This paper analyzes different existing projects about pervasive persuasive games for energy conservation. The design, pervasiveness, persuasion methods and long term results are discussed for each of them. By comparing them on different aspects, some points appear more valuable than others to achieve long term goals. A set of important elements for a successful game is then derived from the comparison of the projects. It appears that in order to reach the long term goal, such a game should convince the player to maintain the positive behavior acquired through the game, even after the game ended. It is hoped that future studies in the same field will apply those elements and reach a higher success rate than what has been done so far.

Keywords
serious games, pervasive persuasive games, energy conservation

1. INTRODUCTION
Reducing CO₂ emissions has become a major challenge in our society. A lot of improvement can be done on individuals level in order to reduce the energy consumption, ans thus CO₂ emissions as well. In order to convince them to adopt a more environmentally friendly behavior, some researchers created pervasive persuasive serious games. Games appear to be a good way to pass information to users, as they are more entertaining than other types of interfaces. Pervasive systems are systems which can provide context awareness, mainly using sensors. They seem to be of great value in the field of energy reduction in the household, as they allow to gather and process information about energy usage in a way that is in most cases transparent for the user. Such systems are also used as they add contextualization and personalization to the interaction with users, which can help changing their habits. However, some persuasion techniques need to be executed in order to convince the players to change their behavior in a sustainable way. This paper analyzes and compares different existing projects based on those aspects, and tries to highlight to most efficient techniques used. A key aspect is the effect of the game on the long term behavior change, which will ensure a significant reduction of energy consumption.

2. DESCRIPTION OF THE PROJECTS
In this section, the different projects found on the subject are described. First, the main goal of the project is explained, then the design of the game is described. Finally, a brief description of the results is given.

2.1 Professor Tanda
Professor Tanda [1] is a project realized in 2007. Its aim is to create an application for mobile phones that collects contextual information about the habits of the user, in order to convince him to change them to more environmentally friendly ones.

The application consists of activities, through a series of dialogues between the user and digitalized pictures of professor Tanda, a fictional character. The game sessions must be downloaded each day on the mobile phone from a server. Two activities are played per day, one started by the user and one triggered by the application. For this last type, the context is first established, using cell ID location. Then, the context is inferred from the location, allowing the application to propose a suitable activity to the user. Note that during this study, the generation of activities was done manually by an operator, and that more accurate location methods were not yet available. After having completed the activity, the user enters information about it, for example the time of a shower. Professor Tanda can then provide some feedback and advice about the energy consumption of the player, in order to change his habits. The game does not include any social interaction with other players, the motivation to play the game should come from the fact that interactions with the virtual character of Professor Tanda are enjoyable to the user.

The tests were led during two weeks, with 30 adults participating. Results showed that participants were satisfied with the game, but would have preferred longer interactions, and more activities per day. Future work could include automation of processes and longer test periods, in order to measure long term changes in behavior.

2.2 Eco Island
Eco Island [2] is a study conducted in 2009, which aim is to apply different persuasion techniques in order to modify the behavior of users to a more environmentally friendly one.

The system is less pervasive than the ones of the other projects, the study rather focuses on the motivation factors. The system consists of a desktop application, a mobile phone application and a display, projecting a representation of a family on a virtual island. The users set a target CO2 emission, they then report manually consumption levels using the desktop or the mobile application. If they fail to stay below the consumption limit, the level of water around the island rises, threatening the avatars living on it. In order to reduce the level of water, several tasks are proposed. As users cannot calculate their exact electricity usage, they will report actions they took to reduce their energy consumption. These actions can include energy reduction in the house such as unplugging some devices, or outside the house, such as using public transports instead of a car. By doing so, they also earn virtual money, which they can exchange online with other families who did not reach target level of emissions, or they can also buy items to decorate their island. The paper discusses extrinsic and intrinsic motivation. Extrinsic motivation should come from different incentives, with the objective of helping the player to perform desirable tasks. The completion of these task should then reach the intrinsic motivation, which should ensure that the player adopts the desired behavior, even once the game stops.

