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Abstract:
ENTROPY aims to change users' energy consumption behaviour in order to achieve energy savings. The recommender system creates personalized recommendations based on user profiling. The profiling is initially done explicitly, then the recommendations are adjusted based on further implicit profiling of user. This deliverable explains our methodology for creating personalized recommendations by tracking users' interaction with the platform through ENTROPY applications. Additionally, we present the initial implementation of the recommender engine for the first campaign.

Keywords:
Recommender engine, adaptive persuasive technologies, gamification, personalized interventions, rules, behavioural change

Revision History

The following table describes the main changes done in the document since created.

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V1.0	17.03.2017	Final version	Umutcan Simsek (UIBK)

Executive Summary

This document introduces the recommender system that serves personalized recommendations to the ENTROPY applications, targeting change in users' energy consumption behaviour.

After we give an introduction to the recommender engine and the significance of the behavioural change for energy savings, we start the Section 2 with revisiting the goals of the recommender engine as well as the overall project alongside the defined KPIs in the relevant deliverable.

We explain our methodology in connection with the established literature of persuasive technologies and adaptive persuasive technology. The conceptualization of the recommender engine that reflects our defined methodology concludes the Section 2.

The gamification user types that were part of the initial survey conducted on ENTROPY pilots are explained in Section 3, as well as indicative personalization mechanisms regarding to those types. A detailed list of customized recommendation content for the first campaign is given in the appendix.

The first implementation of our concept is presented in the Section, including the existing modules in the platform technologies used for the implementation.
We conclude the document with Section 5, which gives a summary and shows the next steps for the recommender engine, including full implementation and test of the concept. Additionally, we briefly address the ethical concerns regarding collection and publication of users' behavioural data and implicit profiling for the adjustment of the recommendations.

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1. INTRODUCTION

ENTROPY platform hosts a recommender engine that creates recommendations based on context changes defined on sensor data streams. The recommender engine provides personalized recommendations by taking user attributes and behavioural traits into account. This recommendations are then used by the ENTROPY applications, namely the personalized mobile application and serious game.

A report from European Environmental Agency [1] shows that measures targeting behavioural change of consumers may help to achieve energy savings up to 20%, which would help member states significantly, to achieve the goal of reducing the primary energy consumption by 20%.

The behavioural interventions can be done in many ways, for instance constant feedback to consumers about their energy consumption. While providing feedback to consumers is effective, the interventions may increase their impact by personalization and context awareness. A report [18] that investigates the human factor in energy efficiency shows that it is important to be aware of the context, drivers to which the consumer susceptible and the adaptation of an intervention. Therefore, within the ENTROPY platform, we provide a rule based recommender engine that personalizes intervention content according to user's behavioural traits.

In this deliverable, we provide a methodology for creating recommendation targeting behavioural change in energy consumption, the overall conceptualization of the recommender engine including the personalization mechanisms based on statistical and knowledge based methods, as well as the initial implementation that will be used in the first campaign. Additionally, we also introduce the initial set of rules identified based on the existing infrastructure of the pilot sites and suitable recommendation content corresponding to the identified gamer types by the pilot surveys. We will conclude the deliverable with a summary and planned next steps for the recommender engine.

2. RECOMMENDATIONS AIMING BEHAVIOURAL CHANGE

In this section we will describe the goals of the recommender engine in terms of changing energy consumption behaviour and the methodology for achieving those goals. Additionally, we will introduce the conceptualization of the recommender system and the current implementation that will be used for the first campaign, in order to collect initial data to create a baseline for the behavioural change.

2.1 Goals and KPIs

The main goal of the recommender engine is changing the energy consumption behaviour of users through personalized recommendations based on users' behavioural profile. Table 1 shows the KPIs defined for the overall evaluation of the effectiveness of the intervention. The KPIs defined to measure the overall effectiveness of the interventions in terms of energy savings are coloured with blue. The rest are used to evaluate the change in user's energy consumption behaviour, which is more strongly related to the recommender engine [4].

Table 1 ENTROPY Evaluation KPIs [4]

Success criteria	Possible KPIs	Possible baselines	Evaluation method
Energy use reduction / energy Saving	Measured energy saving (analysis of collected data) • Per building • Per pilot (total)	- Energy consumption before ENTROPY Intervention	Compare predicted use with actual use
Oil use reduction/ oil saving	Measured oil saving (analysis of collected data) • Per building • Per pilot (total)	- Baseline consumption in tons of oil equivalent	Compare predicted use with actual use of oil
Carbon footprint reduction	Measured equivalent CO_2 saving • Per building • Per pilot (total)	typical CO_2	Compare predicted with actual carbon emissions
Deployment Cost	Deployment Cost of Entropy solutions per pilot	Typical infrastructure cost	Add all possible implementation costs
Time cost	• Measured time per process after Entropy platform • User perceived time use	• Time per process before the intervention • User perceived time use before intervention	• Compare time needed before and after intervention • User survey to evaluate time impact

Success criteria	Possible KPIs	Possible baselines	Evaluation method
Cost vs Benefit	• Costs • Benefits: economic, environmental and social	Expected benefits	• Measure the actual economic savings e.g. electricity gains • Measure the perceived benefits by users
User energy awareness	user energy awareness level	initial awareness level	Execute survey to determine user awareness before and after ENTROPY intervention
User behavior change	• #users with a more energy behavior after the intervention vs. those acting green due to intrinsic motives • User green knowledge gain • Participation to serious games • Participation to entropy tests	• Energy awareness level before intervention • Baseline green knowledge level • Expectation for green knowledge gains	• Measure #users acting more green • Survey • Compare perceived user energy use before and after intervention • Compare users with different roles
User satisfaction	• Perceived user satisfaction of the system in terms of user interface, enjoyment etc. • Perceived user satisfaction of energy saving	Prior user expectations	Survey to estimate user satisfaction
User system adoption (or intention to adopt)	• #users trying ENTROPY platform • #users using ENTROPY platform • Perceived user intention to continue to use the system	Prior user expectations	Survey
Personalized solutions effectiveness	User satisfaction and intention to use after usage (does it match the user's profile?)	-	Survey
Recommendation system effectiveness	User satisfaction and intention to use after usage (does it match the user's profile?)	-	Survey

2.2 Methodology

Our methdology is based on the concept of "captology", which stands for "computers as persuasive technology" [9]. Throughout the years, history shows that usability is not enough for

user engagement and behavioural change. Norman points out the basic levels of processing [17], adding on Nielsen's Usability theory [15] and the emotional design concept. Norman also tested the existence of correlation between design and usability, concluding that attractive things make people feel good and in turn makes them think more creatively and examine multiple alternatives. Behavioural Economics takes those concepts, and uses them as it seeks to find how users make their decisions and thus how to influence their choices.

The methodologies and techniques that emerged from the aforementioned fields have also been applied to Fogg's captology model [10]. Fogg presents the FBM framework, in which he points out the three elements to converge for a behaviour to occur: Motivation, Ability, and Trigger. Our approach for the personalized application on behavioural training takes these components into account in order to boost user's participation and eventually achieve the bigger goal - making the application a habit.

The effectiveness of persuasive technologies has been also analysed. A survey on empirical studies [11] shows that %54.7 of the persuasive technologies in the literature had positive results. At the same time, %37.9 showed partially positive results. This means %92.6 of the empirical studies on persuasive technologies showed positive results on either all or some of the behavioural outcomes.

The overall network of relationships between a set of related constructs is called a nomological network [2]. We use this approach to present how Fogg's framework components work together (Figure 1).

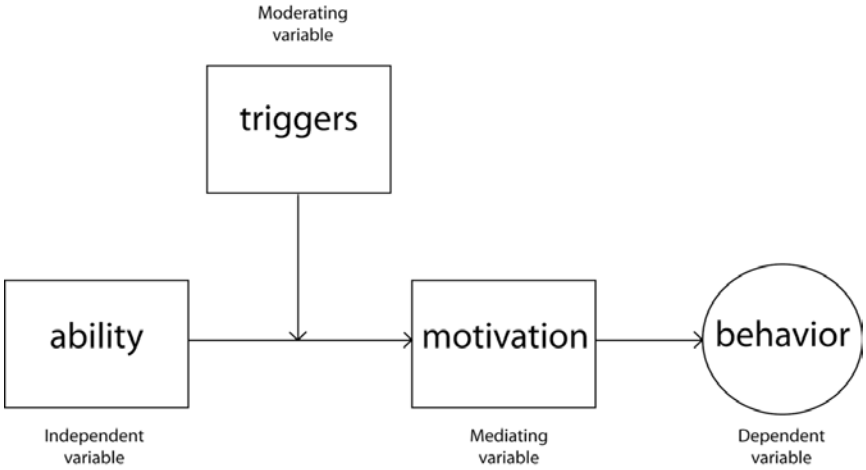

Figure 1 Representation of Fogg's principles [10] as a nomological network

In the scope of ENTROPY project we use serious games and gamified personalized applications to provide the aforementioned factors for the behavioural change. The ability factor is provided by learning materials through the personalized application. The delivery characteristics of the learning material is determined by the recommender system. The recommender system produces a part of the triggers for the behavioural change by providing context aware recommendations. Last but not least, it contributes to the motivation factor by providing recommendation content tailored to users' behavioural traits and gaming preferences.

