individually by the model in terms of five year time increments. PRIMES Biomass Supply is calibrated to Eurostat statistics for the years 2000 to 2010. If necessary, missing Data can be fulfilled through other statistical sources (Capros, 2012).

The aim of the PRIMES Biomass Supply is to model and project energy system data for the EU Member States, and to assess the impact of policies that promote renewable sources of energy. The model can work separately or interact with PRIMES.

This is an economic supply model and it calculates the best use of biomass and the waste resources and investment, on each level of transformation, to meet the demand of the final biomass and energy waste products.

The biomass supply model calculates the consumer prices of the final products of biomass used for energy purposes. It also calculates the consumption of other energy forms in the processing of biomass products (including production and transport). The structure of PRIMES BIOMASS is seen in Figure 2.

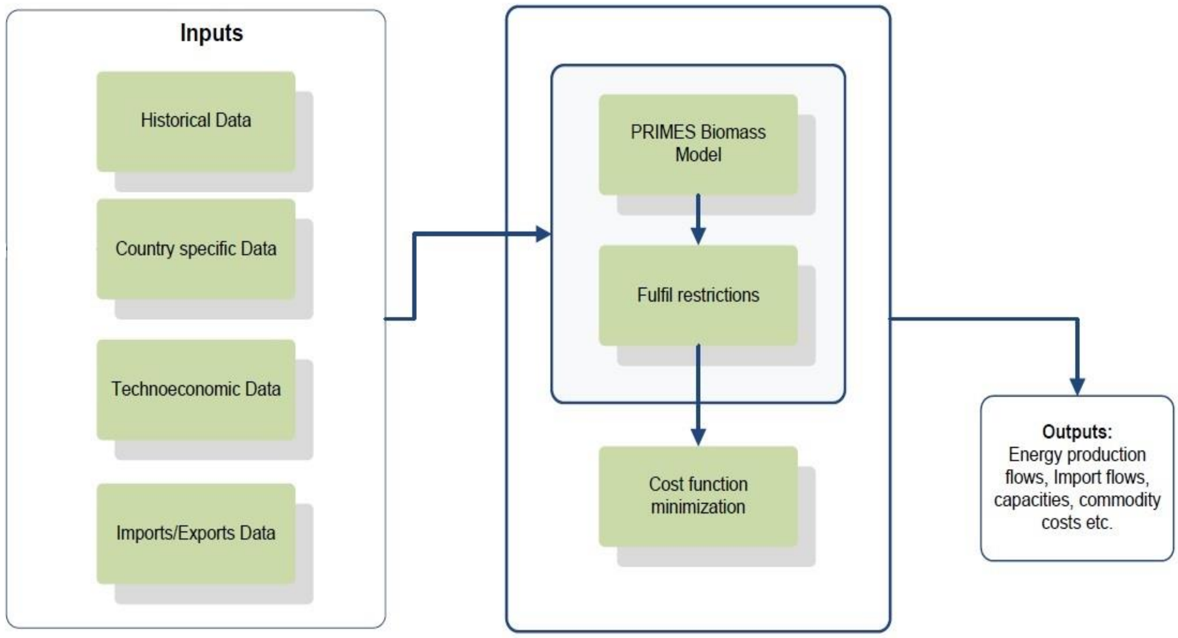

Figure 2. PRIMES BIOMASS MODEL STRUCTURE (Capros, 2012)

Primes Biomass can be used in education of ECO-BOT's user. After specifying how much the user generates sewage sludge (based on example on bills from local water supplier), under condition of proper utilization, program may calculate their transformation into energy (like Waste gas).

Table 14 Short synthetic description of the PRIMES BIOMASS model

Lp	Synthetic description of the model						
1	Purpose of the model	Energy demand	X	Energy Supply		Environmental impact	X
2	Geographical Coverage	EU27 Member States					
3	Sectoral coverage	Residential	X	Commercial	X	Other	
4	Time step	five year.					
5	Renewable Technology inclusion	YES					
6	Storage Technology inclusion	NOT					
7	Cost inclusion	YES					
8	Findings to ECO-BOT	Education of ECO-BOT's user how much energy can be gained from sewage sludge, under condition of proper utilization					

5.2.2. Top-down models

In the first stage, following models from a group of macro scale models of top-down were examined for suitability to the ECOBOT:

- Micro-MELODIE,
- DTI,
- ERASME,
- MRN,
- MEFM,
- Kuwait model,
- ENERPLAN.

These models are of macroeconomic nature, so most of them are not directly applicable to creating Eco-Bot. Below, only two of them are presented to draw attention to technical aspects and variables used in those models that can be adapted to Eco-Bot.

DTI

The DTI model, which was created by the Department of Business, Entrepreneurship and Reforms of the United Kingdom (formerly the Department of Trade and Industry - DTI), is an example of a top-down approach. It is used to forecast energy consumption and future estimates of carbon dioxide emissions (Bhattacharyya, 2011).

The DTI energy model is a partial equilibrium model. It covers both supply and demand for electricity. The demand side consists of over 150 econometric equations of fuel demand for the real estate, transport, industry, service and agriculture sectors. The model has 13 end users who are divided into four main sectors: industry, transport, services and the country. Each sector of these end users is additionally disaggregated by fuels (Bhattacharyya i Timilsina, 2009).

This model requires a number of assumptions, mainly concerning fossil fuel prices, economic growth and demographics.

The structure of the model is presented in Figure 3, while the main variables of demand are presented in Table 15.

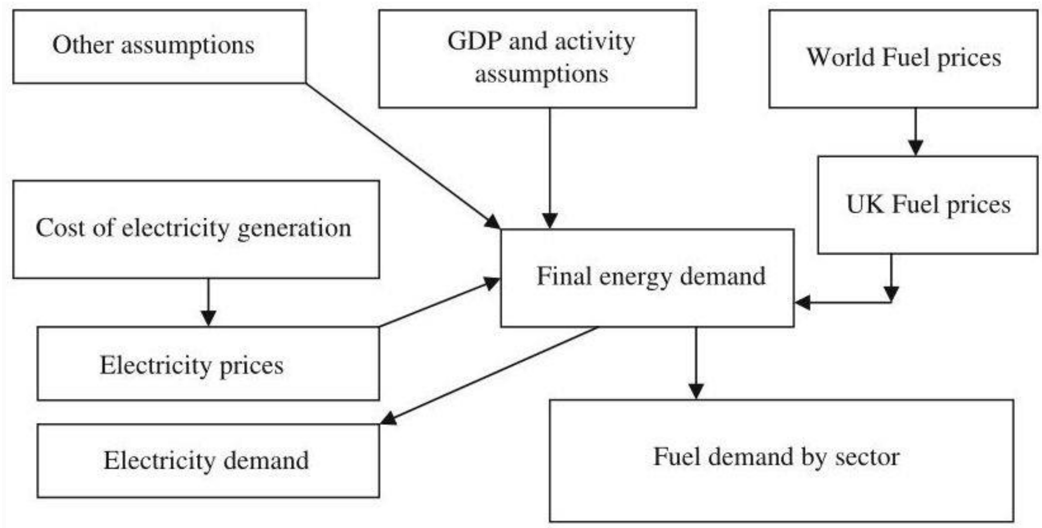

Figure 3: DTI energy model overview Source: (Bhattacharyya, 2011)

Table 15 Demand drivers of DTI model

Sectors	Activity variable	Price variable	Appliance stock	Weather	Other
Domestic	Real personal disposable income	Domestic energy prices	Major appliance take up	External temperatures	Number of households
Transport	GDP, OECD GDP	Petrol price, other fuel prices	Car ownership level, goods lifted, track		Population and number of households

			length		
Service	GDP	Service sector energy prices		External temperatures	Public sector share, employment
Industry	GDP	Industrial sector prices, fossil fuel prices, electricity prices			Physical output

Source: (Bhattacharyya and Timilsina, 2009)

As a national model, DTI is not easy to use in Eco-Bot. However, it is worth analyzing the use of variables related to the number of households, employment and fuel prices in the model.

Table 16: Synthetic description of the DTI model

No	Synthetic description of the model							
1	Purpose of the model	Energy demand	X	Energy supply	X	Environmental impact		X
2	Geographical Coverage	National						
3	Sectoral coverage	Residential		Commercial		Other	industry, transport, services, country	
4	Time step	Long term						
5	Renewable Technology inclusion	YES						
6	Storage Technology inclusion	NOT						
7	Cost inclusion	YES						
8	Findings to ECOBOT	Only some aspects related to the number of households, employment and fuel prices are important						

GEM-E3

The GEM-E3 is the General Equilibrium Model for Energy-Economy-Environment interactions, which represents both 37 regions of the world and 24 European countries. It provides detailed information on macroeconomics and its interaction with the environment and energy system. The model has been developed as a multinational collaboration project, partly funded by e.g. the Commission of the European Communities and by national authorities.

The model is characterized by (Capros at al. 2013):

- It covers all simultaneously related markets and represents the system at the appropriate geographical level, the subsystem - economy, energy, environment and the mechanisms of agent's behavior.
- It covers all production sectors and institutional entities of the economy.
- Energy production technology is represented by this model.
- It takes into account the prices of goods, services, labor and capital and calculates the equilibrium prices for these factors.
- It also determines the optimal balance between energy demand and supply and between emissions and pollution reduction.

The model put emphasis on [Capros at al. 2013]:

- The analysis of market instruments related to energy environmental policy, such as regulations, subsidies, taxes and emission permits. This analysis is used to assess world, national and sectorial policies
- The evaluation of the impact of programs and policies, including social equity, employment and cohesion for less developed regions.

The authors of report (EC4MACS 2012) write: "The model intends, in particular, to analyses the global climate change issue a theme that embraces several aspects and interactions within the economy, energy and environment systems. To reduce greenhouse gas emissions it is necessary to achieve substantial gains in energy conservation and in efficiency in electricity generation, as well as to perform important fuel substitutions throughout the energy system, in favor of less carbon intensive energy forms."

Figure 4 gives the basic micro-economic scheme of the model

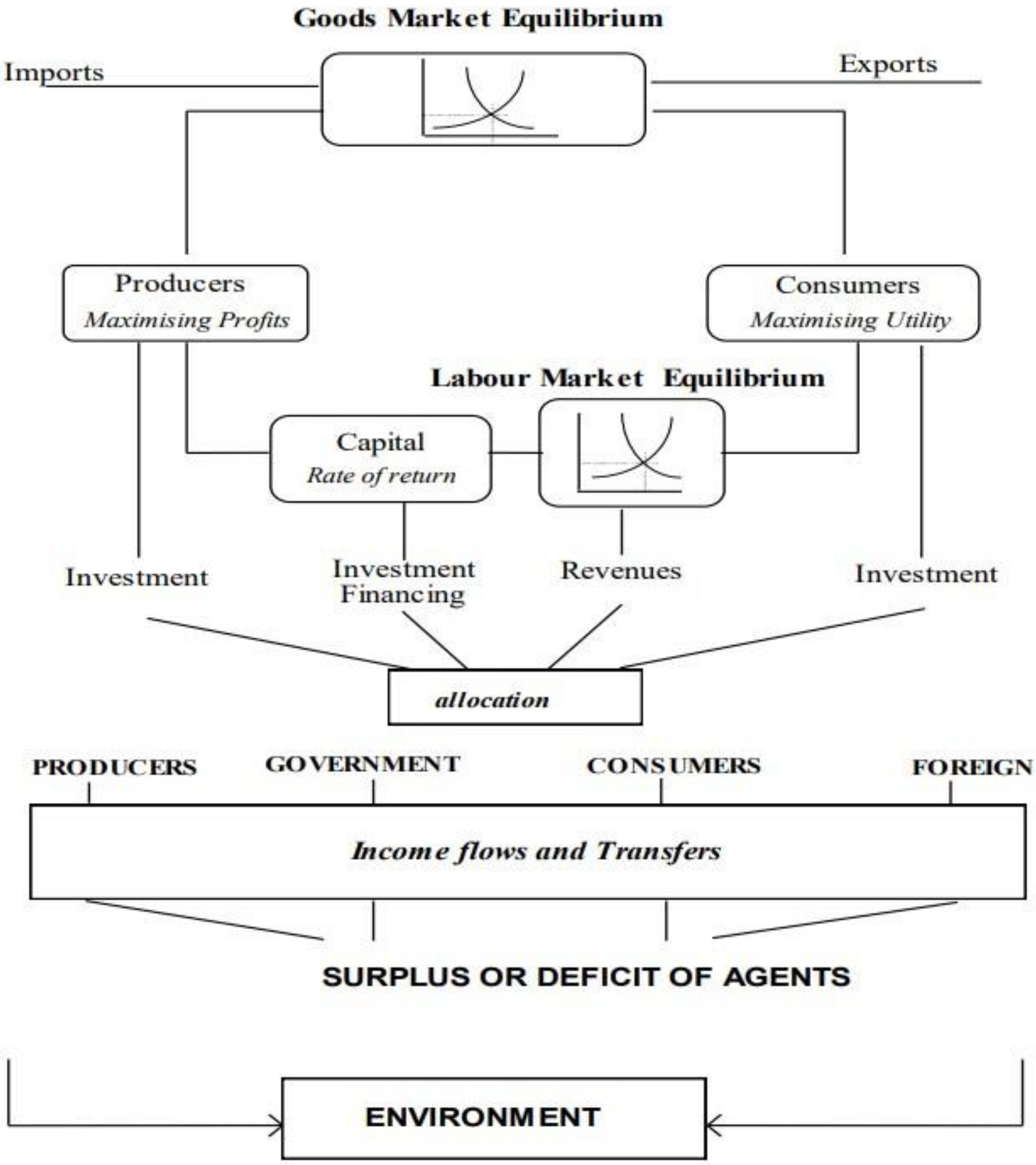

Figure 4: GEM-E3 model design Source: (EC4MACS, 2012)

As a global and national model, GEM-E3 is not easy to use in Eco-Bot. However, it is worth analysing solutions related to efficiency in electricity generation, use of fuel substitutes and emission of pollutants. It is also worth paying attention to the technical aspects of the model construction, including the appropriate preparation and input of data to the model.

Table 17: Synthetic description of the GEM-E3 model

No	Synthetic description of the model						
1	Purpose of the model	Energy demand	X	Energy supply	X	Environmental impact	X
2	Geographical Coverage	Global, national, sectoral					
3	Sectoral coverage	Residential		Commercial	X	Other	X
4	Time step	Long term					
5	Renewable Technology inclusion	YES					
6	Storage Technology inclusion	NOT					
7	Cost inclusion	YES					
8	Findings to ECOBOT	Only in some aspects, e.g. solutions related to efficiency in electricity generation, use of fuel substitutes and emission of pollutants. Also some technical aspects of the model construction and preparation of data are important.					

5.2.3 Hybrid energy models/modelling tools

This part of the report will be devoted to the hybrid energy modelling tools distinguished by analytical approach they apply. Hybrid models are the result of long-lasting discussions on the pros and cons of both conventional (bottom-up and top-down) approaches to modelling their origins that can be tracked to the beginning of the 1990s. It was then when, in addition to conventional models, the first attempts to combine both approaches began to appear in order to better model the actual state of affairs and to compensate for the limitation of each of the conventional approaches. The hybrid approach to modelling introduces moderate technological detail (characteristic for bottom-up models) into macro-economic approach (characteristic for the top-down models). It started simple: certain models started to include some aspects previously linked with the opposite one, i.e. BU models started to incorporate the macro-economic feedback into their calculations or TD become more detailed in the technological aspects of their structure (Hourcade et al., 2006).

Due to the approach used to create a given model, the hybrid models can be divided into models as follows (Böhringer & Rutherford, 2008):

1. models that link two independently developed, full-featured models,
2. models that put more emphasis on one of the approaches in a combined system,
3. models that integrate both approaches into a single framework.

At times in the literature from the field, the first approach (a coupling of existing bottom-up and top-down models) is described as a ‘‘soft-linked” hybrid models and the third approach (a single integrated model) is described as a “hard-linked” hybrid models (Helgesen, 2013).

A large part of currently used models (especially those developed after 2010) are hybrid models. Due to their quantity of developed models and uncertainties as to the classification of some of them, this study is not an exhaustive list of all existing hybrid models. After through consideration of different hybrid models:

- CIMS,
- E3MG,
- ENPEP,
- LEAP,
- MARCAL-MACRO,
- MESAP,
- NEMS,
- OSeMOSYS,
- POLES,
- SAGE,
- WEM,
- WEPS+
- WITCH.

on the basis of desk research of publicly available resources such as model descriptions, model documentations, model websites, scientific papers, report and deliverables from considered models it was decided to present those, that despite being the tools mostly used for analysis of the energy demand on the broad (global, regional or national scale) included elements that could be related for the purpose of the ECO-BOT. Those examples are one global (POLES) scale and one national scale (NEMS) energy demand models.

Prospective Outlook on Long-term Energy Systems – the POLES model

The POLES was initially developed in the early 1990s by Institute of Energy Policy and Economics (IEPE) in Grenoble, France and since then it is constantly being developed in cooperation with Enerdata and the European Joint Research Centre (IPTS). There are different versions of this model, the described version named POLES-JRC (simulation software) is used for the JRC Global Energy and Climate Outlook series (GECO) (Keramidas et al., 2017). POLES is a recursive, disaggregated global energy model, that allows for analysis and simulation of the entire energy system. Model allows to prepare long-term energy supply and demand scenarios, including related emissions, both for different countries and regions and on the global level. It also includes different renewable energy sources and technologies, and allows for simulating their role in future, using concepts of learning curves and niche markets (Keramidas et al., 2017). Figure 5 presents the schematic representation of the POLES-JRC model architecture.