The tests included 6 families, for a total of 20 participants. During 4 weeks, they played the game and interacted with each other. Results showed that while users enjoyed playing the game, they found that the manual reporting was quite a burden, and that they were more motivated by having a nicely decorated island than by changing their attitude towards the environment.

2.3 Power Agent

Power Agent [3] was developed in 2009, it aims at inducing a positive behavioral change about the environment by both promoting information about it and by providing team competition.

The system consists of a mobile phone-based game, coupled with an electricity meter connected to the house, automatically reporting electricity usage to a central server once a day. Players are proposed one mission per day, centered on energy conservation. These missions consist of reducing the energy consumption in the household for a given period, mostly during the evening. In a first part, a virtual boss assigns the mission, unlocking a small platform video game allowing to collect virtual batteries. Those provide clues for the incoming mission. The morning after the mission, the boss gives feedback according to the performance accomplished. Most missions occur during early evening, when the energy consumption is at its highest. After a certain number of missions, the performance of all players is compared, and the competition winners are announced. The winning team is the one who performed the higher relative reduction of their energy consumption. As the energy usage of the entire household is taken into account, it is expected that the players will convince their family to participate in the game. The study states that in order to adopt an good behavior towards energy consumption, the users must be both the motivation to perform such environmentally friendly actions and the information on how to perform these actions.

The tests took place during 10 days, with two team each consisting of three players and their family. Results showed that the overall energy consumption decreased during the test periods, some families investing themselves more than others to reduce energy. However, no significant energy reduction was observed on a long term period.

2.4 Power Explorer

Power Explorer [4], led in 2009, is a sequel project of Power Agent. The main difference of design between the two projects is that Power Explorer now provides instant feedback, as it is believed that it encourages both a more casual gaming and greater long term behavioral changes.

The system consists of WiFi equipped electricity sensors placed on various appliances, automatically reporting consumption levels to a server giving instant information back to a mobile phone application. The gameplay of the mobile application consists of a blob monster which can visit four different areas. The first one represents the actual general energy usage. In this case, the aim of the game is to keep the monster healthy, by consuming a fairly low level of energy. The second area is a pile of several monsters, representing the ranking of the different players according to their energy usage. A third area consists of a race game between two users. They mostly need to adjust the speed of their monster in order to avoid obstacles, by turning on and off some devices. The aim of this is to give information about the energy usage of the different appliances in the home. The last area is also a competitive game. In this case, both monsters are located on an iceberg. In order to win the duel, a player has to make the other monster fall into water by throwing objects at it. Those objects are earned by switching on and off appliances, the size of the object depending on the power of the appliance. In this case, the objective is to inform users about power usage, rather than energy usage. For instance, a washing machine consumes a lot of power, but is used a few minutes per day, so that users may not notice its energy consumption through the day. With this game, players are aware of both energy and power usage.

After a testing period of one week including 15 teenagers, the study showed an effective reduction of energy consumption after ten weeks. While the energy reduction was less important during the game than the one observed in Power Agent, long term results were more satisfying with Power Explorer. These results are explained by the combination of instant feedback and the fact that the game could be played in a casual style, without spending hours per day on it.

2.5 Energy Life

EnergyLife [5, 6] is a project led in 2010. It is aimed at informing users about sustainable behavior, as well as applying this knowledge in order to reduce energy consumption.

The system consists of wireless electricity meters connected to a base station, communicating in real time with an appli-
The tests were conducted over three months, in which 24 participants were playing the game. A certain number of their electric appliances were monitored. Results showed that users found the application useful for awareness of energy conservation. Based on the results, researchers decided to modify the application to better suit the expectations of the users, for instance by providing contextualized tips. These tips are formulated using energy usage information and additional information about the consequence of this consumption, for instance the number of trees that were needed to absorb the CO₂ emissions produced by the player in a given period.

