bEhaVioral Insights anD Effective eNergy policy acTions

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Acronyms

Acronym	Explanation
BCT	Behaviour Change Technique
BCTv1	Behaviour Change Taxonomy version 1
DOI	Digital Object Identifier
EPC	Ethics and Privacy Committee
GDPR	General Data Protection Regulation
IOT	Internet of Things
JSON	Java Script Object Notification
Kw/h	Kilowatt per hour
MMAT	Mixed Methods Appraisal Tool
NavMesh	Navigation Mesh
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-analysis
RCT	Randomised Control Trial
SUS	System Usability Scale
UI	User Interface

Executive Summary

Through examining the role of behavioural interventions within energy policy, the EVIDENT project seeks to determine how best to support residential consumers in making more efficient energy choices. The current deliverable seeks to determine how serious games will be employed to meet the EVIDENT project aims. The primary purpose of this deliverable is to provide a detailed overview of the concept and design of the EVIDENT serious game including its software specifications and architecture. Serious games are particularly advantageous in comparison to other research methods in that they allow the researcher a high degree of experimental control and the opportunity to explore conditions not available in real-life settings while offering participants a more engaging experience. A serious game will be employed within use case four of EVIDENT, namely the "Relation of Energy Consumption Behavioural Biases with Consumers Financial Literacy Level", to allow us to best examine our research questions. In this instance, the serious game will be used to explore the impact of financial, energy and environmental literacy on decisions to repair or replace household appliances across different resident types. This deliverable outlines the design of this serious game.

This deliverable is divided into four main sections corresponding to different aspects of serious game design. The first section presents a systematic review and content analysis of serious games for energy efficiency. This section examines the use of behaviour change techniques within past similar serious games and determines how behaviour change techniques may be best incorporated into the EVIDENT serious game to support participant behaviour change. In addition, based on past similar serious games, methodological and gamification elements that should be considered for the EVIDENT serious game are discussed. The second section presents the concept for the EVIDENT serious game. Detail is provided on game objectives, user roles, game protocol and research aim. This section also provides detail on how user-input into design will be gathered to support participant retention, acceptability and usability. The third section describes the technical details of the serious game, outlining the software specifications and architecture. A detailed description of the user and scenario parameterization, game environment modelling and implementation characteristics are presented. The fourth section outlines the data storage and management considerations relevant to the serious game. This section outlines the measures to be undertaken to support data protection and to ensure all aspects of the game are in compliance with GDPR. Discussion of how serious game data will be made accessible to other researchers is also described in this section. Through this detailed description and consideration of the serious game implementation design, it is hoped to ensure that the serious game best meets the needs of the EVIDENT project. Through this, we hope to maximise the scientific and policy learnings from the serious game and the EVIDENT project as a whole.

1. Introduction

1.1 Purpose of the Deliverable

The purpose of the current deliverable is to define the specifications for the use of the gamification engine within the EVIDENT project. As such, this deliverable will present detail on how serious games will be employed across the EVIDENT project to address research questions and project aims. Serious games are a particularly attractive solution in that they do not require the time resources of a randomised control trial (RCT) and allow the researcher the ability to more closely manage experimental conditions presented through game design. Serious games may also be more attractive to participants in offering a fun, engaging and competitive experience and may allow for sharing or integration with social media. In addition, through the creation of novel environments within serious games researchers have the opportunity to present experimental conditions which may not be possible or practicable in real life, for example where technology is not available on the market or is still in pilot stages. The EVIDENT project shall take advantage of the opportunities offered by serious games within use case four "Relation of Energy Consumption Behavioural Biases with Consumers Financial Literacy Level". Within this use case a Serious Game will be employed to examine the impact of financial, energy and environmental literacy on decisions to repair or replace household appliances. This deliverable presents in detail the proposed design of this serious game.

1.2 Relation with other Deliverables and Tasks

Deliverable 2.3 falls under Task 2.2 'Serious game for energy efficiency' which outputs the serious game implementation design and runs from M06-M12. This deliverable is led by TCD and supported by UOWM, PPC, the JRC, CERTH and CWATT. This deliverable considers the learnings from deliverables 'Field Studies, Serious Game and Surveys Protocols Design and Pilots Design' (D2.1) and 'Specifications of Preparatory Actions for RCT, Surveys and Serious Game' (D3.1) in developing serious game design and implementation protocols. Further, this deliverable informs the task 'Exploration of analytical qualitative and quantitative tools requirements' (4.1) and task 'System Architecture and Design Specifications' (6.1) through providing outlines of the expected serious game design.

1.3 Structure of the Document

This deliverable is structured as follows:

- Section 1 – Introduction: This section introduces the deliverable and outlines its scope.
- Section 2 – Serious Games for Energy Efficiency – Systematic Review and Content Analysis: This section includes a systematic review and content analysis of past serious games for energy efficiency. Recommendations for the EVIDENT serious game are presented.
- Section 3 – Serious Game Concept: This section outlines the concept of the serious game, its protocol and objectives and how user input into design will be obtained.
- Section 4 - Software Specifications and Architecture: This section describes in detail the technical considerations when developing the serious game.
- Section 5 - Data Storage/Management: The section discusses key considerations regarding data protection within the EVIDENT serious game and describes how data will be gathered and stored.

2. Serious Games for Energy Efficiency – Systematic Review and Content Analysis

2.1 Rationale

Serious games relate to the use of game elements outside of typical game contexts in which the goal is education or skill development rather than pure entertainment [1], [2]. Due to this balance between learning and fun, serious games are seen as a useful tool in supporting engagement [3] and discussion [4] on key issues. Such games provide a safe environment for individuals to explore the impacts of their behaviour and actions [5], with the aim of supporting engagement through feedback, competition, goals, or similar game strategies. The role of serious games in energy consumption has been established [6], [7] with significant research demonstrating its efficacy.

While the impact of serious games is well established in the literature [6], [7], the role of Behaviour Change Techniques (BCTs) within serious games has yet to be examined. BCTs are the observable and objective aspects of an intervention that is intended to impact the frequency, form, or function of a behaviour [8]. As such, BCTs are techniques used to alter behaviour and can be considered the 'active ingredient' of behaviour change interventions [8]. While BCTs can be used alone, often they are combined within interventions to result in meaningful behaviour change. BCTs, while not termed as such, are commonly used within serious games. One such example is a study by Whittaker et al. [9] which examined the relative impacts of reward-based and meaningful information within a serious game to increase sustainability behaviours. Results noted the positive impacts of rewards-based strategies on user behaviour and attitude. This highlights the important role of behavioural strategies such as reinforcement on the outcomes of serious games. The use of BCT taxonomies within the design of serious games is limited. One study which did consider the role of BCTs in serious game design used the '*Behaviour Change Wheel*'[1] when designing a game for energy conservation [11]. The use of peer comparison and feedback were highlighted within the game design. However, no analysis of the use of BCTs within serious games for energy consumption was found in the literature.

While interest in serious games continues to grow, there is a lack of analysis of the mechanisms by which games have their effects on user behaviour [12]. A systematic review of theoretical approaches within serious games found a wide variety used [12]. In addition, the importance of goal identification, nudges, feedback, and social interaction as key principles were noted. While these reflect key behavioural concepts, no analysis to date has examined the use of BCTs within serious games for energy efficiency. As such there is a need for increased understanding of the mechanics by which serious games achieve their impact [13].

To determine current knowledge on the use of BCTs within serious games for energy efficiency a systematic review and content analysis was conducted. Through this, the impacts of behaviour change techniques on energy behaviour change were explored. Further, the impact of BCTs on engagement in serious games, specifically seeking to understand if the use of BCTs impacts engagement over time

[1] The Behaviour Change Wheel [10] is a system used to analyse the behavioural components of interventions. It consists of three interconnected wheels. The innermost wheel consists of three behaviour systems namely capability, opportunity, and motivation. Around this is a middle circle consisting of nine intervention functions which address these behaviour systems. Finally, the outermost circle consists of seven policy categories which can support these interventions.

in serious games, was investigated. The findings from this systematic review were then used to inform the development of the EVIDENT serious game.

2.1.1 Behaviour Change Techniques

Interventions that seek to change behaviour, such as those targetting energy consumption behaviours, often include many intervention components which overlap and interact with each other [14]. This can create difficulties in replication of effects and in practical applications of interventions across treatment settings [8]. For those interventions that involve many elements or are complex in nature, difficulties may emerge in identifying active components, thus limiting our knowledge of the specific factors contributing to behaviour change [8]. An additional complication is the variety of terminology used to describe components of interventions, limiting comparison [15]. Additionally, the meanings of common behavioural terms are often inconsistently or incorrectly applied (for example negative reinforcement vs negative punishment), again causing difficulties in comparing intervention effects [8]. To enhance our understanding of how best to support energy behaviour change, we must first understand the active components of past interventions and their impact.

To support reliable analysis and comparison of behaviour change interventions, a means to reliably characterise the active ingredients of interventions is needed [15]. One such approach is through the identification of BCTs [15], or the directly observable, repeatable and measurable aspects of interventions that seek to impact the frequency, intensity, duration or temporal latency of behaviour. By analysing the contents of behaviour change interventions to determine the BCTs employed, comparison across interventions is facilitated. In addition, through identifying which BCTs are associated with positive behaviour change across domains, key mechanisms through which behaviour change can be supported and maintained can be identified. BCTs have been identified and employed with success across a wide number of domains from physical activity [16] and health behaviour (i.e. smoking cessation [17], alcohol consumption [18]) to occupational behaviour [19].

To allow for content analysis to be practicable, taxonomies of commonly occurring BCTs are needed. One such taxonomy is the Behaviour Change Taxonomy (BCTv1; [8]). The BCTv1 has demonstrated good reliability [15] and has been used across a wide variety of domains [8]. It has also been used in practice settings to guide future intervention development [20]. While past similar tools have been tied to specific domains (i.e. smoking or health behaviour) or require fluent application of theory, the hierarchical nature of the BCTv1 has been found to facilitate both ease of use by researchers through its strong coherency and structure [8]. Key benefits of the use of such a taxonomy include ease of replication for interventions, a cohesive language to describe BCTs across domains, and ease of analysis of active change agents for interventions within systematic reviews [8]. In addition, future behaviour change interventions may be more effectively developed through enhancing the understanding of important BCTs.

The BCTv1 has been noted as the most comprehensive taxonomy of behaviour change techniques [21]. While the examples included within the BCTv1 are commonly directed towards health behaviours, they can be successfully applied across a wide variety of non-health domains. The BCTv1 also allows for a greater depth of analysis in comparison to other similar tools such as the Expert Recommendations of Implementation Strategies [22] or the Effective Practice and Organisation of Care [23] taxonomies. This depth of analysis allows for a greater comparison of intervention effects.

2.2 Methodology

2.2.1 Search Strategy

A structured search of seven databases was conducted between the 20th and 24th of September, 2021 to identify all articles examining serious games for energy behaviour. Seven databases were searched (Web of Science, EBSCO Host, IEEE Explore, Scopus, SagePUB, Wiley Online, and Science Direct) with the following search terms used: "Serious game" OR "Digital Game" OR "Video Game" OR "gamif*" AND "Energy" OR "Energy Consumption" OR "Energy Behaviour" OR "Energy Efficiency" OR "Energy Use" OR "Energy Saving" OR "Pro-Environmental Behaviour". Due to the pace of change within serious games and energy efficiency research, only those studies published in the past 10 years were included.

Following searches of the databases, all articles were exported to EndNote[2] and the duplicates were removed. Following this, an abstract and title review was completed using RAYYAN[3] [24]. For both title and abstract, and full text screening a second independent researcher examined 10% of articles for the purposes of inter-observer agreement. To be included in the present review, an article was required to examine the use of a serious game on energy behaviours of participants. Full inclusionary and exclusionary criteria are presented in Table 1 below. Backward and forward citation searches of all included articles were also conducted.

Table 1: Inclusionary Characteristics

Criteria	Inclusionary Criteria	Exclusionary criteria
Participants	Must include human participants	Any study which does not include actual participants (i.e. modelling of behaviour) will be excluded.
Intervention	Any intervention which includes a serious game. A serious game is defined as the use of gamification or any game elements within an energy efficiency intervention. Both digital and non-digital serious games will be included. Interventions are also required to target energy behaviours. These are defined as any intervention which targets participant energy related behaviours across Residential, commercial, or public areas. These include appliance purchasing, appliance use, retrofits, etc.	Interventions which do not include a serious game, or which do not examine energy behaviour.
Comparison	While comparison studies are preferred any quantitative analysis of a serious game will be included.	Qualitative analysis of serious game effects, case studies or reports which do not include objective data on intervention effects. Design, Usability and feasibility studies will be omitted.
Outcomes	Energy consumption behaviour of participants (i.e. appliance use, appliance selection, energy use in the home etc.). Outcome data may be objective (i.e. energy meters) or subjective (i.e. participant self-report). Non-direct energy consumption	Non-energy consumption behaviour of participants (i.e. technology that increases energy efficiency such as lightbulbs) or travel choices (i.e. electric vehicles, public vs private transport, etc.)

[2] EndNote is a referencing software. Available at: https://endnote.com

[3] RAYYAN is a web and mobile application used to support multiple reviewers in completing systematic reviews. RAYYAN allows for blind review of manuscripts across researchers, facilitating comparison of disagreements. Available at: https://www.rayyan.ai

	behaviours such as the purchasing of appliances or retrofitting will also be included.	
Study	Any study published in a peer reviewed journal in the last 10 years in the English language will be included. In addition to grey literature which is academic in nature but not published in a journal will be included, specifically dissertations, reports and deliverables will be included.	Studies published before 2011 or not available in English will be excluded. Non-academic grey literature (i.e. news reports, blogs etc.) will also be excluded.

2.2.2 Data Extraction

Microsoft Excel was used to analyse extracted data. Study characteristics and interventions were analysed in table form. Extracted data included authors, publication year, location, research question, independent variables, dependent variables, design, duration, participants, characteristics of the serious game, serious game duration, serious game design, and follow-up data.

2.2.3 Inter-Observer Agreement

To ensure inter-observer agreement a minimum of 10% of articles were screened by a second independent reviewer (12.27% of title and abstracts, and 11.1% of full text articles). For title and abstract screening agreement of 91.4% was obtained. All disagreements were resolved through discussion, with only one article which could not be agreed upon being out forward for full-text analysis. For full text screening agreement of 100% was obtained.

2.2.4 Content Analysis

To examine the volume of BCTs within the included serious games, the behaviour change taxonomy v1 [BCTv1; 8] was used. The BCTv1 was selected due to its demonstrated efficacy in past reviews and its hierarchical nature allowing for ease of analysis. Additional rationale for the selection of the BCTv1 can be found in section 2.1.1. This measure seeks to characterise the use of specific behavioural techniques within interventions using a hierarchical structure. The BCTv1 includes 93 individual BCTs categorised into 16 clusters. Clusters include goals and planning, feedback and monitoring, social support, shaping knowledge, natural consequences, comparison of behaviour, associations, repetition, and substitution. comparison of outcomes, reward and threat, regulation, antecedents, identity, scheduled consequences, self-belief, and covert learning. Each eligible serious game was examined and scored against the list of 93 BCTs with a 1 marking the inclusion of a specific BCT and a 0 marking its absence. Where insufficient information was available on the contents of the serious game additional sources of information were sought including the game itself and other available documentation (i.e. website, project deliverables, etc.).

2.2.5 Methodological Quality Assessment

The Mixed Methods Appraisal Tool (MMAT) [25], was used to determine the quality of included studies. The MMAT is a critical appraisal tool designed to support researchers in examining the quality of manuscripts. The MMAT has been found to have good reliability and ease of use [26]. The MMAT was used as it allows for appraisal of a variety of research designs including qualitative, Randomised Control Trials (RCTs), non-randomised studies, descriptive analyses and mixed methods studies. As a variety of research designs were included within the current analysis the MMATs ability to allow for

comparisons across multiple designs was beneficial. Each included manuscript was graded on five criteria, with greater scores indicating higher quality.

2.3 Results

Database searches yielded 6090 articles. Following de-duplication 2268 articles were removed, leaving 3822 articles for review. Following title and abstract screening, a further 3776 articles were removed, leaving 45 articles for full text review. These 45 manuscripts were downloaded and examined with 21 meeting inclusionary criteria. Of the 24 articles excluded, 10 included a protocol for a serious game only, 5 discussed user input into design only, 5 did not include energy efficiency measures, 2 had no gamification, 1 included data modelling only, and 1 was published before 2011. A detailed description of the search protocol is presented in Figure 1.

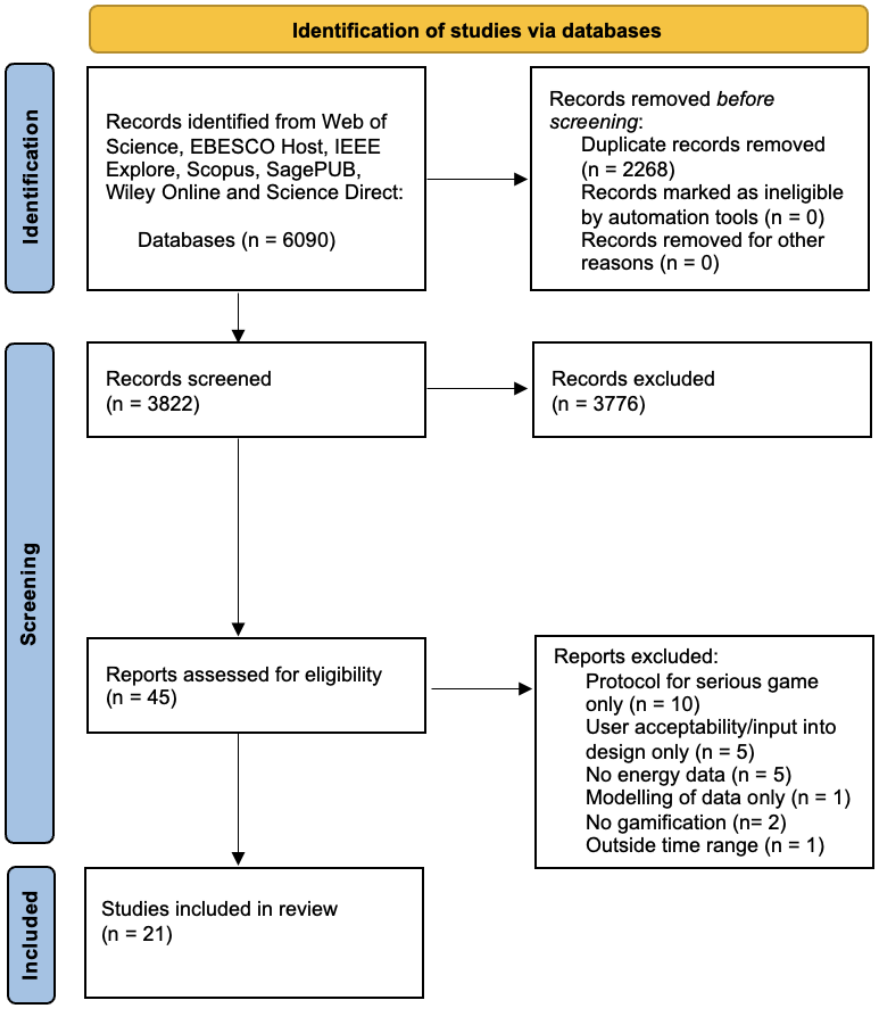

Figure 1: Prisma[4] Diagram

[4] Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is an evidence-based approach to the reporting of systematic reviews.

