MOBISTYLE

MOBISTYLE
MOtivating end-users Behavioral 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 work done in task T3.2: *Methodological framework of the monitoring campaigns and feedback programs based on indoor environmental parameter and health implications* that will be used for the purposes of MOBISTYLE project, funded under European Union Horizon 2020 Innovation Action programme (H2020).

To provide interesting information for different building user types, certain parameters have to be monitored in chosen demonstration buildings. The objective of the MOBISTYLE task T3.2 is to develop a methodology to perform easy, non-intrusive and cost effective measurements and monitoring of the overall indoor environmental quality, in order to realize all the case specific MOBISTYLE objectives. MOBISTYLE project builds upon the understanding that different information provision mechanisms should be provided for different types of users. Furthermore, based on the ambient conditions and possible parameters measurements of the surrounding environment further define the boundary conditions of the information provision possibilities. This deliverable shows which Performance Indicators (KPIs) were selected for the different user types living in the different demonstration buildings as also the types of feedback solutions used to disclose the information. It provides tables of indicators based on monitored environmental conditions for each of the five demonstration cases, in terms of KPIs related to energy consumption and Indoor Environmental Quality (IEQ). In addition, for demonstration case 5 (Dutch case study), health monitoring parameters were introduced in the feedback process and are presented in Chapter 7. For a more comprehensive understanding of MOBISTYLE demonstration and monitoring actions at each of the five MOBISTYLE pilot case studies, the reader should refer to D6.1 [5].

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1 Introduction

The purpose of MOBISTYLE is to raise consumer awareness and motivate behavioural change towards more energy conscious building use, improved indoor environment and healthy lifestyle. The goal is to utilize the data gathered by existing sensing devices installed in the buildings and translate this data into attractive and easy comprehensible information for the identified building users.

Outcomes of the work done at an earlier stage of the MOBISTYLE (see outcomes of MOBISTYLE deliverable D2.2 *Inventory of user needs and expectations* [1] and D2.3 *Recommendations for improvement and further development of solutions* [2]), highlight that combined information on energy use with other relevant information such as the actual indoor environmental quality or their well-being is more interesting for building users than just solely energy consumption data.

To allow this, appropriate measuring devices needed to be installed in relevant building locations and connected to the common database. The additional devices were chosen based on the latest state-of-the-art devices available on the European market. The inventory of measuring equipment presented in the deliverable D2.1 *Inventory of supplied data* [3] was used as a basis. Based on the desired parameters to be measured at each demonstration site, additional sensors were purchased as described in D2.5: *Composition of specific sets of data acquisition for the five study and demonstration cases*. For a deeper understanding of architecture of the MOBISTYLE monitoring system and connection of all sensors to the MOBISTYLE database and to the platform, the reader should refer to D4.1 *Applicable hardware and software solutions for sensing technologies* and D4.2 *Applicable platform and database for software and information interoperability* [4].

This deliverable, D3.2, presents the methodology and chosen KPIs, that can be devised based on the parameters measured by the devices installed in the rooms at the demonstration buildings. By application of appropriate data analyses techniques and MOBISTYLE behavioural change methodology described in D3.1: *Detailed monitoring and information campaign parameters based on combined feedback about energy, IEQ and health*, the specific KPIs were linked in order to define certain actions that can be performed (and monitored) by the target groups. This KPIs and derived MOBISTYLE actions and suggestions will be implemented in the MOBISTYLE project for ICT solutions and awareness campaigns. Due to different types of buildings and end-users also different feedback campaign techniques are applied.

For the five demonstration cases detailed monitoring action plans were defined that will help realizing MOBISTYLE main objectives as also case specific objectives. The five real life environments where MOBISTYLE demonstration takes place are:

- A residential building complex in Aalborg, Denmark;
- Smart homes in Wroclaw, Poland;
- A hotel in Turin, Italy;
- Faculty buildings of University of Ljubljana, Slovenia;
- An office environment in Heerlen, the Netherlands.

More detailed description and information on the MOBISTYLE demonstration cases is available in the deliverable *D6.1 Detailed final monitoring, awareness and information campaigns for the five cases* [5].

1.1 Aim of the report

This document, MOBISTYLE deliverable D3.2, presents selected Key Performance Indicators (KPIs) that will be used for the purposes of the MOBISTYLE project for each of the 5 demonstration cases. It includes description of KPIs areas related to indoor environmental quality, energy consumption and health. Attention is given to intended behavioural changes, awareness and feedbacks techniques for each demonstration case that should be used to provide attractive information to different users based on these specific KPIs.

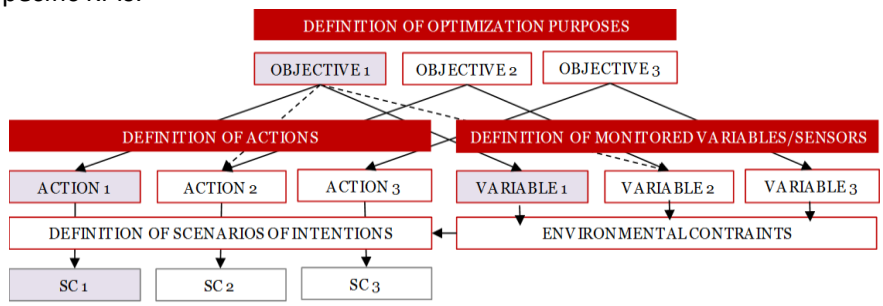

Figure 1: Structure of the Behavioural Change Intervention Action Plan, including optimization objectives, definition of actions and the data gathering from sensor, for the implementation of the scenarios of interventions and the feedback system architecture into the MOBISTYLE ICT solutions.