The core of the ENTROPY behavioural change methodology is the personalization. The concept of adaptive persuasion has emerged, in order to define persuasive technologies that are tailored

based on user profiling, which can be done explicitly or implicitly [13]. We combine explicit and implicit profiling for creating personalized recommendations and change energy consumption behaviour through personalized apps and serious games.

Two recent works [3, 20] stands out regarding energy savings through recommendations. The work in [3] adopts a feedback channel to help collaborative creation of recommendations. A machine learning approach in order to mine behavioural patterns from energy consumption is introduced in [20]. Our methodology differs from these two by focusing on behavioural traits of the users and supporting gamification and game elements to motivate behavioural change.

Our methodology for creating recommendations to change energy consumption behaviour consists of the following steps: (a) generating the behavioural baseline for ENTROPY users, in accordance to the defined game and gamification elements (b) creating initial recommendations in order to collect data for the behavioural analysis (c) adjusting the recommendations based on analysis of the implicit and explicit feedback. The high-level depiction of the components involved in the methodology is shown in Figure 3.

The behavioural baseline is created through explicit profiling which includes the detection of energy consumption behaviour, personality and gamer types via questionnaires. The concepts for the profiling are defined in the Entropy Behavioural Intervention Ontology [6]. Detailed results of the questionnaire conducted on ENTROPY pilots can be found in [7].

Initially, the content of the recommendations are customized according to explicit profiles. A set of example recommendations that take the gamer types into account can be found in the appendix of the deliverable. The recommendations are subject to recieve feedback from the ENTROPY users. The feedback is then analyzed in order to tailor the initial user profiles. The behavioural analytics observe the interaction of the user with the application as well as the platform through several metrics.

The behavioural metrics are used to obtain objective reproducible measurements that can be useful for quality assurance, while serve comparability and the easier formation of attention-grabbing conclusions. The metrics will feed the recommender engine and will also take part in various analytics algorithms (e.g. classification, clustering) in order to derive trends and insights that will help the recommender tune more the recommendations.

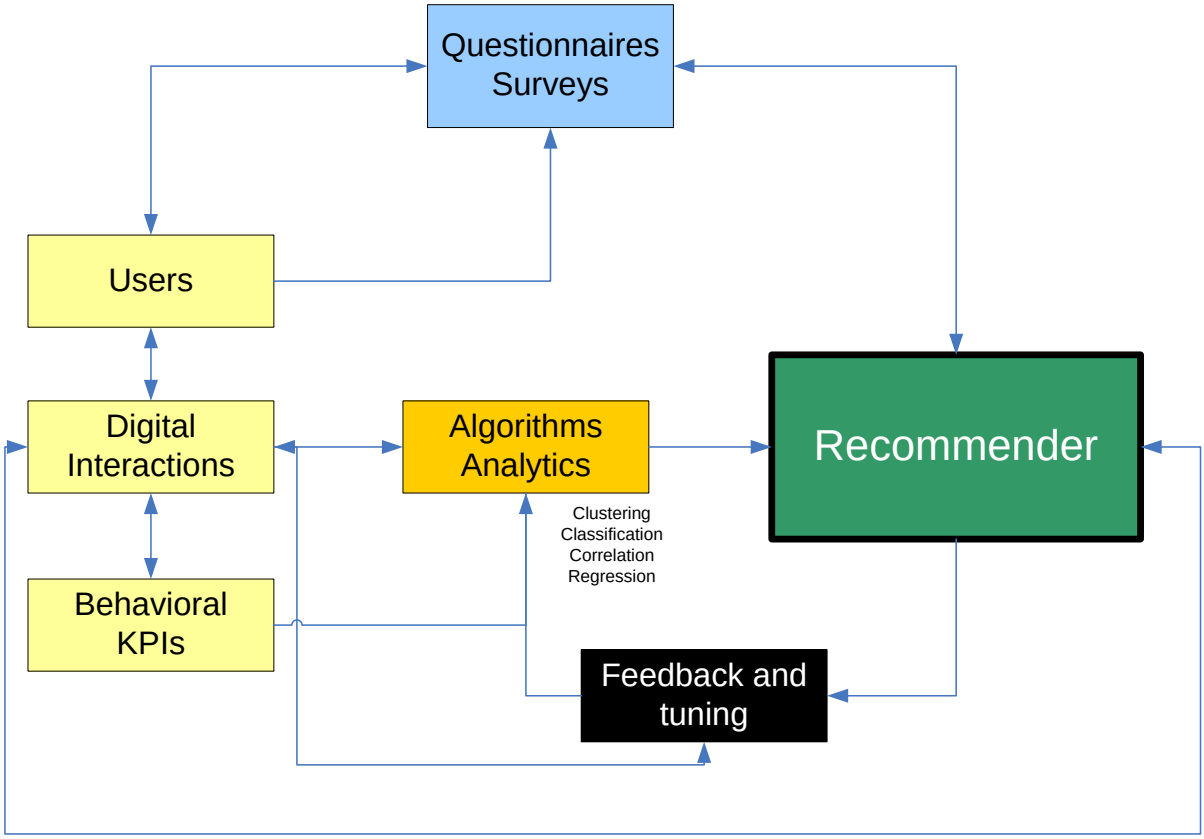

Figure 3 General Behavioral Analytics and Personalization Framework on ENTROPY

In order to assess users' involvement with the content, techniques first for planning and afterwards for evaluating the whole training process, should be used. The following model based on the Kirkpatrick's Four Level Evaluation Model [14] could be also seen as a trouble-shooting heuristic (Figure 4). Below we explain the measurements for the evaluation of the users' interaction with the platform.

Motivation

When a learner goes through a learning process, such as a gamification-based training course, the learner has to make a decision as to whether he/she will pay attention to it. If the goal or task is judged as important and doable, then the learner is normally motivated to engage in it. However, if the task is presented as low-relevance or there is a low probability of success, then a negative effect is generated and motivation for task engagement is low. Moreover, the less relevance the learning package is to a learner, then the more effort that has to be put into the design and presentation of the learning package. That is, if it is not relevant to the learner, then the learning package has to hook the learner through slick design, humour, games, etc. This is not to say that design, humour, or games are unimportant; however, their use in a learning package should be to promote or aid the learning process rather than just make it fun. And if a learning package is built of sound purpose and design, then it should support the learners in bridging a *performance gap*. Hence, they should be motivated to learn—if not, something dreadfully went wrong during the planning and design processes! If you find yourself having to hook the learners through slick design, then you probably need to re-evaluate the purpose of your learning processes.

Learning

This is the extent to which learners improve their knowledge background as a result of participating in a learning process. The learning evaluation normally requires some type of post-testing to ascertain what skills were learned during the process and what skills they already had (pre-testing).

Measuring the learning that takes place is important in order to validate the learning objectives. Evaluating the learning that has taken place typically focuses on such questions as:

- What knowledge was acquired?
- Which knowledge fields were enhanced more?
- What attitudes were encouraged?

Learner assessments are created to allow a judgment to be made about the learner's capability for performance. There are two parts to this process: the gathering of information or evidence (testing the learner) and the judging of the information (what does the data represent?). This assessment should not be confused with *evaluation*. Assessment is about the progress and achievements of the individual learners, while evaluation is about the learning program as a whole.

Performance

This evaluation involves testing the learner's capabilities to put into practice what knowledge was acquired. These evaluations can be performed formally (testing) or informally (observation). It determines if the correct performance is now occurring by answering the question, "Do people indicate through their actions what they've learnt?"

It is important to measure such performance because the primary purpose of learning is to improve results by having its people gain new knowledge and then actually applying them on their daily routine. Since performance measurements must take place when they are acting, the measurement will typically involve instruments that can grasp such information[1].

Results

"Results" measure the effectiveness of the initiative. Although it is normally more difficult and time-consuming to perform than the other three levels, it provides information that is of increasingly significant value as it proves the worth of a learning and performance process. However, using the *Goals/Planning/Evaluation* model should ease the process as we will now have a clear picture of what we are trying to achieve. That is, when we plan for something, then we more readily understand how to evaluate it.

Motivation, *Learning*, and *Performance* are largely soft measurements; however, decision-makers who approve such learning processes prefer results. In general, we could claim that the value of information becomes greater as we go from motivation to results.