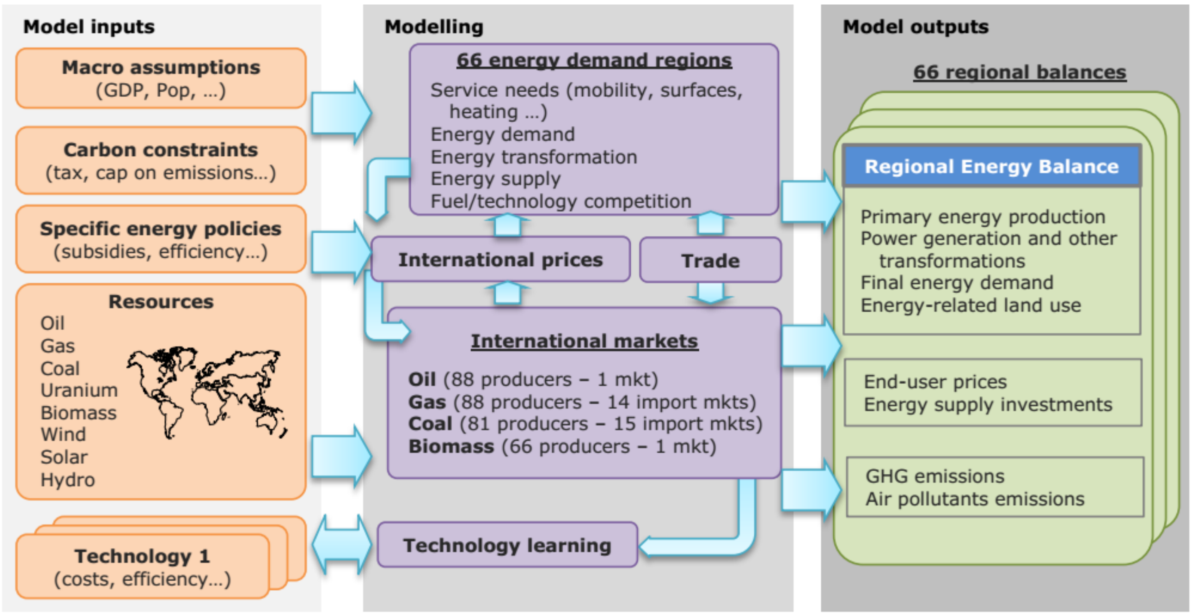

Figure 5: Schematic representation of the POLES-JRC model architecture: Keramidas et al., 2017

The demand side in the POLES-JRC model is analysed using a disaggregated end-use approach. The demand is segregated into homogeneous groups that are represented explicitly by four sectors: industry, buildings (residential and services), transport and agriculture. Uniform approach across the sectors concerning the equipment (new and in-use) in form of standard demand equation is used (combining activity effect, price effect, autonomous technological trend). The residential sector in this model is considered jointly with the service sector on the basis that they share certain common characteristics – they both are related mainly to buildings and activities taking place indoors. In modelling the energy demand for residential sector following factors are taken into consideration:

1. surfaces in residential building derived from the total number of dwellings and surface per dwelling (with three types of surface, associated to a specific consumption pattern: standard, medium and low consumption),
2. energy needs for space heating, water heating and cooking (with consideration of different installations, technologies and fuels used),
3. energy needs for space cooling, appliances and lighting (depending among the others on the income and autonomous technological trend).

The model is well-equipped to use as a tool for forecasting the effects of both different energy-related issues such as energy policies, impact and promotion of renewables and energy efficiency, energy security and climate-related issues at the same time. The POLES model may be used to provide detailed (quantitative, scenario-based) analyses.

Table 18: Synthetic description of the POLES model

Source: based on Keramidas et al., 2017.

Synthetic description of the model							
1	Purpose of the model	Energy demand	X	Energy Supply	X	Environmental impact	X
2	Geographical Coverage	Global (but split in regions)					
3	Sectoral coverage	Residential	X	Commercial	X	Other	X
4	Time step	Yearly					
5	Renewable Technology inclusion	YES					
6	Storage Technology inclusion	Only CCS					
7	Cost inclusion	YES					
8	Findings to ECO-BOT	As a global energy demand model it is not readily applicable for the ECO-BOT. The level of detail is not specific enough. Still the assumption about certain common characteristics for both residential and service sectors (and buildings) may be applied for the modelling purposes of ECO-BOT.					

Socioeconomic and economic model inputs about economic activity are very general and do not include behavioral factors. Different geographic locations are included but no factors concerning weather or specific needs resulting from climate are considered. As for the description of the energy demand side the conclusion is twofold. On the one hand the building sector is represented in too homogenous way – the division between residential and service sectors is not well pronounced. On the other hand different consumption patterns, installations, technologies and fuels are considered. Assumptions about common characteristic for both residential and service sectors (and buildings) may be considered as applicable for the ECO-BOT modeling purpose.

National Energy Modelling System - NEMS

NEMS is a large, regional, energy-economy-environmental model designed and mostly used by US Department of Energy, Energy Information Administration (EIA) to prepare the Annual Energy Outlook (Gabriel et al., 2001). NEMS is an integrated economic-energy model presenting the behaviour of energy markets and their interactions with the U.S. economy. The model aims at achieving supply/demand balance taking regional differences into consideration and reflecting factors such as existing energy policies and industry structure that may influence market behaviour (EIA, 2009).

NEMS was designed as a modular tool in order to better fulfil the needs of different components of the U.S. energy system. NEMS consist of following 13 modules: two conversion modules (electricity market and petroleum market), four end-use demand modules (residential demand, commercial demand, industrial demand, and transportation demand), one module to simulate energy/economy interactions (macroeconomic activity), one module to simulate international energy markets (international energy), one module that provides the mechanism to achieve a general market equilibrium among all the other modules (integrating module).The overall structure for the NEMS is presented by the Figure 6.

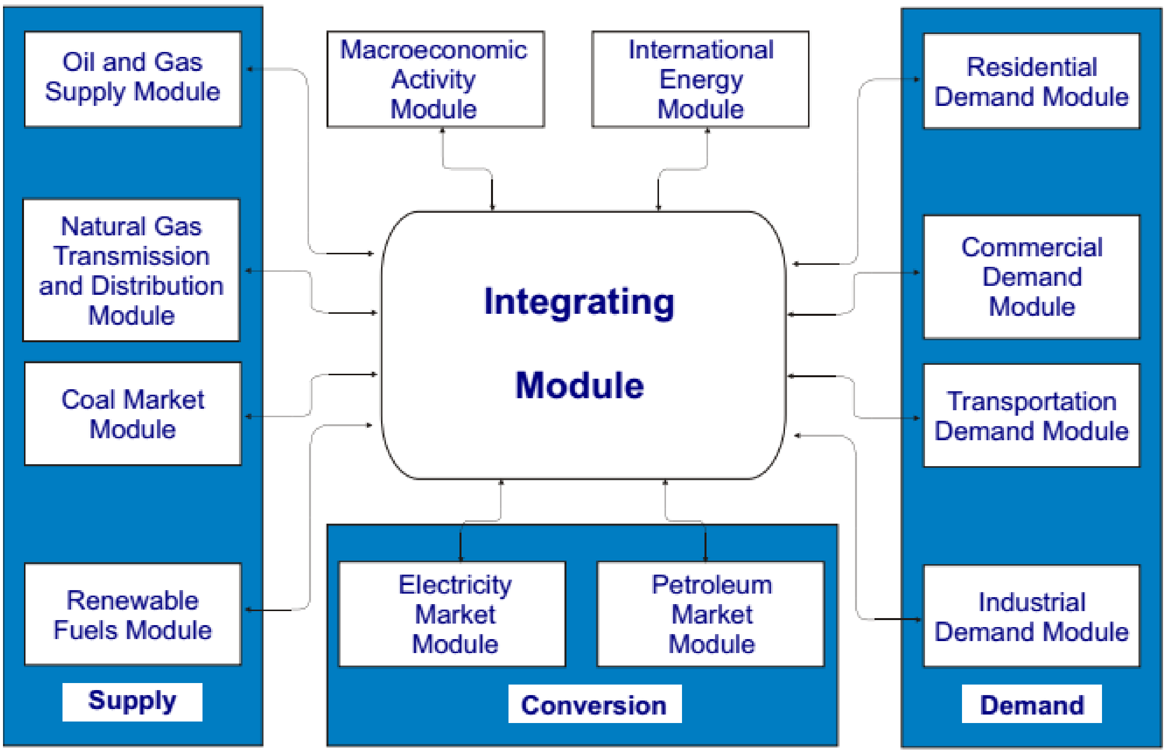

Figure 6: National Energy Modelling System: EIA, 2009.

Residential Demand Module (RDM) projects energy consumption by regions for different energy sources available to the end-users. RDM is a structural model that projects the energy demand based on projections from the residential housing stock and energy-consuming equipment. It interacts with the other modules and consist of six submodules: housing stock submodule, appliance stock submodule, technology choice submodule, shell integrity submodule, distributed generation submodule and fuel consumption submodule. Four categories of factors influencing energy consumption are taken into consideration in the RDM model. Those are: economic and demographic effects, structural effects, technology turnover and advancement effects, energy market effects. Only three types of housing is considered: single-family, multifamily and mobile homes but geographical distribution of the households is taken into consideration as it influences the needs for fuel and certain types of end services (e.g. heating or cooling) (EIA, 2017b).

Commercial Demand Module (CDM) fulfils similar role to the RDM but for the commercial sector. And similar to RDM interacts with other NEMS modules both for obtaining inputs needed for calculations and providing outputs needed for overall modelling results. It consist of 3 submodules: floorspace submodule, service demand submodule and technology choice submodule. Key variables taken into consideration include: census division, building type (11 types), end-use services and fuel. Adjustments for consumer risk are also included as a discount rates used while making purchasing decisions (EIA, 2017a).

Table 19. Synthetic description of the National Energy Modelling System (NEMS) model

Source: based on EIA, 2009.

Synthetic description of the model							
1	Purpose of the model	Energy demand	X	Energy Supply	X	Environmental impact	X
2	Geographical Coverage	National (but split in divisions)					
3	Sectoral coverage	Residential	X	Commercial	X	Other	X
4	Time step	Yearly					
5	Renewable Technology inclusion	Yes (but with some exceptions, e.g. tidal is not included)					
6	Storage Technology inclusion	Not					
7	Cost inclusion	Yes					
8	Findings to ECO-BOT	As a national energy demand model it is not readily applicable for the ECO-BOT. The level of detail is not specific enough. Still there are some assumptions in Residential Demand Module and Commercial Demand Module that may be applicable for the modelling purposes of ECO-BOT, e.g. geographical division and climate zones influencing demand for certain types of end-services (cooling, heating) and fuel consumption.					

The level of detail of information's used as inputs for the modelling purpose of the NEMS is far greater than those of the global level models. It allows for more detailed scenarios but it also requires more data specifically for those purposes. Different geographic locations are included and factors concerning weather or specific needs resulting from climate are considered. As for the description of the energy demand side the conclusion is twofold. Firstly, the residential sector is represented in too homogenous a way, only three types of housing are considered, but the end services and equipment needs are more pronounced (including consumers approach to risk while making decisions about technology choices, equipment performance, costs, efficiency). Complaints about the insufficient level of detail concern also the commercial sector - the number of building types is higher (11) but as it is also a more diversified sector that is not enough. Still some assumptions about building characteristic, technology choices, climatic factors and factors affecting consumer choice may be considered as applicable for the ECO-BOT modeling purpose.

5.3 Mezo level models - Household/buildings energy consumption models

In contrast to their "big" brothers, macro -models covering the whole of the economy, member states or entire regions of the world, mezo-energy models describe individual sectors like housing, residential and others. Can be a component of macro models. The following models are bottom-up models.

The BREHOMES

Model BREHOMES (Building Research Establishment Housing Model for Energy Studies) developed by Shorrock and Dunster is considered to be one of the first estimates of the household energy consumption and carbon emissions (HECCE). It based on the bottom-up modelling approach. Model needs a large amount of data because it works on very disaggregated level. Structure of the BREHOMES is shown on the figure 7. For calculations the energy consumption for individual dwellings BREDEM model is used, especially the annual version "BREDEM-12 annual". (Gupta, 2009). Methodology of BREDEM was described in previous chapter.

Information in BREHOMES is supplied by various data sources, some of which are indicated at the top left of figure 7.:

- HCS- Housing and Construction Statistics;
- FES -Family Expenditure Survey;
- EHCS- English House Condition Survey;
- GfK – information from market research company GfK;

- DECADE-Domestic Equipment and Carbon Dioxide Emissions (team at the University of Oxford).

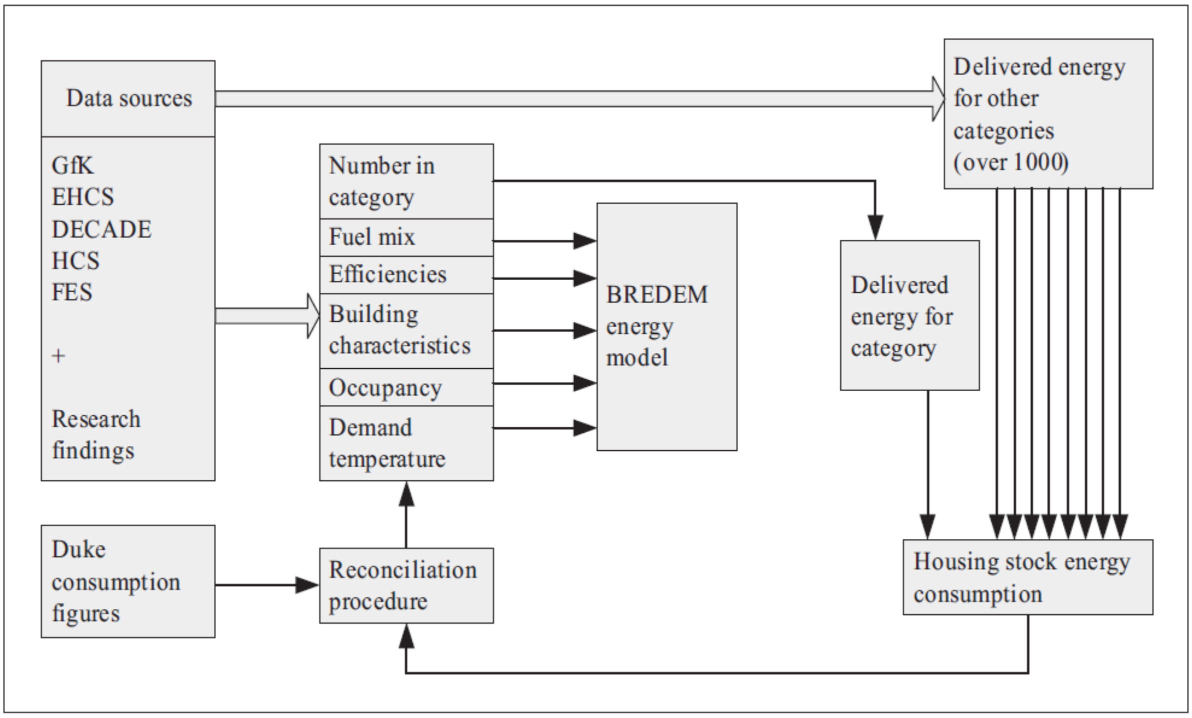

Figure 7: BREHOMES model architecture (Adapted from Shorrock and Dunster, 1997).

The model calculates the annual volume of energy consumption and CO_2 emissions at the national level. The model uses two scenarios (Oladokun et al. 2015):

- Baseline business-as-usual (BaU) called „reference";
- Efficiency scenario.

The first versions of model was based on year 1990 and provided for the trends for 2010. In later versions, based on the year 1993, trends can be generated to 2050. The model is used as a tool to evaluate policies and programs by Department for Environment, Food and Rural Affairs (DEFRA) UK.

Table 20. Short synthetic description of the BREHOMES model

Lp	Synthetic description of the model						
1	Purpose of the model	Energy demand	X	Energy Supply		Environmental impact	X
2	Geographical Coverage	UK					
3	Sectoral coverage	Residential	X	Commercial		Other	
4	Time step	Year					
5	Renewable Technology inclusion	YES					
6	Storage Technology inclusion	NOT					
7	Cost inclusion	NOT					
8	Findings to ECOBOT	To realise the user what is the demand for energy and CO_2 emissions of entire housing stock on UK or UE level					

Diao's model – energy consumption model used behaviour pattern clustering

The presented model was proposed in the paper [Diao et al., 2017]. It is an attempt to combine bottom-up modelling (model of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)), k-mode clustering, neural networks and stochastic simulations. The purpose of this model is to predict energy consumption in residential buildings.

The model is based on the assumption that the physical properties of the building, the behavior of residents, the external environment and the interaction between these factors have the greatest impact on energy consumption. In order to determine the total energy demand in the building, the bottom-up technique was used, however, its innovation is the way of modelling the behavior patterns of residents. This model "integrates clustered behavior patterns with physics-based building energy estimation, which aggregates various energy-consuming components and assesses the sum of whole building consumption" (Diao et al., 2017).

To create behavioral patterns, k-mode clustering method, neural network modelling and occupant features from the Residential Energy Consumption Survey (RECS) were used. Whereas the Markov chain process was adopted to estimate the annual behavior profiles.

The diagram of the model's operation is shown in the figure 8.

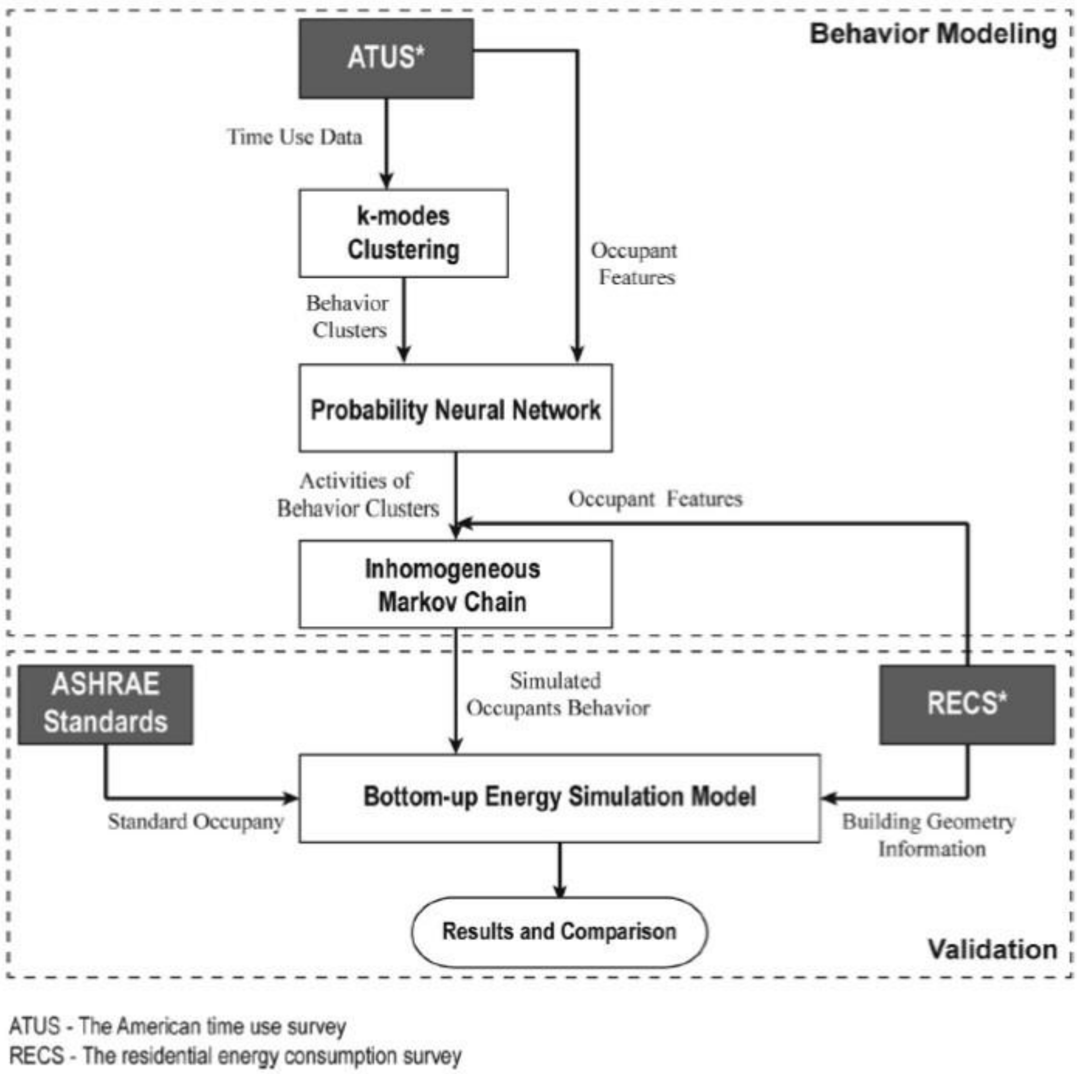

Figure 8: Overview of the proposed behavior simulation model Source: [Diao et al., 2017]

In addition to the variables responsible for the behavioral profiles of residents, the model introduced a number of other factors that characterize the physical properties of buildings (e.g. area, number of stories, material and equipment) and the weather data (e.g. typical hourly dry bulb temperature, global horizontal solar radiation, ground temperature).

