MOBISTYLE

MOtivating end-users Behavioural change by combined ICT based modular Information on energy use, indoor environment, health and lifeSTYLE

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Executive summary

This report is an outcome of the task T2.7: *Catalogue of personas/user profiles* used for the purposes of MOBISTYLE project, funded under European Union Horizon 2020 Innovation Action programme (H2020).

The objective of the MOBISTYLE task T2.7 resulting in the deliverable D2.6 was to categorize the building users in a generic way into a number of MOBISTYLE user profiles (archetypes). The method for MOBISTYLE user categorization is presented in this deliverable where the information about the building occupants was based on the results of tasks 2.1, 2.2 and 2.3.

The deliverable was produced after an alternative was found for the Dutch demonstration case. Thus, it reflects the changes in the project pilots and introduces the outcomes of the focus groups for the new demonstration site in the Netherlands (reported in Annex 1 of this deliverable).

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1. Introduction

1.1Task objectives

Energy saving measures are on top of EU priorities, however, the same does not go for most of EU citizens. These measures are not common motivating factors for occupants to change their behaviour in buildings and they often do not correlate to their wishes and needs. For example, people often do not behave in buildings as originally designed, proposed and planned (e.g. in an energy efficient way). On the other hand, thermal comfort, wellbeing and health have proven to be important motivating factors for occupants to change their lifestyles, daily practices, short-term behaviours and long-term habits, especially with a precondition that occupants are well informed and aware of campaigns, tools and solutions. In this way, wellbeing and health can be considered as a significant advantage for modifying occupants' behaviour in the context of MOBISTYLE project.

In MOBISTYLE, the understanding is that to decrease the discrepancy between the design and actual building usage first we need to understand the people behaviour. For achieving an accurate predictive value of user profiles, a special MOBISTYLE methodology was developed. Its starting point was that building occupants and not buildings actually use energy. A comprehensive analysis of building occupants was carried out by highlighting their habits and daily practices; tying to understand how buildings are in fact used and how people behave in buildings they occupy. Based on this analysis, more reliable situation can be determined that can be used in energy contracts, renovation offers, financing guarantees, etc.

Through different qualitative approaches (questionnaires, focus groups, participant observations; see D2.2 and D2.3), the project team analysed occupants' existing habits. Particular objectives for the investigations were set to obtain information about living conditions (building profiles), occupants' profiles (building occupants), usage profile (occupant interaction with a building, technologies, smart devices, degree of control over building services etc.), socio-economic profile (social status, environment concerns).

1.1Task objectives

In this task, the users were categorised in a generic way into several user profiles in order to define different human-related factors and interactions in building in an efficient and useful way. The user profiles are based on results and feedback of tasks 2.1, 2.2 and 2.3; the categorisation took into account the building profiles, occupant profiles, socio-economic profiles of people and their usage characteristics. The main goal of the task was to aggregate information for different MOBISTYLE user profiles where each of these profiles could represent part of occupant group in a certain country, valid for the same building type with the same energy-related literacy.

1.2 Background

The building's energy performance affects indoor environment and indoor environment affects energy performance. This field has been researched in depth in the last years, especially with the introduction of new technical systems in buildings, aiming at both: energy efficiency and improved indoor environment. However, often these systems do not perform as designed, causing a gap between the predicted (calculated and/or modeled) energy performance and the real energy performance in practice.

Reliable studies[1] have proven that three main causes of energy performance gaps are:

1. human factor – responsible for 80% of performance gap,
2. climate factor – responsible for 15% of performance gap,
3. building intrinsic factor – responsible for 5% of performance gap.

It is clear that to a large extent this is due to ignorance and lack of knowledge of the effect of occupant behaviour (OB) on the buildings performance. This also shows there is a need for better understanding on how building users influence the building's energy consumption and indoor climate and vice versa.

Therefore, MOBISTYLE primarily takes on the human factor, by focusing on behaviours, awareness and information about users, from occupants to owners and building managers.

Moreover, most of the current research in this field to narrow the performance gap is driven toward 'more precise'. However, these predictions are almost at their limits of precision; that is why there is no visible improvement of precision of prediction in the last 20 years and the performance gap still exists. Because the energy use of new buildings decreased from about 200 to 50 $kWh/m^2/year$, the relative error of prediction increased.

The goal of MOBISTYLE is not directly geared to solve the energy performance gap but it can absolutely contribute to bridge it. For MOBISTYLE, the key is not to be found in making 'more precise' predictions, but particularly in:

- focusing on the role of occupants in buildings, i.e. the consequences of their behaviour, the way how occupants use and interact with buildings and its systems, consciousness and motivation in relation to energy use, comfort and well-being in buildings;
- clearly defining the specific case questions that have to be answered and the required accuracy;
- improving monitoring and analysis methods of real building performance and developing databases for statistical information on energy use.

By doing so, it will be possible to proactively establish a behavioural change also towards energy efficiency, thus responding to the ascertained gap in the most effective way, leading to real optimisation.

[1] IEA EBC Annex 53 (2013). Total energy use in buildings. Final report

At first sight, the relation between energy use, indoor climate and occupant behaviour seems simple as shown in Figure 1.

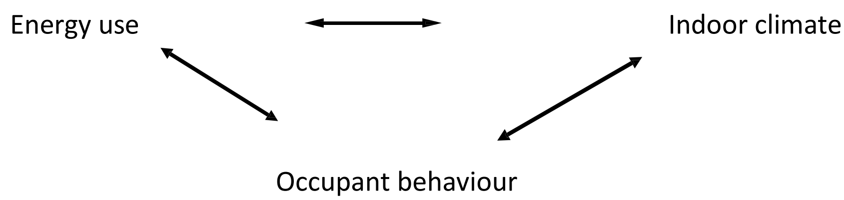


Figure 1: Occupant behaviour can directly or indirectly influence indoor climate and energy consumption (and vice versa).

However, at a second sight (as presented in Figure 2) these relations might be much more complex, especially when we focus on the role of occupant behaviour and its drivers.

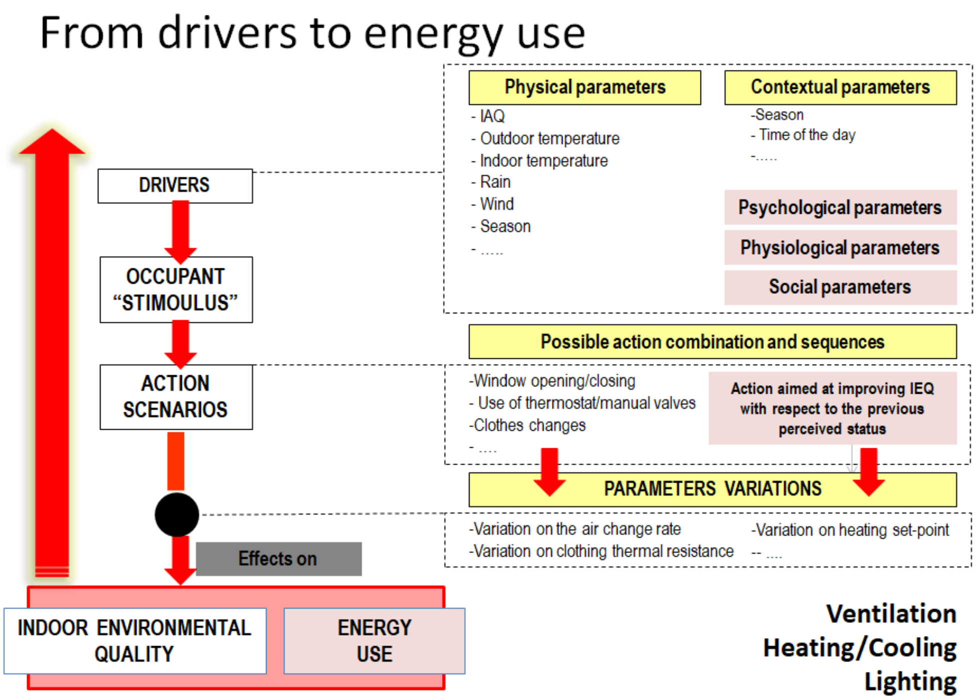


Figure 2: Divers and actions of occupant behaviour (by V. Fabi, POLITO partner)

It is therefore important to analyse the different impact levels of occupant behaviour on building energy performance and indoor climate (influencing users wellbeing) according to different representative cases: different building types (*what)* and different user types (*who)*. Yet, it is very difficult to know and complicated to retrieve what is the actual reason (driver) for certain behaviour in practice. Using various forms of qualitative inquiry, including questionnaires, focus groups and participant observations, more insights are retrieved about specific drivers.

Furthermore, in different design stages (*when*), a different level of accuracy is needed for enabling energy use prediction. It is important that both energy modelling and monitoring (i.e, not only energy but also other building performances such as thermal comfort and IEQ) are cost-effective which implies finding a balance between the accuracy and the simulation and monitoring aim (including allocated time-frame and financial expenditures).

A more elaborated (and more complex) scheme is based on the presence of an occupant at a specific time at a specific location having access to specific building controls. Occupants experience a specific physical environment due to their location, biological, and psychological states, and by the interaction with their environment. Information about occupant presence and activities may be obtained from time-use surveys and occupancy sensing. The interaction between humans, buildings, and building control systems result from a combination of influencing parameters, from now on referred to as driving forces. These driving forces can be regarded as internal and external driving forces. The internal and external driving forces of energy-related occupant behaviour as shown in Figure 3 are ordered according to the following categories: biological, psychological, social, and time, building and building equipment properties, physical environment (indoor and outdoor).

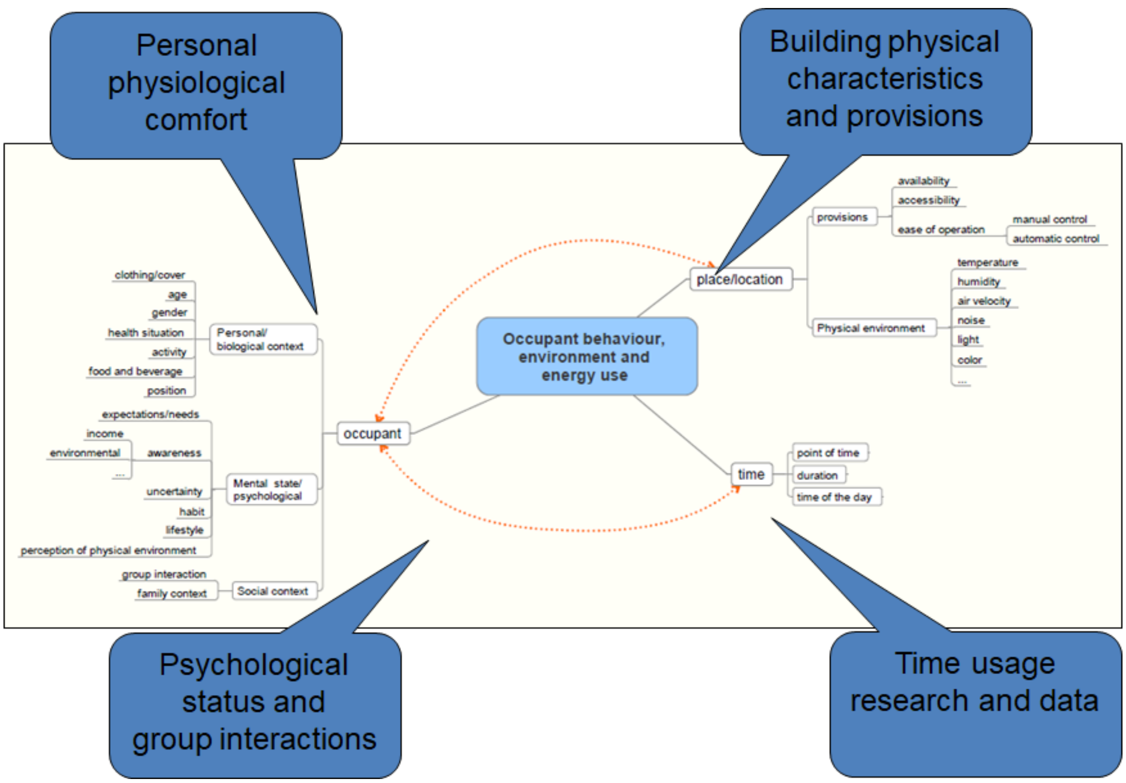


Figure 3: Influencing parameters that have an impact on the relation between occupant behaviour, environment and energy use.

Internal driving forces:

The first three types of driving forces of energy-related behaviour are internal driving forces of the occupant, biological, psychological, and social, and are depicted on the left side of this figure. These are being investigated in the domain of social sciences, economics, and biology. There is strong interaction between biological and psychological aspects, resulting in disciplines such as biopsychology and psychophysiology. Health can be considered as a biopsychosocial unit combining biological, psychological and social elements. Eating or drinking habits are strongly influenced by cultural aspects. Thus, strict differentiation between these driving forces is difficult to handle. A short section on behavioural thermoregulation representing an interface between biological and psychological driving forces with thermal comfort-related interactions with heating, cooling, ventilating, and window opening is included.

Biological driving forces:
Examples of biological driving forces are age, gender, health condition, activity level, hunger, and thirst. These factors together determine the physiological condition of the occupant.

Psychological driving forces:
Occupants tend to satisfy their needs concerning thermal, visual, and acoustic comfort requirements, along with health and safety, to name a few. Furthermore, occupants may have certain expectations of e.g. the indoor environmental quality (such as temperature). Other examples of psychological driving forces are awareness (e.g. financial and environmental concerns), cognitive resources (e.g. knowledge), habits, lifestyle, perceptions, emotions, and self-efficacy (e.g. environmental control). Behavioural thermoregulation: Apart from autonomous biological processes, there is a variety of deliberate regulation options which are listed below. Adequate behavioural thermoregulation can be considered result of learning processes, experiences, and/or culturally-driven factors.

1. Clothing: relevant in hot as well as in cold climate conditions, adequate clothing fosters reducing convection;
2. Thirst as the deliberate regulation of hydration is a crucial issue in people being in need for care or old persons drinking too little (this is of special interest regarding demographic change);
3. Use of external sources for convection or thermal heat;
4. Looking for places which, which are more convenient, e.g. shade, areas with more or less natural convection;
5. Sleep (siesta) as an option to reduce metabolic heat production;
6. Acclimatization: the process by which an individual becomes physiologically, behavioural, and psychologically adjusted to the temperature of the environment. This is of importance regarding the degree by which the individual tolerates actual sensitized temperatures especially when it comes to extreme and unfamiliar climates; acclimatization can be a result of repeated exposure to hot climates.

Social driving forces:
Social driving forces refer to the interaction between humans. For example for residential buildings, this depends on household composition which is linked to the primary decision maker in the household, i.e. which household member determines the thermostat set point or the opening/closing of windows.

External driving forces:
The external driving forces depicted at the right-hand side of this figure (building and building equipment properties, physical environment, and time), are being investigated in the field of natural (or building) science.

Building and building equipment properties:
Examples of building and building equipment properties are the insulation level of buildings, orientation of façades, heating system type, and thermostat type (e.g. manual or programmable), to name a few.

Physical environment:
Examples of physical environment aspects that drive energy-related occupant behaviour are temperature, humidity, air velocity, noise, illumination, and indoor air quality.

Time:
Examples of this type of driving forces that affect energy-relates occupant behaviour are season of the year, week or weekend day, time of the day.

Depending on the scope and goal of energy modelling and monitoring (*why*), different techniques and monitoring strategies can be adopted. More specifically, for monitoring the usefulness and meaningfulness of the monitoring parameters depend to a large extend to both building type and occupant profiles.

During the conceptual design process, simple tools should be sufficient, enabling relatively simple estimation of energy consumption for a certain building type (residential, non-residential) and archetypal user profiles (students, family, elderly). In final design stage, more time-consuming and expensive energy complex software tools should be used in order to increase the accuracy level of energy use predictions.

2. The MOBISTYLE concept

The MOBISTYLE concept is based on the fact that the meaning, consequences and impact of these 'performance gaps' can differ to a large extent, depending on the scale (building, block, district) purpose (energy performance contracts, energy services, grid management, etc.) and the (market) sectors concerned. All these different impact areas have their own characteristics, needs for solutions, methodologies and tools. To a further extent, these specific impact areas need specific business, exploitation models and market products.

This is shown in following matrix (Figure 4), describing how occupant behaviour influences energy consumption for different cases. Sensitivity of occupant behaviour on energy usage is based on different factors (building scale, typology, occupant type and presence, time period). It illustrates that for different levels, different knowledge needs to be obtained in order to predict the energy usage as accurately as possible (OB not the most influencing factor).

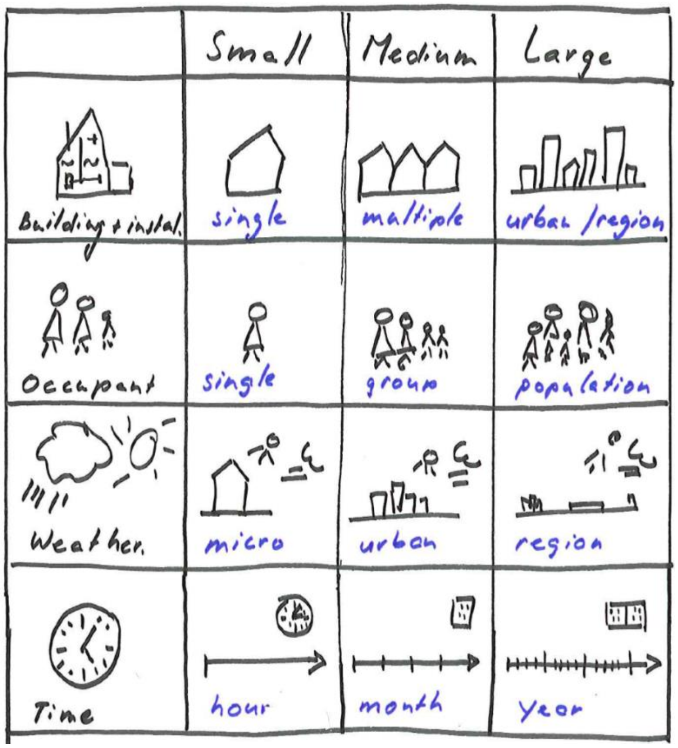


Figure 4: Matrix describing how occupant behaviour influences energy consumption for different cases.