An updated version of the behavioural action plans for the 5 demonstration cases is included in this report, as already introduced in D3.1, Chapter 5.1. The Behavioural Action Plan has the main objective of transforming the intention to change behaviour into tasks for the users, by following the schematic illustrated in Figure 2.

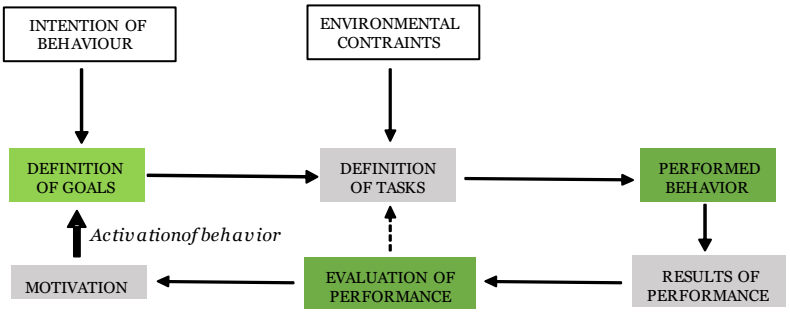

Figure 2: Flow diagram of behaviour action plan where a more comprehensive description of MOBISTYLE behavioural action plan methodology is described in D3.1, Chapter 5.1.

Green boxes indicate inputs/action required from the user, while grey boxes indicate activities performed by the ICT solutions. The following approach was applied:

- First, based on the focus groups discussions with the users of each demo case the personalized goals were defined.
- Secondly, personalized goals are translated in actionable tasks to be performed by the users, also considering possible environmental constraints and the technical requirements of the demonstration buildings (which sensors we can and is beneficial to install).
- Thirdly, advices and suggestions related to the KPIs, such as health, energy and IEQ are presented to the users to evaluate whether these are attractive for them.
- The decision was done on what kind of feedback solutions to provide to users to disclose information in an attractive way. MOBISTYLE game was tailored for residential buildings to

encourage energy savings in a fun way. The game aims to regularly prompt the residents in the buildings with motivational feedbacks (actionable tasks) to help the users achieving the activation of the tailored task-behaviours. On the other hand, via the MOBISTYLE dashboard, the users in public and non-residential buildings are informed about building's performance in a calm, friendly way with user-friendly display where they are free to personally evaluate the performance of his/her behaviour over time and set their own action types.

- Finally, the ICT solutions will keep track of results of the performed behaviours, eventually supporting re-definition of goals and tasks.

For each demonstration case, the user awareness and behavioural action plan included definition of the following as presented in the following chapters 3-7 for each demonstration case.

CASE STUDY	Behavioural Change Objective	Target group	Action	Context	Measure	Sensor	Unit	Sensor	User Engagement [TACT Scenario of intention implemented in the solution]

Hence, as discovered early in the project, it is often much too complicated to look for a direct correlation between the indoor environment parameters and health effects. Therefore, for most of the demonstration cases the person's health was not measured directly. Purposely, for the Dutch demonstration case a specialized investigation is being carried out on the effect of drifting environmental temperatures on physiological health parameters and thermal comfort and acceptance of the people occupying these office spaces.

2 Behavioural change strategy based on tailored feedback provision

This deliverable provides overviews of each specific demonstration case with respect to tailored behavioural action plans, KPIs and related potential behaviour changes, awareness, actions and suggestions linked to health, energy and IEQ.

2.1 Behavioural Action Plans

Based on the MOBISTYLE aim to change existing behaviour of users towards a more conscious behaviour, the actions are defined depending on the context of each demonstration case. Based on the defined parameters, a special focus was put on the definition and description of the behavioural change objectives, actions to be influenced, depending on the building context of reference (residential, office, university building, hotel rooms, etc.). This chapter provides an overview of behavioural change objectives per each demo case based on the parameters that will be measured (name of sensing/measuring devices and units).

2.2 Tailored indicators based on environmental conditions

Along the lines of the KPI definition in D3.1, data analysis approaches were established in order to transform the monitored (or raw) data into functional KPIs, hence, providing applicable information for the IT and platform developers (WP4 and WP5). This section of the report focuses on the key task of WP3 concerning the transformation of data coming from the building and from the users into useful and understandable information that can change the behaviour of the users at these different demonstration sites. This chapter sets the foundations for the potential energy awareness campaign strategies for engaging different types of end-users/persons to adopt (a healthier) and energy-conscious behaviour in the long-term.

2.3 Energy, IEQ, and health related advices and suggestions

A list of energy, IEQ, and health related advices and suggestions that directly link to the KPIs has been generated. As part of the task 3.4, “Elaboration of methodologies to turn monitoring data into knowledge for the end users”, further synergies were investigated between energy, IEQ and health.
As a support to measurable actions, general advices were developed and should be integrated in the feedback process to further support the attractiveness of MOBISTYLE solutions and success of the awareness campaigns. Advices targeting energy, IEQ, and health were developed for all case studies and categorized based on the areas of interest (Chapter 8).

2.4 Tailored ICT feedback solutions for target groups

MOBISTYLE has taken an anthropological people-centric approach (e.g. focus groups were organized at all the demonstration sites), with the users at the centre of the development process. In the preliminary design workshops that included users from the different MOBISTYLE testbeds, the use of technologies and possible scenarios of MOBISTYLE were broadly discussed and investigated with a perspective of co-design of the ICT solutions. The use of AR was deemed of significant low value with a strong preference for the gamified App (MOBISTYLE Game for residential building and their occupants) and the dashboard (MOBISTYLE Dashboard for non-residential buildings, users that do not own the buildings they occupy) available as mobile applications.

