GRETA
GREEN
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TRANSITION
ACTIONS

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D2.4
Design Principles for Energy Interfaces

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Executive summary

The Executive Summary:
This deliverable represents the final report for WP2 within the GRETA project. The work package as a whole is concerned with *information sensemaking and sharing within, between, and beyond energy communities.* The task to which this deliverable pertains is specifically focused on the creation of a set of design principles to support the creation of interfaces to showcase energy information that supports the needs of different types of energy citizen. Within GRETA we understand energy citizenship behaviour as being facilitated or prevented by individual and community circumstances and constraints. As such, there can be no one size fits all approach to creating interfaces to support people in discovering how they can improve their own activities towards energy transition, to become more aware, more active and mor involved. The primary focus of this deliverable is the utilisation of the outputs of the clustering of the GRETA multinational survey data that elicited over ten thousand responses from people across Europe regarding their attitude, knowledge and behaviour towards the green transition. The clustering outputs - previously reported within deliverable D4.4 (Kuronen & Lensu, 2023) - yielded 8 distinct clusters, each representing a different type of energy citizen. In this report, we describe the process of converting cluster data into descriptions of personas that are then presented in graphical ways to make them more accessible for people to engage and empathise with. Each persona summarises key characteristics of the cluster as well as proposes questions that people who most associate with that group might consider in order to improve their level of awareness, activity, or advocacy. The personas have several purposes. The first is as a basis for deriving design principles, as an output for this deliverable and for informing future energy interface design. The second is as a basis for developing tools to allow people to find which cluster they most likely identify with and therefore what type of energy citizen they are likely to be, thus prompting them with questions they might want to explore further. The third is to provide input for GRETA policy briefs and media communications. In addition to reporting on the core process of persona creation from clusters, we also report on some preliminary studies using personas to filter different types of energy and energy related data.

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Authors (partners)	Ajesh Kumar (LUT), S M T Rahman (LUT), Annika Wolff (LUT), Toni Kuronen (LUT)
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Summary (For dissemination)	This report details the process of creating 8 energy citizen personas, each representing one of the clusters created by clustering the GRETA multinational survey data.The personas are mainly utilised in the creation of a set of design principles for creating interfaces to energy and energy-related information that reflect different energy citizenship needs.
Keywords	energy data visualization, energy communities, energy personas, energy literacy, energy interfaces

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0.1	15-08-2023	First Draft

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Abbreviations and acronyms

2D: Two Dimensional

3D: Three Dimensional

AR: Augmented Reality

EV: Electric vehicle

GRETA: GReen Energy Transition Action

VR: Virtual Reality

UK: United Kingdom

USA: United States of America

1 Introduction

This deliverable is part of Task 2.3 of the GRETA project which aims to report on identified design principles that can be used to design energy interfaces using energy data to serve the different needs of different types of energy citizen. It is argued that having a better understanding of energy data could help increase awareness of the types of actions people could take and especially those that would be most useful to their own personal or communal context. To understand energy citizenship, we draw on prior GRETA work towards understanding energy citizens and the types of actions they might take, and we base our work on the following premises:

- That energy citizenship is related to activities that both individuals and communities can enact, such as:
    - taking greener actions in everyday lives
    - adopting green energy solutions such as installing solar PV or buying an electric vehicle
    - joining or forming an energy community

- That the possibility to act may be facilitated or hindered by a variety of factors, including:
    - personal awareness and motivation to act – in positive or negative ways.
    - personal or communal circumstance, such as economic means to invest in green solutions.
    - community infrastructure and local investment, including provision of grants for low-income households or to support setting up of energy co-operatives.

- That energy and energy related data can be utilized to provide important information to individuals and communities that can empower them to reflect on their personal and community circumstances, improve their levels of awareness and better understand what actions they can take.

- Crucially, that the transformation of such data into useful information and presentation towards end users is not always a good fit to individual or community needs as it does not consider specific context and circumstances.

Based on the abovementioned, the aim of the work described in the deliverable is to identify design principles that can be used to design energy interfaces using energy data or energy related data that are a better fit to the needs of energy citizens, both individually and collectively.

This work has been conducted through the following approaches:

1. A review of existing approaches to energy visualization, with a focus on designing for communities and communal use (section 2.1)

2. Visualisation of models created in WP4 in the form of different energy citizen personas and the testing of the utility of a persona-based approach for helping people to reflect on what kind of energy citizen they are, and what actions people like them could take to increase their level of energy citizenship. This work has occurred across several iterations:

a) Ideation of energy personas based on GRETA concept of awareness levels (unaware, aware, active, advocate) and evaluation during 2 workshops with consortium members.
b) Utilization of personas in experiments to evaluate the utility of a persona-driven approach for filtering different types of energy data based on identification of a user with a specific profile of energy citizenship.
c) Refinement of personas based on the modelling outputs of WP4, in which multinational survey data was clustered, and the clusters described according to GRETA concept of awareness levels (unaware, aware, active, advocate), yielding a set of 8 energy citizenship personas.
d) Derivation of design principles based on energy personas.

2 Background

2.1 Energy Data and Energy Citizenship

Energy data plays an extremely pivotal role in bringing to light the otherwise imperceptible and invisible dimensions of energy consumption and production.

In the realm of energy, a data-driven approach aids visibility and becomes a liberating force by exposing concealed patterns and revealing the intricacies of energy systems by making informative and expressive experience of data (Thomas & Cook, 2016; Magoulès, 2016). By capturing information and by bringing to light factors that are often overlooked, energy data empowers policymakers, researchers, and businesses to make informed decisions for a more sustainable future (Magoulès, 2016; Loukissas, 2019).

The utilization of energy data enables the deciphering of concealed consumption patterns that remain hidden from the naked eye (Thomas & Cook, 2016). Through smart metering and advanced data analytics, researchers gain insights into temporal and spatial variations of energy usage (Faustine & Pereira, 2020). These insights are critical in developing targeted conservation strategies and designing energy-efficient infrastructures that align with actual consumption behaviours (Thomas & Cook, 2016; Nawaz et al., 2022; Faustine & Pereira, 2020).

Enhancing awareness of energy consumption has also been shown to influence individual attitudes and behaviours towards energy usage (Roslina et al., 2021; Shekari et al., 2021). For example, individuals who are aware of their specific energy usage patterns and know their personalized energy usage data are more likely to become conscious of their energy consumption habits and make efforts to reduce their energy usage (Thomas & Cook, 2016). They are more likely to view energy transition as a personal responsibility and are more motivated to take action to reduce their energy usage (Lv et al., 2021; Mohamad et al., 2020). As such, they show a heightened sense of responsibility towards solving the energy crisis and hold stronger environmental beliefs (Li et al., 2021). As Gifford (2011) highlighted, "Knowledge can lead to changes in attitudes, which can lead to changes in behaviour."

As well as impacting individuals' attitudes towards the energy transition, increased knowledge about energy consumption through energy data can also lead to a shift in societal attitudes toward energy transition. Initiatives that increase knowledge about energy consumption, such as educational programs, workshops and awareness campaigns may result in more efficient energy usage (Al-Daraiseh et al., 2013).

All this demonstrates that the impact of increased energy knowledge is significant in affecting attitude towards the energy transition. It can shape individuals' as well as

community perception and may lead to greater willingness to adopt energy-saving behaviours and support policies that promote sustainable energy use.

2.1 Review of Energy Data Visualization methods

Where in the previous section we explore the role of energy data in supporting energy citizenship actions, in this section we focus on the visualization of such data. The purpose of visualizing data is to curate and communicate it in a way that provides a specific viewpoint over the data and makes it easier for people to read and understand. As such, energy data visualization techniques have emerged as essential tools for comprehending complex energy systems and fostering informed decision-making across various industries. As Börner et al. (2009) noted, visualizations "provide a compact representation of data and offer analytical insights."

Visualization of energy consumption is not a recent concept, rather it dates back to 1978, when researchers used posters as a mode for visualization to display energy consumption at a medical institution (Bittle et al. 1978) which contributed towards energy conservation. In recent years, usage of techniques such as 2D and 3D has helped in visualizing energy consumption. The majority of research into energy visualization has focused on methods targeted towards individual households. However, there are many reasons why it is necessary these days to understand how communities of households engage with energy related information and how interfaces can be designed to support such communal use. This is especially true these days when people may be participating in energy communities or community-based demand response schemes.

The visualization of energy information can be broadly characterized in terms of 1) the visualization mode 2) the visualization technique 3) the information type.

Common **visualization modes** include:

- Mobile applications (e.g., Chalal et al., 2020; Bartram et al., 2010)
- Web-based applications (e.g., Bartram et al., 2010; Ruiz et al., 2020; Tarabieh et al., 2015)
- Public touch displays (e.g., Pousman et al., 2008; Valkanova et al., 2013; Valor et al., 2019; Xu et al., 2021)
- Ambient canvas/lighting (e.g., Bartram et al., 2010; Hansen et al., 2020)
- Embedded displays (e.g., Bartram et al.)

Common **information types** include:

- Energy consumption (e.g., Francisco and Taylor, 2019)
- Economic savings (e.g., Chalal et al., 2020; Jensen et al., 2021)
- Renewable energy (e.g., Jensen et al., 2021)

Common **visualization techniques** include:

- 2D visualization, e.g., pie charts, time charts, bar charts, google map integration.
- (e.g., Chalal et al., 2020; Valkanova et al., 2013; Valor et al., 2019; Xu et al., 2021)
- 3D visualization, e.g., using 3D models and possibly using VR (e.g. Pousman et al., 2008; Francisco and Taylor, 2019)

It is clear that some of the **visualization modes** may be more suited for individual use and others for community energy engagement. In particular, web and mobile applications – whilst popular - are not always suited for real-time collaborative use. This is why some researchers such as Xu et al. (2021) focus on public displays for visualising urban energy data beyond individual household scale. Ambient canvases (Bartram et al., 2010; Hansen et al., 2020) and embedded displays (Bartram et al.) have been utilised in residential households to allow more than one member of a household to easily access information about energy consumption/production and such approaches have also been shown to work in more public settings amongst communities. Some examples of public displays of communal energy data include 1) the Tidy Street initiative (Bird and Rogers, 2010) in which energy data was temporarily presented within one UK street to prompt the residents to think more collectively about the energy usage in their area 2) Reveal-IT (Valkanova et al., 2015) which was a public interface for viewing either individual or communal energy data, through which people could stop and add their own information and to reflect on any pre-conceptions they may have about their own energy behavior in light of information from their community 3) a touch table interface for exploring urban indicators (van der Laan et al., 2013), including information about energy and emissions, intended for use as a Planning Support System (PSS).

With regard to 2D versus 3D **visualization techniques**, while both might be suited to individual use, a 3D visualization may be better than 2D for fostering community collaboration over data. This is because it could support exploring data from multiple perspectives at the same time. Such an approach might be facilitated by the use of a shared Virtual Reality (VR) world, however in such cases the capability to directly communicate with another person is hindered. Augmented Reality (AR) applications could help to overcome some of these issues (Lock et al., 2019; Elvezio et al., 2018).

Regarding the common **information types**, the focus of research has typically been on energy consumption and generation, as well as economic aspects. However, GRETA has identified many different types of energy and energy-related (i.e., contextualizing) information that might be useful both for individual households and for communities to support their decision-making. These include, for example: *energy-infrastructure maps, solar infrastructure, solar effective surface percentage, solar PV installed capacity, various building statistics (such as roof area, building height, building ownership), zoning and other legal regulations, EV charging points, local demographic data, seasonal data, energy*

consumption data at different scales and time periods, and so on. The needs that both individuals and communities might have for such data arehighly context dependent, varying according to their specific goals and individual or collective circumstances.

The goal of GRETA is to understand how to design energy interfaces that support energy citizenship, that provide the information that individuals and communities can relate to their personal circumstances, and which will answer the questions they have - or didn't even know they had. Through this, we aim to empower people to transition to higher forms of energy citizenship.

3 Persona-based approach

In order to identify the most appropriate visualization mode and visualization techniques for energy and energy-related data we need to first understand:

i) *Who are the different types of users?*
ii) *How their needs differ, i.e., what type of energy information might be most relevant to them depending on their context.*
iii) *How to communicate this information in an accessible way.*

For this purpose, we have chosen to use a *persona-based* approach in which we use data collected from the GRETA multinational survey (Kuronen & Lensu, 2023) to inform the creation of *personas* representing different types of energy citizen with varying levels of awareness in accordance with the GRETA concept (**Error! Reference source not found.**):

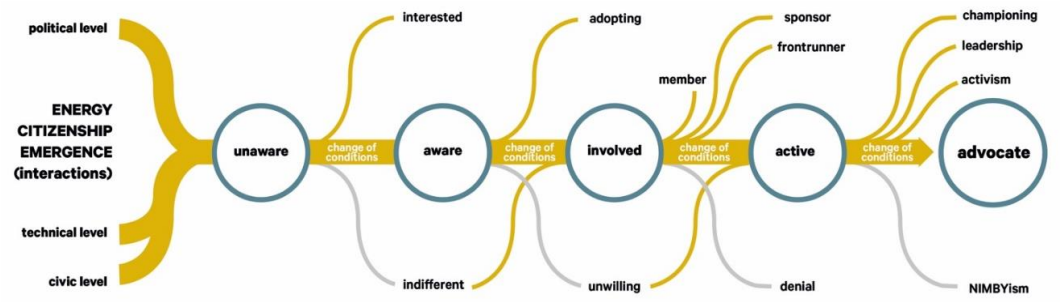


Figure 1 - Energy citizenship emergence, levels of engagement, and some of its possible forms of manifestation.