### 2.6 Gaea
Gaea [7] is a project realized in 2011, aimed at providing good recycling attitudes towards teenagers and adults. While it is not centered around energy conservation, it presents all the aspects of pervasive persuasive gaming, and focuses on waste recycling.

The game is meant to be played outside, where users will use a mobile phone to pick up virtual waste on given locations, and then put them in a virtual recycle bin. There are situated near a projector, called public display. The user is then rewarded with points, but can also earn them by reading recycling facts presented on the mobile application, as well as answering quizzes shown on the public display. The purpose of this display is to bring cooperation in the game by attracting other people who can then participate in the game themselves. The application can connect to Facebook in order to share results and advertise the game. The phone communicates with a server either by 3G network, or LAN when available.

Two tests were made, in order to evaluate both the level of persuasion of the game and the quality of its gameplay. Both tests were done within one day during students events, using respectively 15 and 37 students. The results of the first test, done one week after the play session, showed that participants increased their motivation towards recycling. The results of the other test showed that participants enjoyed the game and its interface. Facebook community was also a great success, users sharing their results with their friends.

### 2.7 LEY!
LEY! (Less energy Empowers You) [8, 9] is a project realized in 2011. This game aims at making people understand their energy usage, as well as encouraging them to adopt better behaviors.

The project consists of a game on mobile phones, which can connect to a server to directly retrieve real-time data from sensors inside the household. At the beginning of the game, the user defines an avatar presented as a virtual house, which can be personalized according to the conditions of the real house. The main screen displays the avatar, which is given a score, ranging from A+++ to D, taking into account several parameters, such as the overall consumption, participation to quizzes or community interactions. A player can also win challenges against another player by responding to a quiz, or by obtaining the highest score over a given period. In addition, users are given general feedback once a month, but notifications can also be triggered by a too high level of energy consumption. The study focuses on the aspect of personalization by collecting data such as number of log-in per day, in order to determine the profile of the user. This allows to categorize users, providing them adapted interfaces and contents such as changing the display of the different screens. This personalization of the application suggests that the game should be personal and not played in a cooperative way. However, as the electricity usage calculated includes the whole household of the player, other inhabitants are implicitly invited to participate in the game.

The game is meant to be played for adults or teenagers. No tests were found in the articles, so it is hard to discuss the performance of the application, either on the design quality or on any behavior change. This is explained by the fact that the main focus of the study was the personalization of the game, rather than performance on energy usage.

### 2.8 Energy Battle
Energy battle [10] is a study realized in 2012, of which objective is to convince households to reduce energy consumption. The study analyzes the different psychological factors allowing a long term behavioral change. The project is in the form of a competition between teams.

The system consists of an energy meter and an online platform. The energy meter displays the energy usage in real-time on a screen. Users then have to upload these data manually from the meter to a server, which is surprising given the fact that the meter itself has an integrated display. The other part of the system is an online platform, where users can see their energy consumption over time once they have uploaded it, as well as some tips, a ranking of the teams participating, and finally a block construction game. The more points the team of the user gets, the more blocks they receive in order to build up a nice figure. The winning team is the one having saved the most energy, but the block construction is also taken into account. The game is also cooperative, as students of the same household must cooperate to get the best possible score, which is calculated for the whole household. The paper explains the different existing intrinsic and extrinsic motivation factors, and explains that they are both taken into account in the study in order to change the behavior of the players.

This competition took place during four weeks, with 30 households of students participating. The winning team
earned €750 worth of kitchen appliances. Despite having good results during the competition, researchers observed a big decrease in energy savings one month after it, and most competitors were not trying to save energy anymore eight months after the game. These results are explained by the fact that the game was quite immersive, so that participants were not willing to maintain this level of efforts to keep a low consumption level.

