D4.2
Definition of the modelling framework

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Executive summary

The Executive Summary:
The GRETA project aims to improve the understanding of the conditions and barriers for the emergence of energy citizenship, considering that energy citizenship in GRETA is about the active participation of citizens in energy systems in a particular geographical area.

WP4 *Data processing and explicit modelling* will contribute to the general aim of GRETA by generating a solid base of analysis for the project, based on the generation of different types of energy and behavioral models. As part of WP4 activities, this deliverable presents the results of the work done under T4.2 *Definition of the modelling framework* umbrella.

The methodological framework aims to simplify the willingness of citizens from a specific location for energy citizenship to provide information for decision-making. For this purpose, the conceptual model proposed integrates all modelling perspectives adopted in WP4 through an analytical and operationalization approach based on Lotka-Volterra equations. Originally, these equations were born in the context of ecology to explain the relationship between preys and predators and how they interact. In the context of GRETA, Lotka-Volterra equations are used to represent the interactions between citizens, companies, and policy makers. When analysing a specific location, the interaction modalities between the 3 agents are determined according to dynamic features called energy citizenship analytical components. This comprises technical, behaviour and other components evolution and provides the dynamic and transdisciplinary perspective followed.

As the main result of the deliverable an Energy Citizenship Actions Catalogue is presented. The catalogue comprises 22 energy citizenship actions from sustainable mobility, clean and affordable energy, circular economy and sustainable consumption and diet habits fields. The catalogue includes the calculation method proposed to understand the potential of emergence of each action, based on the analytical components that characterize them.

The energy citizenship actions catalogue presented in this deliverable is the first version of how to model each energy citizenship action. The catalogue will be under development until the end of the WP4 and the work carried out in Tasks 4.3 to 4.6 will serve both to enrich the catalogue and to validate/test the developments.

Project information

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Keywords	Energy citizenship, model, Lotka-Volterra equations, analytical components, decision making.

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V1.0	13/01/2023	Contributions from partners
V1.1	24/01/2023	D4.2 for revision
V2.0	29/01/2023	D4.2 reviewed version for project coordinator

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Abbreviations and acronyms

Acronym	Description
GIS	Geographical Information System
EU	European Union
GRETA	GReen Energy Transition Actions
CEP	Clean Energy Package
CF	Carbon Footprint
WP	Work Package
DR	Demand Response
DIKW+E	Data Information Knowledge Wisdom Enlightenment
ABM	Agent Based Model

1 Introduction

The European Union´s energy system is undergoing a profound transformation driven by the need to reach the EU climate objectives through further decarbonisation and to supply secure and affordable energy to consumers and businesses. The European Union has noticed that consumers have an essential role to play in achieving the flexibility necessary to adapt the electricity system to variable and distributed renewable electricity generation [1]. Empowering and providing consumers with the tools to participate more in the energy market, will help to achieve the EU renewable energy targets and enable EU citizens to benefit from the internal market for electricity [1] [2].

In recent years, technological innovation and the decreasing cost of technology have made new forms of consumer participation in energy production and management more accessible. Consumers have started to produce, store and consume their energy and can support the operation of power grids and the energy market by changing their load patterns. New forms of collective energy action have also started to emerge, enabling a more active role of consumers in the energy system. In some Member States, local communities already get involved in initiatives to collectively reduce energy use, manage energy better, and generate or purchase energy [3].

The Clean Energy Package (CEP) has elaborated on the central role that collectively acting consumers can play in the energy transition and have established a suitable legislative framework where "jointly acting consumers" and "jointly acting renewable self-consumers" have more opportunities to get actively involved. The CEP also introduced the concept of "citizen energy communities" as a way to engage consumers and increase the acceptance of renewables. Communities and individuals are given the right to produce, store, consume and sell their energy and are recognized as key stakeholders in the new energy system [3].

Beyond the production, storage and consumption of clean energy, citizens can put in place relevant actions that have a positive impact towards the energy transition. For example, citizens play an important role in implementing clean and sustainable mobility solutions and can contribute strongly to achieve the objectives set by the European Commission (90% reduction in greenhouse gas emissions in the transport sector until 2050 [4]). Moreover, citizens can put in place other kind of actions that will also contribute to the energy transition goals, like by adopting sustainable consumption habits.

Identifying the drivers and barriers that can promote or obstruct the deployment of energy citizenship actions will help to understand where energy citizenship is more likely to emerge and will provide information for decision making purposes.

The GRETA project aims to improve the understanding of the conditions and barriers for emergence of energy citizenship. Within WP4 a solid **base of analysis** for the project, based on the generation of different types of energy and behavioral **models** will be achieved.

1.1 Description of the deliverable

Deliverable 4.2 presents the results of task 4.2 "Definition of the modelling framework".

Section 2 describes the 8 steps procedure followed for the modelling framework definition and includes the results obtained in the 3 firsts of the 8 steps. Section 3 describes the analytical approach adopted and how the results will be visualized. Section 4 is dedicated to collect the energy citizenship analytical components that will allow to characterize the actions. Section 5 presents the main result of the T4.2, the energy citizenship actions catalogue. The catalogue collects a classification of energy citizenship actions and a proposal of the technical and behaviour components that characterize the emergence potential of each of them. Section 6 explain the next steps that will be undergone until the end of the WP4 and Section 7 includes the conclusions of the work done.

The modelling framework presented in this deliverable has been developed in collaboration between the T4.2 participants. Experts from different fields have been providing their knowledge and enriching the different perspectives that the model has to cover. Table 1 presents the contributions from partners. Sections that are not specified in the table have been developed by Tecnalia (TEC).

Table 1: Contributions from partners

Section	Contribution	Partner(s)
#NA	General framework definition	TNO, LUT, GESIS, TEC
#NA	State-of-the-art revision	TNO, LUT, GESIS, TEC
Section 3.1	Mathematical approach description	TNO
Section 3.2	Results visualization	GESIS
Section 4.2	Behaviour analytical components	TNO
Section 4.3	Other analytical components	LUT
Section 5	Energy citizenship actions catalogue	TNO, TEC
Rest of the sections	Main sections development and description	TEC

2 Procedure followed for modelling framework definition

At the early stages of the task, an 8 steps process was developed to define the modelling framework:

1. Key terms definition: the framework needs to define clearly what GRETA understands for the terms that are the key for the modelling framework definition.
   - ➔ Detailed in section 2.1 Key terms definition

2. Define the objectives of the model and desired results.
   - ➔ Detailed in section 2.2 Define the objectives of the model and desired results

3. Define starting point characteristics that the model should fulfil
   - ➔ Detailed in section 2.3 Define starting point characteristics that the model should fulfil

4. Modelling framework definition
   - ➔ Detailed in section 3 Modelling Framework

5. Identifying the components needed to be part of the model at:
   - ➔ Detailed in section 4 Energy citizenship analytical components

6. Understanding how the components can be assessed
   - ➔ Detailed in section 5 Energy citizenship actions catalogue

7. Test – Case studies
   - ➔ Starting in T4.3 and T4.4 Developing and testing energy and non-energy (respectively) related based models at local level
   - ➔ Finalising in T4.6 Developing and testing models and scenarios for spatial analysis at regional, national and supranational levels.

8. Improve and redesign if needed
   - ➔ To be decided T4.6

Steps 1, 2 and 3 are detailed in the following sections.

2.1 Key terms definition

The first step was to define clearly what GRETA understands for the terms that are the key for the modelling framework definition. Energy citizen and energy citizenship terms definitions from the GRETA glossary of terms has been adopted.

An **energy citizen** in GRETA is understood as an individual who participates individually or collectively in the **transition of energy systems** in a particular geographical area. Energy citizens use, consume, produce and/or store energy in an improved or reduced manner. Energy citizens' activities and behaviours affect the decarbonisation of current energy systems in the long run. Their energy-related knowledge, when shared, allow energy citizens to have also an advocacy role. The effects can be positive (e.g supporting the clean energy transition, investing in energy-efficient appliances or participating in a local energy initiative), or negative (e.g., public resistance to new forms of renewable energy) or neutral.