We then intend to utilize these personas as a method for deriving design principles for designing energy interfaces that are sensitive to different energy citizen needs.

3.1 Background to personas

Persona design is a widely recognized tool in user-centred contexts and its application has extended to the realm of scientific data exploration. This arises from the understanding that personas provide valuable insights into users' goals, needs, and behaviours, facilitating effective communication between designers and scientists involved in data analysis. By utilizing persona-based approaches for scientific data exploration, researchers can better understand how different user groups engage with data visualization tools or analytical techniques. Personas allow designers to create targeted designs by embodying specific characteristics of various user types within the

community. These personas not only represent fictional representations but are grounded on real-world observations through rigorous research methods such as interviews, surveys, and observations.

Researchers have explored personalization techniques in the context of energy and found that presenting energy data through personas could significantly influence people's energy consumption patterns leading to reduced energy cost for households. In the context of energy companies, it allows the opportunity to use personalization as a feature in digitalized energy service that can also help in better demand response by reducing peak time response as well as provide a responsible energy experience (Zhukovskiy et al., 2019).As an example, researchers employed a persona approach in a case study in the Grove Park neighbourhood in Atlanta, Georgia, USA to stimulate and model future energy scenarios (Deng et al., 2019).

Personas have also been used to critique a narrow and problematic perspective of energy transition where the central idea is of a data driven, technology driven, home energy user who is both interested in and capable of making efficient resource-management decisions based on energy data presented. Using a counter persona who currently has no, or extremely limited access to electricity, the researcher highlighted how excluding energy poor while designing energy transition policies could potentially hinder progress and showed how a persona can be used to identify a neglected set of users and their unique needs, thereby strengthening energy justice (Strengers et al., 2014).

In a community perspective, a persona can be used to model energy citizens, who are differentiated with respect to energy consumers in energy transition literature like modelling their lighting requirement (Sokol et al., 2014). Researchers have argued that energy transition initiative success should not be calculated based solely in terms of energy produced but energy citizens produced. Personas can help identify conflict scenarios in energy community settings (Strengers et al., 2014).

Researchers have used technology to create information panels that when used in combination with a user mobile could help deliver content pertinent to those users who are interacting with the panel (Pisarovic et al., 2018). Such systems could also be employed in publicly accessible places to provide energy information most relevant to the user. A persona-based approach has also been found to be useful in motivating home renovators with energy efficiency interventions by enabling the creation of more targeted and tangible representation of end users (Haines, 2014).

Overall, using personas in the context of energy has been found to offer a valuable framework for optimizing energy data exploration by enabling the accommodation of needs and preferences of diverse user groups. From the literature referenced above, the persona method demonstrates efficacy in furthering energy transition and energy citizenship by bridging the gap between energy data and information complexity and user(s).

3.2 Creating personas for GRETA

The creation of personas for GRETA has been undertaken through three distinct iterations. Each iteration and their main goals are described below:

1. *Mapping energy citizens to data.* This iteration involved the creation of personas representing energy citizens with different levels of awareness and activity towards the green transition. The aim of creating these personas was to create an ideation tool for exploring more concretely the relationship between different energy citizen profiles and their information needs. For example, an energy citizen who is already active and owns solar panels might have less need to look at information about investment potential of solar PV than an aware energy citizen who is yet to take action but is thinking about doing so. This activity utilized the outputs of deliverable 4.1 (Kuronen, 2022), which were transformed into data cards. The personas and data cards were utilized in two workshops.
2. *Evaluating the benefits of personas for direct data exploration*. This iteration involved the utilization of the personas and insights from iteration 1 within a prototype of a digital tool through which selection of a persona narrows down the focus of available data, so that the first data presented is most relevant according to that persona needs. This digital tool was used in an experiment to compare against thematically organized data in order to understand what the benefits could be for using a persona-based approach for direct data exploration.
3. *Evidence-based personas from GRETA clustering outputs*. This iteration involved the creation of data-driven personas based on characterization of the outputs of the clustering of the GRETA multinational survey data deliverable D4.4 (Kuronen & Lensu, 2023) into different energy citizen types with different levels of awareness. The goal of this approach was to create personas that were based on evidence, and which truly represented the different types of energy citizens across Europe.

The following sections provide details of the work done in each of the above iterations and the insights that were derived from them.

3.3 Mapping energy citizens to data

3.3.1 Pilot study 1 at LUT University, Finland

This section describes a small pilot study that was conducted at LUT university for the purpose of refining a planned workshop on the persona-based approach for mapping energy citizens to data types. This study – and the comparison of interfaces described later in this document - was conducted as part of a master's thesis (Rahman, S. M., 2023).

For this initial study, three personas were created. Several themes related to energy citizenship were identified which contributed to identification of needs and goals of the personas, reflecting varying concerns about household waste reduction, global fuel price surge, using of renewable energy etc.

Figure 2 - Representation of Persona 1, John Hopkins.

Figure 2 represents Persona 1, which represents John Hopkins. John is a manager at an energy company residing in Berlin, Germany. He has solar panels on the roof of his home, and he drives a Tesla. His pain points include Co2 emissions by energy companies and lower availability of EV charging stations. His goal is to sell electricity stored from his solar farm and he dreams of building solar powered airplanes.

Figure 3 - Representation of Persona 2, Elisa Thorn.

Figure 3 represents Elisa Thorn, who's an environmental researcher residing in Madrid, Spain. She's a vegetarian who enjoys sustainable living. Her frustration includes food wastage and sound pollution. She feels the need to monitor her energy

usage. She also wishes to create an interface as part of an experiment to investigate her household appliance usage.

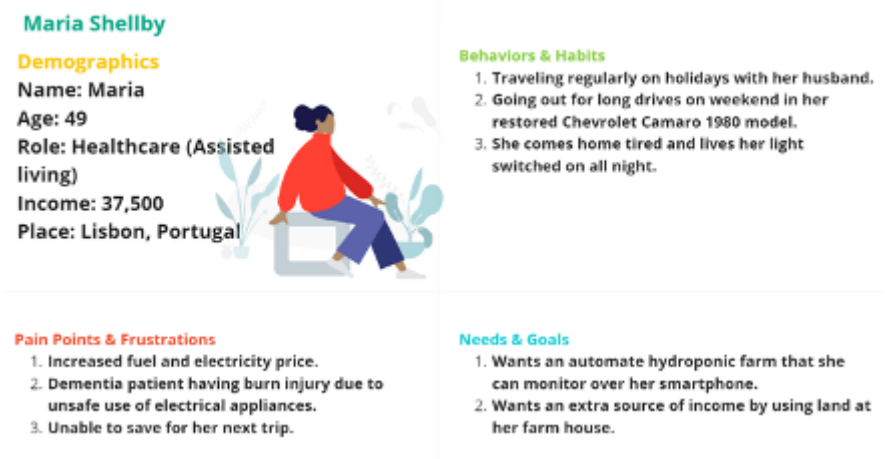
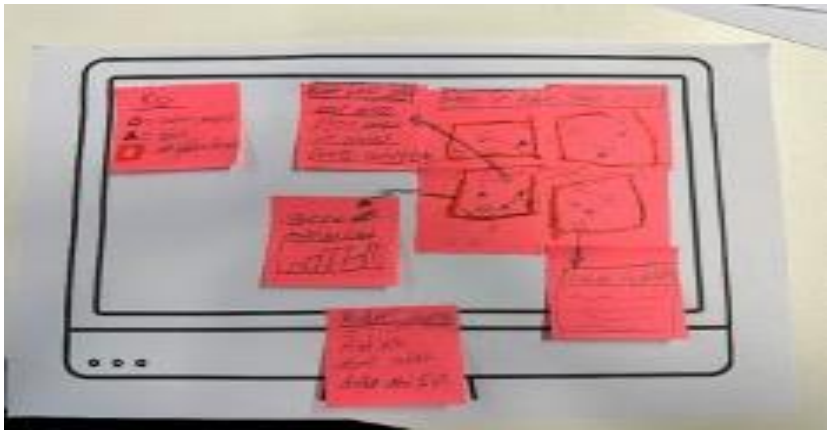


Figure 4 - Representation of Persona 3, Maria Shellby.

Figure 4 represents the user persona of Maria Shellby. Maria is a healthcare professional who enjoys vacations abroad with her husband. Her frustration includes increased prices of fuel and electricity. She wishes to build an automated hydroponic farm which could be monitored from her smartphone.

On 15th March 2023, an internal workshop was conducted at the premises of LUT University, Lappeenranta campus. The workshop included these three personas and several data cards that were based around the GRETA energy and energy-related datasets. 8 people participated in the workshop and were divided into 3 groups. Each group were tasked with exploring the different personas, after which each group were assigned one persona to continue working with. The goal was to search through the data cards and to identify data types that they thought would be relevant to the persona and then to sketch an interface through which they might access the data. The purpose was to inform the next iteration of the workshop which would take place amongst the GRETA consortiums. Figure 5 and figure 6 show different outputs from this activity. The GRETA project team members who conducted the session asked for feedback from the participants and for ways to improve the presentation of the task

Figure 5 - First example of and ideation output from the pilot study.



prior to the main testing.

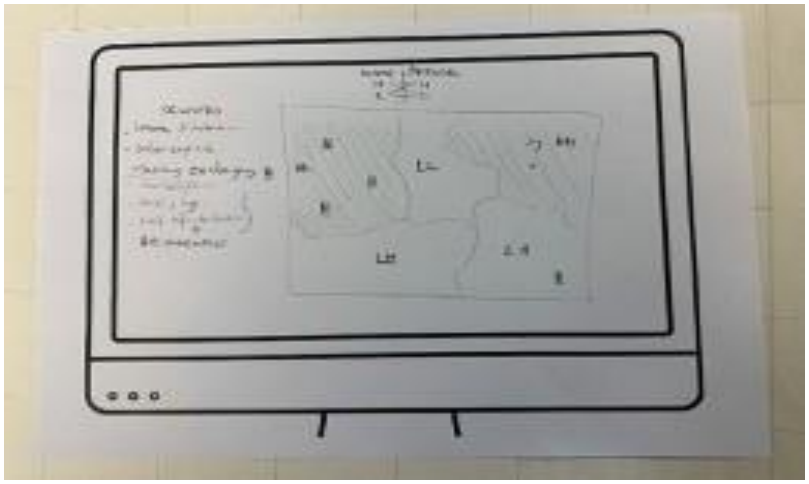


Figure 6 - Second example of and ideation output from the pilot study.

3.3.2 Pilot study 2 in Bilbao, Spain

This section describes a workshop that was conducted at Tecnalia Campus, Bilbao, Spain with the GRETA consortium members for the purpose of testing the persona-based approach for mapping energy citizens to data types to create scenarios relevant for personas. This study was conducted to identify relevant data and interface needs of different personas.

For this workshop, three additional personas were created to identify different set of energy information needs using a co-design approach.

Figure 7 - Representation of Persona 4, Greta.

Figure 7 represents Persona 4, which represents Greta. Greta is a student who lives in a small home with her father, and they can't afford to install solar panel while electricity prices keep on rising, making it difficult for her father to manage monthly expense. She is a climate activist and travels on invite to climate conferences and avoids air travel because of its emissions. Her goal is to reach all energy poor neighbourhoods that find energy prices difficult and can't invest in sustainable green energy without any government support and demand policymakers to provide them energy justice.

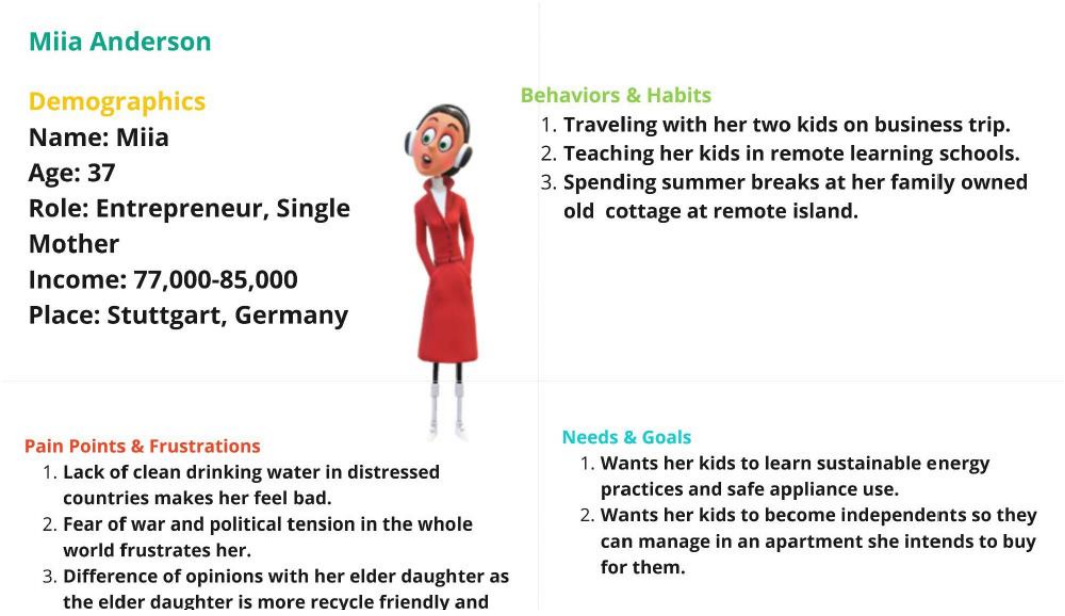


Figure 8 - Representation of Persona 4, Miia Anderson.

