# Gaming at work to save energy – Learnings from workers playing a cooperative game

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**ABSTRACT**
Workplaces constitute a substantial part of the world's energy consumption. In this paper we study how a cooperative game, EnerSpace, could be used to increase energy awareness and support energy conservation. In the study, after a one-week baseline period, 8 workers played EnerSpace for one week. They competed in two teams that each powered a spaceship with their energy saving on a resource exploitation trip to Mars. Each worker also had an avatar in the spaceship that reported personal consumption data using face recognition. The participant efforts and abilities to conserve energy affected the speed of the spaceship and the living condition of their avatars. The results show that workers decreased their overall energy consumption, especially on the weekend. Based on our results we discuss 1) designing for energy conservation when absent from the workplace, 2) how using the coffee room created energy conservation narratives but hampered local experimentation and learning, 3) team formation to support energy conservation and team spirit, and 4) challenges concerning games centered on baseline comparison for energy conservation.

**Author Keywords**
Persuasive technology; gamification; visualization; energy consumption; energy awareness; behaviour change.

**ACM Classification Keywords**
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## 1. INTRODUCTION
The rapid growth of energy consumption has raised increasing concerns over the last decades. According to the International Energy Agency there has been a dramatic increase in primary energy use (49%) and CO2 emission (43%) from 1984 to 2004 [1]. Moreover, energy consumption is estimated to keep rising due to economic and population growth [1]. The U.S. Energy Information Administration has reported that the building sector consumes 20% of the worldwide energy [2]. It has similarly been found that around 40% of energy was consumed by buildings in Europe in 2015 [3]. Those numbers proved the urgency to cut down energy consumption and increase energy efficiency in buildings, which calls for the attention of both organizations and individuals.

Several studies have shown that there is a gap between estimated energy consumption and the actual energy consumption of buildings [4, 5]. One cause for this gap is that energy estimations fail to account for occupant behavior, potentially highlighting the potential for occupants to lower their consumption. Therefore, increasing occupant awareness of energy consumption and persuasive design becomes an interesting option to promote behavioral change.

To increase energy awareness and promote behavioral change through persuasion, researchers have introduced gamification and social networks into eco-visualizations in order to engage users through competition and interpersonal relations [6-8]. Studies have also focused on providing energy education [9] and gamified energy feedback [10, 11]. Overall, these studies have focused on using either individual and cooperative approaches to energy conservation (e.g. [12]). Researchers have also designed gamified missions, competitions and cooperation to motivate energy conservation [13, 14]. For instance, Power Agent was a persuasive game designed to encourage energy conservation of a family by team competition [14]. However, while many of these attempts have demonstrated short-term positive effects the long-lasting effects are questionable as people tend to disengage over time [15].

In this paper we turn our attention towards workplaces by exploring and evaluating how a cooperative game could support energy conservation. We do this by presenting the design, implementation and evaluation of a cooperative game designed to motivate workers to reduce electricity consumption in a commercial office setting.

## 2. BACKGROUND

### 2.1 Theoretical Model of Behavioural Change
In order to design for behaviour change, it is important to understand how occupants' current behaviour is shaped and influenced. A well-known behavioral theories is the Theory of Reasoned Action [6]. They believed that individuals' intention to perform a certain behaviour led to the actual behaviour and the behavioural intention was determined by the attitude towards behaviour and subjective norm. Subjective norm is the social pressure that individuals perceive for a certain behaviour and it is decided by individuals' normative belief and motivation to comply.

The Theory of Planned behaviour extended this model by adding perceived behavioral control [16]. A perceived behavioural control means how much an individual has control over a specific behaviour. The Theory of Planned

behaviour has been shown to explain 46-61% of the variance in occupants' intention in performing pro-environmental behaviour [17]. The findings highlight that in order to understand the occupants and design for persuasion, it is beneficial to take occupants' attitudes, subjective norms and perceived behavioural control into consideration.