By defining the building design requirements (*what, who, when, why*) first, actual needs and purpose of building occupancy model application should be recognized. Such categorization strategy can:

- decrease the mismatch between predicted and actual energy use;
- increase the usability of suitable developed tools (OB models, energy simulation software);
- increase the confidence in using the obtained results.

Furthermore, the practitioners can in such a simple way, acquire a better understanding of the impact of the occupant behaviour on building energy use for different cases. Moreover, if one knows the future users, one can predict the energy use more accurately and with less risk.

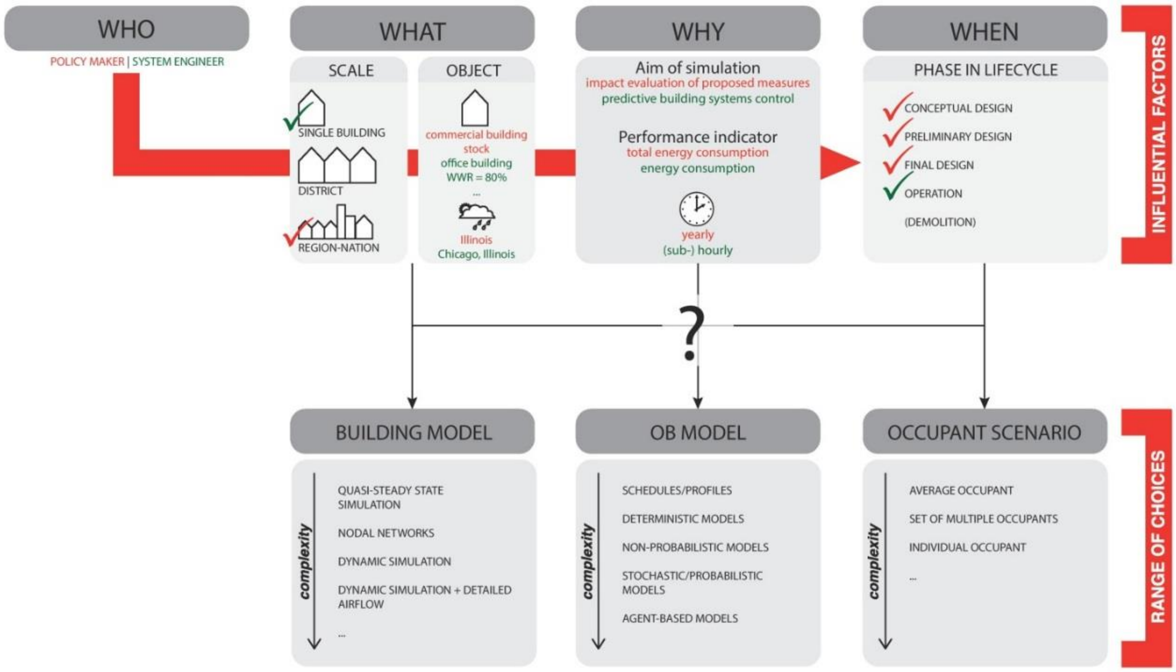


Figure 5: The four requirements (who, what, why, when) should serve as a starting point in any occupant and building profiling and modelling.

From here, the driving factors can be reduced to three effective dimensions that define the main objectives of both energy modelling and energy monitoring:

- Who and why: Stakeholder and problem;
- What: Building type, services and provisions; and
- When: Process stage and tools.

Figure 6 summarizes classification approach described earlier that should be adopted before conducting actual energy performance simulations or behaviour modification campaign. This approach presents the first step of energy modelling where by defining the three dimensions; main objectives of the simulations are answered. This stimulates and triggers the designer to address the occupant behaviour impact and by understanding the OB impact level (high/low) on energy use, he can choose an OB model and energy prediction technique that would be the most suitable for that case. It is believed that such approach can lead to a more accurate estimation of the energy performance. The limited understanding of occupant behaviour leads to discrepancies in building energy use prognosis.

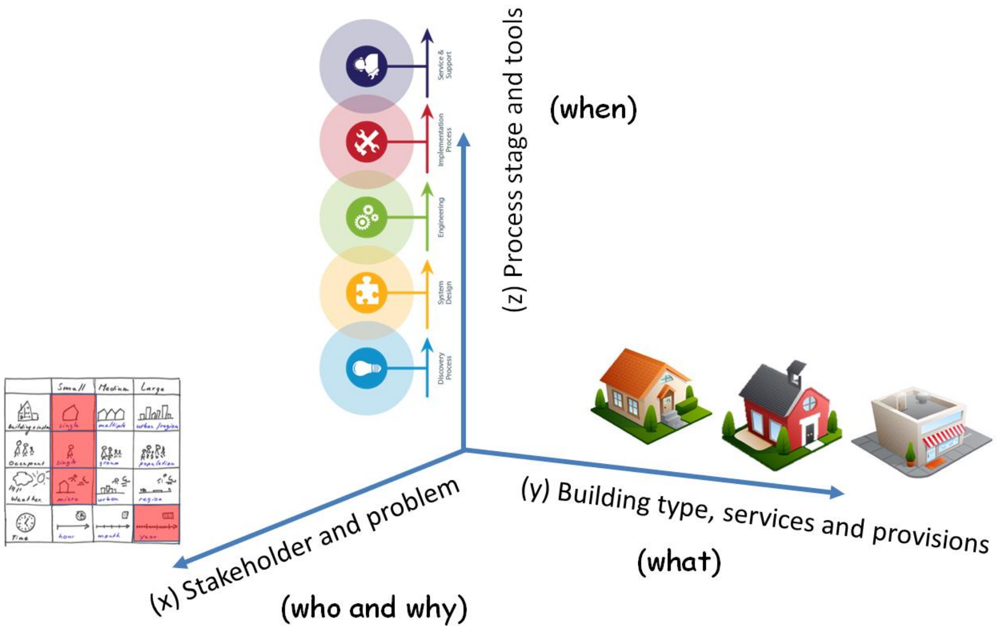


Figure 6: Three dimensions defining main objectives of the energy modelling [Ad van der Aa 2016].

By adopting this categorization approach model and determining the three dimensions, the factors influencing the energy use and their impact is assessed (high/low). This shapes the needs and requirements of the OB model. An appropriate energy prediction approach (even “rule of thumb”, benchmarking, design guides if sufficient) and software are chosen based on determination of the model needs for that particular case. By defining clear objectives for each case, the risk of mis-applying complex and time-consuming models is avoided. The impact of the occupant behaviour on energy use is quantified and a suitable OB model can be chosen from among the available suitable energy prediction tools.

3. Occupant behaviour impact on building's overall performance and a need for user profiling

Impact of occupant behaviour on building energy consumption and indoor climate is often not accurately assessed since each person behaves in a distinctive way and differently interacts with the surrounding environment (directly or indirectly influencing building energy consumption and indoor climate).

3.1 Occupant behaviour impact on buildings energy usage

To reduce the gap between the predicted energy use and actual building consumption, better understanding of OB and appropriate assessment of the impact of OB on energy use is essential. However, it differs to a large extend if OB really matters and is significant on energy use.

3.1.1 Residential buildings

In residential buildings occupants have often a big impact on the energy use, by having direct individual control and interactions with various systems of the building leading to energy consumption as also to impact on indoor climate (light switch on/off, fan on/off, thermostat up/down, and window/door opening and shading positioning). The study from the Netherlands, where the energy use of 106 Passive houses in Almere, the Netherlands have been compared (Figure 7) shows a difference in energy use between the house using the least and house using the highest energy up to factor of 12. In high-performing buildings (like passive houses) the relative weight of OB becomes crucial and much higher that in buildings with lower performances.

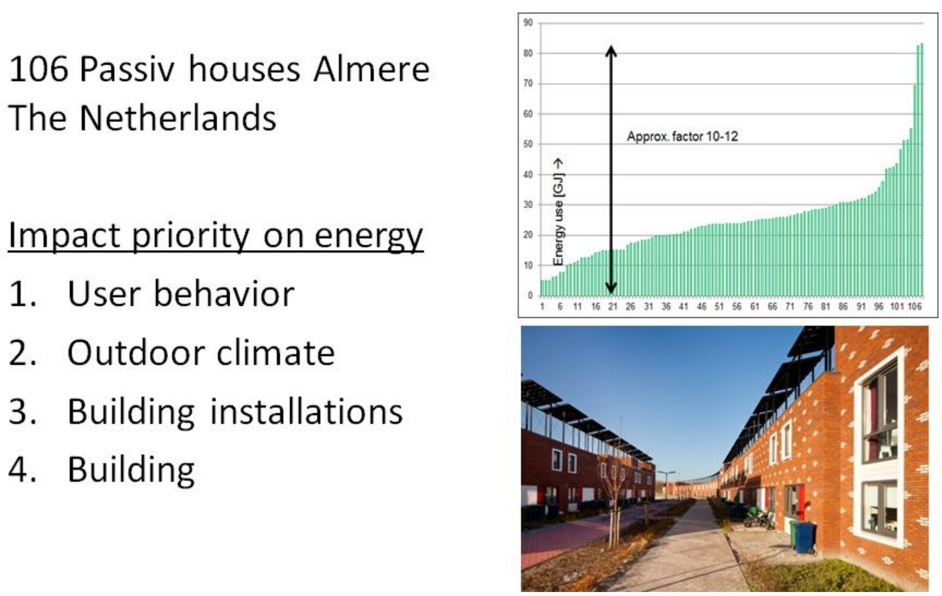


Figure 7: Comparison of energy use for 106 passive houses in Almere, the Netherlands.

This variation in energy use is in a large extent related to the behaviour of the occupants of the dwellings, since identical buildings and installations having the same energy efficiency have been considered in this study. User behaviour and lifestyle means that energy consumption in otherwise identical homes can vary by a factor 10-12.

Furthermore, a study of 1000 quite similar residential buildings in a suburb of Copenhagen, show huge variation in energy consumption in spite of their similarity. The comparison of heating energy use for completely identical houses showed that households using the greatest heating energy used a three time more heating energy than the households using the least energy for heating. For electricity use, an even larger variation was found; households using the greatest electricity used five times as much as the households using the least electricity[2].

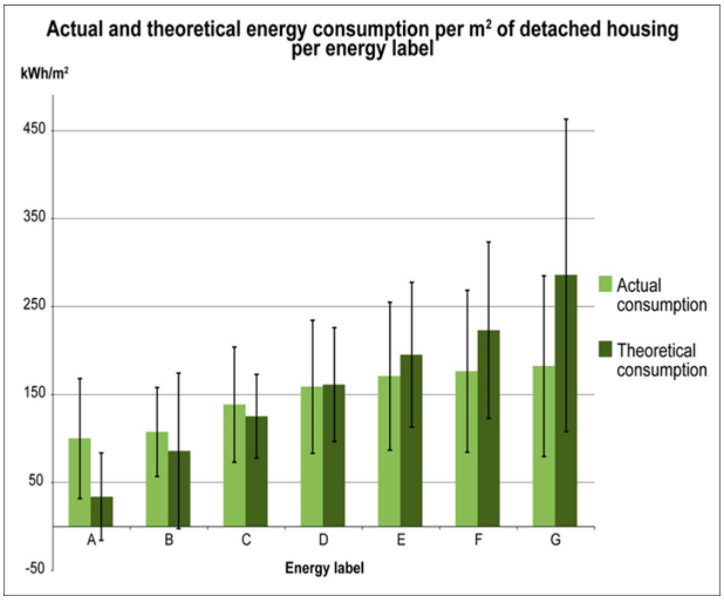


Figure 8: Actual and theoretical consumption for the residential buildings in suburbs of Copenhagen, Denmark. Figure from: UserTEC – User Practices, Technologies and Residential Energy Consumption. P. Heiselberg, AAU, Denmark LINK).

3.1.2 Non-residential buildings

In non-residential buildings, the impact of OB is much more variable and depends on the building function and on the technological and the architectural configuration of the space. For example, in a theater or a department store, the impact that single users can have on the overall energy consumption is extremely low.

3.1.2.1 Office environment

In an office building, this impact could be much more important, based on the building configuration and on the level of control that each occupant has within the building. For example, in an open plan office, single employees have a different control level from small or even single offices. In fact, the larger the working space, the lower the singular control level over the space. However, this does not mean that in

[2] UserTEC – User Practices, Technologies and Residential Energy Consumption. P. Heiselberg, AAU, Denmark LINK

open plan offices single occupants do not have a significant weight on energy consumption, but only that their behaviour will be highly influenced by the social rules established in the office.

Therefore, even if it would be reasonable to think that in smaller offices (or even single ones) the relative weight of single occupants will be higher than in larger ones, it should be also taken into account that in open plan offices, the control level of singular occupants will not only depend on the architectural and technological configuration of the space but also on the social norms pertaining to that specific office.
About the architectural and technological configuration of spaces, in a fully automatized office building, in which the occupants has almost no control independency (no thermostats, automatized artificial lights etc.), the impact of OB is usually reduced. Differently, in an office characterized by a higher level of control exercised by occupants (operable thermostats, windows, artificial lights etc.), the overall weight of OB will be extremely high. One of the main reasons why the influence of OB in several non-residential buildings, and especially in offices, should not be neglected is the role of energy management. In fact, while in residential buildings the occupant and the building manager personas coincide, this is not usually the case in non-residential buildings, in which normally the building manager is a specific person setting all automatic systems of the building. For this reason, in non-residential buildings is usually more difficult to establish indoor environmental conditions that satisfy all occupants. For this reason, in non-residential buildings it is more common to find situations in which occupants try to override systems' settings by adopting solutions that, very often, cause energy wasting. For this reason, also in fully automatic buildings, OB weight in determining the building's energy efficiency should be carefully evaluated.

In this context maybe possible interventions / actions / behaviour can be used that are defined for each MOBISTLE demonstration case and can be stimulated by the awareness campaigns per demo case.

For different building types, energy usage caused by other occupant actions (using equipment or home appliances) needs to be determined. Once carefully characterized the specific building's characteristics in terms of potential interactions of occupants with energy-related controls, for the cases where occupant behaviour has a relatively low impact on energy usage, simpler OB models and energy prediction techniques can be sufficient. Hence, it is important to distinguish between different building typologies having different occupancy schedules in order to choose appropriate energy usage prediction techniques.

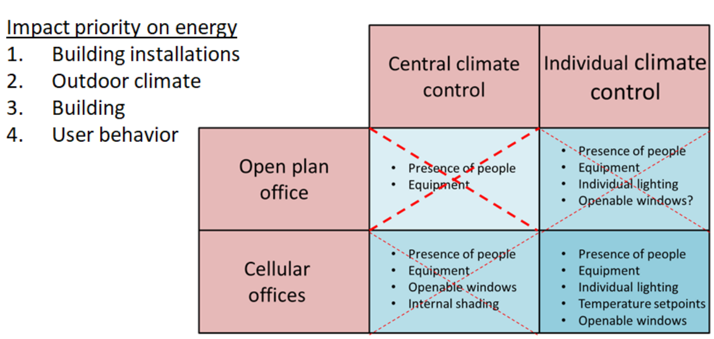


Figure 9: Influencing parameters of OB in office spaces.

3.1.2.2 Hotel environment

The impact of occupant behaviour in hotel environment might be at first glance compared to impact in residential building situations. However, characterizing living patterns and occupant profiles in a hotel cannot be done in the same way as in a residential building. The first and most obvious reason is that building occupants – the guests, are not permanent ones. The second aspect to be highlighted is that each room or apartment (in the case of short-term rentals or B&B) can be considered as a singular unit, characterized by different living patterns from all the other. This means that the investigation level cannot be the whole building one, but it has to be the single room/apartment, and that also the temporal scale should be taken carefully into account. In fact, the analysis of habits will necessarily be limited to the time of stay of each guest to define the reference patterns for it.

3.2 Occupant behaviour influence on indoor environment and well-being

Not only that occupant behaviour impacts building's energy performance but also affects indoor environment and vice versa. Due to concerns about health issues related to the indoor environment (e.g. asthma, allergies) or due to perception of numerous indoor climate parameters (e.g.: high CO_2 level), indoor climate can affect user behaviour (e.g. opening windows). These indoor climate parameters are related to thermal, atmospheric, acoustic and visual indoor environment aspects.

To meet the strict EU energy targets and improved indoor environment for all Europeans, it is therefore important to obtain much more knowledge on the user behaviour influencing energy consumption and indoor environment to include and affect these aspects in a positive way. There is an enormous diversity of the different occupants' profiles, with different needs, priorities and therefore the energy consumption of buildings can vary a lot.

It is important to distinguish between different building typologies and their user groups having different impact on the building energy use and indoor climate. In MOBISTYLE is for the five-demonstration buildings investigated how to come to sufficient number of user groups for the different building types to different archetypes (personas) with their typical user profiles based on individual building occupants' behaviours but still provide sufficient accurate information per each group.

As for the different building typologies, in general following overview can be considered in relation to building services, several provisions for controlling the indoor environment and the specific OB aspects to consider.