The following table introduces the developed MOBISTYLE solutions:

	MOBISTYLE Dashboard	**MOBISTYLE Game**
What is it?	An application for non-experts that visualizes end-users data on energy use and IEQ (buildings performance) which are based on measured 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.	A mobile application, that based on defined objectives for preferable user practices, nudges 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 sensors data available), complemented by healthy "tips".
For which purpose?	Monitoring & Raising awareness	Behavioural change & Raising awareness
For whom?	Building manager & Occupants	Residential users (have most control of their environment)
Where is it tested?	Non-residential buildings	Residential buildings
In which demo cases?	Slovenian case & Italian case	Polish case & Danish case

In the coming months, the results and analyses of the demonstrators and feedback from the user groups will be used to adjust and fine-tune the methodologies, tools, services.

In the first phase of the Dutch demonstration case, it is tested in a laboratory situation how people perceive drifting indoor conditions physiologically (change of metabolic rate, heart rate etc.). Next to the real life living lab (Demo-case Qeske), the drifting temperature will be applied and tested.
However, it has been shown earlier that lower temperatures indoors are healthier (physiological measurements) for occupants and at the same time lead to building energy savings. Therefore, in the different demo cases people will be educated via ICT solutions. It is expected that this positively affects their acceptance.

3 Danish demonstration case (residential)

3.1 Description of target groups and key learning objectives

As described in D6.1 [5], the Danish demonstration case is represented by a residential housing area located in Kildeparken, Denmark. The main MOBISTYLE aim for this demonstration case is to leverage a sustainable behavioural change leading towards a significant reduction of energy use by offering ICT based solution giving information and knowledge regarding occupant's IEQ and energy use. Additional requirement is that the developed MOBISTYLE solutions should work with the already established and offered services for the residents at Kildeparken. For the Danish demonstration building (representing colder climate), the main goal in terms of energy saving is to achieve reduction in energy uses for space heating and domestic hot water use. As the residents are occupants in social housing apartments, the idea is to stimulate the improved IEQ where improving their indoor air quality can furthermore improve their sleeping quality. As the families have the possibility to control heating setpoints individually, such actions will be encouraged to avoid overheating problems. Through the game, actions will be encouraged to optimize window operation strategies and domestic hot water use (e.g. shorter showers etc.).

3.2 Behavioural action plan

The Behavioural Action Plan for the Danish demonstration case is intended for residential users and is illustrated in Table 1. The table presents the correlation between different optimization objectives related to health, energy and IEQ. In particular, the occupants in Kildeparken are tenants in social housing apartments where the idea was to engage them into these (energy saving, improving IEQ) actions via a MOBISTYLE game. They can set their personalized goals and also look at their score compared to other family members or how they perform in comparison with an average Kildeparken tenant's profile (competition).

Table 1: The Behavioural Action Plan for the Danish demonstration case

	Behavioural Change Objective	Action	Context	Measure	Sensor	Variable [app control measure]	Unit	Sensor
RK 1	Health - IEQ	Opening closing window	Home	[0/1]	Window magnet	CO_2 concentration/ RH	[ppm]	CO_2/RH Sensor
RK 2	Health/Comfort IEQ - Natural Ventilation	Opening closing window (night)	Bedroom	[0/1]	Window magnet	Room temperature	[°C]	Temp. Sensor
RK 3	Energy Saving - Heating (active BMS)	Change setpoint for radiator valve	Home	[0/1]	Calculated based om temperature measurement	Set Point temperature	[°C]	Calculated based om temperature measurements
RK 4	Energy Saving - DHW	Reduce frequency and length of showers	Home	[0/1]	Water meter	DHW consumption	[m^3] or [kWh]	Water and heating energy meter
R5	Energy Saving - Stand-by Power	Switching stand/by power	Home	[0/stand by/1]	Smart Plugs equipment	Electricity Consumption	[kWh]	Smart Plugs / Hub / Cloud App
R6	Energy Saving - Off-peak hours	Shifting consumption off-peak	Home	[kWh]	Smart Plugs equipment	Electricity Consumption	[kWh]	
R7	Energy Saving - Off-peak hours (active BMS)	Equipment usage	Home	[kWh]	Smart Plugs equipment	Electricity Consumption	[kWh]	
R8	Energy - equipment (with Smart Plug)	Dishwasher and Washing Machine	Home	[kWh]	Smart Plugs equipment	Water and Electricity Consumption	[kWh]	

3.3 Key performance indicators

The table below presents the KPIs that will be used to satisfy the MOBISTYLE objectives for the Danish demonstration case. It can be seen how the KPIs can be translated into an easier understandable information for the user. The decision on further translation was done as part of the focus groups where it was investigated whether the users in Kildeparken understand the KPIs values or not. Based on the chosen KPIs, certain actions will be encouraged to stimulate a behavioural change (as described in the table for each KPI).