Energy citizenship in GRETA is about the **active participation of citizens in energy systems in a particular geographical area**. Active participation can be both social and political, either as individuals (e.g., through energy efficiency measures in households) or in larger groups (e.g., through engagement with energy policy in climate activist groups or energy communities). The effects of energy citizenship can be positive (e.g supporting the clean energy transition, investing in energy-efficient appliances or participating in a local energy initiative), or negative (e.g., public resistance to new forms of renewable energy) or neutral.

On the other hand, for WP4 purposes it is also needed to define what is understood as a model. In this case, the definition from [5] has been adopted. Therefore, in the WP4 of GRETA a **model** is understood as a simplified description of a complex entity or process.

Therefore, the complexity that GRETA modelling framework aims to simplify is the willingness of citizens from a specific location for energy citizenship.

2.2 Define the objectives of the model and desired results

Considering the key terms definition, the objectives of the model have been defined. Firstly, the question that the model aims to answer is "**Where Energy Citizenship is more likely to emerge?**". Taking into account this question, the main objective of the modelling framework is "**to allow the identification of where Energy Citizenship is more likely to emerge**". Therefore, the desired result is the "**characterization of the geographical areas according to their willingness to energy citizenship emergence**".

There are other kind of questions that the model will allow to answer, for example:

- What enables citizens to take action on energy?
- Which are the interactions among the agents participating in the energy citizenship emergence?
- Does the regulatory framework promote the emergence of energy citizenship?

These questions have been classified into 3 main themes: energy/technical, behavioural and non-energy /others. The energy citizenship emergence will be considered as the integration of these 3 themes.

2.3 Define starting point characteristics that the model should fulfil

In order to understand the starting point characteristics that the model should fulfil, a state-of-the-art revision was done. The state-of-the-art revision was conducted between TNO, LUT, GESIS and Tecnalia. In order to facilitate the exchange of information, a repository in google drive was created. The repository aims to classify and organize the relevant information extracted from the literature review. Table 2 summarizes the type of information collected.

Table 2: Information collected during the bibliographic analysis

Reference Title, Author, Year	**Type of document** Scientific article, project deliverable, book, publication…	**Who is including the information?** TNO, LUT, GESIS, Tecnalia	**Interest for the purpose of the task. Comments.** Low, Medium, High.
Main objective of the document	**Dimensions covered** Main, energy, environment, social, behavioural, economic, other.	**Analysed energy uses** Heating, cooling, electricity, other.	**Key terms covered** Energy community, energy citizenship, energy justice, CTP, ECC.
Spatial scale - Scope Building, district, city, regional, National, Supranational	**Fields of interest for the methodology definition** Methodology, tool, predictions, trends, scenarios analysis, GIS, other.	**Case studies**	**Link**

As a result of the revision, 65 references were studied according to the following classification:

- Scientific article: 59
- Project deliverable: 4
- Book: 2

Most of the studied references are focused on Energy (24/65) and behavioural dimensions (11/65). Six out of 65 references are focused on the social dimension, while the remaining references cover issues like interactions between regulators and innovators, spatial methods and/or tools, etc.
In the case of the key terms covered, it is remarkable that only 16/65 references cover any of the identified key terms: Energy citizenship (7/65), Energy community (6/65) and CTP (1/65). On the other hand, almost of half of the references (29/65) include methodologies. A representative number of references are GIS-based (13/65) and some of them include tools (6/65). Explicit scenarios analysis is partly covered (4/65) while trends are only covered by one reference.

Combining both the key terms and the issues of interest for the methodology definition, it has to be highlighted that 5 out of the 7 references that are referred somehow to **energy citizenship**, include **methodologies** as well. Elaborating these 5 references in detail:

- “Robust space–time modeling of solar photovoltaic deployment” (S. Copiello and C. Grillenzoni) aims to set up robust space-time models to enable the investigation of the drivers of solar PV deployment. Energy citizenship is not mentioned by itself, but it is stressed that the willingness to adopt PV systems increases for those who see friends, colleagues or neighbours adopting them. Spatial lags imply the occurrence of peer and neighbourhood effects.
- “Sunny days: Spatial spillovers in photovoltaic system adoptions” (N. B. Irwin [7]) is more focused on the important role of peer effects from neighbouring actions have on one´s own decisions for residential PV systems. Therefore, the topic of interest is in estimating the spillover effect from neighbouring PV system installations, that, as the article concludes, PV system adoptions have a positive multiplier effect. However, once again, energy citizenship is not mentioned by itself.
- Considering the year of publication of the article “Does localized imitation drive technology adoption? A case study on rooftop photovoltaic systems in Germany” (J. Rode and A. Weber [8]), it can be anticipated that the term energy citizenship does not appear in the article. However, it is interesting because when studying the spatio-temporal diffusion of rooftop households PV installations the authors conclude that, in accordance with the other articles, imitative adoption behaviour is an important factor of household photovoltaic systems.
- “The effect of group decisions in heat transitions: An agent-based approach,” (G. del C. Nava-Guerrero, H. H. Hansen, G. Korevaar, and Z. Lukszo [9]) explores, through agent-based modelling (ABM), how individuals and group decisions would influence natural gas consumption and heating costs. Once again, energy citizenship is not mentioned by itself but, as it is concluded, group decisions can influence adoption decisions and should be taken into consideration for the design of policies.
- “Agent-based modeling of energy technology adoption: Empirical integration of social, behavioral, economic, and environmental factors,” (V. Rai and S. A. Robinson [10]) with the goal of developing a model capable of representing the bounded rationality of individual decision-makers, the article presents the architecture of a theoretically-based and empirically-driven agent-based model of solar PV adoption by integrating social, behavioural, economic and environmental factors. In the model two key elements determine the decision of the agents to adopt or not adopt solar: an attitudinal component and a control component. Even though energy citizenship is not mentioned as itself, this article stresses the importance of considering different factors to drive decision-making of policymakers and utility planners (in the solar programs design context of the article).

Even though the term energy citizenship is not explicitly mentioned in these articles, the relevance of the implication of citizens to promote the energy transition is clearly highlighted.

Moving to the two remaining references related to **energy citizenship** but not methodology specific, [6] explores the hypothesis that citizens´ engagement through energy citizenship is a key driver towards the societal impact of the energy transition. Even though it concludes that transdisciplinary approaches are being developed but are still immature, the energy citizenship concept is understood closely to citizen engagement, while in GRETA is related to the active participation in the energy systems. In the case of [7], the concept is more closely understood as it is in GRETA, focusing on individuals as agents of change. However, for the purpose of the modelling framework, the article is interesting because it classifies the energy citizenship literature. Modelling energy citizenship, however, is not part of it.

Coming back to articles focused on **methodologies,** there are 29/65 references covering different types of methodologies. 6 out of 29 are focused on behavioural factors; 21 on energy related methods and 1 on tools to support the analysis. These methodologies, models and tools will be further described in dedicated deliverables 4.3 *Energy related base models at local level* and 4.4 *Non-energy related models at local level.*

It has to be noted that the technical feasibility of implementing energy technologies has been largely studied. Even the social acceptance of measures implementation, the economic repercussion and the legal framework that can act as a driver has been studied quite well. The relevance of citizens taking part in the energy transition is evident. It is also clear the relevance of identifying where energy citizenship is more likely to emerge and how facilitating this emergence will promote the energy transition.

It has to be highlighted as well that there is no specific evidence for models which target the emergence of energy citizenship behaviour in a holistic way.

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Continuing with the starting point characteristics that the model should fulfil, Figure 1 combines the phases and/or components that are typically part of Data science, DIKW+E pyramid and Models. The combination of the three disciplines has been used to define the characteristics that GRETA model should fulfil and has been useful to understand the content that has to be developed in order to build a proper model.