2.3.1 Demographic Characteristics

Of the included manuscripts, fourteen were published in peer-reviewed journals, one was a dissertation, and six were conference papers. Included articles were primarily published in 2017 (n=6), though a good distribution over time was noted with some published in 2020 (n=4), 2019 (n=3), 2018 (n=3), 2016 (n=1), 2015 (n=3), and 2014 (n=1). Serious games were used primarily in residential settings (n=10), though some examined commercial (n=8) and educational settings, (n=1) and public buildings (n=2). Interventions were conducted worldwide, though primarily in North America (USA=4, Canada=1) and Europe (Denmark =1, Netherlands =1, Germany=1, Portugal=1, Switzerland=1, Luxembourg=1, Sweden=1, United Kingdom=1), with one study conducted in Thailand. Only one study was conducted across multiple locations which explored the use of a serious game across five European cities [27]. No location was reported for five studies.

2.3.2 Experimental Design and Quality

The details of intervention characteristics are presented in Table 2Table 1. In terms of experimental design used, most employed a pre/post-test of energy consumption behaviour (n=17). Of the remaining interventions, one used a RCT in a residential setting, and three used non-randomised control trials in which the experimental group was self-selecting (1 residential, 2 commercial). The number of participants employed varied widely from 5 to 1909 (mean=177.6). Intervention duration also ranged widely from 30 minutes to 14 months, with an average length of 94 days.

Study quality as determined by the MMAT was mixed with an average score of 3 (range 2-5). Of the studies analysed five obtained scores of four or higher, suggesting good quality. Six obtained a score of two suggesting poor quality. Common limitations primarily pertained to unclear descriptions of sample selection processes and representativeness of the target population. Inadequate description of how participants were recruited, together with attrition and demographic information was noted across many of the included articles. Measurement and data analysis approaches undertaken were generally found to be appropriate.

2.3.3 Intervention Characteristics

In terms of measures of energy efficiency employed, the majority reported actual change in energy use (n=16). Of these, most employed sensor technologies (n=7) or energy provider recordings (n=7) to report on energy use. Two studies used camera recordings to determine changes in specific energy behaviours. Self-reported energy behaviour change was used in three instances, and in-game energy consumption behaviours were measured in two instances.

Interventions which sought to reduce energy consumption as a primary objective were the most commonly observed across included articles (n=19). For commercial interventions three sought to reduce consumption through monitoring plug loads, four sought to reduce consumption of an office or building (with one also seeking to increase pro-environmental behaviour and one seeking to increase energy awareness) and one used the Internet of Things (IOT) to support reductions in energy consumption. For interventions based in educational settings or public buildings (n=3) all sought to reduce consumption within specific areas of a building. Team competition between areas was also common in these settings (n=2).

Interventions targeting residential energy use common aims included reducing consumption through increasing awareness (n=4), load shifting to off-peak times (n=2) or to times where more renewable

sources were available (n=1), using IOT to support reduced consumption (n=1), rebound effects (n=1), and collective action to reduce pressure on energy systems (n=1). For those serious games targeting residential energy use 40% reported percentage change in energy consumed, with decreases ranging from 3-36% (M=15.2%). Reporting of percentage change in actual energy consumption was higher in commercial settings with 62.5% of studies including this information. Energy use in commercial settings reduced by between 4-34% (M=18.4%). All interventions in public buildings reported percentage energy change, with impacts ranging from 4.79-30%.

Table 2: Intervention Characteristics

Citation	Aim	Design	Duration	Participants	Data collection	Impact on Energy Consumption	Impact on other measures	MMAT
Bourazeri et al., [28]	Social Mpower requires users to work together within an online community to reduce energy consumption and avoid a black-out. Seeks to determine if collective awareness can be enhanced through a serious game.	Pre-Post Design	30 minutes	87	In-game decisions	Reduction in in-game consumption by 43.7%	N/A	2
Brewer et al., [29]	Sharebuddy is a serious game to encourage energy load shifts.	Pre-Post Design	1) 8 day 2) 3 weeks	1) 32 2) 30	Energy sensor Hot water sensor Survey Qualitative interview	Self-reported reduction in energy use across participants	N/A	2
Akasiadis, et al., [30]	The Energy Saving Game provides specific strategies to aid consumers in managing energy demand to maximise money savings, minimise energy use and support the stability of the overall energy system. Two versions of the game were tested, one which focused on economic gains and one which focused on social motivations using peer comparison.	Pre-Post Design	15 days	50	In-game decisions Questionnaire	Both resulted in in-game load shifting, with the social game slightly more effective	Good acceptance - 69.1%.	3
Lu [31]	Impact of an IOT playful cyber-physical system to support residential energy savings.	Pre-Post Design	2 hours minimum	22	Cameras recording energy use	Reduction in energy by 37%	N/A	2
Casals et al., [32]	Energy Cat is a serious game which seeks to reduce energy consumption and carbon emissions within social housing through linking game activities to real energy use within participants' homes.	Pre-Post Design	15-36 days	5 families	Application use Energy monitoring	3-10% reduction	N/A	2

Cowley & Batement, [27]	Green My Place seeks to reduce energy consumption through behaviour change.	1) Field trial 2) RCT	1) 1 year 2) 3 months	1) 419 2) 79	Online browser use Sensor for energy consumption	7-30% savings in energy across test sites	Game visits	5
Engel et al., [33]	Sema (Social Energy Management) seeks to motivate users to modify their energy sources to match renewable source production.	Pre-Post Design	2 months	17 households - 35 people	Game use Semabox and sensors used to record electricity use and presence at home	Shift in load profile for users observed	N/A	3
Fijnheer et al., [34]	Sought to examine if energy attitude, knowledge, engagement, and behaviour differed following use of the Powersaver Game in comparison to energy feedback in the absence of gamification.	RCT	5 weeks	21 households, 49 participants	Attitude, Engagement Energy use	21.4% reduction energy	Increased knowledge about energy conservation. No attitude change. High engagement	2
Gandhi, [35]	Cool Choices seeks to motivate the behaviour of office employees to reduce water and energy consumption through team-based competition.	Pre-Post Design	Not reported	24 employees	Plug load monitoring, Survey on behaviour change	Self-reported increase in pro-environmental behaviours. Small reduction in actual energy use for office appliances.	Good Engagement	3
Garcia et al., [36]	NRG serious game investigates residential rebound effects	Pre-Post Design	Not reported	50 users	In-game energy choices	Greater reduction of in-game energy behaviour for low efficiency houses in comparison to high efficiency houses	N/A	3
Hedin et al., [37]	Energy Piggy Bank seeks to facilitate more sustainable energy habits through information provision. Emphasis on different player types based on Bartle Player Types is noted.	Pre-Post Design	7 days	39 engineering students	Survey on intrinsic motivation and future behaviour change	Self reported increased in frequency of energy saving behaviours	Good motivation and engagement	3

Iria et al., [38]	GReSBAS seeks to support energy efficiency within office settings.	Pre-Post Design	14 months	400 users of an office building	Smart metering App use	20% reduction in energy use	N/A	4
Wuttipan et al., [39]	Power School seeks to support energy efficiency within schools	Pre-Post Design	3 weeks	134	CCTV Survey on behaviour change	Positive self-reported impacts on energy saving behaviour. Direct observation of classroom behaviour showed increased positive energy behaviours.	N/A	4
Koroleva et al., [40]	Outlines the design of a socio-technical behaviour change system for energy efficiency and tests its efficacy.	Control Trial	9 months	66 households	Actual energy consumption	5.81% decrease in energy consumption	Engagement - 54% used it once per month, good acceptance.	3
Kotospoulos et al., [41]	Museum Visitors Game seeks to support energy savings in an art museum by visitors. Protocol for a museum staff game is described but not tested.	Pre-Post Design	2 months	271 visitors	Stair use in comparison to elevator use	4.79% energy savings visitors.	Good usability and acceptance	3
Lou et al., [42]	Examined the impact of EnerSpace, a team-based serious game, on energy awareness and consumption in an office environment.	Pre-Post Design	2 weeks	8 employees (6m, 2f)	Energy meter readings Survey Interview	Average hourly consumption reduced by 21%	Increased energy awareness.	3
Orland et al., [43]	The Energy Chickens seeks to determine the impact of a serious game to reduce plug loads in an office setting.	Control trial	16 weeks	57	Plug load sensors Survey.	13% reduction in plug loads for game group	Increased energy awareness	4
Rafsanjani et al., [44]	Examined the impact of an IOT based smartphone assistant to support office energy savings.	Pre-Post Design	12 weeks	10	Energy load data	34% energy savings	N/A	2

Ro et al., [45]	Development and testing of Cool Choices, a serious game to encourage sustainable energy use in the office.	Pre-Post Design	1) 6 months 2) 2 months	1) 220 2) 1909 individuals	1) electricity bills 6-month pre/post 2) Self-report energy behaviour change	1) 4% energy savings 2) 442.01 kWh per year saved	Attitude towards sustainability increased	4
Oppong-Tawiah et al., [46]	Examined the use of the design cycle to develop Kewai mobile app to reduce office energy consumption and increase pro-environmental behaviours.	Control Trial	6 weeks	12	Consumption Survey on acceptability and enjoyment	Greater reductions for intervention group. Maintained at 2 week follow-up	Good enjoyment	3
Hafer et al., [47]	Examined the use of an IOT based smartphone assistant to support office energy savings through reduced plug loads.	Pre-Post Design	71 days	20	Energy consumption Acceptability	21% reduction in consumption	Good acceptability	3

2.3.4 Serious Game Characteristics

The serious game characteristics are described in detail in Table 3. Of the included serious games, eight were played using smartphone applications, seven used an online browser, three were played on desktop computers, two included an online platform and application, and one used both sensors and a desktop computer. Across the included serious games, only four reported user input into the design. Common means of which included focus groups, user requirements analysis, and ongoing user input within the design cycle. Follow-up data was captured by four serious games with follow up periods ranging from eight days to one year. For three out of four games, the energy behaviour changes were maintained over time.

Table 3: Serious Game Design

Citation	Serious Game	User input into design?	Technology Used	Follow-up conducted?	Key Game Components	BCTs included
Bourazeri et al [28]	Social Mpower	Not reported	Desktop computer	Not reported	Social networking Feedback Incentives	12
Brewer et al [29]	ShareBuddy	Not reported	Application	Not reported	Feedback	15
Akasiadis et al [30]	Energy Saving Game	Not reported	Online browser	Not reported	Financial incentive Competition	11
Lu [31]	IoT-Enabled Cyber-Physical System	Not reported	IOT-sensors, desktop	None	Pet raising incentive Feedback	6
Casals [32]	Energy Cat	Yes- focus groups, user requirement analysis and user co creation.	Application	Not reported	Feedback Competition	15
Cowley & Batement, [27]	Green My Place	Not reported	Online browser	Not reported	Competition Individual rankings Social media	12
Engel et al., [33]	Sema	Not reported	Online platform and app	Not reported	Peer comparison	13
Fijnheer et al., [34]	Powersaver	Yes - iterative user-centred game design methodology	Online browser	21 day follow-up	Peer comparison Feedback Competition	10
Ro et al., [45]	Cool Choices	Not reported	Application	6 month & 12 month follow up with reduction remaining.	Feedback Competition Peer comparison	
Gandhi et al., [35]	Cool Choices	Not reported	Online browser	None	Competition Feedback	12
Garcia et al., [36]	NRG	Not reported	Online browser	None	Feedback Aim	2
Heidin et al., [37]	Energy Piggy Bank	Not reported	Application	Not reported	Incentive Prompts Social comparison Habit formation	10
Iria et al., [38]	GReSBAS	Not reported	Desktop computer	None	Feedback	12
Kiatruangkrai & Siricharoen, [39]	Power School	None	Online browser	None	Points Challenges	5

					Competition	
Koroleva et al., [40]	Integrated socio-technical behaviour change system for energy saving	Yes - user centred design process.	Application	Not reported	Comparison Leaderboard Tips Prompts Feedback.	10
Kotospoulos et al., [41]	Museum Visitors Game	Not reported	Application	Not Applicable	Progression Reward Feedback	4
Lou et al., [42]	EnerSpace	Yes user input into design.	Online browser	None	Competition Feedback.	12
Orland et al., [43]	Energy Chickens	Not reported	Desktop computer	8 week follow-up. Energy changes did not persist.	Feedback Goals	12
Rafsanjani et al., [44]	Developing a gamified mobile application to encourage sustainable energy use in the office	Not reported	Application	Not reported	Individualised feedback	5
Oppong-Tawiah et al., [46]	Kewai mobile app	Yes- user focus groups and feedback.	Online platform and application	Results maintained at 2 week follow up	Tracking Feedback	5
Hafer et al., [47]	IOT based smartphone assistant	Not reported	Application	Not reported	Tracking Feedback Points	6

2.3.5 Content Analysis

The content of all included serious games was analysed using the BCTv1. On average, a good volume of BCTs was noted across serious games with an average of 9.45 individual BCTs included (Range=2-15). 36 individual BCTs were included across all the serious games analysed. It is of note that for "NRG" [36] which contained only 2 BCTs, the aim of the serious game was the exploration of rebound effects rather than any specific intent to change behaviour which may explain the lower BCTs included.

The BCT groupings most commonly featured were feedback and monitoring (n=66 BCTs across 21 serious games), rewards and threat (n=31 BCTs across 15 serious games), goals and planning (n=27 BCTs across 15 serious games), social support (n=15 BCTs across 10 serious games), and comparison of behaviour (n=13 BCTs across 12 serious games). No BCTs from regulation, antecedents, self-belief or covert learning groupings were found.

Of BCTs themselves the most commonly included were those associated with monitoring of behaviour. Monitoring of behaviour by others without feedback (n=18) was the most commonly occurring BCT. Feedback on behaviour (n=17) and self-monitoring of behaviour (n=12) were also commonly observed across serious games, with many including visualisations or graphs outlining energy consumption over time. Social comparison (n=12) and social support (both practical n=7 and unspecified n=8) were both common across serious games with many including team or individual competitions to support behaviour change. Refer to Table 4 for frequency of BCTs across serious games.

Table 4: BCTs within Serious Games

BCT	Number of Games Included In
2.1. Monitoring of behaviour by others without feedback	18
2.2. Feedback on behaviour	17
2.3. Self-monitoring of behaviour	12
6.2. Social comparison	12
2.5. Monitoring of outcome(s) of behaviour without feedback	11
1.6. Discrepancy between current behaviour and goal	9
5.3. Information about social and environmental consequences	9
2.7. Feedback on outcome(s) of behaviour	8
3.1. Social support (unspecified)	8
13.1. Identification of self as role model	8
3.2. Social support (practical)	7
1.2. Problem solving	6
10.1. Material incentive (behaviour)	6
1.3. Goal setting (outcome)	5
7.1. Prompts/cues	5
10.8. Incentive (outcome)	5
10.10. Reward (outcome)	5
1.1. Goal setting (behaviour)	4
10.3. Non-specific reward	4
10.4. Social reward	4
1.4. Action planning	3
4.1. Instruction on how to perform the behaviour	3
8.3. Habit formation	3
14.2. Punishment	3
10.2. Material reward (behaviour)	2
10.5. Social incentive	2
1.7. Review outcome goal(s)	1
6.1. Demonstration of the behaviour	1
7.5. Remove aversive stimulus	1
8.2. Behaviour substitution	1
8.4. Habit reversal	1
9.3. Comparative imagining of future outcomes	1
10.6. Non-specific incentive	1
10.9. Self-reward	1
10.11. Future punishment	1
14.9. Reduce reward frequency	1

2.4 Implications for EVIDENT

The results of the present systematic review and content analysis present several implications for EVIDENT.

2.4.1 Outcomes

Firstly, the results of the systematic review provide support to the impact of serious games on energy consumption, with all interventions reporting positive effects on energy outcomes. Additionally, the emphasis on objective measures of behaviour is clear, with most serious games (n=16) including measures of actual energy behaviour rather than self-report only. It is of note that 60% of residential serious games did not report the degree of change in actual energy consumption, with two studies reporting on load shifting, two using self-reported changes in energy behaviour and one reporting in-game energy decisions only. To allow for comparison of intervention effects, objective measures of actual behaviour change following serious games use are needed. In the context of the EVIDENT project, consideration will need to be given to how best to ensure that behaviour change in response to the serious game is accurately captured in a manner that allows for impact on energy behaviour to be determined.

2.4.2 Experimental Design

A notable finding from the current systematic review pertains to the methodological quality of included studies. While some included studies were found to be of high quality, common limitations included unclear descriptions of participant recruitment and demographics, making the representativeness of the sample difficult to determine. Additionally, of the included studies, only one employed an RCT while three used non-randomised control trials with the vast majority of studies using a pre/post-test design. This reliance on quasi-experimental methods may limit the reliability and external validity of findings [48]. These methodological limitations are consistent with past research [6], [7]. This suggests a need for additional consideration regarding the methodological design to be used to examine the impact of the EVIDENT serious game. Increased use of RCTs should be considered to demonstrate a more robust analysis of effects. Efforts are needed to ensure that large, representative samples are employed and that treatment and control conditions are representative of the population at large. The EVIDENT project will address these limitations through the use of a large-scale randomised-control trial to determine intervention effects.

2.4.3 Follow-up

A further factor of note is the absence of follow-up measures. Only four studies included follow-up data, of which three demonstrated maintenance of effects over time. Of these four studies, most were of very short duration, with three containing follow-up periods of three weeks or less. It is encouraging however, that in one instance energy behaviour was maintained at 12 months [45]. For serious games to be effectively employed energy behaviour change must maintain over time. To this end, consideration should be given to including follow-up measures to determine the impact of a serious game over time. Within the EVIDENT serious game, a follow-up survey will be conducted at least 6 months following completion of the serious game. This will allow for analysis of effects over time as well as provide an opportunity for participants to engage in repair/replacement decisions.

2.4.4 Game Components

The results of the systematic review highlight several gamification strategies employed with success within serious games for energy consumption. Common strategies included ongoing feedback on energy use and progress within the game, incentives, competition, peer comparison, prompts, and challenge setting. With regards to peer comparison, the use of a leaderboard to compare points accumulated or progress within a game was commonly used. In addition, a number of serious games were team rather than individual-based, with teams working together to meet a goal while competing against other teams. These results highlight the importance of considering the role of different game components within the serious game design to support user engagement and behaviour change. Within the EVIDENT serious game, consideration will be given to the use of these game components, with peer comparison, incentives, prompts, feedback, and competition key components to be employed.

2.4.4.1 Werbach's Gamification Framework

While gamification techniques continue to progress, gamification often is ineffective due to an absence of clear formal planning within the design process [50]. To ensure gamification is effectively employed within EVIDENT consideration should be given to game design theory [51]. Consistent with the approach taken by past H2020 projects [37], Werbach's gamification framework [49] will be used to determine how gamification will be employed within the EVIDENT serious game. Detail is provided below on each of the six aspects of the framework as they apply to EVIDENT.

