

D.2.3.1

## Toolkit for energy upskilling

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This report presents the toolkit for energy upskilling used for the pilot experimented in WP2 of the FlexBeAn project, seeking to upskill households representatives towards more energy literacy and flexibility. The toolkit is implemented as a mobile-first application, One2Day, which delivers daily content related to energy flexibility to participants, encouraging regular engagement to enhance their energy consumption behaviors. We document the development, implementation, and underlying software components of the One2Day app, and detail the specific approach driving the app behaviour, based on a personalised nudging strategy (from profiles following our household model – see D2.1.4) to encourage behaviour change. The application’s design adapts to individual users’ personality traits, as measured by the Big Five model, to provide personalized paths that support energy flexibility.

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# 1. Energy upskilling toolkit: One2Day technical overview

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This section provides a high-level technical overview of the different software components developed to implement the Upskilling Pilot. The Pilot has been implemented as a mobile first app, named *One2Day*, that delivers to pilot participants one content related to the energy flexibility topic per day. Participants are expected to connect regularly (ideally every day) to consult the available content. The following sections provide more details on the technology stack involved.

The One2Day App is designed to deliver to registered users a single daily content related to the energy flexibility domain. To implement this service, a typical cloud-native app architecture<sup>1</sup> has been developed. The One2Day app itself is designed as a Progressive Web App<sup>2</sup> that can be accessed via a smartphone or a desktop computer. The content delivered by the app is encoded and managed via a dedicated CMS and served to the app by custom API. An internal service implements the app content selection algorithm used to personalize the users' content feeds. Finally, a monitoring stack has been deployed to provide insight on the progress of the Pilot via pre-configured dashboards.

## 1.1. Technical Architecture overview

As illustrated in Figure 1, the One2Day system is composed of the following main software components:

- *One2Day*, a Progressive Web App accessible to end users
- A CMS used to encode and manage the app content
- A backend-service, the *User Feed Service*, exposing the necessary APIs to power the app
- An internal service responsible for executing the different data preparation tasks

The system is relying on the FlexBeAn project SSO server (i.e. Keycloak) to act as an Identity and Authentication provider.

All the above listed components are packaged and deployed as Docker<sup>3</sup> containers on a Kubernetes<sup>4</sup> cluster as illustrated in Figure 2. A Kong API Gateway is introduced at deployment time to control the APIs exposed by the User Feed Service.

Each component source code and deployment resources are stored in a dedicated Git repository on LIST Gitlab server.