According to the Theory of Planned behaviour, social factors play a crucial role in influencing occupants' behaviour. Social comparison serves as a trigger for motivating sustainable behaviour. Also, comparisons with others who are slightly better can have a positive effect on performance [18]. What this suggests is the importance to ensure that there is always a chance for each side to win in a competition. The facility also plays an important role in promoting an energy conservation culture by organizing relevant events and workshops, which was proved to be related to the energy-saving behaviour of occupants in the building [19]. Moreover, another study revealed that public recognition of energy-saving behaviour led to a higher decrease in energy consumption than solely self-monitoring behaviour [20].

Cost reduction has also been reported to be a motivation to save energy at offices [19], but the actual effects depended on the personal sensitivity to price [21]. In addition, psychologist Richard Katzev and his team found that commitment to conserve resources is more influential for occupants' behaviour than monetary incentives [10]. This might suggest that intrinsic motivation is stronger than extrinsic motivation. However, a survey with 229 students on campus showed that the majority of participants agreed on the importance of energy conservation, but they reported that they lack clear motivations [19]. Contextual factors, such as perceived behavioural control, have been found to partly explain this low level of motivations [19]. In an office building, the energy consumption is mainly influenced by energy planning and management, which results in occupants' low sense of control and insufficient engagement in energy conservation.

### 2.2 Persuasive Technology

Persuasive technology aims at using technology to achieve behaviour change without coercion [22]. BJ. Fogg has introduced his behaviour model that stressed three elements of persuasive technology: motivation, ability and trigger [23]. Motivation is the reason why a person shows a certain behaviour. Ability indicates whether the person has the required ability to complete a behaviour. A trigger can be a reminder, deadline or other elements that cause the person to perform a behaviour. Those three elements are of necessity to achieve the persuasion of a certain behaviour. A study that followed this model claims achievement of the energy saving goal [24], which suggests that taking those three elements into consideration could be beneficial.

Many studies have worked on applying gamification to eco-visualization in order to provide energy education and feedback on energy consumption [7, 11, 25, 26]. One study introduced a game called EnerCities to promote energy education by asking users to run a sustainable city [9]. The results showed that the experimental group who played the game had better knowledge about the impact of their consumption behaviour than the control group [9].

Regarding providing gamified feedback, Energy Chicken is a game that relates the energy consumption of each device in the office environment to an object in a virtual farm [26]. The size and condition of the chicken in the virtual farm was influenced by the users' energy consumption. In a 12-week evaluation with 49 occupants after collecting the consumption baseline for 4 weeks, an energy reductions of 13% was achieved [26].

Another game called Coralog visualized energy consumption as the health status of a coral reef, whose size and colour changed [7]. While users were motivated to change behaviour using Coralog, they also expressed wishes to see the data of daily energy consumption besides the more abstract representation of the coral reef. This highlights the importance to keep a balance between abstract and factual representation in persuasive system.

In addition to providing energy consumption feedback on an individual level, researchers have introduced social network, competition and cooperation on a group level in order to achieve better user engagement through interpersonal relationships and the sense of belongingness [7, 9, 13, 14, 27]. Art project Nuage Vert was a city-scale light installation in Helsinki that lasted for a week [12]. The artist illuminated vapour emission with a lime-hued laser animation that visualized the real-time electricity consumption of citizens in Helsinki. This collective visualization invoked a sense of community and contribution. Boork and her colleagues introduced a collective prototype called Super Graph that employees in the office crafted together [28]. The Super Graph was hung in the lunchroom and moved vertically according to the collective energy consumption. This served as a symbol that represented the employees' efforts and created the sense that every employee was a part of something bigger. Climate Race is a persuasive game that was co-designed by workers in the office, whose team goal was to reach 1000000 points collected by energy saving and by completing missions [8]. While Climate Race achieved the change of workers' motivation, it also revealed a provoking finding that workers preferred explicitly requesting feedback over immediate notifications. This finding is especially crucial for how to provide feedback in a non-intrusive way.