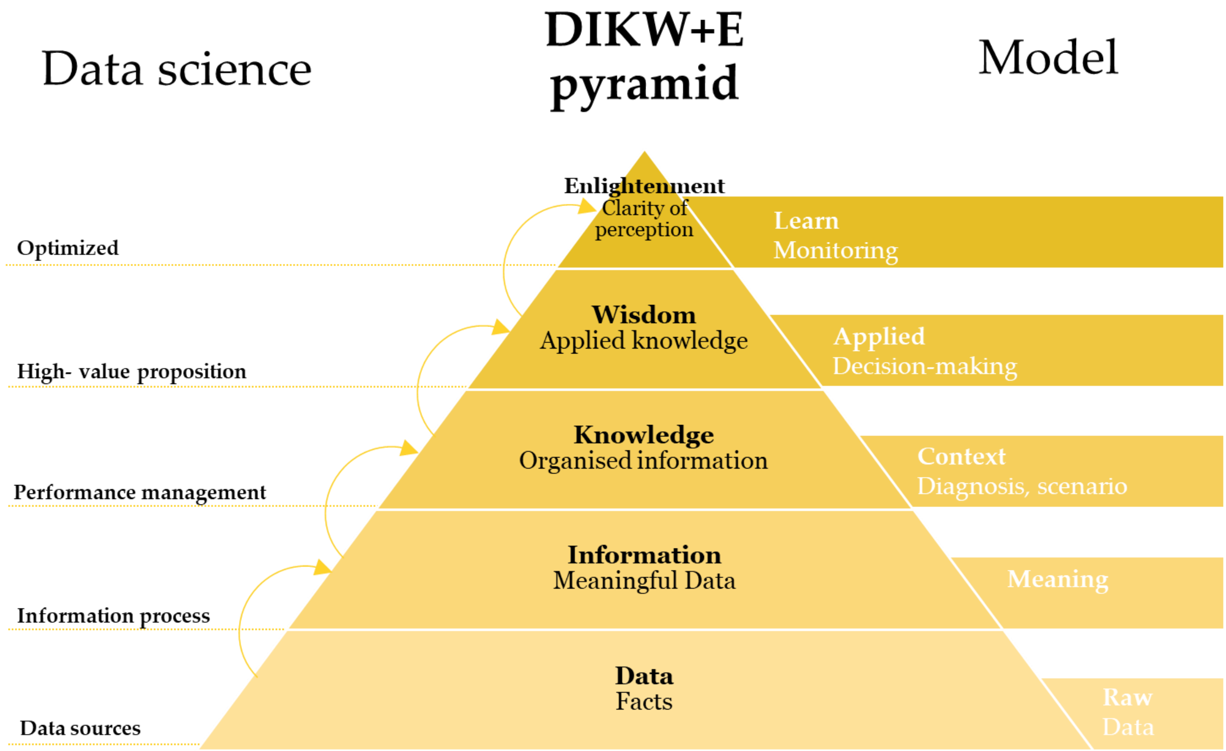

Figure 1 Relationship between data science, DIKW pyramid and GRETA Model. Source: own elaboration.

The first issue that has to be defined is: who is going to be **the user of the model**. The intended use of the information about energy citizenship emergence is what defines the user of the model.

The idea is that the user of the model will utilize the results for **decision-making purpose**s (wisdom in Figure 1) supported with the knowledge provided by the simplification of the reality generated by the model and based on meaningful data.

Decision making could be done for different purposes. For example, a user with a business profile could be interested in understanding where it could be more successful to invest in energy transition actions considering the willingness of the citizens for this kind of change (capacity for reception). Moreover, it would be even more interested if technically, politically, etc., the implementation is more feasible. A politician could have similar reasons: identifying where will be more feasible the social acceptance of actions implementation.

On the other hand, a citizen could be also a user of this kind of information. For example, as by itself is an energy citizen and wants to identify where their actions could be seconded by the neighbourhoods. So, they can use this information to decide where to live.

Table 3: Potential user profiles and preferences

Profile	Potential interest	Focus
Academia / technician	Knowledge creation	Technical feasibility, social acceptance
Politician	Decision support to develop plans, promote investments, etc.	Technical feasibility, social acceptance
Business	Decision support to do investments.	Technical feasibility, social acceptance, business opportunities
Citizen	Representativeness	Behaviour

Considering that GRETA modelling framework aims to identify where Energy Citizenship is more likely to emerge, the members of the **academia/technicians and politicians** will be the main target users of the model. For the interrelations, three different actor groups will be considered: **citizens, business and policy makers** (more explanations in Section 3 Modelling Framework).

The interrelations between the agents will be determined according to the main components: technical, behaviour and other components (more explanations in Section 4 Energy citizenship analytical components).

Regarding the **scale**, T4.2 will start by defining the model at **local scale**. T4.3 and T4.4 will work at local scale as well to develop and test energy and non-energy models respectively. In next steps of the WP4, T4.6, finally, will elaborate on upscaling model components to the **regional, national and supranational levels**.

Taking into account these considerations, Section 3 Modelling Framework explains the approach adopted in GRETA to model the energy citizenship emergence.

3 Modelling Framework

The modelling framework in GRETA aims to analyse the willingness of citizens to take action in the energy transition. The actions that citizens can take to promote the energy transition vary, as it is described in section 5, and have to be analysed individually. Therefore, each energy citizenship action and the willingness of citizens to implement that action, is evaluated in a unique form.

This section explains the common methodological framework proposed to understand the probability of occurrence of energy citizenship actions and how to visualize it. As it is explained below, this probability varies over time due to changes and interactions between agents and conditioners.

The modelling framework is mathematically based on Lotka-Volterra equations. Originally, these equations were born in the context of ecology to explain the relationship between preys and predators and how they interact. Afterwards, the equations have been used in other fields like in the development planning of a new product to understand the interaction between a product (system technology) and the components and elements (component technologies) that are combined to form the product [8]. In the context of GRETA, Lotka-Volterra equations are used to represent the interactions between citizens, companies, and policy makers. When analysing an specific location, the interactions among the 3 agents are determined according to the technical, behaviour and other components situation. Lotka-Volterra equations were selected to be used for energy citizenship modelling purposes because they allow to consider the different perspectives and how they influence each other at the same level.

Based on Lotka-Volterra equations, section 3.1 explains the first version of mathematical approach adopted for energy citizenship emergence. It has to be noted that this approach it will be tested and further developed in next steps of the WP4. Moreover, section 3.2 explains how the results of the model will be visualized on GIS.

3.1 Lotka-Volterra equations

Here we describe the general mathematical approach to modelling the sustainable behaviours and interactions of the various actor types, which we write as $\Psi_n(t)$, where t is the time, and n is the actor index (corresponding to citizens, companies, and policymakers). The behaviour $\Psi_n(t)$ is a generalized action towards sustainability. For solar panels, that would be purchasing them for citizens, subsidizing/promoting them for policy makers, and producing them for companies. For other sustainability topics, such as electric vehicles, similar behaviours apply.

The general equation for these behaviours is:

$$\frac{d\Psi_n(t)}{dt} = \Psi_n(t)\Gamma_n(t)$$

Where $\Gamma_n(t)$ is a function of all the behaviours $\Psi_n(t)$ of all stakeholder types. This is essentially saying that the way the behaviour of an actor changes with time is influenced by the behaviours of all other actors (including themselves). What happens is the following: the actions of all stakeholder types impact objective elements (example: subsidies from policy makers, strategic decisions from manufacturers, and purchases from citizens all have an impact on the purchase prices of devices). These objective elements influence the subsequent actions of stakeholders. This influence happens in various manners, depending on the objective element, the action, and the stakeholder. This takes into account the subjective manner in which the stakeholder process objective information. In other words, the $\Gamma_n(t)$ functions tell us how the stakeholders subjectively process objective facts/information that are influenced by their own actions and those of other stakeholders and thus combines the objective factors of energy citizenship actions (see Chapter 7) and the way stakeholders subjectively process them (which we will need to determine in order to perform the modelling).