Table 2: KPIs for the Danish demonstration case

Target User/ Demo case	Area KPI	KPI (please refer to list from D3.1)	Unit	Translation for the user (if needed)	Unit (for user)	Which behavioural change/awareness objective can the KPI support?	Related actions	How is the KPI used?
Building residents/ Kildeparken (DK)	IEQ	**Indoor Air Temperature**	°C			• Improve perception of comfort • Improve IEQ conditions for health • Save energy (heating/cooling) • Decrease environmental impact • Decrease environmental impact	• Opening/closing window • Radiator thermostat adjustments • Adjust clothing	• Mission in the Game App • Alerts if temperature is too high/too low
		Indoor Relative Humidity	%			• Improve perception of comfort • Improve IEQ conditions for health	• Opening/closing windows	• Mission in the Game App • Alerts if relative humidity is too high/too low
		CO2 concentration	ppm			• Improve perception of comfort • Improve IEQ conditions for health	• Opening/closing windows	• Mission in the Game App • Alerts if CO2 level is too high
	Energy	**Heat consumption (apartment)**	kWh/day	• Change in %, comparing with historic consumption • Costs in DKK/month • Relate to Outdoor air temperature	• kWh/week • kWh/month • kWh/year	• Save energy (apartment level) • Decrease environmental impact	• Radiator thermostat adjustments • Adjust clothing • Opening/closing windows	• Mission in the Game App to reduce consumption • Feedback via alerts in Game App
		Domestic hot water use (apartment)	l/day	• Change in %, comparing with historic consumption • Costs in DKK/month	• l/week • l/month • l/year	• Save energy (apartment level) • Decrease environmental impact	• Reduce frequency and length of showers • …	• Mission in the Game App to reduce consumption • Feedback via alerts in Game App
		Domestic cold water use (apartment)	l/day	• Change in %, comparing with historic consumption • Costs in DKK/month	• l/week • l/month • l/year	• Save energy (apartment level) • Decrease environmental impact	• Reduce frequency and length of showers • …	• Mission in the Game App to reduce consumption • Feedback via alerts in Game App

4 Polish demonstration case (smart city)

4.1 Description of target groups and key learning objectives

The Polish demonstration case is covering the monitoring of the residential buildings located in Wroclaw whose building owners are clients of Polish energy provider TAURON – MOBISTYLE consortium partners (connected to the Smart city Wroclaw). As described in the previous deliverable D6.1 [5], the main objective for this MOBISTYLE demonstration case is to monitor electricity consumption and investigate how to motivate and change behaviour of users towards more energy efficient building use in their homes. The electricity from the appliances and plug loads will be monitored where the data will be translated into KPIs and actions to stimulate the reduction of unnecessary usage of electricity and improvement of indoor air quality (sleeping quality in bedrooms). Families will have their own control over the heating setpoints and window opening therefore it will be monitored the data coming from these sensors. Through the actionable tasks, users will be encouraged to improve their building related behaviour. Furthermore, by using data coming from the installed Whirlpool smart washing machines, the usage of the families washing cycles will be optimized by giving users weekly challenges that they can sign for.

4.2 Behavioural action plan

The Behavioural Action Plan for the Polish demonstration case is intended for residential users and is illustrated in Table 3. The families in the smart cities will be encouraged to behave better through a MOBISTYLE game that will give their family members possibility to sign up for different challenges (actionable tasks) where scores will be given to them in case where the actions will be actually done. Also, users will be able to personalize goals (energy saving goals) themselves and be able to monitor their progress.

Table 3: The Behavioural Action Plan for the Polish demonstration case

	Behavioural Change Objective	Action	Context	Measure	Sensor	Variable [app control measure]	Unit	Sensor
RT 1	Health - IAQ	Opening closing window	Home	[0/1]	window sensor	Room temperature, humidity level, CO_2 concentration	[°C], [%], [ppm]	temperature/ humidity/CO_2 sensors information about outdoor air quality (external service)
RT 2	Thermal comfort	Turning on/off heating, opening closing window	Home	[0/1]	window sensor	Room temperature, humidity level	[°C]	temperature sensors
RT 3	Energy Saving - Natural Ventilation	Opening closing window (night)	Bedroom	[0/1]	window sensor	Room temperature	[°C]	temperature sensors
RT 4	Energy Saving - Stand-by Power	Switching standby power	Home	[0 standby/1]	Smart Plugs Equipment	Electricity Consumption	[kWh]	Smart Plugs / Hub / Cloud App
RT 5	Energy – Equipment (with Smart Plug)	consumption measurement	Home	kWh	Smart Plugs Equipment	Electricity Consumption	[kWh]	Smart Plugs / Hub / Cloud App

4.3 Key performance indicators

Table 4 presents the KPIs that will be used to satisfy the MOBISTYLE objectives for the Polish demonstration case. It can be seen how the KPIs are translated into an easier understandable information for users even further. The decision on further translation was done as part of the focus groups where it was investigated whether the users in Wroclaw smart homes understand the KPIs values or not. Based on the chosen KPIs, certain actions will be encouraged to stimulate a behavioural change (as described in the table for each KPI).

Table 4: KPIs for Polish demonstration case

Target User/ Demo case	Area KPI	KPI (please refer to list from D3.1)	Unit	Translation for the user (if needed)	Unit (for user)	Which behavioural change/awareness objective can the KPI support?	Related actions	How is the KPI used?
householders/ Tauron Poland	IEQ	**Indoor Air Temperature**	°C	Equivalent of 1°C drop - you saved …kWh of gas, electricity what is worth …EUR or is a number of trees etc.		• Improve perception of comfort • Improve IEQ conditions for health • Save energy (heating/cooling) • Decrease environmental impact	• Lower temperature set-point in winter • Raise temperature set-point in summer	• Visualization on dashboard • Alerts if temperature is too high/too low
		Indoor Relative Humidity	%			• Improve perception of comfort • Improve IEQ conditions for health	• Adjust relative humidity levels	• Visualization on dashboard • Alerts if RH is inadequate
	Energy	**Electricity consumption (hosuehold)**	kWh/day	Emission of CO_2 equivalent translated into number of trees that it takes to absorb emissions Costs for electricity consumption	number of trees/year €/day	• Save energy (household level) • Save money (household level) • Decrease environmental impact	• Reduce overall energy use	• Visualization on dashboard • Feedback via alerts or report
		Electricity consumption (smart plug 1/2/3/4)	kWh/day			• Save energy (appliance 1/2/3/4) • Decrease environmental impact	• Depends on the appliance connected to the smart plug e.g. reduce stand-by actions, reduce number of washing cycles	• Visualization on dashboard • Feedback via alerts or report
		energy consumption/washing machine WHP	kWh/day kWh/washing cycle			• Save energy (washing machine) • Decrease environmental impact	• Reduce number of washing cycles	• Visualization on dashboard • Feedback via alerts or report
		water consumption/washing machine WHP	m3/day m3/washing cycle	Water save, equivalent transalted into the needs of people or trees for water (you saved 2l and this is the need for grown up and %of population is missing water) Costs for water consumption		• Save water (washing machine) • Decrease environmental impact	• Reduce number of washing cycles	• Visualization on dashboard • Feedback via alerts or report