1) Define Objectives: The primary goal of the EVIDENT serious game is two-fold. Firstly, the serious game seeks to determine the impact of energy related financial literacy, demographic factors, and behavioural intention on decisions to repair or replace Household appliances across resident types. Secondly, the serious game seeks to teach users how to make more effective repair/replace decisions, when considering both the financial and environmental impacts.

2) Delineate Target Behaviours: The primary target behaviour is for players of the serious game to choose the most environmentally and financially effective option when presented with the opportunity to repair or replace an appliance. In response to these choices gauges on the screen that indicate comfort, environmental and financial impact will change to reflect the impacts of choices made. Based on these gauges players will be given points and feedback on how to make better choices in the future. Points will be used to determine the users place on a leaderboard at the end of the game to allow for competition and peer comparison. A secondary target behaviour is for the user to engage with their virtual home. This will consist of interacting with appliances as they go about their virtual lives (i.e. turning lights on/off etc).

3) Describe your player: The EVIDENT serious game targets a wide variety of individuals as players. As appliance purchasing is a common activity, any adult may find value in playing the game. Individuals with a particular interest in energy efficiency or environmental matters may be more likely to play the game, as this topic is likely of interest to them.

4) Device Activity Cycles: The game will take place across a series of days with players tasked with trying to maintain their home environment across this period. While the game will mimic a typical day, the in-game speed will be increased so that one day will take approximately 2 minutes to complete.

5) Don't forget the fun! Fun will be enhanced for users through the use of points and competition. Users will be tasked with trying to maintain their comfort, environmental impact and financial impact gauges so as to gather as many points as possible and get a higher place on the leaderboard. This competition is hoped to enhance player motivation and engagement. Additionally, feedback and tips on energy decision making will be provided in a light and entertaining manner, again to support user enjoyment while developing skills.

6) Deploy Appropriate tools: The following game components will be employed, namely, peer comparison, incentives, prompts, feedback and competition.

2.4.5 Behaviour Change Techniques

The results of the content analysis suggest a strong use of BCTs within serious games for energy efficiency. BCTs pertaining to the monitoring of behaviour, provision of feedback on behaviour, support to self-monitor own behaviour, social comparison and social support commonly occurred across included serious games. It is also interesting to note the relatively low inclusion of BCTs pertaining to habit formation and prompting. As energy use is often a habit or routine driven behaviour additional support to ensure behaviour change becomes a part of a person's typical routine may support ongoing behaviour change. In light of these findings, consideration has been made regarding how BCTs will be employed within the EVIDENT project. Outlined below are the BCTs which will be considered for inclusion within the EVIDENT serious game.

BCT 1.2. Problem solving: The EVIDENT serious game will support the user to examine their decision-making pertaining to repairing or replacing an appliance and analyse the factors influencing their decision. The aim of this is to help the individual to understand more fully the factors that impact their decision and give them the skills to understand how to make more energy efficient choices while considering these important factors through the provision of strategies.

BCT 2.2. Feedback on behaviour: The EVIDENT serious game will monitor the in-game energy decisions made by users. Information and feedback will be provided to users based upon the decisions.

BCT 4.1. Instruction on how to perform the behaviour: The EVIDENT serious game will provide information and feedback to users on how to go about making repair/replace decisions while considering both environmental, financial and personal (i.e. time constraints, local market, physical space) considerations. Information and skills training will be provided in tandem with feedback following the players first repair/replace decision. Consideration will also be given to the use of prompts and in-game advice to support ongoing effective choices within the game.

BCT 4.4. Behavioural experiments: Through the provision of information on how best to determine whether to repair or replace an appliance, users will be given the tools to conduct their own behavioural experiments in practice by collecting needed data and establishing which choice would be most effective.

BCT 5.3. Information about social and environmental consequences: Through drawing attention to the environmental and financial impacts of inefficient energy decisions users will be made more aware of the impacts of their choices both in the short and long term.

BCT 5.5. Anticipated regret: Through drawing the attention of users towards the financial costs of ineffective repair/replace decision making over time, the EVIDENT serious game may draw regret over future losses by users.

BCT 6.2. Social comparison: The EVIDENT platform will include a leaderboard that will allow for users to compare own performance to that of their peers. In-game decisions will result in points gained or lost for the user which will be included anonymously on the leaderboard.

BCT 8.1. Behavioural practice/rehearsal: Through repeated opportunities to practice repair/replace decision making and to gain feedback on the decisions made, behavioural rehearsal is facilitated. Repeated practice opportunities are hoped to support skill development for the user allowing for generalisation to real-life decision-making scenarios.

BCT 10.3. Non-specific reward: Rewards in the form of points will be provided to users for more efficient repair/replacement decisions. Users will be given or deducted points following a repair/replace decision based upon the option chosen to show both the financial and environmental impacts of their decision.

BCT 10.4. Social reward: Praise and feedback will be provided to users in response to more efficient in-game choices.

BCT 10.8. Incentive (outcome): Users of the EVIDENT serious game will be advised at the start of the game that the aim is to accumulate as many points as possible while maintaining their in-game home. At the end of the game, users can compare scores with peers and see where they place on the leaderboard. This incentive is hoped to support users to engage in the game and make more considered decisions.

BCT 10.9. Self-reward: Self-praise will be prompted through the provision of feedback within the game following user decision making. When users make more efficient decisions or show progress praise will be provided as well as prompts for self-praise.

3. Serious Game Concept

3.1 Concept

The EVIDENT serious game has two primary purposes. Firstly, it seeks to examine how different consumers determine whether an appliance should be repaired or replaced and what factors impact this decision. Specifically, the impact of financial, environmental, behavioural and socio-economic factors on willingness to repair or replace a household appliance will be explored. Additionally, the EVIDENT serious game seeks to support individuals to make more effective decisions by providing them with advice on how to determine which option is best for their circumstances, while considering financial, environmental and personal concerns. Through this, the users of the serious game will learn simple rules and tips which they can apply in real-life when making similar choices.

The serious game itself is a life simulation type game within which players are tasked with maintaining a home over the passing of time. Participants will be assigned a role in keeping with their residential status (i.e. landlord, tenant or homeowner) and will be given an avatar to represent themselves within the game. The participants then can move this avatar around their virtual home and complete a series of actions, all with the aim of maintaining both their avatars home and their comfort. The overall aim for participants will be to try to keep their avatars comfort score up, while also making sure their environmental impact doesn't get too high. Participants will be given a monthly sum of money which they have to stick to while making sure they can pay rent, heat, and food amongst other costs. The participants actions in the game will be guided by indicative gauges which will show their comfort, environmental impact (based upon Kw/h of energy use within the game) and finances. Comfort ratings will reduce should an avatars basic needs not be met (i.e. food, heat etc.) and is included as a means to motivate users to engage in actions in their home environment. At the end of the game, participants will be given a final score based on their environmental impact, comfort and finances and can see where they fall on a leaderboard.

Shortly into the game, an appliance will break and users must decide whether they would like to repair or replace the appliance. Users will be prompted to call a repairperson and will enter into a discussion about the options available to them. Users will have the option to choose to purchase a repair for the broken appliance or can purchase a new appliance. For new appliances, differing levels of energy efficiency and cost will be available. Depending on the option selected participants will then enter into a negotiation with the repairperson to determine their willingness to pay for a repair, or a more efficient appliance if choosing to replace. For those who are landlords or tenants, discussions will vary slightly, with tenants given the option to pay more rent or a small fee in exchange for a better appliance, and landlords given the option to accept more rent from tenants in exchange for a better rated appliance. Once a final choice is made users will be given some feedback on their decision and some advice on how to more easily determine whether to repair or replace a broken appliance. Users will then continue in the game, navigating more appliances that break. Upon completion of the game, users will be given a final score and informed of where they fall on the leaderboard.

3.2 Game objectives

3.2.1 User Objectives

The primary goal for users is to try to maintain their virtual home while keeping comfort, environmental and financial gauges as high as possible. These gauges will be impacted by decisions within the game, with points gained for good energy choices and lost for poor energy choices. At the end of the game the points gained will be given as a total score and the user informed of their place on a leaderboard. Postings on the leaderboard will be anonymous. Users will be advised also of where their score falls relative to the average. For example, they may be told "Your score is in the top 10% of all users". Consideration is also being given as to whether local leaderboards could also be provided based for participants. This would allow a group of users based in the same location or in the same office or university to determine where they fall relative to their neighbours.

3.2.2 Research Aims

Broadly, the serious game seeks to determine two primary questions of concern. Firstly, it seeks to establish the impact of financial, energy and environmental literacy on decisions to repair or replace appliances across different resident types. Secondly it seeks to determine the impact of providing information on financial literacy on future repair/replace decisions.

Four secondary research questions will also be examined. Firstly, the impact of the salience of financial information (i.e. how the financial cost of the decision over time is displayed) on decisions to repair or replace will be considered. Secondly, the impact of information framing on willingness to pay for a repair or replacement of an appliance will be examined. Specific frames to be explored may include financial, lifecycle and environmental. Thirdly, using a follow-up survey, the impact of serious game learnings on actual behaviour will be examined (i.e. did users have an opportunity to make a repair/replace decision and what was chosen). Finally, through qualitative analysis an in-depth exploration of the factors which may impact decisions to repair or replace will be conducted.

3.3 User roles

Three user groups will be included within the serious game. These include residential property owners, tenants and landlords. Based on a participant's current role (as determined through the pre-game survey), users will play the game as that same resident type. For those with more than one residential status (i.e. those that are both landlords and homeowners), a role will be randomly assigned from one of those selected.

Homeowner: Property owners are defined as individuals who have purchased and currently reside in that property.

Tenant: Tenants are defined as those who are living in accommodation rented from a landlord, letting company or similar entity.

Landlord: Landlords are those who own a property which they charge rent on. Landlords who rent only a portion of their current residence (i.e. they reside with their tenants) will also be included.

3.4 Protocol

The serious game consists of a series of decision points in which the user is tasked with 1) maintaining their home, 2) maintaining their comfort, and 3) choosing whether to repair or replace a broken

appliance, and how willing they are to pay for this. An overview of the flow of the serious game is presented below (See Figure 2). Additional detail on the proposed protocol can be found in D2.1 "Field studies, serious game and surveys protocols design and pilots design".

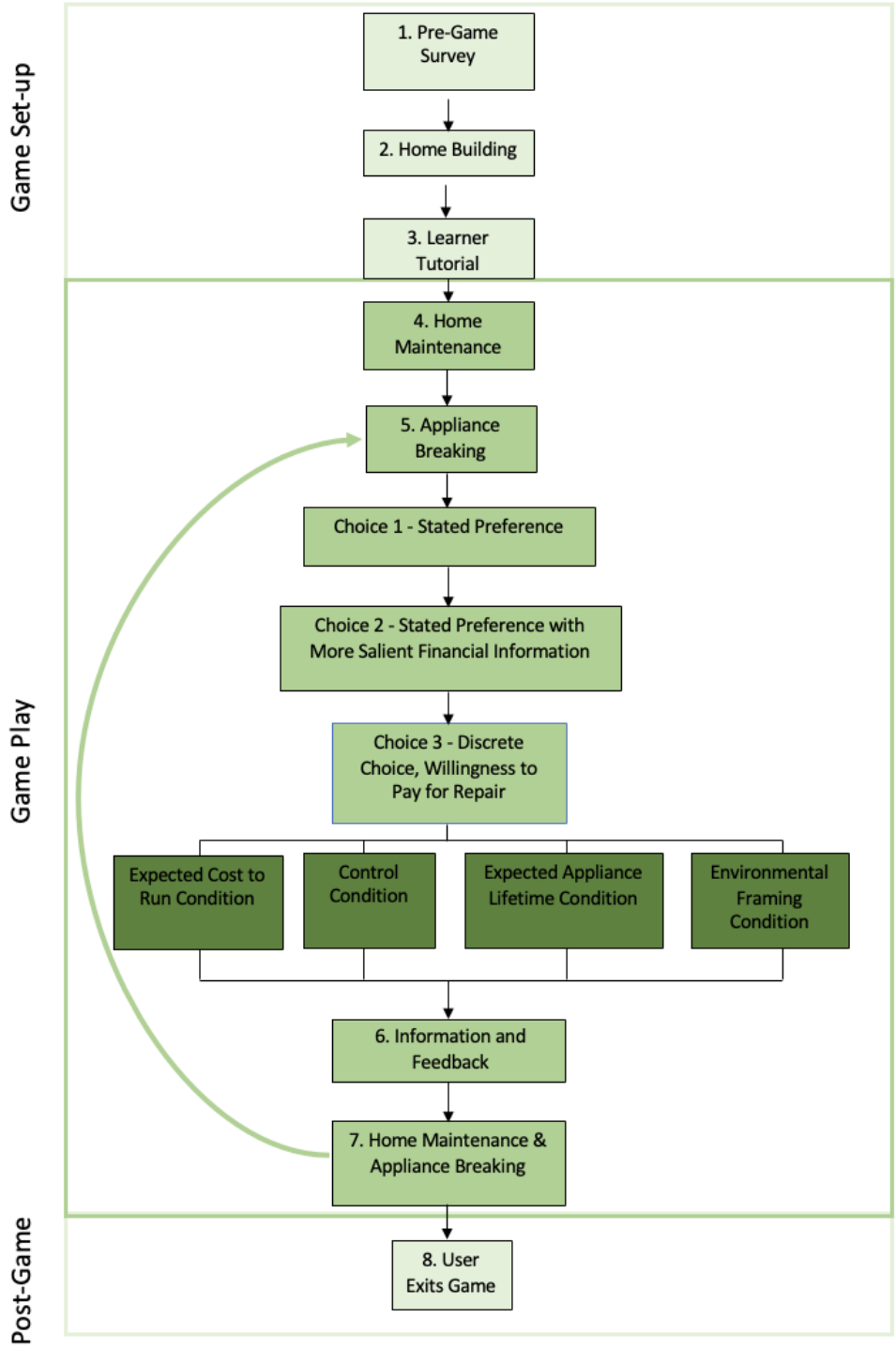

Figure 2: Serious Game Protocol

1) Pre-game Survey

Prior to starting the serious game the user will complete a short survey to examine the participants energy related financial literacy, behavioural intention, environmental literacy and other socio-demographic factors. The specific context of the survey and measures to be included will be

determined based on the recommendations of D1.2 “Behavioural biases and financial literacy”. An outline of survey questions can be found in D2.1 (section 4.1.3.2.).

2) Home Building:

After completing the survey users will enter into the serious game and begin to build both their avatar and home. Users will be given their avatar and shown their virtual home. While the user will be unable to amend the layout and positioning of objects within the home, they may change some aesthetic aspects of some home appliances and their energy rating.

3) Learner Tutorial:

Once the user has personalised the layout of their home, they will complete a short interactive tutorial wherein they will be shown how to interact with the game to move their character and complete actions. This tutorial will take place over the course of one virtual in-game day. Pop up boxes will be used to guide users to engage in actions and will provide information on the meaning of the icons. Appliances that can be interacted with will be illuminated to guide the user to interact with them. In addition, the overall goal for the user will be made clear. User attention will be directed to the three gauges and the actions required to positively affect these scores. As mentioned previously, users are given three point scales, one for comfort, one for environmental impact and another for financial impact. Their aim is to keep these gauges as high as possible while maintaining their house

4) Home Maintenance:

The user then enters into the first stage of the game wherein they are prompted (through the comfort gauge and pop-up notifications) to interact with the different appliances in their house. For example, users may be reminded to turn the lights on at night time so their avatar can see, or to turn up the thermostat if the weather turns cold. Each of these actions will result in changes to the users environmental, financial and comfort gauges to show the impacts of their actions.

5) Appliance Breaking:

As the user continues to maintain and interact with their home, they will be faced with an appliance breaking. The user will be informed an appliance has broken through both a visual representation (i.e. smoke, flooding) and through a pop-up notification. Users will first be given an option to try to repair the machine themselves should they wish. This will be ineffective, and as such the user must call a repairperson to repair or replace the appliance. They discuss with the repairperson the options available to them. Three opportunities to choose between repair or replace will be presented, with each choice building on the last. The information provided at each choice point will differ depending on the experimental condition to which the individual is assigned. During each choice point the time within the game will be paused, to ensure users have sufficient time to consider their options without negatively impacting their avatar (i.e. the avatar remains frozen while each choice is made so comfort level will not change).

Choice 1: Stated Preference. The repairperson provides the player with four options. These are to 1) repair the appliance, 2) replace the appliance with one that is more expensive with a higher energy efficiency rating 3) replace the appliance with one that is less expensive and less energy efficient or 4) replace the appliance with one with the same energy efficiency rating that is mid-priced. For all options the cost, kilowatts per hour and an average cost of one kilowatt per hour of energy is provided

Choice 2: Stated Preference. The same options as above are presented but with more salient financial information provided. In this instance, the monthly cost to run the appliance will be given to the user to help them determine if they would like to change their choice.

Choice 3: Discrete Choice. Once the user has decided their preferred option, they negotiate with the repairperson to determine their willingness to pay for a repair. For those who chose to replace the appliance, the repairperson will bargain with the user and offer a 'deal' that reduces the price to repair. For those who chose to repair, the repairperson will find a more expensive problem with the appliance and, as a result, the price of repair will increase. In both instances, this will allow us to determine how willing the user is to pay for a repair for their appliance. To determine the impact of financial and environmental information on the willingness to pay for repair participants will be allocated to one of four conditions for this choice. These may include expected appliance lifetime, expected cost to purchase and run appliance over lifetime, environmental framing, and a control condition.

6) Information and Feedback

Once a user makes their final decision to replace or repair, the repairperson will either fix or replace the broken appliance. Following this, feedback will be given to the user on the financial and environmental impacts of their choice through both the point gauges and written pop-up feedback. The user will then be shown a short set of tips on how best to make these decisions, including how to calculate the cost of an appliance over time and how to determine the expected lifecycle of a product. Attention will also be directed to the future financial savings associated with purchasing a more expensive, but more efficient appliance.

7) Home Maintenance & Appliance breaking

The user then returns to the task of maintaining their home, again monitoring the impact of their actions on their avatars comfort, energy use and finances. After a while, additional appliances will break and users will return to step 5. Users will now have the opportunity to use their newly acquired skills in determining whether to repair or replace the broken appliances.

8) User exits game

The user can continue to loop between steps 5 to 7 until they choose to exit the game. Upon exiting the game the user is shown their total points attained, their resulting place on the leader board and where they fall relative to the average user. Additional information and tips on energy efficiency and financial literacy are provided.

3.5 User Input Into Design

3.5.1 Preliminary User Workshop

As part of European Researchers' Night (22 September 2021) a workshop titled "Save money and the planet? Help the EVIDENT project understand decision making and impact climate change!" was conducted to gather some preliminary user input into the design of the EVIDENT serious game[5]. Members of the general public attended and information was shared with them on the goals of the EVIDENT project, and insight was gathered on how the serious game should be designed and what it

[5]European Researchers' Night workshop link: https://www.tcd.ie/research/start/evident.php

should consider. Attendees were given an overview of energy efficiency, serious games and the EVIDENT project and participated in a series of interactive activities and discussions.