Determining these elements will be key to this research and will require identifying the right behavioural factors, as explained below in this section and in the behaviour analytical components section below. Note that the behaviours in $\Gamma_n(t)$ can be evaluated at a prior time than t (at least in principle), reflecting the fact that the actor might react to other actors (including its peers) with a time delay. Note that the reaction to its own behaviour is in the $\Psi_n(t)$ factor in front of $\Gamma_n(t)$ and has no time delay. This is also schematically illustrated in Figure 2.

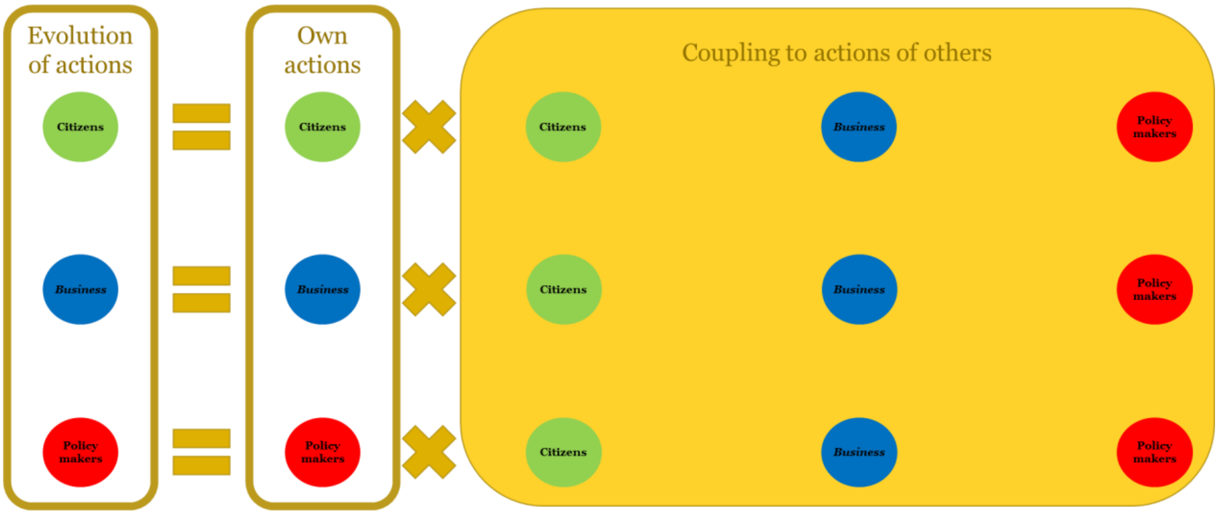

Figure 2 Schematic view of action coupling

We rewrite $\Gamma_n(t)$ as:

$$\Gamma_n(t) = \Phi_n(t)\Lambda_n(t)$$

Where $\Phi_n(t)$ is a product of agency factors and $\Lambda_n(t)$ is a weighted sum of decision factors.

$$\Phi_n(t) = \prod_{j_n=1}^{k_n} \varphi_{j_n}(t)$$

$$\Lambda_{\mathrm{n}}(\mathrm{t}) = \sum_{l_n=1}^{m_n} \omega_{l_n}\lambda_{l_n}(t)$$

We did this to reflect that the behaviour of an actor is determined by two types of elements:

1) Agency/practicality: These multiply each other, as not being able to afford a device or not having the right personnel to build the devices will prevent an actor from acting.
2) Choice/decision: This reflects that some elements are balanced against each other (for example extra cost versus personal benefits such as ease of use and comfort).

Note the $\varphi_{\mathrm{j_n}}(\mathrm{t})$ and $\lambda_{l_n}(t)$ coefficients are a combination of objective elements (such as price, market share, infrastructure status, etc.) and of subjective ways the stakeholders are processing them, in the same way explained above for $\Gamma_{\mathrm{n}}(t)$. The former objective elements are listed and explained in Chapter 7.

We expand the practical and decision factors with respect to small couplings to the attitude functions: $\Psi_1(t-\delta_{n_1}), \Psi_2(t-\delta_{n_2}), \Psi_3(t-\delta_{n_3})$ (the δ_n factors represent the time delay for the actor to react to the behaviours of other actors:

$$\varphi_{\mathrm{j_n}}(\mathrm{t}) \approx K_{j_n} + \nu_{j_n,1}\Psi_1(t-\delta_{n_1}) + \nu_{j_n,2}\Psi_2(t-\delta_{n_2}) + \nu_{j_n,3}\Psi_3(t-\delta_{n_3})$$

$$\lambda_{\mathrm{l_n}}(\mathrm{t}) \approx C_{l_n} + \eta_{l_n,1}\Psi_1(t-\delta_{n_1}) + \eta_{l_n,2}\Psi_2(t-\delta_{n_2}) + \eta_{l_n,3}\Psi_3(t-\delta_{n_3})$$

meaning that we neglect all the terms of order 2 and higher in these coupling coefficients. In other words, we look at the case where the impact of other actors is relatively weak and only look at first-order effects. This linearization is also schematically shown in Figure 3

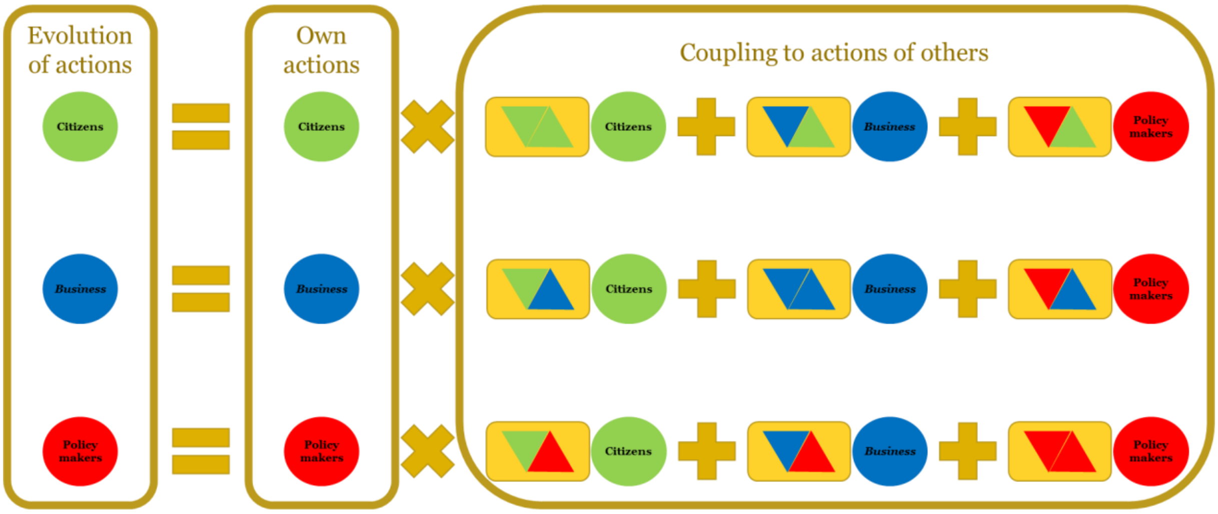

Figure 3 Linearising the coupling to actions of others

Using these forms and once again neglecting terms of order 2 and above means that $\Gamma_n(t)$ has the following form:

Equation 1

$$\Gamma_n(t) \approx \mu_{n_0} + \mu_{n_1}\Psi_1(t-\delta_{n_1}) + \mu_{n_2}\Psi_2(t-\delta_{n_2}) + \mu_{n_3}\Psi_3(t-\delta_3),$$

Where the μ_n factors are a grouping of the other factors that remain after we only keep first-order values.