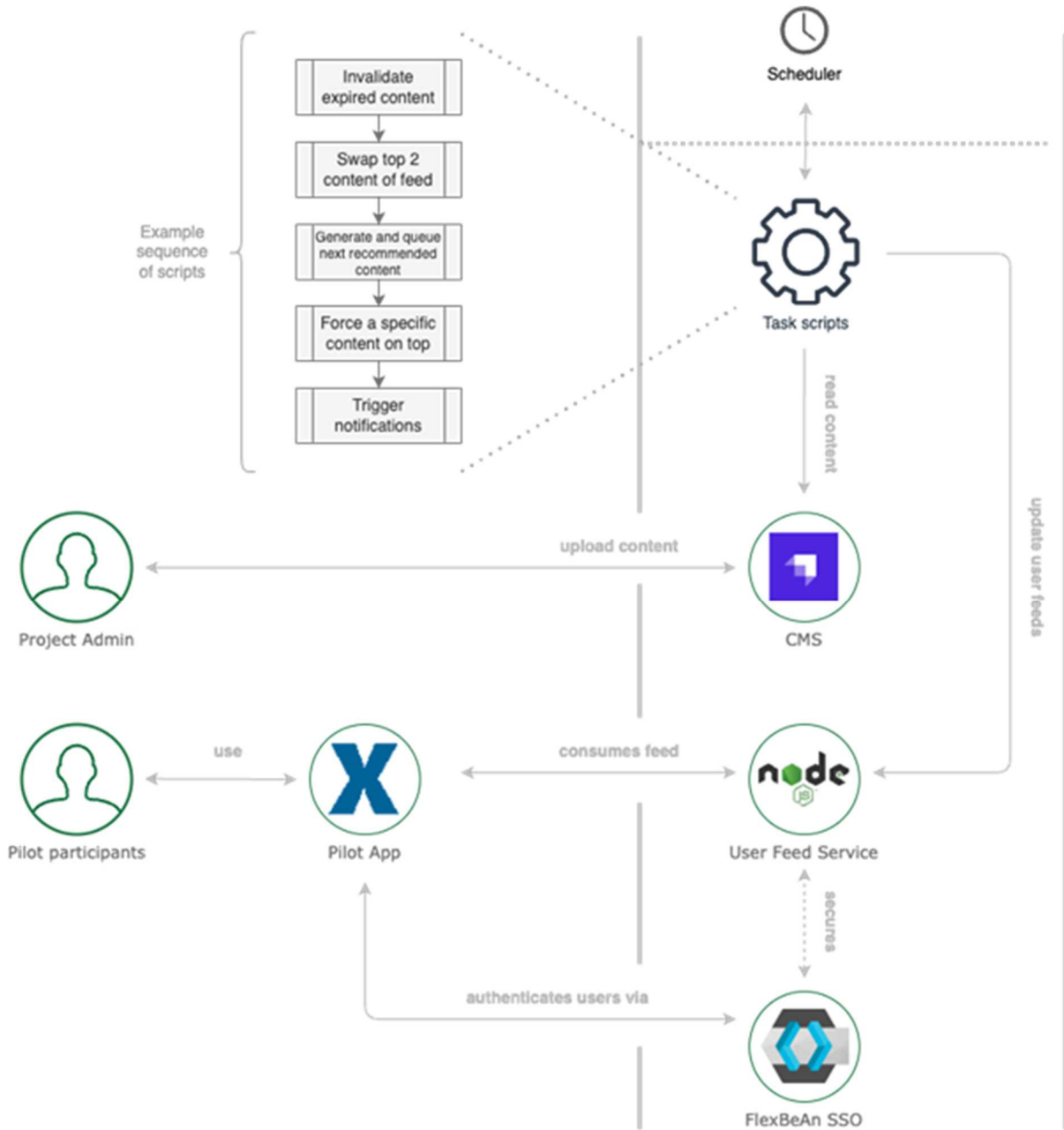


Figure 1 One2Day System Architecture

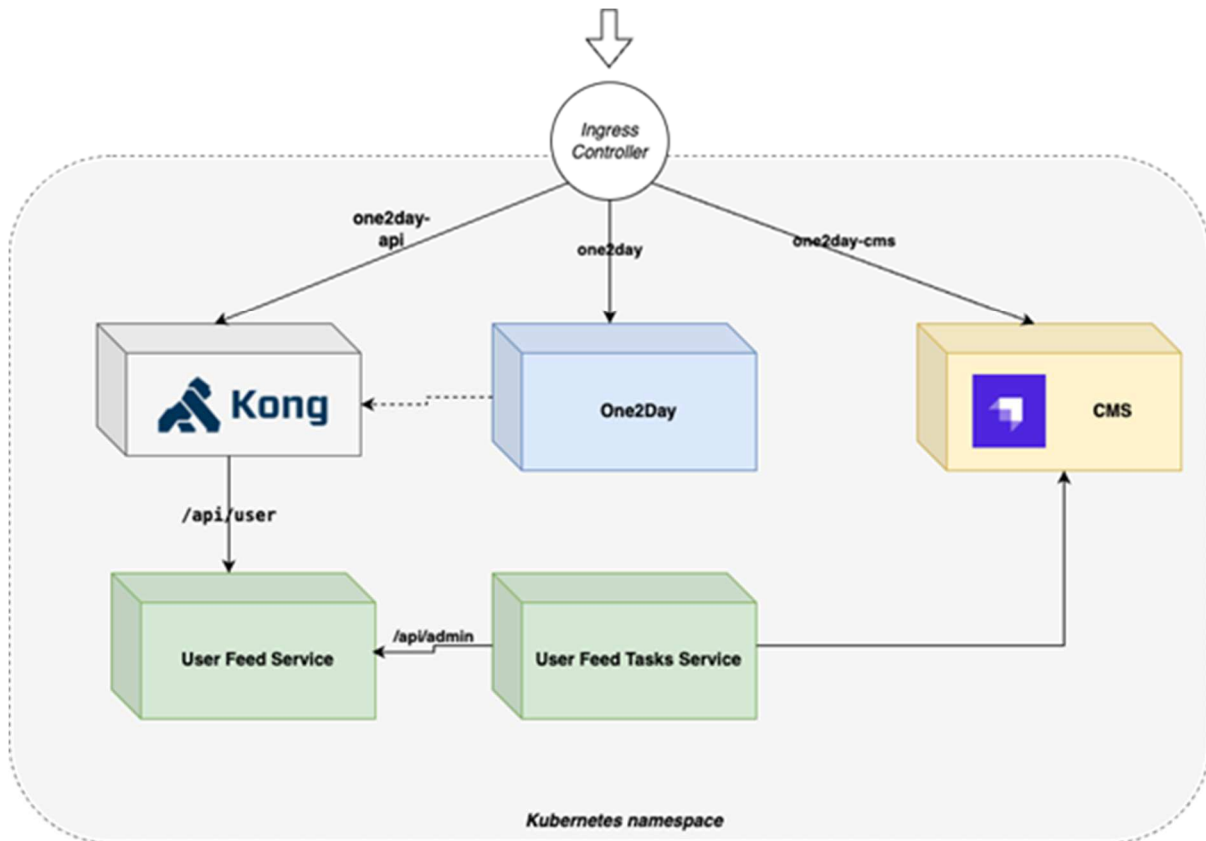


Figure 2 One2Day deployment architecture

In addition to these “operational” components, a monitoring stack is also present. It is composed of a scheduled tasks that extracts data from the operational databases to populate a reporting table used to feed Grafana dashboards.

## 1.2. One2day, a progressive WebApp

The One2Day app is built as a Progressive Web App, or PWA. This means it is designed to deliver an app-like experience to users. In particular, it can be “installed” on the user phone.

The app is built using the Ionic framework<sup>5</sup>, a modern, web-based, cross-platform app development framework. We chose the Angular version of the framework to perform the development.

Registration is required to access the app. This can be achieved either by creating a dedicating account, or by reusing an existing FlexBeAn Smarty+ account.

Once registered, the user can start consuming personalized content tailored based on the user profile.

### 1.3. Content Management System (CMS)

All the app content is managed via a dedicated CMS system. We chose Strapi<sup>6</sup> as a CMS solution for this project. A series of utility scripts have been created to upload the content created in the context of the project, as excel files, onto the CMS.

The following content types exists:

- *Did you know*: a "fact" related to the energy domain presented to the user. The user is prompted to indicate in-app if they already knew about the fact or not.
- *Today's action*: a call for action presented to the user to trigger a change of behavior.
- *True/False*: a statement that may be valid or not. The user is asked to indicate if they think it is valid or not.
- *Quizz*: a multi-choice question that the user must answer
- *Tip*: a simple information that can help the user better understand the energy domain.

These contents can be encoded using the CMS *Content* form.

Contents are then structured in *Chapters* which effectively correspond to a week of content as illustrated in Figure 3. A dedicated CMS form exist to facilitate the encoding.

Finally, the experiment *Programme* orchestrate the different chapters by selecting on which *slot* of the experiment (effectively *week* of the Pilot) they will be presented. A dedicated CMS form exists to manage the content of the programme.

### UpSkilling programme overview

Week 1	Chapter 1					Extra Content	Extra Content
Week 2	Chapter 2					Extra Content	Extra Content
Week 3	Chapter 3					Extra Content	Extra Content
Week 4	Chapter 4					Extra Content	Extra Content
	...	...	...	...	...	...	
Week 13	Chapter 13					Extra Content	Extra Content
Week 14	Chapter 14					Extra Content	Extra Content
Week 15	Chapter 15					Extra Content	Extra Content

5 days of thematic content
2 days for extra content

The CMS supports internationalization (i18n) to translate the content in the different Pilot languages. Currently configured languages are English (default), French and German.

The CMS relies on a cloud Postgres database to persist its data.

## 1.4. User Feed Service

The *One2Day* app interacts with a set of custom REST APIs to manage the user data. These APIs, and related logic, are implemented inside a NodeJS<sup>7</sup> component called the User Feed Service.

This service exposes the following APIs:

- */user/profile*: a set of APIs used by the app to interact with the User Profile
- */user/feed*: a set of APIs used by the app to interact with the user feed of content
- */admin*: a set of APIs used by internal services and scripts to administrate the content of the app.

The full API is documented using the OpenAPI standard. The latest documentation is available [here](#). The internal logic of this service is basically just CRUD operations. The actual logic to curate the user feeds is delegated to an internal User Feed Tasks service.

## 1.5. User Feed Tasks Service

This service implements the algorithm used to generate and populate user feeds with content from the CMS. It is implemented as a NodeJS<sup>8</sup> component exposing internally its own REST APIs.

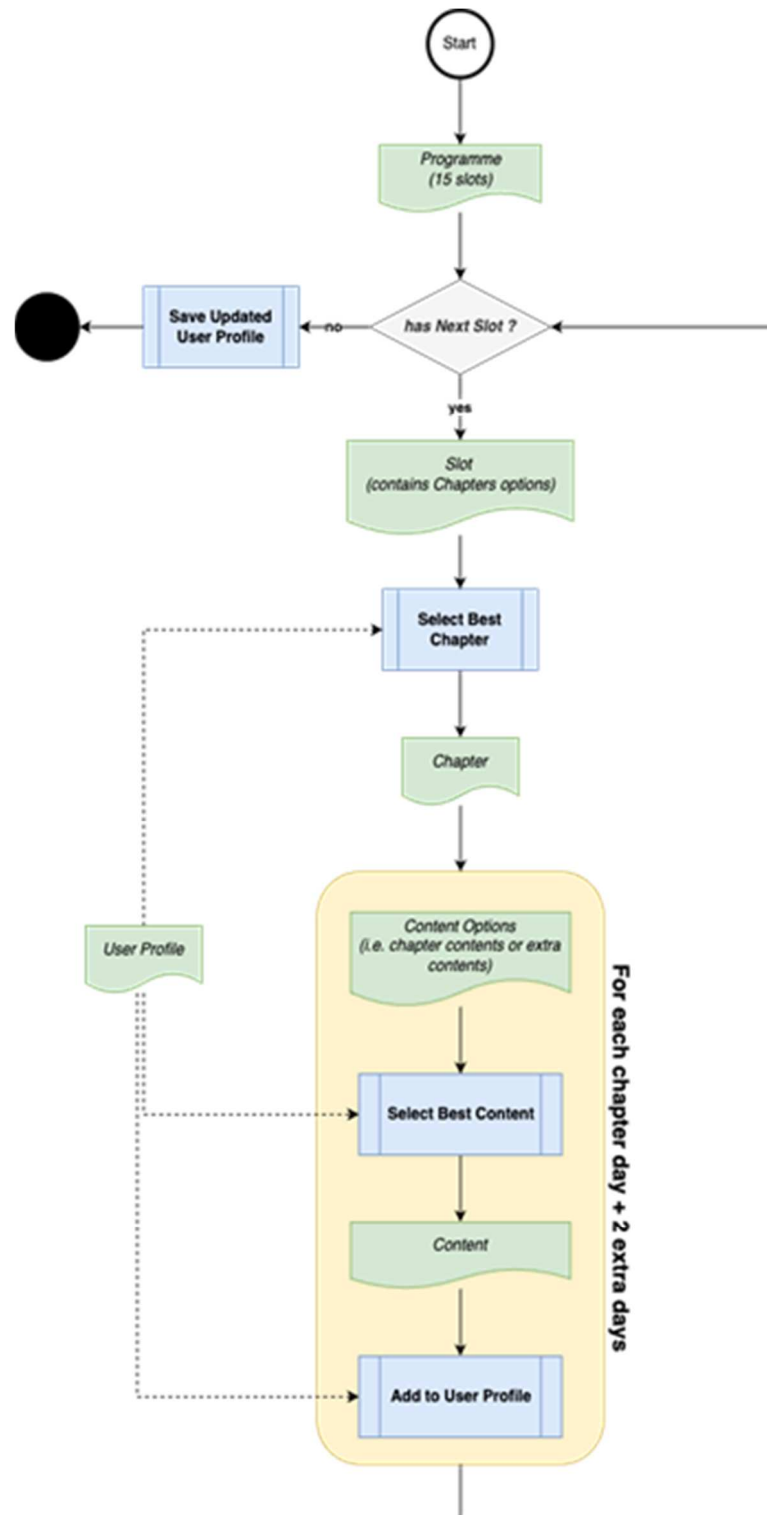


Figure 4 Content selection algorithm.