Figure 8 represents Persona 5, which represents Miia Anderson. Miia is an entrepreneur and single mother of two girls who lives in Struttgart, Germany. She travels regularly on business trips and orders her food from outside which produces regular plastic wastes that her elder daughter dislikes. She would prefer to keep them at home when she travelled, but she fears that electrical appliances at home are not safe enough for kids to be around them without adult supervision or use it safely at young age.

Figure 9 - Representation of Persona 4, Anish Khan.

Figure 9 represents Persona 6, which represents Anish Khan. Anish is an immigrant student in Rotterdam, Netherlands. He finds living in Netherlands expensive and is looking for additional source of income. He is tech savvy and wants to create applications. He is currently looking to enter a competition by an energy company to create digital apps for them.

On 23rd March 2023, a workshop was conducted at Tecnalia Campus, Bilbao, Spain with the GRETA consortium members. The workshop included six personas in total and several data cards that were based around the GRETA energy and energy-related datasets as shown in Figure 10. A total of 17 people from the GRETA consortium members participated in the workshop and were divided into 6 groups as shown in Figure 11. Each group were assigned one persona and tasked with exploring them, after which each group were to explore all data cards which were laminated, and other stationary items were given to each team members to use them for ideation purpose. The goal for the participants of the workshop was to search through the data cards and to identify data types that they thought would be relevant to the persona and then to come up with an energy interface scenario where such data would be relevant to meet the needs of the persona. The purpose was to use personas in identifying interface requirements using co-design approach to identify data needs for energy interface scenarios as well as to test if persona-based approach could be useful for the said purpose. In the end of the workshop, feedback was collected about the use of personas in identifying interface requirement.

Figure 10 - Workshop materials such as personas, data cards and stationary items for participants.

Figure 11 - Workshop participants working in groups.

The snapshot of some of the data card used and instruction provided to participants is shown in Figure 12. For the first 10 minutes the participants took time to get familiar with the personas and data cards. They discussed among themselves about possible data cards that would be relevant for the personas and that would allow them to create scenarios where such data would fulfil the interface requirement for the given scenario.

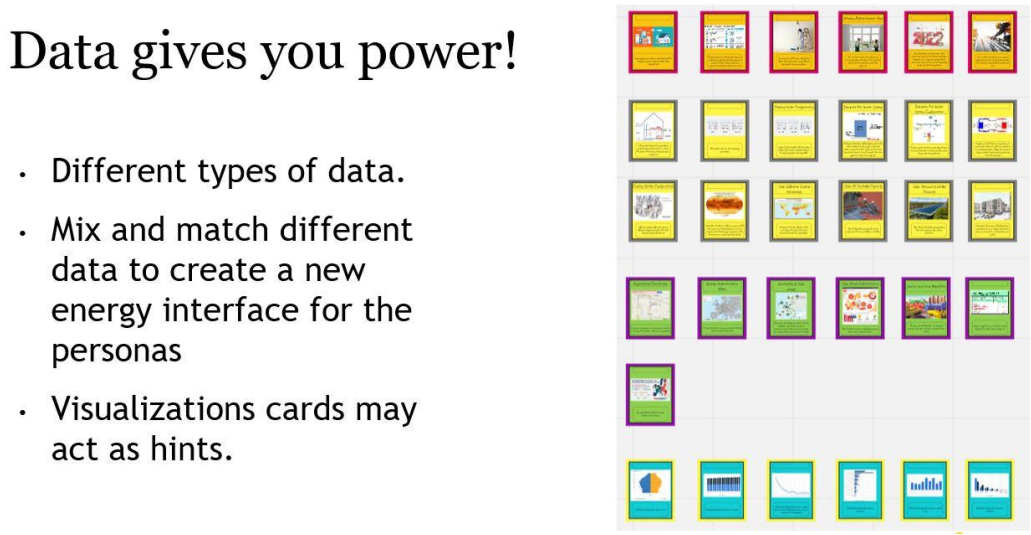


Figure 12 - Snapshot of data cards and instructions provided to the participants.

In the second leg of the workshop one participant switched between teams following a method called SCAMPER as shown in Figure 13, which was modified to allow participants to apply only those steps from the SCAMPER method that they deemed

most fit. It was done both to accommodate time as well as to not make the exercise too complicated for participants.

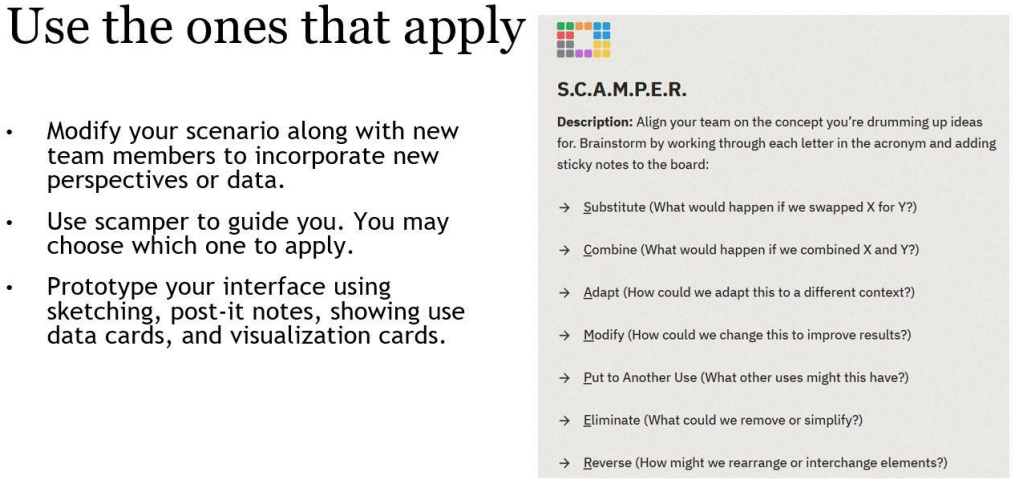


Figure 13 - Snapshot of SCAMPER activity instruction provided to participants.

In the last leg of the workshop participants wrote brief scenarios for each persona as shown in Figure 14 and responded to an online Mentimeter based survey that was setup before the workshop began. Several scenarios related to energy interfaces were created which contributed to identification of information and data needs of the personas, reflecting varying settings where persona-based approach could be utilised to identify unique needs of end users of energy interface.

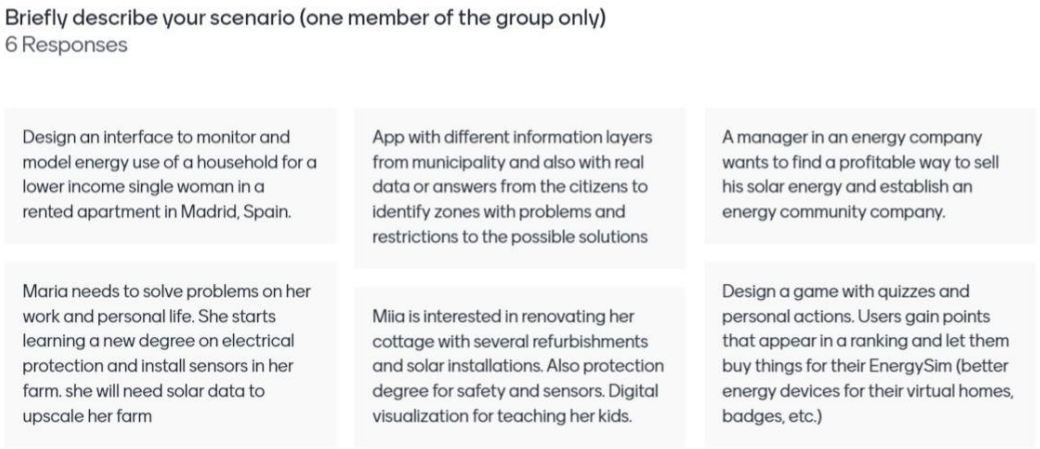


Figure 14 - Scenarios described briefly by each group after workshop activities.

The survey had three statements that are presented below:

- The persona-based approach can be helpful towards identifying the user needs for energy interfaces.
- The use of 'data cards' along with personas was useful in creating a scenario.
- Scenarios could be useful in creating energy interfaces that meets user's energy needs.

The participants had 5 options in Likert Scale format to assess their opinion. The options provided were:

- Strongly Disagree
- Disagree
- Neutral
- Agree and
- Strongly Agree

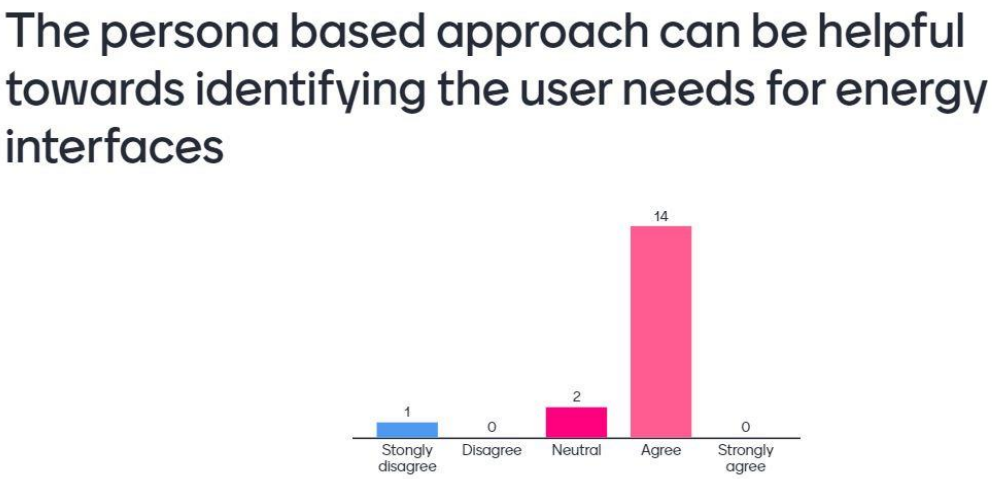


Figure 15 - Result for statement 1.

For the statement that "the persona-based approach can be helpful towards identifying the user needs for energy interface", out of 17 responses 14 agreed and 2 were neutral, while one strongly disagreed and none strongly agreed with the statement, as shown in Figure 15.

For the statement that "the use of 'data cards' along with personas was helpful in creating a scenario", almost double number of respondents agreed than disagreed with the statement while largest share of participants were neutral to the statement as shown in Figure 16.

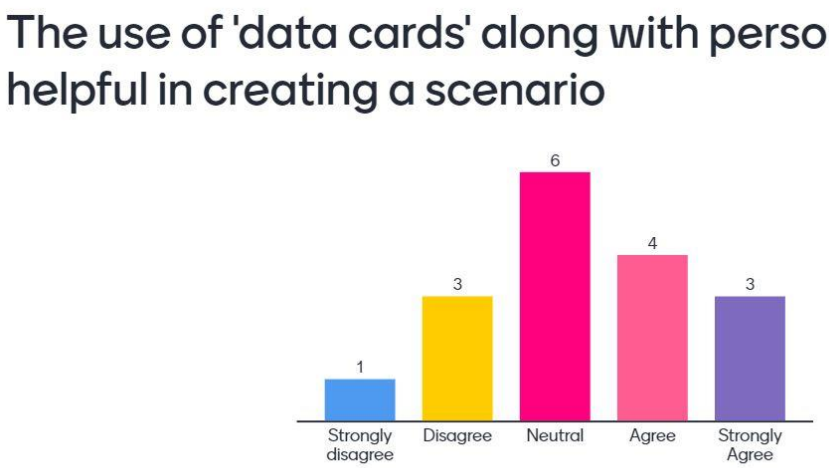


Figure 16 - Result for statement 2.

For the statement that "Scenarios could be useful in creating energy interfaces that meet user's energy needs", 10 number of respondents agreed and only one disagreed with the statement while 4 participants were neutral as shown in Figure 17.