This means that the equations for the attitudes of the three stakeholder types have the form:

$$\frac{d\Psi_1(t)}{dt} = \Psi_1(t)\left(\mu_{1_0} + \mu_{1_1}\Psi_1(t-\delta_{1_1}) + \mu_{1_2}\Psi_2(t-\delta_{1_2}) + \mu_{1_3}\Psi_3(t-\delta_{1_3})\right)$$

$$\frac{d\Psi_2(t)}{dt} = \Psi_2(t)\left(\mu_{2_0} + \mu_{2_1}\Psi_1(t-\delta_{2_1}) + \mu_{2_2}\Psi_2(t-\delta_{2_2}) + \mu_{2_3}\Psi_3(t-\delta_{2_3})\right)$$

$$\frac{d\Psi_3(t)}{dt} = \Psi_3(t)\left(\mu_{3_0} + \mu_{3_1}\Psi_1(t-\delta_{3_1}) + \mu_{3_2}\Psi_2(t-\delta_{3_2}) + \mu_{3_3}\Psi_3(t-\delta_{3_3})\right)$$

Those equations are three elements Lotka-Volterra equations with time delays.

The idea here is to perform a stability analysis that is typical of Lotka-Volterra equations, as illustrated below for a system of predators, preys, and resources.

If we look at the long-term (i.e. some time after the initial conditions) populations of predators, preys, and resources (food that can be eaten by both predators and preys), we have essentially two possible outcomes illustrated in Figure 4 and Figure 5: We can either have a situation where the populations stabilize (with possible small fluctuations), or we can have a boom-and-bust cycle where a fast growth in resources triggers a fast growth in preys, which in turn triggers a fast growth in predators, which then leads to a collapse of the former two, and then the predators themselves. The cycle then starts again. Similar patterns could occur for our analysis, with either a stable growth situation or a boom-and-bust cycle.

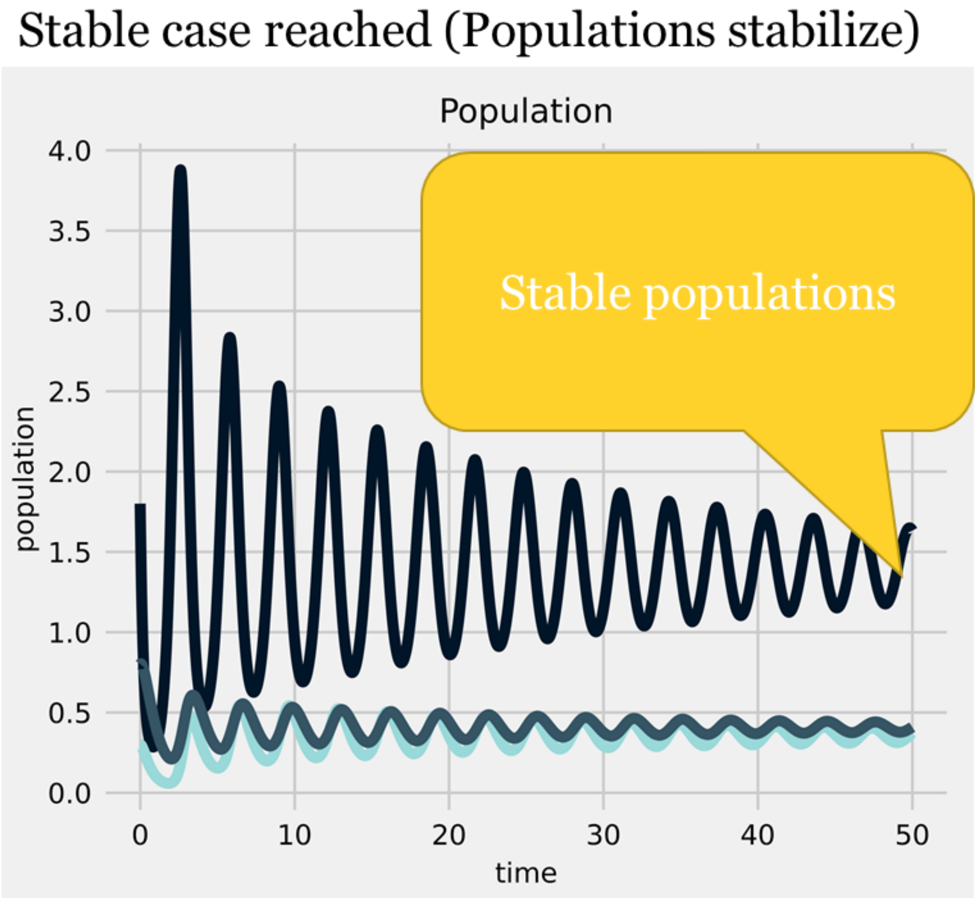

Figure 4 Stable predator-prey-resources

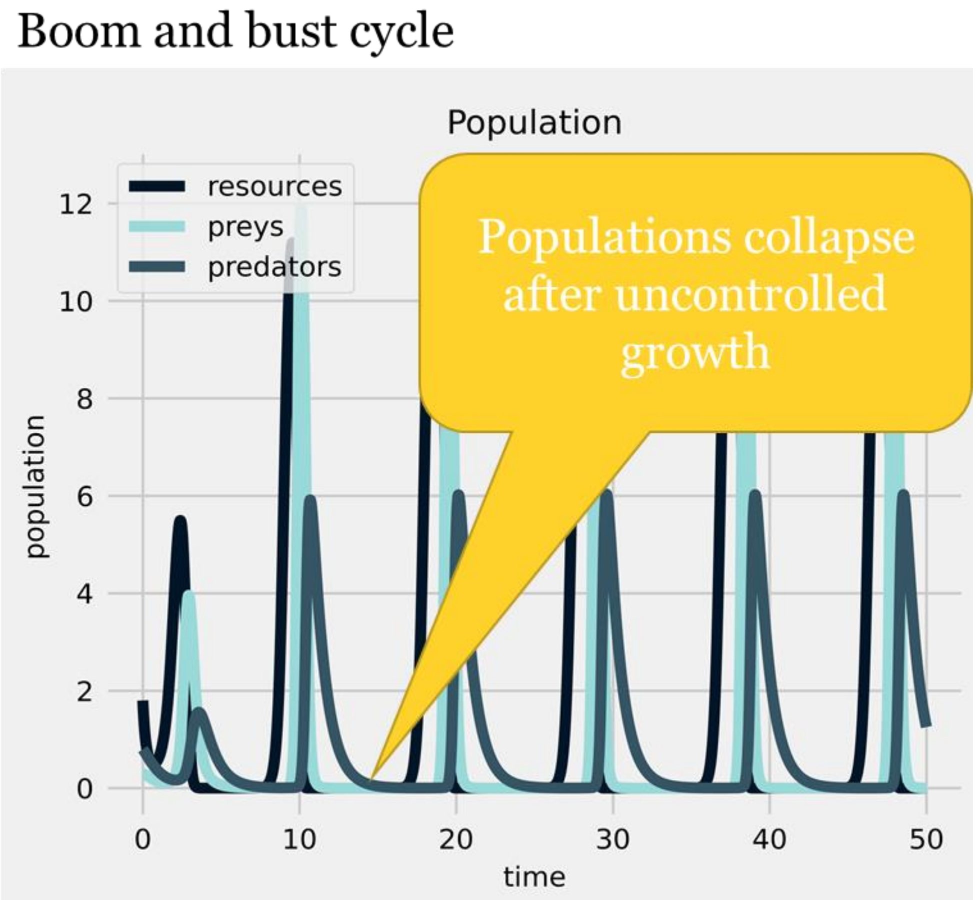

Figure 5 Unstable predator-prey-resources

The typical main analysis of a system described by Lotka-Volterra equation is a stability analysis, where we vary some parameters (typically two) and look if changes to these parameters make us switch from a stable to a boom-and-bust situation. Figure 6 shows this for a variation of two parameters: competition between predators and prey loss, displaying zones where the parameter values combinations lead to a stable situation (dark blue) or a boom-bust one (in light blue).