For each user, the algorithm illustrated in Figure 4 is applied.

The *Select Best Chapter* algorithm is documented in Figure 5 below.

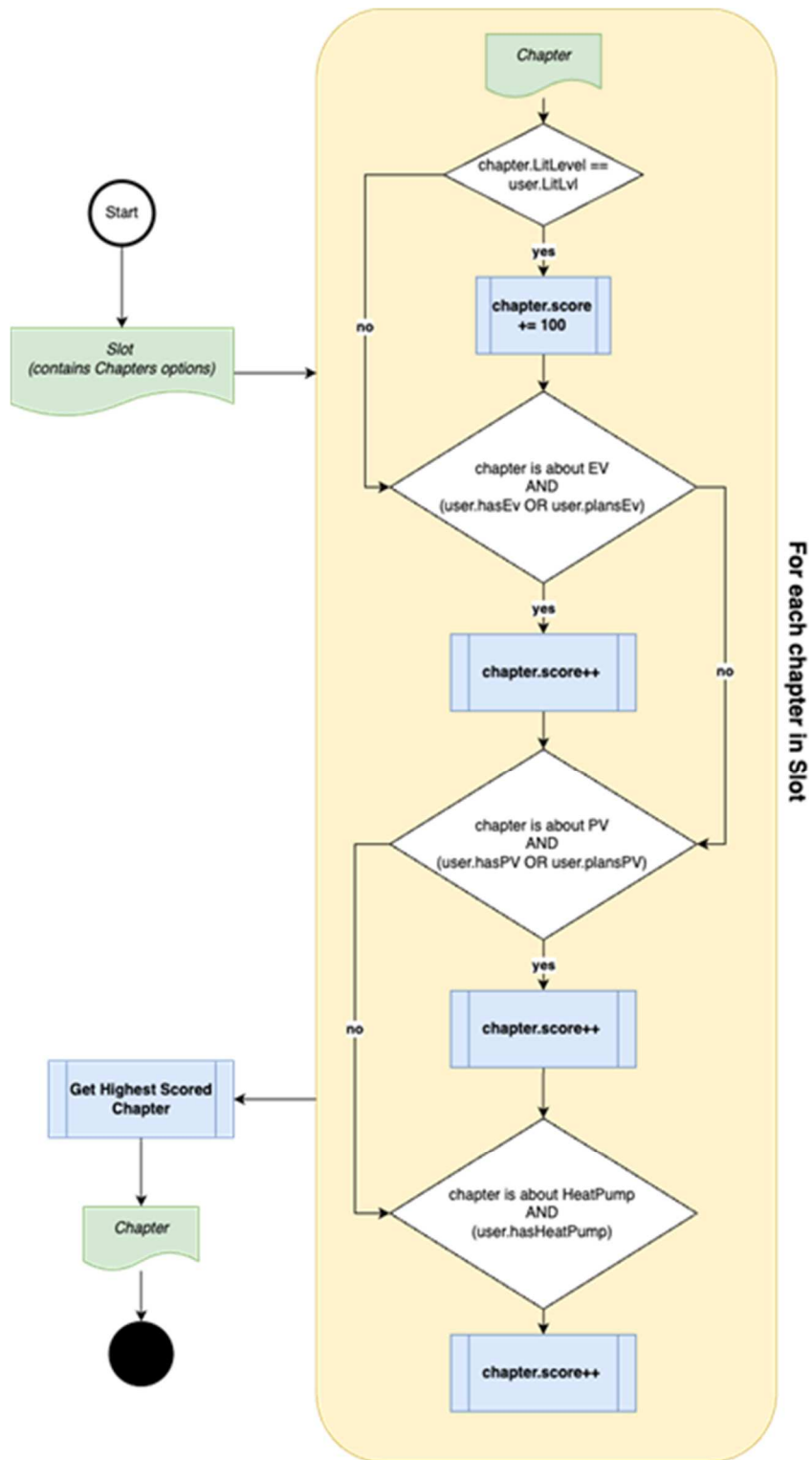


Figure 5 Select Best Chapter

The *Select Best Content* algorithm is documented in Figure 6 below.

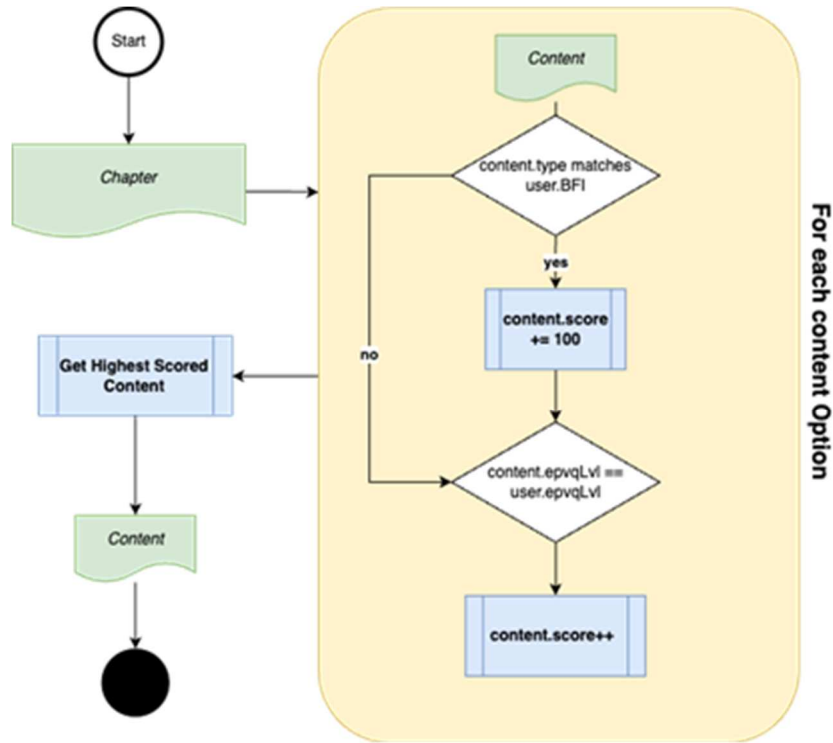


Figure 6 Select Best Content

The table below illustrated the hypothesis used to match the BFI scores of the user profile with the different content types.

Contenu	High Op	Low Op	High Co	Low Co	High Extr	Low Extr	High Agr	Low Agr	High Neur	Low Neur
Did You know	+	+	+			+		+	+	+
Agree/Disagree	+		+			+				+
Quizz	+		+	+	+	+	+	+	+	+
Tips	+		+	+		+			+	+
Actions	+	+	+		+	+	+	+		+

Bleu : hypothèse basée sur le Big-5  
 Jaune : hypothèse basée sur la littérature  
 Quand deux contenus risquent d’être préférés de manière égale, les proposer de manière random 50/50 et adapter selon les « likes » et préférences de l’user.

The above algorithm is triggered as a scheduled task every night and updates in batch all the user feeds based on the available content from the CMS.

Other utility tasks are implemented to extract and load content from the CMS and manipulate specific user feeds.