Type of building	Subtype (represented in the project)	Installations and control	Provisions	Aspects of OB to consider
Residential	- Single family apartment - House	- Individual - Collective	- Openable windows - Operable thermostat - Solar shading	- Heating (thermostat operation) - Ventilation - DHW - Lighting
Office	- Open floor - Cellular	- Individual control - Central BMS	- Openable windows (in the Slovenian case) - Solar shading	- Internal heat load - Lighting - Openable

				windows (in SI)
School	- University	- Individual control - Central BMS	- Openable windows - Solar shading	- Occupation pattern
Hotel	- Hotel - Short-term rent apartments	- Individual control - Central BMS	- Openable windows - Operable thermostat - Solar shading - Other appliances (e.g. frigobar)	- Heating (thermostat operation) - Ventilation - DHW (including washing machine, fridge) - Lighting

Figure 10: Based on the different building type (what), OB has different impact on the building's performance due to the level of control they have.

The energy-related aspects of occupant behaviour in this scheme refers to actions and activities related to the categories heating, cooling, ventilation and window operation, domestic hot water, electric appliances / lighting, and cooking. These categories are briefly introduced underneath and are discussed in greater detail in the subsequent sections of this chapter.

1) *Heating:* The activities of occupants have become more important within energy efficient buildings. Studies have shown that user behaviour and lifestyle can affect energy consumption by up to a factor of three. Occupant behaviour related to heating concerns temperature set point, number of heated rooms, heating duration, gender, age, expectations, knowledge of control function and meteorological conditions. In evaluating the influence of heating-related behaviour of occupants, it is crucial to understand which are the related control interfaces available, regardless the building type.
2) *Cooling:* Depending on the type of system, occupant behaviour has a significant influence on the use of cooling. From the general to the detailed, this starts in some cases with the choice of cooling system, the duration and frequency of usage, the choice of set-point temperatures, and the frequency of maintenance.
3) *Ventilation and window operation*: Investigations on window opening behaviour and natural ventilation have mainly been carried out with two aims: to find whether or not occupants are provided with adequate fresh air and to find the influence on energy consumption. Moreover, many efforts has been made in trying to individuate the behavioural drivers influencing the action of opening windows. While the studies in the area of indoor air quality have usually been carried out in dwellings with a health or a comfort perspective, the ones related to energy efficiency have mostly been studied in offices with a comfort and energy performance perspective. Regarding ventilation, occupant behaviour concerns both mechanical ventilation operation, natural ventilation inlet operation and window opening or closing. These categories are quite different from each other, both in terms of drivers influencing the actions (AHU operation or windows operation) and the frequency and modalities of the actions themselves. More specifically, it is not said that the same occupant would operate a mechanical ventilation system in the same way in which he would operate windows. This, because the interface type has a huge influence in OB. For this reason, also for this type of building-human interaction the characterization of the control type is very important.

4) *Domestic hot water:* Occupant behaviour can significantly influence the use of hot water in residential buildings. Examples of energy-related occupant behaviour related to domestic hot water use are the frequency of taking a shower, duration and intensity of showers; frequency of taking a bath; frequency of sink use; frequency and temperature of washing machines and dishwashers, and efficiency of water usage. In non-residential buildings the use of domestic hot water is usually very reduced. Gyms and hotels represent an exception. However, even these two types of functions differ very much. In fact, the use of DHW in hotel is much more similar to the residential category, with the difference that normally occupants are not permanent users of the building and there is a higher density of DHW in respect to a house. In fact, each room is normally provided with a shower and the behavioural patterns cannot be related to the whole building, but to the single room.
5) *Electric appliances / lighting*: The use of electric appliances and lighting in residences is strongly influenced by occupant behaviour. When the energy consumptions for appliances and lighting are considered, large variations are found, which partly relates back to socioeconomic parameters such as income, persons per household, age, education etc. The number of appliances and their energy efficiency, as well as the usage frequency and duration determine the energy use. In non-residential buildings, and especially in offices, occupants' use of electric appliances is a crucial contributor to the building's energy consumption. For example, encouraging workers to switch off desk appliances has a strong potential in reducing the overall energy consumption.
6) *Cooking:* Many different appliances can be used for cooking purposes, such as microwave ovens, ovens, stoves, pressure cookers, kettles, etc. The type of equipment used and their corresponding energy consumption as well as the number of meals prepared will determine energy use for cooking. About non-residential buildings, cooking is a fundamental contributor to energy consumption in a few type of building functions, such as restaurants and house-rent hotels.

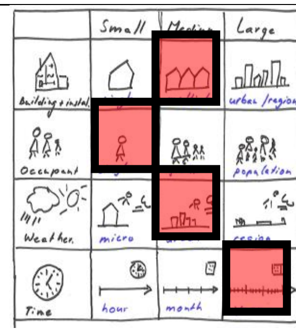
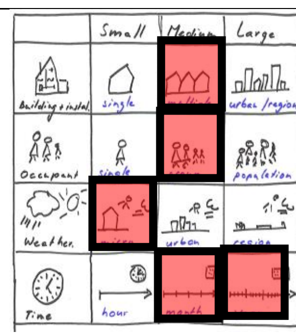
Energy-related occupant behaviour may be use, purchase, or building maintenance related. The effects of energy-related occupant behaviour (e.g. building control actions) on residential and non-residential energy use and indoor environmental quality may be calculated quantitatively using building simulation software packages.

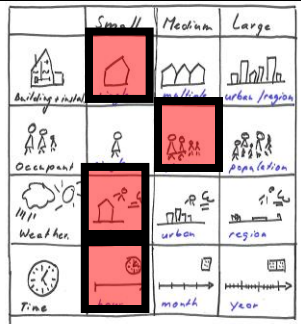
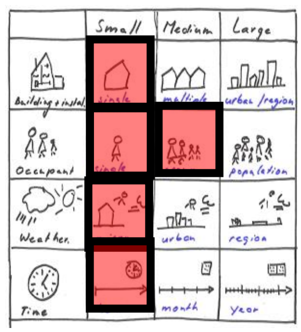
3.3 Different building types (what) and archetypal user profiles in MOBISTYLE (why)

Besides assessing user behaviour in buildings, it is important to distinguish the building types and control the users have per each building typology. In general, in "public" non-residential buildings (like theaters and department stores) occupants have much less impact on the total building energy usage and indoor environment as in residential buildings where they can have direct control over building services and components. In MOBISTYLE it will be investigated the impact of users in residential and non-residential buildings.

Identification of user types and observation of their everyday lifestyle is a prerequisite in user profiling. In the first year of the project, the MOBISTYLE project focused on an anthropological observation of users, scrutinizing their level of engagement with building components, technology, energy systems and ICT tools in their everyday life. The observation of users in their daily interactions with buildings and various systems in the buildings (e.g. opening windows, turning thermostat) revealed the impact on energy consumption and the indoor environment (how they use the systems).

In MOBISTYLE five different building typologies with different user types are identified for the demonstration cases, based on the matrix in figure 4:

Demonstration case	Project description and building typology	Type of users	Scale matrix	Remarks
Denmark	Social housing apartments at Kildenparken, Aalborg	Social housing, residents		Communication on real energy performances as well as IEQ based on reliable predictions using real household profiles can avoid these discussions and gain the acceptance by tenants. The main problem is that the building may consume more than predicted and the question is: does this consumption comes from the quality of the renovation, or from the user behaviour, or from weather (the last one is the easiest to correct).
Slovenia	University buildings at the University of Ljubljana, Ljubljana	Students, professors, students, visitors, other staff		In this case we are dealing with medium sized groups of users to be informed, each with different needs and characteristics. Time can considered on a monthly or even yearly basis.
Italy	Apartments at the Hotel Residence L'Orologio, Turin	Hotel guests, staff		Hotels are perhaps the most difficult buildings to consider for information to users. On building scale, it can be considered on typically one building, or in a hotel chain between more hotels in the chain. Weather and time is typical short-term.

The Netherlands	Office buildings, Qeske Kerkrade and Brightlands, Sittard	Employees, employers, building managers		Offices are typically considered on a small scale concerning building, weather and time. Occupants normally on medium scale, in MOBISTYLE was done an experiment on individual scale.
Poland	Residential houses as part of the Smart City Wroclaw, Wroclaw	Residents	 	For grid management building, occupants and weather are normally considered on a large scale. For effective grid management time on short scale (e.g. peaks) For individual information to households (energy community) it is important to have information on a small scale basis. In case of energy communities a medium scale (small district or block) is also possible

4. User profiling in MOBISTYLE

4.1 Introduction to the user profiling approach in MOBISTYLE

Based on gathered behavioural and building data from the five demonstration sites, combined with outcomes from the anthropological inquiries (focus groups, questionnaires etc.), individual building users for different building typologies were classified in archetypes (personas), each with their typical energy and occupant profile, information approach and strategy to come to lasting behavioural change and motivation (students, families, employees).

Four types of profiles have been distinguished as listed in the following. However, based on the building type, different approaches were used in the profiling, since different behavioural characteristics can be monitored in different building typologies and configurations.

<u>Building profile:</u>

- Building type (residential, non-residential, public, office building etc.) and property characteristics;
- Description of a demonstration case building based on architectural and building physics properties (see D6.1).

- Products group: description of the products, services, appliances installed in a building.

Occupants profile:

- Enumeration of the occupant's characteristics: age, gender, number of occupants. This is information to be used for both non-residential and residential buildings;
- Lifestyle and values;
- Physiological characteristics (if this data is available).

Usage profile:

- Usage of building services, equipment, appliances
- The degree of control that a user has over the building, building services and appliances
- ICT literacy (what device, when using them, how long etc.).
- Specifically for dwellings: the moments and amounts of domestic hot water

Socio-economic profiles:

- Social status
- Financial status
- Behavioural analysis: attitude, social norm (influence of others), perceived behavioural control
- Degree of affinity with the environment/sustainability concerns

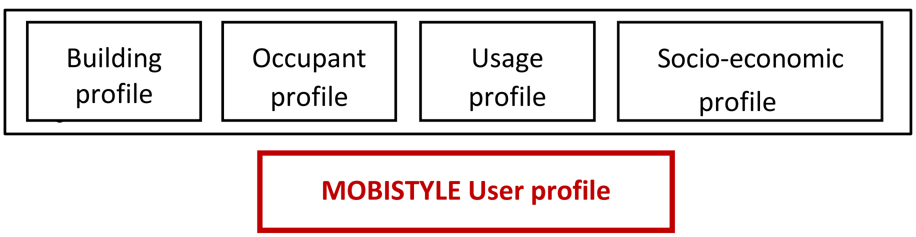


Figure 11: Schematic link between MOBISTYLE User profile pattern and associated Profiles.

Based on this distinction also tailor-made behaviour and saving advices can be given for the identified profiles.

4.2 Occupant profiles for residential buildings

The living pattern and occupant profile for an individual house can be retrieved by asking the right questions about the house, the occupants, the usage and socio-economic factors. This can also be achieved by using focus groups (as described in D2.3). A powerful tool to enhance communication with occupants and for the supplying building parties (e.g., real estate developers, housing companies etc.) is to group and aggregate occupants' profiles into larger subsets.

In paragraph, a design is given for an aggregation of occupant profiles and patterns based on the method of Mosaic[3].

The living patterns are inspired by the way in which the Mosaic method distinguishes households groups and types. This is combined with literature on the occupancy behaviour in relation with energy use (IEA Annex 53 and IEA Annex 66). This can be used for example to provide more detailed input for energy calculation, based on real used (instead of default, standardized input like EPBD based calculations).

The result is that each occupant profile and pattern represents a part of the households with the same typical characteristics for (total) energy use, with the limitation that the method and results are typically based on Dutch households.

This method distinguishes and classifies 10 occupancy patterns are inspired by the classification of Mosaic households of Experian. (Experian has designed so called Mosaic Households to identify and classify all over seven million households in the Netherlands, especially for marketing and communication purposes). The result is a classification that gives a clear picture of Dutch consumers in terms of their socio-demography, lifestyle, culture and (purchasing) behavior. In the figure below, the fourteen main groups are shown against the most distinctive aspects, age and prosperity.

[3] www.experian.nl ; Experian is the global leader in providing information and analysis and marketing services to businesses and consumers

Figure 12: Example of a classification of 10 occupancy patterns for Dutch households

Within the overall spending of consumers, the use and purchasing of energy is a commodity that is part of a necessary need for heating, domestic hot water and electricity. Therefore, it can be argued that purchasing energy can be considered in the same approach and emotion can be taken as other expenditures with a similar pattern needs.

The first step to make is to study and analyze the data of Mosaic for energy use. There are a number of Mosaic households in which energy use is not a distinction. Also there are Mosaic groups where a subdivision has been made that does influence energy use. Finally, 10 profiles were chosen and adopted based on the Mosaic Households. The following table describes the 10 Mosaic occupant profiles.

Table 1: Standard households

Description of the profile	Mosaic classification	Features	Percentage Population in NL
Young Working		Single or cohabiting, part time/fulltime working, high or scientifically trained, apartment in the city	7,8%
At home	A: Young Digitals	18 - 65 years, students, starters, unemployed, living single, no children, no full-time job, dwelling < 90 m2 Simple housing	9,3%
	B: Urban Balancers		3,4%
	G: Social Tenants		7,9%
Single parent, at home	C: Start together	25 - 45 years, live together or single Sometimes children, low income, working part-time or not, low level of education, dwelling 90 - 135 m2	7,1%
Single parent, working	E: Average spending families	30 - 50 years children at home < 12 year, wage-earner works full-time, average income, dwelling 90 - 135 m 2	6,2%
Traditional family	E: Average spending families		
Two earner family	F: Child and career	30 - 55 years, living together, several children, good income, high-skilled, little at home, dwelling > 90 m2	7,3%
Mature couple, at home	H: Mature middle class	50 - 75 years, married and living together, no Children or child of at least 13 years old, still working fulltime or part time, income is low to 1.5 times average, high-skilled, dwelling 90 - 135 m2	7,6%
Mature couple, working	H: Mature middle class		
Seniors at home	N: Grey simplicity	65 +, retired, no children living at home, pension, income is Down Modal, low education and low-skilled jobs	8,7%
Seniors reasonable often at home	J: Golden Edge	55 +, Retired, married, no children living at home, good pension, high education, reasonable often At home	5,5%
	K: Elite top -class		4,3%
	L: Rural life		6,8%
	M: Well-deserved enjoying		8,9%

* Group I Is not a separate group (8.8%), the households are spread about the adjacent groups.

The energy use in dwellings is subdivided into a number of main groups, so-called energy use items. In these energy items a further subdivision is made to parameters that should provide input in order to come to a reliably calculation of (real) energy use.

In the occupant profiles the values of these parameters can be further defined and determined. The following table shows the several ‘energy items’ that can be distinguished in MOBISTYLE with a description and, in a generic way, how it could be monitored in the demonstrators.

Table 2: Main groups calculate energy use and Monitoring principles.

Energy item	Description	Monitoring principles basic	Monitoring principles advanced
Presence	Average number of hours present	Self-reporting, (app, on line)	Presence detection Video detection (offices)
Heating	Setting thermostat	Self-reporting	Smart thermostat
	Use shutters/curtains	Self-reporting	Magnet sensors (shutters)
	Use inner doors	Self-reporting	Magnet sensor
Ventilation	Use ventilation system ME	Self-reporting	Data logging
	Use of ventilation grills	Self-reporting	Indirect by CO2. Magnet sensors
	Airing	Self-reporting	Magnet sensor
Lighting	Presence lighting	Self-reporting	-
	Use of lighting	Self-reporting	Smart plugs, meter clamps
Hygiene	Presence bath and /or shower	Self-reporting	-
	Use sanitary services	Self-reporting	Data logging (T)
Cloths washing	Use washing machines	Self-reporting	Smart plug, smart washing machines
Dish washing	Use dishwasher	Self-reporting	Smart plug, smart dish washers
Cooking	Use stove	Self-reporting	Smart plug, smart stove
	Use oven	Self-reporting	Smart plug, smart oven
Equipment	Presence equipment	Self-reporting	Meter clamps
	Use equipment	Self-reporting	Meter clamps, smart plugs

In the report D3.2 'Development indicators based on environmental conditions' these monitoring principles are further elaborated for each demonstration and study case, aiming to perform an easy, non-intrusive and cost effective measurements and monitoring. This also includes monitoring of the overall indoor environmental quality, in order to realize all the case specific MOBISTYLE objectives. D3.2 provides an overview of relevant energy, IEQ parameters and (in the Dutch demo case) physiological parameters with their potential impact on human comfort, health and wellbeing on the one side, and on the other side their relation to energy use.

4.3 Occupant profiles for non-residential buildings

4.3.1 Open-plan offices

For the Netherlands, two open plan offices were used for the MOBISTYLE demonstration (Qeske and Kerkrade). To stimulate interaction between coworkers and optimize the usage of space, offices are more and more designed or transformed into open space environments. Due to design practices, installations and lighting systems in these multi-user environments are implemented per whole area/grid.

Consequently, purely personal control over installations (heating, cooling, ventilation, air-conditioning) and lighting is not achievable in most cases. When applying the adaptive comfort model [5], indoor temperatures were allowed that drift along with the out-side (daily and seasonal) temperatures, and in so doing, energy consumption can be reduced substantially compared with the scenario of maintaining constant indoor temperatures recommended by standards such as ISO 7730 and ASHRAE 55. It should be noted that in none of these two office environments used for MOBISTYLE demonstration occupants are able to open the windows their fore the occupant profiling in office environment is only looked in respect to temperature settings. For the Qeske and Brightlands, the preference profiles were modelled based on dynamic condition profiles and occupant's preference information. Occupants individual feedback and satisfaction of occupants with their surrounding indoor environment is gathered via the MOBISTYLE Office App and based on their satisfactions, indoor temperatures were adjusted +- 1-2 °C.