In total four members of the general public attended and shared their suggestions on the serious game. Participants noted price as their primary concern when seeking to purchase or repair an appliance. Ensuring the appliance was at an acceptable price point was a primary concern, with other factors secondary to this. Following price, ensuring the appliance would fit within the existing space (i.e. physical dimensions, colour etc), and delivery time were also seen as important. Energy ratings were dismissed as unimportant by participants, with distrust in such ratings raised. This input highlights the need for EVIDENT to examine how we may be able to increase consumers' willingness to consider energy ratings when choosing an appliance. It is clear that the financial impacts of appliance purchases are of high importance with price a big concern. Through directing consumer attention towards the cost savings associated with higher energy ratings over a product's lifetime, increased willingness to consider energy ratings may be considered.

With regards to the use of serious games, participants had not had the opportunity to play a serious game but were interested in their use. When asked how long a serious game should take to complete participants noted that they would only play a serious game for 5-10 minutes, including any time needed to complete pre-game surveys or tutorials. However, should the topic be of interest they may be willing to play a little longer. This highlights the importance of ensuring user fun and engagement within the EVIDENT serious game to reduce the risk of attrition. In addition, ensuring the game does not take too long to complete also appears important, with participants willing to leave a game quickly if it is not a topic of interest. This will be particularly important when considered in the context of ensuring participants are representative of the population as a whole, as those who are not motivated by environmental concerns may not be willing to complete the game or may quit the game prematurely.

3.5.2 User Focus Groups

To further examine user perspectives on the serious game a series of focus groups will be conducted. The primary objectives of these focus groups will be to ensure that the serious game is engaging while having high usability and acceptability. Further, user feedback on the learnings gained through the game will also be considered to ensure the game is meeting its aim of supporting consumer decision making. To address these goals a series of focus groups will be conducted. Focus groups will consist of between 10-20 individuals, with between 20-50 individuals total contributing across groups. Efforts will be made to ensure that users who participate in the focus groups are representative of the population as a whole, with specific efforts to be made to recruit individuals from each residence group and those who are elderly or low income.

Within the focus groups, participants will be asked to complete the serious game and associated surveys. Following this feedback will be sought through individual surveys (including both open and close-ended questions) and group/individual interviews. Insight into the alignment of the serious game with decision making contexts in real-life environments will be queried to ensure all necessary variables are accounted for. Specific measures of the usability will be employed through the System Usability Scale (SUS). The SUS is a 10-item measure that enables users to provide insight into how difficult a game is to play. The SUS allows for a total usability score to be obtained, with scores below 68 considered to have poor usability [52]. Input gathered through the user focus groups will be used to guide further game development and will allow usability and engagement to be increased prior to piloting.

4. Software Specifications and Architecture

This chapter describes the software specifications and the architecture of the EVIDENT serious game. The way in which the platform will be implemented, the technology used and the reason it was created will be described in detail. Finally, the different scenarios and modes that the player can choose will also be mentioned.

4.1 User and Scenario parameterization

By design, the EVIDENT Serious game is a configurable game. The configuration will have two parts. The first part is the scenario parameterization part. There are two JSON files that are used for the serious game's configuration. JavaScript Object Notation (JSON [53]) is a lightweight data-interchange format. It is easy for machines to parse and generate and also for humans to read and write. JSON is built on two structures:

- A collection of name/value pairs. In various languages, this is realized as an object, record, struct, dictionary, hash table, keyed list, or associative array.
- An ordered list of values. In most languages, this is realized as an array, vector, list, or sequence.

The first JSON is responsible for the scenario parameterization, where the creator of the game can change some key components of the game. With that JSON the administrator can customize the scenario based on the objectives of their research. There are some key factors that the administrator can decide if they should be part of the scenario or not. First of all, the administrator chooses which home appliances should break down and which should not. That should be quite useful in case the administrator wants to determine the users' decisions regarding specific home appliances. Also, other factors such as the user's age, role, income, gender etc. could be considered by the administrator when deciding whether to amend the scenario. As an example, the user's finances, which will be one of the game's gauges and will be described later, can adapt to the user's real income. The second JSON file will be a file that will have the user's unique ID and the data which the user had given earlier. That data will have to do with the factors described previously, like the user's gender and income. Presented below is how one of the above JSON files is structured and how the game deserializes the JSON file. The second JSON file with the user's answers will be used as an example. See that JSON file in Figure 3. We have the user, the session ID, the date and the answers of the user on a previous questionary, until line 14. Then the answers are about the answers of the user inside the serious game.

```
1  {
2    "export_date": "13/08/2021",
3    "session_id": "654",
4    "user": "300",
5    "answers_amount": 2,
6    "answers": [
7      {
8        "ID": 656,
9        "234": {
10         "user_type": "landlord",
11         "user_age": "30",
12         "user_income": "10000",
13         "user_gender": "female"
14       },
15       "454": {
16         "answer_one": "334",
17         "answer_two": "yes",
18         "answer_three": "25.000€"
19       },
20       "121": {
21
22       }
23     },
24     {
25       "ID": 600,
26       "234": {
27         "user_type": "home_owner"
28       },
29       "454": {
30         "answer_one": "250",
31         "answer_two": "yes",
32         "answer_three": "18.500€"
33       },
34       "121": {
35
36       }
37     }
38   ]
39 }
40
```


Figure 3: A JSON file with the user's ID example

For deserialization of the JSON file, a parser is needed. A parser is a class that will contain every class of the JSON file, so the deserialization process knows how to store every data from the JSON file to a C# object. Figure 4 shows the classes for the above JSON file. As there are some classes with numeric names, JsonProperty was used because in C# field names cannot start with a number.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Newtonsoft.Json;

1 reference
public class AnswerJsonParser : MonoBehaviour
{
    1 reference
    public class _234
    {
        0 references
        public string user_type;
        0 references
        public string user_age;
        0 references
        public string user_income;
        0 references
        public string user_gender;
    }

    1 reference
    public class _454
    {
        0 references
        public string answer_one;
        0 references
        public string answer_two;
        0 references
        public string answer_three;
    }

    1 reference
    public class _121
    {
    }
```

```
1 reference
public class Answer
{
    0 references
    public int ID;
    [JsonProperty(PropertyName = "234")]
    0 references
    public _234 _234;
    [JsonProperty(PropertyName = "454")]
    0 references
    public _454 _454;
    [JsonProperty(PropertyName = "121")]
    0 references
    public _121 _121;
}

3 references
public class RootAnswers
{
    0 references
    public string export_date;
    0 references
    public string session_id;
    0 references
    public string user;
    0 references
    public int answers_amount;
    0 references
    public List<Answer> answers;
}

}
```

Figure 4: Parser for parsing the JSON file in Unity

Finally, the deserialization process takes place. With the parser and all classes ready, with the DesializeObject command, the JSON's data is converted into C# classes, as shown in Figure 5.