Moreover, the model considered energy consumption in the case of heating, cooling, ventilation, lighting and other home appliances.

This model is based on data from the American Time Use Survey (ATUS), but **it is worth analyzing because both variables and statistical methods used in this model can be treated universally and adapt in the Eco-Bot**.

Table 21: Synthetic description of the Diao's model

No	Synthetic description of the model						
1	Purpose of the model	Energy demand	X	Energy supply		Environmental impact	
2	Geographical Coverage	local community, single-project					
3	Sectoral coverage	Residential	X	Commercial		Other	
4	Time step	Short, medium and long term					
5	Renewable Technology inclusion	NOT					
6	Storage Technology inclusion	NOT					
7	Cost inclusion	NOT					
8	Findings to ECOBOT	Methodology – k-mode clustering for to segmentation of building occupants' behavior, nonparametric methods like neural network and Markov chain process for estimate the behavioral profiles of residents. Variables - the physical properties of the building, the behavior of residents, the external environment characteristics					

The Cambridge Housing Model (CHM) model

The CHM is building physics-based bottom-up model for estimation of energy use and carbon emission of households in United Kingdom. It was developed as a Microsoft Excel model and uses for input's data from various official sources like English Housing Survey (EHS) and Scottish House Condition Survey (SHCS) or available climate data. It uses calculations formulated and established by SAP 2009 (BRE, 2011) and BREDEM engine. It was used in preparation of energy use estimates by the Department of Energy and Climate Change (DECC) – it replaced the Building Research Establishment Housing Model for

Energy Studies (BREHOMES) – and it now feeds into the National Household Model (NHM).

Housing data, climate data and B Physics Parameters are used to calculated the energy performance of dwellings (Fig. 9). Certain assumptions about the prevalent use of end-technologies and most popular types of fuels used in calculations are based on the overall characteristics of British building stocks. The model was not conceived for the calculations on the national or subnational level and certain adjustments were made original calculations (Hughs et al., 2013).

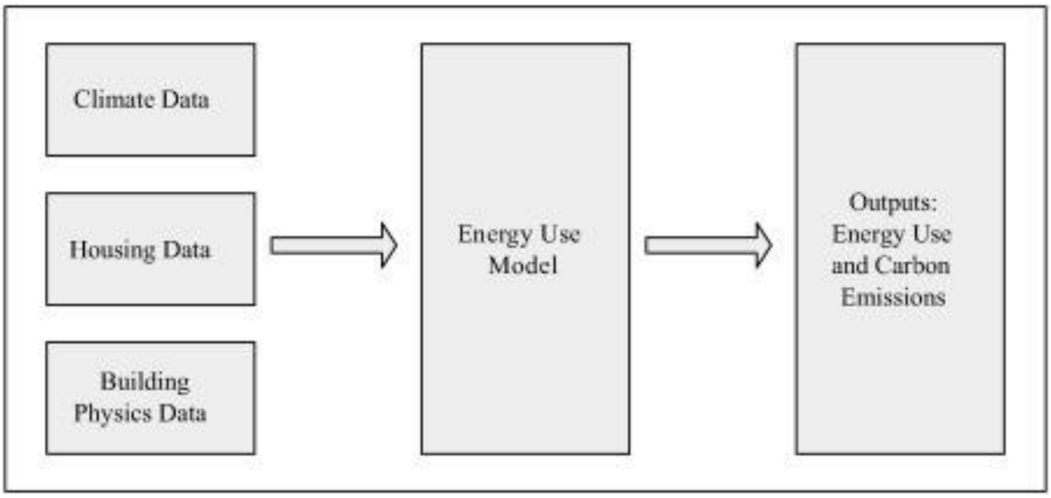

Figure 9: Schematic representation of the CHM model architecture: Oladokun & Odesola, 2015.

The amount of data, both relating to the characteristics of the building, end-use services and external (climate and weather) allowed for detailed information about energy consumption (and carbon emission) according to fuel and end-use, that were representative for given dwelling types. As all calculations were performed in the excel the results and whole process was transparent and possible to replicate. The model documentation and model spreadsheet is available to the general public for use (DECC, 2015).

Table 22: Synthetic description of the CHM model

Source: based on Hughs et al., 2013.

Synthetic description of the model							
1	Purpose of the model	Energy demand	X	Energy Supply		Environmental impact	X
2	Geographical Coverage	Building stock on regional and national level					

3	Sectoral coverage	Residential	X	Commercial		Other	
4	Time step	Yearly					
5	Renewable Technology inclusion	Yes (but not all types)					
6	Storage Technology inclusion	Yes (but not all types)					
7	Cost inclusion	Yes (but not all types)					
8	Findings to ECO-BOT	As a domestic energy use model it is not readily applicable for the ECO-BOT. The model depends heavily on the available data from the official sources like household surveys. Another significant problem is the fact that the household appliances are not very well represented. The same goes for behavioural factors. On the other hand the detailed description of housing stock and climate factors may be applicable for the modelling purposes of ECO-BOT					

Although this model cannot be readily transferred for the ECO-BOT purposes as it does not include behavioral factors and takes only general assumption about household appliances and their uses there are some factors worth considering for the elaboration of the ECO-BOT modelling – primely the building physical characteristic that are affecting the energy performance of the given building and weather and climate factors that will influence the behaviors of people living in a given building and making decisions concerning implementation of different technological solutions and later on about their usage.

National Household Model - NHM

National Household Model is a currently used analytical and modelling tool for estimating domestic energy use and various factors influencing it in the UK. It is used by Department for Business, Energy & Industrial Strategy (BEIS) of which Department of Energy and Climate Change (DECC) become part in 2016. It uses similar assumptions, inputs and calculating engines as CHM (e.g. BREDEM, SAP, EHS, SHCS). It is an open source tool (documentation, data resources and most up-to-date version with source code) are available for the general public (BEIS, 2017).

It is far more sophisticated and flexible then the CHM as it is possible for users to set different scenarios, but doing so requires the knowledge of specialist scenario language (the proper user manual is also publicly available and adjusted for changes in particular program version (BEIS, 2017). It also includes more factors both describing the households (physical factors, geographical factors and socio-demographic factors) and external factors that may influence the energy demand (e.g. weather, taxation, fuel prices and even some behavioural aspects) (CSE, 2018).

Table 23. Synthetic description of the NHM model

Source: CSE, 2016.

Synthetic description of the model							
1	Purpose of the model	Energy demand	X	Energy Supply		Environmental impact	
2	Geographical Coverage	Flexible: from single building to national level					
3	Sectoral coverage	Residential	X	Commercial		Other	
4	Time step	Yearly					
5	Renewable Technology inclusion	Yes (but not all types)					
6	Storage Technology inclusion	Yes (but not all types)					
7	Cost inclusion	Yes (but not all types)					
8	Findings to ECO-BOT	As a domestic energy use model (as the CHM) it is not readily applicable for the ECO-BOT. Similar to the CHM it depends heavily on the available data from the official sources and the household appliances are not very well represented. But a lot more factors are included in the NHM than in the CHM, the major difference is the inclusion of socio-demographic that may provide better representation of the end-users behaviours concerning the energy use. Also taxation, fuel prices and capital costs of technology are factors indirectly influencing the energy use of households.					

Although this model cannot be readily applicable for the modelling purposes of the ECO-BOT it includes far more factors that may be potentially important than other described models. Inputs used for the purpose of scenario preparations by the NHM consider both factors directly and indirectly influencing the household energy consumptions. The list of factors may be used while preparing the inputs requirements for the ECO-BOT modelling purpose. But it should be remembered that it is necessary to take fuller consideration of home appliances and their usage and different behavioral factors influencing the energy consumption.

synPRO

synPRO is a stochastic bottom-up model that is used “for generating synthetic electric load profiles for German households” (Fischer et al., 2015). Ultimately, the described model is to assess the household demand for electricity of all possible devices (used for cooking, cooling, heating, electric vehicles), the initial version applies only to domestic electrical appliances used for non-thermal purposes. Electric load profiles generated by the model take into account the following factors: consumption habits of residents, characteristics of buildings, available home appliances and potential seasonal fluctuations.

The model was developed using the experience derived from older stochastic and bottom-up models and includes many factors affecting the energy demand of the household that previously were not accounted for. Socio-economic factors (such as family status and situation, working patterns, age) are considered in addition to the building characteristic, available household appliances and habits related to their use. Also the time distinction is far more accurate than in previously described models both in case of profiling days (e.g. weekdays, Saturdays and Sundays) or the time step used for measuring household appliances energy consumption. In case for assessing energy consumption for household appliances equipment profile, frequency od use, time of use and duration of each occurrence was accounted for.

Table 24. Synthetic description of the synPRO model

Source: Fischer et al., 2015.

Synthetic description of the model							
1	Purpose of the model	Energy demand	X	Energy Supply		Environmental impact	
2	Geographical Coverage	Generalizations based on individual households					
3	Sectoral coverage	Residential	X	Commercial		Other	
4	Time step	Very detailed: sub-minute level (10s intervals) but in the model verification 1 hour intervals were used					

5	Renewable Technology inclusion	Not included
6	Storage Technology inclusion	Not included
7	Cost inclusion	Not included
8	Findings to ECO-BOT	This model is highly relevant for the ECO-BOT modelling purpose – the amount of highly detailed data allows for profiling the households energy use with focus on short time periods and accounting for different (and relevant) socio-economic, technical and behavioural factors. The main drawback of this model from the ECO-BOT perspective is the fact that data obtained from smart meters were not used.

The great amount of various data (socio-economic, technical, behavioural, seasonal) used as inputs for generation of the electric load profiles allows for generation of very detailed profiles that can be used for different reasons, among others as a basis for advising on more energy efficient behaviours of the household residents – that said this model is highly relevant for the ECO-BOT modelling purposes, even though it does not use data obtained from smart meters. The validation of the model against data from German households covers yearly and daily electric consumption with great level of accuracy, but it should be remembered that the described model does not account for thermal-electric heat generating technologies, and even taking into account seasonal fluctuations, extreme events (like state holidays) are not so well represented.

Integrated energy-saving behaviour model of casual relations

The model was developed as a support tool for local government actions and interventions oriented on promoting more energy efficient behaviours among Netherlands household residents. Latent class model (LCS) was used for segmentation based on observed factors and individual characteristic of the residents. Data for modelling purposes were obtained form residents through the online questionnaire. Respondents were asked set of questions concerning preferred type of intervention, energy-use behaviours, knowledge, motivation, previous experience, undertaken investments and others. The developed model takes into consideration contextual factors (possible outcomes of energy-saving aimed interventions and their results) and individual factors (socio-demographic, financial and behavioural) (Han et al., 2013). The structure of the model is presented by Figure 10.

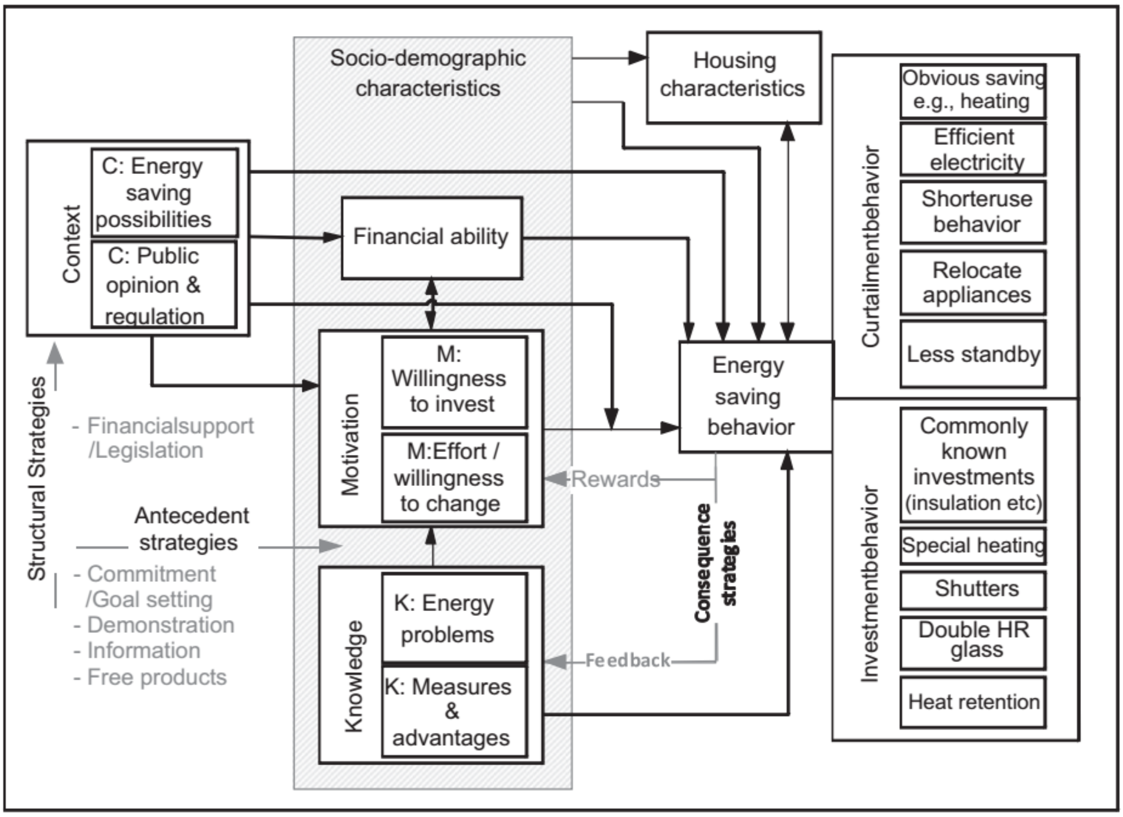

Figure 10: Schematic representation of the energy-saving behaviour model: Han et al., 2013.

Respondents were divided into four segments based on their individual characteristics and preferences. All groups differ significantly from each other basic on their average profile and are more prone to react to different types of energy-efficiency promoting interventions (Han et al., 2013). Nonetheless the model requires further research and adjustments as it is strongly sample and situation dependent – the respondents are only from one municipality in Netherlands so different factors should be taken into consideration when applying it for modelling of other groups of residents. Also detailed household characteristics were not taken into account, as the lifestyle choices of the residents.

Table 25. Synthetic description of the energy-saving behaviour model

Source: Han et al., 2013.

Synthetic description of the model							
1	Purpose of the model	Energy demand	X	Energy Supply		Environmental impact	
2	Geographical Coverage	Generalizations based on individual households					

3	Sectoral coverage	Residential	X	Commercial		Other	
4	Time step	Does not apply to this model					
5	Renewable Technology inclusion	Not included					
6	Storage Technology inclusion	Not included					
7	Cost inclusion	Yes (but not all types)					
8	Findings to ECO-BOT	Some aspects of this model may be relevant for the ECO-BOT modelling purpose – the inclusion of contextual factors accounting for the motivation, knowledge and experience of household residents. Also the assumption about importance of socio-demographic factors like age and financial factors like income levels as important for reactions toward energy-efficient interventions may be useful for ECO-BOT purposes.					

The factors used for segmentation of the household residents in the case of this model may be useful for the ECO-BOT purposes, as this example shows that different factors (socio-demographic, economic, behavioural and others) may be better suited for different groups of residents even not taking into account characteristics of the buildings. It would stand to reason that if one group of possible future ECO-BOT users would differ (in this case household residents) such differences would be also observed in the case of commercial buildings' user group. Important drawback of this model is the fact that certain important modelling factors from the perspective of ECO-BOT were not included (technical characteristic of the buildings) in the inputs during development.

5.4 Micro level - consumer behaviour models/theories

Micro models are usually an integral part of the mezo models. They are responsible for the calculation of the ecological effect on the level of a single entity/building. They are necessary for the operation of models with a smaller level of accuracy that describe the entire sectors of the economy.

BREDEM

Building Research Establishment Domestic Energy Model (BREDEM) is a physical model used to estimate the amount of energy consumed in dwellings based on their characteristics. It also allows to use some behavioral factors. Methodology BREDEM is a kind of industry standard and is used in many models such as BREHOMES, EEP and SEP (Gupta 2009). The detailed methodology of the latest version, marked "BREDEM-2012" is available on the https://www.bre.co.uk/page.jsp?id=3176.

The output of a BREDEM-2012 is fuel requirements which can be converted to fuel cost or CO_2 emission. The program calculates various energy requirements and gains for end-users in dwellings like (among others) (Henderson 2015):

- Energy consumption for lights, appliances and cooking, requirements for water heating;
- Dwelling's specific heat loss, thermal mass;
- Renewable energy sources like the solar heat gain and the amount of electricity generated by photovoltaics and wind turbines;
- Space heating and the cooling energy consumption;
- The internal heat gain and the mean internal temperature.