[1] *Remember ibeacon technology!*

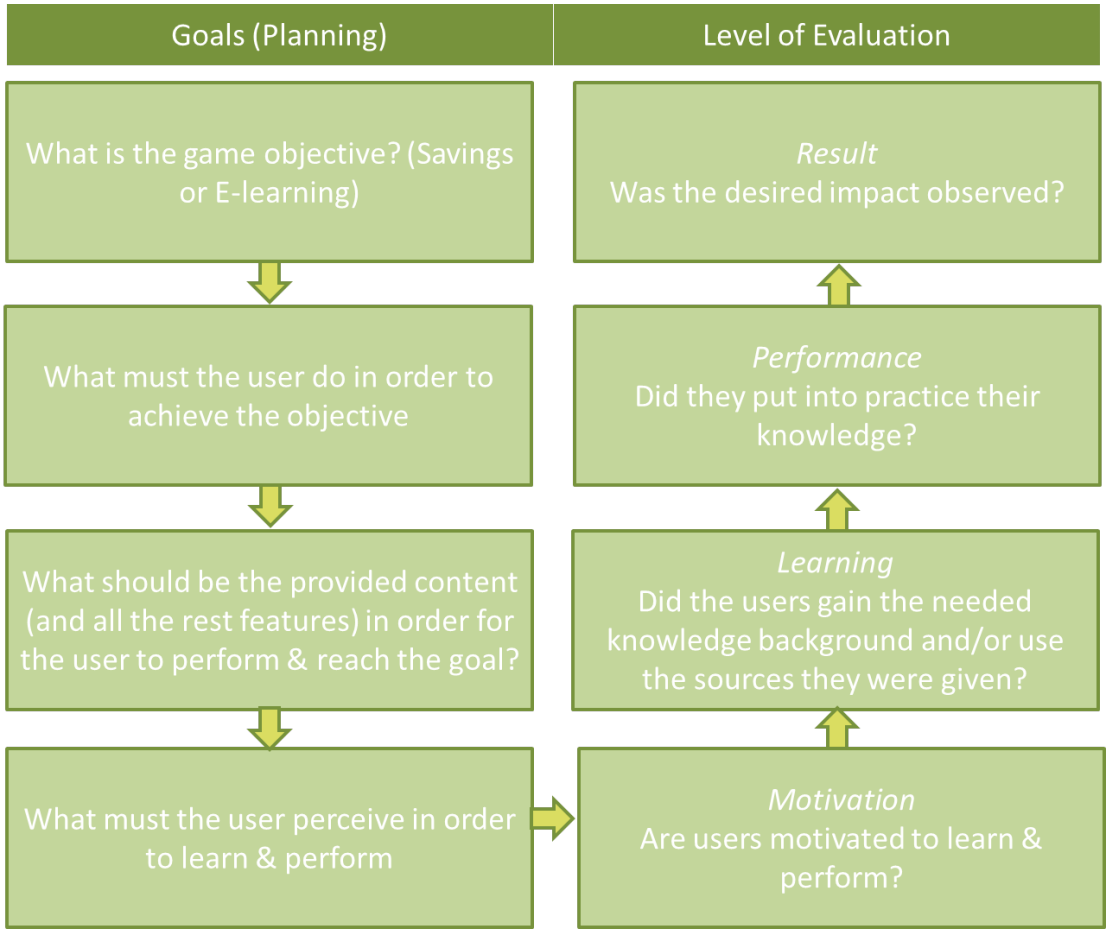

Figure 4 Evaluation Model for deriving ENTROPY's Behavioral KPIs

First and foremost, we have to understand the different levels of the training process and only then, we will be able to stipulate the metrics that better correspond to each level of ENTROPY behavioural educational process.

In accordance with the training process, we find the corresponding metrics as illustrated in Figure 5:

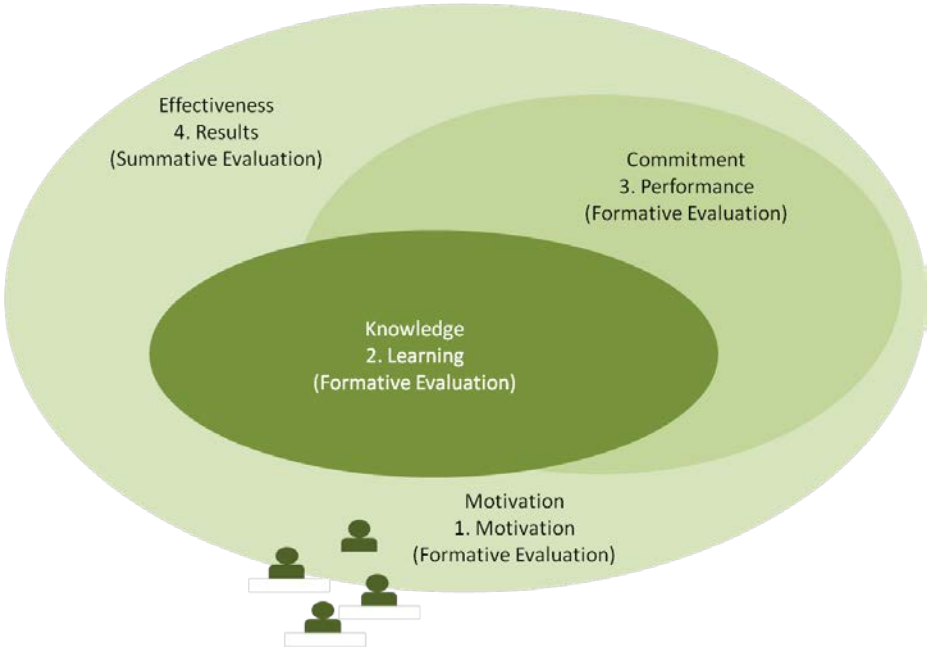

Figure 5 Metrics for user's interaction with content

Apart from user's interaction with the content, another topic of our interest, and of course admin's interest, should be user's interaction with the platform (web & mobile app). Again, user's behavior inside the platform should be tracked and those particular features that can "lock-in" the user should be carefully studied. The ultimate goal is to provide a metric (KPI) that aggregates all that information and easily depicts it to stakeholders.

To that point seems crucial mentioning that it is mostly the UI and all the persuasive techniques that have undertaken the role to trigger user's excitement and ensure user's loyalty to the platform. In other words, features that are basically met in social media can also act as motivators in order for users to show higher level of interaction with the platform.

The extracted metrics from the digital interactions

Even the use of a single KPI could serve our needs for measuring user's interaction with the platform itself. By measuring users' three basic metrics [16]:

"*Engagement*" (KPI). "*Knowledge*" (KPI), "*Effectiveness*" (KPI) with the mobile app, important conclusions can be drawn that will afterwards drive recommender decision making. To achieve so, the digital mobile application interactions listed below, should be considered:

- **Registration** - the user registers as a user in the web/mobile application
- **Login** - the user logs in to the web/mobile application
- **Content read/selected** - the user completes a search within the web/mobile application
- **Quiz/Questionnaire taken** – the user completes a survey or quiz/questionnaire
- **Level/Grade Achieved** - the user completes a level/grade in the web/mobile application
- **Content View** - the user views particular content.

- **Comment** – the user leaves a comment to a particular action/content/feature or registers a Fault

Indicative digital interaction statistics are shown in Table 2:

Table 2 Digital interactions

Field	Description
Player ID	The player's id (positive int)
Tips read	Positive int or Boolean
Total tips sent	Positive int
Time spent on Reading a Tip	Timestamp difference (from Tip sent to on-click Tip to read)
No of Questions sent (Quiz)	Positive int with timestamp
Questions read	Positive int
Time spent on Questions	Timestamp difference (from quiz open to quiz close)
No of Questions answered correctly	Correct answered on Quiz
Total questions in Quiz	Positive integer
Faults registered/Player ID	Positive integer
Total faults from all users	Positive integer
Full Player's ID click journey	Full click journey (store all clicks on specific mobile application features with timestamps)
Push notifications read	When reading a push notification with timestamp
Push notifications sent	

The quantification of the occupant's participation in the ENTROPY personalized applications' educational challenges constitutes a separate behavioural metric and undoubtedly is one of the most critical metrics. Participation is planned to track the actions occupants do and approve their active involvement with the challenges. Participation is first calculated on an individual level and then it is either aggregated to provide a robust summary of the overall performance of occupants.

Based on the interactions below, the three main Behavioural KPIs will be calculated, based on specific mathematical equations. The calculation will take place at the ENTROPY back-end and ENTROPY admin panel.