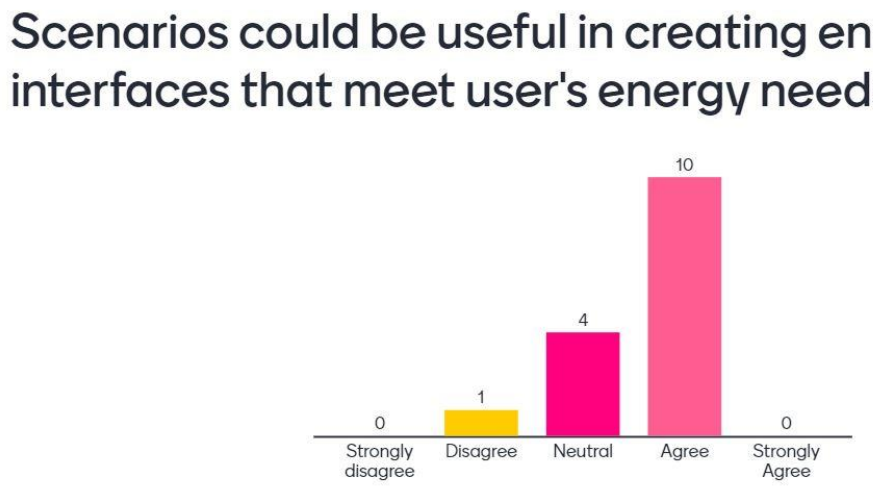


Figure 17 - Result for statement 3.

Several scenarios related to energy interfaces were created which contributed to identification of information and data needs of the personas, reflecting varying settings where persona-based approach could be utilised to identify unique needs of end users of energy interface.

From the above set of two workshops, the usefulness of persona as a tool to explore energy data, as well as how this data can be presented in an energy interface were tested. This allowed, based on empirical evidence, to use persona-based approach to create further evolutionary interfaces and respective data that should be associated with it. In terms of other benefits, the workshops provided a snapshot of energy information needs that varied across different personas and their socio-economical context from the scenarios and interfaces that were co-designed in the two workshops.

From the workshop, it was also established that energy interfaces need to incorporate design principles that cater to different sets of people who may have different set of circumstances or ability to participate in green initiatives or use energy interfaces.

3.4 Evaluating the benefits of personas for direct data exploration

In this step, three of the personas created in the previous iteration were utilized to create a digital interface through which some of the data types utilized in the previous step could be explored (**interface A**). An alternative interface was then created in which the same data was organized and explored thematically (**interface B**). A small-scale experiment was then conducted to understand the pros and cons of persona-based exploration of data. The following explores the prototyping of the two interfaces, using the Figma prototyping tool. Figure 18 shows the landing page for *interface A* which is the persona-based exploration tool. From the landing page, people can select a persona they relate to.

Figure 18 - Landing page for interface A.

Upon clicking on a persona, for example John, users would get to visualize energy data based on the persona of John and his traits. Figure 19 depicts such a scenario where among many data types, one is about carbon emissions in Germany from the year 2010 till 2022. In this figure, the yellow bar indicates carbon emissions solely by energy companies, whereas the blue bar indicates carbon emissions by all other industries altogether. The reasoning behind seeing this data would be that John feels frustrated about carbon emissions, specifically by energy industries.

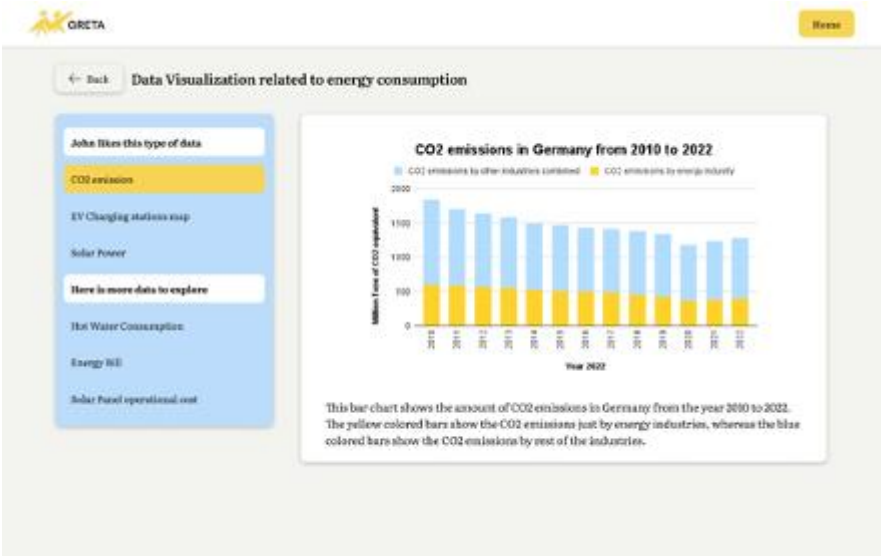


Figure 19 - Data visualization portrayed after clicking on persona "John".

In figure 20, we can also see that a user is not restricted to visualizing data solely based on the first selected persona. They can navigate to any other persona by clicking on the 'back' button placed on the interface. They can also view other data irrespective of the persona by clicking on the data available under the section "Here is more data to explore", in this case information about hot water consumption.

Figure 20 - Data visualization less relevant to the selected persona.

Interface B is designed based on thematically organised data types such as electric vehicle data, solar panel data, monitoring household energy data. The landing page for this interface is shown in figure 21.

Figure 21 - Landing page of Interface 'B'.

As figure 11 shows, upon clicking on the data type "*monitoring household energy data*", a user gets to navigate different data related to monitoring household energy data, such as food wastage within a household in a month, energy consumption by different appliances of a household and hot water consumption of a household in a month.

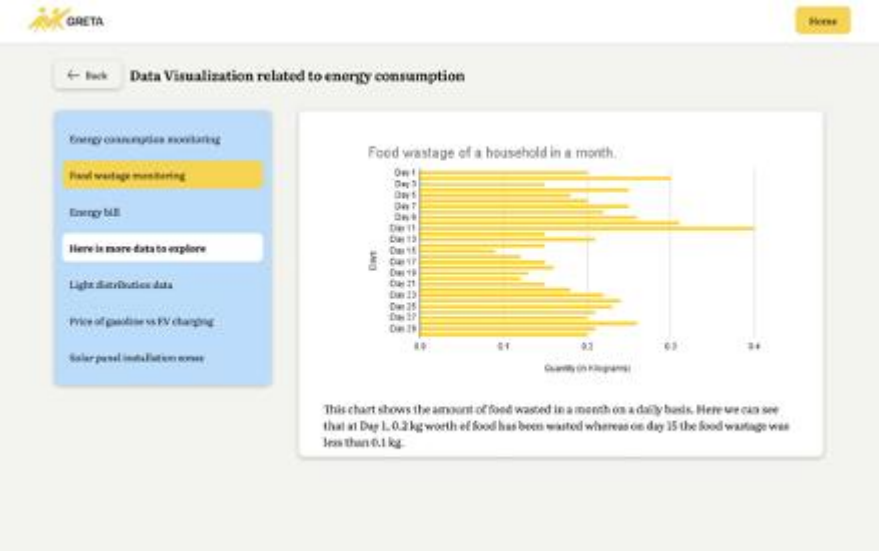


Figure 22- Data visualization based on data type "Monitoring household energy data."

In figure 23, upon clicking on "Price of gasoline VS EV-charging", the user gets to see a different data which is not related to the data type.

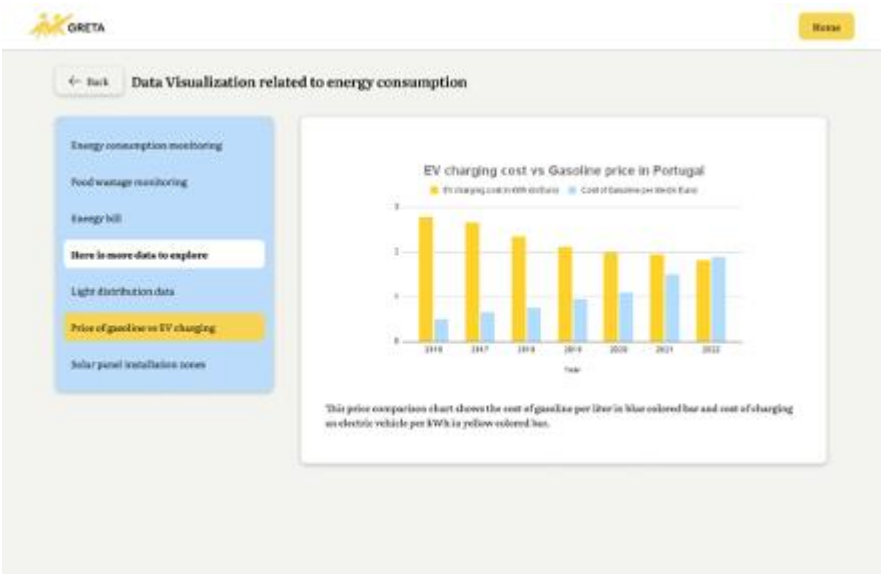


Figure 23 - Visualization of other kind of data irrelevant to the data type.

Thus, as with interface *A*, it is possible to navigate to view any of the available data visualizations even if they are not directly related to the initially selected data topic. Both interface A and interface B have been designed to be comparable, to contain the same number of data types and the same number of actions required to navigate data, so that the primary difference is in whether the starting point for exploration a persona or a data topic is.

3.4.1 Experiment and results

A small-scale experiment was conducted with students at LUT University who showed interest in participating in this experiment, and they were divided in a group of 20 peopleutilizing interface A and 20 utilizing interface B. People were assigned randomly to the groups. Each set of participants were asked to explore the interface according to information presented in the information itself (e.g., in interface A to select the persona they most identified with to start the data exploration) and then to answer the same list of questions reflecting on their experience in exploring the data. For the questions, there were six statements where the participants had to pick between five options such as: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. These statements were as follows:

- The interface was easy to use and navigate.
- I was able to accomplish my tasks efficiently using the information presented by the interface.
- I was able to interpret and use the interface easily.
- I found the organization of information within the interface logical and easy to understand.

- The interface enhanced my understanding of energy related topics.
- The interface helped me relate to energy information at a more personal level.

Furthermore, there was 1 question asked based on the comfort level of the participants navigating the interface and 3 open ended questions. The questions were as follows: -

- On a scale of 1 to 5, where 1 indicates the lowest comfort level and 5 indicates the highest comfort level, how comfortable did you feel navigating the data?
- If you had access to real data, what kind of data you would have liked to visualize in the interface?
- How many visualizations did you look at? What were these visualizations about? What did you find most interesting in the data?
- Were there any specific features or aspects that you liked or disliked about the interface? If yes, what were they?

For the evaluation of *interface, A*, 20 participants were selected randomly out of total 40 participants. The remainder of the 20 participants were selected for evaluating interface B. Participants evaluating both the interfaces were provided with the link of the prototype and they were given the instruction of navigating through the prototype and to use it as they see it fit. They were also provided with the survey link where they were asked to fill some demographic data regarding age and gender and to answer those questions based on their experience of navigating the interface. The survey was targeted towards people from diverse backgrounds.

For i*nterface A*, out of 20 participants, 4 participants were in age group 18-25, 12 in age group 26-35 and in age group 36-45. 8 identified as male, and 12 identified as female. In the case of *interface B*, out of 20 participants, 8 were in age group 18-25, 10 were in age group 26-35 and 2 were in age group 36-45. 14 identified as male, 5 identified as female and 1 preferred not to say.

As such, the data that people engaged with was pre-curated and not necessarily of direct relevance. The fact that people could not then explore data further for themselves was also a limitation. With a small sample it is not possible to find significant differences between groups, but we present the overall impressions based on the answers from the feedback surveys, which are that there were no significant differences between the two interfaces in terms of answers to the main usability questions. For example:

- Participants in both groups thought the interface was easy to use and navigate, with no respondents answering either disagree or strongly disagree to this question.

- Participants in both groups felt they were able to accomplish tasks efficiently using the interface, with no respondents answering either disagree or strongly disagree to this question.
- Participants in both groups felt they could interpret and use the interface easily, with no respondents answering either disagree or strongly disagree to this question. However, there was more certainty to this answer amongst those using interface B, with 40% strongly agreeing – compared to 25% of people in the persona group.
- Participants in both groups found the organisation of information within the interface logical and easy to understand, however, in both cases there was a little uncertainty amongst two people who answered either 'disagree' or 'neither agree nor disagree'.
- Participants in both groups thought the interface enhanced their understanding of energy related topics, although those who used interface B were more likely to *strongly agree* to this (50%) than those who used the persona-based interface (15%).
- Participants in both groups thought the interface helped them to relate to energy information at a more personal level, although those who used the persona-based interface were slightly more inclined to strongly agree (40%) than those who used interface B which was organised by topic (30%).
- Participants in both groups indicated a high level of comfort when navigating the data, however those using the persona-based interface A were slightly more likely to give the highest rating of 5 (50%) compared to those using the topic-based interface B (40%) but were also more likely to give a lower rating of 3 (25%) compared to the other group (5%).

Phrases extracted from Interface 'A'	Phrases extracted from Interface 'B'
Reduce consumption.	Solar panels
Food waste	EV charging
Energy consumption	Price of gasoline vs price of EV
Price of gasoline VS price of EV charging	Home energy tracking
Consumption monitoring	Food wastage monitoring
Energy bills	EV charging station maps
CO2 emissions	
Pie chart	
EV charging was interesting.	

Table 1: Key Phrases Extracted from Open-ended Question 1

For the open questions, a lightweight coding was done to extract key phrases from the answers. Table 1 shows the key phrases extracted from the first open-ended question which was regarding the number of visualizations they looked at and what they were about. From the table it can be seen that participants navigating data using Interface A, the persona-based interface, explored - or at least recalled exploring - more different types of data than those using the thematically organised interface.