Some data are behavioral and input by user :

- Proportion of light provided by low energy lamps
- Number of showers per day
- Hot water use per shower
- Number of baths per day
- Internal temperature for cooling

BREDEM 2012 is a monthly calculation methodology. For this reason, it is important to understand the parameters that change during the year and those that remain constant. BREDEM is a model used in the UK so most of the parameters are given for the above region. It seems, however, that its adaptation to the ECOBOT would be relatively easy. Example ot the specific (geographically) parameters it uses are (APPEDIX A of methodology):

- External temperature and solar radiation;
- Mean external temperature (°C) at typical height above sea level for region;
- Mean monthly wind-speed (m/s).

These parameters are generally available to most EU countries. Parameters like efficiencies for common heating system types, responsiveness of boilers and heat pumps seems to be similar in EU countries. Local guidelines for calculating the energy efficiency characteristics can be useful to estimate of certain parameters.

Table 26 Short synthetic description of the BREDEM model

Lp	Synthetic description of the model						
1	Purpose of the model	Energy demand	X	Energy Supply		Environmental impact	X
2	Geographical Coverage						
3	Sectoral coverage	Residential	X	Commercial		Other	
4	Time step	Month					
5	Renewable Technology inclusion	YES					
6	Storage Technology inclusion	YES					
7	Cost inclusion	NOT					
8	Findings to ECOBOT	To realise the user what is the demand for energy and CO_2 emissions of his building. The ability to optimize energy consumption and reduce CO_2 emissions for a single building					

Commercial sector energy modelling

Analysis of energy models at the meso and micro level often overlaps, the boundary between models is therefore fluid. Generalizing the assumptions of micro modeling, we create assumptions of meso models.

The commercial sector is not as well described as the residential sector in terms of energy efficiency. This is partly due to the large diversity of this sector, which includes various types of buildings used in service and retail sectors. We are talking here about SMEs (such as small cafes or florists) as well as large facilities such as hypermarkets or hotels serving up to several hundred guests at the same time. Each of the commercial use of buildings will have different requirements for the equipment needed to provide a given type of service as well as different energy needs. The requirements for the ice-cream parlour will differ from the requirements of a restaurant specializing in grilled dishes. Differences between the various types of use will be even greater, e.g. a hotel in a historic tenement house in the old town will differ significantly from a large-scale grocery store. Mostly because of those mentioned diversity, the attempts to develop the energy efficiency models for commercial sector are not very advanced, and usually are overly simplified and require a lot of adjustments to the particular building (Vujošević and Krstić-Furundžić, 2017) or are overly generalized and made with the use of one of the macro-models, e.g. modelling of Italian hotel sector with the use of LEAP model (Bianco et al., 2017).

Nevertheless, interest in more energy-efficient solutions in the commercial sector is high, as evidenced by projects at the EU and national level striving to identify the potential for energy savings in this sector.

The ComeON*Energy* (European Commission, 2017) project focusing on shopping malls in the EU is an example of actions taken to increase energy efficiency. The ComeON*Energy* project allowed to identify typical features of shopping centers as well as technical and social inefficiencies affecting the overall energy-efficiency of this type of buildings. Four types of technical inefficiencies (lighting, HVAC, building envelope and architecture & design) similar to those that can be observed for different type of buildings use (both commercial and residential) were identified. But more important was the identification of the different groups of stakeholders that were the cause of the observed social inefficiencies. Three identified groups of stakeholders (owners & managers, tenants, customers) have different goals when it comes to using given building and their approach towards increasing its energy-efficiency varies greatly (owners & managers being those most aware and most interested). Basing on the findings the economic assessment tool (available on the project website) was developed. This tool can be used to generate (using provided information about building characteristic, types of activities, opening hours, technical solutions) recommendations about areas in which actions toward increasing energy-efficiency may be undertaken. Other developed tool shows aggregated data and forecasts for the retail sector in EU and Norway for year 2030 (with the focus mainly on shopping malls) (ComeON*Energy,* 2018). Unfortunately none of those tools is particularly relevant for the ECO-BOT modelling purpose as it is adjusted to only one type of commercial buildings (shopping malls), level of detail is low and social factors are not accounted for (even if the stakeholders behaviours were identified as a potential source of energy-inefficiencies).

Similar situations can be observed in the case of supermarkets, with majority of works focusing on identification of the common characteristic influencing the energy-use (Tassou et al., 2011, Ochieng et, al., 2014; Ríos Fernández and Roqueñí, 2018) or focusing on particular aspect or technical solutions affecting energy performance of a given building (Zlatanović et al., 2011). Even when a modelling attempt is undertaken it either provides very general conclusions (Arias, 2005; Spyrou et al., 2014; Braun et al., 2016) or describes a specific case (Mylona et al., 2017). Benchmarking or simulation tools are available for restaurants and hotels as well, e.g. EnergyPlus model or tools developed by NREL with funding from EU projects. Still modelling is usually done on a case to case basis for a given building and generalization of a given model for the given type of commercial buildings, like hotels, is difficult (Hotel Energy Solutions, 2011). It is reasonable to assume, that generalization for the whole commercial sector, taking into account its diversity will be even harder to achieve (Buso, Corgnati, 2017).

In case of the commercial sector, promoting more energy-efficient behaviours and habits will be substantially more difficult than in case of the residential sectors. Social and behavioural factors should be taken into consideration as in commercial areas of any type (hotels, shops, restaurants) a lot of different people interact with each other and with their environment (both staff working in a given place and their customers) and all of them influence the energy demand and performance of any given building. This diversity of the users should be stressed and accounted for during the ECO-BOT modelling process, as all potential stakeholders have different goals and most probably will react to different stimuli. Another issue for further consideration is the fact, that in the case of the residential sector, building stock is well described in the EU due to EPISCOPE and TABULA projects (EPISCOPE, 2018), while no such database exists for the commercial building stock. That fact together with the diversity of commercially used buildings is also an important factor/barrier to consider during the ECO-BOT modelling process.

Selected theories of consumer behaviour in relation to energy

The real challenge is to try to develop a holistic approach that takes into account the most complete set of factors affecting consumer behaviour that will combine aspects of individual energy consumption, economic aggregates and social factors. An approach like this will, therefore, combine the assumptions of traditional models (bottom-up, top-down, hybrid), with consumer behaviour models.

Van Vliet (2002) argues that: [Social-psychological models] "lack a proper scheme for analysing the interplay between 'action' and 'structure' or between 'micro' and 'macro' levels. Economic models […] do not pay attention to the 'motives' or 'reasons' of citizen-consumers behind a certain pattern of behaviour. Within the economic theory of 'revealed preferences', everything judged an 'irrational' factor is excluded from conceptual schemes" (Van Vliet, 2002, page 11).

Behavioural models are necessary to understand what consumers are doing and why. Such models vary considerably depending on the theory, concepts and applications (Axsen and Kurani, 2012). They consist of various factors that influence the behaviour and practices of consumption, and more importantly, the relationship between the various factors and the human element is dynamic, not static. It must be underlined here, that the aforementioned change over time, causing consumer behaviour and the consumption practices process to be somewhat irrational and to some extent unpredictable (EEA Technical report No 5/2013).

At this point, the report should list selected, existing consumer behavior models / theories that influence consumers' decision to save energy and change existing habits.

I. The RATIONAL CHOICE THEORY

It has been used in energy-saving research in the 1970s, with scientists using measures such as information campaigns and workshops as tools to highlight the benefits of energy savings at home (see, for example, Becker, 1978; Bittle *et al*., 1979). However, the theory of rational choice is tightly bound because it does not take into account the influence of factors such as habits, emotions, social norms, moral behaviour and cognitive limitations (Jackson, 2005).

II. The DIFFUSION MODEL OF INNOVATION (DoI)

DoI describes the process of social communication through both person-to-person and the media channels that influence individual decisions regarding the adoption of technology. The model assumes that decisions are a process with identifiable stages of transition from change of knowledge to behaviour change. Moreover, the decision-making process is initiated by previous conditions like perceived needs or social norms. In this model, both the adopter characteristics and an innovation's attributes influence how knowledge is formed into object-specific attitudes. These attributes are described in Table 27 as a relevant for residential energy use. Feedback from the later stages of the decision process to the initial stages here is both internal and psychological, external or communicative. To save energy, people at home need to know how energy behaviour and consumption are related and must be motivated to save. In this simplified model, the information is provided first, the incentives provide the latter, but only the feedback provides both (Wilson & Dowlatabadi, 2007). The Diffusion of Innovation theory leads to the segmentation of society. It divides people into five "adopter categories" based on their willingness to adopt innovations. These include 'innovators', 'early users', 'early majority', 'late majority' and 'marauders'. The sixth segment is outside the model: "change agents" who encourage innovation (Wilson & Dowlatabadi, 2007).

Table 27: Attributes of innovations that support adoption decisions, with examples from studies of residential energy use

Source: Wilson & Dowlatabadi, 2007

Attribute (from DoI) and its description	Example of attribute in a residential energy context
Relative advantage over the incumbent technology or practice (e.g., more convenient, flexible, cheap)	Cost savings, personal comfort, and family health from weatherization measures
Compatibility with existing needs or problems, prevailing social norms, and behaviour	Energy efficiency is unattractive if framed as a major deviation from behavioral norms
Complexity, i.e., the skills, capacity, and effort required to adopt an innovation	A perceived barrier to solar photovoltaic adoption
Trialability, e.g., whether innovations can be tested prior to adoption	Peer experience or social feedback is important to reduce uncertainty about irreversible

	weatherization measures; conversely, clock thermostats can be tested in situ
Observability, e.g., whether innovations are highly visible (to potential adopters)	Solar technologies have greater normative appeal than less visible measures such as home insulation

The main weakness of the DoI model is the linear representation of knowledge, awareness, intention and behaviour. It has the weakest explanatory power when the adoption is limited by situational factors such as lack of resources or access to technology. DoI also suggests that adoption barriers are the inverse of adoption drivers, but this cannot be assumed. The energy efficiency gap is a good example of these points. A homeowner can have a well-informed and positive attitude towards the low cost of weatherization measures and necessary resources, but may not translate it into action, even if the results are clearly beneficial and meet the perceived need (Wilson & Dowlatabadi, 2007).

III. The THEORY OF PLANNED BEHAVIOR (TPB) and The THEORY OF REASONED ACTION

TPB is an extension of an earlier the Theory of Reasoned Action in which attitudes and perceived social norms explain behaviour (compare Figures 11 and 12). This theory adopts a cognitive approach to explaining behaviour which centres on individuals' attitudes and beliefs. This theory is used in pro-environmental studies, including research on recycling, selection of travel types and choices related to energy consumption (Jackson, 2005). It has also been applied in other areas such as the breaking of smoking habits, in blood donation and in internet use (Kalafatis *et al.,* 1999). However, this model was used more to measure the relationship between attitude, intention and perceived behavioural control, not to measure real behaviour or changes in behaviour (Jackson, 2005; Kalafatis *et al.,* 1999).

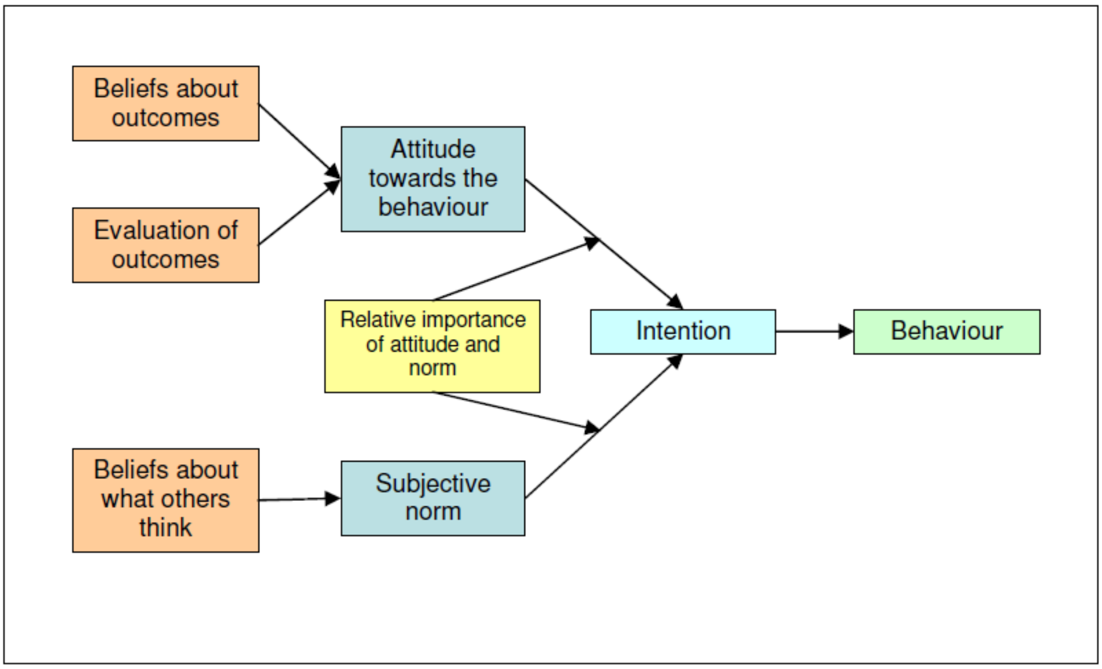

Figure 11: The Theory of Reasoned Action – model: Jackson, 2005

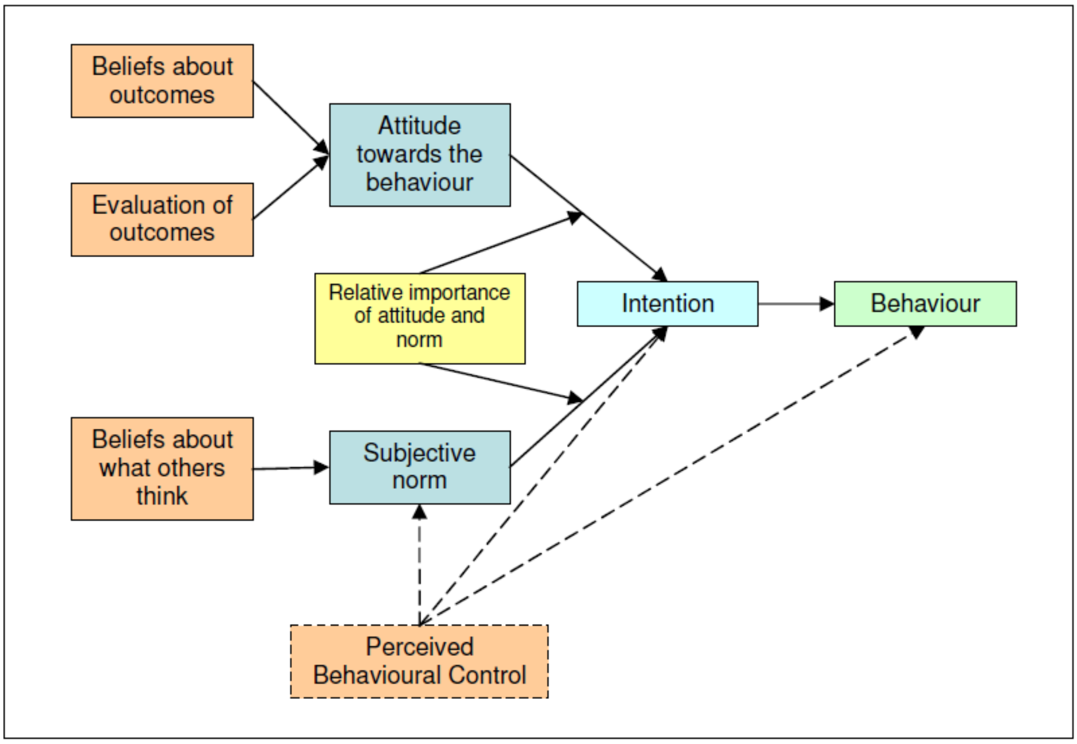

Figure 12: The Theory of Planned Behaviour – model: Jackson, 2005

The TPB model has added a perceived behavioural control as a third set of factors. They affect intention and behaviour and it is the perceived ease or difficulty with which a person will be able to perform a behaviour and is very similar to the concept of self-efficacy (Bandura, 1986, 1997; Terry *et al.,* 2000).

Perceived behavioural control in TPB is a subjective assessment of the impact of contextual factors on behaviour. This issue is further explored in social cognitive theories about self-efficacy, and about the views of individuals on how well they can work towards coping with a prospective situation. Self-efficacy can determine whether a person will persist with regard to a given task, and is influenced by past experience, the example of others and self-perceived coping skills. Strengthening self-efficacy by setting achievable goals and providing feedback clearly promotes energy conservation, for example, by changing the way devices are used (Wilson & Dowlatabadi, 2007).

IV. Stern's VALUE BELIEF NORM THEORY (VBN)

VBN (2000) is based on the principle that pro-social attitudes and personal moral norms are predictors of pro-ecological behaviours (Jackson, 2005). The VBN theory is based on the causal chain of five variables that define human behaviour (personal values, ecological worldview, adverse consequences for valued objects, perceived ability to reduce threat and pro-environmental personal norms (Stern, 2000, p. 412) (see Figure 13).

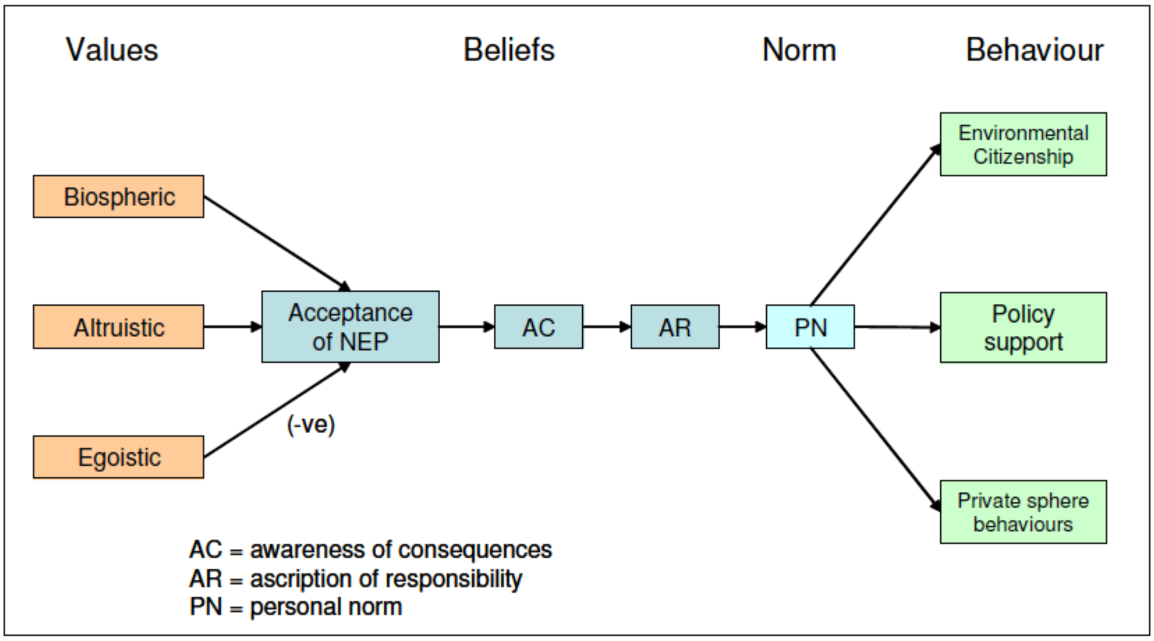

Figure 13: Stern's Value-Belief-Norm Model: Jackson, 2005

Beliefs are three variable causes. They lead from values to personal standards and activate environmental behavior. Herein, information can play an important role in influencing beliefs, which in turn can change the pro-ecological norms that ultimately lead to environmentally-relevant behaviours. The following causal factors influence the above determinants: attitudinal factors, contextual forces, personal capabilities and habit or routine, see Table 27 (Martiskainen, 2007).