Based on the interactions metrics and the behavioural KPI calculation, we will have a very clear and solid view and analysis of all user's behavioural profile inside the mobile application. One of the basic objectives (engagement, knowledge and effectiveness) will be under a continuous recursive calculation, in order to feed the recommender. The recommender will also tune and personalize more the content, per groups, per user groups, per individual profiles, per user selections, and per user persona. This will be initially tuned by the questionnaire input and general demographics

The three Behavioural KPIs will be calculated as the Table 3 and Table 4 shows:

Table 3 Behavioural KPIs[16]

Behavioral Metric	Formula	
Engagement	Y=0.4(logins per user of last 30 days / top player's logins)+0.4(PV's per user of last 30 days /top player PV's)+0.2(faults registered/top player's faults)	Measures the interaction of the player with the applicationand the content
Knowledge	Y=0.2(tips read/sent)+0.3(correct questions/read)+0.3(commitments fulfilled/engaged)+0.2(faults per player resolved/total resolved)	Measures the knowledge level of the users, acquired from his interaction with the content
Effectiveness	Y=0.4(average timestamp or read/content itel)+0.1(tips read/sent)+0.1(questions read/sent)+ 0.1(correct answers/read)+0.1(commitments fulfilled/engaged)+0.2(faults registered)	Measures the effectiveness and speed of user interaction with the content and app

Table 4 Indicative Content Based Engagement Calculation

Total number of question sections	10
Total number of question sections completed	6,3
Σ [Return Rate (per user)*/ Avg Return Rate] (per day)	1,8
Number of users that logged in at least once (per day)	2
Σ [Number of unique pageviews (per user)**/ Avg of unique pageviews] (per day)	1,67
Total number of tips sent per day	12345
Total number of tips taken per day	10245
Total number of surveys sent per day	1200
Total number of surveys answered per day	1000
Total number of quizzes sent per day	3673
Total number of quizzes taken per day	2000

Engagement	**0,77266**

The three main Behavioural KPIs above will also take part in the analytics/algorithmic analysis, producing many behavioural insights that will further tune the recommender. The weights of user's preferences will be updated based on the aforementioned KPIs.

2.3 Conceptualization of the Recommender Engine

In order the reflect the aforementioned methodology the workflow of recommender engine consists of three main steps: (a) creation of rules that match predefined user groups with customized recommendation content, based on the surveys done with the pilot sites (b) publication of initial set of personalized recommendations to the users (c) discovery of new group memberships for users based on the feedback they give to the initial recommendations.

The recommender engine uses condition-action rules that uses context changes as condition and initiates the business logic that selects target users for recommendations based on the matching that is made in the action part of the rule. The conceptualization of the Entropy recommendation workflow is depicted in Figure 6.

A context change may be detected in two ways. The first way is through the context listener which periodically listens the sensor data streams, the second one is sourced from the application layer (i.e. serious game or the personalized application) as on demand notification of the new

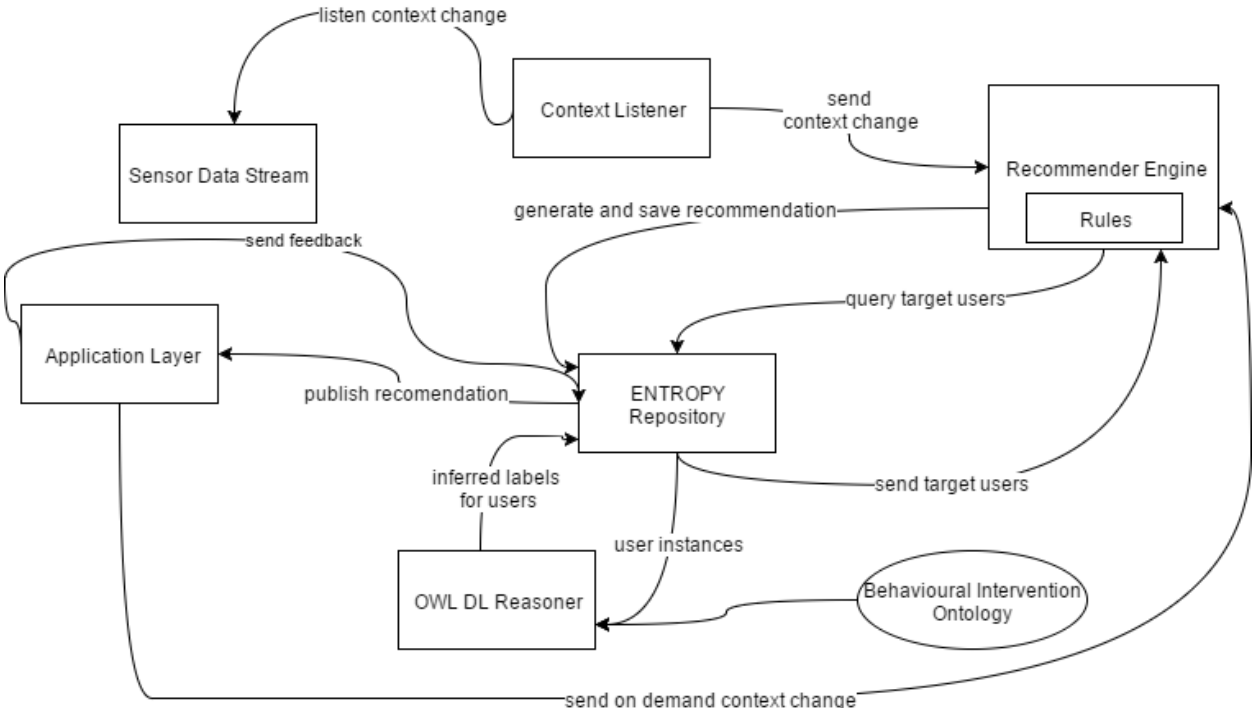

Figure 6 Entropy Recommendation Workflow

context.

The initial rules defined based on the pilot surveys can be found in the appendix. In order to demonstrate the workflow, we take the rule described in Table 5.

The first requirement for generating a recommendation is the detection of the context change, which is the change in the measurement of the CO_2 level in a certain building space. The measurements are obtained from sensor data streams, which consist of the components such as the sensor, the frequency and the type of the measurement. For the example in Table 1, the sensor data stream may be defined with the CO_2 sensor and hourly frequency. The type of the measurement can be the average measurement value. This means the rule condition checks every hour, if the last measurement in a building space (e.g. an office) is over 1000 ppm.

Table 5 A rule definition for the personalized recommendation for different gamer types

		Personalized Content based on the Gamer Type		
Condition	**Recommendation**	**Philantrophist**	**Socialiser**	**Free Spirit**
CO2 > 1000ppm	Open the door for 2 minutes	The air quality can become better. Let's open the door for 2 minutes to freshen up and get closer to earning the Refresher Badge (after N times of action)	The air quality is poor for all in the office. Open the door for 2 minutes to freshen the atmosphere and become the Fresh Air Challenge team leader for now	The air quality is quite poor. Open the door for 2 minutes to freshen up and get closer to unlocking a new functionality (N more actions remaining) // to progress to the next level (N more actions remaining)

As mentioned above the main goal of the recommendations in ENTROPY is to provide personalized interventions in order to change energy consumption behaviour. Therefore the recommendation content is tailored according to existing behavioural attributes like gamer types. Table 5 shows three different content examples targeting three different gamer type.

When the condition holds, the recommender engine assigns target users to the selected recommendation content. The target user groups are defined by the system administrator. An example group may be the Philanthropist users who have activities at the office where the CO_2 sensor is located.

After the creation of recommendations for each target user, the recommendation is published to ENTROPY applications. A published recommendation contains the identification of the target user, the recommendation content, the measurement attributes that are involved in the creation of the recommendation and the possible reward for the completion of the recommendation as well as the validation method for it. The attributes involved in the creation of the recommendation is provided for gamification purposes, since different measurements may work towards earning different rewards (e.g. the points earned from completing a task regarding CO2 consumption may have an impact on earning a so called “Refresher Badge”).The rewards are registered to a user upon the completion and validation of a recommendation. The method of validation of a recommendation differs according to the type of the recommendation. For instance, a task may be validated by checking the status of the sensors on the involved building objects (e.g. a window), while the validation of a quiz is done inherently by answering all the questions.

Every recommendation receives a feedback from user, although the nature of the feedback may vary. Initially, we distinguish two types of recommendations, namely, Task and Message. The

difference comes with the nature of feedback and the validation method. Tasks require one or a series of action from the user that can be validated by the existing infrastructure. In case of the CO2 sensor scenario, if the door has a sensor, the platform can validate whether user took the recommended action. The validation of a message is done implicitly, by detecting whether a user read the message. These are, for instance, simple tips to raise awareness of a topic or yes no questions to collect further information about user's preferences.

As mentioned above, the target users are selected based on pre-defined attributes. The values of some of these attributes (e.g. gamer type) are defined based on the surveys conducted on pilot sites. Since the project aims to customize recommendations according to users, the possible changes in user preferences such as game elements should be reflected to the platform. ENTROPY recommendation workflow includes statistical and knowledge based methods for adjusting user preferences and initial labels produced based on the results of the pilot surveys. The statistical methods for behavioural analysis based on user's interaction with the platform are explained in detail in Section 2.2. Additionally we adopt knowledge based methods to discover new labels for the user. An example would be finding new gamer types for a user based on their game element preferences. For instance, the survey results show that there is a correlation between preferring badge and role game elements and being a Philanthropist[2]. We may enrich our semantic model with the general class axiom shown in Listing 1, where Badge and Role are instances of game element preference and game element preference is subclass of a WeightedInterest[3]. A weighted interest contains a weight element, which will be updated based on the behavioural analytics results.