The dynamic indoor conditions were introduced for winter and summer profiles. In winter, lower temperatures indoors were allowed and in summer higher. It has been previously proven that this can improve health as also reduce energy consumption [6]. These studies have demonstrated that heat/cold acclimatization does take place when regularly exposed to warm or cold environments. This means that with longer variation in indoor temperatures, this positively influences long-term comfort and health. Still, by taking into account occupants' preferences, it was possible to manipulate the control system (BMS) if dissatisfaction with conditions was high. A flexible framework for dynamic indoor-climate-design permissible temperature ranges were introduced in Qeske and Brightlands.

Preferences between neighbouring users might differ due to their mood, activity, or preference. Providing everyone with satisfying conditions becomes a challenge. Therefore, MOBISTYLE feedback provision via the Office app was introduced to first evaluate their acceptance and find the best profiles for the given group and through the feedback look, increase the acceptance with the dynamic office conditions indoors by educating building occupants.

As previously proven by the MOBISTYLE Partners Maastricht University [5], there are significant differences between preference profiles of users also due to the different bio-physiological

Building occupants can be profiled based on their preference and control behaviour in the following ways:

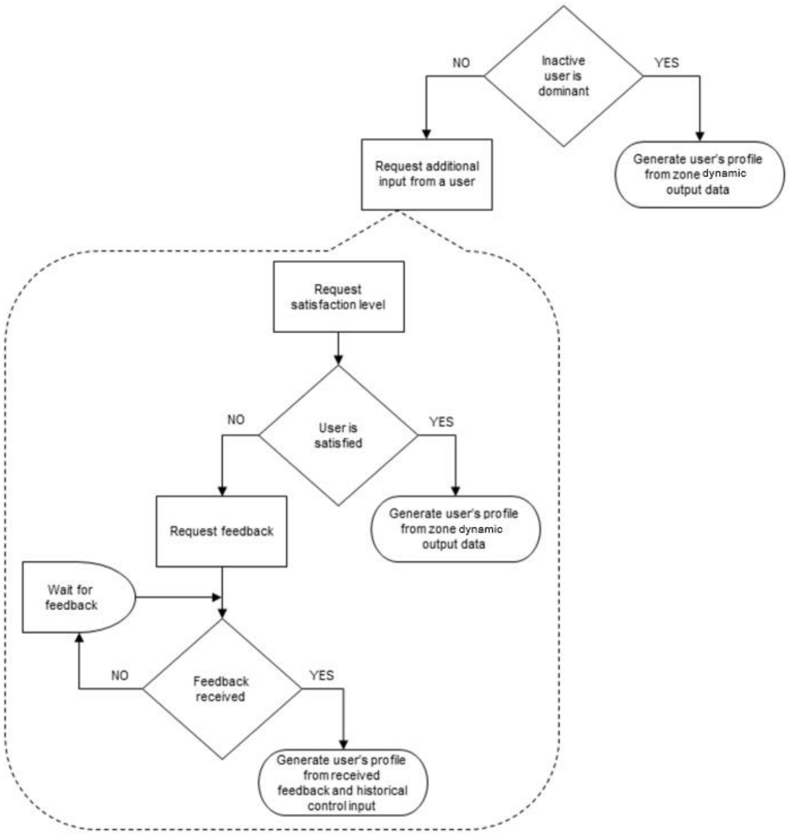
- *Physiology and activity level*: The human metabolism (activity), body fat, clothing, relative humidity, air velocity, operative temperature all affect human's physiological response on the imposed surrounding conditions. The level of activity of each user can be determined based on the number of user control actions. The user's control actions are a good basis to derive the user's preference profile. Having only a few control actions of a user, makes derivation of the user's profile difficult. The
- *Tolerance and psychological response:* A tolerant user will select a broader range of dynamic conditions meaning that he can work under a larger variety of conditions. Contrarily, an intolerant user will demonstrate a more preference for stable conditions. When weighing users' preference profiles to offer satisfying conditions for multiple users, the tolerance of the users should be taken into account. The preference of an intolerant user asks for a higher weight, meaning that the proposed level should be shifted towards the preference profile of the intolerant user. Users with a high tolerance will less likely experience conflict.
- *Dominance*: Dominance is observed via the correlation between a particular user preferred temperature level and the prevailing output in that zone. The dominance of a user is determined as a fraction of time the temperature output matched the temperature set by that user. If the

output of the heating/cooling is set according to the user's preference for most of the time, the user is dominant in that control zone. Submissive (non-dominant) users are intimidated by others and manifest conflict avoiding behaviour, resulting in not changing the temperature level even when dissatisfied.

- *Preference*: The level preference of a user is the control setting that is most comfortable for that user, leading to the highest user's satisfaction with dynamic conditions. Having opposing preferences in one control zone might introduce dissatisfaction of the users and pose a risk of conflict. Intolerant users will be more active to achieve their preferred zone, unless they are submissive in relation to their neighbours in the same control zone. In those cases, the risk of dissatisfaction is high. Tolerant users, who will prefer a broad range of selected temperature and lighting ranges, are expected to be less active in their control behaviour and will have a lower risk of dissatisfaction. Furthermore, submissive users are assumed to be in general less active than dominant due to their conflict avoiding character.
- *Education*: Investigating individual differences can assist in creating a preferred profile for coworkers sharing the same open plan office space. However, providing occupant sufficient information and knowledge can further improve individuals' beliefs and acceptance with the surrounding conditions if this help them to become healthier, more productive and efficient.

The proposed classes for activeness, dominance, and tolerance represent general categories and for the classification, exposure to the dynamic conditions with wider temperature range might lead to a higher risk of conflict. Intolerant users, who prefer a stable temperature range, will be more active to maintain their preferred temperature, unless they are submissive in relation to their neighbours in the same control zone. Furthermore, education on the healthy benefits of these dynamic conditions to building occupants can further improve their acceptance. Tolerant users, who prefer a wide illuminance range, are expected to be less active in their indoor climate control behaviour and will have a lower risk of dissatisfaction.

Scheme 1: Flowchart of control zone classification



n.

A MOBISTYLE semi-automatic system shown in Figure below can automatically adjust the dynamic temperature profiles in finding consensus between the different occupant's acceptance and in addition to the healthy benefits of dynamic thermal model. The users' control actions in terms of offering satisfactory thermal conditions can be performed based on the contextual data collected in the office. Furthermore, access to thermal preference profiles of office users can improve design decision making as well as help facility managers to optimize their building operation strategies.

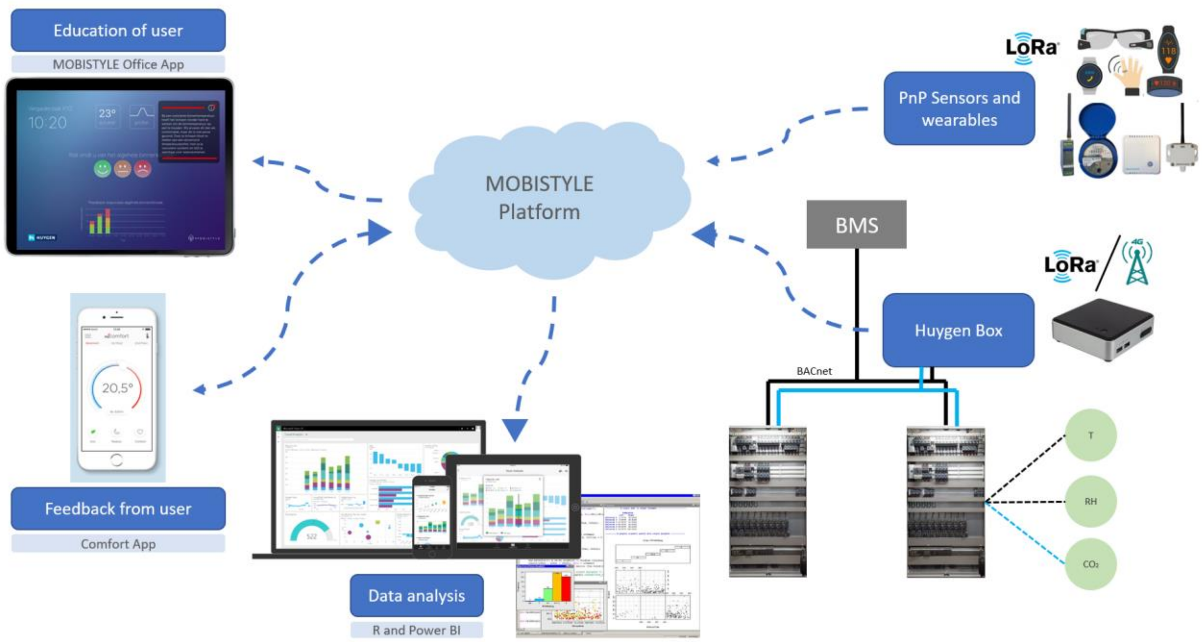


Figure 3: MOBISTYLE ICT System allowing dynamic conditions in open plan offices while taking into account users feedback to define best dynamic profiles.

4.3.2 Cellular office

In detailed measured part of Slovenian demonstration building, there were offices at 2 faculties[4] which are part of one complex. Detailed interaction of people with building systems (thermostat, windows, access etc.) was measured for 2 years in 8 rooms. There were 2 different typical office sizes; small one 14-22 m^2 and larger ~63 m^2. Each room has possibilities to control lighting, heating and cooling via thermostat, open windows and manipulate external shading. All the room selected for MOBISTYLE demonstration at this site had no mechanical ventilation.

Ethnographic research was done for the room users to ease the understanding and to come up with possible typical profiles. Findings from ethnography relevant for profiling are summarized in the table below.

Table 3: Room and people information

No	Room ID	Area [m^2]	People	Some remarks from ethnography
1	K1N0623	18	2	2 people (woman and man), occasionally 3 (visitor), but not more than 1-2h at the time. They usually arrive in the office at 7.00 in the morning. They state, that they open the window a lot. They do not get direct sunlight. Both of occupants spend a lot of time around the premises, not in the office. It is often empty, and never occupied full 8h/day.

[4] Faculty of Chemistry and Chemical Technology (FCCT) and the Faculty of Computer and Information Science (FCIS).

2	K1N0624	18	1	Single person, mostly present .
3	K3N0605	14	2	2 persons both teaching assistants, so they spend time also in the lab and classroom. Woman states that she is usually in the office until appr. 9.00, than around the premises. She opens the window, when she sees the red light (on the sensor).
4	K3N0618	14	1	Single person, professor regularly switching between lab and office.
5	R2N0805	63	~6	Lab, occupied all the time. They have regular coffee breaks, one around 10am, one around 3pm. The first to come into the room opens a window, especially in the summer. Two of them open the window if the light is red. They work the longest, mostly till 6pm. They open the window just in the summer, mostly May and June. If co2 levels are bad, they will open the window, but mostly in the afternoon (5pm, 6pm).
6	R2N0634	22	2	Typical professor, often locked in the room (so he has peace to work). He says that as soon as he arrives, he opens the window, but only for a few minutes to ventilate. He doesn't like to come to work early, so he comes later and leaves later. He sets the external shading himself, saying that when they close on their own, he must intervene manually.
7	R3N0644	16	1	Typical professor, rarely in the office, likes to ventilate the room. He doesn't like draft. He says he uses the thermostat a lot. He prefers light, dislikes shading. Present almost only in the morning (before 12pm). Opens windows only in April, May and September.
8	R3N0808	63	~6	Lab, occupied all the time. They say they have the window opened almost all the time in summer, after they got the sensor with LED. They have a lot of plants in the room. They ventilate often. Open windows in the morning, between 8 and 10 am. Typical seasonal trend: windows rarely open in the winter and in the peak of the summer.

Based on findings, we can distinguish offices based on several factors such as:

- Occupancy
  - Fully (~8h/day)
  - Occasionally (few h/day due to nature of work)
- Nr. of users
  - One or 2
  - 2 or more

In terms of project domains (IEQ, health and energy), the OB plays the key role. After possible human-building interactions were determined, the tailored campaigns have been developed together with the rooms users. The information to the room users was distributed via several channels on site. Some of them well established (LCD screens), some new (frames on the strategical locations) in combination with app notifications.

In this part of Slovenian demo (offices) the 3 MOBISTYLE domains are determined by several factor with different weight of OB for each. In IEQ, the artificial lights need to be turned on manually, but are switched off automatically after 15 minutes if the room is locked. External horizontal shading position is determined by illumination sensor on the roof and sun position (date and time). If the user intervenes, they remain in the desired position until the next day. IAQ is determined only by opening windows and doors. We are gathering data about window opening, but cannot know the door opening as a result of sensors with LED deployed. Thermal comfort or the set point (SP) temperature are determined by several means. The overall it is determined by the building manager and is changed at least when the heating/cooling season starts/ends. Manager can change the setting for each room as well. They are automatically changed in the morning and evening on the workdays and when user unlocks the room. The room user can change them in limited range and the room regulation determining the actual temperature in the room specific rules, that can be summed as the allowed range/offset from the desired value. In the weekend +/- 3K, but when occupied, +/-1K from the desired value determined by schedule or user. The desired temperature therefore determined the energy use that can be influenced by the user; lower in heating and higher in cooling period. Health is influences by several building properties/parameters and mostly human behaviour.

4.3.3 Hotel environment

As introduced in 3.1.2.2, profiling hotel hosts becomes really challenging. Moreover, since several types of hotels or bedrooms' facilities can be found, also within the same building (let's think to different classes of bedrooms, from economy to suite), also identifying the targeted guests is crucial. To do so, both general information (like age or gender) and reason of the stay (for example business trip or leisure stay) have to be reported. As already mentioned, also the time of stay (short term, medium and long term) is a parameter to be taken into account, since it may influence the usage of big appliances as washing machine and dishwasher. Moreover, another aspect to be considered is the number of guests for each bedroom, since the energy usage (e.g. for domestic hot water) will be highly dependent on this variable. To summarize, characteristics of interests to set a profiling analysis for guests per each stay are:

- General information (e.g. sex, age, etc.);
- Reason for the stay (e.g. business);
- Length of the stay (short, medium or long term);
- Number of guests using the room.

Personas (defined as guest types) for a hotel could be defined based on the combination of those information to build clusters of guests.

Then, the means to acquire the information for characterizing the personas' profiles can vary, ranging from the self-reporting to the monitoring of habits-related variables than have to be processed to indirectly define living patterns and habits. To do that, a first analysis should be addressed to identify the control opportunities and interfaces that can be found and, therefore, analyzed. An aspect to take into account, which supports the choice of opting for "objective monitoring" in the profiling process, is that the engagement of hotel guests is extremely difficult in comparison to other building occupant categories. For example, an office worker who is not content of his workplace indoor environmental conditions will be more likely willing to participate in a self-reported questionnaire, also to express its preferences or complain about uncomfortable situations. Differently, a hotel guest, who normally will stay in a hotel for a limited amount of time, would more likely be less interested in participating to such surveys. For the same reason, in hotels it would be very hard to create focus groups or establish peer-competition, because usually guests do not even know each-others and, more importantly, they do not directly "pay" for the energy they consume, since the price of the bedroom/apartment would be the same regardless to the consumed energy.

For all these reasons, within the MOBISTYLE project, the hotel users were profiled based on monitored data series, clustering data based on classes defined through objective information as reported by the staff, such as the stay time (short-term, medium-term and long-term) and the number of guests per room, that may influence the living patter to be defined. In this study the personas/guest types have been identified according to the following assumptions:

- 1 person = single (S)
- 2 persons = couple (C)
- 3 persons or more = family (F)

while the length of the stay could be:

- Short stay: less than 5 days (a)
- Medium stay: between 6 and 14 days (b)
- Long stay: more than 15 days (c)

in order to define a set of 9 clusters from the combination of these 6 variables.

The first step in the profiling process, then, was made based on reporting from the staff in the third year of the MOBISTYLE project. The results of this operation are shown in the following table (Table 3), which enumerates the distributions of the different personas/guest types that were individuated within the project.

Table 3: Personas/guest types – statistics from the Italian case study in one year

Description of the profile	**Features**	**Percentage of guests in respect to the total**
Single	Single guest living at the hotel for: less than 5 days; between 6 and 14 days; 15 days or more. (statistics for one year)	39%
		3%
		4%
Couple	Couple living at the hotel for: less than 5 days; between 6 and 14 days; 15 days or more. (statistics for one year)	24%
		2%
		5%
Family	Guests who did reservation for three people or more, living at the hotel for: less than 5 days; between 6 and 14 days; 15 days or more. (statistics for one year)	16%
		3%
		4%

Data series to be analysed to define profiles per each persona are gathered thanks to a monitoring system. The 'energy items' that can be distinguished in households are reported in Table 2, where self-reporting is one the main technique to profile habits according to a basic monitoring principle. Since in hotels the self-reporting is unlikely to be considered an option, some alternatives to the advanced monitoring principles are suggested in Table 4 for the hotel case study.

Table 4: Main groups calculate energy use and Monitoring principles in the hotel case study.