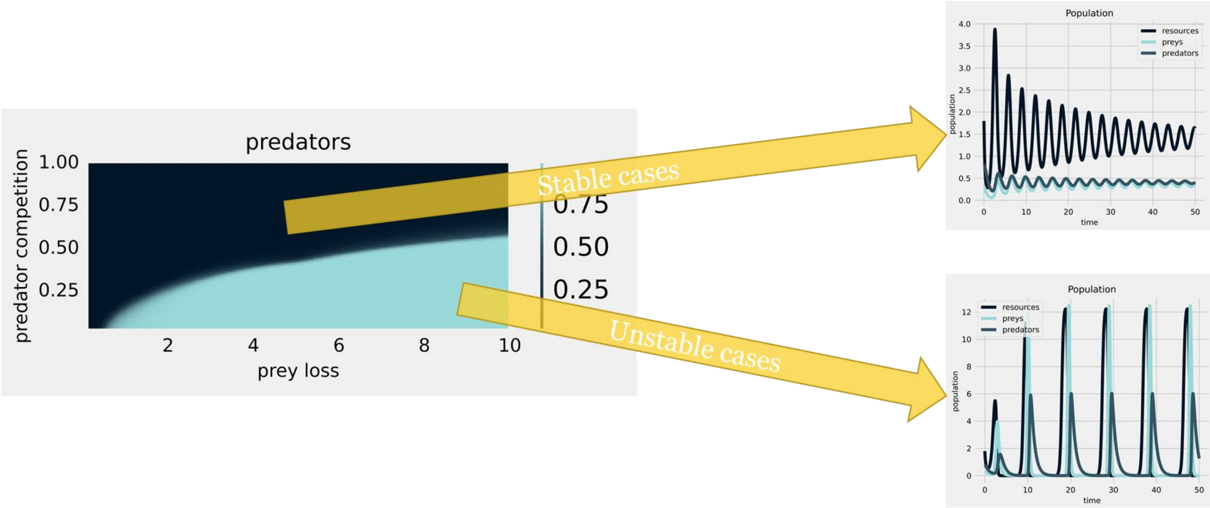

Figure 6 Lotka-Volterra stability analysis

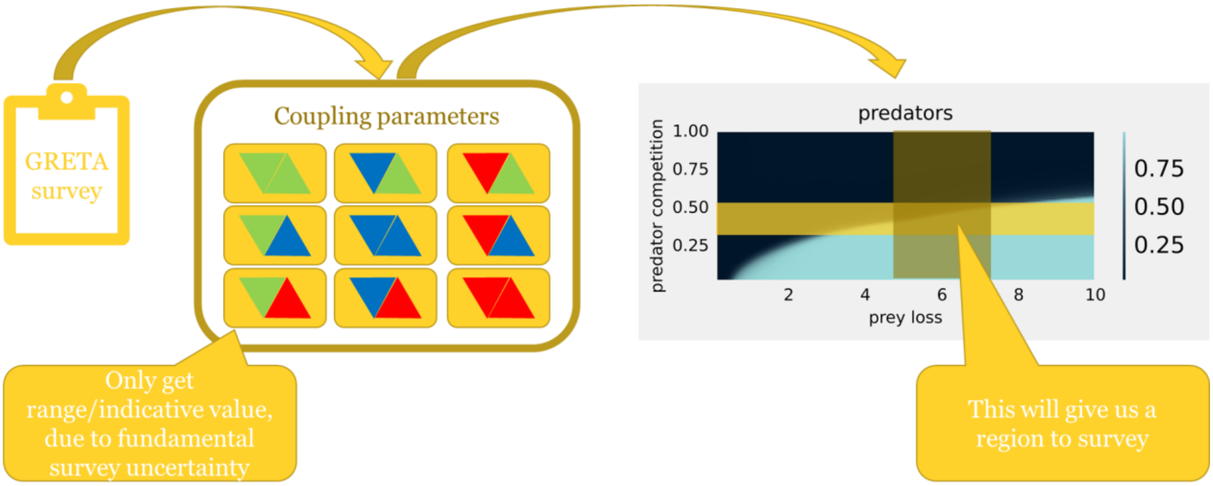

Figure 7 From survey to stability analysis

This actually connects well with the uncertainty inherent to using a survey in GRETA. Behavioral factors are inherently difficult to quantify precisely, especially if based on a survey/self-reported elements. It is however generally possible to deduce an order of magnitude/range value of the parameters. We can then use this to guide us on how to determine the parameter zones we want to explore and see if any of these result in a switch from a stable to a boom-and-bust situation, which would draw attention to elements that can be addressed to ensure that sustainable solutions/behaviors are adopted optimally.

3.2 Results visualization

In conjunction with tasks 4.6 and 5.2, the output of the modelling approaches in WP4 is used for further spatial analysis. This speaks to the taxonomy developed in task 5.1 and the categorization of different geographical levels. To prepare and comprehensively process this data, we follow the "GISualization" framework proposed by Adelfio et al. (2019) [9]). The multi-layer framework was developed to adaptively and iteratively manage complex data integration tasks in mixed-method approaches for "knowledge production in urban transformation processes" (p. 163). It is also described as a "collaborative communication platform" that supports the navigation between various data formats and methodological approaches and is therefore highly suitable for transdisciplinary projects like GRETA. It is furthermore suitable for stakeholder involvement and community participation. GIS-based visualization represents the core of the framework but is integrated with other additional methodological approaches. The WP4 modelling output represents crucial primary data which will be georeferenced and spatially harmonized in task 4.6 and transformed into input for the GIS tool in task 5.2.

What is needed to accomplish the goal of receiving georeferenced data are tools for georeferencing, which are implemented as part of Geographic Information Systems (GIS). GIS relates to a framework and software solutions to process, analyze, and visualize geospatial data. One of the essential steps to get georeferenced data is the exploitation of geocoding, i.e., the conversion of indirect spatial identifiers (e.g., a location name) to geocoordinates. Given the geographical resolution of the multi-national survey and considering the subsequent modelling output from WP4, we expect regional and national unit of analysis. Therefore, aggregation of output data to regional and national levels will be performed in T4.6. Once aggregated, we can apply the data integration and pre-processing workflow as laid out in section 4 of D5.2. This workflow performs several spatial linking steps of primary and secondary data and produces integrated datasets for the GIS-based tool. Based on these pre-processing steps, the visualization of the output will be performed in R.

Data visualization of geographic data poses a different challenge than ordinary data visualization. Geographic space is highly complex, subjective by nature, and inherently three-dimensional. In order to create informative and tangible maps, geodata needs a sensible projection, orientation, generalization, and map design. R packages can assist in an illustrative mapping process. First, and most importantly, the ggplot2 package provides various geographic mapping helpers and complete integration of spatial objects created by sf and stars. This package provides the baseline for all mapping (and general plotting) endeavors in R. It can be extended by several auxiliary packages, such as ggspatial and ggsn for adding spatial orientation (such as north arrows or scales), ggmap for spatial context (i. e., base maps), ggrepel for readable place annotations, or packages like classInt, RColorBrewer and viridis for designing insightful symbologies. The packages tmap, chloroplethr, cartography, and its successor mapsf are mapping frameworks based on ggplot2, but incorporate cartographic design principles in a more intuitive workflow. While these approaches work well for presenting static maps, e.g., for reports, the goal of T5.2 is to develop a GIS-based tool that requires more interactive types of visualization. For this purpose, the packages leaflet and plotly interface the identically-named JavaScript libraries to create interactive maps for web visualizations. Usually, to create interactive illustrations, an entirely different skill set is required. The leaflet and plotly packages are entirely integrated into R and need no knowledge of JavaScript. Interactive maps are (web) applications that depict dynamic geometries or raster grids on a base map. Users can pan and zoom on the map and select and manipulate geometries. Roth (2013) argues that interactivity promotes the visual thinking of exploratory and analytical science [10]. While static maps are simplified based on the author's subjective perception of what is important, interactive maps allow users to freely explore a thematic and effectively remove cartographic generalizations and geographic boundaries. Perdana et al. (2018) and de Mendonça et al. (2012) show that interaction in spatial data visualization improves the explorative and analytical performance of professionals and policymakers [11] [12].