All the terms and relationships among them that recommender engine uses in order to understand the data are defined in Entropy semantic models [6]. Recommender engine makes a heavy use of one of these models, namely, ENTROPY Behavioural Intervention Ontology (EBIO) which represents the interventions and user attributes, such as demographics, interests and personality types.

```
(hasPreference value Badge and hasPreference value Role) subClassOf Philanthropist.
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Listing 1: An OWL DL class expression for inferring gamer types in OWL Manchester Syntax [12]

[2] More detail about the results of the survey can be found in [7]

[3]For more information: http://vocab.sti2.at/entropy

3. GAMIFICATION USER TYPES

This section summarizes the user typology for the gamification purposes of ENTROPY. The detailed recommendation content customized for the different gamer types can be found in the appendix.

3.1 Gamification User Typology – Preferences

Based on the survey conducted on the pilot sites, described both in terms of its design, as well as its results in [7], the following table provides an outline of the user typology suggested, as well as the characteristics of the six different HEXAD (Human Engagement, eXperience and Activity Design) user types [8,19] (Table 6).

Table 2 Summary of gamer types

Philanthropist
Characteristics:
Motivated by purpose, altruistic and willing to give without expecting a reward.
Suggested Design elements:
collection and trading, gifting, knowledge sharing, and administrative roles.
Selected - Preferred Elements:
badges and roles
Socialiser
Characteristics:
Motivated by relatedness – want to interact with others and create social connections.
Suggested Design elements:
guilds or teams, social networks, social comparison, social competition, and social discovery
Selected - Preferred Elements:
points, badges, rewards and roles
Free Spirit
Characteristics:
Motivated by autonomy, freedom to express themselves and act without external control – like to create and explore within a system
Suggested Design elements:
exploratory tasks, nonlinear gameplay, Easter eggs, unlockable content, creativity tools, and customization
Selected - Preferred Elements:
points, badges, progression, status, levels and roles
Achiever
Characteristics:
Motivated by competence – seeks to progress within a system by completing tasks, or prove themselves by tackling difficult challenges.
Suggested Design elements:
challenges, certificates, learning new skills, quests, levels or progression, and epic challenges (or “boss battles”)
Selected - Preferred Elements:
no specific preference towards any of the elements
Player
Characteristics:
Motivated by extrinsic rewards – will do everything to earn a reward within a system, independently of the type of the activity
Suggested Design elements:
points, rewards or prizes, leaderboards, badges or achievements, virtual economy, and lotteries or games of chance
Selected - Preferred Elements:
rewards, points, badges, leaderboards, status
Disruptor
Characteristics:
Motivated by triggering changes – tends to disrupt the system, directly or through others, force negative or positive changes, test the system’s boundaries and try to push further. Although disruption can be negative, it can also work towards improving the system
Suggested Design elements:
innovation platforms, voting mechanisms, development tools, anonymity, anarchic gameplay
Selected - Preferred Elements:
Status

3.2 Recommendation personalisation mechanism for gamer types

As users may possess a mixture of gamification types, in various levels in their profile, we propose that the following approach is followed by the recommendation mechanism:

According to the users' score on each gamification user type (scores are between 1-7 and can also receive decimal values - not necessarily integers), we suggest that they are given proportional recommendation of each type. E.g. Let us assume that a user has the following scores in the six user types as follows:

User "EXAMPLE_USER" Gamification User Type Profile:

{Philanthropist=7, Socialiser=6, Free Spirit=2, Achiever=3, Player=1, Disruptor=1}

The user above should receive recommendation proportionally, e.g. for each amount of messages equal to the sum of his scores (7+6+2+3+1+1=20), a.k.a. for every 20 recommendation messages, he should receive 7 Philanthropist type messages, 6 Socialiser, 2 Free Spirit, 3 Achiever, 1 Player and 1 Disruptor message. Therefore, the mechanism should distribute the messages according to the profile of the users in a proportional (and probably random) way.

Overall the approach of the Gamification Recommendation proposed follows the modular structure presented in the following:

[Intro][Entropy tip/Action Required]...and...[Gamification Reaction // Alternative Gamification Reaction]

- Intro: Short sentence that adheres to the "Relatedness" factor from Self Determination Theory in terms of the user relating to the ENTROPY System's proposal as opposed to another person

- ENTROPY Tip: The tip that is pushed to the user

- Action Required: The action that ENTROPY proposed to the user for the present scenario

- Gamification Reaction: The effect/benefit the user will receive in case of validated user compliance with Tip/Action. Example Gamification reactions have been introduced that are framed around the different types of users. A short explanation can be found at the end of the email.

Therefore in the case of tips requiring the user to take action the modular approach can show the gamification effect of his/her reaction real time or it can be broken down for later time upon validation. In the case of not real time tracking of effect of the user's action the part of the message following the "and" becomes first sentence followed by the reason for its effect as presented in the following example:

e.g. CO_2 < 800ppm & Close the windows

- Real time validation of user compliance: The air quality is quite good for all in the office. Let's close the windows to help the environment and get closer to earning the Refresher badge (after N times of action)

- Delayed validation of user compliance: You got closer to earning the Refresher badge by closing the windows

The actuals names and processes of the Points / Challenges / Badges / Points etc. are to be further discussed and the ones appearing here are proposals.

- XXX Sustainability Points: Base type of points awarded to participating users.

- Refresher Badge: A Virtual representation of an achievement to comply with air quality best practices around the office

- Summer Temperature Badge and Winter Temperature Badge: A Virtual representation of an achievement to comply with temperature best practices relative to season around the office

- Illuminator Badge: A Virtual representation of an achievement to comply with lighting best practices around the office

- Doors Challenge or Windows Challenge or Fresh Air Challenge : Individual or Team based challenge pertaining to compliance with air quality best practices

- Temperature Challenge: Individual or Team based challenge pertaining to compliance with temperature best practices

- Lights Out Challenge: Individual or Team based challenge pertaining to compliance with lighting best practices

- Levels of Difficulty in actions: The aforementioned could be introduced in different levels (e.g. clustering of more effort requiring actions or different levels of same achievement like white silver gold in badges)

- Unlocking new functionalities: The present gamification reward adheres to hidding / showing different functionalities in the app/game as a reward. Unlocking mechanism or easter egg mechanism.

4. IMPLEMENTATION FOR THE FIRST CAMPAIGN

The recommender engine comprises one of the main architectural modules of the ENTROPY architecture (Figure 7). It is implemented as a separate web service and fully integrated to the platform. The implementation of the module itself can be found at ENTROPY Github repository[4]. It mainly interacts with the ENTROPY Big Data Repository through the "repository" module and is triggered by the core ENTROPY application through a set of specified and implemented APIs. However, the information consumed for triggering of recommendations may be provided by the various ENTROPY components. Such information may regard the data coming from real-time or aggregated sensor data streams, data provided as the results of a data mining and analysis process as well as data coming from the set of personalised mobile applications and serious games -including crowdsensing data.

[4] *https://github.com/ubitech/entropy/tree/master/recommendation-engine*

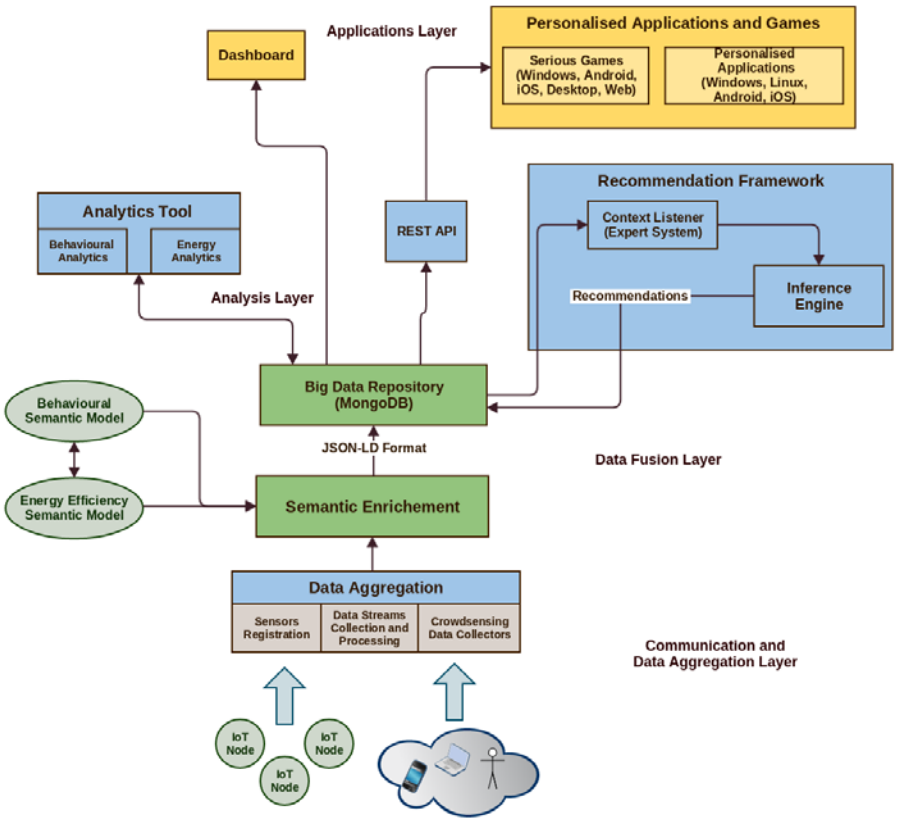

Figure 7 ENTROPY Reference Architecture