Key Phrases extracted from Interface 'A'	Key Phrases extracted from Interface 'B'
Environment friendly vs normal habitual usage	Industrial energy consumption
Cost savings data	More interactive data with mouse hover or touch on the chart
Prediction based data.	Similar set of data based on different countries.
Carbon footprint calculator	Levelized cost of solar energy.

Table 2 - Key Phrases Extracted from Open-ended Question 2

Table 2 shows the key phrases extracted from the survey responses of participants for the question regarding what real-time data they would have liked to see in the interface. In both cases, respondents were able to identify credible data that they would like to explore.

The last open-ended question in the survey asked participants about their liking or disliking towards specific feature or aspects of the interfaces. Table 3 summarises the results. While for interface B respondents mentioned the ease of use of the interface, for interface A there was in addition some specific mention that the personal aspect of the interface was relatable.

Phrases extracted from Interface 'A' participants	Phrases extracted from Interface 'B' participants
Graphs were easy to visualize.	Easy to navigate.
Personal aspect of the interface was relatable.	User friendly interface
User friendly interface	Effective use of visualization

Table 3 - Key Phrases Extracted from Open-ended Question 3

Finally, the survey data was explored to understand better how the interface might increase level of awareness of energy topics. For this, the qualitative data was searched using terms that indicated awareness and interest: *awareness, aware, information, clicked, looked, interesting, informative, helped, enhanced.* The results are shown in figures 24 and 25.

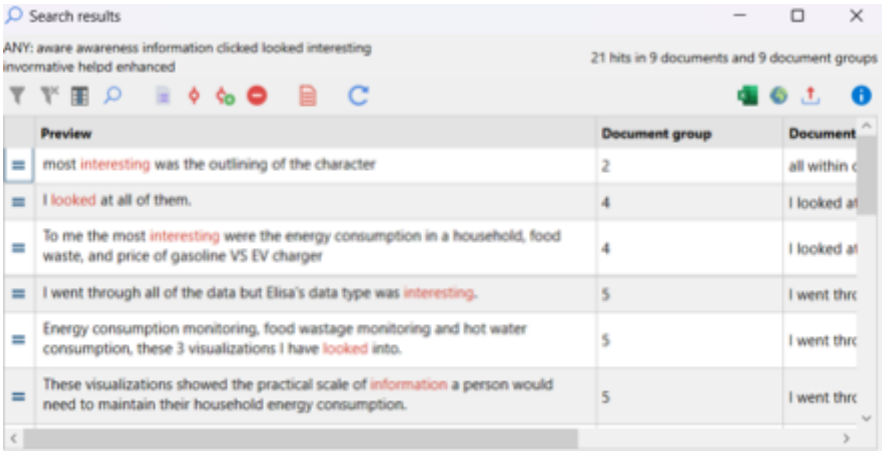


Figure 24 - Result after applying search strings on survey dataset of Interface 'A'.

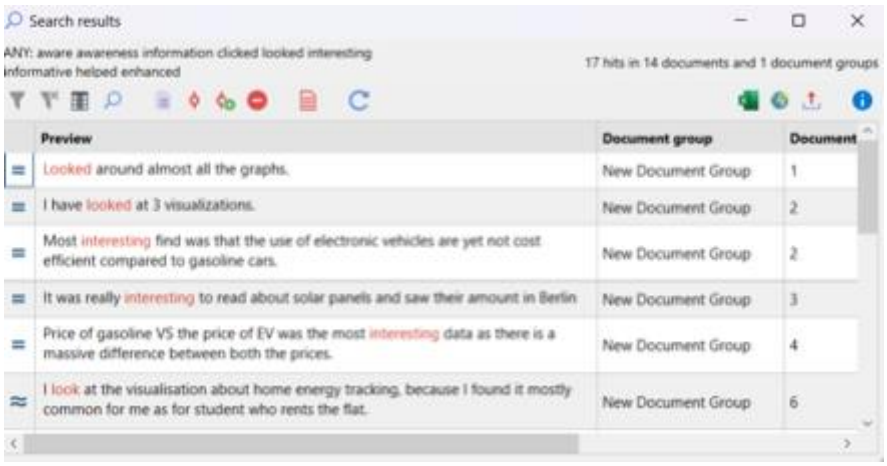


Figure 25 - Result after applying search strings on survey dataset from Interface 'B'.

What was notable from these results is that both interfaces provoked similar levels of interest, however looking at feedback regarding the persona-based interface, the respondents made specific mention to finding the character interesting "most interesting was the outlining of the character" and also memorising the data in terms of the data "I went through all of the data, but Elisa's data type was interesting".

Overall, the small-scale experiment did not show too many notable differences between the two interfaces, however they do give some indication that they may promote increased exploration and recall of the data being searched. There were several other limitations of this work: the first is the small sample size, the second is that the interfaces were clickable prototypes that gave a feeling of interaction but were not genuinely interactive. As such, the data that people engaged with was pre-curated and not necessarily of direct relevance. The fact that people could not then explore data further for themselves was also a limitation.

3.5 Evidence-based personas from GRETA clustering outputs

Figure 26 outlines the process that has been undertaken in order to define personas based on the clustering of multinational survey data and to turn this into a set of design principles.

Figure 26 - Process of deriving design principles from survey

3.5.1 Multinational Survey Data

The GRETA project commissioned a multinational survey that had a large set of questions in form of a questionnaire that was designed by consortium members studying energy transition from different perspectives such as their knowledge of energy transition activities, their energy needs, usage and cost, their trust on government, media and other institutions, etc.

The survey was then deployed online for people to respond for more than a month. Once the survey was closed, data of respondents were extracted for pre-processing

activities before clustering activities could be performed. The whole multinational survey data consists of 10488 responses (rows) in total and 1504 features (columns). Thus, there were 10488 responses in total, 9414 citizens, 536 business, and 538 from policy makers who had participated in the survey from 16 different European countries. More details about the survey can be found in deliverable D4.4 (Kuronen & Lensu, 2023).

3.5.2 Clustering of Multinational Survey Data

The global survey, which was done in 16 EU nations, provides a comprehensive dataset that includes multiple socio-cultural contexts, allowing for adequate study of energy behaviour trends across different regions. For data analysis, the ClicoT approach was used as described in found in deliverable D4.4 (Kuronen & Lensu, 2023), which allowed for the clustering of individuals based on both categorical and numerical factors in survey data while also taking into account the hierarchical links between the variables.

The research conclusions suggested 9 separate clusters of people depending on their energy behaviour patterns. These clusters are distinguished by various socioeconomic, demographic, and behavioural characteristics, offering light on the diversity of energy behaviours among local communities. These clusters formed the basis for the remainder of the work described in this report.

3.5.3 Creating personas based on the clusters

Cluster analysis has emerged as a robust technique for identifying distinct user segments within a dataset, enabling the creation of personas that accurately represent user diversity. As Jain et al. (1999) highlighted, "Cluster analysis groups similar objects together." Converting cluster attributes into personas is a critical step in transforming data-driven insights into actionable user profiles. The conversion of cluster attributes into personas offers several advantages. Personas provide a human-centred lens for interpreting cluster data, enhancing empathy and understanding among stakeholders (Nielsen, 2002). They simplify complex data sets, making insights more accessible for design and decision-making. However, a potential disadvantage lies in the potential oversimplification of cluster characteristics during persona creation. The nuances captured by clustering algorithms might not be fully captured in personas, leading to loss of granularity (Hoonhout et al., 2020).

In this section, we describe a process of turning the cluster outputs from D4.4 along with additional cluster analysis output, a total of 72 cluster analysis into cluster

snapshot as shown in figure 27 and figure 28 that represented a holistic view of each cluster which were then converted to energy citizen personas.

In the first step, the clusters were analysed based on the key criteria, such as:

- How do people within this cluster generally live? (House size income, energy cost, etc.)
- How educated are they?
- What do they think of the environment?
- What do they think about energy transition?
- How likely they are to take part in the energy transition?
- How much do they trust public institutions?
- How much do they trust the media?
- How much do they rely on family and friends for energy information?
- How much do they practice energy savings?
- How likely they are going to buy EV or sustainable transport?

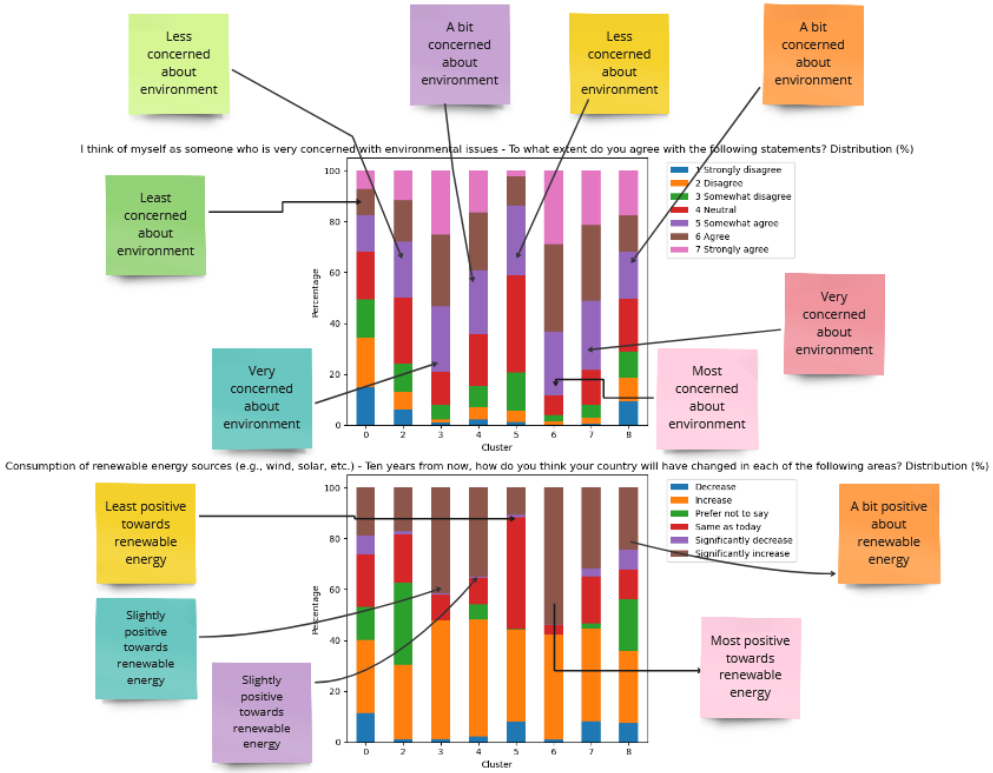


Figure 27 - shows a snapshot of a Miro board that was used for profiling clusters based on the above questions.

Figure 28 – Snapshot of Miro board used for profiling clusters.

In the second step, a snapshot was created of each cluster that identifies the most salient information about the cluster. This process was carried by copying colour coded post it notes from cluster analysis on Miro board, where each colour is assigned to a cluster and each post it notes represented the most interesting observation about the cluster attributes as shown in figure 29.

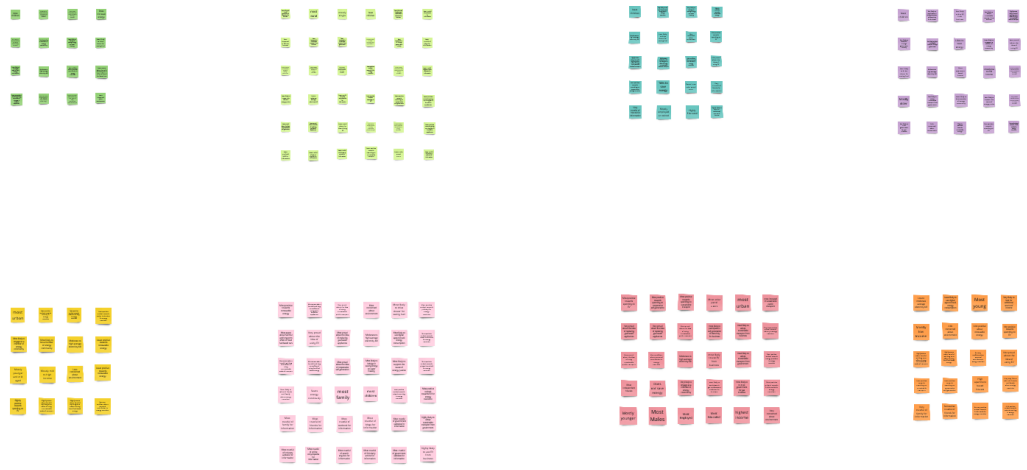


Figure 29 - Snapshot of a Miro boar in which salient features of clusters were identified.

A close-up view of one cluster is show in figure 30. Some clusters had more attributes identified than others. It was observed that for the clusters considered based on questions listed above, some clusters lay at both extremes and thus had more attributes identified and listed, while others did not show much variation in the aspects considered.

Figure 30 - A close-up view of a cluster's most salient attributes.

The full list of attributes for each cluster can be found in Appendix 1.