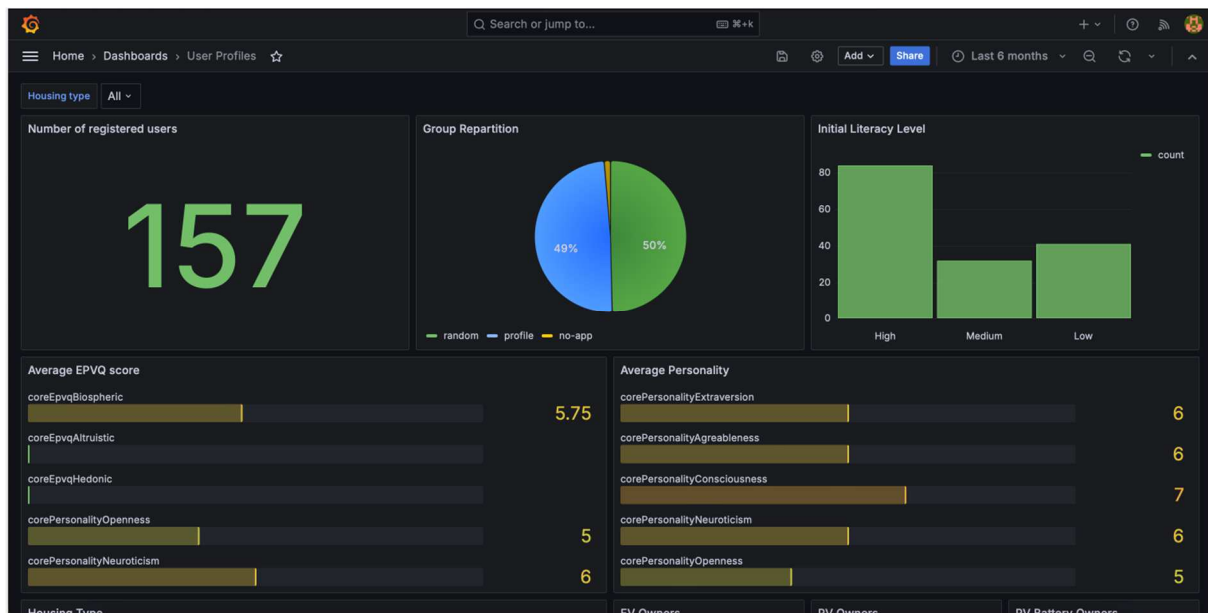
## 1.6. Monitoring stack

The project monitoring stack is composed of

- a custom ETL script that will obtain data from the *User Feed Service* using the *admin* APIs and load it to a Postgres database
- a Grafana<sup>9</sup> server instance connecting to the Postgres database

Two dahsboards are available to monitor the progress of the Pilot:

- **User Profiles** documents aggregated data related to the user profiles of registered users.



**Program Overview** documents overall consumption of content by registered users



### 1.7. Links

How to access the Pilot tools:

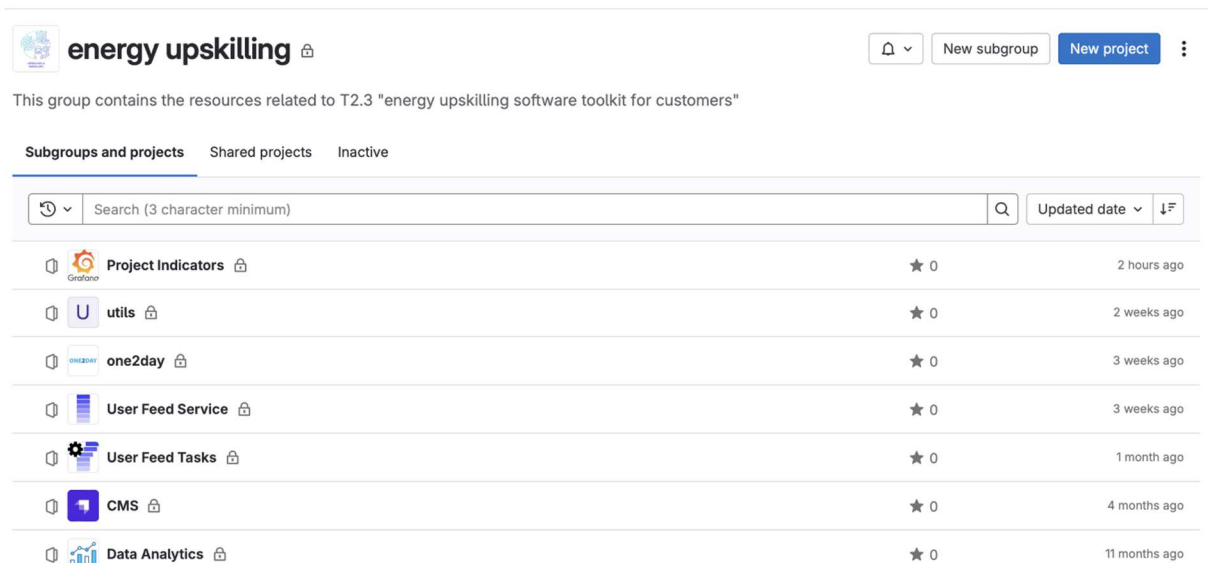
The One2Day applications is available at <https://one2day.flexbean.lu>.

The CMS is available at <https://cms-one2day.aida-cluster-6fb15c141b13202f00901f551abdf43d-0000.eu-de.containers.appdomain.cloud>.

The monitoring dashboard is available at <https://one2day-dashboard.aida-cluster-6fb15c141b13202f00901f551abdf43d-0000.eu-de.containers.appdomain.cloud/>.

How to access source code and technical documentation:

All source code of the One2Day system is available on LIST Gitlab under: <https://git.list.lu/flexbean-project/energy-upskilling> as illustrated below.



## 2. The app and its personalized nudging strategy

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In this section, we discuss the development of the application, the persuasive strategies employed, its limitations, and potential future improvements. It is explained in particular how nudges can be chosen from the household profiles instantiating the model detailed in D2.1.4, exploiting results from the survey analysis (D2.1.4 and D2.2.2). The work reported here is a copy of a scientific article published in ECCE '24: Proceedings of the European Conference on Cognitive Ergonomics 2024:

Zehnder, E., Gronier, G., & Deladiennée, L. (2024, October). Towards the design of a mobile application with persuasive elements to increase energy flexibility. In *Proceedings of the European Conference on Cognitive Ergonomics 2024* (pp. 1-4). <https://dl.acm.org/doi/abs/10.1145/3673805.3673825>

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### **Design of a mobile application incorporating persuasive elements to promote energy flexibility**

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Global demand for electricity is set to increase in the coming years, particularly with the growing use of electric vehicles. To avoid consumption peaks, users will need to be more energy-flexible. This article therefore presents an application that aims to help users become more flexible in their energy consumption. To design this application, an initial survey enabled us to identify user profiles. Alongside this, nudges and persuasive techniques were listed that could be used in the application to encourage users to change their behaviour. Several user paths were then designed to adapt the persuasive elements of the application to each user, notably according to their personality traits (Big Five model). Finally, the application, its limitations and prospects are presented.

CCS CONCEPTS • **Human-centred computing** • Interaction design • Interaction design process and methods

**Additional Keywords and Phrases:** Application, Persuasion, Energy Flexibility, Personality, Design, Nudge

### **INTRODUCTION**

Global demand for electricity from individuals and industries is increasing from year to year. In developed countries, it is the transport domain that contributes most to this increase due to the introduction of electric vehicles (EV): according to the most optimistic scenarios, the market share of electric vehicles is set to increase from 8% in 2021 to 50% in 2030 [1]. In emerging countries, the demographic increase and installation of cooling systems (such as air conditioning) have a high impact on the demand for electricity. According to forecasting models, by 2050, this demand will increase from 75% to 150% at the global level [1].

The production of electrical energy is also subject to strict environmental constraints. For example, the European Union has set itself the objective of producing 80% of its electricity from renewable sources by 2050 [2]. In the shorter term,

from 2030, the aim is for 60% of electricity to come from wind or solar power [3]. This represents many challenges, including managing intermittency: renewable energies do not produce electricity all the time and the power they supply can vary considerably over short periods.