With regards to the implementation technologies, the recommender engine implementation is based on Drools[5] that is a Business Rules Management System (BRMS) solution. Drools is based on Java and thus the implementation is fully consistent with the overall ENTROPY software stack. The main criterion for the selection of Drools for the implementation of the Recommender Engine is the high performance and scalability that can be achieved. Rules are easier to understand for the administrator and are not hard-coded at the code part. Each ENTROPY recommender engine installation may be triggered based on different rules that can be graphically defined thought a unified user interface. Reasoning mechanisms, as extracted by the two ontological models, are also incorporated for supporting the required reasoning functionalities within ENTROPY.

A Publish/Subscribe framework is used for publishing the set of produced recommendations. All recommendations are targeted to specific end user and are the result of specific rules. Based on the subscriptions in the Publish/Subscribe framework, these recommendations are consumed by the interested services (e.g. view of recommendations by the personalised mobile application) and forwarded to the end users. The set of produced recommendations are also stored in the relevant MongoDB collection and made available to the set of ENTROPY services for further usage (e.g. view history of recommendations, provide feedback on a recommendation). The supported REST API's that are consumed by the personalized applications and games, are presented and continuously updated at the https://github.com/ubitech/entropy/wiki/Exposed-API's .

[5] *https://www.drools.org/*

Interaction with the MongoDB is based on the design and implementation of a set of APIs (as described in [5]) that support the acquisition of recommendation per end user including filtering options with regards to their type and the collection of feedback with regards to the acceptance or not of the recommendation by the end user and the associated follow-up actions information.

The definition of a recommendation is followed by an "Action" that optionally can be evaluated by the recommender engine. The "ValidationAction" checks whether the feedback of the user leads to specific context aware results, and if so the user is informed and/awarded with specific points or badges.

It should be noted that two collections are available in MongoDB, namely the Recommendation and RecommendationTemplate collections. The first one regards the storage of the instances of the produced recommendations, while the latter one regards the storage of templates that can be used for the production of recommendations.

A query builder is also implemented (Figure 8) based on MongoDB Query Builder for facilitating the design of queries in a user friendly way. Such queries may regard the specification of the group of users where a recommendation should be targeted. By combining a recommendation template with the set of users belonging in the resulting group of the query, a set of instantiations of recommendations is produced.

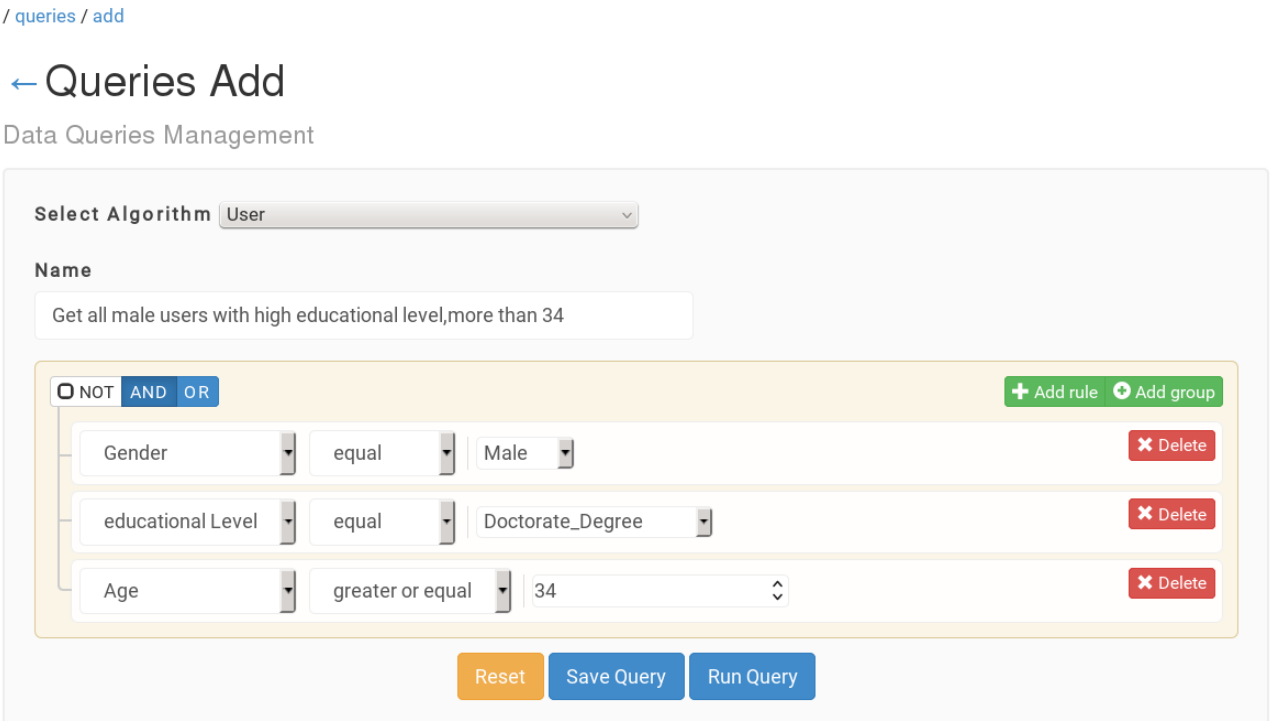

Figure 8 ENTROPY Query Builder

5. CONCLUSION AND NEXT STEPS

In this deliverable we described the goals of the personalized recommendations and the methodology to achieve those goals. We referred to the KPIs defined in the previous deliverables for the evaluation of the overall platform and the recommender engine. Within the methodology, we introduced an extensive customization mechanism for the recommendation based on users' interaction with our applications that serve recommendations. Additionally, we introduced the KPIs for measuring user interaction and awareness.

We also conceptualized a recommender system that reflects our methodology and an initial implementation of our concept, in order to enable the data collection for the first campaign, which will take the initial set of context changes and recommendations based on gamer types into account.

Our next steps will be improving the implementation in order to cover the entire conceptualization. This will also help us to test our concept and make necessary changes, if needed.

The data collected and produced by the behavioural analytics and the recommender engine will be published as linked data after it is anonymized and properly aggregated. For instance, the personalized recommendation content based on identified user profiles may be a valuable data for future projects and researchers. The details of the anonymization and publication will be given in the next Data Management Plan.

We are aware of the fact that the profiling and collection of behavioural data come with certain ethical concerns. Especially implicit profiling should be handled carefully, since the user is not necessarily informed. However, we will provide proper consent forms to the users in order to inform them about the data being collected and the processes will be applied to the collected data.

BIBLIOGRAPHY

[1] Barbu, A., Griffiths, N., & Morton, G. (2013). Achieving energy efficiency through behaviour change: what does it take? European Environment Agency Technical report. Luxembourg: Publications Office. Retrieved from http://dx.publications.europa.eu/10.2800/49941

[2] Bhattacherjee, A. (2012). Social science research: principles, methods, and practices. University of South Florida, Tampa

[3] Chao, K. M., Shah, N., Matei, A., Zlamaniec, T., Li, W., Lo, C. C., & Li, Y. (2011). Intelligent interactive system for collaborative green computing. In Proceedings of the 2011 15th International Conference on Computer Supported Cooperative Work in Design (CSCWD) (pp. 690–697). http://doi.org/10.1109/CSCWD.2011.5960193

[4] D1.5 – Pilots Description, Performance Evaluation Methodologies and Acceptance Criteria, ENTROPY Project Deliverable

[5] D2.2 – Design of Wireless Sensor Networking and Data Fusion Mechanisms, ENTROPY Project Deliverable

[6] D3.1 – Citizens Environmental Friendly Behavioural Semantic Model, ENTROPY Project Deliverable

[7] D3.3 – Gamification Framework, ENTROPY Project Deliverable

[8] Diamond, L., Tondello, G. F., Marczewski, A., Nacke, L. E. & Tscheligi, M. (2015) The HEXAD Gamification User Types Questionnaire : Background and Development Process, in Workshop on Personalization in Serious and Persuasive Games and Gamified Interactions.

[9] Fogg, B. (1998). Persuasive computers: Perspectives and research directions. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, (April), 225–232. http://doi.org/10.1145/274644.274677

[10] Fogg, B. (2009). A behaviour model for persuasive design. In Proceedings of the 4th International Conference on Persuasive Technology. http://doi.org/10.1145/1541948.1541999

[11] Hamari, J., Koivisto, J., & Pakkanen, T. (2014). Do persuasive technologies persuade? - A review of empirical studies. In Persuasive Technology (Vol. 8462 LNCS, pp. 118–136). http://doi.org/10.1007/978-3-319-07127-5_11

[12] Horridge, M., Drummond, N., Goodwin, J., Rector, A. L., Stevens, R., & Wang, H. (2006, November). The Manchester OWL Syntax. In OWLed (Vol. 216).

[13] Kaptein, M., Markopoulos, P., de Ruyter, B., & Aarts, E. (2015). Personalizing persuasive technologies: Explicit and implicit personalization using persuasion profiles. International Journal of Human-Computer Studies, 77, 38–51. http://doi.org/10.1016/j.ijhcs.2015.01.004

[14] Kirkpatrick, D. L. (1979). Techniques for evaluating training programs. Training and development journal.

[15] Nielsen, J. (1995). Usability inspection methods. In Conference companion on Human factors in computing systems (pp. 377–378). New York, NY, USA: ACM. http://doi.org/10.1145/223355.223730

[16] Nikolopoulos, V., & Staikos, K. (2016). Patent Number: WO2016058645 A1. Interactive activities for environmental resource saving. World Intellectual Property Organization. Retrieved from https://www.google.com/patents/WO2016058645A1

[17] Norman, D. (2002). Emotion & Design: Attractive Things Work Better. Interactions, 9(4), 36–42. http://doi.org/10.1145/543434.543435

[18] Pegels, A., Figueroa, A., & Never, B. (2015). The Human Factor in Energy Efficiency. Retrieved from https://www.die-gdi.de/uploads/media/The_Human_Factor_in_Energy_Efficiency_FINAL_LOW_RES.pdf

[19] Tondello, G. F., Wehbe, R. R., Diamond, L., Busch, M., Marczewski, A. & Nacke, L. E. (2016). The Gamification User Types Hexad Scale, in Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play - CHI PLAY ’16. doi: 10.1145/2967934.2968082.

[20] Zehnder, M., Wache, H., Witschel, H. F., Zanatta, D., & Rodriguez, M. (2015). Energy saving in smart homes based on consumer behavior: A case study. In 2015 IEEE First International Smart Cities Conference (ISC2) (pp. 1–6). http://doi.org/10.1109/ISC2.2015.73662

APPENDIX: PERSONALISED RECOMMENDATIONS FOR ALL USER TYPES

Based on the user typology characteristics outlined in the previous section, the following tables (Table A2-7) include a list of common recommendations, tailored to the six different gamification user types. Table A1 shows the variables used in the rule conditions and their explanations.

Table A1 Rule Variables and Explanations

RULE VARIABLE	EXPLANATION
CO2	CO_2 Level
IN_TEMP	Inside Temperature
OUT_TEMP	Outside Temperature