In the third step, each set of cluster attributes was carefully analysed in turn and each cluster assigned the following:

- A label, describing what type of *energy citizen* a person who fit the cluster profile was most likely to be.
- A position within the GRETA levels of energy citizenship, from *unaware*, *aware*, *active*, *advocate* and either *negative*, *neutral* or *positive*.
- A *summary description* of the cluster based on the salient cluster attributes as well as some suggestions as to potential motivators - for people that fit within the profile of the cluster - to improve their levels of awareness or activity. These suggestions were based primarily on 1) things that were already indicated as being potentially interesting to people within the cluster, e.g., they had indicated a potential interest in joining an energy community, therefore supporting them to find out ways to do this might benefit them 2) more general approaches through which people might change perspective, e.g., finding new information about a topic from more trustful sources than normal.
- A set of *statements* that summarised people belonging to that group of energy citizens.
- A set of *aspirations* summarising the potential motivators, as described above. These were posed as questions on the basis that if people were to directly engage with information about a cluster they belonged to, they might see those questions and relate to them, thereby being prompted to find out further information on those relevant topics.

The following presents the outcome of this process. Note that cluster 1 is missing as this was a cluster typified by people that mostly skipped answers. We have kept the numbering the same to facilitate comparison to the earlier clustering deliverable, however we have reorganised the clusters in terms of negative to positive and unaware – advocate position on the energy citizenship scale.

Cluster number	**0**
Name	Energy Indifferent
Position	Unaware - neutral
Summary	People in this group don't pay much attention to climate issues, as such they are quite unaware of the long-term future impacts of fossil fuels and don't have any great concerns for the environment. Possibly for this reason, they are fairly indifferent to saving energy and don't think their individual actions would make much difference, anyway. However, they express possible

	interest in being part of an energy community – maybe this is something that could save them money and perhaps if green energy does not have to affect their lifestyle too much, they would be happy to adopt it.
Statements	1. We don't generally indulge in a sustainable lifestyle. 2. Paying attention to energy savings doesn't seem very worthwhile. 3. Of course, we are aware of climate issues, but must we really do something ourselves? 4. We don't see society around us transitioning to green energy very soon.
Aspirations	1. Although… if the rest of the community is already energy efficient maybe we should consider it 2. What if an EV is as fast as a traditional car! Could it be?

Table 4 - Energy Indifferent persona attributes

Cluster number	**2**
Name	Energy Skeptic
Position	Aware - negative
Summary	People in this group might be somewhat aware of the climate debate but they are very sceptical of nearly all sources of information. They are not positive that their individual actions would have any impact, anyway, and are very unlikely to invest in any green technologies or join any energy co-operatives. Their energy costs are not very high, which possibly further adds to their lack of motivation. People in this group might therefore feel more positive towards taking action if they found sources of information they could trust, or they could somehow see the benefit to their daily lives.
Statements	1. Individuals, governments and the media won't be the ones to sort out climate change.

	2. No information should be trusted without question, and it is almost impossible to find any reliable source. 3. Green energy will require investment and is not really worth it for us. 4. Our own energy costs are not that high anyway
Aspirations	1. We might change our mind about green energy if we had access to sources of information we could trust. 2. Especially if someone can explain how this is relevant to our daily lives

Table 5 - Energy Skeptic persona attributes

Cluster number	**4**
Name	Energy Constrained
Position	Aware - neutral
Summary	People in this group are aware of climate issues but put their trust mostly in science to resolve the problem. They don't see themselves taking any significant actions, beyond saving some energy in their daily lives. They don't have much disposable income and anyway they are likely to live in apartment buildings where they are limited in what they can affect – e.g. they cannot place solar panels and they may live near to shops and if they use a car it is only rarely for long journeys making large investment to transport unnecessary. They are also likely to be older and not to have any children living at home. They don't believe that energy companies or governments will do much to impact the situation. They are constrained in what they can do by their personal living circumstances, but they might be interested in new energy saving advice especially if it saves them money and they may also be interested to find ways to support the energy transition that will not cost them money, or require changes they cannot make, for example sharing tips to others.
Statements	1. It's probably true that as a whole we need more sustainable transport and renewable energy. 2. Energy providers, government and media are unlikely to impact the energy transition. 3. We ourselves can save some energy at home, but there's probably not much else we could do based on our income and living situation.

	4. Scientists are working hard to find answers and we trust their work!
Aspirations	5. Maybe there are still some energy saving tips we don't know about? Saving money would be nice. 6. Perhaps there is another way to make a difference by sharing what we have learned with others?

Table 6 - Energy Constrained persona attributes

Cluster number	8
Name	Energy Mindful
Position	Aware - positive
Summary	People in this group are likely to be young, live in apartment buildings and lack disposable income. They are a bit concerned about the environment and fully understand that there is a need for greener transport solutions. They also think that renewable energy is probably a good idea. However, possibly due to their living situation they are unlikely to take any actions that would require upfront investment and they are also constrained by apartment life. Possibly due to their younger age, they are more trusting of the information provided to them by family than friends but will happily talk with about the energy transition. Since this group are aware of climate issues but are unlikely to take action due to financial issues and other constraints, they may be most motivated to take positive actions themselves, if they have a change in income, or if actions have no financial cost to them at all. However, since they are happy to talk with friends and family who might have different circumstances, they have the potential to become advocates. They might also be unaware of small actions they can take that don't cost money.
Statements	1. We believe in the need for increased greener transport solutions and renewable energy. 2. It's difficult to take action ourselves – we don't have spare money and we can't do much to our apartment buildings. 3. When we need really trustful information, we turn to our family first and then our friends.

	4. We discuss climate issues amongst our friends and family
Aspirations	1. Maybe there are some small actions we can do to help the climate that won't cost money? 2. Even if we can't adopt green energy ourselves, can we advise our friends and family to do this?

Table 7 - Energy Mindful persona aatributes

Cluster number	**5**
Name	Energy Cognizant
Position	Active - neutral
Summary	People in this group aren't very concerned with environmental issues. They don't have a positive attitude regarding the role of national institutions, industry, scientist or even themselves towards the energy transition. Despite this, they are curious about participating in something like an energy community and in fact may already be doing so. Overall, this group appears to be more driven by social factors than environmental ones. They might therefore join other initiatives if they can see there are like-minded people already participating there,
Statements	1. We're not that concerned about environmental issues. 2. If there are problems, those in power should help but we don't have much faith in them. 3. Individual investment in green technologies is not that appealing. 4. Participating in energy communities with others might be of interest to us.
Aspirations	1. What other opportunities might there be to cooperate with others like us? 2. What benefits would this bring to us and others?

Table 8 - Energy Cognizant persona attributes

Cluster number	**7**
Name	Energy Participant
Position	Active - positive
Summary	People in this group have a high income. They are very concerned about the environment and are willing to take positive action, but they prefer actions that rely more on investment of money, than time, which due to their busy working lives is a rare commodity. They are happy to invest in solar PV, EVs (especially company supplied) and to use other forms of sustainable transport. They similarly understand that communal actions may be useful for achieving impact and as such, they would be likely to participate as a member of an energy community – however, given their busy lifestyles, they might be concerned about what would be required from them – offering specialist technical knowledge might be more appealing than offering their time to manage aspects of the cooperative.
Statements	1. We are very concerned about environmental issues. 2. Investing in renewable energy creates more impact than many small-scale energy saving activities. 3. We are fortunate to have enough disposable income to consider solar panel and EVs. 4. If a green action fits with our lifestyle we will definitely take it
Aspirations	1. Might there be some kind of energy co-operative we could join? 2. What skills and knowledge would we have to contribute towards such a community?

Table 9 - Energy Participant persona aatributes

Cluster number	**3**
Name	Energy Practical

Position	Advocate - Neutral
Summary	People in this group recognize the importance of taking green actions. They are likely to discuss environmental issues with their friends and family and trust the information they get from them. They are much more cautious about taking actions that require significant investment or to rely on others. They are likely to be either employed or retired, but still seeking additional sources of income. Therefore, availability of grants might influence people in this group to make more significant investments in green energy. They might also be interested to hear more everyday hints and tips that they could put into practice and share with the people around them.
Statements	1. Climate change is real, and we believe we all need to do our part. 2. Simple things like heating less water can help our pockets AND the environment! 3. Sharing tips with friends and family is a good way to make sure we are all helping. 4. We are cautious about green actions that are expensive or require us to depend on others, though.
Aspirations	1. Maybe owning an EV could be affordable after all, especially if there are grants available? 2. If not, then perhaps there are other good energy saving actions we can take…

Table 10 - Energy Practical persona attributes

Cluster number	**6**
Name	Energy Activist
Position	Advocate - positive

Summary	People in this group are very trustful of information they encounter from governments, scientists and various online sources. They are very well acquainted with environmental topics and understand that everyone needs to do their part to tackle climate change. As such, they consciously try to save energy and will happily use apps to help achieve these goals. They are also sensitive to issues of energy justice. People in this group already use apps to support energy saving and therefore might be more likely than others to be curious about other new technologies to support sustainable living. They might be interested to make a difference and get involved towards a just energy transition due to their sense of fairness.
Statements	1. We trust websites, scientists, the government and others to provide accurate information. 2. The climate crisis is real and all of us living in private households must consciously do our part, too! 3. Actively sharing information amongst friends and family is a useful thing to do. 4. We believe that everyone should have equal access to energy, and no one should be unfairly impacted by green initiatives.
Aspirations	1. What new technologies can help sustainable living and how can we participate? 2. Are there opportunities to get involved in ensuring a just energy transition?

Table 11 - Energy Activist persona attributes

3.5.4 Representing personas in graphical form

The following presents the 8 identified energy citizenship personas in a graphical form. The purpose of the graphical summary is to provide a snapshot that people might be able to understand and engage with, essentially acting as a way of curating one perspective of the multinational survey in a way that a general audience with no special data handling skills could engage with quickly and easily. The identified 8 different personas are represented in a graphical form with their statements which give insight into their lives and their aspirations that a person may be able to identify with when presented in front of them as an artifact.