5 Italian demonstration case (hotel)

5.1 Description of target groups and key learning objectives

As described in D6.1 [5], the Italian demonstration case presents a hotel building located in Turin where hotel guests are mostly long-term stayers. The MOBISTYLE demonstration will cover four apartments and the reception area. The specific objective for the Italian demonstration case is to monitor IEQ and electricity consumption in order to provide the hotel guests with feedback on energy use with guidance on how to save energy while creating a healthy and adequate indoor environment.

The main idea is to optimize the HVAC and home appliances operation while consequently reducing overheating problem and improving IEQ.

The relation and interaction between the hotel performance and guest's influence on it will be made visible to the hotel guests by deploying the guests an easy to understand and attractive MOBISTYLE dashboard and mobile application (disclosing the KPIs information shown on Table 6). It is believed that the users will become more aware and conscious about their overall daily actions (even these that will not be directly measured by MOBISTYLE project).

5.2 Behavioural action plan

The Behavioural Action Plan illustrated in Table 5 for the Italian demonstration case targets the hotel guests and receptionists.

Table 5: The Behavioural Action Plan for the Italian demonstration case

	Behavioural Change Objective	Target user	Action	Context	Measure	Sensor	Variable [app control measure]	Unit	Sensor
H1	Energy Saving – Heating, Cooling /IEQ	Hotel guest	Adjusting setpoint temperature	Hotel Apartments	[°C]	BMS	Air temperature	[°C]	T/RH/ CO_2 sensor
H2	Energy Saving		Reduce overall energy consumptions	Hotel Apartments	[kWh]	Smart meter	Electricity consumption	[kWh]	
H3	Energy Saving – Washing machine		Switching off stand by power – Reduction and optimization of washing cycles	Hotel bathroom	[kWh]	Smart plug	Electricity consumption	[kWh]	
H4	Energy Saving – Dish washer		Switching off stand by power – Reduction and optimization of washing cycles	Hotel Kitchen Living	[kWh]	Smart plug	Electricity consumption	[kWh]	
H5	Energy Saving - TV		Switching off stand by power – Reduction of viewing activity	Hotel Kitchen Living	[kWh]	Smart plug	Electricity consumption/ power	[kWh]/[kW]	
H6	Energy Saving - Microwave		Switching off stand by power	Hotel Kitchen Living	[kWh]	Smart plug	Electricity consumption/ power	[kWh]/[kW]	
H7	Health - IAQ		Opening/closing window	Hotel Bedroom	[0,1]	BMS	CO_2 concentration	[ppm]	T/RH/ CO_2 sensor
H8	Energy Saving - PC	Hotel staff	Switching off stand by power	Reception	[kWh]	Smart plug	Electricity consumption/ power	[kWh]/[kW]	

H9	Energy Saving printer		Switching off stand by power	Reception	[kWh]	Smart plug	Electricity consumption/ power	[kWh]/[kW]	

5.3 Key performance indicators

Table 6 presents the KPIs that will be used to satisfy the MOBISTYLE objectives for the Italian demonstration case. Based on the chosen KPIs, certain actions will be encouraged to stimulate a behavioural change (as described in the table for each KPI). Since energy consumptions might not be easy to understand for the hotel guests, the units are translated into “number of trees that it takes to absorb emissions”.

Table 6: KPIs for the Italian demonstration case

Target User/ Demo case	Area KPI	KPI (please refer to list from D3.1)	Unit	Translation for the user (if needed)	Unit (for user)	Which behavioural change/awareness objective can the KPI support?	Related actions	How is the KPI used?
Hotel Guest/ Polito (Italy)	IEQ	**Air Temperature**	°C			• Improve perception of comfort • Improve IEQ conditions for health • Save energy (heating/cooling) • Decrease environmental impact	• Lower temperature set-point in winter • Raise temperature set-point in summer	• Visualization on dashboard • Alerts if temperature is too high/too low
		Level of relative humidity	%			• Improve perception of comfort • Improve IEQ conditions for health	• Adjust relative humidity levels	• Visualization on dashboard • Alerts if RH is inadequate
		Level of CO_2	ppm			• Improve perception of comfort • Improve IEQ conditions for health	• Opening/closing windows	• Visualization on dashboard • Alerts if CO_2 level is inadequate
	Energy	**Electricity consumption (apartment)**	kWh/day	Emission of $CO_{2,\ equivalent}$ translated into number of trees that it takes to absorb emissions Costs for electricity consumption	number of trees/year €/day	• Save energy (apartment level) • Decrease environmental impact	• Reduce overall energy use	• Visualization on dashboard • Feedback via alerts or report
		Electricity consumption (washing machine)	kWh/day			• Save energy (washing machine) • Decrease environmental impact	• Reduce number of washing cycles	• Visualization on dashboard • Feedback via alerts or report
		Electricity consumption (dish washer)	kWh/day			• Save energy (dish washer) • Decrease environmental impact	• Reduce number of washing cycles	• Visualization on dashboard • Feedback via alerts or report
		Electricity consumption (TV)	kWh/day			• Save energy (TV) • Decrease environmental impact	• Reduce stand-by use	• Visualization on dashboard • Feedback via alerts or report
		Electricity consumption (microwave)	kWh/day			• Save energy (microwave) • Decrease environmental impact	• Reduce stand-by use	• Visualization on dashboard • Feedback via alerts or report
		Electricity consumption (oven)	kWh/day			• Save energy (oven) • Decrease environmental impact	• Reduce stand-by use	• Visualization on dashboard • Feedback via alerts or report
Hotel Staff (Reception)/ Polito (Italy)	IEQ	**Air Temperature**	°C			• Improve perception of comfort • Improve IEQ conditions for health • Save energy (heating/cooling) • Decrease environmental impact	• Lower temperature set-point in winter • Raise temperature set-point in summer	• Visualization on dashboard • Alerts if temperature is too high/too low
		Level of relative humidity	%			• Improve perception of comfort • Improve IEQ conditions for health	• Adjust relative humidity levels	• Visualization on dashboard • Alerts if RH is inadequate
		Level of CO_2	ppm			• Improve perception of comfort • Improve IEQ conditions for health	• Opening/closing windows	• Visualization on dashboard • Alerts if CO_2 level is inadequate
	Energy	**Electricity consumption (PC reception)**	kWh/day			• Save energy (PC) • Decrease environmental impact	• Reduce stand-by use	• Visualization on dashboard • Feedback via alerts or report
		Electricity consumption (printer reception)	kWh/day			• Save energy (printer) • Decrease environmental impact	• Reduce stand-by use	• Visualization on dashboard • Feedback via alerts or report