Table 28: Causal variables influencing environmentally significant behaviour.

Source: Martiskainen, 2007

Causal variable	Indicators	Examples
Attitudinal factors	✓ Norms ✓ Beliefs ✓ Values	✓ General pro-environmental predisposition ✓ Personal commitment ✓ Product attributes
Contextual forces	✓ Interpersonal influence ✓ Advertising ✓ Monetary costs/benefits ✓ Regulation ✓ Support policies ✓ Status	✓ Persuasion within communities ✓ EEC ✓ High energy prices ✓ Grant programme ✓ Owned/rented house
Personal capabilities	✓ Knowledge and skills ✓ Availability of time ✓ General capabilities and resources / socio-economic data	✓ Understanding of the function of a micro-generation technology ✓ Information gathering ✓ Literacy, money and social status
Habit or routine	✓ Energy consuming behaviour	✓ Switching lights off ✓ Leaving appliances on standby

The models discussed earlier focus mainly on internal (attitudes, values, habits and personal standards) or external (fiscal and regulatory incentives, institutional constraints and social practices) affecting behaviours. However, in order to fully understand behavior, we also need to look at models that combine both internationalist and external perspectives (Jackson, 2005).

V. MODEL OF PRO-ENVIRONMENTAL BEHAVIOUR

On the Value Belief Norm Theory basis, Wilson & Dowlatabadi (2007) took up the issue of energy-related behaviours and decision-making, and had developed a MODEL OF PRO-ENVIRONMENTAL BEHAVIOUR. In this, they described the relationship between a) personal and b) contextual spheres, also c) between attitudes, habits, capabilities and external conditions (Figure 14).

This approach is an attempt to create a model of consumer behaviour common to socio-economic research. Wilson & Dowlatabadi (2007) introduce the possibilities of combining both socio-economic factors and psychological aspects as norms, beliefs and values. This reflects the necessary step to analyze consumer behaviour in a more holistic way by identifying economic, as well as behavioural factors. This leads to the integration of public economics, marketing and social sciences (Schmidt & Weigt, 2013).

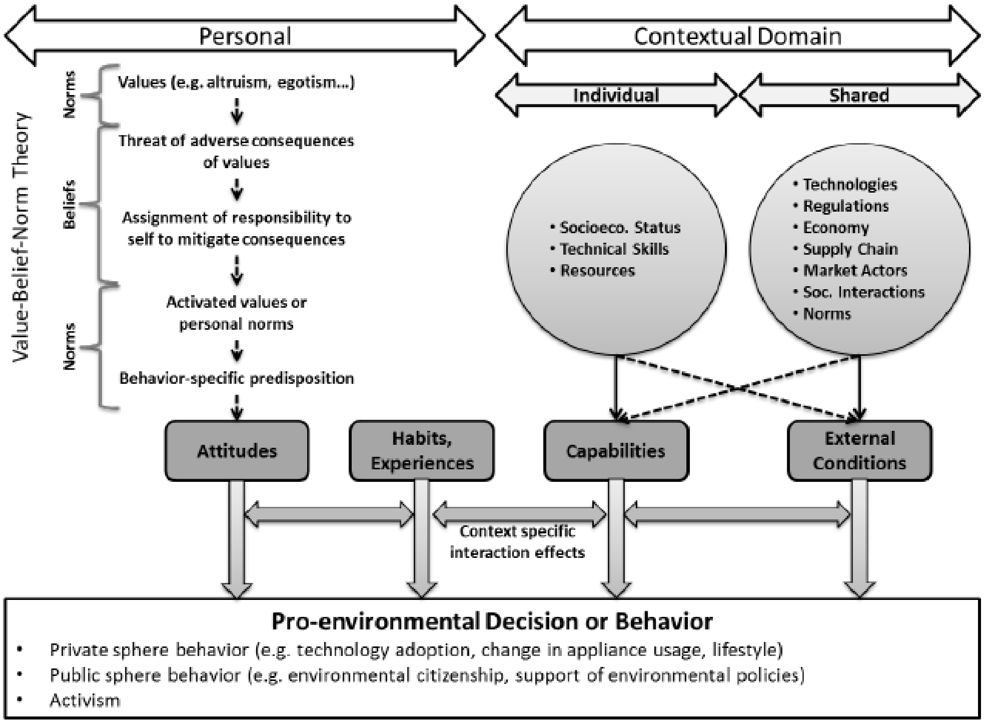

Figure 14: Model of pro-environmental behaviour: Wilson & Dowlatabadi, 2007; after Schmidt & Weigt, 2013

VI. The ATTITUDE-BEHAVIOUR-CONTEXT model (ABC).

This trend is also part of the ATTITUDE-BEHAVIOUR-CONTEXT model (ABC). It is based on the understanding that "behaviour is a function of the organism and its environment" (Jackson, 2005, page 92). In other words, behaviour (B) is an interactive result of personal attitude variables (A) and contextual factors (C). Attitude variables include beliefs, norms, values and tendencies to act in a specific way, while contextual factors include monetary incentives and costs, physical capabilities and constrains, social norms, institutional and legal factors. The main dimension of the model is the interaction between attitudes (internal) and contexts (external) (Jackson, 2005).

VII. TRIANDIS' THEORY OF INTERPERSONAL BEHAVIOUR (TIB)

However, the ABC model does not take into account the impact of the habits that are recognized by some other models, such as TRIANDIS' THEORY OF INTERPERSONAL BEHAVIOUR (TIB) (see Figure 15). This theory also highlighted the importance of past behavior on the present. In the Triandis' model, intentions, and habits affect behaviour that is also affected by facilitating conditions (external factors). According to TIB, behaviour in a given situation is a function of what a person intends, and what his/her habits are, as well as the situational factors and conditions in which a given person operates within (Jackson, 2005). This model has been used in pro-environmental studies, for example, in determining whether morality and habit influence the use by students of private automobiles (Bamberg & Schmidt, 2003). In addition, according to the Triandis' model, the intentions of a person are influenced by rational thought, as well as by social, normative and emotional factors. In more recent writings, the attempt to incorporate emotional antecedents into a model of action has received a lot of support (Bagozzi et al., 2002, Steg et al., 2001). However, in general, the more complex the model, the less it has been used in experimental research, hence, the Triandis' model, for example, has not been used as widely as some of the previously discussed models. Still, after an in-depth analysis of the assumptions of the model, the authors of the report chose this model as the basis for creating an individualized multi-factor model of consumer behaviour for the needs of the ECO-BOT project. This theory can be used as a framework for empirical analysis of the strengths and weaknesses of component factors in different situations.

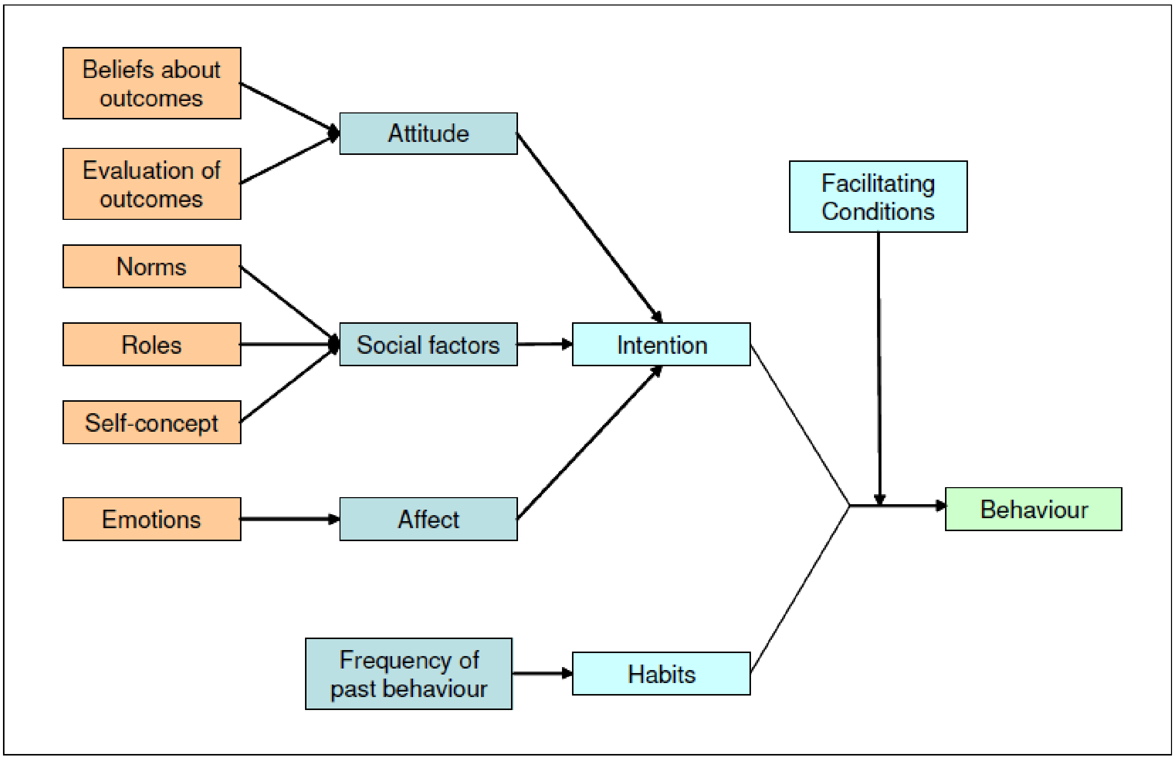

Figure 15: Triandis' Theory of Interpersonal Behaviour: Jackson, 2005

VIII. The HIERARCHY OF EFFECTS MODEL and THE STAGES OF CHANGE MODEL

Other behavioural models shift attention from psychological processes to social communication and feedback. The HIERARCHY OF EFFECTS MODEL, for example, examines how different communication channels (e.g., mass media or person to person) influence decision-making at each layer of the hierarchy, from information, knowledge, attitude and intention, to behaviour. In this model, media channels are presumed to have an impact on overall energy awareness, but have little impact on specific residential conservation behaviours. THE STAGES OF CHANGE MODEL, developed from study to addiction, emphasize the gradual and repeated strengthening of the individual's readiness for action. Herein, when individual people go through the subsequent stages of the decision-making process, their performance is improved, as is their ability to act. Accordingly, the intervention project should, thus, be focused on individual processes that affect change at every stage. An example is the behaviour of setting the thermostat. Hence, raising awareness is more important for decision-makers at an early stage, and strengthening the choices through feedback is more appropriate at later stages (Wilson & Dowlatabadi, 2007). The model was originally developed based on a meta-analysis of data on cessation of smoking. With time, it began to be used for other behaviours, usually in the sphere of health. However, the main value of the model lies in its segmentation of people, and this strategic approach is important in broader policy areas.

Lifestyles are another, but rarely used approach to explain behaviours related to energy consumption. The classical analysis of economic panels combined with a wider social analysis of the social environment gives an idea of the fragmentation in society, and thus the possibility of cooperation between economic and social sciences. Lifestyle is characterized by similar socio-demographic and socio-economic factors, as well as values, preferences and competences that cause specific patterns of behaviour (Schmidt & Weigt, 2013). Therefore, life styles have great potential to a) reveal energy-related decision-making processes and b) create the basis for joint socio-economic research. It describes social structures and supports the explanation of the aggregation of individual behaviours in common patterns of energy consumption. Reusswig *et al.* (2003) show a high share of lifestyle-related emissions, especially in western countries, while another fragment of literature shows the differences between groups of lifestyle in relation to individual energy consumption (Birch *et al.,* 2004; Wei *et al.,* 2007; Weber & Perrels, 2000, Lutzenhiser & Hackett, 1993: Fong *et al.,* 2007: Schmidt & Weigt, 2013).

Stephenson *et al.* (2010) develop a framework for energy culture to better understand energy consumer behaviour. This framework refers to the interaction between cognitive norms, material culture and energy practices. These three concepts are themselves interactive systems and are also influenced by broader systematic aspects. Sweeny *et al.* (2013) extend this framework to an internal level that includes the individual's motivation, which is related to the surrounding cultural level through barriers and supporting aspects. Stephenson *et al.* (2010) use this framework to identify areas of intervention in the household heating sector, while Lawson& Williams (2012) apply it for grouping energy consumers (Schmidt & Weigt, 2013).

6. Development of ECO-BOT Taxonomy

6.1 Findings concerning consumer analysis

The most important trends in consumer analysis include (Sagan, 2011); :

- Consumer theories related to the assumptions of economic rationality of behaviour, classical assumptions of *homo oeconomicus*, praxeological principles of human activity, theories of usability and calculational and ecological rationality (works by such authors, among others: B. de Mandeville; A. Smith, J. S. Mill, H. Gossen, S. Jevons, F. Y. Edgeworth, L. Robbins, J. Hicks, R. D. G. Allen, J. von Neumann, O. Morgenstern)

- Cognitive, psychological theories of information processing, creating beliefs and consumer attitudes (works by such authors, among others: R. Lutz, J. R. Bettman, M. Fishbein, I. Ajzen, S. S. B. Mackenzie, J. T. Cacioppo; R. E. Petty, J. Rossiter),

- Behavioural theories of consumer choice and preferences, sensory consumer models, analysis of symbolic consumption and consumer rituals (works by such authors, among others: G. R. Foxall, V. K. James, J. M. Oliveira-Castro, T. C. Schrezenmaier, G. McCracken, J. Sherry, M. Dingeny, J. O'Shaughnessy, E. Hirschmann, M. Hoolbrook).

These approaches do not cover a whole range of research in the analysis of consumer behaviour, they are related to the theoretical orientations that most strongly exploit quantitative analysis, and in particular structural modelling. These theories are the background for the construction of various measurement models, on the basis of which empirical analyzes of real consumer behaviour are carried out.

For ECO-BOT purposes, the biggest challenge is to create a model of energy consumer behaviour that will combine these approaches. **A correctly constructed model of ECO-BOT consumer behaviour should include: goals (maximization of usability), restrictions (consumer budget), incentives (internal, external), characteristics and predispositions of the consumer, the environment and the ability to predict the behaviour of individuals or groups**.

6.2 Modelling approaches used for explaining consumer's behaviour

In order to comprehensively explain the consumer's behaviour, the following model approaches are used (Wawrzyniak, 2015; see also table 29):

1. Structural - they reflect mental processes that lead to specific consumer behaviours and show the most important features and the relationships between them – this approach can be used in creating the ECO-BOT model, taking into account the preferences and individual/personality factors affecting the acceptance of new energy solutions by consumers.

2. Sequential - they emphasize the decision-making process, while explaining the determinants of these decisions. Consumption models of households are shaped by a number of economic, social, cultural and political factors. In Europe, the most important of these include: increased income and improved household wealth; globalization of the global economy with the opening of markets; increasing individualization of society; new technologies; marketing and advertising activities; dwindling households and, in some regions, aging population. These factors affect the consumer's behavior and are characterized by a high dynamics of change. Therefore, ECO-BOT should consider them and analyze them in detail, as changing external conditions often contributes to changing internal stimuli, which play an extremely important role in the acquisition and consumption process.

3. Stochastic - they are used to predict consumer behaviour using the probability theory, and also capture the dependencies between inputs - stimuli and outputs – reactions. As noted in the presented theories of behavioural economics, the behaviour of consumers is not accidental, so it is difficult to adequately present them using stochastic models. Therefore, methods based on the probability theory for ECO-BOT are not recommended.

4. Simulation- using them you can simulate consumer behaviour in changing conditions with the assumption of a numerically defined starting point. These models are based on computer simulation techniques, are computationally complex, require a multiagent modeling approach - not recommended under ECO-BOT conditions due to the overly complex analysis structure.

Table 29: Methods of research consumer behaviour - comments for ECO-BOT

Source: adopting after: W. Rand, R. T. Rust: Agent-Based Modelling in Marketing: Guidelines for Rigor. International Journal of Research in Marketing 28(3)/2011, s. 183.

Method	Advantages	Disadvantages	Notes for ECO-BOT
Analytical modeling	Generalizing, giving insight into strategic decisions made in companies or households	The results are difficult to compare with actual data, sometimes far-reaching simplifications are needed	Due to the purpose of the ECO-BOT project, this approach has to be supplemented with the study of individual behaviours and attitudes
Econometric and statistical modeling	Useful to find behavioural patterns based on real data and to make predictions about future consumers behaviour.	Rarely associated with behavioural theories at the level of individual consumers or companies. They require having the right kind of data for showing relations.	Economic rationality is not always taken into account by consumers when making decisions. Consumer behavior is conditioned, among others innate and acquired needs, conscious and unconscious processes as well as rational and emotional factors, hence this approach must be supplemented with behavioural models
Consumer behaviour experiments	They give a theoretical insight into consumer decisions and reactions to marketing actions	They rarely refer to large groups and / or examine complex consumer-consumer interactions.	Strongly recommended approach. The model can be created on the basis of the concept of consumer behaviour theory and take into account the assumptions of the ECO-BOT project. An advantage of the approach is the current use of experiments in the field of energy by researchers
System dynamic modeling	It allows a systematic examination of the whole complex interaction system	Behaviour rules must be described at the level of the entire system and studying the heterogeneity is difficult on an individual level.	Not recommended due to the complexity of the interaction and the overly complex shape of the model is not adequate to the needs of ECO-BOT
Multi-agent modeling	It allows you to analyze the theory of individual	Computational complex, results	Not recommended due to the complexity of

	consumers behaviour, and the results can be transferred on a larger scale.	cannot be generalized beyond the analyzed cases	calculations and the inability to generalize the results

6.3 Analyzed models factors useful for ECO-BOT purposes

The review of energy efficiency models allowed to distinguish models that are relevant for the modelling process for the needs of ECO-BOT. However, even for models that have not been recommended as the most suitable, attention should be paid to the factors contained in them that can be used when developing further tools and, finally, the ECO-BOT model itself. Factors that were found to be useful in further work on ECO-BOT modelling purpose are presented in table 30 divided into following categories: demographic; economic; behavioural; climate & seasonal; building characteristics; appliance characteristics; calculated.