## 3. METHODS

### 3.1 Participants and Procedure

In the study, 8 engineers (6 males and 2 females) working at a corporate research center volunteered to participated in a two-week-long study with a one-week baseline period followed by a one-week cooperative gaming period with our game EnerSpace. The age distribution was four between 31-

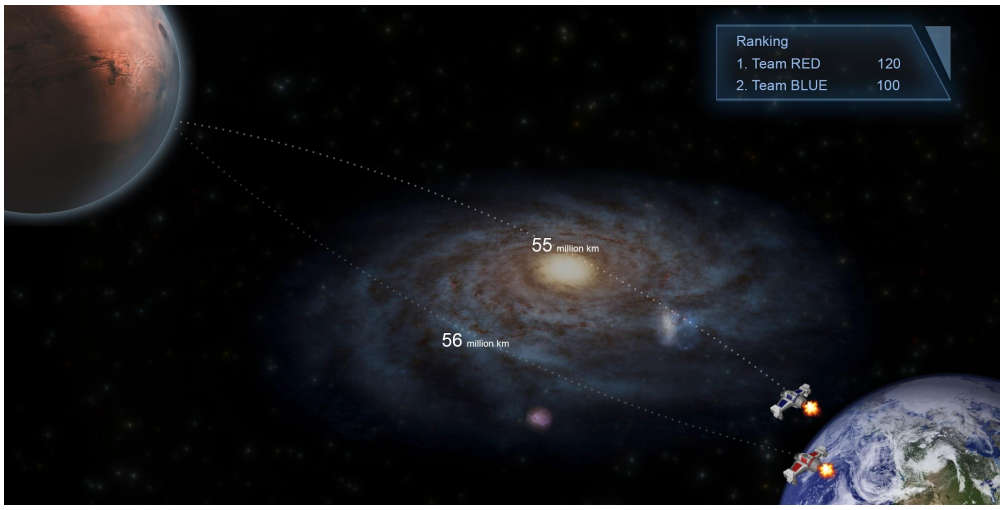


**Figure 1. The main interface of EnerSpace: competition between two spaceships, team red and blue. The dotted lines show the route towards the next planet to exploit, on the line there is a text showing the distance left for each spaceship. In the upper right corner there is a ranking list.**

40 years old, two between 41-50 years old, one between 20-30 years old and one above 51-year-old. All participants signed an informed consent.

At the beginning of the study we installed an energy meter in each workers office and collected a one-week hourly average energy consumption (Wh) baseline. Data logging was designed to collect 5-6 points per minute. All the devices around each personal workspace were connected and in the control of the participant. This included desk lights (not ceiling/room armature), computer, monitor and other peripherals such as smartphone chargers. Prior to the study each worker also completed a pre-questionnaire about their energy awareness.

After the baseline period, the workers competed in two teams (red and blue team) using EnerSpace for 7 days. The teams were formed randomly by the researchers. During the study we did not prompt for team meetings, everything that happened in the study was on the participants own initiative. At the end of the study, each worker completed a post-evaluation questionnaire about their energy awareness and user engagement and a 20-min interview concerning their experiences with EnerSpace. During the study, participants also logged the time when they came to and left the desk.

### 3.2 Data Analysis

This study collected qualitative data from the interview and quantitative data from the questionnaires as well as the experiment. As for qualitative data, we performed a thematic content analysis for analyzing the transcripts from the interview [29]. In this process we generated codes from the transcripts, defined themes and interpreted the results. As for the questionnaires, we compared the pre- and post-questionnaire to assess whether the cooperative game increased the energy awareness of occupants and looked at how the participants self-rated (5-point Likert) the EnerSpace impact on energy awareness.