In this context, energy flexibility is considered a necessary adaptation from the point of view of both electricity producers and consumers. For producers, energy flexibility is defined as the ability to react to unexpected changes in electricity demand [4]. For consumers, flexibility refers to the ability to adjust their own demand (and their energy production, if necessary) depending on the global demand on the electricity network and local conditions (such as weather conditions) [5]. It is therefore essential that consumers are willing to be flexible and are ready to change their habits in the way they use electricity.

This research focuses on the ways in which it is possible to change the attitudes and behaviours of consumers concerning energy flexibility. By concentrating on persuasive technology [6] and the use of nudges, a mobile application was developed to guide users in these different changes. In this article, we present the design process of this application and the way in which the persuasion elements were selected in order to correspond with the profiles of electricity consumers.

## **THEORETICAL FRAMEWORK**

In recent years, diverse works have enabled different types of persuasion elements to be showcased in technologies. A first wave of authors [7]–[10] defined different persuasion criteria, techniques and principles. These are the accumulation of interactions and interface elements that enable the user to change his/her behaviours and attitudes. The *nudges* appeared at a later stage [11]: these are more accurate than persuasion techniques as their objective is generally to guide the user towards a specific behaviour. However, in this case, the user remains free to make his/her own choices and there is no attempt to change him/her.

To enable an application to persuade users, concepts such as engagement and retention were studied. They show the attraction and effectiveness of an application and enable users to be encouraged to continue using it. For example, engagement is examined at the same time as user experience for applications related to mental health [12]. First referenced in marketing for talking about customer engagement, it can be understood as the voluntary investment in the cognitive, emotional and behavioural resources of a client or user in interactions with the brand (or a technology) [13]. This is related to retention, which is an engagement metric since it considers an extended use rather than just the initial adoption [12]. As for user retention, this is generally defined as the number of initial users that are still active within a specified time period.

### **Captology and persuasion**

To attempt to change behaviours using technology, several authors have mentioned persuasion methods or techniques that take place through technology. Within the scope of captology (acronym of Computers As Persuasive Technologies) [14] described persuasive technologies as being non-coercive, with a real intention to change a person through technology (thus differentiating planned changes from simple side effects), and lastly, having to seek to change attitudes or behaviours, or both.

In his book, [8] mentioned seven types of techniques that could be integrated into the technology: reduction (simplifying a complex task in order to increase the benefit-cost ratio of a behaviour), tunnelling (guiding users through a process or an experience in order to persuade them during it), tailoring (providing information tailored to needs, interests, personality, use context, etc.), suggestion (suggesting behaviours at the appropriate moment, for example), self-monitoring (offering feedback to users for them to adapt their attitudes or behaviours to fulfil an objective), surveillance (observing the behaviours of others) and conditioning (reinforcing target behaviours).

Other authors such as [9] have added different types of persuasion criteria. Some are considered dynamic, such as solicitation (the first step that briefly attracts the user and encourages him/her to initiate a relationship), priming (media elements that prompt a persuasive influence), engagement (the system continues to involve the user through a process) and ascendancy (submission and obedience through the realization of engaging scenarios); and other criteria are considered

static, such as credibility (the ability of the interface to inspire confidence), privacy (concerning personal data), personalization and attractiveness.

[7] was the first to define influence strategies in which the context was human-human interaction. That said, they had already been used in human-machine interaction [15], [16]. In his book, Cialdini mentions persuasion methods (in human-human interaction) such as reciprocity (being likely to return favours that others have done for us), engagement and consistency (ensuring that the user commits to a behaviour by accepting it), social proof (being likely to do what other people do), sympathy (being likely to agree with people we like or do things for them), authority (being likely to listen to authority figures or obey them), scarcity (being likely to demand something that is considered more rare or difficult to obtain). In another article [17], Cialdini also adds the consensus method (inform other people of a decision when we are not sure about it).

Fogg et Cialdini's principles of persuasion have been used in various studies [18], [19], in the context of energy consumption. The work of [18] demonstrated, for example, that the cause and effect, conditioning and self-monitoring principles could be more effective to encourage different user profiles to adopt more environmentally friendly measures in the workplace. Fogg's criteria were used to design an application to encourage more environmentally friendly behaviours from the employees in the study [19].

### *Engagement and retention*

The engagement of users to an application is important, as it prevents them from stopping using it. Engagement, as a psychological state, comprises a dynamic and interactive relationship with an agent or an object (for example, a brand, a product or a medium), which meets the instrumental (e.g. utility) and experiential (e.g. emotional satisfaction) values of a user [20]. Engagement may have a positive or negative valence [21], [22].

User retention, a concept close to engagement, is widely used to measure the success of applications as it corresponds to a higher level of adoption and engagement [29].

Retention can be influenced by numerous factors. In his works, [30] observed that these latter concerned the ease of use of an application, its aesthetics, telephone assistance, trust in its security, storage, performance and adaptability; whereas the factors leading to an application being uninstalled were the time needed, expectations of the application, its size, outages, waiting time, social influence, access to personal data and usefulness. As with engagement, retention can also be measured by behavioural metrics. For example, in the study of [31], the retention rate was considered as the number of users continuing to use an application  $n$  days after using it for the first time. It therefore appears that a high level of engagement and high retention rate is necessary in an application order to lead users to progressively change their behaviours and attitudes concerning energy flexibility.

### **Nudges**

In 2009, [11] presented *nudging* as a concept influencing human behaviour, based on the design of environments with different choices (also called choice architecture) in order to improve human decision-making. In the digital domain, therefore, elements of the user interface are created to guide user behaviour [32]. To date, there is no consensus on a taxonomy of nudges that gives an exhaustive view of them. Sometimes, some of them are confused with persuasion techniques (for example, engagement or pre-engagement strategies). However, certain authors have attempted to resume [11]'s responses related to choice architecture. Following on from the work of [35], [36] established a list of nudges that can encourage environmentally friendly behaviour, such as prompting (using non-personalized information/messages to promote or raise awareness of a targeted behaviour), sizing (changing the size or quantity of an object), proximity (making activating options easier or more difficult), priming (suggesting indicators in the environment to influence unconscious decisions), presentation (modifying the visual design or presentation of an object to attract attention, for example), labelling (highlighting "approved" information) and functional design (modifying the design of an object to influence its use).

Part of the literature studies how the nudges allow behaviours related to the environment to be changed. [38] found, for example, that groups that tested a nudge with a status quo bias had more environmentally friendly behaviours than a

priming nudge, which had no effect. [39] highlighted that goal framing with monetary benefits in the interface led to a greater flexibility concerning the charging of electric cars. [40] showed that individual, real-time feedback on the consumption of electricity, alongside recommendations to economize electricity, are more effective than feedback on electricity costs and savings made, which tend to increase consumption.

An initial literature review [41] highlighted that the feedback nudge, social reference (which attracts attention to the behaviour of others), default choices and framing were identified as effective for modifying, reinforcing or establishing environmentally friendly behaviours. Another study [42] showed that the priming nudge, planning of aims, default, decoy (having to choose between two alternatives, with a third, less attractive alternative), feedback, social comparison and framing have generally been effective in inciting environmentally friendly behaviours. Certain works included in these meta-analyses combined several nudges. As such, in the same way as persuasion techniques, certain nudges (in isolation or combined) may incite users to become more flexible in their energy consumption.

#### *Nudges and personality*

Certain authors have attempted to establish a link between personality traits and the importance of nudge or persuasion techniques to allow the nudges to be better adapted to users. Most of the time, personality is described according to the Big Five Factor model [43] [44].

[45] consequently studied the links between personality and Cialdini's persuasion strategies. They showed that:

- *Conscientious* people are more sensitive to engagement and reciprocity but less sensitive to sympathy;
- *Agreeable* people are more sensitive to authority, engagement and sympathy;
- People who are less *open* are more sensitive to authority, consensus and sympathy;
- People with a high *neuroticism* score are more sensitive to consensus.