6 Slovenian demonstration case (university)

6.1 Description of target groups and key learning objectives

As described in D6.1 [5], the main MOBISTYLE demonstration in Slovenia is related to the monitoring of the faculty buildings at the University of Ljubljana (UL) where the specific objective for this demonstration case is improved indoor environment quality (IEQ) as result of modified behaviour. Energy saving is to be achieved in parallel due to improved IEQ. The demonstration will take place at the specific rooms of Faculty of Computer and Information Science (FRI) and Faculty of Chemistry and Chemical Technology (FKKT).

The main goal in terms of energy saving is to achieve reduction in energy use due to a change of IEQ. The idea is to encourage actions that help to reduce overheating, glare problem and improve IEQ, lighting quality and view to outside. This can help improving the occupant's mood and well-being (also productivity) while improving the interaction (and understanding) of users with building systems. The professors, researchers and permanent students occupying the offices will be encouraged to actions which they can control themselves. The information about their behaviour and suggestions on how to improve these actions will be given to them via the MOBISTYLE dashboard.

6.2 Behavioural action plan

The Behavioural Action Plan for the Slovenian demonstration case is targeting professors, administration staff, researchers, and permanent students of the Faculty buildings. The table below shows two examples where correlation between the IEQ, energy and health parameters was sought.

Table 7: The Behavioural Action Plan for the Slovenian demonstration case

	Behavioural Change Objective	Action	Context	Measure	Sensor	Variable [app control measure]	Unit	Sensor
O1	Health - IAQ	Opening/closing window	Office Space	[0/1]	Window Position	CO2 concentration	[ppm]	Co2 Sensor
O2	Energy Saving - Heating	Adjusting setpoint temperature	Office Space	[°C]	SCADA	Set point temperature	[°C]	SCADA

6.3 Key performance indicators

Table 8 presents the KPIs that will be used to satisfy the MOBISTYLE objectives for the Slovenian demonstration case. The focus groups showed that the students and professors occupying the university buildings to the most extent understand (and relate to) the information coming from KPIs values, therefore no further translation was needed. Based on the chosen KPIs, certain actions will be encouraged to stimulate a behavioural change (as described in the table for each KPI).

Table 8: KPIs for the Slovenian demonstration case

Target User/ Demo case	Area KPI	KPI (please refer to list from D3.1)	Unit	Translation for the user (if needed)	Unit (for user)	Which behavioural change/awareness objective can the KPI support?	Related actions	How is the KPI used?
Professors, Admin Staff, Researchers, Permanent Students (room users)/ Slovenia	IEQ	**Indoor temperature setpoint**	°C		°C	Energy Saving - Heating, Cooling Health - Heating, Cooling	Adjusting setpoint temperature: Lower temperature set-point in winter and higher in summer	Visualised on thermostat, used as measure of behaviour
	IEQ	**Indoor Air Temperature**	°C		°C	Energy Saving - Natural Ventilation	Opening/closing window	Visualization on dashboard (+ actual position of valve for heating and cooling) Alerts if temperature is too high/too low
	IEQ	**CO_2 concentration**	ppm		ppm	Health - Natural ventilation	Opening/closing window	RGB LED on a sensor changes colour based on values Visualization on dashboard Alerts if CO2 level is inadequate
	IEQ	**Light intensity/CCT**				Health - Natural light	Adjusting shading position, switching lights	Visualization on dashboard (external shading position and lights operation) Feedback via alerts or report
	IEQ	**Stair use**				Health - Energy Saving (electricity)	Using stairs, not elevators	Feedback via report
	Energy	**Electricity consumption (building)**	kWh	Costs	€/day	Energy Saving - Equipment	Optimize usage of office equipment / Reduce overall energy use	Feedback via report
	Energy	**Electricity consumption**	kWh		kWh	Energy Saving - Artificial Lighting	Switching off/lights	Feedback via report
		Hot water use	m^3		l	Energy Saving - Water Saving	Use less (hot) water	Feedback via report
		Electricity consumption	kWh		kWh	Energy Saving -Stand-by Power	Switching stand/by power Reduce stand-by use	Feedback via report
	Energy	**Electricity consumption**	kWh			Energy Saving – Adaptive behaviours	Dinking hot/cold water, adding/removing layers of clothes, take a walk into a colder/warmer	Feedback via report