```
1 reference
private RootAnswers LoadData(string filename)
{
    string _path = Path.Combine(Application.persistentDataPath, filename); //the path of the file
    string _data = File.ReadAllText(_path); //read the file
    return JsonConvert.DeserializeObject<RootAnswers>(_data); //Deserialize JSON
}
```

Figure 5: Deserialization of a JSON file

4.2 Game Environment Modelling

The 3D model of the building, the furniture and the home appliances were created using the Blender application, which is a free and open-source 3D computer graphics software toolset. See Figure 6 below for an overview of the serious game's main building on Blender. The 3D models were created by using "low poly" logic, because of the nature of the application. As the application will be both an android and a WebGL application, which will be described in more detail below, "low poly" 3D models were necessary for the application to be as lite as possible. It is well known that the more triangles there are in a mesh, the more detailed the object is; however, more computationally intensity is needed for it to be displayed. In order to decrease render times the number of triangles in the scene was reduced using low poly meshes. That provides the opportunity to create an application with the lowest requirements possible.

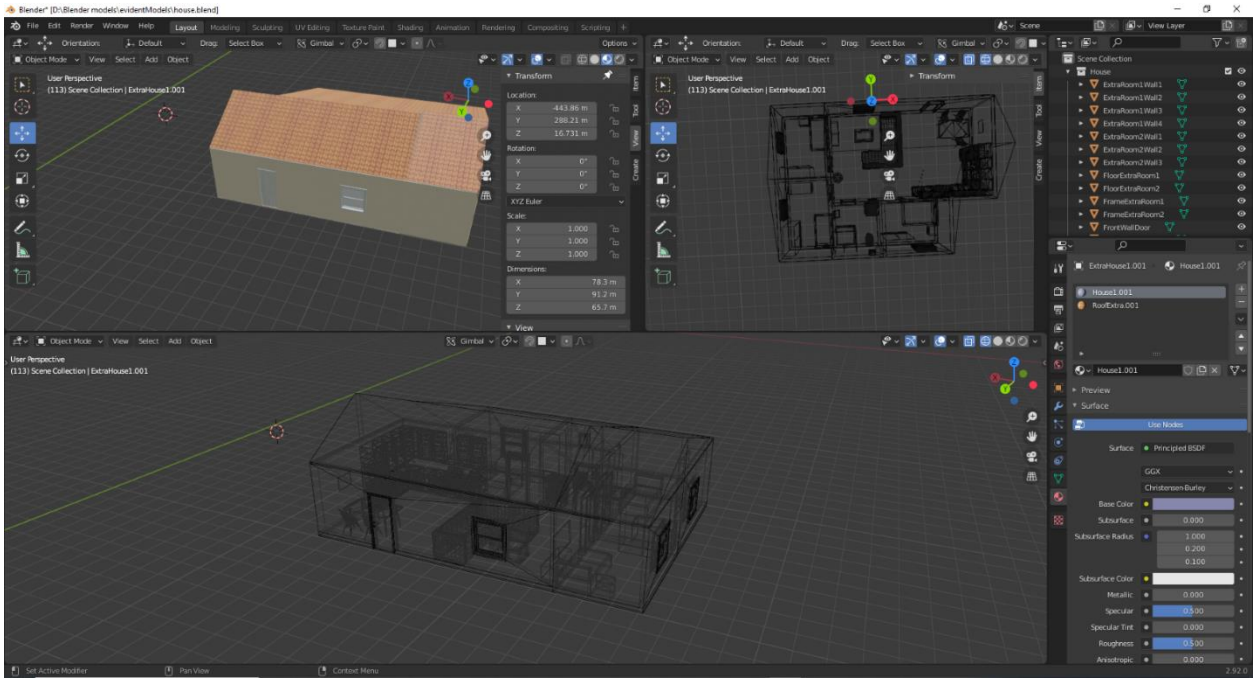

Figure 6: Blender Application

4.2.1 Main Building Structure

The main building is the building in which the player will be able to move around and interact with the predefined home appliances. Henceforth, it will be termed the main building. In addition to the "low poly" logic that applied to all the 3D models created for EVIDENT serious game, it was crucial to follow some basic principles during the creation of the main building. So, in some cases more complex models were created, due to the interaction those models will have with the player later on. As an example, we could not make a fridge with four polygons, because the fridge door may be opened. Another important requirement was to have a building with the capacity to have one or two more rooms, to allow for each possible scenario concerning the player. As such, within the main building (shown in Figure 7), the right part shows the rooms that can be missing if that is required for the scenario.

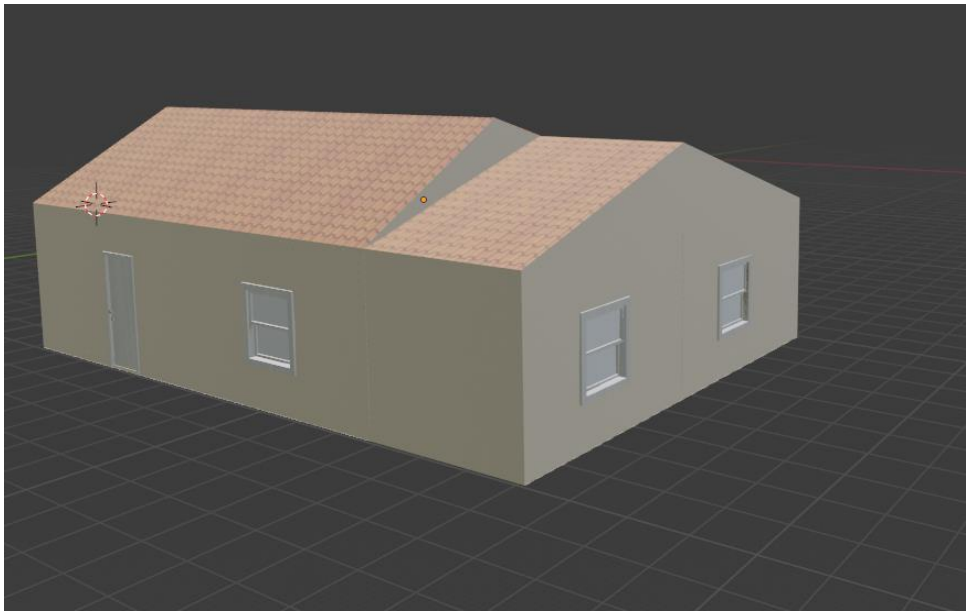

Figure 7: Main building

Concerning the “low poly” logic, a very efficient way to create a simple mesh is to use some textured materials. Some parts of the model need to be more complex, to allow for some extra properties like depth. A way to overcome that problem is to use a texture with depth instead of creating the actual depth to the mesh. As an example, in Figure 7, the roof is a texture of roof tiles and not actual roof tiles, but the outcome is identical by using much fewer polygons.

4.2.1.1 Walls

The walls and the roof are the most important structural building components. Our main concern during the creation of the walls was creating a fade function for them. When a wall is faded, it is important to have a part of the wall visible on the floor just to show that there is a wall there. For that reason, the floor mesh has a frame on each spot where there are walls, as shown in Figure 8.

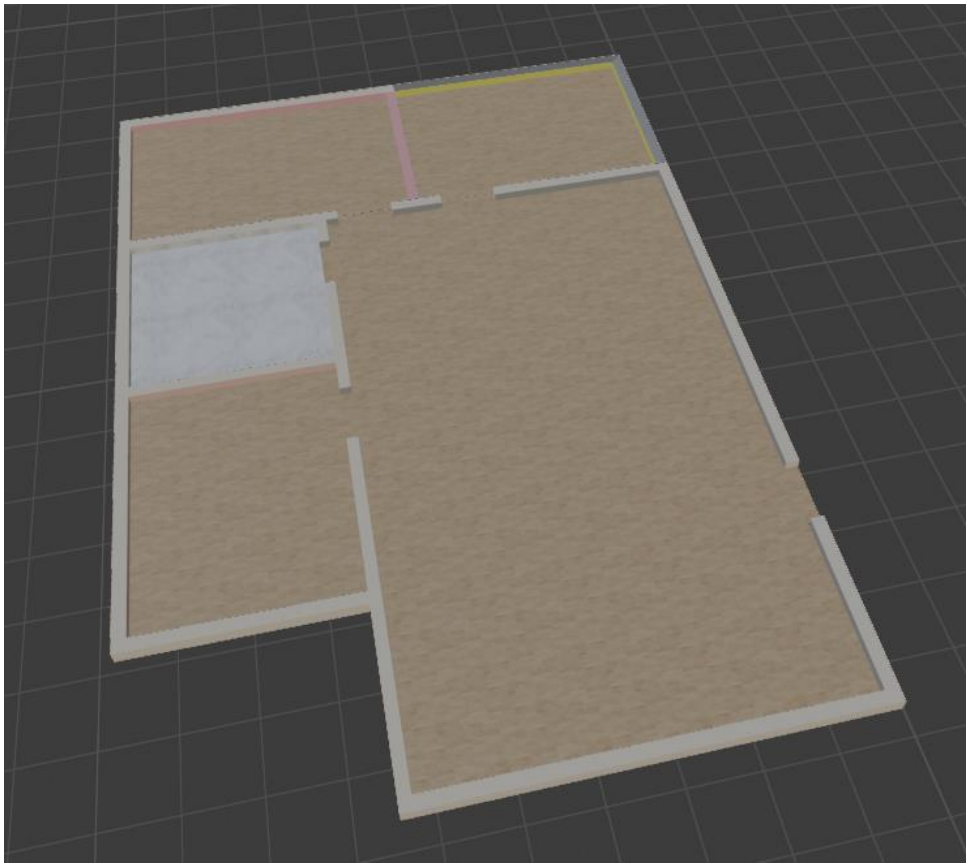

Figure 8: Floor Mesh

Also, every frame has the same material as the wall above it. The main part of the wall placed on the top of that frame, as it is shown in Figure 9, and that is the way a full wall is created. The development of the fade function will be described later on this deliverable.

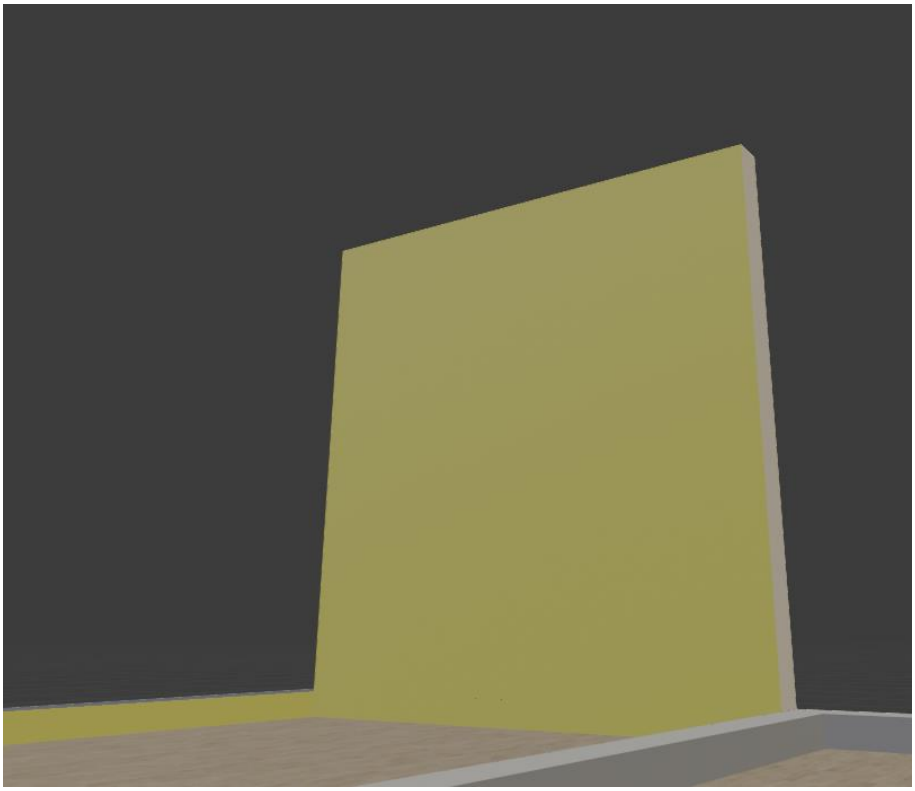

Figure 9: Floor Mesh

Finally the roof of the building had to be implemented. Here our only concern was to have a different part of the roof for every extra room in case those rooms will not be displayed in the scenario. An example of the main building with only one room is shown in Figure 10. The highlighted part with an orange colour is the roof part of the existing extra room.

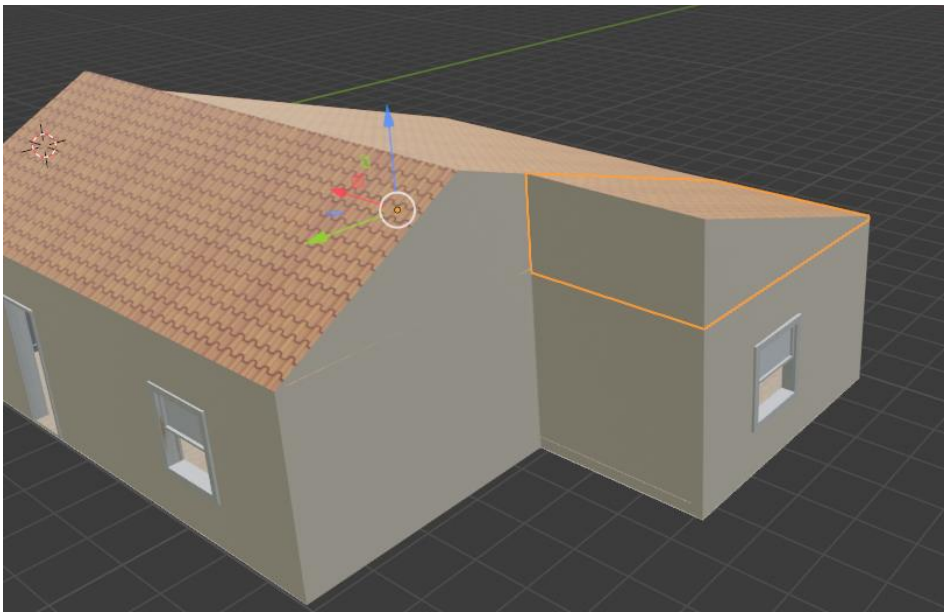

Figure 10: Main building with only one room

4.2.1.2 Doors and Windows

Another important structural building component are the doors and the windows of the building. Both door and window models have to have one moving part as shown in Figure 11 with an orange outline.

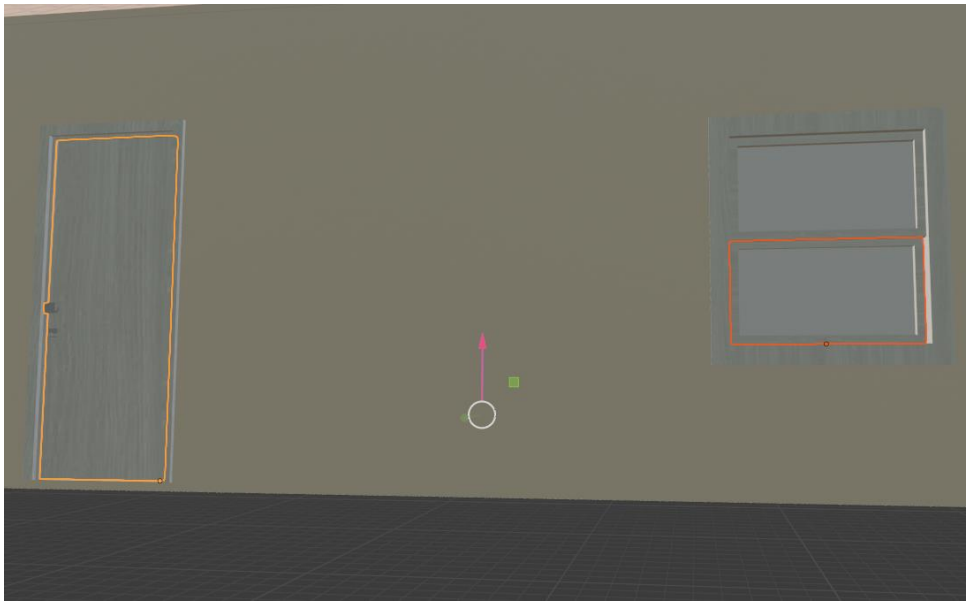

Figure 11: Door and window moving parts

4.2.2 Home appliances and Furniture

The next important issue that needs to be mentioned is the creation of home appliances and furniture to furnish the main building.

4.2.2.1 Furniture

The fundamental principle followed during furniture modelling was to keep the number of polygons as low as possible. The furniture will not be interactive, but the home appliances will be, with the furniture models used only as decoration. Because of this, every furniture model has been created as one mesh, with the lowest possible number of polygons. An example of a closet model is presented in Figure 12 below. Notice that there is only one face per side (faces are highlighted with a black outline).

Figure 12: Closet model example, with Faces

4.2.2.2 Kitchen Appliances and Washing Machine

The player will be able to interact with home appliances, requiring home appliance models to have more than one mesh per model. The purpose of this was that each home appliance model should have some moving parts, to provide feedback to the player, that they have actually interacted with it. As an example in Figure 13, you can see a fridge with the doors as a different mesh, where the player will be able to open and close the fridge. In Figure 13, every mesh has an orange outline.

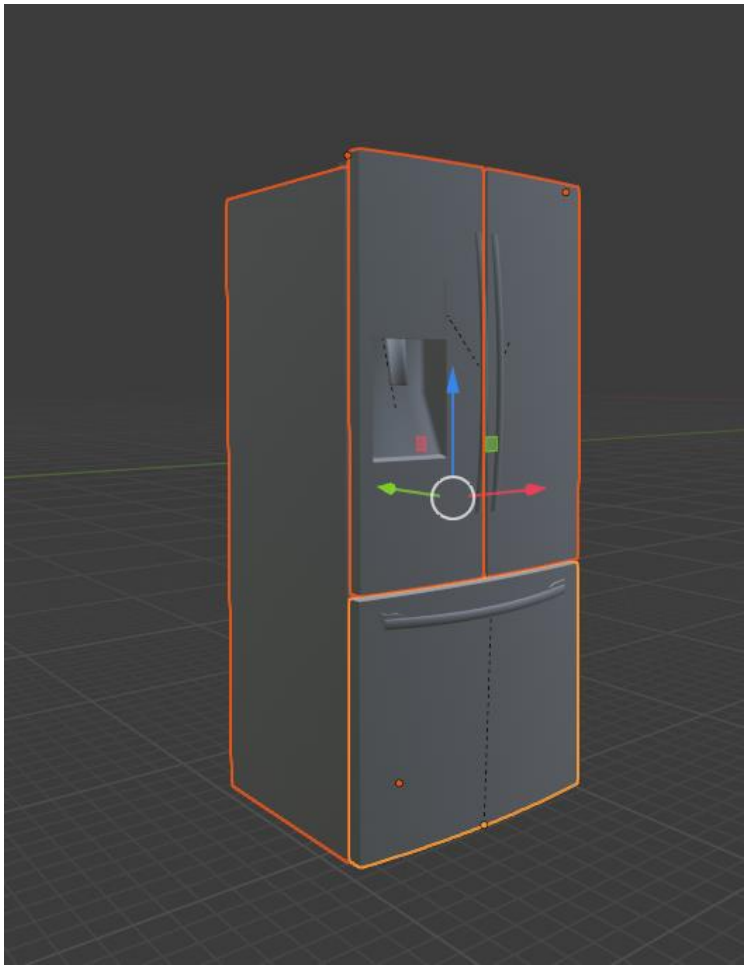

Figure 13: Closet model example, with Faces

4.2.2.3 Luminaires

Another concern was the creation of the luminaire on the main building. The luminaires will operate both as a light source and a light switch and they had to be placed on a spot where the player could easily click on them. As such wall luminaires were created, as shown in Figure 14.

Figure 14: Lights

As the bulb has a different material it can be lighted to create a more realistic depiction for the luminaires. The way that this can happen will be explained later in this deliverable. A luminaire was placed in every room of the main building.

4.2.3 Buildings for Background

Also, it was important to have some extra buildings for the background. These buildings will not be accessible to the player and will be used as decor for the background of the game. As such, it was important to be as low poly as possible, as the player will be unable to see how detailed those models are. See an example of such a building in Figure 15.

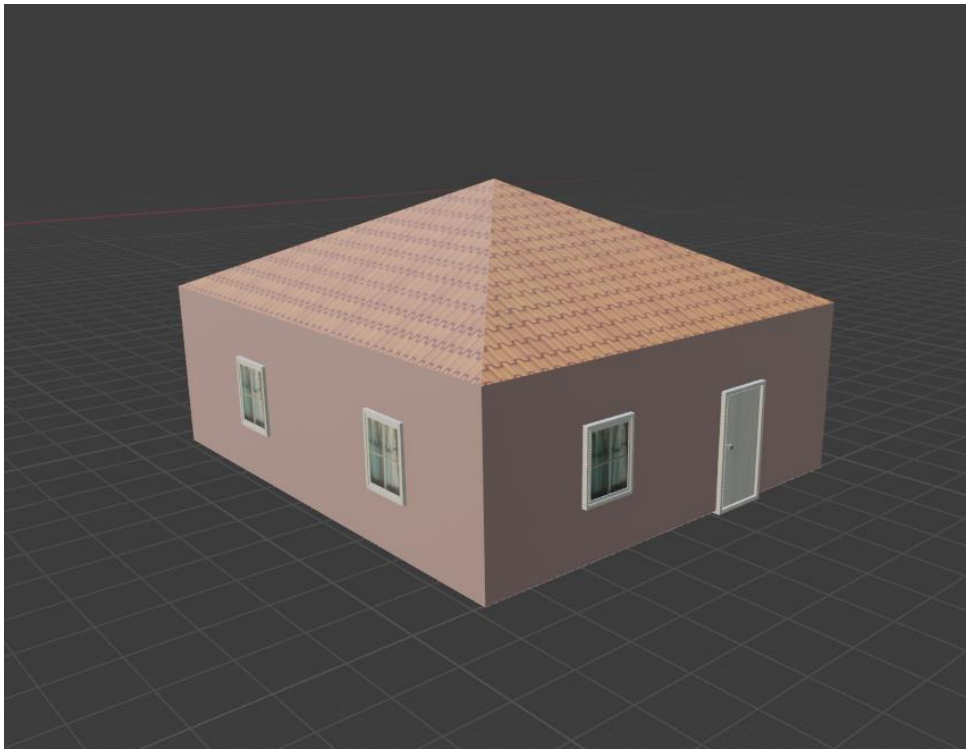

Figure 15: Example of a 3D background house model

In this 3D model, the walls and the roof are one single mesh, with different materials. To create a window with the fewest possible polygons, a frame with a wood material and an inside face, with the windowpanes textured as curtains is included (see Figure 16). As this is a model that will be placed far away from the camera, the result during rendering will be almost the same as a more detailed 3D model.

Figure 16: Window of a 3D background house model

Finally, the outside colour of those house's 3D models can easily be changed, to provide a big variety of models to create a small "village" outside the main building.

4.3 Implementation Characteristics

4.3.1 Technical Requirements

The most important factor was to determine the tool that will be used to set up the entire project. The output of the project will be both an android application and a webGL application for the EVIDENT platform. The serious game will be a 3D game so Unity, a cross-platform game engine developer, allows not only for 3D games but also can export them to multiple platforms, making it the best option for the EVIDENT serious game. See Unity's environment in Figure 17.

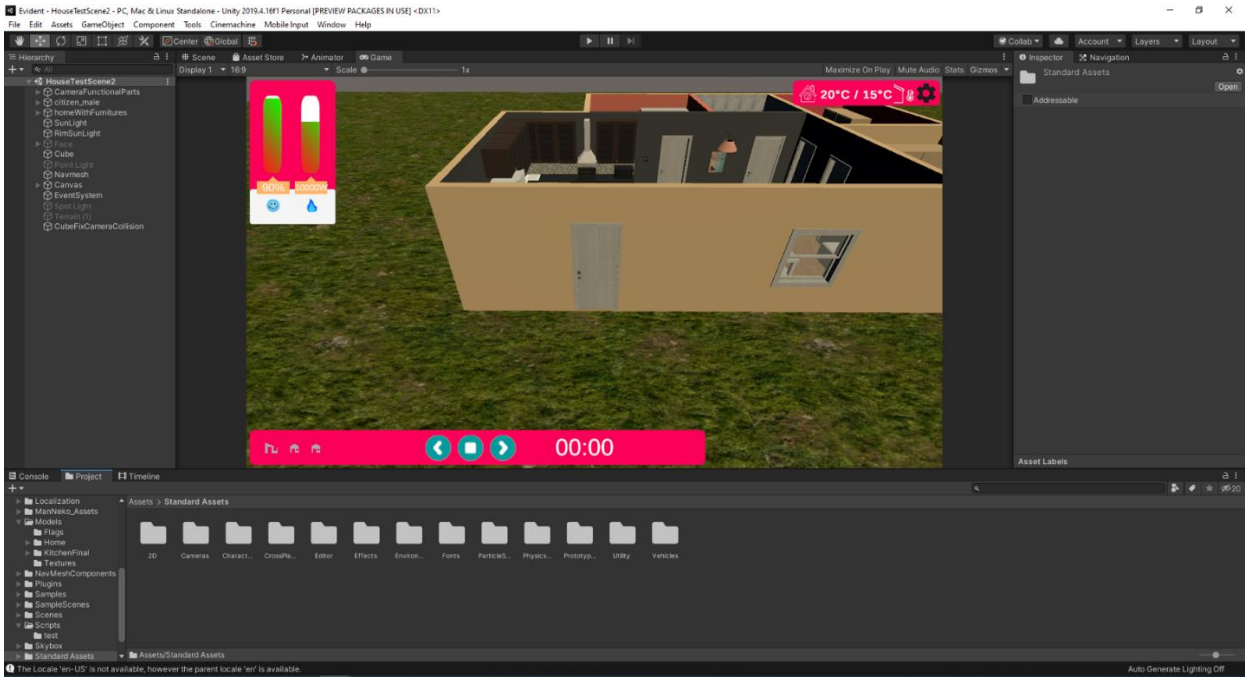

Figure 17: Window of a 3D background house model

Unity provides many tools for game development, the most valuable of which is the possibility to create custom components using C#. C# is a general-purpose, multi-paradigm programming language encompassing static typing, strong typing, lexically scoped, imperative, declarative, functional, generic, object-oriented (class-based), and component-oriented programming disciplines [54]. By scripting in C#, Unity gives the possibility to control almost everything from a C# script, by using that script as a component on Unity's gameObjects. GameObjects are the fundamental objects in Unity that represent characters, props and scenery. They do not accomplish much in themselves but they act as containers for Components, which implement the real functionality [55]. Now that each of these are clear, the basic components which will be used within the EVIDENT serious game are described.

1. Building Models: The models created in Blender as described above.
2. 3D humanoid models: Some 3D humanoid models may be used for representing the player and the repairperson for the EVIDENT Serious Game, based on the scenario that is described in the protocol in section **Error! Reference source not found.**. These models will be described later in this deliverable.
3. Unity's standard assets: Unity's standard assets is a collection of assets, scripts, and example scenes that can be used as the basis for projects. [56]. For the EVIDENT Serious Game, it was important to use an animation set and an animator controller for the character's movement on that project. Unity's standard provides us with a fully working animation set and with a ready animator controller for the 3D humanoids models that will be used on that project.
4. Animator controller: An Animator Controller allows you to arrange and maintain a set of animation clips and associated animation transitions for a character or object [57]. The EVIDENT serious game requires a full set of animations for humanoids. An animator controller is used for connecting those animations and arranging transactions between them. For this project Unity's standard assets animator controller is used.
5. Navmesh: A navigation mesh, or navmesh, is an abstract data structure used in artificial intelligence applications to aid agents in pathfinding through complicated space [58]. Unity has its own navmesh component for finding a path between two points. The way that a navmesh was set in Unity will be described later in this deliverable (see section 4.3.2.1.1).

6. Tags and Layers Manager: Tags are marker values that you can use to identify objects in your Project. Layers are a way to create groups of objects that share particular characteristics [59].
7. Unity's raycast class: Raycast is a procedure where a ray is sent by the camera to the scene, to find all the colliders that stand in that ray. Unity's raycast class has two basic methods, raycast which returns the first gameObject with a collider on its path, and raycast all which returns an array with each gameObject with a collider on its path.
8. TextMeshPro: TextMeshPro is a text solution for Unity and replaces Unity's UI Text and the legacy Text Mesh [60]. TextMeshPro is preferred over Unity's UI Text because it has a better optical output and it provides a lot of parametrization options.

4.3.2 Humanoid Models

The first component of the EVIDENT serious game are the humanoid models. The game needs two basic models. The first one will represent the player of the serious game. This model will be the one that will be controlled by the player. In the next sub-section, the way the player will control that 3D humanoid model will be described. The second one will be a 3D humanoid model of a repairperson. That model will come into view when a home appliance breaks down, based on the scenario that is described in the protocol in section 3.4. A concern during the EVIDENT serious game development was creating a more personal game, making the player feel like they live in that scenario. Besides that, it was essential to respect gender equality and to provide each player of the EVIDENT serious game the ability to choose the character that will represent them in the game. Both male and female 3D humanoid models have been created to give the players the option to choose their in-game gender. Figure 18 shows the two 3D humanoid models. The model that will represent the player is displayed on the right and the one that will represent the repairperson is displayed on the left.

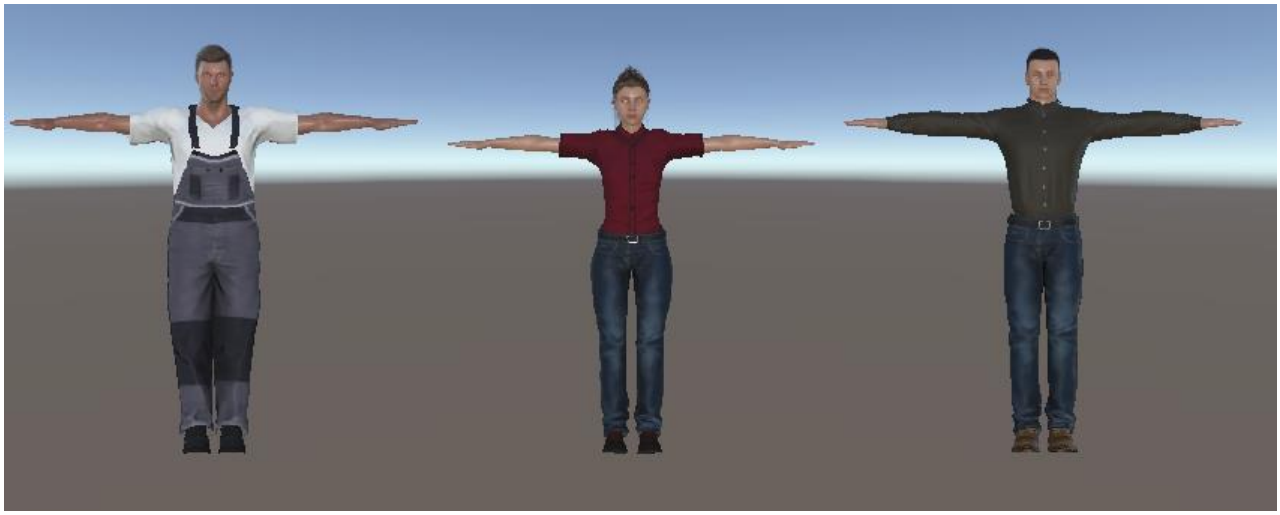

Figure 18: 3D humanoid models on T-Pose

4.3.2.1 Point and Click Character Control

The next step was to figure out how the player will move around. As it is a basic game and the playtime will be short, it was important to keep the gameplay as simple as possible, to ensure the player does not waste time understanding the gameplay mechanisms. For these reasons point and click character control was the best option for the gameplay. The player will just click on the point where he would like the avatar to go, and the avatar will obey if there is a path with no obstacles to that point.

4.3.2.1.1 NavMesh Creation

The next issue was to figure a way to calculate the path the avatar has to follow to get to the point the player points at. For that reason, the NavMesh Unity's component is used. By using the NavMesh surface script and including every layer and all collect objects, we set that the humanoid avatar can walk everywhere on the scene. See these options in NavMesh Surface Script in Figure 19.

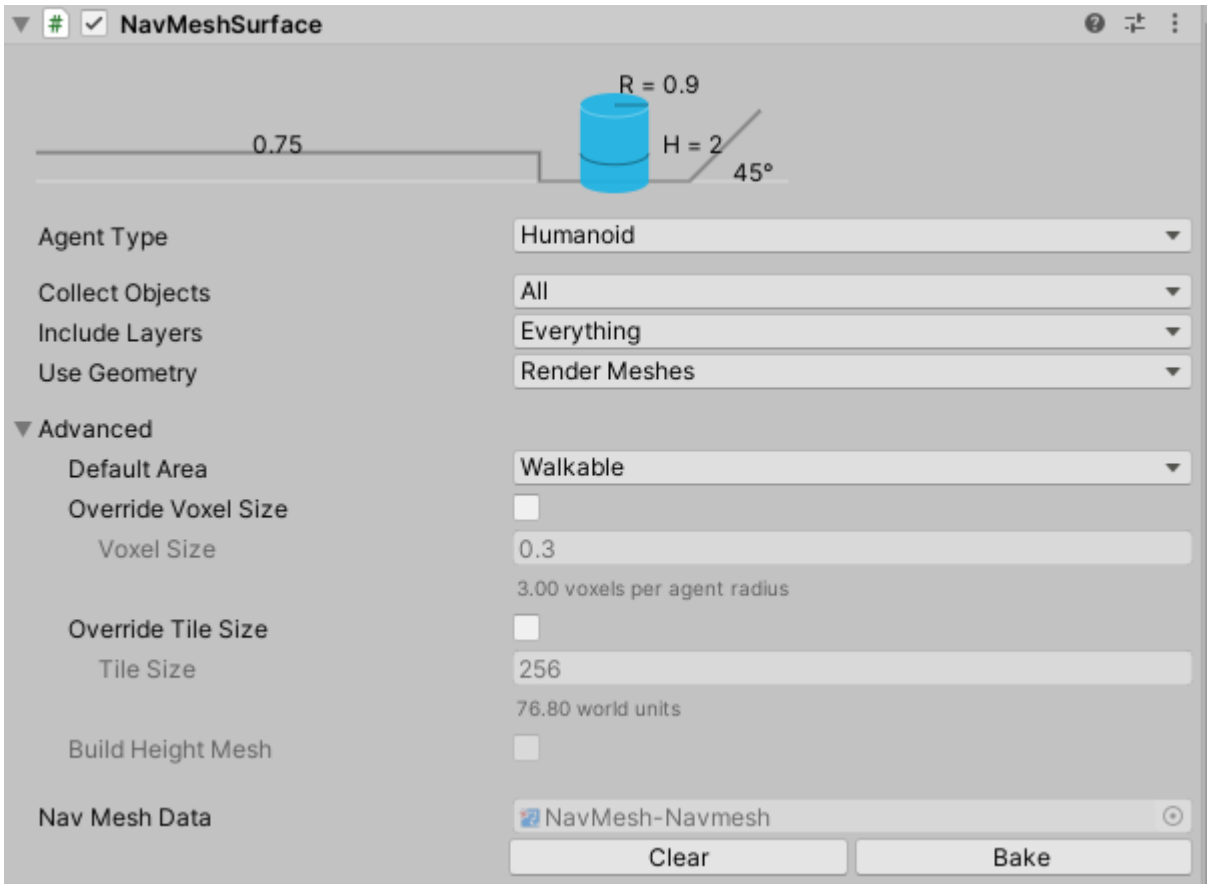

Figure 19: NavMesh Surface Options

The next step was to determine the parts of the building where the avatar should not walk into, such as the walls and furniture. The static obstacles are just needed a NavMesh Modifier Component. By setting the Override Area as "true" and the area type not walkable, the avatar will not be able to walk where the mesh of that object stands. See these options on NavMesh Modifier Script in Figure 20.

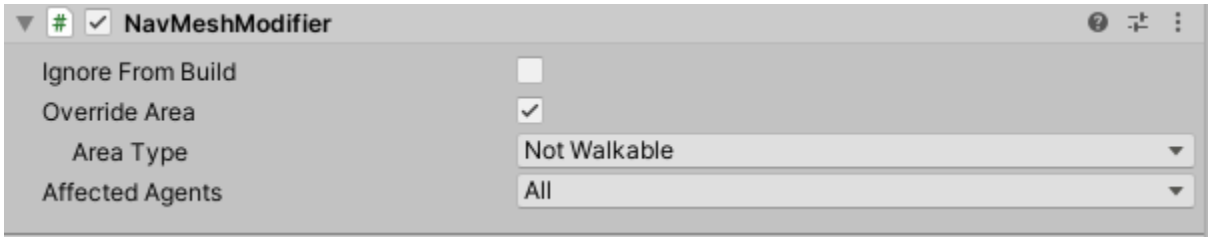

Figure 20: NavMesh Modifier Script for furniture

Finally, some obstacles are not static, like the doors. If a door is closed the avatar should not walk through that door. But when the same door is open, the NavMesh should find a path from there. In that case, there is the NavMesh Obstacle component, which is combined with a NavMesh Modifier Component with the "Ignore from Build" option is set as true. See these options on NavMesh Modifier Script and NavMesh Obstacles in Figure 21.

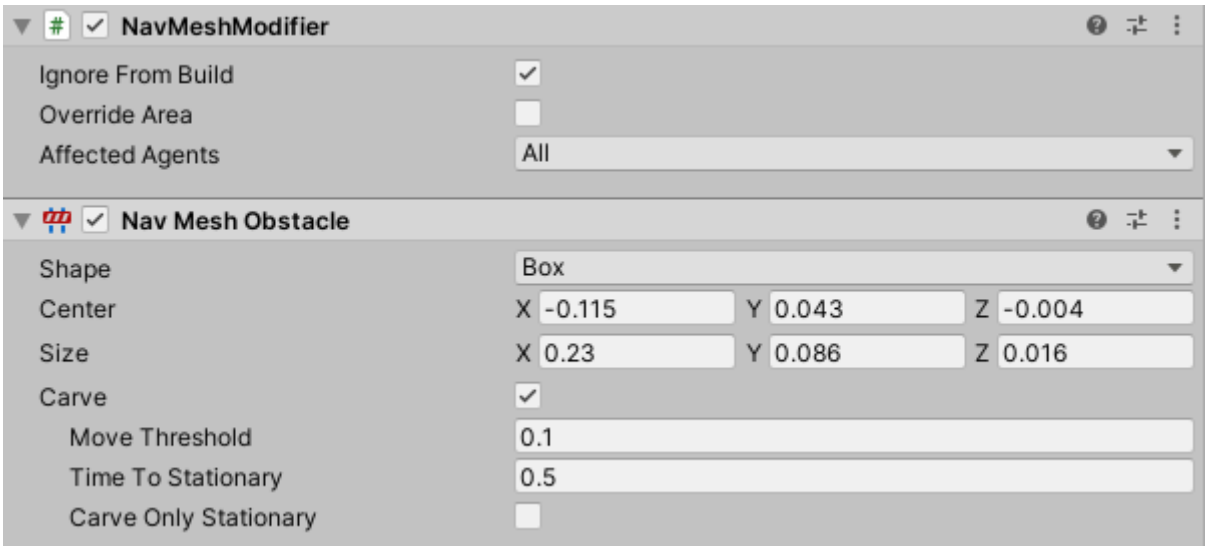

Figure 21: NavMesh Modifier Script and Navmesh Obstacle component for Doors

4.3.2.1.2 NavMesh agent and Character Movement

The final step was to prepare the 3D humanoid model for moving into the NavMesh. Firstly, the model needed to have a NavMesh Agent Component. With this component, we can determine that the 3D humanoid model will be able to walk into the mesh that was created before. See the option for the Nav Mesh Agent in Figure 22.

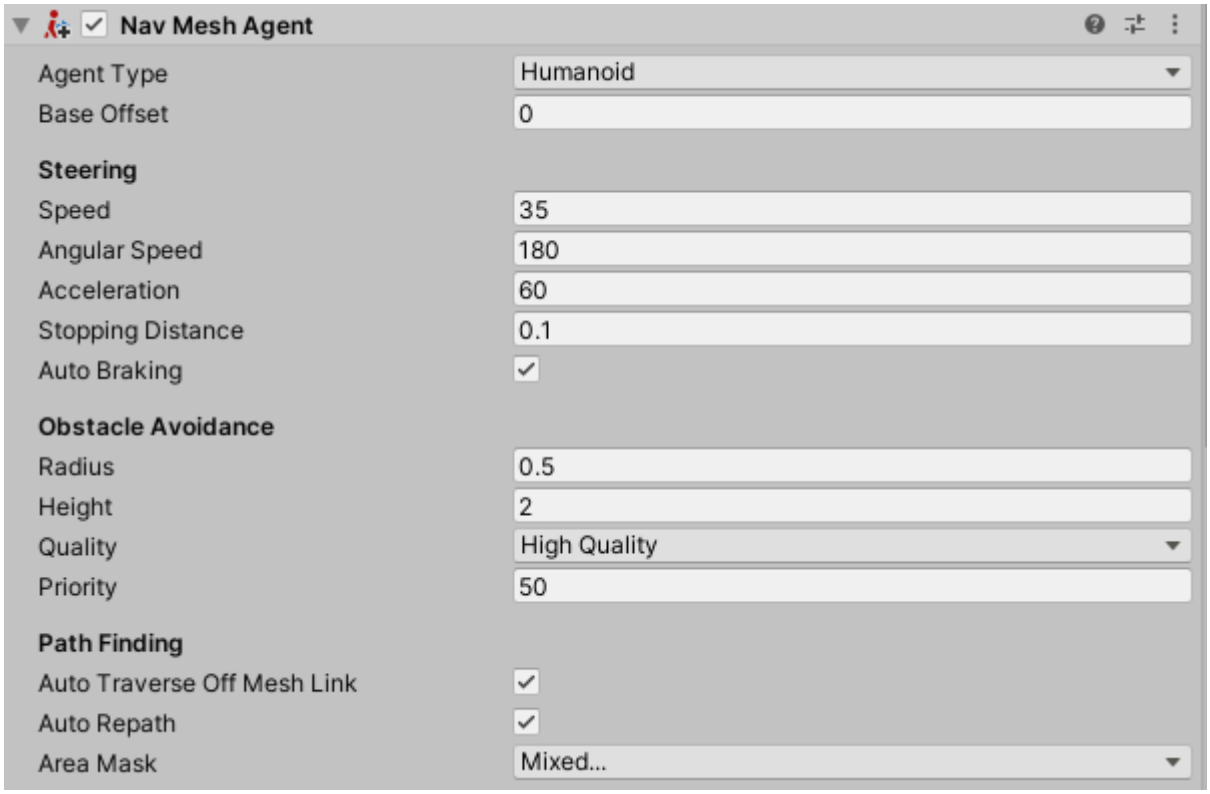

Figure 22: NavMesh Agent Options