[46] observed that a high level of *neuroticism* is the strongest predictive factor of susceptibility to social influence, followed by not being very *open* to new experiences and not being very *conscientious*. In the study of [47], those with a high level of *agreeableness* and a *conscientious* character were considered more sensitive to conformity values. In a health context, [48] noted that more *conscientious* people were less susceptible to using applications with cooperation and competition strategies; more *agreeable* people were more sensitive to reinforcement strategies; the more *open* people were to experiences, the more sensitive they were to extrinsic, intrinsic and negative reinforcement strategies. [49] observed that *conscientious* people were more sensitive to authority and that *agreeable* people were more sensitive to sympathy.

In a gamified system, [50] observed other links between personality traits and nudges:

- a great *openness* makes people less sensitive to cooperation, comparison, competition and rewards;
- *extraverted* people are more sensitive to personalization, self-control, feedback, comparison, punishment, objective-setting, suggestions, competition and rewards;
- *conscientious* people are more sensitive to simulations in the game, objective-fixing and suggestions;
- *agreeable* people are more sensitive to cooperation, simulation, punishments, personalization, competition and rewards in the game.

Finally, [51] observed that *extraverted* persons were more sensitive to loss aversion, which is also linked to willingness to take risks. As for *openness to experience*, this is related to greater risk tolerance [52]. However, it must be noted that when personality is evaluated, it is done trait by trait without taking the entire profile into account. If, for example, a user has a high level of agreeableness and a low level of conscientiousness, will he/she still be sensitive to conformity values?

Table 1 resumes the authors' conclusions cited above concerning the Big 5 personality traits.

Table 1: Effectiveness of persuasion techniques according to the personality traits in the Big 5 model.

Personality trait	Nudge or persuasion strategy	Author(s)
Openness to experience (high)	Reinforcement Less sensitive to Cooperation, Comparison, Competition and Rewards	[48], [50]
Openness to experience (low)	Sensitive to Authority, Consensus, Sympathy, Social influence	[45], [46]
Conscientious character (high)	Sensitive to Engagement, Reciprocity, Conformity to Authority, Simulation, Objective-fixing and Suggestion Less sensitive to Sympathy, Cooperation, Competition	[45], [48]–[50]
Conscientious character (low)	Social influence	[45]
Extraversion (high)	Loss aversion, Personalization, Self-monitoring and feedback, Comparison, Punishment, Objective-fixing, Suggestion, Competition, Rewards	[50], [51]
Extraversion (low)	-	-
Agreeableness (high)	Sensitive to Authority, Engagement, Sympathy, Conformity, Reinforcement, Cooperation, Simulation, Punishments, Personalization, Competition and Rewards	[45], [46], [48]–[50]
Agreeableness (low)	-	-
Neuroticism (high)	Sensitive to Consensus, Social influence	[45], [50]
Neuroticism (low)	-	-

### Other factors that trigger flexible or environmentally friendly behaviours

Persuasive technologies have been used in energy-flexible contexts and in contexts in which we seek to produce more environmentally friendly behaviours. Although these two concepts are related, they remain different. Energy flexibility implies adapting to the energy demand depending on how much is generated, while environmentally friendly behaviours relating to energy aim to reduce its consumption. Environmentally friendly behaviours could therefore facilitate energy flexibility.

Energy literacy is a broad term that covers knowledge of the content, as well as citizens' understanding of emotional and behavioural aspects [53]. Energy literacy is an element that allows users to be more adaptable and flexible from the point of view of their energy consumption. According to certain studies [54]; [23], users tend to adopt environmentally friendly attitudes, for example, if they are conscious of their overuse of energy (higher costs, higher CO<sup>2</sup> emissions, network instability, etc). Energy literacy is sometimes not enough to change behaviours. Geller's study [55] showed that despite the willingness of the study's participants to reduce energy after a 3-hour workshop, very few of them acted on this afterwards. Therefore, having more knowledge about energy and energy consumption could potentially help a user to adopt more flexible behaviours from an energy and environmentally friendly point of view.

### Research problem and hypothesis

The aim of this study is to match the nudges with persuasion techniques, according to the personality of users, in the framework of a mobile application that seeks to change the attitudes and behaviours of consumers in terms of flexible energy.

The general underlying hypothesis of this study is that changes in attitudes and behaviours are more visible and more effective if the indicators (here the nudges) are adapted to the psychological profile of the consumer.

## METHODOLOGY

### Context of the study

This study falls within the general framework of a collaborative study carried out in the Grand Duchy of Luxembourg involving its main electricity supplier and two research institutes. This project, called FlexBeAn (“Flexibility potentials and user Behaviour Analysis” - <https://www.flexbean.lu/>), aims to better understand the energy flexibility capacity of residents in Luxembourg in order to act on them. One of the means of action favoured and developed was the design of a mobile application integrating persuasion elements that are adapted to electricity consumers.

### Identifying user profiles

In order to identify different personality profiles and match them with the most appropriate nudges and persuasion techniques, we devised an online questionnaire with five main sections:

The aim of the first section was to collect different sociodemographic data relating to the respondent, such as gender, age, level of studies, profession, level of income, members of the household, type of accommodation (house/apartment...) or the main heating system within the accommodation. The second section attempts to identify the values related to behaviours and beliefs in terms of the environment. For this, the “Environmental Portrait Value Questionnaire” (E-PVQ) questionnaire [63] was used. This questionnaire consists of 17 items in the form of affirmative phrases that describe the attitude of a person, for example, “Equal opportunities are very important to him/her”. The respondent is asked to indicate, on a 7-point Likert scale, whether the attitude described “does not resemble me at all” (1) or “completely resembles me” (7). L'E-PVQ measures four factors that have a positive or negative impact on environmental values: 1. An interest in protecting nature and the environment (biospheric) (positive impact); 2. Altruism and a sense of justice (altruism) (positive impact); 3. The search for pleasure and amusement (hedonism) (negative impact); 4. selfishness and the search for power (egotism) (negative impact). The third section analysed the personality of the respondent. For this, the French version of the Big Five Inventory with 10 items (BFI-10) [44], translated into French by [64] was used. The BFI-10 comprises the 10 most representative items for measuring the 5 personality traits in the Big Five model. Each trait is assessed by 2 items, meaning the questionnaire can be completed quickly but nevertheless has excellent psychometric qualities according to the validation of [64]. The fourth section aimed to assess whether respondents felt comfortable or not with the technologies. We considered this important to ensure that the people that contacted us would be able (or not) to use the mobile application that we are developing. For this measure, we used the standardized Affinity for Technology Interaction (ATI) questionnaire [65]. This consists of 9 items that enable a profile to be created relating to interaction affinity and the ability to adapt to technologies in day-to-day life. The fifth and final section of the questionnaire comprised 13 questions concerning energy, in order to assess the participants' level of energy literacy. For example, one of the questions was: “How much electricity is needed to fully charge an electric vehicle?” with the following possible responses: 0.3-1 kWh; 1-30 kWh; 30-100 kWh; 100-300 kWh; 300-1000 kWh-; I don't know; I don't understand the question.

### Design of the mobile application

The mobile application, aiming to change consumer attitudes and behaviours around flexible energy, was designed according to a human-centred approach, in line with the ISO 9241-210 norm [66]. For this, together with the project team, made up of 2 User Experience (UX) researchers, 1 information science researcher and 2 IT specialists, we first defined the different user experiences, from the downloading of the application to the different contents that users could consult (see Results section for the different types of content offered).

We then held several brainstorming sessions to generate as many ideas as possible around the functionalities that could motivate users to consult the application regularly. For example, we identified that social influence could be an important motivating factor. On this basis, we established that users should be able to share content, add friends, share the results of a quiz, like or comment on content, compare themselves to other user groups, etc.

Finally, we made several models of the processes we had defined, integrating the functionalities into them (Figure 1).