### 2.9 Climate Race

Climate Race [11] is a project realized in 2012, its aim is to reduce energy consumption, but it targets office workers. Before the actual game, researcher were helped by participants to create the prototype of the game. In this aspect, it focuses on the user-centered design. The project also has constraints of non-obtrusiveness and privacy, due to the office space.

The game is in the form of a mobile phone game, as well as notifications of desktop computers, but only when the mobile application is running. To match the non-obtrusiveness constraint, the mobile application does not produce any sound, but vibrates. Data is collected from various appliances using smart plugs. Workers must cooperate to reach a certain amount of points. They can earn or lose points by several means: switching on/off appliances, completing given quests within a certain time, or by random events. The difficulty to earn points increases as the players gain levels.

The tests included five office workers, during two weeks. Results on energy savings were good, but the game was still obtrusive for some participants. Some other players expressed their willing to have a competition between different groups. The tests did not reveal which factor contributed the most to the decrease of energy consumption. Unfortunately, no long term energy measurements were made.

### 3. ANALYSIS AND COMPARISON OF THE PROJECTS

In this section, the different projects explained above will be compared on some points. These include the pervasive-ness of the system, the efficiency of the different persuasion methods, and the behavior change in the long term. It is interesting to notice that apart from pervasive-ness and game design, the aspects are more related to psychological than technological factors. This is because those projects aim at changing the behavior of individuals. This process includes a high number of psychological factors, technology being only used to support them. This aspect is also reflected by the fact that most projects are done using a psychological methodology and structure. Table 1 lists for each project some of the features described in this section.

#### 3.1 Design and Gameplay

The different games vary in several aspects of their design. The proposed features can be classified so: advices, feedback, quizzes, and games. Games in this case mean a short period of game in the kind of an actual video game. All projects are considered games, but only few of them include an actual video game. Power Explorer proposes two different games based on online competition. Power Agent also includes a game, but it is only a prequel for a phase of energy reduction, which is considered as the actual game. Those two games are played on mobile devices. Eco Island and Energy Battle include desktop video games in the form of tower construction or island management. These four projects have teenagers or students as target users, the gaming aspect would probably attract them more than just text interactions. The importance of knowledge is discussed in each paper, it is through that the user will be aware of the possible actions in order to reduce energy consumption. Information about the consequences of the behavior of the user. In order to pass this information in an efficient way, most projects include feedback and advices. Quizzes are also present on some projects, they allow to test the knowledge of the user at a given time, and to give useful information back to the user.

Most systems are accessible with a mobile phone. This technology allows a more casual kind of game, and a higher availability. Climate Race uses desktop notifications during the game periods, in addition to a mobile application. Eco Island proposes a desktop interface in order to have a clear view of the game. In this case, many small elements cannot be displayed efficiently on the mobile devices. Finally, Energy Battle consists of a desktop interface only, where users upload data, play a building blocks game, or can see their current ranking.

Those different interfaces have all the same purpose of being an efficient interface for the user, since it is through it that users will be involved in the game.

#### 3.2 Pervasiveness of the System

The two next parts describe and compare the pervasiveness of the system by dividing it in two main parts: the collection of data and the contextualization of the game according to the collected data.

##### 3.2.1 Data Collection

Normal video games are played most often on one single device, not connected to any other component, except an Internet connection. Pervasive games in general require already more than that. Information such as location is gathered, most of the time using GPS location. In the case of pervasive games for energy conservation, not only does the location become of less importance, but also new data must be acquired, i.e. energy consumption. The location is used in two projects: Professor Tanda and Gaea. In the first, location data is required in order to determine the current context, which could trigger some event. Note that in this case location is not found by using a GPS component, but by retrieving the current cell ID of the phone, which is mediocre in precision. The second project was realized later, when GPS technology was already integrated in mobile phones, which allows the game to be centered around the location of the player.