Some of these factors describe the existing state, which at the given moment is not subject to change (e.g. demographic, economic categories), but which must be taken into consideration for the modelling purpose and preparation of recommendation for the ECO-BOT end users. Other factors, although they describe the existing state (for example, climate & seasonal; building characteristics) and either they are not subject to many or any changes (climate & seasonal) or their change requires time and expenditure on the part of the end user (building characteristics) should be taken into account because they are relevant for changing end users behaviour to more energy efficient one. Users can, for example, be encouraged to change the habits related to thermal comfort (change of heating behaviour in winter and less use of air conditioning in the summer season) or to undertake investments related to, for example, building insulation to reduce energy demand for heating purposes. The same goes for appliance characteristics category - even if it is also a description of the existing state - it can be changed more easily than previous ones. Possible change may occur both by making an investment and replacing the used equipment with a more energy-efficient one and by changing the users behaviours concerning the use of their devices - for example, creating a conscious habit of turning off the device when it is not used in any way. The category of behavioural factors is at the same hand the hardest to properly define in a way that will be useful for the ECO-BOT modelling purposes and the most important one as it allows for potentially the fastest way of improving energy efficiency in all kind of buildings (both residential and commercial). The last category – calculated, describes the set of assumption made for the modelling purpose in order to simplify the model – it will also be important for the ECO-BOT purposes as some presumptions are required in order to made the process of interaction between the ECO-BOT and end user more convenient and user friendly.

In creating the model of energy consumer behavior for ECO-BOT, modern non-parametric modeling will be used, ie classification trees, random forests, support vector machines. Classic parametric modeling has many limitations and assumptions that are unlikely to be met in the case of Eco-Bot. In addition, non-parametric methods are more flexible, more accurate and allow taking into account the quality variables in the model. However, classic models are still interesting in the context of preparation for Eco-Bot design, because they show what variables should be used for modeling. In general, the methodology used in classical models is not very important in the case of ECO-BOT, but the model approach presented in the previous chapters will be used as an inspiration to choose a variable and a reference point. Table 30 shows the variables that were used in the models described in the previous chapters. These variables should be analyzed due to possible use in ECO-BOT. The described models can not be directly applied to the creation of ECO-BOT, but it is worth using elements of the presented methodology in this modeling and it is worth taking into account a part of these variables that have been presented in tabular form.

Table 30. Factors relevant for creating the ECO-BOT model

Source own development based on (Cheetah, 2017)

Type of Factors: Demographic (D); Economic (E); Behavioural (B); Climate, Seasonal (C); Building characteristics (BC); Appliance characteristics (AC); Calculated (CA)

Focus: T = Technology adoption, B = Behaviour adoption**, Type of data:** QL = Qualitative, QN = Quantitative