4 Energy citizenship analytical components

This section explains the dynamic features of energy citizenship. These dynamic features have been called **energy citizenship analytical components** and will allow to reflect the engagement and interaction modalities.

In early stages of the modelling framework definition, six different analytical components were considered to be part of the energy citizenship modelling framework (Figure 8).

Figure 8 Potential energy citizenship analytical components

- **Technical**: taking part in energy transition needs to be technically feasible. The technical status will be determined by components like the renewable resource availability, existence of suitable infrastructure, etc.
- **Behaviour**: Citizens behaviour will strongly affect the participation of citizens in energy transition.
- **Social**: Social status (I.e., income, employment/occupation, and education) is strongly influenced by income and comes with mostly positive impact on environment. However, higher the wealth the more likely to have a high energy impact. Moreover, for example, neighbourhood satisfaction, health, and gender have been significant factors when defining subjective social status.
- **Economic**: Energy citizenship can be promoted economically in 2 different ways. On one hand, the energy prices (electric and thermal) and the technology prices. On the other hand, the existence of fundings will contribute to take action in energy transition.
- **Legal/regulatory**: a suitable legal/regulatory framework and economic policies will contribute to economic growth and green transition.
- **Environmental**: For example, small environmentally friendly actions, such as, turning off the lights, filling the dishwasher/washing machine full before starting it, driving

slower/more economically or utilizing public transport, or larger actions such as decisions not to travel by plane anymore.

When it comes to analyse the willingness to act, the analytical components are analysed through a combination of factors. As mentioned in the Lotka-Volterra modelling section 3.1, the factors that define the equations are divided into practical/capability ones (barriers that multiply each other), and choice/decision ones (a weighted sum). Technical components are practical/capability factors while behaviour and other factors, like social or economical factors, can be either practical/capability and/or choice/decision ones. This is further explained in the sections below.

3) Agency/practicality: These multiply each other, as not being able to afford a device or not having the right personnel to build the devices will prevent an actor from acting.
4) Choice/decision: This reflects that some elements are balanced against each other (for example extra cost versus personal benefits such as ease of use and comfort).

Energy citizenship analytical components have been divided in three main groups: 1) Technical components (explained in section 4.1); 2) Behaviour components (explained in section 4.2); and 3) Other components (explained in section 4.3).

4.1 Technical analytical components

Technical components define the technical feasibility of acting. The willingness of citizens to put in place actions that promote the energy transition will depend on how easy or difficult is acting. For example, suitable technology, renewable resources, etc., must be available to facilitate a citizen that wants to be energy self-sufficient and wants to base its energy generation in renewables. On the other hand, even if a citizen wants to act to promote the energy transition, the lack of technical resources would prevent the citizen from acting.

Technical components are agency/practicality in Lotka-Volterra equations since they multiply each other. The influence of technical issues over the citizens´ decisions about acting is analysed in GRETA through the factors that characterize four different technical components:

- **Space availability**: some energy citizenship actions will require the availability of space to be able to put them in place. For example, and as it is further described in Energy Citizenship Actions Catalogue, the action "To install solar panels in their homes", necessarily needs a suitable place to make the installation.
- **Renewable resources availability**: to make possible some energy citizenship actions; renewable resources must be available. Following with the previous example, to make an efficient solar panel installation, solar radiation at the installation place must be appropriate.
- **Other resources availability** (e.g., technology): beyond the renewable resources availability, other type of resources must be available to promote the energy citizenship. Following the example, suitable solar panels must be available to allow citizens deciding to make a solar installation. Other resources availability technical components are very closely

related to economical factors like the affordability of the technology and the income level of the citizens. This will be studied in other analytical components section.

- **Infrastructure existence**: the technical feasibility of putting in place several energy citizenship actions will depend on the presence of a suitable infrastructure. For example, if citizens want to use alternative modes of transportation to cars, a suitable bicycle and public transport network, walkability pathways, etc., must exist.

The factors that describe these four analytical components will define the technical feasibility of putting in place an energy citizenship actions. Regarding the agents involved in the components, in most of cases business agents will play an important role. For example, they are the providers of a suitable technology. Policy makers will play an important role as well, for example, by promoting the creation of a suitable clean mobility infrastructure when planning cities.

4.2 Behaviour analytical components

As mentioned in the Lotka-Volterra modelling section, the behavioural factors are divided into practical/capability ones (barriers that multiply each other), and choice/decision ones (a weighted sum), which we explain further below. During this explanation, we shall identify specific factors. These factors will be described in a general fashion. These will be described in a more specific way for each sustainable action in the energy citizenship actions catalogue (section 7).

The explanation/approach is an adaptation/variant of the CODEC model [13] [14], which was developed to model consumer purchasing decisions such as solar panels or electric vehicles. In this project, we will extend the underlying modelling to the other actors (companies and policy makers), as there are clear parallels to draw between the actors.

The CODEC model includes three phases: attention (Figure 9), enable (Figure 10) and intention (Figure 11), which correspond to the three elements that trigger a purchasing decision for a consumer/citizen (for companies, that would be producing devices/products, and for policy makers, that would be promoting/subsidizing them).

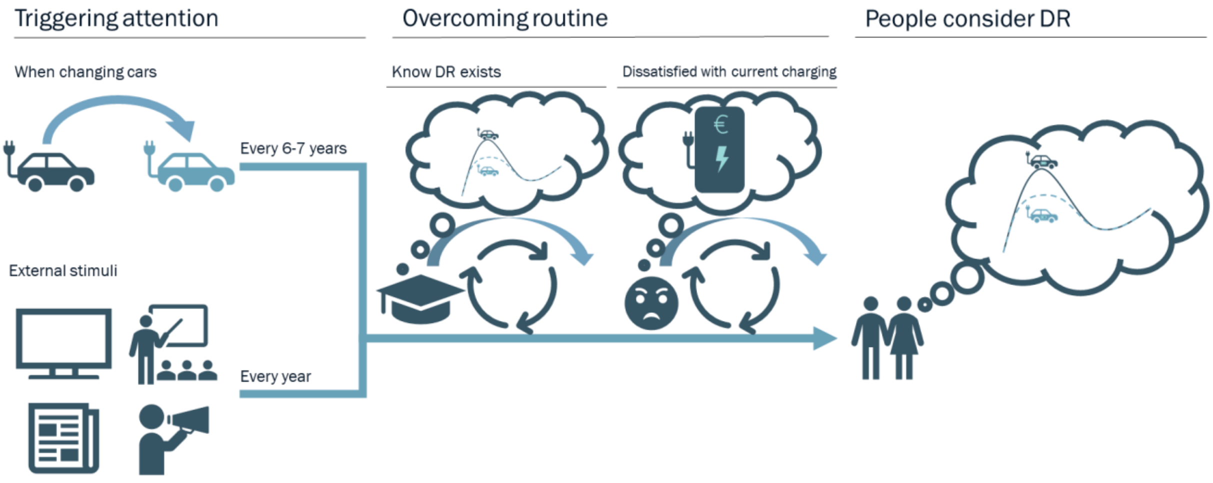

Figure 9 CODEC Attention for Demand Response (DR) charging of electric cars

The first phase (which we rolled out into the practical/capability group in the Lotka-Volterra modelling described above) is shown in Figure 9 (for the example of demand response, as the other illustrations throughout this section), is the Attention phase, which tells us if the actor is considering taking action. This is built as follows:

- First, the actor needs to be attentive. This is mostly driven by habits that occur at fixed intervals. This holds for all three actors: Consumers/citizens purchase devices/services at fixed intervals (as long as they are good enough or in relation to their contract length), companies have set times for retooling their production lines (for example, base elements of trucks are only replaced every ten years [15]). The timeline for policy makers is also driven by fixed elements such as elections, treaty deadlines, or conferences (such as the COP).
- While these intervals are relatively fixed, they can sometimes change through information campaigns or news items about sustainability (or the action itself).
- There is one extra step between this attention and considering an action: The actor needs to be aware that the product/service exists, and they also need to have some degree of unsatisfaction with their current product/service. Otherwise, they would just redo what they had done previously (repurchased, remade, or supported an existing product/service).