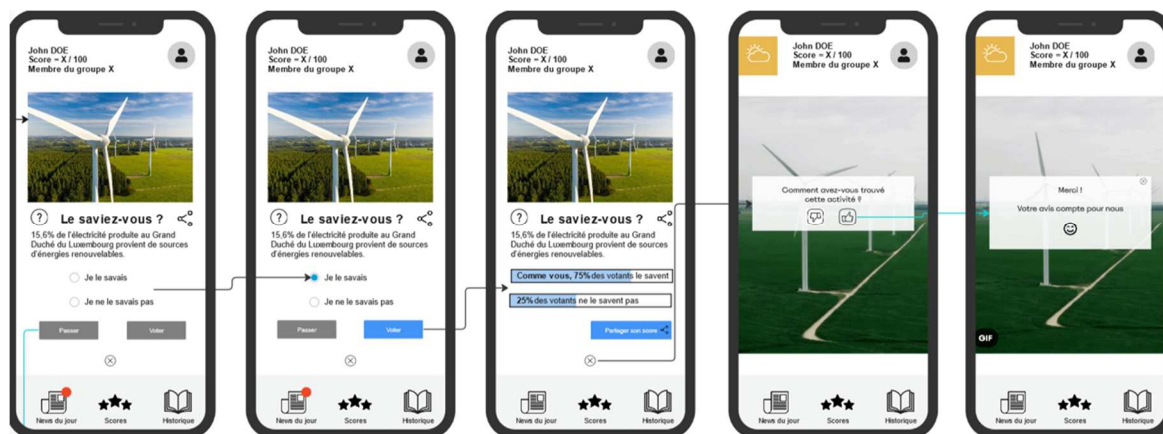


Figure 1: Example of a model made when designing the mobile application.

## RESULTS

### Identification of user profiles

There were 459 responses to the survey carried out to find out the profile of electricity consumers in Luxembourg. The general sociodemographic profile of the respondents is resumed in Table 2.

Table 2: General sociodemographic description of the survey respondents.

Variables	(n=459)
<b>Gender</b>	
Female	95 (21%)
Male	361 (79%)
Non-binary	2 (0.1%)
Prefer not to say	1 (0.1%)
<b>Age groups (years old)</b>	
18-25	1 (0.1%)
26-35	79 (17%)
36-45	114 (25%)
46-55	117 (25%)
56-65	107 (23%)
Over 65	41 (9%)
<b>Homeowner or tenant</b>	
Homeowner	428 (93%)
Tenant	31 (7%)
<b>Type of housing</b>	
Apartment	60 (13%)
Detached house	215 (47%)

Semi-detached house	126 (28%)
Terraced house	56 (12%)
Other	2 (0.1%)

Concerning the personality traits of the Big 5, the general profile of the respondents is as follows: As a reminder, possible scores range from 1 to 5. The higher the score, the stronger the personality trait in this dimension:

Extraversion: 2.78

Agreeableness: 3.48

Conscientious character: 3.27

Neuroticism: 2.66

Openness to experience: 2.92

Each personality trait was cross-referenced with different variables to check whether it influenced them. The two versions are presented in Table 3. The significant influences are highlighted in bold.

Table 3: Links between personality traits of the Big 5 and a selection of variables measured during the questionnaire.

Personality traits of the Big 5					
Variables	Extraversion	Agreeableness	Conscientious character	Neuroticism	Openness to experience
<b>Gender</b>	F(1.454) = 0.075, p = 0.784	<b>F(1.454) = 5.099, p = 0.024*</b>  (Female = 3.668; Male = 3.427)	F(1, 454) = 0.366, p = 0.545	<b>F(1.454) = 6.931, p = 0.009***</b>  (Female = 2.900; Male = 2.593)	F(1.454) = 0.143, p = 0.706
<b>Homeowner-Tenant</b>	F(1.454) = 0.089, p = 0.765	F(1.454) = 0.548, p = 0.460	F(1.454) = 0.693, p = 0.406	<b>F(1.454) = 8.291, p = 0.004***</b>  (Homeowner = 2.620; Tenant = 3.161)	F(1.454) = 0.877, p = 0.350
<b>Type of housing</b>	<b>F(1.454) = 3.230, p = 0.012*</b>  (Apartment = 2.742; Detached house = 2.707; Semi-detached house = 2.703; Terraced house = 3.277; Other = 2.500)	F(1.454) = 0.684, p = 0.603	F(1.454) = 0.611, p = 0.655	<b>F(1.454) = 2.921, p = 0.021*</b>  (Apartment = 2.833; Detached house = 2.770; Semi-detached house = 2.424; Terraced house = 2.563; Other = 2.500)	F(1.454) = 2.108, p = 0.079
<b>E-PVQ: biospheric</b>	<b>r = 0.098, p = 0.037*</b>	<b>r = -0.100, p = 0.032*</b>	<b>r = 0.133, p = 0.004***</b>	r = -0.018, p = 0.706	r = 0.019, p = 0.687

<b>E-PVQ: altruism</b>	$r = 0.015, p = 0.007^{***}$	$r = 0.006, p = 0.904$	$r = 0.139, p = 0.003^{***}$	$r = -0.097, p = 0.038^*$	$r = 0.060, p = 0.198$
<b>E-PVQ: hedonism</b>	$r = 0.026, p = 0.585$	$r = -0.116, p = 0.013^*$	$r = -0.067, p = 0.150$	$r = 0.029, p = 0.534$	$r = -0.065, p = 0.168$
<b>E-PVQ: egotism</b>	$r = -0.027, p = 0.564$	$r = 0.106, p = 0.023^*$	$r = -0.132, p = 0.005^{***}$	$r = -0.0002, p = 0.996$	$r = -0.066, p = 0.158$
<b>ATI</b>	$r = -0.092, p = 0.050^*$	$r = -0.029, p = 0.536$	$r = 0.064, p = 0.171$	$r = -0.081, p = 0.085$	$r = 0.039, p = 0.409$

\* = significant correlation at the 0.05 threshold; \*\* = significant correlation at the 0.01 threshold; \*\*\* = significant correlation at the 0.001 threshold.

It can therefore be observed, for example, that gender influences agreeableness and neuroticism, with scores significantly higher for women than for men. Tenants also have significantly higher levels of neuroticism than homeowners.

Considering connections with the “Environmental Portrait Value Questionnaire” (E-PVQ) [63], it seems, in particular, that the more consumers are interested in protecting nature and the environment (biospheric dimension), the more extraverted and conscientious they are (significant positive correlations), but the less agreeable they are (significant negative correlation). Finally, the more consumers declared themselves at ease with the technologies (ATI questionnaire), the less extraverted they were.

### Design of nudges

The literature review showed that several elements included in a persuasive technology could incite users to demonstrate environmentally friendly or more flexible behaviours concerning their energy consumption: energy literacy, persuasion strategies and finally, a connection to nature. In a first phase, nudges and persuasion techniques will be introduced into the application in the form of different types of daily content proposed to users, as follows:

The “Did you know...” type of content asks the user if he/she knows about certain information in particular (relating to energy or the environment, for example). This type of content enables a user’s energy literacy to be measured and increased. After answering, “Yes, I know” or “No, I didn’t know”, users see the percentage of other users that chose each response.

The “Do you agree...?” type of content asks the user if he/she agrees with a particular statement. This type of content enables the user’s energy literacy to be measured and his/her engagement to be maintained via an action that positions him/her (solicitation and engagement technique) [9]. Here also, users will be able to see the percentage of users that chose each response.

A “Daily action content type”, which suggests that the user commits to carrying out an action to be more flexible in terms of his/her energy consumption or to be more economical with it. This type of content reappears a day or a week later to request confirmation that the user has carried out the action. Here, the aim is to get the user to commit (aims and planning [34]; triggering of the intention to act [11], engagement [7], [9], engagement and consistency [7]; pre-engagement strategies [11]. If the user carries out an action successfully, an encouraging message is displayed (conditioning technique, Fogg, 2002, rewards and threats [34]).

An “Energy suggestions” type of content, the aim of which is simply to give advice and tips for improving energy flexibility and possibly reducing consumption (shaping knowledge) [34]. In this way, users’ knowledge of flexible energy will also increase.

A “Nature suggestions” content type suggests activities or information related to nature to the user. The aim is to strengthen the feeling of connection to nature to increase environmentally friendly behaviour and energy flexibility. By

suggesting certain activities at the appropriate time (e.g. looking at shooting stars), this type of content could respond to the loss aversion nudge [37] or to the suggestion technique [8] .