Energy item	Description	Monitoring principles basic	Monitoring principles advanced
Presence	Average number of hours present	Doors switch sensors/keycard detection/reporting from the staff	Presence detection Video detection (offices)
Heating	Setting thermostat	Reporting from the staff	Smart thermostat
	Use shutters/curtains	-	Magnet sensors (shutters)
	Use inner doors	-	Magnet sensor
Ventilation	Use ventilation system ME	Reporting from the staff	Data logging
	Use of ventilation grills	-	Indirect by CO_2. Magnet sensors
	Airing	-	Magnet sensor
Lighting	Presence lighting	-	-
	Use of lighting	-	Smart plugs, meter clamps
Hygiene	Presence bath and /or shower	-	-
	Use sanitary services	-	Data logging (T)
Cloths washing	Use washing machines	-	Smart plug, smart washing machines
Dish washing	Use dishwasher	-	Smart plug, smart dishwashers
Cooking	Use stove	-	Smart plug, smart stove
	Use oven	-	Smart plug, smart oven
Equipment	Presence equipment	-	Meter clamps
	Use equipment	-	Meter clamps, smart plugs

Indoor parameters, instead, are always monitored through indoor sensors placed in the rooms. To detect users' interaction with the building and with the systems (e.g. window openings), in the hotel it is more likely with respect to households that already existent sensors could be used to gather the necessary data. In the report D3.2 'Development indicators based on environmental conditions' these monitoring principles are further elaborated for each demonstration and study case, aiming to perform an easy, non-intrusive and cost-effective measurements and monitoring based on the behavioral action plan goals.

4.4 From occupant profiles to input for energy calculations

The overall aim of MOBISTYLE is to motivate behavioral change by raising consumer awareness and by providing attractive personalized combined pro-active knowledge services on energy use, indoor environment, health and lifestyle. Awareness and behavioral change can contribute in bridging the energy performance gap. However, this needs a fundamental understanding of the variance of the estimation of the three main inputs that determine energy use, i.e., *buildings* (building envelope and building services), *users* (user behavior) and local *climate*. This understanding is necessary and needed to come to a comparison between measured energy use ('real world') and the predicted energy use

('virtual world'). The common reason to use and to know this comparison is that consumers have an interest in the *real* performances of buildings, both on energy as on indoor environment and health. Then it can be a basis for the development of further business models and applications (for example for energy performance contracts, energy cost propositions, certainty of energy savings, grid load characteristics etc.)
The starting point is the awareness that it is impossible to guarantee the total energy use as this will require that all the inputs in simulation are exactly the same as in real life. What can be done and guaranteed is the performance of the *intrinsic properties* (building, building services and controls). In addition no performance guarantees are 'meaningful' for user behavior or climate.

The MOBISTYLE occupant profiles can contribute in understanding the influence of occupants behavior on the real energy use. The MOBISTYLE family profiles can be used to provide input for:

- Energy calculations (predictions of expected real energy use)
- Explanations of deviations in real energy use in practice (monitoring) or expectations on energy use by occupants/households (for example after a deep renovation)
- To determine which parameters are meaningful to monitor (which are less meaningful)

To understand the differences between the 'real world' (monitored energy use) and the 'virtual world' (predicted energy use) an analytic fitting process is necessary by peeling of the total energy use in following loop:

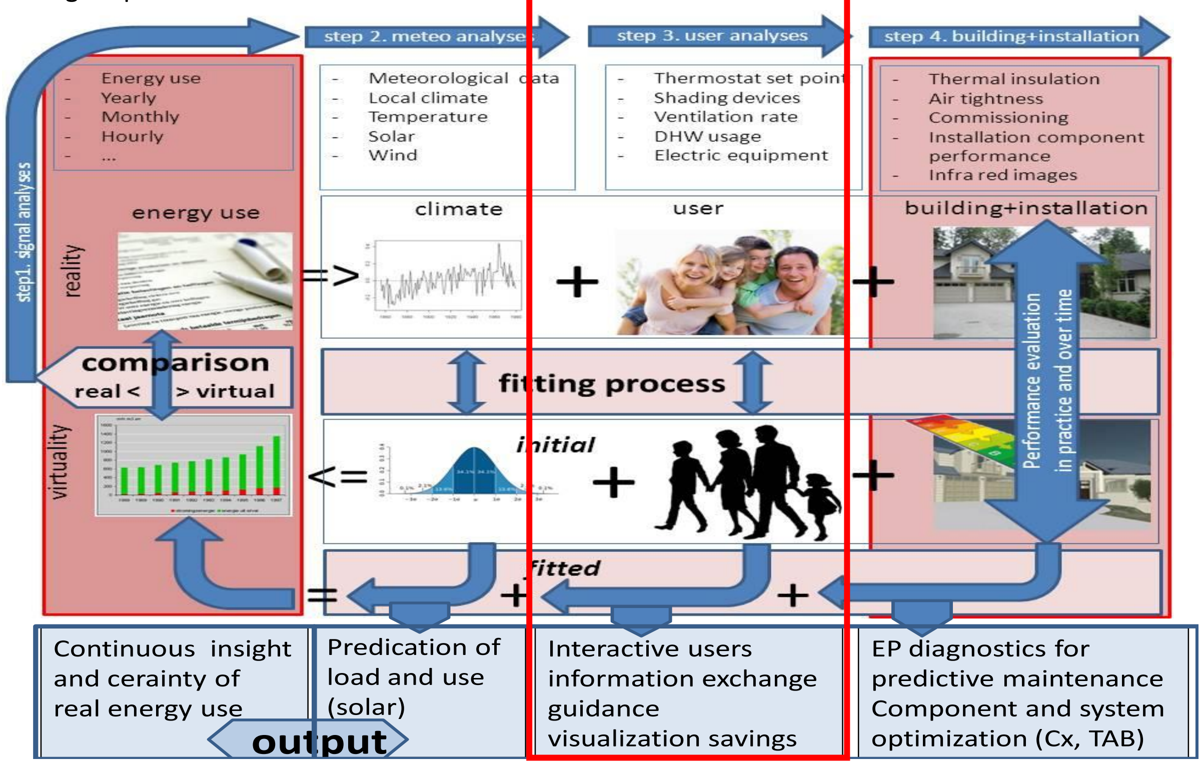


Figure 14: Schematic view of a fitting process to compare real and predicted energy use and the role of occupancy behaviour

The MOBISTYLE Occupant profiles are the core in this fitting process. Therefore we need to know:

- What are the possible human-building interactions for each user
- What are the desired behaviours (for example opening and closing windows, ventilation grilles, change thermostat set points and time programs, etc.
- Channels and activities to influence this behavior

It has not been chosen to maintain a bandwidth because it cannot be used to calculate an unambiguous value. It has been acknowledged that in these assumptions on the basis of household descriptions the necessary uncertainties persist, in particular on the equipment and the intensity of the use of it. We can speak of a best educated guess. When validating the occupants profiles and patterns, it can be further examined how it can be possible to categorize and fine-tune energy behavior of households and non-residential buildings and how to tailor communication on energy use.

Residential buildings

Table 5 shows the extreme values of the bandwidth to be entered for each parameter. In table 6 the 10 usage profiles are given with the determined input parameter. The energy consumption can be calculated for each occupancy pattern.

Table 4: Indication of a bandwidth of parameters for predicting and monitoring energy use; occupant profiles and user profiles

Bandwidth of parameters when predicting energy use (residents ' profile + Usage profile)

Presence							
Number of seniors	-	The number of seniors (> 65) in the household	0	1	2	3	≥ 4
Hours of presence seniors	Hour/Day	The average number of hours seniors are at home per day (incl weekend)	0 - 16		17 - 20	20 - 24	
Number of adults	-	The Number of adults axles (> 18 years < 65 years) in the household	0	1	2	3	≥ 4
Hours of presence adults	Hour/day	The average number of hours adults are at home per day (incl weekend)	0 - 16		17 - 20	20 - 24	
Number of young people	-	The Some Young people (> 12 And < 18 Year in the household	0	1	2	3	≥ 4
Hours of presence young people	Hour/day	The average number of hours young people are at home per day (incl weekend)	0 - 16		17 - 20	20 - 24	
Number of children	-	The Number of children (< 12) in the household	0	1		3	≥ 4
Hours of presence children	Hour/day	The average number of hours children are at home per day (incl weekend)	0 - 16			20 - 24	
Heating of the Indoor Air							
T Thermostat heating	°C	Setting Thermostat in the room where the primary temperature control takes place	18	19	20	21	22
% unheated	%	Part of the dwelling that is not heated as % of floor area	80 - 100	60 - 80	40 - 60	20 - 40	0 - 20
Hours night set back	Hour/day	The number of hours per day night set back	16 - 24	12 - 16	8 - 12	4 - 8	0 - 4
Days of absence during day	Day/week	Average number of days/week absence with setback of thermostat	0				
Cooling of the Indoor Air							
T Thermostat cooling	°C	Setting Thermostat in the room where the primary temperature control takes place	0				
% uncooled	%	Part of the dwelling that is not cooled as % of floor area	0				
Cooling power	W	Installed power emission (for wall and floor cooling: 50 W/m²)	0				
Hours use of cooling	Hour/day	Number of hours cooling is switched on when outside is warm (> 24 °C)	0				
Influencing thermal insulation							
% Curtains/ shutters open	%	% of the windows that have curtains/shutters open at night if outdoor temperature < 15 °C	50				
% Inner doors open	%	% of the inner doors open if outdoor temperature < 15 °C	50				
% Screens open	%	% of the windows where sunscreens are open during sunshine	50				
Heat loss to unoccupied adjacent dwelling							
Surface partition adjacent dwelling	m²	Surface partition wall with dwelling with occupants having a different heating pattern	0				
Thermal insulation partition adjacent dwelling	-	If heat loss: is there thermal insulation or not	0				
Heating behavior neighbors	-	Indoor temperature neighbors much less -, less (1 to 2 °), same, more (1 to 2 °) or much more	0				
Cooling behavior neighbors	-	The Neighbours don't cool their dwelling (1), or cool their dwelling (2)	0				
Use Mechanical Ventilation							
Hours MV high	Hour/day	Hours per day that the ventilation system is in high position	2				
Hours MV middle	Hour/day	Hours per day that the ventilation system is in middle position	2				
Hours MV low	Hour/day	Hours per day that the ventilation system is in low position					
Use of openable windows							
% open window	%	% of windows is usually open if outdoor temperature < 15 °C	0 - 20	20 - 40	40 - 60	60 - 80	80 - 100
Hours windows are open	Hour/day	Number of hours per day that the windows are opened if outdoor temperature < 15 °C	1	2	3	4	>5
Use Electric Lighting							
Hours lighting living room/kitchen	Hour/day	Number of hours/day lighting is used in living room/kitchen (yearly average)	1	2	3	4	>5
Number of bulbs living room/kitchen	Pc.	Number of bulbs is used in living room/kitchen (yearly average)	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10
Power of bulbs living room/kitchen	W	The average power of bulbs is used in living room/kitchen	LED 1 - 5 W		Energy saving bulb 5-15 W	Traditional bulb 25 - 75 W	
Number other rooms with lighting	Pc.	How many other rooms in the dwelling is usually lighted (> 1 hours/day)	1	2	3	4	>5
Number of bulbs other rooms with lighting	Pc.	Average number of bulbs in other rooms that are used (yearly average)	1	2	3	4	>5
Power of bulbs other rooms	W	The average power of bulbs is used in other rooms	LED 1 - 5 W		Energy saving bulb 5-15 W	Traditional bulb 25 - 75 W	
Preparation of Meals							
Number of meals	#/week	Number of meals average/week prepared on the stove	1-2	3-4	5-6	7 -8	9 - 10
Type Stove	-	Type of stove: Gas stove, electric (cast iron, ceramic, halogen) or induction	Gas = 1		Electrical = 2	Induction = 3	
Hours of cooking	Hour/day	How many hours/day is spent on cooking: short < 0.5 hours; average: 0.5-1 hours; long: > 1 hours	< 0.5 Hours		0.5-1 Hours	> 1 Hours	
Oven	#/week	Number of times as average/week that oven is used (> 15 Minutes)	1	2	3	4	>5
Type Oven	-	Which type is used: gas oven (1) or electric oven (2)	Gas =1			Electric = 2	
Hygiene							
Number of showers taken	#/week	Average number of showers taken/week (average 0.80 showers pp/day	Depends on family size				
Duration of showers taken	min/turn	Average duration of showers In minutes/turn (short:< 4 mi; average: 4-12 min; long: > 12 min	0-5 Minutes		6-10 Minutes	> 10 Minutes	
Type of shower	-	Water saving showerheads, traditional or luxury (comfort shower, multiple heads)	Default = 1		comfort /rain shower = 2		
Number of baths taken	#/week	Average number of baths taken/week	0 (included in shower use)				
Type of toilet	-	Number of toilets with limiter water volume	All toilets =1		Half of the toilets = 2	No toilets = 3	
Number of wet cleanings of the house	#/week	Average number of wet house cleanings/week	1				
Dishes							
Number of dishes	#/week	Average number of times/week that dishwasher is used	0 - 2	3-4	5-6	7 -8	9 - 10
Type dishwasher	-	Type of dishwasher: none, traditional (older than 10 yr), economical (label A), extra economical (hot fill or label A ++)	Extra economical = 3		Economical = 2	Traditional = 1	
Use dishwasher		Energy conscious use of dishwasher, (low temperature or short times) or without these facilities	Energy conscious =1		Not energy conscious = 2		
Manual dish washing	#/week	Average number of times/week manual dish washes	1-2	3-4	5-6	7 -8	9 - 10
Washing							
Number of washes	#/week	Average number of times/week that washing machine is used	1-2	3-4	5-6	7 -8	9 - 10
Type of washing machine	-	Type: traditional (older than 10 y), saving (label A), extra economical (Hot fill or label A +++)	Extra economical = 3		Economical = 2	Traditional = 1	
Use washing machine		Energy conscious use of washing machine, (low temperature or short times) or without these facilities	Energy conscious		Not energy conscious = 2		
Number of tumble dryers	#/week	Average number of times/week that tumble dryer is used	1-2	3-4	5-6	7 -8	9 - 10
Type of tumble dryer	-	Type dryer: traditional (older than 10 Jr), saving (abel C), extra saving (label A or better)	Extra economical = 3		Economical = 2	Traditional = 1	
Use of tumble dryer		Energy conscious use of tumble dryer, (low temperature or short times) or without these facilities	Energy conscious =1		Not energy conscious = 2		
number of manual washes	#/week	Average number of times/week manual washes	1				
Equipment							
Number of TV sets	-	Number of TVs in house that are daily used	0	1	2	3	≥ 4
Type of TV sets	-	Type of TV: LED, OLED, LCD, Plasma	LED = 3		Tradiotional/lcd = 2 5-6	plasma = 1	
Use of TV sets	Hour/day	Average number of hours per day TV's are on	1-2	3-4		7 -8	9 - 10
standby of TV sets	Hour/day	Average Number of hours per day TV's in standby mode	0				
Number of computers	-	Number of computers in house that are daily used	0	1	2	3	≥ 4
type of computer	-	Type: Traditional (image tube/older than 5 yr/server), Average (LCD), Extra E-Economical (LED Screen or Laptop	Economical PC = 3		Avergae PC = 2 5-6	Traditional PC = 1	
Use of computer	Hour/day	Average number of hours per day PC's/laptops are used	1-2	3-4		7 -8	9 - 10
standby time computer	Hour/day	Average Number of hours per day PC's/laptops in standby mode					
Number of fridges	-	Number of fridges in house that are used	1		2	3	
Type of fridges	-	Type: traditional fridge/freezer (older than 10 yrs), economical (label A), extra economical (label A ++)	Extra economical		Economical =	Traditional = 1	
Use of kitchen appliances/utilities	-	Use of kitchen appliances/utilities: often (1), average (2) or seldom (3)	= 3 Little = 3		2 Average = 2	Many = 1	
Use of other equipment	-	Use of other electrical appliances in the dwelling: often (1), average (2) or seldom (3)	Little = 3		Average = 2	Many = 1	
Special Facilities							
Number of electric heaters	-	If applicable, the number of electrical heaters for extra heating	0		1	2	
Power of electric heaters	W	Average power of electrical heaters	1500				
Use of electric heaters	Hour/day	Average hours/day electrical heaters are used during colder days	0 - 2		2 - 4	4 - 6	
Use of other local heater	Days/year	Average days/year other heaters are used?	0 - 10		10 - 20	20 - 40	
Number of water beds	-	Number of water beds in house	0		1	2	
Type of water beds	-	Type: hardside 800 l , softside 600 l or light weight 200 l or mix/type unknown	Light weight 200 L = 3		Softside 600 L = 2	Hardside 800 L = 1	
Number of Aquariums	-	Lighting, heating power	No Aquarium		Aquarium = 1		
Use of outdoor Lighting	-	Do you regularly use outdoor lighting with a power > 10 W (1) or not (0)	No Outdoor Lighting		Outdoor Lighting = 1		
Number of swimming pools	-	Do you have an outdoor pool/whirl pool (1) or not 0)	No swimming pool		Swimming pool = 1		
Number of saunas	-	Do you have a sauna/infrared cabin (1) or not (0)	No sauna		Sauna = 1		
Number of solarium	-	Do you have a solarium (1) or not 0)	No solarium		Solarium = 1		
Power other equipment	W	Average power of other equipment with substantial consumption electricity in house					
Use other equipment	Hours/year	Hours/year other equipment is used					