Persona Energy Indifferent

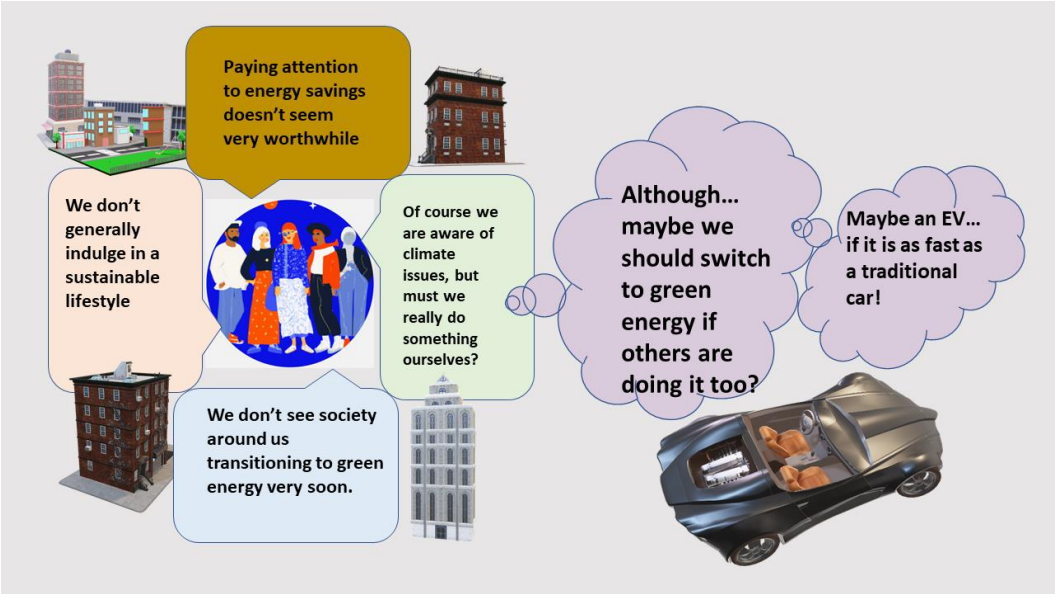


Figure 31 - Representation of Persona - Energy Indifferent

Persona Energy Skeptic

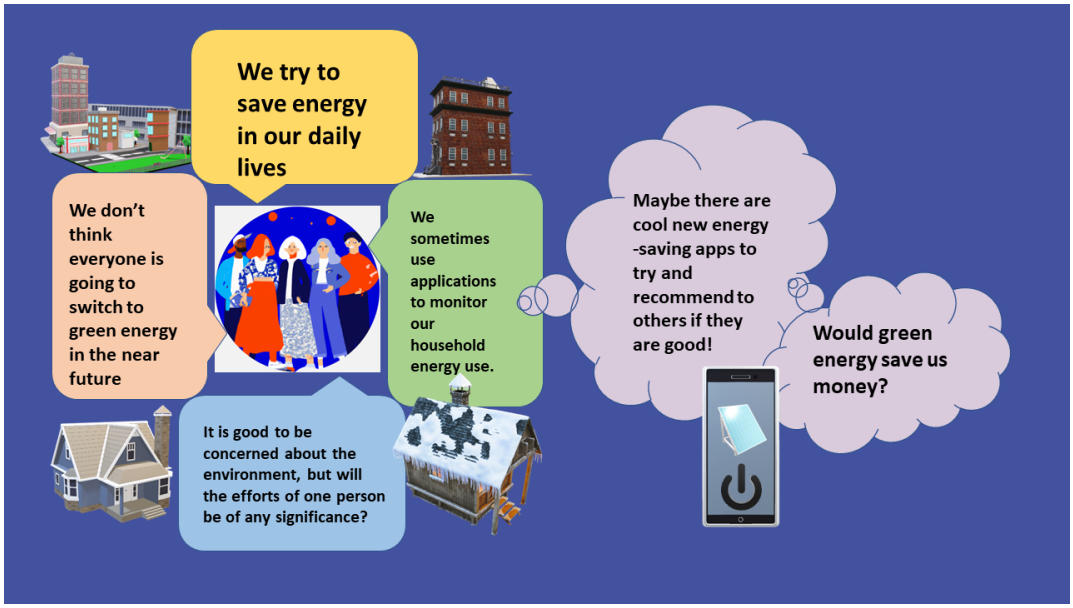


Figure 32 - Representation of Persona - Energy Skeptic

Persona Energy Constrained

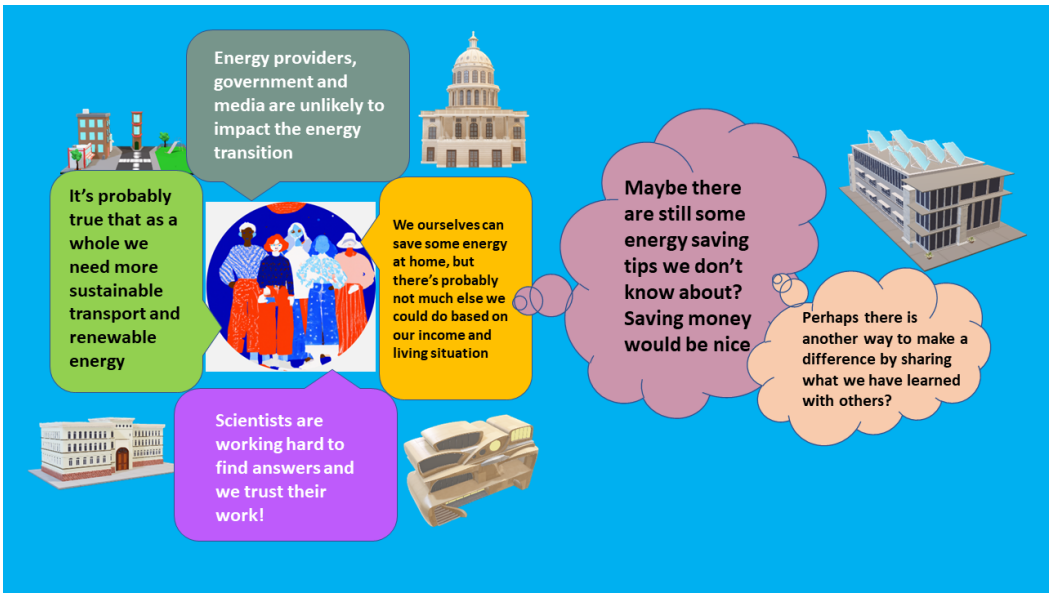


Figure 33 - Representation of Persona - Energy Constrained

Persona Energy Mindful

Figure 34 - Representation of Persona - Energy Mindful

Persona Energy Cognizant

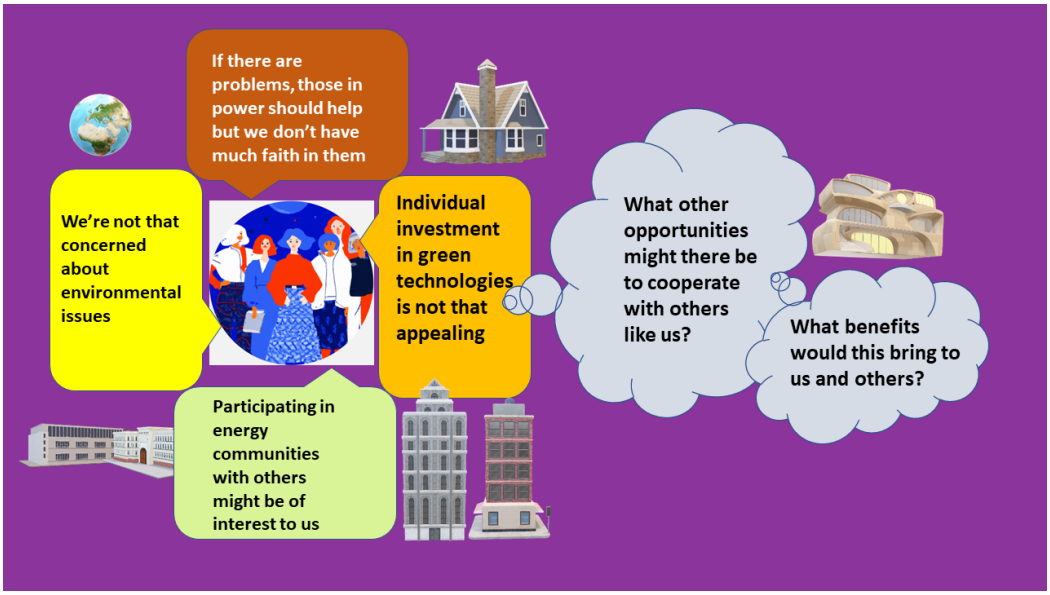


Figure 35 - Representation of Persona - Energy Cognizant

Persona Energy Participant

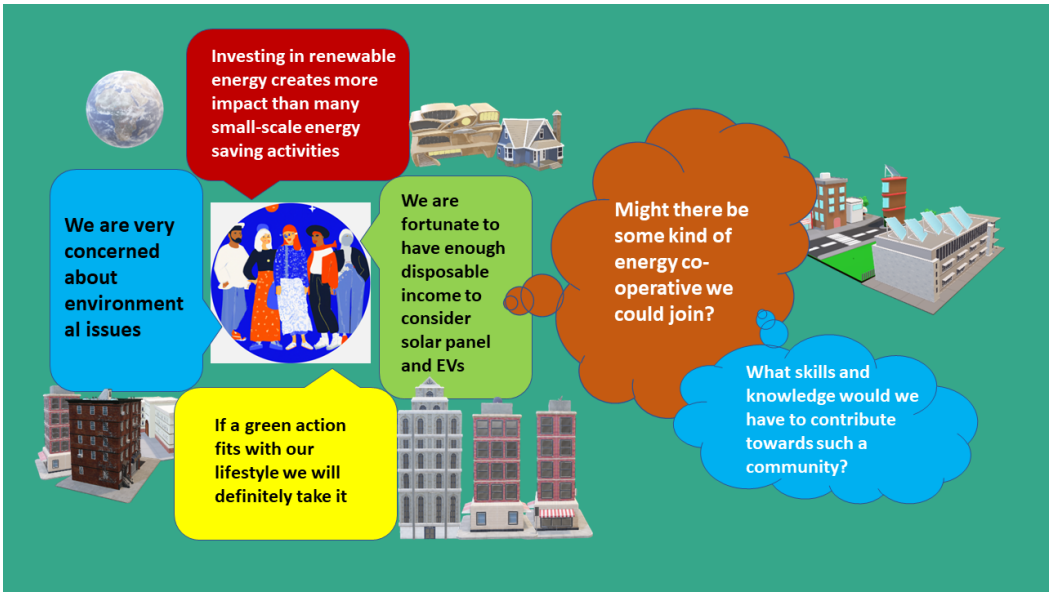


Figure 36 - Representation of Persona - Energy Participant

Persona Energy Practical

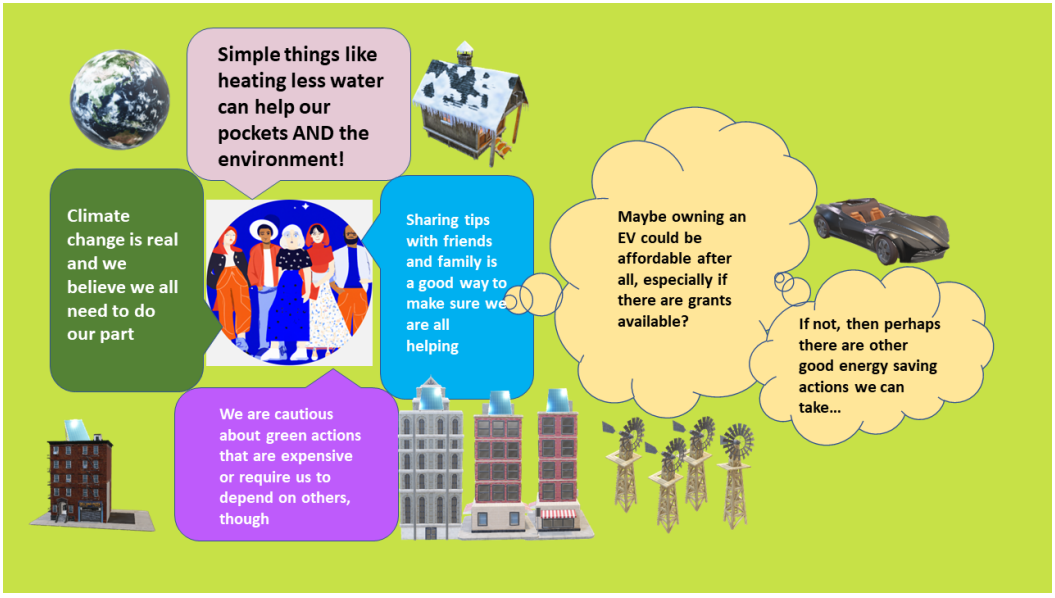


Figure 37 - Representation of Persona – Energy Practical

Persona Energy Activist

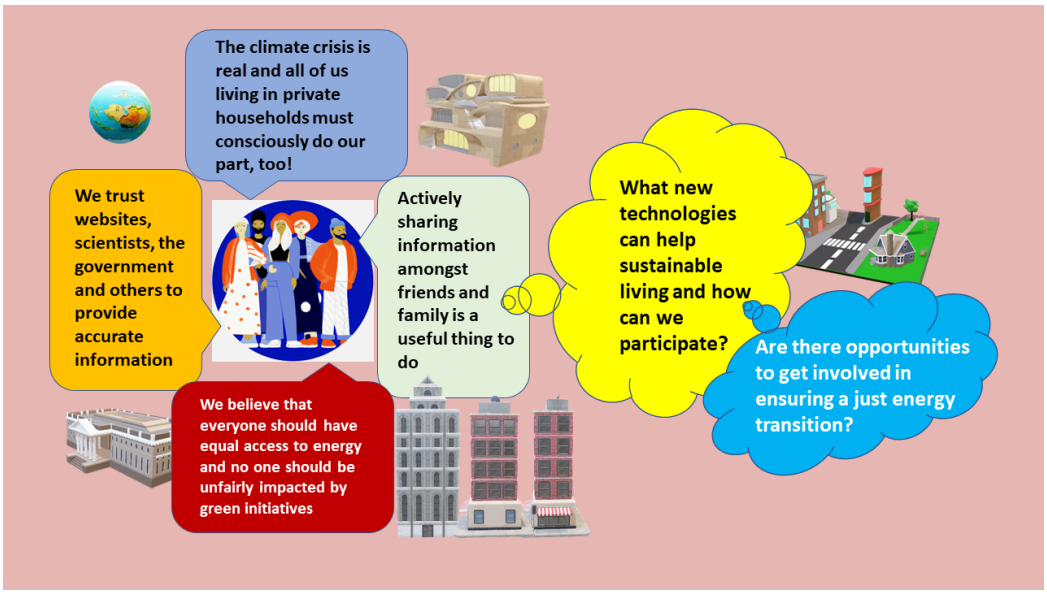


Figure 38 - Representation of Persona - Energy Activist

3.5.5 Identifying design principles from persona

In this section we analyse each persona and identify design principles that could guide design of energy interfaces for these different types of energy citizen.

Persona Energy Indifferent

People in this cluster don't pay much attention to climate issues, however they may be motivated by the opportunity to save money while contributing to the energy transition, which is a positive result for their action for them. People in this group might be supported in achieving new energy transition goals if energy interfaces are designed to make it easy to identify financial burdens or savings. Linking the financial benefit to environmental benefit may further incite positive feelings within this group of people. This can be summarized by following design principles.

Economic impact of Energy Transition: "*Energy interface should make it easy to identify financial burdens or savings related to green actions*."

Environmental impact of Energy Transition: "*Energy interface should make it easy to identify environmental benefits and impacts related to green actions*."

Dependencies of sustainability: *"Energy interface should make it easy to see dependencies between economic, social and environmental aspects of sustainability to support decision-making".*

Persona Energy Skeptic

People in this cluster are aware of climate issues but are skeptical of information sources as well as the significance of individual actions in daily lives. People in this group may feel reassured and more likely to trust information when they can 1) identify credibility of information e.g. by reference and access to primary sources 2) enter into open debate on the content 3) it is conveyed in an authoritative and professional manner, for example no clickbait, grammatical and typing errors and so on. People in this group may better appreciate the potential impact of individual actions if they can perceive their role in the context of the greater picture of the green transition. This can be summarized by following design principles.