We analyzed and compared the quantitative hourly consumption data between the baseline and the game period. In this process, we divided the consumption data into three categories according to the participants personal logs: working hours (7:00-19:00), non-working weekday hours (19:00-7:00), and weekends (not working). Six of the participants logged their exact time of arrival and departure while two provided a timetable of their daily routine. Due to instable data logging of the energy meters, in particular during the night when we sometimes had hourly dropouts, average hourly consumption was calculated using only hours with constant data.

## 4. GAMIFIED VISUALIZATION: ENERSPACE

### 4.1 The Design of EnerSpace

The design of EnerSpace went through the stages of field study, defining personas and scenarios, design iteration and developing a working high-fidelity prototype. The field study included an observation of energy consumption behavior in a corporate research building and an interview with 15 workers who work in the building. The findings from the field study suggested that they had low energy awareness, knowledge and engagement in energy conservation. Although the workers generally considered themselves motivated for energy conservation, they did not actively monitor or take actions to save energy.

The coffee room was selected as the setting for the game as it is the commonplace where co-workers have a break and chat. Assuming this would be a natural setting for teams to discuss and follow their efforts.

On the basis of the field study, 8 ideas were generated and a brainstorming was conducted together with 2 UX designers


**Figure 2. Individual page (a,) animation where the avatar talks about the estimated time of arrival. (b) a postcard sent by the avatar when arriving to Mars. (c) The heating system is turned off due to over-consumption. (d) The team is ready for a for a space jump since they have saved energy for 5 consecutive days.**

to converge the ideas to a competition between departments in a space trip context.

### 4.2 Gamification Mechanics

The narrative of Enerspace is that two spaceships are sent to the Universe for a resource exploitation to cope with the resource shortage on Earth (see Figure 1). Users are divided into two teams (team red and blue) and each team owns a spaceship whose color corresponds to its team color. The spaceships are powered by the energy that the team members save in the office by comparing the team's current hourly average consumption (Wh) the baseline period on working hours and non-working hours respectively. This was visualized in the gamified by the speed of the spaceship and rotation of the flame behind it. The more the team members saved, the faster the spaceships moved and the flame rotated. If the energy consumption exceeds the baseline, both elements stopped. A dotted line shows the route of a spaceship with a number indicating the distance. The dotted line of the leading spaceship is presented slightly clearer than the other in order to show the ranking in a subtle way. When arriving at a planet they can start exploiting recourses. The amount of collected resources is shown on a ranking list at the top-right corner of the interface (Figure 1). When the resources on a planet are depleted, the spaceships continue to the next destination.

Besides the main view, an individual view was shown when a participant's face was recognized. Face recognition was chosen to remove the need for login and make the experience more ubiquitous. On the individual view, the participant's consumption data is visualized as the living condition of an avatar and also displayed on a control panel on the interface. Each user has an avatar on the spaceship who serves as a concierge to introduce the user's personal consumption data. In this animation, the avatar first greets, then talks about the user's personal consumption data and the estimated time of arrival to the destination (see Figure 2(a)). The consumption data shown on the control panel include an average hourly consumption (Wh), a percentage of saving compared to the user's baseline and a ranking within the team. When the spaceship arrives at a destination, the avatar will send a postcard or souvenir to the user as a reward (see Figure 2(b)).

#### *Gamified Feedback*

The energy consumption of the whole team influences the living condition of their avatars. When the consumption of a team exceeds the baseline, there are three levels of power failures inside the spaceship that move from running out of coffee to shutting down the heating system (see Figure 2(c)).

#### *Increasing Gamification Engagement*

Special events are triggered when specific conditions occur to increase gamification engagement. When a team keeps saving energy for 5 consecutive days, the spaceship accumulates enough energy for a space jump that shortens the distance to the destination (see Figure 2(d)). Other events

may also occur in order to award the leading team and encourage the other team.