Table 5: Elaborated user profiles

		Young (18-40)	Young At home	Low income single parent	Parent Family Working	Traditional Family	Earning Family	Childless (40-65) Working	Childless (40-65) t home	Seniors often at home	Seniors little at home
Presence											
Number of seniors	-	0	0	0	0	0	0	0	0	2	2
Hours of presence seniors	Hour/Day									22	8
Number of adults	-	1	1	1	1	2	2	2	2	0	0
Hours of presence adults	Hour/day	10	20	22	10	22	10	10	20		
Number of young people	-	0	0	0	2	0	2	0	0	0	0
Hours of presence young people	Hour/day										
Number of children	-	0	0	2	0	2	0	0	0	0	0
Hours of presence children	Hour/day										
Heating the Indoor Air											
T Thermostat heating	°C	20	19	18	21	20	21	21	19	22	22
% unheated	%	80	70	70	70	30	30	80	70	50	50
Hours night set back	Hour/day	20	8	8	12	4	4	12	8	8	12
Days of absence during day	Day/week	0	0	0	0	0	0	0	0	0	0
Cooling of the Indoor Air											
T Thermostat cooling	°C	0	0	0	0	0	0	0	0	0	0
% uncooled	%	0	0	0	0	0	0	0	0	0	0
Cooling power	W	0	0	0	0	0	0	0	0	0	0
Hours use of cooling	Hour/day	0	0	0	0	0	0	0	0	0	0
Influencing thermal insulation											
% Curtains/ shutters open	%	50	50	50	50	50	50	50	50	50	
% Inner doors open	%	50	50	50	50	50	50	50	50	50	
% Screens open	%	50	50	50	50	50	50	50	50	50	
Heat loss to unoccupied adjacent dwelling											
Surface partition adjacent dwelling	m²	0	0	0	0	0	0	0	0	0	
Thermal insulation partition adjacent	-	0	0	0	0	0	0	0	0	0	
Heating behavior neighbors	-	0	0	0	0	0	0	0	0	0	
Cooling behavior neighbors	-	0	0	0	0	0	0	0	0	0	
Use mechanical Ventilation											
Hours MV high	Hour/days	2	2	2	2	2	2	2	2	2	2
Hours MV middle	Hour/days	2	2	2	2	2	2	2	2	2	2
Hours MV low	Hour/days	2	2	2	2	2	2	2	2	2	2
Use of-open- Windows											
% Open Window	%	10	10	10	10	10	10	10	10	10	10
Hours window Open	Hour/days	1	1	1	1	1	1	1	1	1	1
Use electric Lighting											
Hours lighting living room/kitchen	Hour/days	3	5	5	4	5	4	3	5	5	4
Number of bulbs living room/kitchen	stks	5	5	4	6	6	8	8	5	7	7
Power of bulbs living room/kitchen	W	25	25	25	25	25	25	25	25	25	25
Number other rooms with lighting	stks	2	2	4	6	6	5	2	2	3	3
Number of bulbs other rooms with	stks	0	0	0	0	0	0	0	0	0	0
Power of bulbs other rooms	W	25	25	25	25	25	25	25	25	25	25
Preparation of Meals											
Number of hot Meals	number/wk	3	5	7	7	9	9	4	5	7	6
Type Stove	-	Gas Stove	Gas Stove	Gas Stove	Gas Stove	Gas Stove	Gas Stove	Gas Stove	Gas Stove	Gas Stove	Gas Stove
Hours of cooking	hour/days	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
Number Oven	/wk	1	2	3	3	4	4	2	2	3	3
type oven	-	gas	gas	gas	gas	gas	gas	gas	gas	gas	gas
Hygie											
Number of showers taken	number/wk	6	6	12	15	18	21	11	11	11	11
Duration of showers taken	Min/turn	12	8	4	8	8	10	12	8	5	8
Type Shower	-	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Number Baths	/wk	0	0	0	0	0	0	0	0	0	0
type toilet	-	50% flush limiter	50% flush limiter	50% flush limiter	50% flush limiter	50% flush limiter	50% flush limiter	50% flush limiter	50% flush limiter	50% flush limiter	50% spoelbegrenzer
Number of wet house cleanings	/wk	1	1	1	1	1	1	1	1	1	1
Dishes											
Number of dish washes	/wk	3	0	0	5	7	7	4	0	0	0
Type Dishwasher	-	Close	No	No	Close	Close	Traditional	Close	No	No	No
Use Dishwasher	-	Not Energy	Na	Na	Energy conscious	Energy conscious	Energy conscious	Energy conscious	Na	Na	Na
Number of Hand dish washing	/wk	1	5	7	7	3	3	1	5	7	6
Wash											
Number of washes	/wk	2	2	5	5	7	7	4	4	4	4
Type of washing machine	-	Close	Traditional	Traditional	Close	Close	Extra Close	Close	Traditional	Close	Close
Use washing machine	-	Not Energy	Energy conscious	Energy conscious	Energy conscious	Energy conscious	Not Energy conscious	Not Energy conscious	Energy conscious	Energy conscious	Energy conscious
Number of tumble dryers	/wk	1	0	0	3	4	4	2	2	0	2
Type of tumble dryer	-	Close	Na	Na	Close	Close	Extra Close	Close	Traditional	Na	Close
Use of tumble dryer	-	Not Energy	Na	Na	Energy conscious	Energy conscious	Not Energy conscious	Not Energy conscious	Energy conscious	Na	Energy conscious
number of manual washes	/wk	1	1	1	1	1	1	1	1	1	1
Equipment											
Number of TV sets	Pieces	1	1	1	3	1	3	1	1	1	1
Type of TV sets	-	LED	plasma	Traditional/LCD	plasma	plasma	LED	LED	Traditional/LCD	Traditional/LCD	Traditional/LCD
Use of TV sets	Hour/days	2	5	6	4	5	3	2	5	5	2
standby of TV sets	Hour/days	0	0	0	0	0	0	0	0	0	0
Number of computers	Pieces	1	1	1	1	1	3	1	1	1	1
type of computer	-	Economical Pc	Average Pc	Traditional Pc	Average Pc	Average Pc	Economical Pc	Economical Pc	Traditional Pc	Traditional PC	Traditional Pc
Use of computer	Hour/days	2	2	2	2	2	2	2	2	2	2
standby time computer	Hour/days	0	0	0	0	0	0	0	0	0	0
Number of fridges	Pieces	1	1	1	1	1	2	1	1	1	1
Type of fridges	-	Close	Traditional	Traditional	Close	Close	Extra Close	Close	Traditional	Traditional	Close
Use of kitchen appliances/utilities	-	Average	Little	Little	Average	Average	Many	Average	Little	Little	Average
Use of other equipment	-	Many	Little	Little	Average	Many	Many	Many	Little	Little	Little
Special Facilities											
Number of electric heaters	-	0	0	0	0	0	0	0	0	0	0
Power of electric heaters	W	Na	Na	Na	Na	Na	Na	Na	Na	Na	Na
Use of electric heaters	Hour/days	Na	Na	Na	Na	Na	Na	Na	Na	Na	Na
Use of other local heater	days/y	Na	Na	Na	Na	Na	Na	Na	Na	Na	Na
Number of water beds	-	0	0	0	0	0	0	0	0	0	0
Type of water beds	-	Na	Na	Na	Na	Na	Na	Na	Na	Na	Na
Number of Aquariums	-	0	0	0	0	0	0	0	0	0	0
Use of outdoor Lighting	-	No	No	No	No	No	No	No	No	No	No
Number of swimming pools	-	0	0	0	0	0	0	0	0	0	0
Number of saunas	-	0	0	0	0	0	0	0	0	0	0
Number of solarium	-	0	0	0	0	0	0	0	0	0	0
Power other equipment	W	0	0	0	0	0	0	0	0	0	0
Use other equipment	Hours/yr	0	0	0	0	0	0	0	0	0	0

Non-residential buildings: hotel

In the following, Table 7 introduces the usage profiles for relevant parameters of the hotel guests' personas/guest types individuated and described in Paragraph 4.3.

- Single – short stay (Sa)
- Single – medium stay (Sb)
- Single – long stay (Sc)
- Couple – short stay (Ca)
- Couple – medium stay (Cb)
- Couple – long stay (Cc)
- Family – short stay (Fa)
- Family – medium stay (Fb)
- Family – long stay (Fc)

Table 7. Hotel users profiles per guest types/personas – statistics from the Italian case study

Personas	Daily mean air temperature [°C] - (September)	Daily mean relative humidity [%] – (September)	Daily mean CO_2 concentration [ppm] – (September)	Daily electric consumption [kWh/day] – (May18-May19)
Sa	25.2	54.2	608.7	5.43
Sb				4.00
Sc				3.61
Ca	25.7	64.6	658.5	3.98
Cb				4.20
Cc				5.63
Fa	26.0	62.9	680.2	3.55
Fb				3.41
Fc				3.69

In Table 7, medium indoor parameters per guest types/personas are reported for a reference month. They are daily mean value computed as part of the definition of the baseline for the Italian case study in WP6. No diversification based on the duration of the stay is considered, since it is not an influencing parameter on indoor condition preferences of the guests. On the contrary, the mean daily consumption for the whole room is computed per each of the 9 guest types/personas.

Thanks to MOBISTYLE project, some of the appliances are monitored through smart plugs in the rooms. During the third year of the project, some of the data coming from the hotel have been processed for evaluation purposes. Thanks to this, a better characterization of the usage of the appliances can be reached in terms of frequencies. In particular, Table 8a – Table 8d show the percentage of times in which every guest type/persona used an appliance (TV, microwave, dishwasher and washing machine) at each hour of the day. Percentage of times is evaluated clustering the days of the year in the 9 guest types/personas, computing the ratio between the times when a consumption is detected at a certain hour of the day and the total of the times when the room was occupied[5] by each guest type at the same hour.

Table 8a. Hotel users profiles – statistics from the Italian case study – percentage of usage - TV

TV																								
	Hour of the day																							
%	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*
Sa	5	2	0	0	0	0	2	2	0	2	2	2	2	4	7	5	0	0	6	15	28	39	41	29
Sb	3	0	0	0	0	0	0	0	0	3	6	3	6	3	0	0	0	0	0	0	3	3	3	6
Sc	10	12	6	3	0	0	1	1	1	3	5	7	9	12	10	10	7	8	12	12	17	25	22	20
Ca	12	10	2	0	0	0	6	20	16	12	20	10	11	19	15	10	8	10	12	18	18	27	34	24
Cb	23	36	9	9	0	0	14	32	18	9	5	25	11	6	6	5	10	14	48	29	27	38	41	43
Cc	10	7	3	1	0	1	3	22	23	15	16	20	33	60	44	18	14	17	22	69	67	68	74	55
Fa	3	6	0	0	0	0	0	13	9	18	16	15	16	13	16	13	9	9	22	18	27	38	36	22
Fb	0	0	0	0	0	0	5	0	8	5	14	5	5	5	5	11	8	8	3	5	10	5	5	3
Fc	3	9	1	0	0	0	5	19	31	38	24	10	14	14	19	16	11	13	28	60	68	71	55	27

Table 8b. Hotel users profiles – statistics from the Italian case study – percentage of usage - Microwave

MICROWAVE																								
	Hour of the day																							
%	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*
Sa	0	0	0	0	0	5	5	10	14	4	0	0	0	4	8	4	4	0	0	11	15	15	0	0
Sb	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4	0	4	0	4
Sc	0	0	0	1	0	0	0	0	1	0	0	1	2	3	1	1	2	0	0	7	10	3	1	1
Ca	0	0	0	0	0	0	0	4	10	0	5	5	5	0	5	5	0	0	0	5	9	0	4	0
Cb	0	0	0	0	0	0	0	0	0	7	7	0	0	0	0	0	0	0	0	7	0	7	0	0
Cc	1	0	2	0	1	1	18	51	49	29	11	2	10	49	32	25	23	15	8	14	63	15	8	3
Fa	0	0	0	0	0	0	0	0	11	10	0	0	0	0	0	0	0	0	5	0	6	6	6	0
Fb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0
Fc	0	0	0	0	0	5	5	10	14	4	0	0	0	4	8	4	4	0	0	11	15	15	0	0

Table 8c. Hotel users profiles – statistics from the Italian case study – percentage of usage - Dishwasher

DISHWASHER																								
	Hour of the day																							
%	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*
Sa	0	0	0	0	0	0	0	0	0	0	4	4	4	0	0	4	4	0	0	0	0	4	8	4
Sb	0	0	0	0	0	0	0	0	0	3	6	6	3	0	0	0	0	0	0	7	7	7	0	0
Sc	1	1	0	0	0	0	0	0	1	3	3	3	2	1	3	3	4	1	1	0	0	0	0	1
Ca	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	0	0	0	0	0	0	0	0	0
Cb	0	0	0	0	0	0	0	0	0	31	31	25	10	0	0	17	8	0	0	8	14	15	14	0
Cc	5	2	0	0	0	0	0	0	1	2	2	1	1	1	2	2	0	0	1	1	13	51	55	18
Fa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0

[5] based on booking status, not on real occupation.

Fc	11	11	0	0	0	0	0	0	0	11	17	11	6	0	11	11	6	0	0	0	0	6	6	6

Table 8d. Hotel users profiles – statistics from the Italian case study – percentage of usage – Washine machine

WASHING MACHINE																								
	Hour of the day																							
%	***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***21***	***22***	***23***
Sa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sb	0	0	0	0	0	0	0	0	0	0	4	4	8	4	0	0	4	4	8	4	0	4	4	0
Sc	1	0	0	0	0	0	0	2	4	4	4	4	3	2	3	3	2	3	2	1	5	2	1	0
Ca	0	0	0	0	0	0	0	0	0	10	10	5	5	6	0	0	0	6	5	11	12	12	6	0
Cb	0	0	0	0	0	0	0	0	0	10	10	5	0	0	0	0	5	0	5	5	5	5	5	5
Cc	0	0	0	0	0	0	0	0	6	13	14	8	7	4	3	1	3	5	11	13	9	4	1	0
Fa	0	0	0	0	0	0	0	5	13	9	10	0	0	0	0	0	0	0	8	8	8	4	0	0
Fb	0	0	0	0	0	0	0	6	19	34	38	21	17	18	15	21	12	16	33	26	13	3	6	3
Fc	0	0	0	0	0	0	0	4	19	29	20	10	9	11	7	9	9	10	20	21	8	6	7	4

Some qualitative evaluation on appliances usage can be done analysing the raw data. Starting from the dishwashers very rarely there is more than one cycle per day. However, dishwashers are characterized by long cycles. There are few cases in which there are two cycles in one day (choice of the couples who occupied the rooms). Considering the washing machine, it has different cycle's type with different energy consumptions, and it can be used more than once in a day. In particular, families that spend in hotel medium/long period often use the washing machine twice in a day, rarely three times. For what concern the washing types, the washing machine installed in the hotel allows to use 12 different washing cycles. The one with lower consumption, 0.04 kWh, lasts 1 hour and 15 minutes and it is characterized by three peaks of power, the highest has a recorded power of 0.3 kW. The most energy-intense cycle lasts about 2 hours and 15 minutes and presents three peaks of 1.56 kW, consuming 0.23 kWh per cycle. From the recorded data, it emerges that singles prefer to activate the washing machine in the late afternoon/evening, while for families that use the washing machine twice a day, the first cycle is done in the morning and the second in the late afternoon/evening.

The occupant profiles influence both the building-related energy consumption and the energy consumption. For this purpose, energy calculations should take the input parameters from the occupant profile from table 6 or 7 (in the case of a hotel), and take these parameters as the starting point for the calculation of the energy consumption for heating, domestic hot water preparation and household electricity (plug-bound). Hence, an occupant profile can lead to a higher need for space heating, and, for example, a lower need for tap water, or vice versa. The final effect on the energy consumption 'on the meter' depends on the dwelling and the building services to meet the requirements for climatization.

As a result, for example, an occupant profile with a high demand for DHW demand but in a dwelling with a thermal solar system for DHW will result in a lower energy cost increase than in a dwelling without a thermal solar system. The occupant profile in itself is therefore not yet sufficient to be able to determine an energy use, for which a combination of a usage profile with a specific home is always required.

4.4 Data collection in practice: what matters in residential buildings

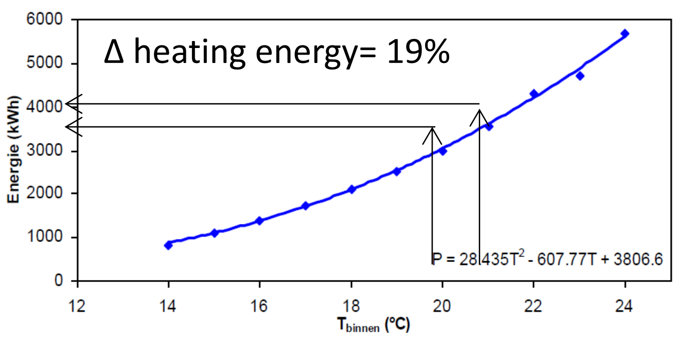
In the framework of the Dutch TKI projects TRECO home and TRECO office[6] a large scale study was conducted to the how the energy performance gap can be closed a better understanding of both predicting energy use and monitoring energy use in buildings.

One of the findings was that user behavior is strongly dominated by:

- Individual thermo-physiological properties
- Individual habitual behavior with regard to clothing

Therefore it is not possible predict energy use in buildings without knowing the actual occupants. It appears necessary to use these occupant profiles in order to identify these characteristics.

If these characteristics are known, i.e. if the occupant profiles can be identified, a good match between predicting models, monitoring and measurement values and the information exchange is possible. Hence. Energy predictions can be used for example for propositions for deep renovations and energy savings and energy cost guarantees.



Another finding from is that user behavior patterns for space heating, domestic hot water and electricity consumption do not show a relationship. This means that these profiles should be determined separately from each other. This has also indications for monitoring indoor conditions and, as a further step, predicting energy use (and savings).