Data about electricity consumption is the core element of all projects, excepted Gaea. In Professor Tanda and Eco Island, players have to report consumption levels manually. Since no energy meter is used, the data consist only either of environmentally friendly actions taken by the players, or measurements, such as the time used to perform an activ-
ity. In Energy Battle, players have to manually upload consumption data. This is clearly defined as a burden by some participants, and it is sure that it removes a pervasive aspect of the game. Note that participants of this project were given a device displaying the current energy usage, but not connected to the rest of the system. Those three games certainly could have been found more interesting if users did not have to spend time on a tedious task. The energy usage is automatically updated to the system for all the other projects. Power Agent, LEY! and Energy Battle reported only the overall consumption of the household, while Power Explorer, Energy Life and Climate race gathered energy usage of different appliances separately. Finally, data about the application usage is gathered automatically in most projects. These data can include the time spent on the application, but also the number of activities completed.

### 3.2.2 Personalization and Context Awareness

An important aspect of pervasive systems is that they are able to adapt to the current context and/or the user. Table 2 shows the importance of the different types of data for contextualization. Blank spaces mean that this kind of data is not gathered in the game.

The energy usage is the main type of data that is being collected, however it is not always used to contextualize the game. Energy Life does not contextualize the game according to this data, but it contextualizes tips, in a intelligent way. A general information is transformed into a personalized one by using the energy consumption of the player. He will for instance be notified of the number of trees that needed to absorb the CO₂ emissions produced by him during a certain time, or be alerted of a device left switched on during an abnormally long time. Climate Race uses this data by integrating the notion of levels in its gameplay. Once enough energy saving is achieved, the player enters a new level, which makes it more difficult to earn points. This is quite efficient, as the game adapts itself to the level of performance of the player. Power Agent does not really use this data to modify the gameplay, it is only given as a feedback to the user. The other games use the energy consumption in a static manner, it is however still integrated in the game as pure data.

Location is one of the central element in most pervasive systems; however it becomes of less importance in the case of energy reduction. Only Professor Tanda and Gaea use location in their system. Professor Tanda, despite its limitations due to its early development time, is one of the most context aware games described. It uses the cell ID and other information to determine the current context. For instance, the cell ID in which the user is located each evening and night would be saved as home. Based on those observations, the application will propose contextualized activities to the user, such as calculating the amount of water he uses for a shower. However, for this project an operator has to create activities every day, so the system is not fully automated and it is hard to imagine this system deployed on a larger scale than in the study. In Gaea, the location is the center of the gameplay, as the player must go to defined locations to advance in the game. This last case is a bit different from the others. Most projects focus on energy reduction in a close environment, but Gaea is meant to be played outside, and does not take energy consumption into consideration.

The last type of contextual information concerns the amount of time the player spends on the game. Energy Life integrates multiple levels in its gameplay, but in a different manner than Climate Race. Here, the player accesses a new level by spending a certain amount of time on the application. LEY! is the only system of which interface could change according to the profile of the player. The system monitors the interactions between the user and the game. Based on the data collected, the system establishes a possible user profile, in order to best fit its needs, such as proposing the preferred activities more than the others or displaying the most accessed screen in front of the others. Energy Life, Power Agent and Power Explorer propose rankings between players, based not only on energy consumption but also on the fact of playing some video game included in the application. Finally, Gaea ranks players according to the amount of virtual garbage they recycled, which is directly related to the time the player spends on the game.

### 3.3 Feedback

Feedback is of great value in the case of pervasive green gaming, as the player can see the consequences of its actions, possibly in real time, and thus associate his action with the consequence. The best results are observed when the user receives the feedback right after the action is performed. For instance, if the feedback is given once a day, the user cannot know which action is associated with a possible increase of decrease of energy consumption, as they sum up through the day. On this aspect, Energy Life fully achieved this goal. Some participants of the project used the application to check the energy consumption level of different appliances.
in their home. Some of them even switched on and off electric devices to get an idea of their energy consumption. This relates to an important aspect of behavioral change: knowledge. By learning the exact level of consumption of devices, users are aware of which of them consume the most, and can act accordingly. A second aspect to consider is the number of appliances monitored by each sensor. A general feedback as seen in Power Agent, LEY! and Energy Battle only gives the general consumption of the household. It is clear that detailed feedback is more valuable for awareness about the energy usage of the different electronic devices.