LIGHT	Luminosity
RADIATION	Radiation Level
SEASON	Season

Table A2 Recommendations for Philanthropist Gamer Type

		Philanthropist
Conditions	**Recommendations**	**Personalised Recommendation**
CO2 < 800ppm	Close the door	The air quality is quite good. Close the door to save the environment and earn a badge after N times / become energy champion
CO2 > 1000ppm	Open the door for 2 minutes	The air quality is poor. Open the door for 2 minutes to freshen the atmosphere and earn a badge after N times
CO2 < 800ppm	Close the windows	The air quality is quite good. Close the window(s) to save the environment and earn a badge after N times / become energy champion
CO2 > 1000ppm	Open the windows for 2 minutes	The air quality is poor. Open the window(s) for 2 minutes to freshen the atmosphere and earn a badge after N times
IN_TEMP > 24 and Season = Winter	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature and save the environment. Earn a badge after N times / become energy champion
IN_TEMP < 20 and Season = Winter	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature. Earn a badge after N times / become energy champion
IN_TEMP < 23 and Season = Summer	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature. Earn a badge after N times / become energy champion
IN_TEMP > 26 and Season = Summer	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature and save the environment. Earn a badge after N times / become energy champion
IN_TEMP > 24 and Season = Winter	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature and save the environment. Earn a badge after N times / become energy champion
IN_TEMP < 20 and Season = Winter	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature. Earn a badge after N times / become energy champion
IN_TEMP < 23 and Season = Summer	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature. Earn a badge after N times / become energy champion
IN_TEMP > 26 and Season = Summer	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature and save the environment. Earn a badge after N times / become energy champion
OUT_TEMP < 0	It is too cold for opening windows	The temperature outside is below zero degrees. Too cold to open any windows today. Earn a badge after N times / become energy champion
LIGHT > 1000lux AND RADIATION < 500W/m2	You probably do not need so much light	It's very bright in here. You probably don't need all these lights on. Earn a badge after N times / become energy champion

LIGHT > 1000lux AND RADIATION < 500W/m2	Switch some of the lights off	It's very bright in here. Turn off some of the lights and save some energy. Earn a badge after N times / become energy champion
Radiation > 800 W/m²	It is a sunny day. We hope you switched off the lights!	It's a very sunny day today. We hope you switched any unneeded lights off. Earn a badge after N times / become energy champion
Window switch open	The window in the room is open! Do you feel too hot?	The window in the room is open! Do you feel too hot? Earn a badge after N times / become energy champion

Table A3 Recommendations for Socialiser Gamer Type

		Socialiser
Conditions	**Recommendations**	**Personalised Recommendation**
CO2 < 800ppm	Close the door	The air quality is quite good. Close the door to help your team win the challenge and become the team leader
CO2 > 1000ppm	Open the door for 2 minutes	The air quality is poor. Open the door for 2 minutes to freshen the atmosphere and become the team leader
CO2 < 800ppm	Close the windows	The air quality is quite good. Close the window(s) to save the environment and become the team leader after N times / become energy champion
CO2 > 1000ppm	Open the windows for 2 minutes	The air quality is poor. Open the window(s) for 2 minutes to freshen the atmosphere and become the team leader after N times
IN_TEMP > 24 and Season = Season = Winter	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature and save the environment. Become the team leader after N times.
IN_TEMP < 20 and Season = Season = Winter	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature. Become the team leader after N times.
IN_TEMP < 23 and Season = Summer	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature. Become the team leader after N times.
IN_TEMP > 26 and Season = Summer	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature and save the environment. Become the team leader after N times.
IN_TEMP > 24 and Season = Season = Winter	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature and save the environment. Become the team leader after N times.
IN_TEMP < 20 and Season = Season = Winter	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature. Become the team leader after N times.
IN_TEMP < 23 and Season = Summer	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature. Become the team leader after N times.
IN_TEMP > 26 and Season = Summer	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature and save the environment. Become the team leader after N times.
OUT_TEMP < 0	It is too cold for opening windows	The temperature outside is below zero degrees. Too cold to open any windows today. Become the team leader after N times.
LIGHT > 1000lux AND RADIATION < 500W/m2	You probably do not need so much light	It's very bright in here. You probably don't need all these lights on. Become the team leader after N times.
LIGHT > 1000lux AND RADIATION < 500W/m2	Switch some of the lights off	It's very bright in here. Turn off some of the lights and save some energy. Become the team leader after N times.

Radiation > 800 W/m²	It is a sunny day. We hope you switched off the lights!	It's a very sunny day today. We hope you switched any unneeded lights off. Become the team leader after N times.
Window switch open	The window in the room is open! Do you feel too hot?	The window in the room is open! Do you feel too hot? Become the team leader after N times.

Table A4 Recommendations for Free Spirit Gamer Type

		Free Spirit
Conditions	**Recommendations**	**Personalised Recommendation**
CO2 < 800ppm	Close the door	The air quality is quite good. Close the door to unlock new functionality - N more actions to progress to the next level
CO2 > 1000ppm	Open the door for 2 minutes	The air quality is poor. Open the door for 2 minutes to freshen the atmosphere and unlock new functionality - N more actions to progress to the next level
CO2 < 800ppm	Close the windows	The air quality is quite good. Close the window(s) to save the environment and unlock new functionality - N more actions to progress to the next level
CO2 > 1000ppm	Open the windows for 2 minutes	The air quality is poor. Open the window(s) for 2 minutes to freshen the atmosphere and unlock new functionality - N more actions to progress to the next level
IN_TEMP > 24 and Season = Season = Winter	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature and unlock new functionality - N more actions to progress to the next level
IN_TEMP < 20 and Season = Season = Winter	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature. Unlock new functionality - N more actions to progress to the next level
IN_TEMP < 23 and Season = Summer	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature. Unlock new functionality - N more actions to progress to the next level
IN_TEMP > 26 and Season = Summer	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature and save the environment. Unlock new functionality - N more actions to progress to the next level
IN_TEMP > 24 and Season = Season = Winter	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature and save the environment. Unlock new functionality - N more actions to progress to the next level
IN_TEMP < 20 and Season = Season = Winter	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature. Unlock new functionality - N more actions to progress to the next level
IN_TEMP < 23 and Season = Summer	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature. Unlock new functionality - N more actions to progress to the next level
IN_TEMP > 26 and Season = Summer	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature and save the environment. Unlock new functionality - N more actions to progress to the next level
OUT_TEMP < 0	It is too cold for	The temperature outside is below zero degrees. Too

	opening windows	cold to open any windows today. Unlock new functionality - N more actions to progress to the next level
LIGHT > 1000lux AND RADIATION < 500W/m2	You probably do not need so much light	It's very bright in here. You probably don't need all these lights on. Unlock new functionality - N more actions to progress to the next level
LIGHT > 1000lux AND RADIATION < 500W/m2	Switch some of the lights off	It's very bright in here. Turn off some of the lights and save some energy. Unlock new functionality - N more actions to progress to the next level
Radiation > 800 W/m²	It is a sunny day. We hope you switched off the lights!	It's a very sunny day today. We hope you switched any unneeded lights off. Unlock new functionality - N more actions to progress to the next level