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
1.		Miscellaneous Inputs	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
2.		Historical Data and Short-Term Energy Outlook Benchmarking	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
3.		Region	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
4.		Country	ComeONE nergy	energy consumption of a building	T		table/ user input		X
5.	AC	Cooker type coefficients	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
6.	AC	Cylinder heat loss	BREDEM	energy	T(B)	QN	table/ user input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		factor		consumption of a dwelling					
7.	AC	Effective solar volume	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
8.	AC	Efficiency of water heating system 1, 2 etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
9.	AC	Energy for pumps and fans	BREDEM	energy consumption of a dwelling	T(B)	QN	model's data/ user input	X	
10.	AC	Final annual lighting energy	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
11.	AC	Fraction of primary pipework insulated	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
12.	AC	Peak power of the installation	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
13.	AC	Primary circuit adjustment factor for solar water heating	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
14.	AC	Proportion of light provided by low	BREDEM	energy consumption	T(B)	QN	User input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		energy lamps		of a dwelling					
15.	AC	Rotor diameter	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
16.	AC	Specific ventilation fan power	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
17.	AC	Storage temperature factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
18.	AC	Thickness of hot water cylinder insulation	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
19.	AC	Values of U for different types of junctions for calculating heat losses from thermal bridging	BREDEM	energy consumption of a dwelling	T(B)	QN	Different national data e. g. statistics	X	
20.	AC	Volume factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
21.	AC	Water heating efficiency, space heating efficiency and heating	BREDEM	energy consumption of a dwelling	T(B)	QN	Different national data e. g. statistics	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		system responsiveness							
22.	AC	Wind speed correction factor	BREDEM	energy consumption of a dwelling	T(B)	QN	CLIMAT DATA	X	
23.	AC	Stock Equipment Efficiencies	NEMS	energy consumption of a dwelling	T	QN	Dedicated vintaging models		X
24.	AC	Stock Equipment Retired Fraction	NEMS	energy consumption of a dwelling	T	QN	Dedicated vintaging models		X
25.	AC	Stock Equipment Retired Efficiencies	NEMS	energy consumption of a dwelling	T	QN	Dedicated vintaging models		X
26.	AC	Lighting technology menu	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
27.	AC	Distributed Generation Technologies	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
28.	AC	Solar Photovoltaic Penetration Hurdle Model	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
29.	AC	Equipment profile	synPRO	energy consumption of a dwelling	T	QN	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
30.	AC,B	Need for new energy installation	POLES-JRC	energy consumption of a building	T	QN	Historical data		X
31.	AC,B	Additional (non-cooking related) energy consumption for ranges	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
32.	AC,B	Equipment Switching	NEMS	energy consumption of a dwelling	T		Data used from a number of sources		X
33.	AC;BC	Heating Shares in New Construction	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
34.	AC;BC	Major end-use technology menu (except lighting)	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
35.	AC; BC	Characteristics of insulation, heating systems on national level	BREHOMES	energy consumption of housing stock	T		Different national data e. g. statistics	X	
36.	AC; BC	Aperture area of the collector	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
37.	AC; BC	Collector performance factor	BREDEM	energy consumption	T(B)	QN	table/ user input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
				of a dwelling					
38.	AC; BC	First order heat loss coefficient	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
39.	AC; BC	Manufacturer's declared storage loss	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
40.	AC; BC	Measured air-permeability rate	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
41.	AC; BC	Mechanical ventilation heat recovery efficiency	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
42.	AC; BC	Range efficiency, fuel into heat	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
43.	AC; BC	Responsiveness of the main heating system	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
44.	AC; BC	Second order heat loss coefficient	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
45.	AC; BC	Zero loss efficiency of the collector	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
46.	AC; CA	Heat gain from	BREDEM	energy	T(B)	QN	Internal model's	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		pumps and fans		consumption of a dwelling			data, user input		
47.	AC;CA	Heat gain from pumps and fans (cooling)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data, user input	X	
48.	AC;CA	Volume of hot water storage cylinder or storage combi	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
49.	AC; E	Range power consumption	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
50.	B	Annual additional consumption for ranges	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
51.	B	Cooking gain factor	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
52.	B	Daily hot water requirement for showers	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
53.	B	Demand temperature for an *uncontrolled* zone 2 (rest of dwelling)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
54.	B	Floor area of zone	BREDEM	energy	T(B)	QN	User input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		1 or zone 2		consumption of a dwelling					
55.	B	Hot water use per shower	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
56.	B	Hours per day primary hot	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
57.	B	Intermittency factor	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
58.	B	Internal temperature for cooling	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
59.	B	In-use factor	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
60.	B	Length of heating-off period i	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
61.	B	Monthly hot water use factor	BREDEM	energy consumption of a dwelling	T(B)	QN	CONSTANS/TABLE	X	
62.	B	Nominal temperature difference between	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		zones							
63.	B	Number of baths per day	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
64.	B	Number of occupants	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
65.	B	Number of showers per day	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
66.	B	Proportion of water heating by system 1,2 etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
67.	B	Quantity sewage sludge	PRIMES Biomass Supply	Quantity fo bio- energy from wastes	T	QN			X
68.	B	Zone 1 (living room) demand temperature	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
69.	B	Energy needs for space heating, water heating and cooking	POLES-JRC	energy consumption of a building	T	QN	Historical data		X
70.	B	Electricity demand (for lighting, space cooling and	POLES-JRC	energy consumption of a building	T	QN	Historical data		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		appliances)							
71.	B	Service demand and baseload by new housing type	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
72.	B	Working pattern	synPRO	energy consumption of a dwelling	B	QL	Survey	X	
73.	B	Family status	synPRO	energy consumption of a dwelling	B	QL	Survey	X	
74.	B	Frequency of appliance usage	synPRO	energy consumption of a dwelling	B	QN	Survey	X	
75.	B	Duration of appliance usage	synPRO	energy consumption of a dwelling	B	QN	Survey	X	
76.	B	Time of appliance usage	synPRO	energy consumption of a dwelling	B	QN	Survey	X	
77.	B	Household member's characteristic: age	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
78.	B	Household member's characteristic: education	Diao's model	energy consumption of a dwelling	B	QL	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
79.	B	Household member's characteristic: full/part-time job/unemployed	Diao's model	energy consumption of a dwelling	B	QL	Survey	X	
80.	B	Household member's characteristic: metropolitan	Diao's model	energy consumption of a dwelling	B	QL	Survey	X	
81.	B	Household member's characteristic: sex	Diao's model	energy consumption of a dwelling	B	QL	Survey	X	
82.	B	Price of total time resource	GEM-E3	total energy consumption	B	QN	Survey	X	
83.	B	Subsistence quantity of leisure	GEM-E3	total energy consumption	B	QN	Survey	X	
84.	B	Time per day spent on: caring for and helping household members	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
85.	B	Time per day spent on: caring for and helping nonhousehold members	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
86.	B	Time per day spent on: consumer purchases	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
87.	B	Time per day spent on: eating and drinking	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
88.	B	Time per day spent on: education	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
89.	B	Time per day spent on: government services and civic obligations	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
90.	B	Time per day spent on: household activities	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
91.	B	Time per day spent on: household services	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
92.	B	Time per day spent on: personal care	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
93.	B	Time per day spent on: professional and personal care services	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
94.	B	Time per day spent on: religious and spiritual activities	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
95.	B	Time per day spent on: socializing	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
96.	B	Time per day spent on: sports	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
97.	B	Time per day spent on: telephone calls	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
98.	B	Time per day spent on: traveling	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
99.	B	Time per day spent on: volunteer activities	Diao's model	energy consumption of a dwelling	B	QN	Survey	X	
100.	B	Time per day spent on: work and	Diao's model	energy consumption	B	QN	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		work-related activities		of a dwelling					
101.	B	Consummers choices	The Rational Choice Theory	energy consumption of a dwelling	B	QL	Survey	X	
102.	B	Beliefs	TRA	energy consumption of a dwelling	B	QL	Survey	X	
103.	B	Attitudes	TRA	energy consumption of a dwelling	B	QL	Survey	X	
104.	B	Intentions	TRA	energy consumption of a dwelling	B	QL	Survey	X	
105.	B	Subjective/Personal norms	TRA	energy consumption of a dwelling	B	QL	Survey	X	
106.	B	Beliefs	TPB	energy consumption of a dwelling	B	QL	Survey	X	
107.	B	Attitudes	TPB	energy consumption of a dwelling	B	QL	Survey	X	
108.	B	Intentions	TPB	energy consumption of a dwelling	B	QL	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
109.	B	Subjective/Personal norms	TPB	energy consumption of a dwelling	B	QL	Survey	X	
110.	B	Personal Values	VBN	energy consumption of a dwelling	B	QL	Survey	X	
111.	B	Beliefs	VBN	energy consumption of a dwelling	B	QL	Survey	X	
112.	B	Pro-environmental personal norms	VBN	energy consumption of a dwelling	B	QL	Survey	X	
113.	B	Ecological Worldview	VBN	energy consumption of a dwelling	B	QL	Survey	X	
114.	B	Adverse consequences for valued objects	VBN	energy consumption of a dwelling	B	QL	Survey		X
115.	B	Perceived ability to reduce threat	VBN	energy consumption of a dwelling	B	QL	Survey		X
116.	B	Beliefs	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
117.	B	Attitudes	Model Of Pro-Environmental	energy consumption	B	QL	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
			Behaviour	of a dwelling					
118.	B	Norms	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
119.	B	Habits	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
120.	B	Experiences	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
121.	B	Capabilities	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
122.	B	Lifestyle	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
123.	B	Activism	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
124.	B	Socioeconomical status	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
125.	B	Technical skills	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey		X
126.	B	Values	Model Of Pro-	energy	B	QL	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
			Environmental Behaviour	consumption of a dwelling					
127.	B	Predispositions	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
128.	B	Social interactions	Model Of Pro-Environmental Behaviour	energy consumption of a dwelling	B	QL	Survey	X	
129.	B	Beliefs	ABC	energy consumption of a dwelling	B	QL	Survey	X	
130.	B	Values	ABC	energy consumption of a dwelling	B	QL	Survey	X	
131.	B	Norms	ABC	energy consumption of a dwelling	B	QL	Survey	X	
132.	B	Tendencies	ABC	energy consumption of a dwelling	B	QL	Survey	X	
133.	B	Physical capabilities and constrains	ABC	energy consumption of a dwelling	B	QL	Survey		X
134.	B	Social norms	ABC	energy consumption of a dwelling	B	QL	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
135.	B	Intentions	TIB	energy consumption of a dwelling	B	QL	Survey	X	
136.	B	Habits	TIB	energy consumption of a dwelling	B	QL	Survey	X	
137.	B	Beliefs	TIB	energy consumption of a dwelling	B	QL	Survey	X	
138.	B	Roles	TIB	energy consumption of a dwelling	B	QL	Survey	X	
139.	B	Norms	TIB	energy consumption of a dwelling	B	QL	Survey	X	
140.	B	Attitiudes	TIB	energy consumption of a dwelling	B	QL	Survey	X	
141.	B	Emotions	TIB	energy consumption of a dwelling	B	QL	Survey	X	
142.	B	Past behaviour	TIB	energy consumption of a dwelling	B	QL	Survey	X	
143.	B	Social factors	TIB	energy consumption	B	QL	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				of a dwelling					
144.	B	Knowledge	The HIERARCHY OF EFFECTS MODEL	energy consumption of a dwelling	B	QL	Survey	X	
145.	B	Attitiudes	The HIERARCHY OF EFFECTS MODEL	energy consumption of a dwelling	B	QL	Survey	X	
146.	B	Intention	The HIERARCHY OF EFFECTS MODEL	energy consumption of a dwelling	B	QL	Survey	X	
147.	B	Needs	DoI	energy consumption of a dwelling	B	QL	Survey	X	
148.	B	Social norms	DoI	energy consumption of a dwelling	B	QL	Survey	X	
149.	B	Motives	DoI	energy consumption of a dwelling	B	QL	Survey	X	
150.	B	Knowledge	DoI	energy consumption of a dwelling	B	QL	Survey	X	
151.	B, C, BC,	Smart Metering	-	energy	T(B)	QN	Data from	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
	AC	Data		(eletricicty) consumption			electricicty suppliers		
152.	B/BC	Rate of deliberate ventilation via to chimneys, flues and fans	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
153.	B/CA	Electricity consumption per shower	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
154.	BC	Area of building element, i	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
155.	BC	Area of building fabric element i	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
156.	BC	Area of glazed element i	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
157.	BC	Daylight availability	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
158.	BC	Dwelling exposure factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
159.	BC	Floor area of the dwelling's smaller	BREDEM	energy consumption	T(B)	QN	User input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		zone		of a dwelling					
160.	BC	Fraction of zone 2 heated	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
161.	BC	Frame factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
162.	BC	Heat capacity of building elements	BREDEM	energy consumption of a dwelling	T(B)	QN	Different national data e. g. statistics	X	
163.	BC	Heat capacity of building fabric element i	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
164.	BC	Internal volume of dwelling	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
165.	BC	Length of the linear bridge, i	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
166.	BC	Light access factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
167.	BC	Light transmission factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
168.	BC	Linear thermal	BREDEM	energy	T(B)	QN	User input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		transmittance of thermal bridge, i		consumption of a dwelling					
169.	BC	Pitch (tilt) of the surface	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
170.	BC	Site exposure factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
171.	BC	Thermal bridge factor	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
172.	BC	Total area of external building elements	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
173.	BC	Total floor area of dwelling	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
174.	BC	Total window area	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
175.	BC	Transmission factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
176.	BC	U-value of building element, i	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
177.	BC	Zone 2 control fraction	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
178.	BC	Surface per dwelling	POLES-JRC	energy consumption of a building	T	QN	Historical data	X	
179.	BC	Base-year Equipment Stock	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
180.	BC	Square Footage	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
181.	BC	Building shell technology menu	NEMS	energy consumption of a dwelling	T	QN	Dedicated models		X
182.	BC	Historical ENERGY STAR Home Shares	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
183.	BC	Housing Code	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
184.	BC	Number of Dwelling	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
185.	BC	SAP Age band	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
186.	BC	Tenure Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input	X	
187.	BC	Dwelling Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
188.	BC	Basement Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
189.	BC	Basement Storey Height	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
190.	BC	GF Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
191.	BC	GF Storey Height	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				emission of a dwelling					
192.	BC	1F Floor Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
193.	BC	1F Storey Height	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
194.	BC	2F Floor Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
195.	BC	2F Storey Height	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
196.	BC	3F Floor Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
197.	BC	3F Storey Height	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
198.	BC	Room in roof Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
199.	BC	Room in roof Storey Height	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
200.	BC	Chimneys - Main heating	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
201.	BC	Chimneys - Secondary heating	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
202.	BC	Chimneys - Other	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
203.	BC	Open flues - Main heating	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
204.	BC	Open flues - Secondary heating	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				emission of a dwelling					
205.	BC	Open flues - Other	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
206.	BC	Intermittent fans	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
207.	BC	Passive vents	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
208.	BC	Flueless gas fire	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
209.	BC	Structural Infiltration	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
210.	BC	Floor Infiltration	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
211.	BC	Draught Lobby	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
212.	BC	Windows and doors draught stripped	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
213.	BC	Sides sheltered	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
214.	BC	Ventilation System	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
215.	BC	Door Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
216.	BC	Door U-value	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
217.	BC	Windows 1 Type	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				emission of a dwelling					
218.	BC	Windows 1 Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
219.	BC	Windows 1 Frame	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
220.	BC	Windows 1 Overshading	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
221.	BC	Windows 1 Orientation	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
222.	BC	Windows 2 Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
223.	BC	Windows 2 Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focu s T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
224.	BC	Windows 2 Frame	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
225.	BC	Windows 2 Overshading	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
226.	BC	Windows 2 Orientation	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
227.	BC	Roof Window Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
228.	BC	Roof Window Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
229.	BC	Roof Window Frame	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
230.	BC	Roof Window Orientation	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
				emission of a dwelling					
231.	BC	Basement Floor Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
232.	BC	Basement Floor Heat Loss Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
233.	BC	Basement Floor Exposed Perimeter	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
234.	BC	GF Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
235.	BC	GF Heat Loss Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
236.	BC	GF Exposed Perimeter	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
237.	BC	Exposed Floor Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
238.	BC	Exposed Floor Heat Loss Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
239.	BC	Living area fraction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
240.	BC	Basement Wall Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
241.	BC	Basement Wall Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
242.	BC	External Wall Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
243.	BC	External Wall Area	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				emission of a dwelling					
244.	BC	Semi-exposed Wall Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
245.	BC	Semi-exposed Wall Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
246.	BC	Roof Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
247.	BC	Loft Insulation	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
248.	BC	Roof Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
249.	BC	Room in roof Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
250.	BC	Room in roof Heat Loss Envelope Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
251.	BC	Party Wall Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
252.	BC	Party Wall Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
253.	BC	Party Floor Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
254.	BC	Party Floor Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
255.	BC	Party Ceiling Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
256.	BC	Party Ceiling Area	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				emission of a dwelling					
257.	BC	Internal Wall Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
258.	BC	Internal Wall Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
259.	BC	Internal Floor Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
260.	BC	Internal Floor Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
261.	BC	Internal Ceiling Construction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
262.	BC	Internal Ceiling Area	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
263.	BC	DHW System	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
264.	BC	DHW Boiler with Central Heating	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
265.	BC	DHW Electric System Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
266.	BC	DHW Electric System Tariff	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
267.	BC	DHW - Community Heating Tariff	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
268.	BC	DHW - Community Heating Fuel Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
269.	BC	DHW - Community Heating CHP	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		Fraction		emission of a dwelling					
270.	BC	DHW - Community Heating CHP Fuel	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
271.	BC	DHW System Efficiency	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
272.	BC	DHW Cylinder Volume	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
273.	BC	Cylinder Insulation Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
274.	BC	Cylinder insulation Thickness	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
275.	BC	Primary Pipework Insulation	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
276.	BC	Cylinderstat	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
277.	BC	Solar DHW	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
278.	BC	Solar DHW in Cylinder	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
279.	BC	Solar DHW Storage	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
280.	BC	Main Heating System	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
281.	BC	Main Heating - Electric Tariff	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
282.	BC	Main Heating - Community	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		Heating Tariff		emission of a dwelling					
283.	BC	Main Heating - Community Heating Fuel Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
284.	BC	Main Heating - Community Heating CHP Fraction	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
285.	BC	Main Heating - Community Heating CHP Fuel	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
286.	BC	Main Heating - Heater Flue	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
287.	BC	Main Heating - Oil Pump Location	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
288.	BC	Main Heating - Heat Emitter	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focu s T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
289.	BC	Main Heating Efficiency	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
290.	BC	Main Heating Control - Programmer	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
291.	BC	Main Heating Control - Room Thermostat	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
292.	BC	Main Heating Control - TRVs	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
293.	BC	Secondary Heating System	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
294.	BC	Low Energy Lighting	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
295.	BC	EHS Age band	CHM	energy use and CO2	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				emission of a dwelling					
296.	BC	Wall Thickness	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
297.	BC	Window U-value (W/m2K)	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
298.	BC	Wall U-value (W/m2K)	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
299.	BC	Hot Water Usage Calculation	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
300.	BC	Hot Water Storage Loss	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
301.	BC	Internal Heat Gain Type	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
302.	BC	Fuel Costs: Domestic Hot Water (DHW) System Electricity Price	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
303.	BC	Fuel Costs: Secondary Heating System Electricity Price	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
304.	BC	Fuel Costs: Mechanical Ventilation System Electricity Price	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
305.	BC	Fuel Costs: Other Electricity Uses Electricity Price	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
306.	BC	Effective Air Change Rate Calculation Parameters	CHM	energy use and CO2 emission of a dwelling	T	QN	table/ user input		X
307.	BC	Housing-type	synPRO	energy consumption of a dwelling	T	QN	Survey	X	
308.	BC	Total floor area	ComeONEnerg y	energy consumption	T	QN	table/ user input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				of a building					
309.	BC	Gross leasable area	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
310.	BC	Floor number	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
311.	BC	Floor height	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
312.	BC	Window area, North	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
313.	BC	Window area, East	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
314.	BC	Window area, South	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
315.	BC	Window area, West	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
316.	BC	Construction period	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
317.	BC	Building	ComeONEnerg	energy	T	QN	table/ user input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		renovation period	y	consumption of a building					
318.	BC	U-Value Facade	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
319.	BC	U-Value Roof	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
320.	BC	U-Value Ground	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
321.	BC	U-Value Windows	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
322.	BC	Lighting	ComeONEnergy	energy consumption of a building	T	QN	table/ user input	X	
323.	BC	Heating System	ComeONEnergy	energy consumption of a building	T	QN	table/ user input	X	
324.	BC	PV System	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X
325.	BC	Solarthermal System	ComeONEnergy	energy consumption of a building	T	QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
326.	BC	Heated area	Diao's model	energy consumption of a building	T	QN	user input	X	
327.	BC	Number of occupants	Diao's model	energy consumption of a building	T	QN	user input	X	
328.	BC	Number of rooms	Diao's model	energy consumption of a building	T	QN	user input	X	
329.	BC	Number of windows in heated area	Diao's model	energy consumption of a building	T	QN	user input	X	
330.	BC	Surface area of exterior doors	Diao's model	energy consumption of a building	T	QN	Table/ user input	X	
331.	BC	Surface area of exterior walls	Diao's model	energy consumption of a building	T	QN	Table/ user input	X	
332.	BC	Surface area of floor	Diao's model	energy consumption of a building	T	QN	Table/ user input	X	
333.	BC	Surface area of ground floor	Diao's model	energy consumption of a building	T	QN	Table/ user input	X	
334.	BC	Surface area of interior doors	Diao's model	energy consumption	T	QN	Table/ user input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				of a building					
335.	BC	Surface area of interior walls	Diao's model	energy consumption of a building	T	QN	Table/ user input	X	
336.	BC	Surface area of roof	Diao's model	energy consumption of a building	T	QN	Table/ user input	X	
337.	BC	Surface area of windows	Diao's model	energy consumption of a building	T	QN	Table/ user input	X	
338.	BC,B	Specific energy consumption pattern	POLES-JRC	energy consumption of a building	B		Historical data		X
339.	BC,B	Fraction of the TFA cooled	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
340.	BC; AC	Fraction of heat provided by system 1, system 2, etc...	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
341.	BC; AC	Heating efficiency of system 1, system 2, etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	
342.	BC/B	Fraction of the TFA cooled	BREDEM	energy consumption of a dwelling	T(B)	QN	User input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
343.	BC/C	Collector orientation constants for selected orientation	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
344.	BC/C	Latitude of the site	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
345.	BC/C	Overshading factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
346.	BC/C	Solar declination for month m	BREDEM	energy consumption of a dwelling	T(B)	QN	CONSTANS	X	
347.	BC/CA	Thermal mass parameter	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data, user input	X	
348.	BC/S	Horizontal solar flux for month m	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
349.	BC/S	Solar access (overshading) factor	BREDEM	energy consumption of a dwelling	T(B)	QN	table/ user input	X	
350.	C	Average external temperature	BREDEM	energy consumption of a dwelling	T(B)	QN	CLIMAT DATA	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
351.	C	External temperature and solar radiation	BREDEM	energy consumption of a dwelling	T(B)	QN	CLIMAT DATA	X	
352.	C	Monthly average wind speed for region	BREDEM	energy consumption of a dwelling	T(B)	QN	CLIMAT DATA	X	
353.	C	Weather (Degree Days)	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources	X	
354.	C	Monthly External Temperature (oC) by region	CHM	energy use and CO2 emission of a dwelling	T	QN	Climat data	X	
355.	C	Monthly Average Wind Speed (m/s) by region	CHM	energy use and CO2 emission of a dwelling	T	QN	Climat data	X	
356.	C	Monthly Average Horizontal Solar Radiation (W/m2) by region	CHM	energy use and CO2 emission of a dwelling	T	QN	Climat data		X
357.	C	Latitudes (o North) for each region	CHM	energy use and CO2 emission of a dwelling	T	QN	Climat data		X
358.	C	Monthly Solar	CHM	energy use	T	QN	Climat data		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		Declination (o)		and CO2 emission of a dwelling					
359.	C	Solar Hot Water Collector Setting	CHM	energy use and CO2 emission of a dwelling	T	QN	Climat data		X
360.	C	Ratio of Monthly Solar Radiation to Annual Average Solar Radiation	CHM	energy use and CO2 emission of a dwelling	T	QN	Climat data		X
361.	C	Seasonal Effects - light use	synPRO	energy consumption of a dwelling	B	QN	Survey	X	
362.	C	Seasonal Effects - operation of the heating pump in the hydronic system	synPRO	energy consumption of a dwelling	B	QN	Survey	X	
363.	C	Seasonal Effects - use of appliance	synPRO	energy consumption of a dwelling	B	QN	Survey	X	
364.	C	External temperatures	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources	X	
365.	C	Global horizontal	Diao's model	energy	T	QN	Data used from	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focu s T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
		solar radiation forthe whole year		consumption of a building			a number of sources		
366.	C	Ground temperature forthe whole year	Diao's model	energy consumption of a building	T	QN	Data used from a number of sources	X	
367.	C	Hourly dry bulb temperature forthe whole year	Diao's model	energy consumption of a building	T	QN	Data used from a number of sources	X	
368.	C	Month number	BREDEM	energy consumption of a dwelling	T(B)	QN	CONSTANS	X	
369.	C	Monthly rise in temperature required	BREDEM	energy consumption of a dwelling	T(B)	QN	CONSTANS/TABL E	X	
370.	C	Number of days in month,	BREDEM	energy consumption of a dwelling	T(B)	QN	CONSTANS	X	
371.	C/CA	Daylight correction factor	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
372.	CA	Air change rate due to chimneys, flues and fans	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
373.	CA	Amount of electricity generated by a PV	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
		system							
374.	CA	Amount of electricity generated by wind turbine	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
375.	CA	Annual cooking energy (fuel 1, 2)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
376.	CA	Annual electric shower energy requirement	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
377.	CA	Annual energy content of heated water	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
378.	CA	Annual fuel consumption for cooling	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
379.	CA	Annual fuel consumption of system 1, 2, etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
380.	CA	Annual fuel requirements for water heating system 1, 2 etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
381.	CA	Annual incident	BREDEM	energy	T(B)	QN	Internal model's	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		solar energy per m[2] of collector		consumption of a dwelling			data		
382.	CA	Annual output of solar water heating	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
383.	CA	Annual solar radiation	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
384.	CA	Appliance energy used each month	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
385.	CA	Average daily hot water requirement	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
386.	CA	Average temperature for the whole dwelling	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
387.	CA	Average temperature for the whole house	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
388.	CA	Average temperature for zone 1 or zone 2	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
389.	CA	Average weekday temperature in zone 1 or zone 2	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		(weekdays and weekends)							
390.	CA	Background (unheated) temperature	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
391.	CA	Background temperature in zone 1 or zone 2	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
392.	CA	Collector heat loss coefficient	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
393.	CA	Collector orientation parameters for selected orientation	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
394.	CA	Combi loss sizing factor	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
395.	CA	Cooling requirement	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
396.	CA	Cooling time	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
397.	CA	Daily hot water	BREDEM	energy	T(B)	QN	Internal model's	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		requirement for baths		consumption of a dwelling			data		
398.	CA	Daily hot water requirement for other uses	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
399.	CA	Daily hot water requirement in month m	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
400.	CA	Daily storage loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
401.	CA	Degree days at threshold temp +0.5	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
402.	CA	Degree days at threshold temp - 0.5	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
403.	CA	Demand temperature for a *controlled* zone 2	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
404.	CA	Demand temperature in zone 2 for the selected level of control	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
405.	CA	Distribution loss of	BREDEM	energy	T(B)	QN	Internal model's	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recom mended	No use
		centrally heated water		consumption of a dwelling			data		
406.	CA	Dwelling's overall rate of heat loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
407.	CA	Dwelling's total rate of heat loss (at zone 1 or zone 2 temperature)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
408.	CA	Energy for cooking each month	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
409.	CA	Energy for electric shower	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
410.	CA	Energy required for heating in month m	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
411.	CA	Fabric heat loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
412.	CA	Final annual appliance energy	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
413.	CA	Fraction of month requiring cooling	BREDEM	energy consumption	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				of a dwelling					
414.	CA	Fraction of month that is heated	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
415.	CA	Fuel consumed by system 1, system 2, etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
416.	CA	Fuel consumption for cooling in month m	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
417.	CA	Gain to loss ratio for cooling	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
418.	CA	Gains utilisation factor (at zone 1 or zone 2 temperature)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
419.	CA	Gains utilisation factor for whole dwelling	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
420.	CA	Heat gain from electrical appliances	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
421.	CA	Heat gain from lights	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
422.	CA	Heat gains from water heating	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
423.	CA	Heat loss from internal evaporation	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
424.	CA	Heat loss parameter	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
425.	CA	Heat loss rate for cooling	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
426.	CA	Heat supplied by water heating system 1,2 etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
427.	CA	Heat transfer coefficient	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
428.	CA	Heat transfer coefficient (i.e. total heat loss)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
429.	CA	Heating energy from system 1, system 2, etc..	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
430.	CA	Incident solar energy for month	BREDEM	energy consumption	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		m per m^2 of collector		of a dwelling					
431.	CA	Incident solar flux for selected orientation, pitch and month	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
432.	CA	Infiltration rate of the building fabric	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
433.	CA	Initial annual appliance energy	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
434.	CA	Initial annual lighting energy	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
435.	CA	Internal monthly storage loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
436.	CA	Internal temperature without cooling	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
437.	CA	Interzone heat transfer coefficient	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
438.	CA	Lighting energy basic requirement	BREDEM	energy consumption	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				of a dwelling					
439.	CA	Lighting energy used each month	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
440.	CA	Load ratio	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
441.	CA	Low energy lighting correction factor	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
442.	CA	Metabolic gain (from body heat)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
443.	CA	Monthly average solar gain	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
444.	CA	Monthly cooking consumption	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
445.	CA	Monthly cooking energy (fuel 1, 2)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
446.	CA	Monthly distribution loss for centrally heated water	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
447.	CA	Monthly electric shower energy requirement	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
448.	CA	Monthly energy content of heated water	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
449.	CA	Monthly fuel requirement for water heating system 1, 2 etc.	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
450.	CA	Monthly loss for a combination boiler	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
451.	CA	Monthly output of solar water heating	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
452.	CA	Monthly output of solar water heating	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
453.	CA	Monthly primary pipework loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
454.	CA	Monthly storage loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
455.	CA	Monthly total hot	BREDEM	energy	T(B)	QN	Internal model's	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		water related energy requirement		consumption of a dwelling			data		
456.	CA	Monthly ventilation rate	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
457.	CA	Non-cooking related energy consumption of always-on ranges	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
458.	CA	Non-cooking related heat gain from always-on ranges	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
459.	CA	Pitch factor	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
460.	CA	Primary pipework loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
461.	CA	Ratio of heat gains to losses	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
462.	CA	Ratio of heat gains to losses (at zone 1 or zone 2	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		temperature)							
463.	CA	Ratio to convert horizontal solar flux to that for the selected orientation, pitch and month	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
464.	CA	Solar height factor	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
465.	CA	Solar storage volume factor	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
466.	CA	Subtotal; fabric & deliberate ventilation	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
467.	CA	Swept area of the turbine	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
468.	CA	Temperature for an unheated zone 2	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
469.	CA	Temperature reduction in zone 1, zone 2, for unheated period i	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		(weekdays and weekends)							
470.	CA	The time constant	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
471.	CA	Thermal bridging loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
472.	CA	Thermal mass parameter	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
473.	CA	Threshold temperature for heating	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
474.	CA	Total heat gain in month m	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
475.	CA	Total heat gain in month m (cooling)	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
476.	CA	Total internal heat gain in month m	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
477.	CA	Useful heat gain from cooking	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
478.	CA	Utilisation exponent	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
479.	CA	Utilisation factor	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
480.	CA	Utilisation factor exponent	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
481.	CA	Utilisation factor for cooling	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
482.	CA	Ventilation heat loss	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
483.	CA	Zone 2 demand temperature	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data	X	
484.	CA	Activity-related direct consumption of energy	Diao's model	energy consumption of a building	B	QN	Internal model's data	X	
485.	CA	Activity-related indirect consumption of energy	Diao's model	energy consumption of a building	B	QN	Internal model's data	X	
486.	CA	Balance	Diao's model	energy	T	QN	Internal model's	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		temperature of the heating system		consumption of a building			data		
487.	CA	Constant consumption of energy	Diao's model	energy consumption of a building	B	QN	Internal model's data	X	
488.	CA	Consumption of leisure	GEM-E3	total energy consumption	B	QL	Internal model's data	X	
489.	CA	Energy consumption of appliances (e.g. TV, computer, washing machine, wacume cleaner)	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
490.	CA	Energy to compensate for heat gain (in a cooling season)	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
491.	CA	Energy to compensate for heat loss (in a heating season)	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
492.	CA	Heat gain through human activities	Diao's model	energy consumption of a building	B	QN	Internal model's data	X	
493.	CA	Heat gain through solar radiation	Diao's model	energy consumption	T	QN	Internal model's data	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				of a building					
494.	CA	Heat loss through the building envelope	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
495.	CA	Heat loss through ventilation and infiltration	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
496.	CA	Heat loss to the ground	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
497.	CA	Heating duration	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
498.	CA	Indoor daylight lumiance	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
499.	CA	Luminance	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
500.	CA	Occupancy-related consumption of energy	Diao's model	energy consumption of a building	B	QN	Internal model's data	X	
501.	CA	Outdoor daylight lumiance	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
502.	CA	Present-related	Diao's model	energy	B	QN	Internal model's	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		consumption of energy		consumption of a building			data		
503.	CA	Thermal efficiency	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
504.	CA	Ventilation	Diao's model	energy consumption of a building	T	QN	Internal model's data	X	
505.	CA	System Energy Efficiency Ratio	BREDEM	energy consumption of a dwelling	T(B)	QN	Internal model's data, user input	X	
506.	D	Total number of dwellings	POLES-JRC	energy consumption of a building	T	QN	Historical data		X
507.	D	Number of people per household	POLES-JRC	energy consumption of a building	T	QN	Historical data	X	
508.	D	Occupant - Adult	CHM	energy use and CO2 emission of a dwelling	B	QN	table/ user input	X	
509.	D	Occupant - Children	CHM	energy use and CO2 emission of a dwelling	B	QN	table/ user input	X	
510.	D	Household size	synPRO	energy	B	QN	Survey	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				consumption of a dwelling					
511.	D	Age of the occupants	synPRO	energy consumption of a dwelling	B	QN	Survey	X	
512.	E	Total costs of fuel use	POLES-JRC	energy consumption of a building	T	QN	Historical data		X
513.	E	Base-year Unit Energy Consumption	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
514.	E	Miscellaneous Electric Loads (MELs)	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
515.	E	Baseline Electricity Consumption for Energy Efficiency Calculations	NEMS	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
516.	E	Shop types	ComeONEnerg y	energy consumption of a building	T	QN	table/ user input	X	
517.	E	Opening Days per week	ComeONEnerg y	energy consumption of a building		QN	table/ user input	X	
518.	E	Average open hours per day of	ComeONEnerg y	energy consumption		QN	table/ user input	X	