7 Dutch demonstration case (offices)

7.1 Description of target groups and key learning objectives

As described in D6.1 [5], the Dutch demonstration case is an initiative in which education, colleges, universities and companies form a platform. The building users consist of students (age of 20+), young entrepreneurs, experienced professionals, and professors (age up to 65). The MOBISTYLE demonstration will cover one floor of this office building. The MOBISTYLE objective of the Dutch demonstration case is to improve health and well-being and reducing energy use by realizing an optimal dynamic indoor climate in offices through a dynamic indoor temperature over the day that ensures healthy and productive office environment and thus also achieves energy savings compared to a traditional air-conditioned office.

For the office spaces in the Dutch demonstration case temperature training will be imposed where it will be investigated in real-life environment what effect dynamic varying temperatures on building's energy performance, acceptance by the occupant and occupant's health related parameters (heart rate, skin temperatures, physical activity) and well-being (their comfort, sensation, mood, sleepiness, alertness and acceptance evaluated through a questionnaire) have. As for the demonstration case, the main objective is to observe relationships between the changing indoor environment conditions (mainly temperature) and resulting health parameters, comfort and sensation. As explained in chapter 2.4, there is no feedback provision to the occupants of the buildings as it is investigated the actual relation between physiological response of building occupants and the varying indoor conditions. Therefore, no behavioural change action plan is presented as in the first phase it is not intended to change their psychological perception.

7.2 Key performance indicators

Table 9: KPIs for the Dutch demonstration case

Target User/ Demo case	Area KPI	KPI (please refer to list from D3.1)	Unit	Which behavioural change/awareness objective can the KPI support?	Related actions	How is the KPI used?
Office workers/ Maastricht Univ (NL)	IEQ	**Air Temperature**	°C	• Improve perception of comfort • Improve IEQ conditions for health • Save energy (heating/cooling) • Decrease environmental impact	• Variable (drifting) temperature with lower average temperature in winter • Variable (drifting) temperature with higher average temperature in summer	• Demonstration of acceptability of drifting temperature • Demonstration of potential improvement of health and well-being • Demonstration of increase in alertness
		Air velocity	m/s	• Improve perception of comfort • Improve IEQ conditions for health	Opening closing windows	-
		Level of relative humidity	%	• Improve perception of comfort • Improve IEQ conditions for health	-	-
		Level of CO_2	ppm	• Improve perception of comfort • Improve IEQ conditions for health	Opening closing windows	Potential relation with alertness
	Health and Well-being	**Heart rate**	beats/min	• Improve health	-	• Demonstration of the effects of drifting temperature on physiological/health parameters •
		Physical activity	counts and steps	• Improve health	• Increase physical activity on a daily base	• Demonstration of the effects of drifting temperatures on physical activity
		Skin temperature	°C	-	-	• Demonstration of the effects of drifting temperature on physiological/health parameters
		Comfort and sensation	-	-	-	•Demonstration of the effects of drifitng temperatures on comfort, sensation and acceptability

8 Complementary advices targeting energy, IEQ, and health

As part of the task 3.4, *Elaboration of methodologies to turn monitoring data into knowledge for the end users,* further synergies were investigated between energy, IEQ and health. As explained in the Introduction chapter to this deliverable, it is difficult to state direct correlation between measured IEQ and health parameters. Nevertheless, based on broader research findings and well-known health advices, it is possible to give building occupants further information about a healthy behaviour in building that also (directly or indirectly) affects energy savings. As example: we can encourage users to take stairs instead elevator based on general advice and existing scientific literature. Nevertheless, it is impossible to state and monitor the effectiveness of each specific person using space in the demo cases. Especially, because of large individual variation, and, secondly, since most health parameters improve on the long term.

As a support to measurable actions, general advices can be given to further support the attractiveness of MOBISTYLE solutions and success of the awareness campaigns. Advices per each demo case where categorized based on their context, suitability and attractiveness. A large Excel table with possible advices related to energy, IEQ and health was devised based on literature research. This table was discussed with users in the focus groups to find out which are the most interesting advices that could be presented to users at the demo sites. As example, interesting advice for the users was ‘’It’s sunny outside, do you really need a light on?’’

The table below presents examples of complementary advices that can be integrated as part of the ICT solutions (game and dashboard). The ICT developers will together with users define the type, number and frequency of suggestions provision in order to still respect the calm technology principle (one of the important MOBISTYLE principles to follow).