Trustable Sources: "*Energy Interface should allow users to verify information presented to enhance trust*."

Debatable content: "*Energy interface should allow users to enter into open debate on the energy information presented*".

Authoritative style: "*Energy interface should present data and information in an authoritative and professional manner*".

Jigsaw pieces: "*Energy interface should show the cumulative effects of actions at different scales – individual, local, national, global*"

Persona Energy Constrained

People in this group are aware of climate issues but think it is a problem for government and institutions and their individual contribution are limited to practicing energy saving. They might be interested in new energy saving advice and they may also be interested to find ways to support the energy transition. Therefore, people in this group might benefit from access to energy saving tips tailored to their specific financial and living situation. This can be summarized by following design principle.

Tailored Tips: "*Energy interface should provide users with latest tips and insights about energy transition relevant to them*."

Persona Energy Mindful

People in this group are likely to be young, live in apartment buildings and lack disposable income. They are a bit concerned about the environment and fully understand that there is a need for greener transport solutions. They also think that renewable energy is probably a good idea and have the potential to become energy transition advocates. People in this group may benefit from facilities that support sharing tips or advertising events or new energy initiatives.

This can be summarized by following design principle.

Sharing about Energy Transition: "*Energy interface should allow people to share their energy transition actions, events and initiatives in order to inform and motivate others*."

Persona Energy Cognizant

People in this group aren't very concerned with environmental issues and they don't have a positive attitude regarding the role of institutions or even themselves towards the energy transition. However, they may be curious about participating in something like an energy community as this group appears to be more driven by social factors than environmental ones. People in this group may benefit from being able to identify what is happening in their local area, such as what activities other local people are involved in and whether there are opportunities to join with them. This can be summarized by following design principle.

Social Aspects of Energy Transition: "*Energy interface should provide users with information on collaborative activities towards the green transition"*

Persona Energy Participant

People in this group are very concerned about the environment and are willing to take positive actions but rely more on investment of money, than time and effort. They understand that communal actions may be useful for achieving impact and may be likely to participate as a member of an energy community but may be concerned about what would be required from them. People in this group may benefit from being able to see what roles they can take in their individual life or as part of an energy community and exactly what is required from these roles. They may appreciate actionable insights from information over making sense of information for themselves. This can be summarized by following design principles.

Actionable information of Energy Transition: "*Energy interface should be able to convert information into actionable insights based on users' preferences*"

Roles in the Energy Transition: "*Energy interface should make it easy to select between different roles that people can play in the energy transition according to their personal circumstances'.*

Persona Energy Practical

People in this cluster group recognize the importance of taking green actions and are likely to discuss environmental issues with their friends and family and are much more cautious about taking actions that require significant investment. People in this group might be supported to take action if they can easily find out about government supports or financial subsidy. This can be summarized by following design principle.

Financial support: "*Energy interface should inform user about relevant financial subsidy or monetary savings possible for participating in transition as well as support for applying*."

Persona Energy Activist

People in this group are well acquainted with environmental topics and they consciously try to save energy. People in this group might be more likely than others to be curious about other new technologies to support sustainable living and might be interested to make a difference and get involved towards a just energy transition due to their sense of fairness. People in this group might benefit from learning new ways to promote their green knowledge, develop initiatives and communicate to others. They might also benefit from finding existing initiatives that they can learn from or join, Finally, since people in this group have an increased sense of justice they might be interested to understand also about possible negative impacts of transition policies and

initiatives and get involved in mitigating against them and designing a just transition, This can be summarized by following design principles.

Promoting knowledge about Energy Transition: *"Energy interfaces should support information sharing through different channels".*

Democracy of Energy Transition: *"Energy interface should allow user to connect with opportunities to directly get involved in defining energy transition policies or interventions."*

Societal Impact of Energy Transition: *"Energy interface should make it easy to identify societal benefits and impacts of the transition and how these are distributed".*

4 Conclusions and Future work

Converting cluster attributes into personas is a strategic process that bridges data insights with user-centred design. In this deliverable we describe an approach for creating energy citizen personas based on the outcome of clustering the GRETA multinational survey data and identifying design principles based on these. To ensure the efficacy of converting cluster attributes into personas, adherence to best practices is crucial. First, involve diverse stakeholders, including designers, researchers, and users, to validate persona attributes and narratives (Prates et al., 2018). Second, maintain a balance between generalization and specificity, ensuring personas are representative while reflecting the distinct characteristics of each cluster. Third, regularly update personas to accommodate evolving user trends and preferences. Finally, continually validate personas against new data to ensure their accuracy and relevance (Ternovskiy et al., 2021). While within this deliverable we reflect aspects of the first two, it is clear that these are not final energy citizen personas, but instead represent a snapshot of a moment in time, to be updated in the light of new evidence and feedback.

For now, in addition to the utilization of the GRETA personas for deriving design principles, we also anticipate the following uses for the GRETA personas:

1. To directly engage energy citizens in understanding what type of energy citizen they are and to then curate access to data and information in such a way that they find the resources most relevant to them first. Such resources can be selected in a way that would empower that particular type of energy citizen to transition between different levels of awareness or between negative towards positive views.
2. To inform policy making that is sensitive to different types of energy citizens.

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Appendix 1

This appendix contains all the information derived from the clustering that was used to create the clusters, as well as cluster titles, summaries, statement and aspirations

Cluster 0

- Most children.
- Moderate to high average electricity bill.
- Does not save energy.
- Least likely to talk with friends and family about energy transition.
- Least likely to use digital apps to track energy consumption.
- Least aware of harmful and long-term effects of using gas in domestic appliances.
- Least aware of the harmful and long-term effects of using unsustainable transport modes.
- Less likely to be informed about gas replacement initiatives for the business.
- Least aware of the harmful and long-term effects of fossil fuel-based cars.
- Least aware of harmful and long-term effects of using fossil fuel-based energy.
- Positive to be a member of the energy community.
- Least positive outlook toward energy providers in the energy transition
- Least likely to indulge in saving energy on water heating.
- Least likely to drive slower for saving fuel.
- Less confident about personal contribution in the energy transition.
- Least concerned about the environment

Cluster 2

- Least trustful of textbooks for information
- least informed in self-generation of electricity for business
- Most rural
- Mostly single
- Least children
- Least informed about gas replacement initiatives for business
- Least interested in sustainable transport from business
- Least interested in sustainable transport from the government
- Least interested to trust the government for the gas initiative.
- Least trustful of blogs for information
- Least interested in EV from business
- Least interested in EVs through government subsidy
- Least positive outlook towards the judiciary for the energy transition
- Least positive outlook toward private households for the energy transition
- Least positive outlook towards the EU for the energy transition
- Least positive outlook toward public media for the energy transition

- Least trustful of government websites for information
- least interested in sustainable transport through government
- Least trustful online encyclopedia for information
- Least likely to support the cause of energy justice.
- Low to moderate average electricity bill
- Least positive towards spending on cooperative self-generation
- Least positive towards spending on EV
- Least positive towards giving up using gas in domestic appliances.
- Least proud of the idea of cooperative self-generation
- Least proud of the idea of using sustainable public transport.
- Least confident about personal contribution to the energy transition
- Least proud of the idea of replacing gas-based appliances.
- Least proud of the idea of using EVs.
- Least positive towards giving up using gas in domestic appliances.
- Least positive towards spending on sustainable transport
- Least trustful of Scholarly article for information
- Least solar panel users
- Least trustful of industry website for information
- Least trustful of NGO for information
- Least trustful of search engines for information

Cluster 3

- May likely to talk with friends and family about energy transition.
- Least children
- Very likely to indulge in saving energy on water heating.
- Slightly positive towards renewable energy
- Not positive towards spending on EV
- Very concerned about environment
- Moderate to high average electricity bill
- Less likely to drive slower for saving fuel.
- A bit proud about the idea of using EV.
- Highly aware about harmful and long-term effect of using unsustainable mode of transport.
- A bit confident about personal contribution in energy transition
- Highly aware about harmful and long-term effect of using unsustainable mode of transport.
- Tries to save energy.
- Less positive towards spending on cooperative self-generation
- Doesn't use solar panels
- Very trustful of family for information
- Mostly employed or retired.
- Very trustful of friends for information
- Highly Educated
- Highly likely to look for additional source of income.

Cluster 4

- Least children
- Less likely to participate in self-generation of electricity for business.
- Less likely to buy EV from business.
- Less likely to adopt sustainable transport from business.
- Highly aware about harmful and long-term effect of using unsustainable mode of transport.
- Less likely to adopt EV through government subsidy.
- Likes to save energy.
- Less likely to adopt sustainable transport through government.
- Less proud about the idea of using EV.
- Least likely to engage as a member of energy community.
- Mostly low to mid income
- Not very positive outlook towards energy providers in energy transition
- Less likely to drive slower for saving fuel.
- Moderate to high average electricity bill
- Most apartment-based houses.
- Least likely to be a member of energy community.
- Less likely to support the cause of energy justice.
- Very positive outlook towards scientist working in energy transition.
- Less likely to adopt sustainable transport from government.
- Mostly older
- Neutral outlook towards public media for energy transition
- Less likely to trust government for gas initiative.
- A bit concerned about environment.
- Slightly positive towards renewable energy
- Not positive towards spending on EV

Cluster 5

- Least positive outlook towards nation institutions for energy transition
- most urban
- Least positive outlook towards industry in energy transition
- Least positive outlook towards scientist working in energy transition.
- Most likely to engage as a member of energy community
- Most likely to be a member of energy community
- Moderate to high average electricity bill
- Least positive towards renewable energy
- Less concerned about environment
- Mostly mid to high income
- Mostly younger and mid aged
- Slightly aware about harmful and long-term effect of using unsustainable mode of transport.

- Slightly aware about harmful and long-term effect of using fossil fuel based energy
- Slightly positive towards spending on EV
- Not very confident about personal contribution in energy transition

Cluster 6

- Most positive towards renewable energy
- Most aware about harmful and long-term effect of using gas in domestic appliances
- Very proud about the idea of using sustainable public transport.
- Most concerned about environment.
- Most likely to drive slower for saving fuel
- Most positive outlook towards judiciary for energy transition
- Most likely to use digital apps to track energy consumption.
- Most positive outlook towards nation institutions for energy transition
- Moderate to high average electricity bill
- Most aware about harmful and long-term effect of fossil fuel based cars
- Very proud about the idea of using EV.
- Most proud about the idea of replacing gas-based appliances.
- Most positive outlook towards private household for energy transition
- Most likely to support the cause of energy justice
- Most aware about harmful and long-term effect of using unsustainable mode of transport
- Most aware about harmful and long-term effect of using fossil fuel based energy
- Most proud about the idea of cooperative self-generation
- Most likely to indulge in saving energy on water heating
- Most positive outlook towards scientists working in energy transition.
- Most positive outlook towards the EU for energy transition
- Most likely to talk with friends and family about energy transition
- Saves energy consciously.
- Most family
- Most children
- Highly likely to adopt sustainable transport from the government.
- Most trustful blogs for information
- Most trustful government websites for information
- Most trustful of the family for information
- Most trustful of friends for information
- Most trustful of textbooks for information
- Highly likely to use EV for business.
- Most trustful of industry website for information
- Most trustful of online encyclopedia for information
- Most trustful of search engines for information
- Most trustful of Scholarly article for information
- Most trustful of government websites for information

Cluster 7

- Most positive towards spending on sustainable transport
- Most positive towards spending on EV
- Most positive towards spending on cooperative self-generation
- Most solar panel users
- Most urban
- Most interested in sustainable public transport.
- Most likely to adopt sustainable transport from business.
- They have positive outlook towards industry in energy transition.
- Very proud about the idea of replacing gas-based appliances.
- Very proud about the idea of replacing gas-based appliances.
- Most proud about the idea of using sustainable public transport.
- Most likely to participate in self-generation of electricity for business.
- Most likely to adopt sustainable transport from government.
- Most positive outlook towards energy providers in energy transition
- Moderate to high average electricity bill
- Most proud about the idea of using sustainable public transport.
- Most confident about personal contribution in energy transition
- Most likely to use EV from business.
- Very likely to engage as a member of energy community.
- Most likely to participate in gas replacement initiatives for business.
- Most likely to trust government for gas initiative.
- Most positive outlook towards public media for energy transition
- Most independent houses
- Does not save energy.
- Mostly younger
- Most Males
- Very concerned about environment
- Most Educated
- Highest income
- Most Employed

Cluster 8

- Very likely to look for additional source of income.
- Most young
- Low to moderate average electricity bill
- Least likely to use digital apps to track energy consumption.
- A bit concerned about environment.
- A bit positive about renewable energy
- Mostly low income
- Not positive towards spending on EV
- Not proud about the idea of using EV.
- Not very confident about personal contribution in energy transition

- Highly aware about harmful and long-term effect of using fossil fuel based energy
- Highly aware about harmful and long-term effect of using unsustainable mode of transport.
- they may like to talk with friends and family about energy transition.
- High apartment-based houses.
- Less positive towards spending on sustainable transport
- Less positive towards spending on cooperative self-generation
- Not very positive outlook towards public media for energy transition
- A bit positive outlook towards scientist working in energy transition.
- Very trustful of family for information
- Somewhat trustful of friends for information