<u>Indoor environmental quality</u>

The most important parameters for the indoor environmental quality (as concluded in TRECO) are the indoor temperature, the CO_2 concentration and the relative humidity. The occupants usually know quite well how to control and influence the indoor temperature. However, how to control and influence the CO_2 concentration and RH/moisture are less obvious. It is also found in many studies that in practice it is difficult for occupants, controlling the ventilation system (grilles in the facade, position of the fan) and how to influence the CO2 concentration. Especially the latter, little experience has been gained with this in practice.In the case that CO_2 sensors are applied in ventilation systems (demand control), the control is usually automatic. In these cases, occupants don't have an idea in which position the fans are and this position can be influenced by the number of people in the room. In addition, the threshold values (for switching the fans) are not visible, either in numbers (ppm's) or in simple icons. Because of this lack of experience and 'feeling with the system' is missing, it is difficult for occupants to adjust behavior, for example, in cases where additional behaviorial measures are needed to adjust the ventilation system to improve the indoor air quality, and/or avoid condensation (to less ventilation) or to lower the ventilation to limit energy use (in case of too much ventilation, long periods of airing).

[6] RVO, The Netherlands, TKI Energo, TRECO home and TRECO office[6] ('Towards Real Energy performance and Control by predicting, monitoring, comparing and controlling'), 2013 - 2018

Space heating

Both measurement data and model research show that the Delta T is the biggest driving force for energy use. This is directly followed by the ventilation flows (linked to presence). An increase of 1K indoor temperature results in 19% higher energy use. Knowing the exact indoor temperature for energy predictions is therefore necessary.

Figure 15 Impact of increasing indoor temperature on energy use

Energy conversion

As next the energy conversion is an important factor. Conversion efficiency can be measured with smart meters and/or a heat flow meter. Because of the high costs (> 500 euros) this is monitoring is not cost-effective (in individual houses) and, moreover, the user cannot influence the heating generation efficiency by behavior. However, energy services and provisions by the supplier could be deployed here.

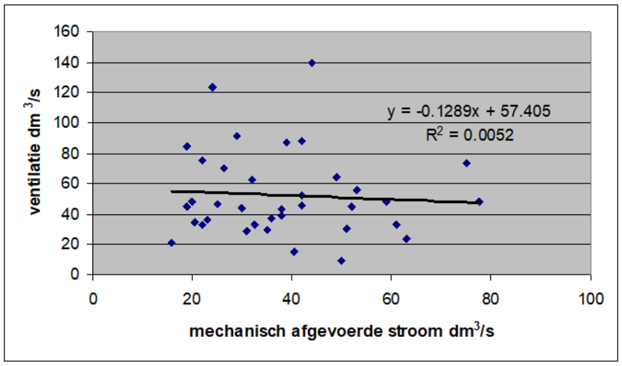
Ventilation and infiltration flows

Occupant behavior is fully dominant for total ventilation of residential buildings[7]. For offices it is, again, depending to the office and building type (presence of openable windows/natural ventilation provisions versus fully HVAC conditioned buildings).

Relation measured total ventilation versus mechanical exhaust

Relation measured total ventilation versus air tightness

[7] RVO, The Netherlands, Dutch National Monitoring Ventilation, De Gids, Op 't Veld, 2008



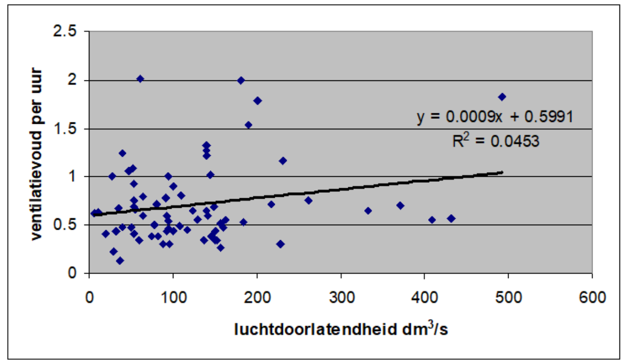


Figure 16: Relation measured total ventilation versus mechanical exhaust and measured total ventilation versus air tightness

These graphs show that there is no correlation between the total ventilation and measured exhaust flow or air tightness level as occupants incline to 'adjust' ventilation according to their own needs and habits. In open plan offices, it should be considered that, as explained before, the actions are strongly dependent on the social norms among the workers. This is particularly relevant for windows' opening, which are one of the most negotiated actions in offices. This also implies that measuring mechanical ventilation flows and air tightness do not give accurate information of the total air flows.

Concerning monitoring of ventilation (i.e. ventilation rates and/or flows) it must be noted that determining real time ventilation flows is very complex. Simple measurements in air ducts or the flow rates of fans is both very inaccurate and momentaneous.

Infiltration can be determined with tracer gas measurements (SF6 dilution measurements) or with diffusion tubes (PFT measurement) over a longer period. But those techniques are costly, need professional analyses and are not suitable for regular monitoring.

<u>Domestic hot water (DHW)</u>

DHW quantity and generation efficiency are also expensive to measure, particularly in comparison with the actual costs of the energy and the boilers. However, a simple method can be developed on the basis of time in which a display is made of the minutes that the shower is switched on. The energy use can be derived from these shower minutes. At this moment boiler manufacturers are using already using sensors and an app to split the total energy use of a boiler in space heating and hot water.

<u>Electricity consumption</u>

Data from smart meter is already commonly used (and often a reason for discussion about peak consumption and standby consumption). This data is accessible to occupants. With the right apps, occupants can actively intervene and use these data for behavioral changes. The number of occupants, the m2 of surface area and the counting of the devices and appliances is already a good predictor for the electricity consumption.

4.5 Data collection in practice: what matters in non-residential buildings

The most important factors influencing the energy demand in offices can be distinguished in four main categories:

1. Building services and the level of automation
2. Control level and available interfaces
3. Outdoor climate
4. Building characteristics
5. Occupant behavior

These factors have an interaction which each other and are also affecting the influence of occupant behavior at the total energy demand of the building. The level of automation of the building services is one of the most dominating factors influencing occupant behavior. Moreover, in non-residential buildings it is absolutely critical to characterize the control-level of occupants and the type of available interfaces (e.g. thermostats, shadings etc.). In fact, as explained before, the building type or space type (e.g. open plan office). Moreover, occupants are often not aware of their control opportunities (e.g. they don't know that they have a thermostat available) or, in case they are aware, they don't know how to properly operate it. In fact, while at home people are aware to be in charge of all systems and technologies management, so they usually try to understand how the interfaces work, at workplace they often think that the building manager is in charge of ensuring a proper system's management, so even if they have a control opportunity they do not try to properly understand how it works. This aspect is also a very recurring reason of energy wasting in office buildings.

The level of automation of the building services determines the combination and the number of parameters that the occupant can manipulate. Roughly, three building categories can be defined:

1. Fully manually operated building,
2. Fully automated controlled building
3. Semi-automatic building.

In a fully manually controlled building, it is assumed that all parameters can be varied, while in a fully automated building the user almost has no parameters to influence. In a semi-automatic building in general the users-related parameters can be influenced. Moreover, as previously mentioned, also in fully-automated or semi-automated buildings the overriding occupants' actions should be considered and analyzed in each case. The tables 8 and 9 give an overview of the occupancy-rate related parameters that can influence the electric an thermal energy demand in buildings with different automation levels. The influencing parameters, related to building use, can be divided into two groups:

1. based on presence ("presence-based")
2. behavior-oriented ("behavior-based").

The parameters that can be influenced by the presence of people in the building can be monitored by the occupancy of the building, while the behavioral parameters vary depending on individual use and the influence on the building services and energy systems.

Table 8: Parameters related to occupancy, influencing the thermal energy demand of a building

Type	Parameters	Fully manual Controlled building	Semi-automated controlled building	Fully automated controlled building
Presence-based	Internal heat gains lightings (presence control)*	×	✓	✓
	Internal heat gains people	✓	✓	✓
	Internal heat gains equipment (kitchen)	✓	✓	✓
Behaviour-based	Internal heat gains lightings (manual switch)*	✓	×	×
	Internal heat gains equipment (computer use)	✓	✓	✓
	Manipulation radiators	✓	×	×
	Manipulation indoor temperature set points	✓	×	×
	Manipulation mechanical ventilation	✓	×	×
	Manipulation windows	✓	✓	×
	Manipulation solar shadings	✓	✓	×

*Parameter that can be classified as presence- or behaviour-based, depending on the type automation level of the system.

Table 9: Parameters related to occupancy, influencing the electric energy demand of a building

Type	Parameters	Fully manual building	Semi-automated building (case study)	Fully automated building
Presence-based	Lightings use (presence control)*	×	✓	✓
	Cooking equipment	✓	✓	✓
Behaviour-based	Lighting use (manual switch)*	✓	×	×
	Manipulation mechanical ventilation	✓	×	×
	Computer use	✓	✓	✓
	Lift use	✓	✓	✓

*Parameter that can be classified as presence- or behaviour-based, depending on the type automation level of the system.

The impact of these parameters with regard to the energy use of a building depends on the number people and the different zones in the building. For example, in a building with presence detection for lighting without division into zones (open office), the impact of one person is equal to a full occupancy. On the other hand, the internal heat load due to personal occupation is proportional with the occupation of the building. With this each variable forms a different correlation (pattern) between the influence on energy use and occupation of the building.

By analyzing the quantity of the affected parameters and the pattern of each parameter, it is expected (even if a case-per-case analysis is always adviced) that the influence of user behavior per person compared to occupancy in the building follows the pattern as shown in next figure.

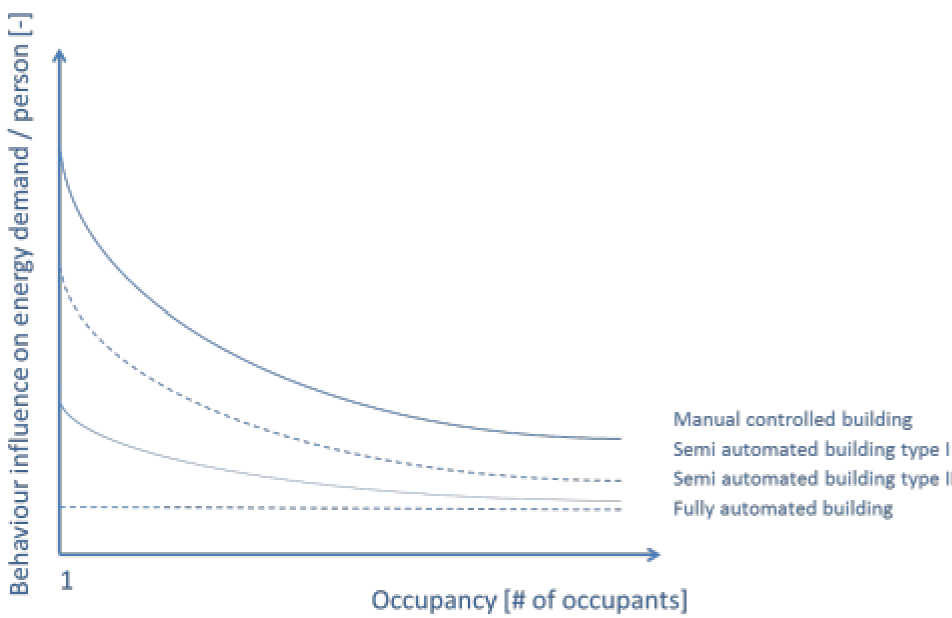


Figure 17: Behaviour influence on energy demand per occupant versus occupancy for different automation levels

In order to analyze the influence of occupant behavior on energy demand, it is necessary to monitor the presence and behavior separately. Table 10 and Table 11 indicate the presence and behavioral parameters that must be measured, including the measurement method, for the thermal and electric energy.

Table 10: Parameters related to occupancy rate, influencing thermal energy demand of a building

Type	Parameters	Measurement method
Presence-based	Internal heat gains equipment (computer and kitchen)	Plug-loads computers and schedule cooking equipment
	Internal heat gains lightings	Plug loads lightings
Behaviour-based	Manipulation windows	Monitoring opening windows
	Manipulation solar shadings	Monitoring solar shadings

Table 11: Parameters related to occupancy rate, influencing electric energy demand of a building

.Type	Parameters	Measurement method
Presence-based	Lightings use	Plug loads lightings
	Equipment (kitchen)	schedule cooking equipment
Behaviour-based	Computer use	Plug loads computers
	Lift use	Plug loads lift

5. MOBISTYLE monitoring and information campaigns based on the profiles

5.1 MOBISTYLE guidance to monitoring and information campaigns - considerations

Introduction

The previous chapters are the basis for the further approach as developed in MOBISTYLE. As indicated in chapter 3.1, the fact if occupancy behaviour matters whether or not in relation to energy use, is to a large extent depending on the building type. More particularly, people do not act the same way in residential buildings as in offices. For example, results from previous research[8] show that thermal comfort levels are lower in offices than in homes. People feel cold and hot more often in offices than in homes during both the winter and summer seasons. The perceived control over room temperature is remarkably low in offices. Higher thermal comfort levels and perceived control in homes are supported by greater adaptive opportunities. In offices people have fewer opportunities of controlling the thermal environment, people deal worse with thermostats, and people have fewer opportunities to adapt to different thermal environments. People tend to be more tolerant if they have control over their own thermal environment, and may find exactly the same temperature variation acceptable or unacceptable, depending on whether it is chosen or imposed.

This means that in MOBISTYLE for each demonstration case specific tailored behavioural action plans, KPIs and related potential behaviour changes, awareness campaigns, and follow up actions and suggestions, linked to health, energy and IEQ, have to be developed.
This is further elaborated for each demonstration case in work package 3, D3.2: 'Developed indicators based on environmental conditions'.

Behavior and feedback to occupants

Especially in residential buildings occupant behavior is expressed in strong patterns. For the largest part of the time that occupants spent in homes they are active in certain 'fixed' occupant patters and a disruption of for example 1 day a week shows only a minor deviation and influence on the total energy use. This is because it is usually a shift from a usual occupancy pattern, which means that the impact on energy use is still limited.
Also from other behavioral research, such as from nutrition and dietetics, it is known that changing behavioral patterns is difficult and complex. This means that it is important to assess behavioral patterns rather than to respond to incidents. For example, for taking showers don't just whipping the moisture of the tiles but try to influence the daily ritual of showering.
In non-residential buildings the type of possible feedback differs a lot depending on the building activity. While in hotels the type of feedbacks could be not very different from residential buildings (maybe

[8] Karjalainen, S. Thermal comfort and use of thermostats in Finnish homes and offices, Building and Environment, Volume 44, Issue 6, June 2009, Pages 1237-1245

limited to the use of only certain appliances or end-uses like DHW), in offices the type of possible feedbacks varies a lot depending on the office type and, as previously explained, the control opportunities and interfaces.

Perception of thermal comfort by occupants

Maastricht University performed laboratory tests showing that thermal comfort is typically an individual characteristic of a person (rather than to be expressed in average perception as in the Fanger models).
Moreover, it appears that women prefer, on average, a higher comfort temperature than men. In general, from our own experience people recognize (and are used to this phenomenon, but now for the first time these results can be quantified. (In a test dwelling/living lab with four test persons, these comfort and human models were validated. It can be deduced from this monitoring campaign that the difference in comfort temperatures between two people can be up to 6K. These findings have consequences for both residential buildings as for offices.
For residential buildings this gives an important indication why in a single-person household the differences in indoor temperature, and related energy use are much larger than in multi-person households.
For offices it can be important to create ‘cooler’ and ‘warmer’ zones in order to give a suitable comfort situation for each worker. This will be tested in the Dutch demonstration cases Qeske and Brightlands. Alternatively, personalized office systems (climatized desks) can be applied for individual control.

Note: To determine the comfort zone limit values for mild heat and mild cold for individuals the Thermal Neutral Zone (TNZ) model is used. For this TNZ, at least two sensors on the skin are needed, plus a sensor on the clothing for the microclimate around the body. With this knowledge of the TNZ, a dynamic temperature profile can be deduced both over a day and per season that also contributes to metabolic health.
In a first pilot, carried out in 2016 and 2017 in the H2020 project MORE-CONNECT (Real Life Living Lab in Heerlen), the TNZ model has been validated for the first time in practice. What has been observed is that occupants behave naturally in such a way (indoor temperature, clothing, type of activity) that they are tended to ‘move’ their thermal balance to the center of the TNZ. (However, in this pilot the exact limits in the TNZ could not be determined). In practice, it is therefore difficult to determine this TNZ for every person and is therefore not yet a practical tool for large scale application. (Follow-up research is taking place now in the Dutch demonstration cases and in the Dutch and TKI-DYNKA project, were people are offered a dynamic temperature profile, followed by an assessment of its acceptance).

Awareness of occupants of their indoor environment

From many demonstration projects it has been experienced in that the occupant awareness of indoor environmental quality is even a bigger challenge than awareness on energy use. In general, occupants in residential buildings are now familiar with a thermostat, the settings and clock programs, and they know how it works. But applying a similar devise for CO_2 and RH, occupants have much more difficulties to understand it and to use it. As previously described, in offices workers are not always aware of their control opportunities and of how to use the available interfaces. These applications apparently need a new step of raising awareness before it makes sense for occupants to use it, to understand the information and the consequences.

In general, on energy use, occupants residents generally only become aware of their energy use, based on their annual consumption. For example, often occupants do not even realize that 80% of natural gas is used during the winter months only, and during the summer season only for showering. However, in many countries occupants are quite keen on the energy use for showering. For example, controlling it directly by keeping track of the minutes a shower is used. For heating this is much more abstract due to the direct relationship with the outdoor temperature and the slowness of the effects of behavior on energy use for heating, i.e., behavioral change do not has a direct effect. If cooling is applied the awareness tends to be bigger, as this often considered as an 'extra feature/appliance' using extra energy.