Table 10: Energy, IEQ, and health related advices and suggestions

KPI	Related health/energy/IEQ advices and other suggestions
Indoor temperature and setpoint	• Lowering the heating/cooling temperature by 1°C can reduce the overall energy by 7%. • lower temperatures are beneficial for heat loss during activities. • Reducing the environmental temperature might increase your alertness • Do the temperature training to increase resilience! • Increase the temperature! Overcooling brings lower performance in the office! • Lower temperatures help to have healthy metabolism! • Reduce the temperature and boost your brains! • Want to lose some weight due to increased metabolism rate? Reduce the heating setpoint in your office! • High temperature might kill your productivity. Switch off heating for a while! • If you feel cool, put on some clothes! • Variable indoor environmental temperature are likely to increase your alertness and well-being. • Variable indoor temperature decreases building energy consumption • When outdoor conditions are suitable, opening the window will freshen your room and provide energy savings. • Fresh air is beneficial for health. However, leaving the window open too long does not benefit much your wallet! Instead you will lose money for heating. • Open the window, it is warmer/cooler outside • Open the window now and for just one minute. You will provide fresh air, without losing money for heating/cooling.
CO_2 concentration	• Fresh air will boost vigilance. Performance might increase after ventilating the room. Fresh air increases well-being. • Frequent ventilation helps reducing formation of mould. • Opening a window will decrease CO2 level in the room. You will be able to concentrate better and stay alert. • Letting fresh air in can decrease humidity and reduce asthma and allergy symptoms. • Do you have trouble to concentrate? Open the window! Feeling tired? Fresh air might boost your vigilance! • Ventilate the room! You might get a headache and your productivity might decline. • Improved sleeping quality by lowering CO2 concentration via opening window
Relative humidity	• Longtherm high humidity indoors will cause microbial growth, and very low humidity, causes dryness and irritiation of eyes and airways (EN15251)
Light intensity/CCT	• Blue light should be increased in the morning hours for increased alertness and less sleepiness • Blue light should be decreased in the evening for a better sleep. • Level of light in your work environment is not sufficient. Increase the amount of daylight or switch on lights. • Turn off the lights and save your eyesight. After all, it is sunny outside!
Stair use	• Climbing stairs is a great way to improve energy, increase the function of immune system and lower risk for diabetes, high blood pressure, osteoporosis and heart disease. • Harvard Medical School reports that stair climbing is an effective way to lose weight and keep it off, since people who walk upstairs, even at a slower pace, burn calories three times faster than when walking at a faster speed on a normal surface. • Climbing just eight flights of stairs a day lowers average early mortality risk by 33%. Seven minutes stair climbing a day can halve the risk of heart attack over 10 years. • Just two minutes extra stair climbing a day is enough to stop average middle age weight gain. Stair climbing burns more calories per minute than jogging. Stair climbing reduces cardio risk by more than 30%. Stair climbing helps control weight and builds muscle tone. People who use stairs have 15% more chances to live to the old age. • For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity – like using the stairs. • Health suggestions: • Taking care of your healthy means also using the stairs. Why waiting for the elevator? Use the stairs, save time, get fit and live longer. Avoid inactivity, use the stairs.
Electricity consumption	• People use significant part of electricity for small equipment. • Being connected 24/7 means information and communication technology (ICT) devices draw energy all the time, even when in standby mode • 1W power is approximately 1€/year • If you aren't frequently using a device, unplug it. • Turn off your computer and monitor. • Use a switchable power strip • Schedule automatic power off. • Its sunny outside, do you really need the light on? • Turn off the light and equipment, if there is no one in the room. • If you will be out of a room for 15 minutes or less, leave it on. • If you will be out of a room for more than 15 minutes, turn it off • Try to reduce electricity wastes and vampire loads. Do you really need all the devices plugged in? • Are the any lights blinking/on? This is stand by use that should be avoided. Unplug chargers from the socket. Use a switchable power strip • Performing activities (e.g. a short walk, use of stairs) increases your metabolism and keeps you warm. • Need to exercise our thermoregulatory system as part of a healthy lifestyle (use it or lose it). By regular exposure outside the thermoneutral zone: Increase brown adipose tissue and energy expenditure capacity, May increase insulin sensitivity, Increase resilience to more extreme weather condition (important for healthy aging) • Computer: A typical office computer turned on for 9 hours a day arrives at consume up to 175 kWh in a year. By setting the energy saving option the consumption drops by 37%, with a saving of carbon dioxide (CO2) emitted in the atmosphere of about 49 kg! • Computer: Be careful about stand-by modus! If we assume that your PC is on average 8 hours a day, the remaining 16 hours it remains in stand-by mode. A stand-by PC consumes up to 20 watts of power per hour depending on the model. In 24 hours this "off" consumed about 300 Wh. In one year, this energy waste will be about 120 kW equivalent to the average annual consumption of a dishwasher (about 180 washing cycles). • Washing machine: It is advisable to fill the washing machine to the nominal load, because if the washing machine is not loaded enough, there is a risk of damaging the fabrics and increasing the consumption of water and energy by up to 20%. • Dish washer: Is it necessary to rinse the dishes before inserting them in the dish washer? False!!! Detergents need dirt to clean and if the dishes are already cleansed, the soap enzymes act less than their potential. Not to mention that the operation involves unnecessary waste of water. To remove food residues, it is better to use a damp sponge or paper towels used during the meal (which would however be thrown away). • Microwave oven: The microwave oven only converts part of the electrical energy into microwave energy. A typical microwave oven absorbs 1,100 W of power to produce 700 W of power in the microwave, with an efficiency of 64%. Therefore, when on the microwave oven control panel, you see written, for example, 700 W, that is not the power absorbed but only that of the microwaves, which as mentioned is more than 30% lower than that absorbed.
Hot water use	• Electricity is needed for transport, preparation, heating and treatment of water. • Do you really need hot water for washing your hands? • You will save money by reducing hot water consumption.

9 Conclusion

This deliverable presents an inventory of the KPIs that can be provided by gathering data through the existing and additional measuring devices that are installed in the five pilot cases for the purposes of MOBISTYLE demonstration. By looking into relation between the different parameters and following people-centric approach, certain actions were devised for each case based on the MOBISTYLE behavioural change methodology (D3.1).

Discussions with the building users led to a definition of the personalized goals, actionable tasks and a clear alignment on which feedback typologies are useful and attractive for the users at the demonstration cases. Based on people-centric approach, the decision was to provide the game for residential users as the easy-to-use dashboard to occupants in other buildings. Besides providing them with actionable tasks, also general advices are given to users to stimulate them even further to behave more consciously and be proactive users of their buildings. The frequency of information provision was decided per demonstration case with the ICT solutions developers.

This delivery 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.

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