Except for the NavMesh Agent, the 3D humanoid model must have an animation set which will be adapted based on the 3D humanoid model's movement, an animator controller to arrange the transaction between the animation clips, and a script to control the animator controller's parameters. From Unity's standard assets, we use the humanoid animator controller which contains a full set of animation clips for every possible movement of a humanoid. Also, we use the third-person character script, which is responsible for handling the animation transactions on the humanoid animator controller of the standard assets of Unity. In the third person character script, by using the "Move" method, with the desired velocity from the NavMesh agent as input, the character starts the walking animation. With zero velocity inputted in the same method, he will just stand. The last step to the character movement is to figure out where the player's click on the ground was, to make him move there. For this reason, all the floor parts layered as ground. By using a raycast, only for the "Ground" layer, the avatar's Nav Mesh Agent's destination is set as the point where the player clicks if the player's click is on the ground. After that, the Nav Mesh Agent calculates the path to that point, if the path exists, and moves the avatar there by setting the animator controller to the walking animation clip for the time the avatar was moving simultaneously.

4.3.2.2 Interaction with Objects

Now that the moving around function has been implemented, the next step for the avatar's functionality is to have the capability to interact with the interactable objects of the serious game. The point and click logic continues to apply to interaction with objects. For this reason, a new layer named "Interactable" is used. So, these objects were layered as interactable. By using a raycast ray, if raycast's hit object is in the interactable layer, the player walks to that object to interact with it. Furthermore, each object has different functionalities. As an example, the door has to open and close, the lights

have to turn on and off, etc. For this reason, every object's tag is based on its kind. Details are provided below for each object the player can interact in the EVIDENT serious game and how it gives feedback back to the player.

1. **Door**: The door can be opened to 90º and can be closed.
2. **Window**: The windows can be opened and closed by moving the one window leaf.
3. **Fridge**: When the player opens the fridge, the doors of the fridge open, and the light turns on. The reverse function happens when the player closes the fridge.
4. **Oven**: The oven has a light on its internal body, to show the player whether the oven is turned on or off.
5. **Washing Machine**: A light turns on the inside of the washing machine when the player interacts with it.
6. **Light Switch**: For the light switches, as was mentioned before, the luminaires will operate both as a light source and a light switch and have to be in a spot where the player could easily click on them. The player will click on a wall luminaire and the light will turn on in the room. Also, it is important to mention that except for the light in the room, the emission of the bulb material will be activated when the player turns on the light. Adding emission to a material makes it appear as a visible source of light. You can see a light bulb with the emission option on (left of image) and off (right of image) in Figure 23.
7. **Thermostat**: The player can control the inside temperature of the main building. This function will be described in section 4.3.3.2.
8. **Air condition:** Except for the thermostat, the player can control the inside temperature of the main building. This function will be described in a later section (see section 4.3.3.2).
9. **Television**: When the player clicks on the television, the television turns on and a video plays on the screen with the videoplayer component. The videoplayer component, as its name suggests, is a component in Unity for playing video on a panel. When the player turns off the television, the television screen becomes black again.
10. **Dishwasher**: The dishwasher door opens and closes when the user clicks on it.

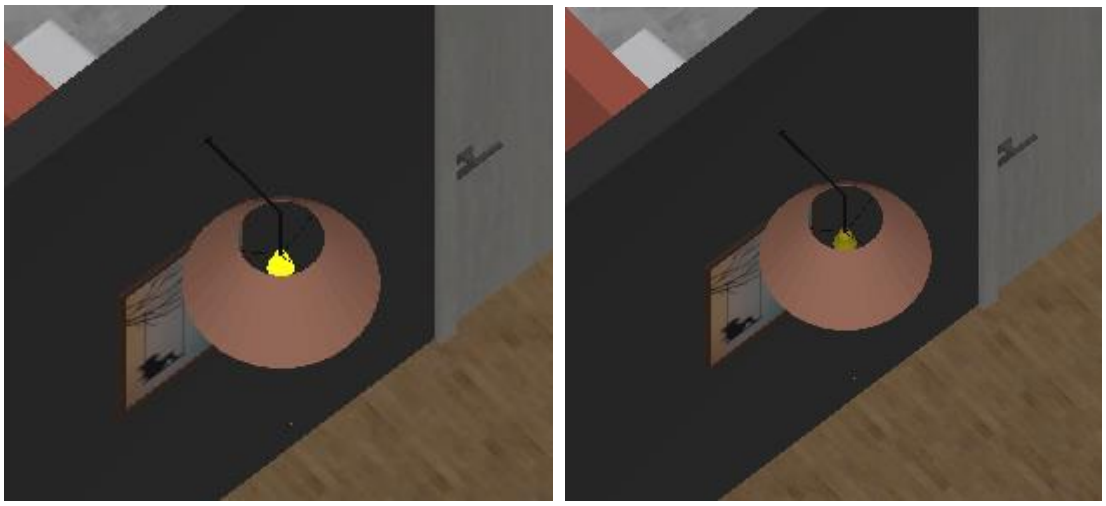

Figure 23: Light bulb with emission on/off

4.3.2.3 Camera Control and Walls Fading

As mentioned, the EVIDENT serious game is a third-person point-and-click game. As such the camera is a third-person camera. The camera focuses on the avatar (representing the player in the game), so

the player can control his avatar from the best possible view. The primary functions of the camera are zooming in and out on the player and rotating around the player's avatar circular. While the camera should always have a clear view of the avatar, there are often obstacles between the camera and the avatar, with the most obvious being the walls. The best option to overcome this was to create a fade function for the walls. For this reason, the walls are tagged as "walls" and a raycast ray is used by the camera to the avatar which represents the player, with the "RaycastAll" method, to find every wall between the player's avatar and the camera for fading it. Figure 24 shows how the main building looks with the front wall faded.

Figure 24: Main Building with the Front Wall Faded

4.3.3 Time Component

The first subcomponent that had to be implemented was a time system for simulating a 24-hour day. For that purpose, it was important to use the Time.deltaTime function, which returns the interval in seconds from the last frame to the current one. To control the flow of the time, it was important to have a variable for real seconds per in-game second. With that variable, the player can make the time pass faster or slower depending on their gameplay preference. Further, the player can pause the time to take a break from the gameplay. The User Interface (UI) from which the player can control time flow is shown in Figure 25.

Figure 25: UI for Control Time Flow and Time Representation

4.3.3.1 Day/Night simulation based on Sun Movement

The second game component was a system for creating a simulation of the sun passing over the game. To allow for a more realistic sun simulation two light sources were needed, one for the main sunlight and one as rim sunlight. The rim light is placed behind a subject that exposes the outline or rim of the subject with light. This lighting highlights the contours of a subject and creates a dramatic and

mysterious effect. The rim light has to be in a light blue hue, while the main light source has to be in a light-yellow hue, to achieve the desired result. See the two light sources on the Unity environment in Figure 26. The light source that points over the main building is the light source and the other one is the rim light.

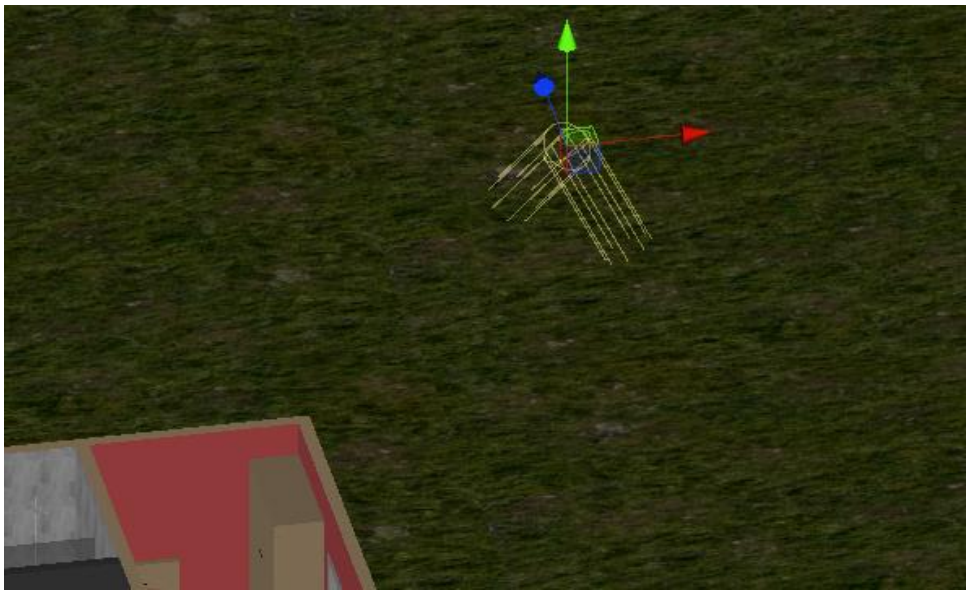

Figure 26: UI for Control Time Flow and Time Representation

The next important issue on that was to achieve the light intensity to follow the time of the day, using only the rim light at night. For that purpose, a function was created that calculates the intensity of the main light source based on a sine function that uses the current hour and minutes.

4.3.3.2 Set Temperature Simulation

Now that the light and sun system has been developed, a temperature system had to be implemented. There are two basic temperature values in the EVIDENT serious game, one for the inside of the main building and one for the environment outside that building. The outside temperature is affected only by the time of the day. For each day, a minimum and a maximum limit are set for the temperature and there is a function that controls the temperature on that range, based on the current in-game time. The indoor temperature is affected by the outside temperature to a small extent, as would be seen with the real indoor temperature of a home. The indoor temperature is also affected by the thermostat that controls the heating system (shown in Figure 27) of the main building or by the air conditioner that controls the cooling system.

Figure 27: Thermostat UI. The Left Temperature is the Current Temperature and the Right is the Outside Temperature.

4.3.4 Multilanguage

As the EVIDENT serious game will be played across countries as part of the serious game platform, it was critical to allow players more choices about the language of the game. For this reason, Unity provides a localization package. In this package, the first choice explores the languages which will be available in the application. Then, for each button, by creating an entry name, it is easy to add a translation for that entry in every language. See an example of such a component on Figure 28, for text with the entry start.

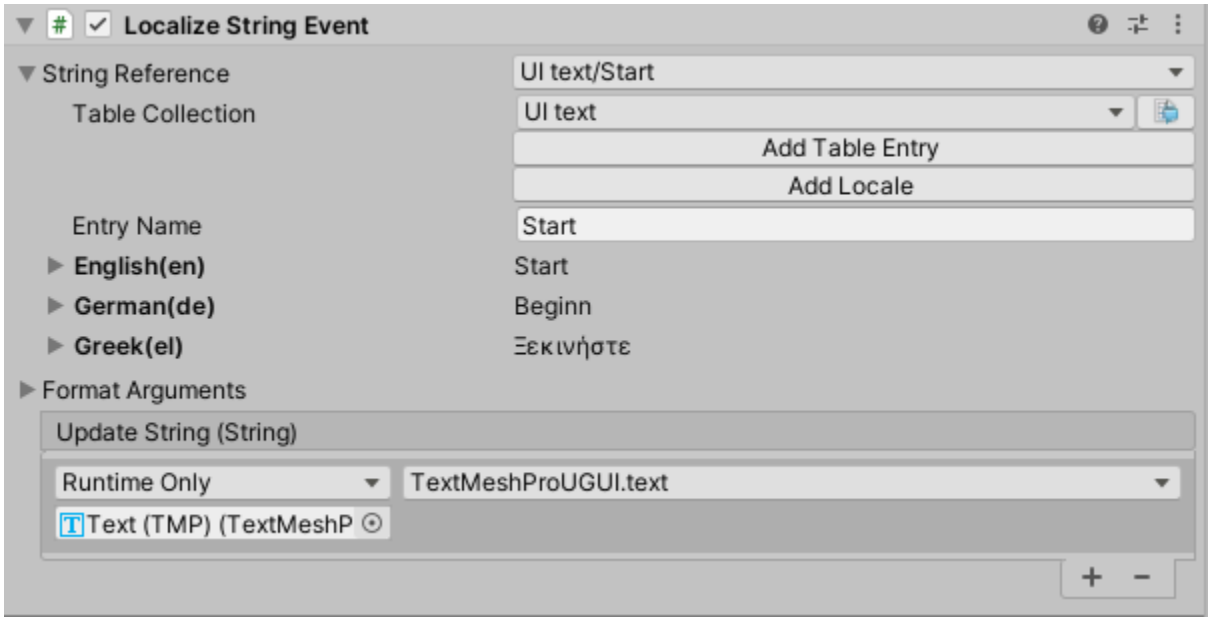

Figure 28: Localization on Unity for an Entry Named Start on English, German and Greek.

4.3.5 Energy Consumption Manager and Comfort indicator

As it was mentioned in section 4.3.2.2, each device has a control script for the player to interact with it. With this script the application will be able to control the device and calculate its energy consumption. It is also important to have a more central control system for the handling of all devices. To allow for this there will be a system that will control the whole system and calculate the whole building's energy consumption. This will be displayed as an environmental impact indicator on the UI of the application. Aside from energy consumption, which is the main objective of the whole project, a way to encourage the player to actually use the home appliances was required. For this reason, a comfort indicator was included. This indicator is shows the player whether their avatar is doing enough activities to meet their basic needs. Also, a financial indicator is included which informs the user of the money remaining. The user should stay on budget during gameplay. That is a way to make sure that the user will not only choose the option he thinks it is the best, but the option that he would probably choose in real life, with the restriction of disposable income. Figure 29 shows the indicators panel with happiness and energy consumption indicators. Also shown is the financial indicator with the money remaining for the user.

Figure 29: **Energy and Happiness Consumption Indicators Panel**

4.3.6 Home Appliance Malfunction system

As mentioned before, every home appliance has a script component that controls its function. On that script, there is a method for when that home appliance breaks down. Every appliance has a different effect for showing its malfunction. As an example, when the dishwasher breaks down, some water will appear, to make clear that the washing machine has a problem. Except for that, it is crucial to have a central system that will be working as the Central Home Appliance Malfunction System. That system, when the scenario requires a home appliance malfunction, will choose a device and use the appropriate method for that to show the malfunction to the user.

4.3.7 Conversation Manager

After a malfunction appears, a repairperson shows up and a conversation between the repairperson and the user starts. For that conversation, a manager is needed, for controlling the conversation's flow. For the EVIDENT serious game, there is no need for very complex conversations. The scenario has a stable flow between the user and the repairperson and after that, the repairperson gives the user some standard options as mentioned earlier. For that reason, a custom conversation manager

was created. This is a script component which will control the flow of the conversation. In there, there is a data structure where all the possible answers and messages are saved. During the conversation, the conversation manager chooses the right answer from the data structure and displays it on the UI panel that has been created for that purpose. See a part of a discussion between the repairperson and the user in Figure 30.

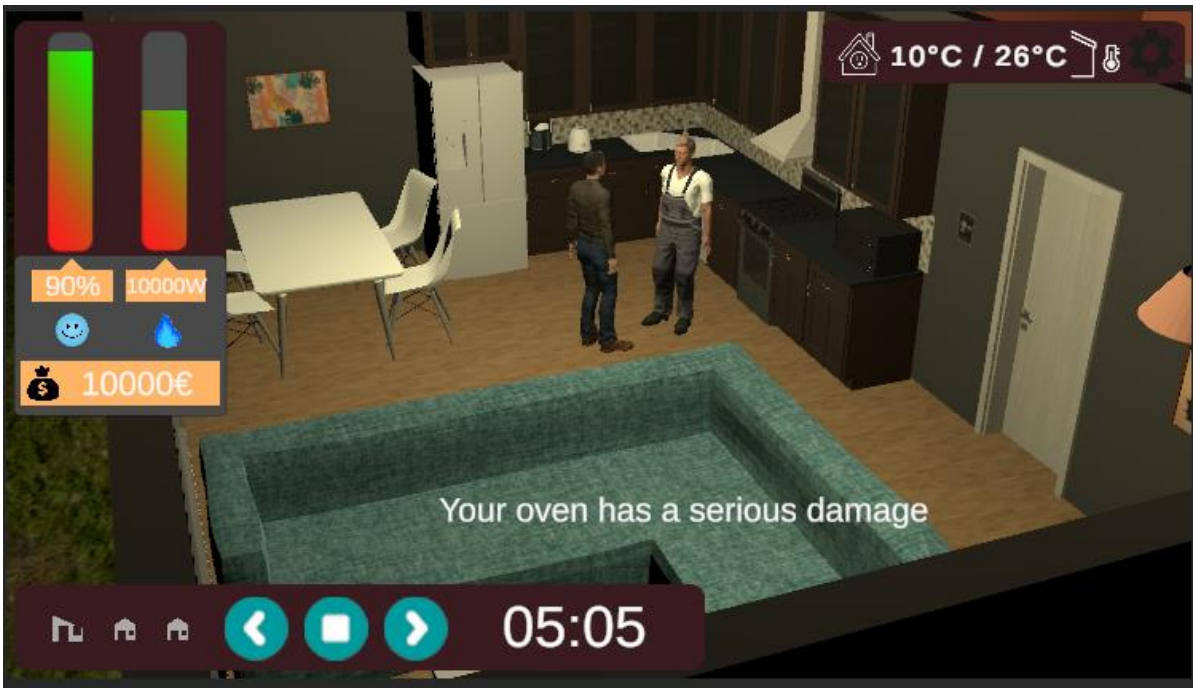

Figure 30: Discussion Between the user and the Repairperson

4.3.8 Game Settings

The user can customize the whole game, based on their needs. They have a lot of variety of colours to choose from, for the coloured parts of the game. Also, the user can change the EVIDENT serious game theme between the classic light theme or a dark theme. Finally, the user is able to change the language of the game. As mentioned in 4.3.4, the game will be played across multiple countries and people of different ages and social statuses. So, the user can choose to change the gameplay language. The settings menu panel is presented in Figure 31.

Figure 31: Setting panel

5. Data Storage/Management

EVIDENT serious game data should be FAIR, **F**indability, **A**ccessibility, **I**nteroperability, and **R**eusability.

Therefore, EVIDENT data must be findable utilizing the metadata. Furthermore, data should be openly accessible and interoperable, with reusability.

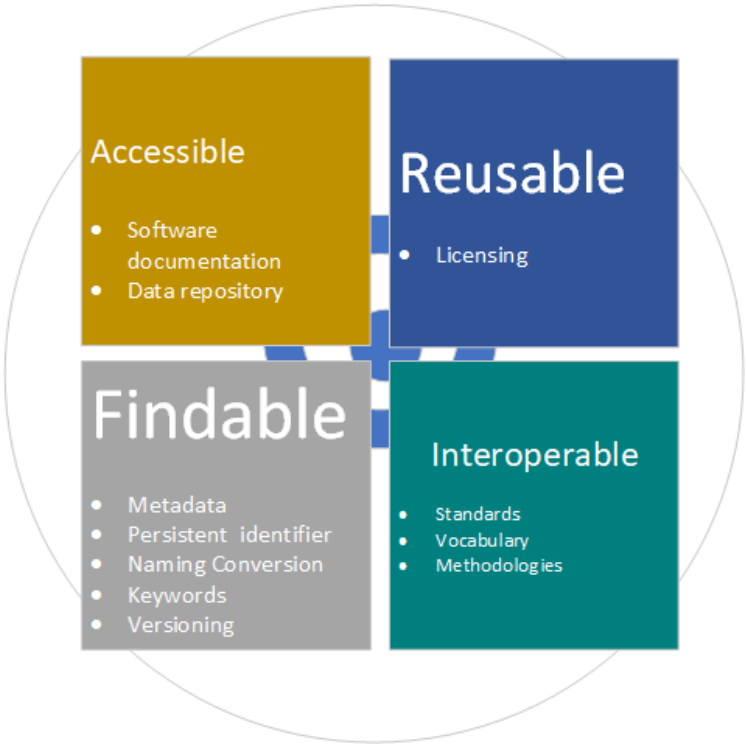

Figure 32: FAIR DATA, Findable Accessible, Reusable, Interoperable

- Findable: Uniqueness of all data that have been stored, resources available, and accurate metadata.
- Accessible: Metadata accessible and data availability.
- Interoperable: Standard terms and format.
- Reusable: Clear license and accurate metadata.

In general data is findable with metadata support in a standard way. Data can be reused when it is well-described. EVIDENT will use open standards and formats, helping integration with other systems.

5.1 Open Access to scientific publications

A part of the EVIDENT data will be public at the OpenAir at Zenodo repository where other scientists can collaborate with it and view it. Open access research data creates opportunities for EVIDENT, as the results can be replicated and validated. The methods and the tools that are required to access the EVIDENT Data should be given, likewise the information for the storage security. The data that are collected during the project and those data used for monitoring do not produce knowledge; those data should be categorized as consortium data.

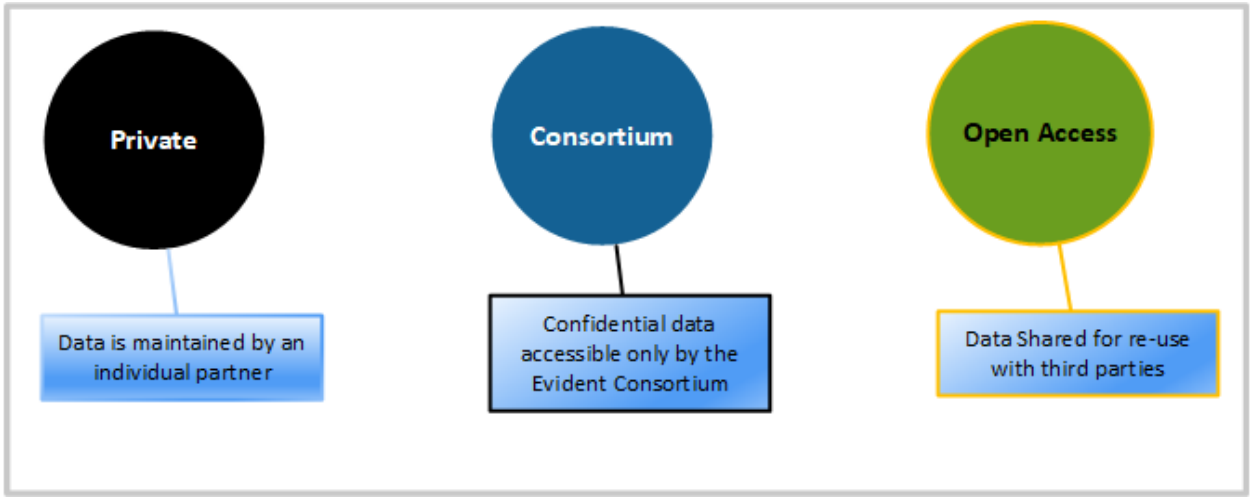

Figure 33: Data Classification Levels

EVIDENT will make the data openly accessible when it is achievable, and metadata should be given. Moreover, all uploaded data are traceable to a registered Zenodo user. Making data interoperable, EVIDENT must make it easy to exchange information with other systems. Zenodo follows FAIR principles and makes the data findable with a DOI (Digital Object Identifier) that adds it to each object in the repository. Likewise, the metadata is compliant with Dacite's Metadata [61] with a few additional enrichments. Every record is searchable directly after being published. To increase data reusability, each record should contain the minimum of Data Cites terms. Likewise, Zenodo uses a JSON Schema as an internal representation of metadata and offers interoperability to export the metadata to other popular formats.

5.2 Data protection, serious games, and EVIDENT

In this sub-section, we provide a brief overview of legislative data protection requirements, and how these are generally addressed in EVIDENT, especially within the context of serious games. Due to the many overlaps, we address both data protection and research ethics.