Power Explorer also reached the goal of knowledge by integrating it in its gameplay. Two parts of the game are not aimed at directly reducing energy consumption, but they focus on consumption awareness. The first is a duel between players, where they need to set the right level of energy usage by switching on and off electric devices. The other consists of switching on and off devices using a certain level of power, in this case the user gets an information about power rather than just energy.

It is clear that projects in which data collection was manual cannot give an efficient feedback in real time. In Energy Battle, data was updated manually, but it was firstly displayed in an ambient interface, which already gave an idea of the energy level. However, participants were not particularly interested in it. In games like Professor Tanda, a feedback was given after completion of a task, in the form of an advice. Finally, the players of Power Agent received feedback the morning following the game session, since the system collecting data was uploading them only once a day, for cost reasons. While this delayed feedback is less valuable than a more direct one, it still provides the player with some valuable information.

### 3.4 Incentives

The purpose of incentives is to motivate people realizing actions. In the projects described in this paper, the motivation source that comes out the most often is competition, which can be classified as a natural incentive. The Energy Battle project rewarded the best team with a price of € 750 in kitchen appliances. Professor Tanda is the only project which does not include either social features or economic incentives. Perhaps in this case, one motivation factor was that users interacted with a virtual character, which could directly motivate the user through dialogs. All these incentives led players to be willing to play the game, hence they actually reduced their energy consumption.

However, when it comes to behavior change, incentives must be used very carefully. “Gardner and Stern[12] describe that incentives can be very effective in changing behaviour. A characteristic of incentives is however, that when they are removed the behaviour is often not maintained”[10]. This could be an explanation of the fact that some studies did not observe any long term change, while the energy reduction observed during the game period was important. This leads to the following observation: too good results in the short term could lead to bad results in the long term.

### 3.5 Time Spent on the Game

The amount of time the user spends on the game is related to the incentives described above. If the game requires a big involvement, players will probably spend a lot of time playing the games. However, once the game is finished, they will consider that the fact of saving energy is over as well. This is probably caused by a too high level of involvement into the game, the rhythm followed during the game cannot be maintained after it. This is observed in Energy Battle, as some participants were reducing their energy consumption in a way that was noticeable for their comfort. Such measures could not be maintained, energy saving could even be seen as a burden.

Power Explorer was based on this idea of low involvement, researchers supposed that the combination of both real time feedback from sensors and a game designed to be played in a casual way could lead to long term effects. These observation were based on their previous study, Power Agent. The Power Explorer project is the one in which the higher decrease of consumption was observed in the long term. They concluded that a casual game gives better results than a game which is time taking, and which does not directly reward players for their energy reduction.

From these cases we can conclude that a high investment during the game is not necessarily related with long term positive results, and could even lead to the opposite effect.

### 3.6 Social Pressure and Community

Social pressure was used by all project, excepted for Professor Tanda. This is an important persuasive technique, which can be divided into competition against other players and cooperation between them. Climate Race focuses on the cooperative aspect of the game, this can partially be explained by the fact that in an office context, competition is not appropriate, as workers are supposed to collaborate. The cooperative aspect gave good results, but some participants expressed their will to have competition between teams.

It is interesting to see that several games (Energy Life, Power Agent, Eco Island and Energy Battle) are composed of both competition and cooperation between users. This is mainly due to the fact that they are aimed at households, each member of the household feeling responsible for the success of the team. As they compete against other households, the competition aspect is also present. Gaia, Power Explorer and LEY! explicitly only include competition in their game.