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
		common areas and restaurants		of a building					
519.	E	Average open hours per day of stores, shops and offices	ComeONEnergy	energy consumption of a building		QN	table/ user input	X	
520.	E	Non-business days except Sundays (e.g. public holidays)	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
521.	E	Owner Utilisation	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
522.	E	Cost of equity	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
523.	E	Cost of debt	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
524.	E	Tax rate	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
525.	E	After-tax Cost of Debt	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
526.	E	Equity adjusted	ComeONEnergy	energy		QN	table/ user input		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
			y	consumption of a building					
527.	E	Debt adjusted	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
528.	E	Weighted Average Cost of Capital (WACC)	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
529.	E	Energy price increase/decrease	ComeONEnergy	energy consumption of a building		QN	table/ user input		X
530.	E	Car ownership level	DTI	energy use and CO2 emission	T	QL	Data used from a number of sources		X
531.	E	Disposable income	GEM-E3	total energy consumption	B	QN	Survey	X	
532.	E	Domestic energy prices	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources	X	
533.	E	Electricity prices	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources	X	
534.	E	Employment	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources	X	
535.	E	Fossil fuel prices	DTI	energy use	T	QN	Data used from		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
				and CO2 emission			a number of sources		
536.	E	GDP	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources	X	
537.	E	Industrial sector prices	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X
538.	E	Major appliance take up	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X
539.	E	Number of households	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources	X	
540.	E	Other fuel prices	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X
541.	E	Petrol price	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X
542.	E	Physical output	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X
543.	E	Population	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X

NO	Type of Factors	Relevant factors	Name of model	Measured impacts	Focus T/B	Type of data QL/QN *	Method used for collecting data	Use in the ECO-BOT Taxonomy	
								Recommended	No use
544.	E	Public sector share	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X
545.	E	Real personal disposable income	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources	X	
546.	E	Service sector energy prices	DTI	energy use and CO2 emission	T	QN	Data used from a number of sources		X
547.	E	Technology adoption	MODEL OF PRO-ENVIRONMENTAL BEHAVIOUR	energy consumption of a dwelling	T	QN	Data used from a number of sources		X
548.	E	Regulations	MODEL OF PRO-ENVIRONMENTAL BEHAVIOUR	energy consumption of a dwelling	B	QL	Data used from a number of sources		X

The presented factors selected from individual models in some cases have been classified into several categories due to their characteristics, e.g. at the same time appliance characteristic and behaviours. The usefulness of this type of factors for the needs of ECO-BOT modelling should be considered in great detail, especially if the data/values of these variables may be difficult to obtain.

In the case of some models, some similarities can be noticed for specific factors, but it should be emphasized that the similarities are in many cases illusory, because despite similar names, these factors differ from each other, for example by: unit, calculation method, source of data used in calculations.

It should be emphasized that the direct transfer of elements from the reviewed models will be most difficult (both factors and modelling methodology) due to the number of barriers and restrictions associated with modelling for the needs of ECO-BOT. The presented factors should be treated as an initial list, which in the subsequent stages will undergo redundancy and transformations in accordance with the requirements of ECO-BOT modelling purpose.

Table 30 contains a very extensive set of variables. Naturally, in the Eco-Bot project, it will be impossible to collect a dataset characterized by such a large number of variables. After the initial analysis, it seems that the most important factors for Eco-Bot will be related to the behaviour of customers (behavioural factors), building and appliance characteristics (data from smart metering), as well as climatic factors. However, appropriate representation of each type of factor, from table 30, should be ensured so that the constructed model could cover clients from different environments and different countries.

As already mentioned, for the modelling we will use nonparametric methods, which do not require a number of restrictive assumptions to be met. These methods also allow simultaneous use of both qualitative and quantitative variables in the model. An unquestionable advantage of these methods is their adaptive nature, which means that during the execution of the algorithm, only the variables that have a significant impact on the outcome are introduced to the model. This means that it is not necessary to check and test the significance of the factors beforehand. The algorithm itself will identify these variables. However, it is worth taking care of delivering a dataset with a slightly larger set of variables so that the algorithms have the opportunity to choose the relevant factors.

6.4 Recommendation for ECO-BOT from Bottom –up and Top-down models

The vast majority of bottom-up models are not used in ECO-BOT due to their specificity. These are models covering the entire energy chains, from extraction to final use at the level of the economy or the country. They often cover entire regions of the world (eg MESSAGE and others).

Top-down models, as global and national models, are not directly applicable in Eco-Bot either. However, these models should be considered mainly due to the variables used in the research. **Demographic features** (e.g. population density, number of households), **climate and weather data, as well as economic data** (e.g. fuel prices or economic indicators) **can be adopted in simulations during the designing stage of the Eco-Bot model**. Perhaps not all of these variables will turn out to be relevant to energy saving aspects, but it is better to prepare a wider set of factors to be able to select some of them to the modelling process.

6.5 Recommendation for ECO-BOT from Diao's model

The presented Diao's model is interesting in the context of preparations for designing Eco-Bot because of statistical tools and also variables used for modeling. First of all, it uses the behavioral profiles of buildings' occupants assigned by k-mode clustering method. This approach can be **easily replicated for other countries**. Moreover, **the behavioral model can be applied to other non-residential buildings such as hotels, offices and so on**. Similarly these behavioral profiles can be obtained by using a clustering method, based on features describing occupants or companies. The k-mode clustering is a modification of the commonly known k-means method, but it deal with categorical data, which is its clear advantage.

Diao's model uses **technical information about the building**, such as surface area of the floor, the roof, exterior and interior walls, doors and windows. Moreover, the power of some typical home appliances is also recorded. In addition, **the model estimates the total energy consumption for heating, cooling, ventilation and lighting, which can also be used to designe the Eco-Bot**, because the Eco-Bot model should combine various aspects of energy consumption.

6.6 Recommendation for ECO-BOT from Smart Metering

When working on the ECO-BOT program, consistency of the data obtained will be extremely important. Data obtained from Smart Meetering (SM) will probably be in the basic version (energy consumption per household). The unquestionable advantage of data from SM is their precision, in particular short time steps. The disadvantage is the lack of division into the energy consumption of individual devices. It will be necessary to supplement them with questionnaire data. When constructing surveys, it is necessary to take into account the necessity to refine the data from the SM, as well as the data necessary to use the BREDEM model. Data on behavioral factors that will significantly affect energy consumption and GHG emissions will be extremely important.

The construction of the model will depend on:

- structure and level of detail of available data from SM,
- available local data, eg climate conditions for individual climate zones (especially for the BREDEM and BREHOMES models),
- structure and detail of available statistical data

6.7 Recommendation for ECO-BOT from synPRO model

For the ECO-BOT modelling purpose the mezzo models dealing with household energy demand are more relevant than the macro models. They provide far better picture of the energy demand of households and due to history of continuous development (that is especially true for the UK residential energy models) they provide far better overlook of the residential sector energy needs. A lot of factors considered in these models (e.g. climate, weather, socio-economic, demographic) are relevant for the ECO-BOT purpose. Projection of the energy use profiles presented by the synPRO model on the example of the German households due to the innovative approach to including social factors and habits concerning use of household appliances should be considered while preparing inputs requirements for the ECO-BOT model. Nonetheless more technical factors (and data obtained from smart meters) and physical characteristic of the buildings should also be considered for the ECO-BOT modelling purpose.

6.8 Recommendation for ECO-BOT from TRIANDIS' model

A correctly applied consumer behaviour model can help ECO-BOT in carrying out the appropriate consumer segmentation and also determine the scope of information needed to create an appropriate communication strategy with the customer/energy consumer.

Consideration of consumer behaviour enables a better understanding of their needs and forecasting future decisions. Development of a model to describe consumer behaviour allows simultaneous analysis of many factors and understanding their mutual interactions.

The identification of factors that have the strongest impact on consumer behaviour can facilitate and accelerate making the right decisions. Such identification of key factors in terms of achieving ECO-BOT objectives will take place in the next phase of the project.

To implement the goals of the ECO-BOT project, it is recommended to use the structural model (initially chosen TRIANDIS' THEORY OF INTERPERSONAL BEHAVIOUR) taking into account the external conditions of the analytical and sequential methods.

Triandis model is described by the formula, according to which the probability of occurrence of a given behaviour is a function of variables such as: customary and emotional behaviour patterns; intentions, stimuli that activate a person to act at a given moment, the degree of activation and weight differentiating the impact of these factors on a given probability.

Triandis developed an integrated model of interpersonal behaviour and recognized the key role that social factors and emotions play in shaping intentions. Very important in his model are past behaviours - because of them, intentions arise at the moment of making decisions. In addition, he emphasized the role of habits that mediate behaviour. According to the assumptions of the model, consumer behaviour is partly due to intentions, habits and situational constraints and conditions. Social factors and rational considerations influence intentions. Behaviour is also influenced by moral beliefs, but their influence is moderated both by emotions and cognitive limitations. Social factors include norms, roles and self-discovery (Triandis, 1977). Emotional reactions to a decision or decision situation are different from rational-instrumental impact assessments and may include both positive and negative emotional responses with different powers.

Triandis offers a clear role of affective factors in behavioural intentions. In newer writings, the attempt to include emotional predecessors in the model of action has received a lot of support (Bagozzi et al., 2002, Steg et al., 2001). This theory can be used as a framework for empirical analysis of the strengths and weaknesses of component factors in different situations.

For the purposes of the ECO-BOT project, the assumptions of the Triandis model can become extremely useful, due to the emphasis on the importance of habits in individual energy consumption. Individual behaviours are very important, including those resulting from habits that contribute to sustainable or unbalanced energy consumption. How users use home appliances is extremely important in shaping future consumer attitudes and in striving to influence the consumers behaviour. Consumers are characterized by a lack of knowledge, awareness and commitment to energy saving. There is also the problem of discrepancies between opinions and behaviour of consumers who declare their willingness to reduce energy consumption, but at the same time do not want to take the effort involved in changing their behaviour and habits.

7. Conclusion remarks

The possibilities of implementing the ECO-BOT application should be evaluated in a multidimensional way. And so, on the basis of theoretical materials (statistical data, literature, reports and EU documents), we can state:

A. **In the geographical/demographic dimension**, based on statistical data, EU Member States show a slow downward trend in energy consumption. This gives opportunities for applications that enhance these trends such as ECO-BOT. China can be considered the most prospective and absorptive non-European market.

B**. Ecological aspects**: the ECO-BOT application complies with the principles of sustainable development and can be promoted as such. Sustainable development in its assumptions recognizes environmental protection and respect for resources as a key element. Improving energy efficiency and saving energy are the best way to reduce the environmental pressures associated with energy consumption.

C. **The policies existing in EU** countries generally strengthen and support the implementation of measures aimed at energy savings, such as ECO-BOT. Both kind of measures: aimed at improving energy efficiency, as well as activities concerning the promotion of renewable energy sources are important here, because in practice they are most often coordinated and combined. The implementation of activities based on behavioural change is visible in many EU countries, although it can be assessed that it is still at the initial stage (the dominant regulatory and economic instruments). In recent years, there has been a wider interest in instruments aimed at changing consumer behaviour. The countries that indicated in progress reports in the promotion and use of energy from renewable resources from member countries to European Commission the importance of soft instruments (aimed at changing behaviour and consumer education) were: Malta, Spain, Luxemburg, the Netherlands, Sweden, Ireland, Denmark, Austria, Belgium, France, Finland and Estonia. Soft instruments strictly aimed at improving energy efficiency relate to countries such as: Germany, Portugal, Greece, Spain, Romania, the Netherlands and Ireland. Important markets for ECO-BOT applications may also be countries implementing Energy Efficiency Obligations (EEO), in particular: Austria, Bulgaria, Denmark, France, Ireland, Italy, Latvia, Luxembourg, Slovenia, Spain, Poland, UK. EEO schemes also have:

- Greece, Croatia - but in this case the EEO is on early stage of development,
- Malta - where the future of EEO is difficult to assess due to changes in political priorities,

Another factor conducive to the implementation of the ECO-BOT application could be planning and implementation of smart metering. Large scale of current and planned implementation of smart metering by 2020 takes place in Denmark, Estonia, Ireland, Greece, Spain, France, Italy, Luxembourg, Malta, the Netherlands, Austria, Poland, Romania, Finland, Sweden and Great Britain, medium scale in: Portugal, Belgium, Czech Republic, Lithuania and low level in: Germany, Latvia, Slovakia.

The report also formulates conclusions regarding the support for the implementation of ECO-BOT in terms of political and institutional support in individual Member States. In this respect, member countries have been divided into four groups:

- I. Group. - countries with low level of support: Hungary, Cyprus, Slovakia, Czech Republic, Lithuania;
- II. Group - countries with moderate level of support: Bulgaria, Croatia, Latvia, Slovenia, Belgium, Germany;
- III. Group - countries with medium level of support: Estonia, The Netherlands, Portugal, Romania, Finland, Sweden, Italy, Great Britain, Poland, Malta;
- IV. Group - countries with a high level of support: Denmark, Ireland, Greece, Spain, France, Luxemburg, Austria.

D. Behavioural aspects can be considered as key elements, the inclusion of which is necessary to achieve the target of energy savings set by the ECO-BOT and to improve energy efficiency. They can both:

1. Strengthen / support the operation of the ECO-BOT application, e.g.

- affect heuristic - using the tendency of clients to follow positive associations;
- availability heuristic - by referring to known people / events / phenomena which builds an atmosphere of trust,
- scarcity heuristic - stressing the costs associated with energy consumption. Depending on consumer preferences, economic costs related to household energy expenditure, environmental costs related to environmental pressure and/or social costs can be emphasized, which can be combined with the perspective: long-term eg the need to preserve resources for future generations, or perspective medium / short-term, for example, creation of new jobs.
- representativeness heuristic – ECO-BOT should use the language appropriate for the given location.
- anchoring heuristic - ECO-BOT should use/invoke specific values speaking about energy savings

- crowd effect - referring to the behaviour of other people and socially recognized norms. ECO-BOT can, for example, refer to data (not indicating specific people) about energy consumption by other people in the neighbourhood / city / region and citing the lowest energy consumption in a similar household.

We can also use some cognitive errors in a positive way:

- hyperbolic discounting, accentuating in the application the quick and direct benefits of energy savings.
- confirmation bias (in the case of people who are convinced of the need to save energy) ECO - BOT can appeal to these beliefs and strengthen them,
- framing effects - the decisions and assessments of a given situation will vary depending on how the alternative actions will be presented. Generating the appropriate form of ECO-BOT communication may use this tendency, for example, by saying that there is a high probability of success (energy / money savings) when taking specific actions.

2. A few of the analysed cognitive errors characteristic of people's behaviour may constitute a barrier to effective operation for ECO-BOT applications. The most important obstacles include: status quo bias, procrastination, myopia, optimism bias, confirmation bias (in the case of people unconvinced to save energy), projection bias, endowment effect, sunk cost effect. The mechanisms of action of these errors boil down to the reluctance of people to change, to make an effort related to energy savings, underestimating the costs associated with energy consumption, the reluctance to change already existing devices / solutions for more energy-effective.

3. The challenges to create an individual model of consumer behaviour - ECO-BOT:

A. Human behaviour and the decision-making process taking place in mind are quite abstract categories, and therefore difficult to identify. These issues are not fully understood, too multifaceted and varied from the point of view of various scientific disciplines, so that a comprehensive, complex model of consumer behaviour can be created. Therefore, the creators of various models analyse, systematise and describe the behaviour of the consumer from different perspectives and in various aspects. These models, along with the passage of time, take on more and more multidimensional and complex forms, but each of them is subject to certain assumptions and limitations. These restrictions, apart from gaps in understanding of certain behaviours, also result from the fact that consumers constitute a strongly diverse group. It also creates the need for certain generalizations and simplifications. **Thus ECO-BOT model should be simple, to make it comprehensible and workable for future studies.**

B. Most models describing consumer behaviour show a simplified version of its dependence on various factors. These models usually differ in nature, complexity, the number of variables and relationships explaining the processes. Consumer behaviour can be called a proceeding consisting of many consecutive stages in a specific order. They are often presented in the literature on the subject as model approaches to consumer behaviour. Many of them have not been verified empirically, especially in the field of energy, which can be attributed to the complexity of consumer behaviour and the specificity of the factors that shape it. **Therefore, the ECO-BOT model should take into account a comprehensive approach to the problem of energy consumers' behaviour on the market, taking into account both aggregate and socio-psychological factors**.

C. Investigating barriers to energy efficiency will help to create and evaluate a proper ECO-BOT behavioural model. The experience of many countries shows that the majority of consumers of electricity are not interested in modern solutions available on the energy market. In addition, consumers are characterized by a lack of knowledge, awareness and commitment to energy saving. **Creating an individual model of consumer behaviour for ECO-BOT purposes will enable designing an application for fully accomplishing the intended goal of the project, which is to change the habits and behaviours of energy consumers towards sustainable consumption.**

D. Building ECO-BOT model of consumer behavior that would reflect real trends in the patterns of energy consumption should be based on the consideration of how consumers perceive the relationship between their own individual goals, preferences, motives and ways to act and the protection of the environment and the use of its resources.

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