Article 8(1) of the **Charter of Fundamental Rights of the European Union** [62] stipulates that "everyone has the right to the protection of personal data concerning him or her". In this context, the **European Data Protection Package** was adopted in 2016 which included, among other initiatives, the General Data Protection Regulation (GDPR) [63], Data Protection Law Enforcement Directive, the obligation for EU countries to set-up national bodies responsible for protecting personal data and the establishment of the European Data Protection Supervisor.

In particular, the GDPR defines an array of legal terms including those on personal data, data processing, data subject, data controller and data processor [64]. GDPR entered into force in May 2016 and became fully applicable on 25 May 2018.

The key provisions of GDPR are **the right** of access, to rectification, to restrict processing, to be informed, forgotten, object, and rights in relation to automated decision making and profiling. As an example of GDPR application within the serious game, documents or reports shall not reveal any personal data concerning the research participants recruited (through informed consent). Furthermore, participants will be provided with contact details for further questions regarding the handling of the data.

Another relevant EU legal act for the EVIDENT serious game is the **ePrivacy Directive** [65] which concerns the processing of personal data and the protection of privacy in the electronic communications sector. This directive complements the rules set forth by the GDPR in the field of, for example, unsolicited calls, cookies, phone traffic data and so on [66]. The more relevant provisions for the serious game concern the principle of specialty, security, confidentiality and prior consent (also known as the 'cookie law'), traffic data erasure and location data.

Data protection in the EVIDENT project

The EVIDENT consortium partners strive to ensure that all activities shall conform to GDPR and other relevant and applicable European personal data protection rules and regulations. For example, the project's Grant Agreement includes provisions on *confidentiality,* and *processing of personal data* (Articles 36 and 39, respectively). An example on the latter, *"The persons whose personal data are processed have the right to access and correct their own personal data. For this purpose, they must send any queries about the processing of their personal data to the data controller, via the contact point indicated in the privacy statement(s) that are published on the Agency and the Commission websites. They also have the right to have recourse at any time to the European Data Protection Supervisor (EDPS)."* The existence of the data controller(s) and their specific roles are described in the GDPR. Further definitions and procedures will (also) be included in the informed consent form that all individuals must fill-in before participating in the serious game. The informed consent form will also include the privacy statement(s). See appendix 1 and 2 for sample participant information leaflets and consent forms.

Furthermore, the Grant Agreement dictates that *"data management and data processing will be carried out in an ethical way that respects privacy and regulatory constraints."* (Description of WP8). This will be monitored by the consortium's Ethics Manager, who is also responsible for the relevant communications with the project's External Advisory Board, Ethics and Privacy Committee, and Work Package Leaders (see Project Management Handbook, D8.1).

In the context of EVIDENT activities, GDPR and research ethics considerations have also been *ex-ante* evaluated by the Authorising Authority [67] and partner organisation's research ethics boards (where applicable) who have provided clearance in all cases. An example is the JRC Research Ethics Board which provided clearance in June 2021 and the Research Ethics Committee for the School of Psychology at Trinity College Dublin from whom ethical approval has been sought (submitted for review September 2021). *Ex-ante* research ethics clearance before collecting data is also a prerequisite requirement for some academic journals.

It is also important to note that the EVIDENT project does not intend to use special categories of personal data ('sensitive data', see Article 9 GDPR) to achieve its research goals. However, in certain circumstances, the processing might be technically required.

More definitions and procedures are included in other sections in the Grant Agreement. For example, Section 5.1.3 "Protection of Personal Data" stipulates that protective measures against infiltration of data protection and privacy of personal data will be provided, logging of project system and appropriate auditing of the peripheral components will be available, etc.

GDPR also defines the circumstances where a data controller or processor needs to appoint a **Data Protection Officer (DPO).** The EVIDENT Project Management Handbook (D8.1 – 2.2.8) lists the Data Protection Officer of each organisation of the EVIDENT consortium and it states that *"The main role of DPO is to ensure that the corresponding organisation processes and handles the personal data based on the applicable data protection rules. Moreover, DPOs should guarantee that the data objects and*

controllers are adequately informed about the respective rights, responsibilities, and obligations". Given that EVIDENT has various distinct data collection and processing activities where different consortium partners are involved, the DPO responsibility is decentralised as each partner takes responsibility for the activities that it partakes.

In addition to the individual DPOs, the EVIDENT project has established an **Ethics and Privacy Committee (EPC)** that ensures that *"the best practices are always followed and provides the appropriate assurance regarding data acquisition, processing, storage, and transmission"* and it will scrutinise the research to guarantee that no undue risk for the user is possible, neither technical nor related to the breach of privacy (EVIDENT Project Handbook). The EPC is chaired by the Ethics Manager who will also warrant that all technical activities, trials, data management and data processing will be carried out in an ethical way that respects privacy and regulatory constraints.

Further information can be found in the Data Management Plan (D8.3), including information on the management of the serious game dataset (list of partners responsible for data collection, analysis, storage etc.).

5.3 The data underpinning the EVIDENT Serious Game

The data from the EVIDENT serious game is derived from two primary sources: i) data from return environment modelling and ii) the user/player constraint data. The user constraint data is the information that inserts from the users into the EVIDENT serious game. The environment modelling data are the user's selection decisions during the game. The EVIDENT Serious game can store the information to a relational database management system and the advantages that systems have. Furthermore, the users will be treated as research participants.

5.4 EVIDENT Serious Game: GDPR into Practice

The growth of the internet and digitalised data has led to an increase in data breaches. As such, security guidelines must be followed for the development of online data collection methods. Taking GDPR principles into account is a key means of protecting users' data from a privacy breach. By ensuring compliance with GDPR, the application is better protected against a privacy breach, supporting the security framework for the EVIDENT serious game. The EVIDENT serious game does not have sensitive data and is consistent with the principles of GDPR.

Figure 34: The Seven Principles of GDPR

- **Lawfulness Fairness & transparency**: The gamer needs to understand lawfulness. The user must accept and understand how their data is used. Moreover, all the procedures relative to their data have to be transparent. The users have to provide consent regarding the data collection.
- **Purpose limitation**: The gamer has given their data with their consent for the agreed purpose. These data must not be used for any other purpose.
- **Data minimization**: The gamer should know that only the given proposal's relevant data are collected and stored; any other data will be deleted. The personal data of the user are not sharable. The data could be shared only when fully anonymized with user consent.
- **Accuracy**: A gamer should understand the authenticity of the user data. The accuracy of users data is a key requirement.
- **Storage limitation**: The data stored for EVIDENT Serious Game should not be retained when not in use. All data not used is deleted.
- **Integrity & Confidentiality**: A gamer should understand the integrity; the data will be protected from authorized access.
- **Accountability**: All the scenarios and the limitation are validated. We measured and documented for compliance with data processing principles.

5.5 Measures to ensure data protection

The EVIDENT serious game, according to the data minimization will not use personal data; the game is accessible only in the EVIDENT Platform for all authenticated users. Each EVIDENT user could become an EVIDENT gamer. However, the EVIDENT serious game does not store or associate any information of the EVIDENT user. The identification number of the EVIDENT user may be linked and

saved for the EVIDENT platform with the game data, though consideration is ongoing. Pseudonymization or anonymization of personal data at the platform level will occur to ensure data protection.

5.5.1 Data collection and accessibility

Data to be gathered will include demographic information, energy awareness, attitude toward environmental issues, financial literacy and in-game decisions. For those who participate in interviews/focus groups, data will be gathered on game experiences and the impact of the game on behaviour in real life. Email addresses will be gathered for those who wish to receive a follow-up survey and for those who choose to be entered into a draw to win a prize (an incentive being employed to support participation). With regards to data collection and accessibility, a number of steps will be taken to ensure participants provide full informed consent for data collection and analysis. Participants will be informed of the data to be collected within the serious game, who will access this data, why data is being gathered, and their rights under GDPR within the participant information leaflet (see appendix 1). Regarding the right to erasure, participants will be advised that they can ask for their data to be deleted up until it has been de-identified and will be provided information on how to contact the researchers should they wish for their data to be removed. A risk assessment of the data protection implications has been completed through TCD, with no data protection concerns identified.

The EVIDENT Serious Game will be part of the EVIDENT platform and a holistic security approach will be followed to ensure information security and protect the EVIDENT Data. The EVIDENT platform and the user interface will offer security services like authentication and authorization of the relevant actors and privacy awareness to every service in the system. Likewise, only authenticated users will have access to collected data. The EVIDENT serious game may use temporal files to store the data for the platform, but these files will be deleted in less than 24 hours; moreover, those files, if necessary, could be encrypted. The specific data collection and storage of the EVIDENT Platform will be discussed in deliverable D6.1. This deliverable will also determine data accessibility and collection.

6. Conclusion

EVIDENT seeks to determine how best to support residential consumers in making more efficient energy choices through examining the impact of behavioural interventions in energy policy. To meet this aim, significant effort is needed to determine the impact of factors such as environmental, financial and energy literacy on consumer energy behaviour. This deliverable seeks to determine how serious games can be employed to support the EVIDENT project in addressing these aims. To this end, a detailed overview is presented on the concept and design of the EVIDENT serious game to examine use case four "Relation of Energy Consumption Behavioural Biases with Consumers Financial Literacy Level". To address the research questions surrounding this use case, a serious game has been developed to explore the impact of financial, energy and environmental literacy on decisions to repair or replace household appliances across different resident types. To ensure that the EVIDENT serious game considers the learnings of past similar serious games a systematic review and content analysis was conducted. While the systematic review suggests the positive impact of serious games on energy consumption, a number of limitations of past analyses were noted which will be addressed through the design of the EVIDENT serious game. These include the need for more effective measures of behaviour change, large representative samples, follow-up measures and the use of a large-scale randomised-control trial to examine the effects of the serious game. Identification of how both BCTs and gamification techniques can be best employed to support the efficacy of the serious game is also described. In line with the learnings from past literature, this deliverable also presented the concept for the serious game. Efforts to ensure both user engagement and research outcomes are considered within the design of the serious game are highlighted. This deliverable also outlines the technical details underlying the development of the serious game. The software specifications and architecture, as well as the user and scenario parameterization, game environment modelling and implementation characteristics are presented in detail. Finally, key considerations to ensure that data is effectively processed and stored were presented. Efforts undertaken to support data protection, GDPR compliance and open access to data for researchers are noted. As such, it is clear that the methodologies employed to design the EVIDENT serious game should ensure that it effectively supports the project objectives and will contribute significantly to policy and scientific understanding.

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Appendices

Appendix I - Sample Participant Information Leaflet – Serious Game

Name of Study: EVIDENT

Site	**Online**
Principal Investigator(s) and Co-Investigator(s) (insert names, titles and contact details)	Dr. Paul Liston, Alison Kay & Emma Delemere Centre of innovative Human Systems, Department of Psychology Trinity College Dublin Dublin 2 Contact: pliston@tcd.ie, alison.kay@tcd.ie , delemere@tcd.ie
Study Organiser/ Sponsor (if applicable)	EVIDENT - bEheaVioural Insights anD Effective eNergy policy acTions
Data Controllers	Trinity College Dublin (for research data) SIDROCO holdings ltd. (for the EVIDENT Platform)
Data Protection Officer	Data Protection Officer Secretary's Office Trinity College Dublin Dublin 2 SIDROCCO Antonios Sarigiannidis asarigia@sidroco.com
EVIDENT Ethics Manager	Tilemahos Eftimiadis Tilemahos.EFTHIMIADIS@ec.europa.eu