*Situation-based Saving Tips*

The avatar gives situation-based saving tips occasionally. For instance, the avatar suggests "*I heard the weather in [town] is great. Why not turn off the lights if it is bright outside?*". Those tips provide users with approaches to increase energy efficiency. The content is based on current situations including but not limited to weather and place.

### 4.3 Implementation

The EnerSpace was set up with a 1080p monitor and a Logitech C920 HD Pro Webcam in the coffee room in the building. The energy consumption of each participant was measured using a FIBARO Wall Plug. The data was collected by a VeraPlus Advanced Home Controller via Z-wave protocol and then sent to a server. The software of EnerSpace was developed in Python Flask, HTML5 and JavaScript. The animation and 3D model in EnerSpace were made in Cinema 4D, Adobe Fuse CC, Adobe Mixamo and Adobe Premiere CC.

## 5. RESULTS

### 5.1 Consumption Data

Participants' baseline average hourly consumption (Wh) varied from 16.99 Wh to 58.45 Wh ($M = 34.33$, $SD = 15.17$). The average hourly consumption decreased by 21% during the game ($M = 27.26$, $SD = 9.14$).

In the analysis the hourly data was categorized as working hours, non-working hours in a workday and weekends. When comparing the average hourly consumption between, before and during the game for these three time periods respectively, all the participants consumed less while playing the game except for the non-working hours in a workday (see Figure 3). For the non-working hours in a workday, the average hourly consumption increased by 48% during the gameplay week ($M = 7.32$, $SD = 8.08$) than before ($M = 4.96$, $SD = 6.29$). Conversely, results indicated a large decrease of 81% in energy consumption during the game ($M = 1.73$, $SD = 2.15$) than before ($M = 9.18$, $SD = 13.93$) during the weekend. Even though both periods are off-duty hours for the participants, the different results might suggest a different behaviour pattern for the weekend and non-working hours in a workday. Besides, the average hourly consumption during working hours was reduced by 23% during the gameplay week ($M = 56.80$, $SD = 21.29$) than before ($M = 74.13$, $SD = 36.57$). These results showed a general tendency of reduction in energy consumption during the gameplay week with different degrees of decrease for the three periods of time.

### 5.2 Questionnaire results

*Pre-questionnaire*

The results indicated that 87.5% of the participants did not know how much energy they consumed and the rest only had a general idea of the amount. All the participants showed interest in energy consumption data and 87.5% of them felt motivated for energy conservation. All participants took actions to save energy either intentionally or by habit. Turning off the lights was mentioned by all participants as an action to save energy, while only 25% of the participants turned off the computer or made it sleep when not in use.

*Post-questionnaire*

Results about energy awareness showed that 25% of the participants knew the amount of their energy consumption while 25% of the participants had a general idea of the amount. Also, 75% of the participants thought they were more aware of their energy consumption after the game. All participants thought it was fun to play the game and reported being engaged with EnerSpace. They were interested in knowing how the competition and space trip goes and 87.5% of them stated that they thought of the game in their spare time. 60% of the participants felt more motivated by the game while 50% of them thought they saved more energy due to it. When asked whether they thought that they saved more energy during the game, the responses were neutral, which was followed up for how the participants viewed their energy conservation during the game in the interview. As many as 75% of participants were interested to keep playing the game. In summary, besides a positive experience, EnerSpace appears to have helped to increase the participants' awareness and knowledge towards energy to some degree.