In non-residential buildings, one of the main barriers to engagement campaigns is that workers do not directly pay the bills, so they are much more difficult to be engaged in saving energy or limit energy wasting. One solution is represented by the possibility to focus on their comfort, trying to transfer the concept that using more energy does not mean to be more comfortable, and that a proper use of energy-related interface can really enhance their experience of the building.

Before starting behavioral campaigns as a provider of energy services or as a housing corporation, the awareness about the indoor environment and climate by occupants is required. This user behavior also includes simple tips such as 'lid on the pan when cooking', 'open window when drying laundry', 'wipe moisture of tiles after showering' or in offices 'use the stairs instead of elevator'. From there behavioral training can be used for increasing energy awareness and efficiency.

Some further recommendations:

- Information campaigns should be geared to 'learning from behavior' as now in practice households are often rusted up in a fixed pattern because there is knowledge of experiences concerning the changing of behavior (i.e., what are the real benefits of behavioral change). Comparing with neighbors might enhance the knowledge of experiences.
- Many effects of behavioral change on relative humidity, moisture and indoor air quality are on a (too) long term to trigger occupants. A solution might be to support occupants with sensors, for example, CO_2 in bed rooms and RH in bath room.
- Give feedback on energy use on at least a monthly basis, linked to the delta T indoor – indoor.
- Give daily feedback on indoor environmental quality in an understandable ways, use icons/emoticons. This might have an impact on a healthy indoor environment although the effects is on a longer term (for example improving quality of sleeping, avoiding moisture and mold).
- For office buildings CO_2 is used in HVAC to control the amount of fresh air in buildings. Recent research shows that employee performance decreases notably already at CO_2 levels previously considered as 'good', i.e. at approximately 1000 ppm. As employee wages amount to about 90% of the total office costs it pays off to measure and control CO_2 levels in offices properly and also to provide information of the air quality to employees.

People as starting point

There are already quite some interfaces or apps developed for occupants, however, these are often experienced as too complicated. A precondition is that for the development of applications to compare energy, indoor environmental quality etc. the knowledge is necessary from anthropologist and designers, with professional experience in developing consumer products. That is why work package 2 'Mapping of data supply and communication needs for different types of end-users' is the starting point in MOBISTYLE, or even more precise, people should be the starting point. Where for professionals and experts indoor quality and energy are quite obvious terms, for non-professional occupants it is still very abstract. This is enhanced by the fact that air quality and RH is less sensible as thermal comfort (indoor temperature and draught). As already mentioned, people are used of having and using thermostats (since the general introduction of central heating in the 60's), which also implies that people have a certain understanding of temperatures. However, this is not the case for CO_2 and RH; also there is not a real understanding of people what is 'healthy' or not. This means that an understandable feedback on displays is necessary. For this information exchange ethnographic characteristics and differences should be taken into account (social, cultural, linguistic) both between individual and groups.

MOBISTYLE modular information services in relation to energy services

One of the objectives of MOBISTYLE is to foster new business models and applications for future developer engagements as the modular information services and data collection offer new business opportunities for developers and designated third parties such as energy services or energy providers.

Typically, rising and changing energy prices at the gas station are discussed on almost a daily basis. But concerning the total energy costs people only seems to worry at the moment they receive the yearly energy bill: 'what do I have to pay extra or get back'? The transparency of an energy bill is often very low. The differences in energy use between an energy conscious and a non-conscious behavior is the basis for the financial benefit for occupants. Moreover, a fraction of these benefits can be converted into a Business to Consumer (B2C) product, for example on the basis of an ESCO construction. These are small amounts on an annual basis and are only possible with large numbers of homes leading to a sound and lucrative business case. This is also the reason that energy suppliers/utilities offer new services such as cable, security, installation maintenance and by offering these services, giving an added value to their clients. For occupants, the proposition is (i.e., could be) achieving the lowest energy use and having a good and healthy indoor climate at the same time.

5.2 Relation between the MOBISTYLE work packages, phases objectives and key tasks.

Following table gives an overview, condensing the position of the work packages, the phases, objectives with key tasks and lessons learned so far.

Table 6: The positioning of the MOBISTYLE work packages

MOBISTYLE WP	MOBISTYLE phase	Objectives	Key tasks	Lessons learnt in MOBISTYLE related to the phase
WP2	**MOBISTYLE Profiling**	- Assessment of buildings and systems and existing sensors - Assessment of users and their needs including occupant's current behavior, awareness & energy usage (waster/efficient user)	- Building inspection and its existing systems performance - Anthropological inquiries to analyse the users	- In practice the assessment of user's needs is not done (only building inspection, commissioning). - We need revolution among users and not anymore evolution of technologies. - Main lesson learnt: ''The building ecosystem is efficient if all the components are mutually conscious.'' – meaning both building occupants & building systems
WP3	**MOBISTYLE Behavioral action plan**	- Definition of the optimization purposes - Development of a behavioral action plan strategy to be followed	- Based on user needs analysis prioritization of the KPIs to be shown and its benchmark definition. - Based on previous analysis of the desirable KPIs, definition on which parameters we monitor	Main lesson learnt: ''Energy efficiency at the heart of EU transition towards sustainable future NOT at the heart of building users.'' - Make invisible connection between the occupants and the buildings visible. Make users matter. - Behavior of occupants in

			- Decision on actions to be stimulated to achieve a behavior change.	the buildings is detached from the building components. It should be taken together.
WP4	**MOBISTYLE Data management and monitoring plan**	- Feasibility study on which sensors can be installed and how to connect to the existing infrastructure - Data privacy and user protection assessment	- Installation of the additional sensoring equipment allowing monitoring of the desired parameters	Main lesson learnt: ''Smart sensors are meaningless without consideration of people. We need smart users!'' - Measure the right parameters to be able to provide right information. - Interoperability between sensors is a problem. - Explain users what and WHY you will measure parameters and what does that mean for them.
WP3, WP6	**MOBISTYLE Feedback campaign execution**	- Decision on the appropriate feedback strategies, ICT solutions etc. -	- Based on measured parameters, appropriate feedback campaign strategy is chosen (ICT solution, supporting dissemination channels, frequency of information provision, severity)	Main lesson learnt: ''Less automation more information.'' - Intuitive user interfaces which are able to provide easy to grasp information on the system to the user in an understandable language, and which nudes users to change current practice in a fun way - Simple visualization of data in dashboard for non-residential, commercial, public buildings – MOBISTYLE Slovenian, Dutch, Italian case. - MOBISTYLE game attractive for residential buildings (building owners and tenants) – MOBISTYLE Polish and Danish case.

As overall conclusion of the outcomes of Work Package 2 is that within MOBISTYLE two solutions should be developed as a tool enabling information provision and feedback loop with building users:

- The MOBISTYLE Dashboard and Office App for monitoring and awareness raising, both for building managers and occupants in the non-residential buildings;
- The MOBISTYLE Game for encouraging behavioral change and awareness raising, especially for occupants in residential buildings

MOBISTYLE Dashboard:
An application for non-experts that visualizes end-user's data on energy use and IEQ (buildings performance) which are based on monitored parameters. Visualisation can be customised for different roles (e.g. building occupant or building manager). Through alerts/push messages recommends specific user certain actions that may avoid excessive energy use and/or improve indoor environmental conditions.

MOBISTYLE Office App:
A simple ICT dashboard created to encourage acceptance with dynamic indoor temperatures. It includes building occupant's satisfaction evaluation through a feedback loop (thermal and visual -sensation, -acceptance, and -comfort). Furthemore, it provides tailored suggestions on dynamic profiles of temperature and its positive effects to increase their acceptance. General tips are given that encourage users to a healthier, more sustainable and energy efficient behaviour and actions (e.g. using stairs).

MOBISTYLE Game:
A mobile application, that is based on defined objectives for preferable user practices. It aims to nudge a user to change practices in a fun way and is able to track the effect of changed practices on energy use and indoor environment over time. It provides scores to users for recommended practices and desirable changes. It uses 'nudges', based on the available sensors data, complemented by 'tips' and information for a healthy living.

In following figure, the MOBISTYLE ICT architecture and the MOBISTYLE solutions are visualized.

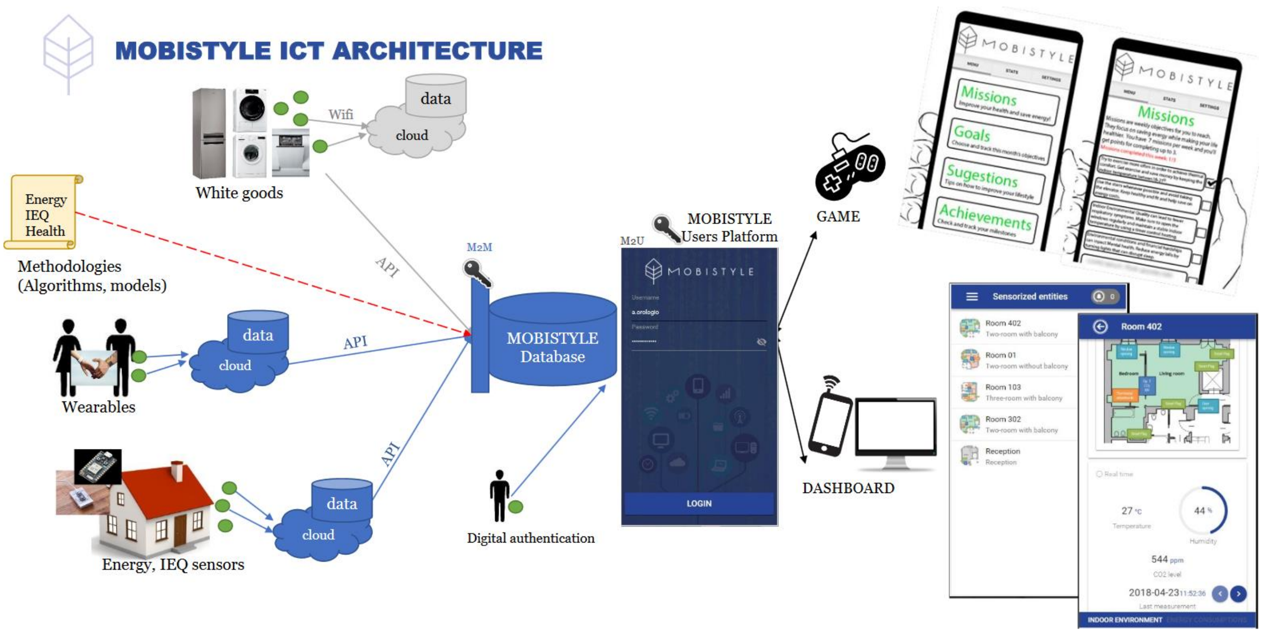


Figure 18: Visualization of the MOBISTYLE ICT architecture and the MOBISTYLE solutions

6. Conclusion

With the rapid technology development, new energy management products, services and solutions are presented on markets almost on a daily basis. However, technology development, and even cost development of sensors are not the main current issue. The main challenge is that the user acceptance, awareness and behaviour are still difficult to comprehend and exactly themes are crucial for thinking about user profiles and patterns of energy efficiency.

In an ideal situation, the impact of MOBISTYLE in motivating behavioural change towards energy efficiency can be substantial, as it can create a predictive "cycle", which includes monitoring, comparing, information services and advise. From there, the predictions can be supported by ICT solutions, such as the MOBISTYLE Dashboard, Office App and the Game.

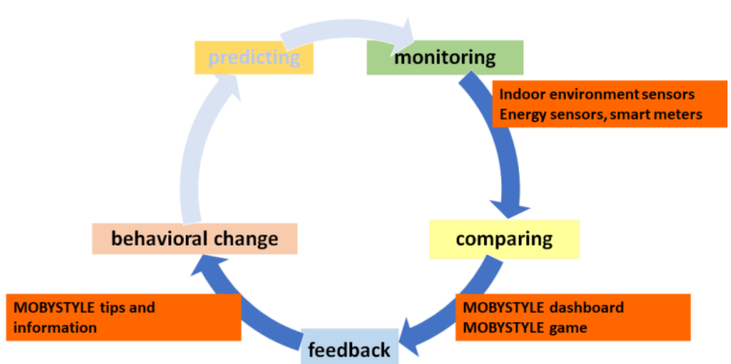


Figure 19: MOBISTYLE cycle.

Within this MOBISTYLE cycle we need to keep in mind that the goal of MOBISTYLE is not directly geared to solve the energy performance gap but by its methodology and approach it can absolutely contribute to bridge it. The key is not to be found in making 'more precise' predictions, but particularly in:

- focusing on the role of occupants in buildings, i.e. the consequences of their behaviour, the way how occupants use and interact with buildings and its systems, consciousness and motivation in relation to energy use, comfort and well-being in buildings;
- clearly defining the specific case questions that have to be answered and the required accuracy;
- improving monitoring and analysis methods of real building performance and developing databases for statistical information on energy use.

By doing so, it will be possible to proactively establish a behavioural change also towards energy efficiency, thus responding to the ascertained gap in the most effective way, leading to real optimisation

However, the impact of MOBISTYLE and its ICT-based solutions are as strong as the weakest link in the cycle. The main issue is that we hardly know how to address indoor environmental parameters and how to communicate about them with the occupant. Therefore, it is important to increase the knowledge about the topic in a broad way and provide information for occupants in order to make them understand how their behaviour affects the building's energy consumption and their indoor environment. In order words, we first need to understand the current different occupant profiles and related occupancy patterns, first leading to an awareness-raising process. From that point, useful and meaningful information can be presented to cycle up towards energy efficient behavior with healthy and comfortable indoor climate.

Crucial for the approach in MOBISTYLE is to consider this paradigm from the people-centred perspective, which tries to understand reality from a position of individuals and communities. This approach teaches a lot about how to transfer information to people, taking into account their cultural, social, historical and economic backgrounds.

Qualitative methods, such as ethnography (questionnaires, focus groups, participant observations; see D2.2 and D2.3) provide deep insights in occupants current habits and information about their living conditions (building profiles), occupants profiles (building occupants), usage profile (occupant interaction with a building, technologies, smart devices, degree of control over building services etc.), socio-economic profile (social status, degree of affinity with environment concerns), which result in solutions that are adapted people and communities they create. In addition, it gives directions for the final MOBISTYLE ICT-based solutions to be developed, i.e. the MOBISTYLE Dashboard, Office App and the Game.

Annex 1. Example of using focus groups: Outcomes of the Dutch demonstration case

Due to the change of a building for the MOBISTYLE Dutch demonstration case, the new focus groups were organized at the Qeske building, Kerkrade, the Netherlands. The focus group was carried by Loes Visser, Huygen team member by face-to-face discussion with 8 employees (2 interns of age 20 and 21 and 6 employees of the age 21-31) at the Qeske, in their meeting room, which is participants everyday workspace therefore their natural environment. Loes has previously been guided on how to elaborate the focus groups by the anthropology expert, PhD Dan Podjed (IRI-UL). The main obstacle in previous focus groups was language barrier as these focus groups were done by anthropology expert not speaking the same language as participants. Therefore, for the new Dutch focus groups, sufficient training of MOBISTYLE team member was done where she elaborated the full focus groups with the anthropology expert's (IRI-UL) support in the back. The same method was used as reported in D3.3 for the previous MOBISTYLE focus groups. Attendees were first informed about the project, where all gave their consent to take part in the project. Furthermore, they agreed regarding the data collection during the focus groups (recording of the session and later analysis) and allowed to take photos.

The participants were mostly young ambitious employees. The purpose of Qeske is to boost the young people to work together on innovative concepts and makes them aware of the fact that they themselves can also be innovators in the entrepreneurial or scientific field. The discussions were guided around the following topics with open ended-questions where people were encouraged to talk to one another. They often commented each other's point of view or exchanged anecdotes.

- **How do they experience the temperature at the working space?**

The temperature is perceived good where they are aware of having control over the air-conditioning unit according to their preferences with the remote control. This almost never ends in an argument between colleagues, because it is also possible to change the fan direction towards a colleague that asked for the temperature change. Although it is never really known what the setpoints of the different units are. "*Sometimes we notice that one* [airco] *is heating and another one in the same room is cooling at full speed*." Also, not everyone knows how the remote control of the units work. "*I always switch it on and hope that cold air is coming out when I want to*". She also doesn't ask the guys to help her, it is to much of an effort compared to what she wants.
They are all satisfied and grateful with the airco units, "*we had an acceptable summer compared to other offices* [which in the summer had great overheating problem] ".

- **How do they experience the lighting at their working space?**

People sitting in the middle say there is too little light (just some lighted spots). A couple of the guys sit facing the windows, they didn't think it was too dark only when they looked behind them they would notice the lack of light. With the spots they would work in their own shadow and they needed to search for an extra light when they needed to do some soldering.

- **How do they experience the air quality at the working space?**

"*I never thought about it, so I think it is ok*". This was the attitude of all people in the room. They have a central ventilation system, so this probably works well. "*It would be nice if we would be able to open a window, to have some really fresh air especially when we solder*". But this is not possible. Sometimes they open the fire escape door to ventilate a bit more the room as opening windows is not possible.

- **Do they go outside during the lunch break?**

Most of them go outside for a lunch break. They go to the supermarket or walk to another place. Some of them smoke and go outside to smoke. They would go out more if the area would be nicer. It is an industrial area. "*If there would be a little park, I would sit there for at least an hour. Now I stay inside most of the times."*

- **How do they come to work in the morning?**

"I cycle because I don't have a driver license or a car". The people that cycle, cycle approximately 20 minutes every morning. The others go by car or motorbike. They also carpool when possible, but more out of convenience then sustainability. One of the carpoolers doesn't have a car/driver license.

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