<table>
<thead>
<tr>
<th>Project</th>
<th>Energy Usage</th>
<th>Location</th>
<th>Application Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor Tanda</td>
<td>medium</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>Eco Island</td>
<td>medium</td>
<td></td>
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</tr>
<tr>
<td>Power Agent</td>
<td>low</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>Power Explorer</td>
<td>medium</td>
<td>medium</td>
<td></td>
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<tr>
<td>Energy Life</td>
<td>high</td>
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<td>high</td>
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<tr>
<td>Gaia</td>
<td>high</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>LEY!</td>
<td>medium</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>Energy Battle</td>
<td>medium</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>Climate Race</td>
<td>high</td>
<td>medium</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Level of contribution of collected data to the game contextualization

- **Climate Race**: Energy usage is high, location is medium, application usage is medium.
- **Energy Battle**: Energy usage is high, location is medium, application usage is medium.
- **LEY!**: Energy usage is medium, location is high, application usage is medium.
- **Power Explorer**: Energy usage is high, location is medium, application usage is medium.
- **Power Agent**: Energy usage is low, location is medium, application usage is medium.
- **Eco Island**: Energy usage is medium, location is medium, application usage is medium.
- **Prof. Tanda**: Energy usage is medium, location is high, application usage is medium.
play. While this is explained for Gaea by the fact that the game is a one time event, Power Explorer and LEY! were designed to be personal to the user, so that it is hard to cooperate on a single device. Still, as Power Explorer and LEY! are based on the energy level of the whole household, other members of the house are implicitly involved. Gaea is the only project which implemented a way to publish results on an existing social media, Facebook. While this is not explicitly a form of social pressure, we can assume that this will be a motivator to achieve the best possible result through the game. In addition, this project proposes a public display in front of which the player must answer a quiz. The idea was that curious people would join the user and participate to the quiz. The effect is double, first the player gets some pressure from the crowd, and the people around can learn from the game, while not playing it entirely.

Interviews with participants of several project revealed that social pressure was a good motivation through the game, either on the collaborative or competitive aspect.

### 3.7 Intrinsic Motivation and Behavior Change

This aspect of the games is perhaps the one which is the most related to psychology, as it does not include any technological element. The papers of Eco Island and Energy Battle discuss extrinsic and intrinsic motivation. Extrinsic motivation is coming from external elements, such as incentives. This motivation vanishes when the motivation factor disappears. As those games are trying to induce a long term effect, they cannot only provide extrinsic motivation. In the Eco Island paper, intrinsic motivation is described as coming from the self-determination of the player who accomplishes tasks to reduce his energy consumption, as well as the player being aware of the relevance of this reduction. In this case, it is explained that extrinsic motivation is used to encourage the player to perform activities, which will then convince him to act in a more environmentally friendly way, so that the behavior will remain even once the game is over.

This is explained a bit differently in the other projects, but the result is the same: induce a long term behavioral change through the game. The game is thus not the final element, but only a tool to reach and change the behavior of the players. Motivation is a huge research field in psychology, and there are quite a lot of theories about how to change the behavior of an individual. For Climate Race, the quantitative tests did not allow to spot the factor that contributed to behavior change. Energy Life focuses on the aspect of knowledge, it is believed to be the key to behavior change. Power Agent also uses this factor, as the study assumes that players need two elements to change their behavior: the motivation to take actions, as well as the knowledge of how to take them.

In Power Explorer, the successful change in behavior is explained by a combination of both the casual gameplay and the low delay between an action and its feedback. These two elements led to encouraging short and long term results. Researchers of Eco Island explain this intrinsic change by dividing the process in two phases of persuasion. They consist of first attracting the attention of the user, in order to then reach his behavior and change it. This relates to one of the explanations described above, which stated that extrinsic motivations to make the user play the game will eventually lead to intrinsic motivation to be reached.