### 5.3 Post-experiment interviews

*Impact of EnerSpace*

The results about the impact of EnerSpace was in-line with the post-questionnaire. All the participants thought they gained a better understanding of their consumption after playing the EnerSpace. Although the company has had a goal to reduce energy use for a long time, they generally felt more motivation and engagement as an individual because of the game. Some participants reported that they sometimes thought about the game before they left the office and that it reminded them to shut down the computer and turn off the lights. However, even though they were motivated for saving energy, they mentioned that some of their regular work tasks (e.g. running simulations) took time to run and that they had to keep those simulations running during the day. Therefore, they tried to save on the occasions that they could, but were

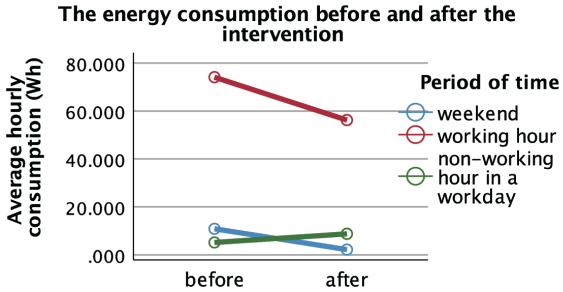


**Figure 3. The line chart shows how the average hourly consumption changed after the game.**

aware that some energy had to be consumed in order to do their job.

*Gamification Mechanics*

As for the mechanics, all the participants agreed that it was fun to play and the competition motivated them to save energy to different extents. Some participants felt motivated by the sense of competing with another team, while others were mostly attracted by the comparison between their current consumption and the corresponding baseline. Knowing their consumption data and how much they saved provided sufficient motivation for them. These participants appeared to consider energy saving as a competition with themselves although the competition still added some additional value.

As for the cooperation, participants who were sitting physically close to each other typically liked the idea of competing as a team because of the sense of community. This made them have in-team discussions around energy conservation and created a social pressure. However, one participant mentioned a shortcoming in the study that they did not experience a process of making up a team, which resulted in a weaker sense of cooperation and belongingness during the week, physical proximity was also mentioned to be an issue for a sense of team.

*Gamified Data Visualization*

As for the game elements, most participants liked how the movement and position of the spaceship represented their energy conservation, since it was easy to see what changes their behaviour brought. Having a personal avatar that introduced the progress of the space trip was perceived as fun and made the game more interactive. Although all participants cared mostly about the consumption data, they would prefer to have both the data and the avatar, which felt more interesting and engaging than solely factual data. According to one participant this was because it made it more into a game rather than facts on a screen. As for the saving advice that the avatar provided, some participants felt persuaded by it and thought "*why not?*". Also, some participants reported a sense of proudness when receiving a compliment and postcard from the avatar.

When talking about the consumption data displayed on the control panel (see Figure 2(a)), all participants thought it gave them an idea of how much they consumed and saved. However, some participants found that only one number of their current consumption was not enough and it was hard for them to get a general idea of their consumption from it. All participants wished to add a line chart of how the energy consumption changed over time, from which they could be aware of how their consumption changed at a different time period of a day and compare the consumption between weeks. Additionally, some participants wished to know how much each device consumes and their total consumption instead of an hourly average consumption. A monetary indicator was suggested to provide a stronger motivation for some participants who preferred to know how much money they saved.

Another complaint was that the participants did not know how much their personal baseline was and how the personal saving was calculated, indicating that a more detailed explanation might have been needed. Also, some participants wanted a clearer representation of the connection between their energy conservation and game, since they wondered how their saving influenced the speed of the spaceship.

Regarding the in-team ranking, some participants that were ranked low found themselves thinking about what they did wrong compared to other teammates. This indicated that the in-team ranking could serve as a reminder for those who over-consume energy.

*Coffee room as the context*

All the participants liked the idea of using the coffee room as the context for EnerSpace. In addition to creating a local narrative for energy conservation, it also raised awareness to other workers in the building. The participants were frequently asked about what was going on and mentioned that it created a discourse around energy conservation. Another reason that was mentioned was that it created a positive "interruption" for work. Note that this was taking place typically in the coffee room during breaks and did not interfere much with their work.

Nevertheless, some participants wanted the game both in the coffee room and in their office. The advantage mentioned was that it would allow checking their consumption more frequently and understand the real-time effects of their behavior in their office context. Also, the coffee room could be hard to reach for some participants who spend most of the time on meetings or in the laboratory.