A “Quiz” type of content, which asks the user to choose the correct response to a question related to energy or the environment. The aim of this type of content is to keep the user committed by challenging his/her knowledge as well as evaluating it, enabling us to assess the effectiveness of the application.

For the “Did you know”, “Do you agree”, “Quiz” et “Daily task” types of content, it is possible for the user (after responding) to see the percentage of other users who responded to each question. In this way, the nudges and persuasion techniques related to social comparison are implemented (social norms nudge [33] ; social reference [41] ; social comparison [42] , social proof principle, [7] , behaviour comparison [34] . After visualizing or responding to content, it is possible for the user to respond to a request for an opinion (with a thumbs up or thumbs down) for the content that he/she has just completed. This is then found in the content history.

Table 4: Nudges and persuasion techniques used in the application

Authors	Nudge or persuasion strategy	Format
[33], [41] , [42]; [7] ; [34]	Social norms, social reference, social comparison, social proof, behaviour comparison	“Did you know?” content
[7], [33], [34], [41], [42], [67]	Social norms, social reference, social comparison, social proof, behaviour comparison, solicitation or engagement technique	“Do you agree?” content
[7]–[9], [34] , [8]	Aims and planning, triggering the intention to act, engagement, engagement and consistency, pre-engagement strategies, conditioning technique, rewards and threats, social norms, social reference, social comparison, social proof, behaviour comparison	“Daily task” content
[8], [37], [60]	Loss aversion, suggestion, connection to nature	“Nature suggestions” content
[7], [33], [34], [41], [42]	Shaping knowledge, social norms, social reference, social comparison, social proof, behaviour comparison	“Energy suggestions” content
[7], [33], [34], [41], [42]	Shaping knowledge, social norms, social reference, social comparison, social proof, behaviour comparison	“Quiz” content

### Development of the mobile application

Based on the nudges identified and the user profiles extracted during the survey for electricity consumers in Luxembourg, we developed an initial prototype in the form of a Web app. The five content categories described in Section 4.2 Design of nudges were developed in view of being tested in a later study. Therefore, Figure 2 first presents the welcome page that the user sees after logging in. In this way, he/she takes note of the content on the page (in this case, an energy suggestion). The content changes every day and adapts little by little to the user’s profile and the individual feedback that he/she gives (“I like this activity” or “I don’t like this activity”). In the “History” heading, he/she can find the content that has already been

presented. In the illustration below, we present an example from each content category (Energy suggestion, Do you agree, Daily task, Did you know, Quiz).

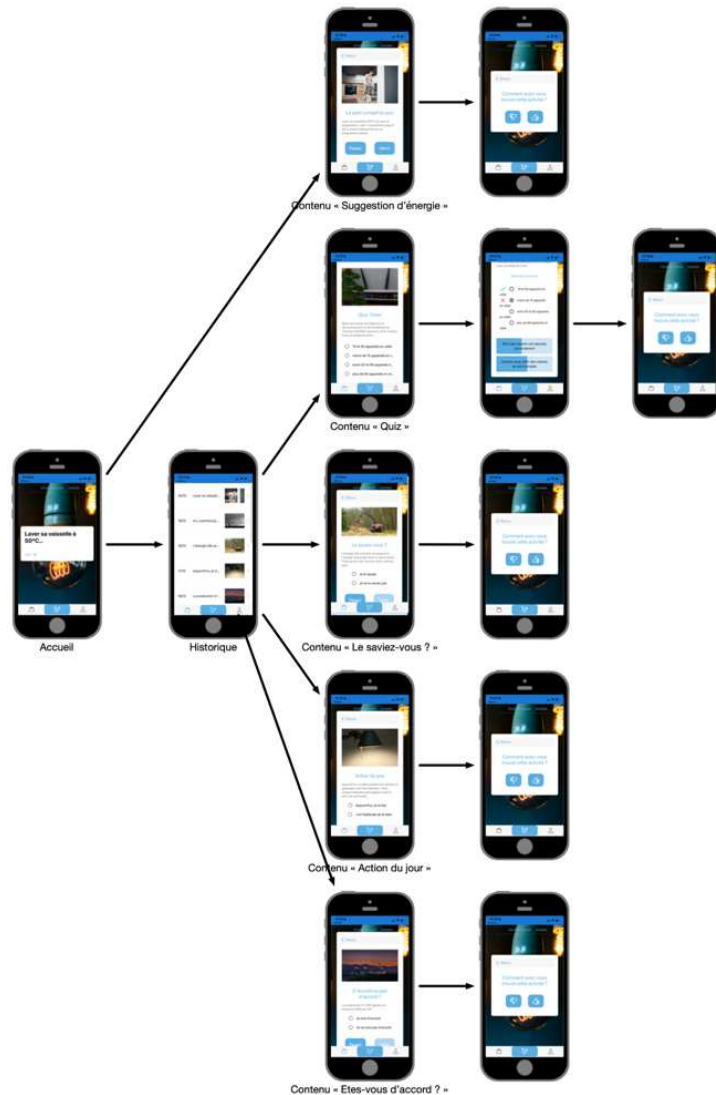


Figure 2: Prototype illustrating the content categories on the mobile application.

**DISCUSSION AND CONCLUSION**

This study presents the development of a mobile application to encourage citizens to be flexible in terms of energy faced with a demand for electricity that will increase in the coming decades. Firstly, the literature review enabled the main nudges and persuasion techniques to be identified in order for them to be implemented into the application while remaining in keeping with the personality of potential users. Secondly, a study enabled different user profiles to be identified in Luxembourg depending on personality, affinity with technology, energy literacy, and behaviours and beliefs concerning the environment.

**Contributions of the study**

Although certain research works have been concerned with matching personality traits from the Big 5 model with nudge types (see Section 2.2.1 Nudges and personality), few of them tried to integrate these results into an interactive system with the view of proposing personalized and adaptive interactions. This is the challenge that this study wants to take up, with the

first steps of its design process being presented in this article. Furthermore, we sought to raise the profile of the targeted users by examining the psychological profile of consumers in Luxembourg during the survey. This survey enabled us to take note of many individual characteristics, for which certain links could be established (see Section 4.1 Identification of user profiles). Thanks to these preliminary steps, an initial prototype of a mobile application was developed with the objective of offering personalized content adapted to the user profile.

### Limits of the study

Nevertheless, this study had several limitations that could affect the results anticipated. Firstly, the personality scale of the Big 5, on which the personalization of the application was based, has also been criticized, despite it often being quoted and used. For example, not only do some personality dimensions exist that go beyond the Big 5, but there are also other personality models, which could mean that this model is sometimes limited for certain authors. Nudges can also affect users' sense of autonomy and be experienced negatively [68]. For example, in the study of [68], participants that were confronted with a default nudge had lower independence and satisfaction scores for choices and higher perceived pressure scores than participants confronted with direct persuasion nudges, based on social norms, or those that did not have any nudges. Nudges are therefore also perceived differently depending on their type.

Concerning the survey carried out in Luxembourg, it is probable that it is not representative of the whole population in Luxembourg. Indeed, we observe an unequal distribution between men and women, for example, with men representing 21% and women 79% of the respondents. However, we can indicate that the persons contacted were invited to respond in the name of their household, and men frequently manage administrative aspects within the home. In addition, 93% of the persons questioned declared that they were homeowners, whereas, in reality, homeowners represented 84.5% of citizens in Luxembourg in 2023.

### Research perspectives

There are several research perspectives that will allow us to continue this study and explore it in more depth. Firstly, we planned and began to test the mobile application with target users in order to validate or correct nudges. This step should allow us to ensure that the application offers a satisfying user experience, on one hand, and to check that the suggested content corresponds to what consumers could expect and encourage them to be more energy flexible, on the other. This could also make it possible to confirm whether or not there are correlations between personality traits and whether certain nudges observed in the literature are effective. Secondly, the implementation of additional functionalities will be considered, in particular, based on a gamification of the content thanks to points and rankings, or even based on a social dimension, by adding friends, leading to more accurate comparisons between users. These functionalities could add new engagement and persuasion dynamics to be considered according to different profiles.

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