EVIDENT is a European Commission-funded H2020 project which aims to investigate the socio-economic non-energy impacts, and role of behavioural insights, on energy efficiency interventions. The EVIDENT consortium, coordinated by the University of Western Macedonia, brings together 9 partners from industry and academia across 5 European countries. The duration of this project is 3 years, extending from December 2020 to November 2023. EVIDENT seeks to create a framework to define the main drivers of individuals' decision making and to establish new relationships between energy consumption and other fields such as financial literacy using a wide range of case studies, experiments, surveys and randomised control trials in conjunction with state-of-the-art econometric methods and big

data analytics. EVIDENT will also develop a platform to raise energy efficiency awareness and support better decision making and policy implementation. This platform will enable future research related to behavioural biases in energy efficiency by housing within the platform a methodology and data hub. Through this, EVIDENT seeks to contribute to energy efficiency policy implementation by evaluating and proposing specific policy interventions to enhance energy efficiency.

You are being invited to take part in a research study that is being done by Dr. Paul Liston as part of the EVIDENT project. Before you decide whether you wish to take part, please read this information sheet carefully. Ask any questions. Don't feel rushed or under pressure to make a quick decision. You should understand the risks and benefits of taking part in this study so that you can make a decision that is right for you. You may wish to discuss it with your family or friends.

This leaflet has five main parts:

Part 1 – The Study

Part 2 – Data Protection

Part 3 – Costs, Funding and Approval

Part 4 – Future use

Part 5 - Further Information

Part 1 – The Study

Why is this study being done?

The EVIDENT project seeks to understand the main factors which impact an individuals' decision making around energy consumption. Factors such as financial literacy (i.e. knowing how to make informed and effective financial decisions), environmental literacy (i.e. the understanding, skills and motivation to make decisions that will positively impact the environment), energy literacy (i.e. knowing how much energy you and your appliances use) and their impact on your energy decisions will be examined. This study, which involves a serious game, looks to understand how these factors might impact decisions to repair or replace appliances that break. Through this, the EVIDENT project hopes to better understand how to support individuals to make better energy decisions and contribute to more effective energy policy implementation.

Why have I been invited to take part?

You have been invited to take part as you are a home owner, tenant or a landlord who is over 18 years of age.

Do I have to take part? Can I withdraw?

Participation is voluntary, you do not have to take part if you do not want to. There will be no negative consequences should you choose not to participate. If you start the study, but decide you don't want to continue, you can quit at any time before you finish the survey and your response will not be counted.

You cannot, however, withdraw your survey after you have submitted it, or serious game response after you start playing, since there is no way of identifying which is yours.

What happens if I change my mind?

You do not have to complete this study if you don't want to. If you start the study, but decide you don't want to continue, you can quit at any time before you finish the survey and your response will not be counted. You cannot, however, withdraw your survey after you have submitted it, or serious game response after you start playing, since there is no way of identifying which is yours.

How will the study be carried out?

This study consists of three parts. Firstly, you will be asked to complete a short survey. This survey will gather some basic information on you, your energy awareness, attitude toward environmental issues and financial literacy. This survey should take between 10 to 15 minutes. After this you will have the opportunity to play a serious game which looks at decisions to repair and replace appliances that break. This game will also give you some tips on making effective repair and replace decisions to help you to decide between repairing and replacing, considering both the financial and environmental impacts.

You can also choose to participate in a short follow-up survey which will be sent out between 6 to 12 months after you play the serious game. This survey will take around 5 to 10 minutes and will look at whether you had the opportunity to repair or replace an appliance and the decision you made. To participate in this, we will ask you to share your contact information so we can send the survey on to you. Your contact information will be stored separately and will not be linked to your responses. All contact information will be deleted immediately after use.

You are encouraged to share this study with friends or family who might also be interested in participating.

What will happen to me if I decide to take part?

If you choose to take part you will be asked to complete the survey and serious game, which should take around 30 minutes. You will also be sent a follow-up questionnaire between 6-12 months after you play the serious game, should you choose to receive it. You can choose if you would also like to participate in a short interview (around 30 minutes) or focus group.

What will happen to my Data?

The researchers listed above will have access to the survey, serious game, and interview responses. Survey and serious game responses will be combined, and results will be reported as a group to ensure anonymity. Interviews will be transcribed, and any identifying information redacted. Interview data will be compiled together prior to being shared to support anonymity. This data will be deleted after seven years. The Data Controller for this research is Trinity College Dublin (for the research project) and SIDROCCO holdings ltd (for the EVIDENT platform). Data gathered within this study will be stored on the EVIDENT data platform. Data from this platform will be accessible to other researchers. To use this platform researchers will be required to apply for approval to access this data using a justification form. Applications will be approved by the project coordinator and the Ethics and Privacy Committee. Researchers will be required to be based within the EU.

According to the EU directive for open data, the access storage of data is being conducted to allow other

researchers outside the EVIDENT consortium to further extend any findings we may make. The members of the consortium have access to the available data before their official release. All data will be anonymised, and no sensitive data will be stored.

Are there any benefits to taking part in this research?

Taking part in this study will not directly benefit you. However, through participating in this research you will help us to better understand how individuals make energy investment decisions.

Are there any risks to me or others if I take part?

There are no foreseeable risks to you by participating in this study.

Will I be told the outcome of the study? Will I be told the results of any tests or investigations performed as part of this study that relate to me?

The results of the study will be reported in scientific journals, on the project website and platform, and disclosed at conferences. No information which reveals your identity will be disclosed.

Part 2 – Data Protection

What information about me (personal data) will be used as part of this study? Will my medical records be accessed?

You will be asked to share some basic demographic information (age, etc) and information on your energy awareness, attitude toward environmental issues and financial literacy. Within the serious game information will be gathered on the decisions you make around repairing or replacing appliances. Interviews or focus groups will gather data on your experience of the game and whether you think it will apply to your behaviour in real life. Should you choose to participate in the follow-up your email or address will be obtained to allow us to contact you for this purpose.

What will happen to my personal data?

Data gathered within the serious game will be stored on the EVIDENT data platform. This data will be accessible to other researchers who have obtained approval to access this data from the project coordinator and the Ethics and Privacy Committee. This open access storage of data is being conducted to allow other researchers to further extend any findings we may make. All data will be anonymised, and no sensitive data stored.

Who will access and use my personal data as part of this study?

Data gathered within the serious game will be stored on the EVIDENT data platform. This data will be accessible to other researchers who have obtained approval from the project coordinator and the Ethics and Privacy Committee. This open access storage of data is being conducted to allow other researchers to further extend any findings we may make. All data will be anonymised and no sensitive data will be stored.

Will my personal data be kept confidential? How will my data be kept safe?

All data will be kept in a confidential manner. A risk assessment of the data protection implications has been completed. No identifying information will be shared that may risk participant's confidentiality. Researchers adhere to the Psychological Society of Ireland code of Ethics [48]

What is the lawful basis to use my personal data?

By law,[6] we can use your personal information for scientific research[7] (in the public interest[8]).

What are my rights?

You are entitled to:

- The right to access to your data and receive a copy of it
- The right to restrict or object to processing of your data
- The right to object to any further processing of the information we hold about you (except where it is de-identified)
- The right to have inaccurate information about you corrected or deleted
- The right to receive your data in a portable format and to have it transferred to another data controller
- The right to request deletion of your data

By law you can exercise the following rights in relation to your personal data, unless the request would make it impossible or very difficult to conduct the research. You can exercise these rights by contacting Dr P Liston or the Trinity College Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: [26]. Website: www.tcd.ie/privacy.

Part 3 – Costs, Funding and Approval

Has this study been approved by a research ethics committee?

Yes, this study has been approved by the Research Ethics Committee of the Psychology department at Trinity College Dublin. Approval was granted on [**DATE].** The EVIDENT project as a whole was approved by H2020 and the Joint Research Centre (JRC) Ethics Board.

Who is organising and funding this study? Will the results be used for commercial purposes?

[6] The European General Data Protection Regulation (GDPR)
[7] *Article 9(2) (j))*
[8] *(Article 6(1)(e)*

This study is being conducted by the EVIDENT consortium which includes 9 partners, amongst which are academic institutions, research institutions, SMEs and energy providers. This project is funded through Horizon 2020.

Is there any payment for taking part? Will it cost me anything if I agree to take part?

It will not cost you anything to take part. To thank you for taking the time to participate in the current study you may be offered a small incentive. This will take the form of entries into a competition to win a voucher for €350.

Part 4 – Future Research

Will my personal data be used in future studies? (May not apply)

As outlined above, some of your anonymised data will be made available on the EVIDENT platform for researchers who have obtained approval to access it. Your responses will be completely anonymised and will not be identifiable in any way.

Part 5 – Further Information

Who should I contact for information or complaints?

If you have any concerns or questions, you can contact:

- Principal Investigator: Dr. P Liston (pliston@tcd.ie)
- Data Protection Officer, Trinity College Dublin: Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie. Website: www.tcd.ie/privacy.

Under GDPR, if you are not satisfied with how your data is being processed, you have the right to lodge a complaint with the Office of the Data Protection Commission, 21 Fitzwilliam Square South, Dublin 2, Ireland. Website: www.dataprotection.ie.

Will I be contacted again?

If you would like to take part in this study, you will be asked to sign the Consent Form on the next page. You will be given a copy of this information leaflet and the signed Consent Form to keep. If you choose to participate in the follow-up survey you will be contacted.

Appendix II - Consent Form – Serious Game

Title Of Study: EVIDENT – bEheaVioural Insights anD Effective eNergy policy acTions **Serious Game to determine the impact of financial literacy on decisions to repair or replace household appliances for different resident types.**
There are 2 sections in this form. Each section contains a number of statements. You are asked to write your initials in the box beside the statement if you agree. If you do not agree with a statement, please leave the box blank. The end of this form is for the researchers to complete. **Please ask the researchers <u>any</u> questions you may have when reading each of the statements.**

GENERAL	**Participant Checkbox**
I confirm I have read and understood the Information Leaflet for the above-named study. The information has been fully explained to me and I have been able to ask questions, all of which have been answered to my satisfaction.	☐
I understand that participation in this study is entirely voluntary, and if I decide that I do not want to take part, I can stop taking part in this study without giving a reason prior to the submission of my data.	☐
I understand that I will not be paid for taking part in this study.	☐
I know how to contact the research team if I need to.	☐
I agree to being contacted by researchers by email as part of this research study.	☐
DATA PROCESSING	**Participant Checkbox**
I give my permission for my data to be processed in line with the aims of the research study, as outlined in the information leaflet.	☐
I understand that a will received a small incentive in the form of entry into a competition for a voucher for participating in this study.	☐
I understand that results from analysis of my personal information will not be given to me.	☐
I understand that the personal information collected in the study will be kept strictly confidential and will only be made available to qualified scientists who are part of the study team.	☐

I consent to participate in the "EVIDENT - Serious Game to determine the impact of financial literacy on decisions to repair or replace household appliances for different resident types"	☐
I do not consent to participate in the "Serious Game to determine the impact of financial literacy on decisions to repair or replace household appliances for different resident types"	☐