*Suggested Improvements*

In addition to the suggestions mentioned above, other desired features were proposed by the participants. One future improvement was to expand the scale of the game and included more equipments into the game, such as the heating system. Since the heating system is one of the main contributors of energy consumption, some participants thought they would be more motivated for saving a larger amount of energy. Another possible improvement mentioned was to add the game to a desktop or mobile platform, making play possible in a wider context.

## 6. DISCUSSION

Combining the results from the data analysis, interview and questionnaire, results indicate that EnerSpace could help increase energy awareness and support short-term behavioral change. Although long lasting effects are unknown, a knowledge acquisition on energy consumption is still an important first step to enable behavioral change.

According to the results, the participants achieved a total decrease of 21% with 23% decrease during working hours and 81% on weekend. Those results indicate a positive effect

of EnerSpace on energy conservation. However, the energy consumption in the non-working hour in a workday increased by 48% during the game. One possible reason was that the experiment period was too short. Another reason according to the interviews might be due to a limited *ability* to change. Although they were aware that keeping the computer on when absent from the workplace was a waste, in this context they had to keep some simulations and experiments running. However, if they were leaving for a longer time, such as over the weekend, they would consider turning everything off. This reasoning might explain the substantial decrease of energy consumption over the weekends compare to non-working hour on workdays. This hints towards a potential to *design for the ability to save energy when absent*, rather than when present, in professional settings where workers may have a limited personal space (ability) for energy conservation at work.

This leads us to a suggestion of remedies to the problem of participants being unable to save much energy on non-working hours on workdays. The main reason mentioned was that participants had simulations running – this was beneficial from a work efficiency perspective – after leaving the office so that they would be completed in the morning. Regardless of the simulation took a few hours or all night, the computer was on all night. A potential remedy would be to investigate if contexts such as this might make better use of automatic shutdown of computers and peripherals on idle or after completed simulations.

Results from the interview data analysis reveal three influential motives that drove the participants to energy conservation, two group level motives and one individual. On the group level, the main motive was the competition, where the participants strived to act more energy efficient to get an advantage. Another motive was social pressure and the responsibility of belonging to a team, which motivated to contribute and also created a sense of guilt for poor performers. Although creating negative feelings may have implications for the game experience and overall motivation, no participants reported lower engagement due to these aversive feelings. This rather caused them to reflect on what they did wrong and what could be improved. This could suggest that aversive feedback does not harm the fun of gamification as long as the participants have the *ability* to change. This implication is in line with the findings of study BinCam [30] and study Power Ballads [31], which both indicate that evoking aversive feelings, such as guilt, does not necessarily deter user engagement. On the individual side, some instead focused on competing with themselves. Managing to save more energy than before created a sense of achievement that satisfied and motivated.

Although some participants reported that they checked the game together and discussed it with teammates, this happened mainly between colleagues whose workplace was physically close. For the others there was less team spirit and a low sense of belongingness to the team. Therefore, it appears crucial to carefully consider the physical proximity of people in the team and the formation process of teams in order to promote cooperation and discussions around energy conservations at workplaces.

Regarding the setup context, having it in the coffee room, this was perceived as positive as it naturally created a center point and it prompted discussions and comparisons for the workers at the department. Furthermore, the workers emphasized that its central and obvious location caused curiosity from other groups and departments at the company and in this way, it created a larger discourse on energy conversation at the company. On the downside, it was difficult for the workers to experiment in real-time with their office environment and therefore it was difficult and tedious to explore and understand how they could improve their energy efficiency and position in the game. Therefore, a reasonable suggestion put forward by some workers was to extend the game to their smartphones to allow for personal experimentation and improvements. Extending it to a personal medium, in addition to personal performance feedback, could potentially also be used in many ways to improve the competition through notifications about advances, ranking, and events.