Window switch open	The window in the room is open! Do you feel too hot?	The window in the room is open! Do you feel too hot? Unlock new functionality - N more actions to progress to the next level

Table A5 Recommendations for Achiever Gamer Type

		Achiever
Conditions	**Recommendations**	**Personalised Recommendation**
CO2 < 800ppm	Close the door	The air quality is quite good. Close the door whenever you see this message for N times in a row and win the "door challenge".
CO2 > 1000ppm	Open the door for 2 minutes	The air quality is poor. Open the door for 2 minutes to freshen the atmosphere - whenever you see this message - for N times in a row and win the "door challenge".
CO2 < 800ppm	Close the windows	The air quality is quite good. Close the window(s) whenever you see this message for N times in a row and win the "window challenge".
CO2 > 1000ppm	Open the windows for 2 minutes	The air quality is poor. Open the window(s) whenever you see this message for N times in a row and win the "window challenge".
IN_TEMP > 24 and Season = Season = Winter	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature, whenever you see this message for N times in a row and win the "temp challenge".
IN_TEMP < 20 and Season = Season = Winter	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature, whenever you see this message for N times in a row and win the "temp challenge".
IN_TEMP < 23 and Season = Summer	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature, whenever you see this message for N times in a row and win the "temp challenge".
IN_TEMP > 26 and Season = Summer	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature , whenever you see this message for N times in a row and win the "temp challenge".
IN_TEMP > 24 and Season = Season = Winter	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature, whenever you see this message for N times in a row and win the "temp challenge".
IN_TEMP < 20 and Season = Season = Winter	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature, whenever you see this message for N times in a row and win the "temp challenge".
IN_TEMP < 23 and Season = Summer	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature, whenever you see this message for N times in a row and win the "temp challenge".
IN_TEMP > 26 and Season = Summer	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature, whenever you see this message for N times in a row and win the "temp challenge".
OUT_TEMP < 0	It is too cold for opening windows	The temperature outside is below zero degrees. Too cold to open any windows today. Win the "window

		challenge".
LIGHT > 1000lux AND RADIATION < 500W/m2	You probably do not need so much light	It's very bright in here. You probably don't need all these lights on. Turn some lights off and win the "lights challenge".
LIGHT > 1000lux AND RADIATION < 500W/m2	Switch some of the lights off	It's very bright in here. Turn some lights off to save some energy and win the "lights challenge".
Radiation > 800 W/m²	It is a sunny day. We hope you switched off the lights!	It's a very sunny day today. We hope you switched any unneeded lights off. Win the "lights challenge".
Window switch open	The window in the room is open! Do you feel too hot?	The window in the room is open! Do you feel too hot? Win the "lights challenge".

Table A6 Recommendations for Player Gamer Type

		Player
Conditions	**Recommendations**	**Personalised Recommendation**
CO2 < 800ppm	Close the door	The air quality is quite good. Close the door whenever you see this message to win "X" points.
CO2 > 1000ppm	Open the door for 2 minutes	The air quality is poor. Open the door for 2 minutes to freshen the atmosphere - whenever you see this message to win "X" points.
CO2 < 800ppm	Close the windows	The air quality is quite good. Close the window(s) whenever you see this message to win "X" points.
CO2 > 1000ppm	Open the windows for 2 minutes	The air quality is poor. Open the window(s) whenever you see this message to win "X" points.
IN_TEMP > 24 and Season = Season = Winter	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature, whenever you see this message to win "X" points.
IN_TEMP < 20 and Season = Season = Winter	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature, whenever you see this message to win "X" points.
IN_TEMP < 23 and Season = Summer	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature, whenever you see this message to win "X" points.
IN_TEMP > 26 and Season = Summer	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature , whenever you see this message to win "X" points.
IN_TEMP > 24 and Season = Winter	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature, whenever you see this message to win "X" points.
IN_TEMP < 20 and Season = Winter	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature, whenever you see this message to win "X" points.
IN_TEMP < 23 and Season = Summer	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature, whenever you see this message to win "X" points.
IN_TEMP > 26 and Season = Summer	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature, whenever you see this message to win "X" points.
OUT_TEMP < 0	It is too cold for opening windows	The temperature outside is below zero degrees. Too cold to open any windows today. Win "X" points.
LIGHT > 1000lux AND RADIATION < 500W/m2	You probably do not need so much light	It's very bright in here. You probably don't need all these lights on. Turn some lights off to win "X" points.
LIGHT > 1000lux AND RADIATION < 500W/m2	Switch some of the lights off	It's very bright in here. Turn some lights off to save some energy to win "X" points.
Radiation > 800 W/m²	It is a sunny day. We hope you switched off the lights!	It's a very sunny day today. We hope you switched any unneeded lights off. Win "X" points.
Window switch	The window in the	The window in the room is open! Do you feel too

open	room is open! Do you feel too hot?	hot? Win "X" points.

Table A7 Recommendations for Disruptor Gamer Type

		Disruptor
Conditions	**Recommendations**	**Personalised Recommendation**
CO2 < 800ppm	Close the door	The air quality is quite good. Close the door whenever you see this message to become the best in your team.
CO2 > 1000ppm	Open the door for 2 minutes	The air quality is poor. Open the door for 2 minutes to freshen the atmosphere - whenever you see this message to become the best in your team.
CO2 < 800ppm	Close the windows	The air quality is quite good. Close the window(s) whenever you see this message to become the best in your team.
CO2 > 1000ppm	Open the windows for 2 minutes	The air quality is poor. Open the window(s) whenever you see this message to become the best in your team.
IN_TEMP > 24 and Season = Winter	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature, whenever you see this message to become the best in your team.
IN_TEMP < 20 and Season = Winter	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature, whenever you see this message to become the best in your team.
IN_TEMP < 23 and Season = Summer	Adjust control valve to higher temperature	The temperature in this room is quite low. Adjust the control valve to raise the temperature, whenever you see this message to become the best in your team.
IN_TEMP > 26 and Season = Summer	Adjust control valve to lower temperature	The temperature in this room is quite high. Adjust the control valve to lower the temperature , whenever you see this message to become the best in your team.
IN_TEMP > 24 and Season = Winter	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature, whenever you see this message to become the best in your team.
IN_TEMP < 20 and Season = Winter	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature, whenever you see this message to become the best in your team.
IN_TEMP < 23 and Season = Summer	Turn up Thermostat	The temperature in this room is quite low. Adjust the thermostat to raise the temperature, whenever you see this message to become the best in your team.
IN_TEMP > 26 and Season = Summer	Turn down Thermostat	The temperature in this room is quite high. Adjust the thermostat to lower the temperature, whenever you see this message to become the best in your team.
OUT_TEMP < 0	It is too cold for opening windows	The temperature outside is below zero degrees. Too cold to open any windows today. Become the best in your team.
LIGHT > 1000lux AND RADIATION < 500W/m2	You probably do not need so much light	It's very bright in here. You probably don't need all these lights on. Turn some lights off to become the best in your team.
LIGHT > 1000lux AND RADIATION < 500W/m2	Switch some of the lights off	It's very bright in here. Turn some lights off to save some energy to become the best in your team.

Radiation > 800 W/m²	It is a sunny day. We hope you switched off the lights!	It's a very sunny day today. We hope you switched any unneeded lights off. Become the best in your team.
Window switch open	The window in the room is open! Do you feel too hot?	The window in the room is open! Do you feel too hot? Become the best in your team.