In conclusion, even if the exact sources of behavioral change are still quite unclear, it appears that some combinations of them are effective at modifying the behavior of players. However, this statement must be taken carefully, as only few projects led to significant long term changes.

### 3.8 Long-term Results

This last point of comparison is probably one of the most relevant aspects for judging if one of the projects is successful. Unfortunately, only a few projects conducted long term tests. Power Agent did not allow to maintain any energy reduction, the level of energy consumption returned to its base value some weeks after the game ended. Eco Island also suggested that no long term changes were observed. Only Power Explorer succeeded in this way, with a stable 14% energy consumption reduction ten weeks after the game.

The reason for those results is hard to explain, however researchers of Power Explorer supposed that this success can be explained by the fact that the game was casual. In this way, good behavior acquired during the game could be maintained after it without too much effort, which could not have been the case in a game demanding a high level of investment.

### 4. DISCUSSION

In this section, a synthesis of the different elements explained above is done in order to highlight what made the different projects successful.

Firstly, it appears clear that the system should not be maintained or updated by the users, since this is a task of non interest for them. Technology now provides cheap and powerful pervasive tools, such as smart meters, to automatically collect and upload data to a system. Thus, if the data collection is transparent to the player, the game will probably be perceived as more interesting, and the player will focus on the gameplay rather than be attracted by some tasks not relevant to the game itself.

The personalization and contextualization of the game are also techniques that can not only emphasize the interest of the player towards the game, but also increase the amount of information that will be perceived as useful, and hopefully retained. The basic approach would be to modify the raw feedback data according to the context, and to integrate it in some relevant advice for the user. The short delay between an action performed by the user and its response from the system is also very valuable. If the system is designed in this way, the user can benefit from the feedback by directly associating the action with the effect. It can also be used in the other way, as the user can be asked by the system itself to modify the energy consumption of some devices, increasing his knowledge about the power of each device separately.

It appears also that the incentives used to make the player wanting to play the game should be of quite low importance, as the good behavior acquired during the game should persist after the incentives are removed, at the end of the game. The extrinsic motivation of the form of incentives presented
during the game should transform itself in intrinsic motivation, provided that some conditions are present, such as low incentives and a level of involvement in energy reduction during the game that could be maintained in the long term.

Social elements can also be used to change the behavior of the user, as they do not only motivate him to play the game in order to be on the ranking top, but also allow the player to compare himself with the others. Both competition and cooperation seem to work well to motivate the player. However, these two tools should not be applied too strongly to the user, as he could feel a too much pressure, and thus associate the game and the energy conservation in general with a bad emotion.

Another aspect which is almost never discussed but could be considered is the length of the playing session, defined by the project. Sure enough, all the studies described have some time constraints, only one game was tested for more than one month. However, it could be interesting to think about a game which could be more casual than others and would be played for a longer period. According to some findings, casual gameplay could reduce the effect of an energy reduction sprint during the game, and could probably better reach and change the behavior of the players.

To summarize what has been found above, we could say that a game which aims at reducing energy consumption of a player in the long term can only do so by inducing an intrinsic motivation to do so. Firstly, the user can be motivated in playing the game by using incentives such as social pressure, but not requiring a high level of effort, keeping the user in his comfort zone. Then, information such as feedbacks and advices given in an direct and intelligent manner may increase the level of awareness of the player, who will hopefully continue to apply measures of small effort in order to maintain a certain reduction of the energy consumption in the longest possible time after the game.

5. CONCLUSION
Pervasive persuasive serious games have probably a great future in helping individuals to reduce their energy consumption. The different strategies used to create the game should be given a particular attention, as they will determine if the player will adopt an environmentally friendly behavior after the end of the game period. A lot of research needs to be done in the field of psychology in order to find the best possible approaches. The successful game surely integrates a mix of techniques that still need to be fully described. However, a few encouraging results in the long term have already been found, which indicate that these kind of games have a real potential to positively change the behavior of individuals.

6. REFERENCES