Another aspect of how the mechanics worked that was questioned by the workers was how their personal baseline was calculated, what it was in comparison to others, and if the competition was fair. This could be particularly interesting information for low performers who struggled in the game, as this might have been due to good performance during the baseline week causing them to chase a difficult goal during the game week. This has caused us to wonder how baseline-based competition could be setup in a fair way and how the baseline should evolve over a longer period of time. For instance, should it be static (fixed on the baseline), or recalculated daily, weekly or monthly. The choice would most definitely affect long term game dynamics and tactics and the question is what way would be the most energy efficiency promoting approach. Our setup used a static baseline, but with a changing baseline performing good one day in the game might lead to low game performance the consecutive day. This approach would require well designed and graspable game mechanics so energy conservation performance does not appear as random, which might disturb learning and have negative long-term effects due to faulty mental models. Another issue that was highlighted was the difficulty to assess what of their equipment in the office contributed mostly to energy use, suggesting de-aggregated energy feedback.

In EnerSpace, data was visualized using both abstract and factual approaches inspired by Coralog [7]. As suggested by the Coralog, this study improved the abstract gamified visualization by displaying an animated avatar and combined a factual and abstract visualization by adding accurate factual data to the animation such as the current energy consumption and saving. All participants liked this combination and

considered it better than displaying solely factual data, similar to previous studies [32]. On the other hand, many participants asked in the post-interview for historical charts, de-aggregated data, and personal baseline data, so some degree of tension between abstract data factual data was captured in the study. This might suggest that factual data is needed for creating trust and learning of consumption, but perhaps this could be hidden but accessible for the curious user to not stand in the way for the overall game experience.

The interest to keep playing the game was high after the study although that would require that the game was expanded with new complexities and additions, for instance by adding a heating system to manage in the game and scaling up the game. Another interesting idea would be that the team could gain more detailed data and game tools by behaving well. For instance, if they have saved energy in consecutive days or reached a goal of collecting resources, they gain a view showing more detailed consumption data as a reward.

As regards the choice of the game theme of resource exploitation, some might argue that this communicates values counter to sustainability. In the design of the game, this was discussed and our thinking was that people could distinguish this as fictional and as a satire of the absurdity of resource exploitation and the current needs of mankind. However, we did not follow up on the interpretation of this.

### 6.3 Limitation

The connection between the FIBARO Wall Plug and the VeraPlus Controller was not fully stable during nighttime, which resulted in a low frequency of consumption data. Although this issue was accounted for by the formula of total consumption, the accuracy probably was affected. Also, the participants' presence in the office was not fully taken into consideration. If the participant left the desk in working hours without shutting down the devices, their consumption data would still be compared to the baseline of working hour, which lowered the accuracy of energy saving. Furthermore, although EnerSpace had a positive influence on the energy awareness and behavior during the short test period, the long-term effects are unknown. Lastly, the fact that the participants where all engineers may have influenced their actions and behaviors, however, their engagement in energy use was prior to the study not remarkable.

## 7. CONCLUSION

In order to understand how to increase worker awareness of energy consumption and motivate energy conservation, we have studied a cooperative game called EnerSpace. After a two-week experiment with EnerSpace, participants achieved a 21% decrease in overall energy consumption during the game week compared to the baseline. Surprisingly our intervention lowered the energy consumption during the weekends substantially, suggesting a potential to design for the ability to save energy when workers are absent. Along these lines better support for automatic or planned shutdown of office equipment can be an important implication All participants reported an engaging and fun experience with EnerSpace in the coffee room, which created a local and extended narrative around energy conservation at the workplace. However, as the central placement was disconnected from their office environment it hampered learning and experimentation locally in the office. Furthermore, the formation and composition of the teams might need to better account for the location of the workers and social connections to enhance the discourse on energy conservation and team spirit. Regarding game mechanics, some workers struggled grasping the baseline comparison and questioned its fairness, which poses challenges for how to design fair and graspable baseline-centered games for energy conservation.

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