We group all these elements into one factor, which we call the habitual behaviour.

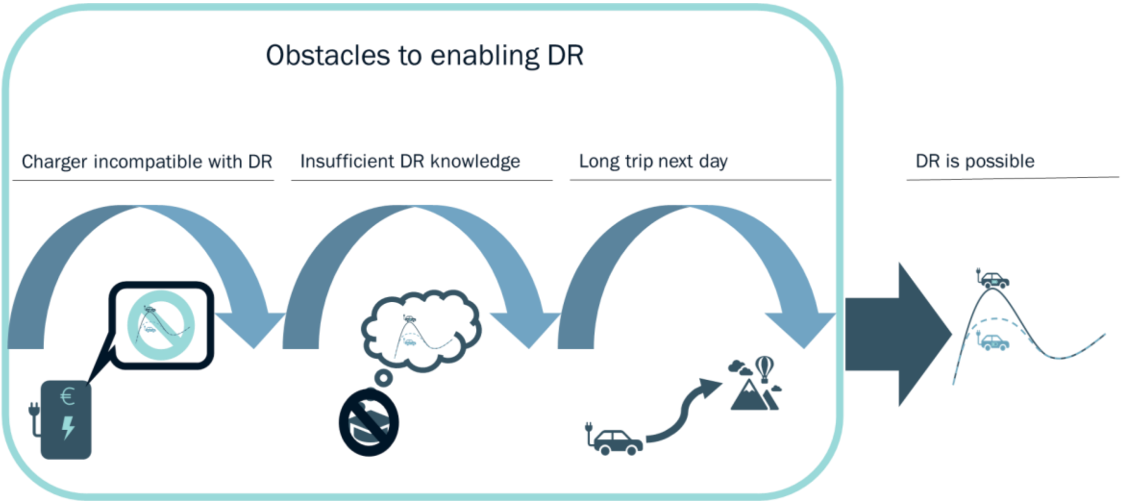

Figure 10 CODEC Enable

The following phase is the Enable phase, which means that the actor needs to be able to perform the action in question. Typical elements that fall under this are financial affordability, practical issues (being able to travel far enough with an electric vehicle, for example), knowing enough about and trusting the technology, and being capable of using the device/service (i.e., having the infrastructure and people to deliver it, having an own roof for solar panels, etc.).

Note that the practical issues are covered in the technical aspects (see above section).

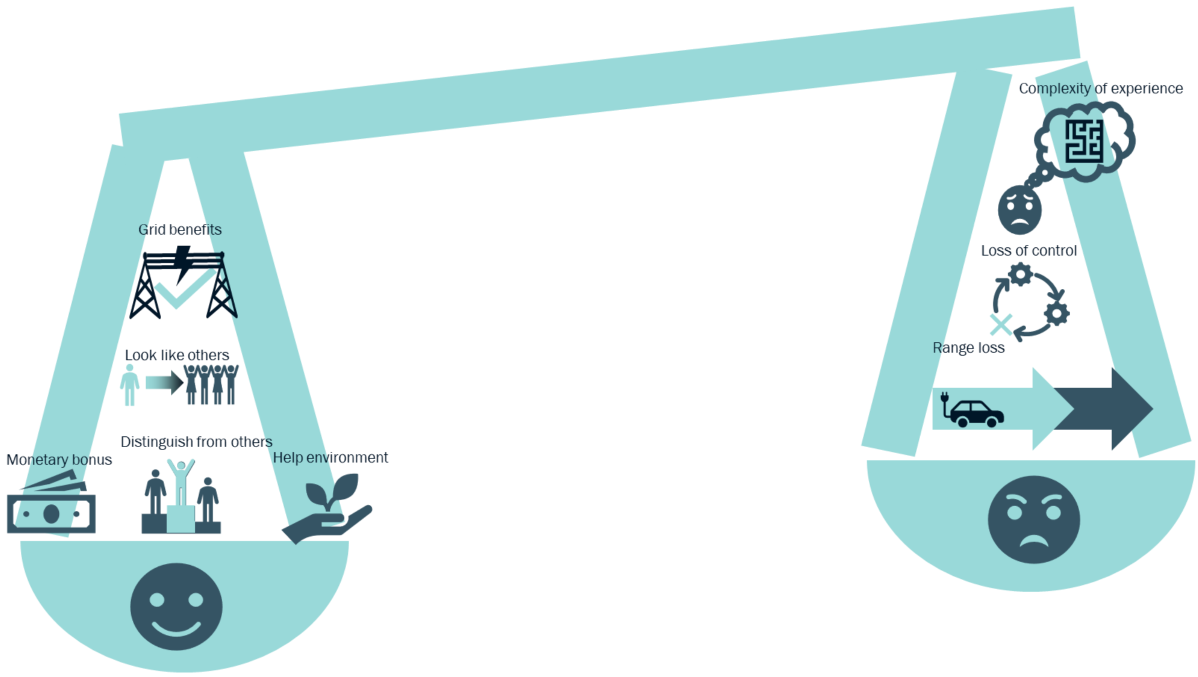

Figure 11 CODEC Intention

The last phase is the Intention phase (see Figure 11), where the actor weighs different elements against each other (i.e., gives them both a score and a weight, which they combine to compare the different options/possibilities they have). The typical elements that fall into this category are:

- Financial aspects (how much does the product cost to purchase/produce/subsidize). In some cases, we can look at investment/purchase costs and running/maintenance costs separately.
- Personal experience aspects such as comfort, ease of use, or good feelings/desire to be sustainable/what the action does for the environment.
- Distinguishing oneself from their peers, i.e., feeling special/being a pioneer.
- Following others/the norm.

In summary, we have the following possible elements as potential behavioral components/factors:

- **Habitual behaviour**, which describes a number of things, including the frequency at which the stakeholder performs the action (such as how often citizens purchase cars, how often manufacturers retool their production lines, or how often policy makers update laws), what they currently/usually do, and what could potentially make them deviate from a habit (such as what makes them dissatisfied).
- **Practical issues and capability** (covered in the technical aspects, see above), which include elements such as having the right space to install devices such as solar panels or electric vehicle chargers, having the right devices and knowledge among personnel to produce devices, having the right operating authorisations (e.g., being allowed to sell a product or a service), or having the authority and/or financial means of imposing policies/delivering subsidies.
- **Trust/knowledge technology**: This covers how much the stakeholders trust and know the action we are analysing (which is one of the elements the stakeholders react to), but also how much they trust/know each other (i.e., the factors that describe their reaction to a given situation).
- **Financial aspects** (both affordability and as a weighted decision factor), where we both need to know the objective information of how much things cost and how stakeholders react to prices. The latter includes elements such as which effective discount rates companies use, what their investment thresholds are, how a stakeholder balances investment/purchase costs and running/maintenance ones, as well as other effects, such as loss aversion.
- **Personal experience**: This covers use experience elements such as ease of use, driving pleasure, as well as elements such as internal feelings generated by performing the action and the resulting external image.
- **Distinguishing from others**: This is related to the fact that some people assign value to being different/a pioneer.
- **Following others**: This describes the fact that some people will purchase certain devices or products if and only if a certain proportion of their peers also do so.

As mentioned above, quantifying these aspects is difficult, especially if we rely on surveys, which are both noisy in terms of data and based on self-reporting. The latter is particularly crucial for social aspects, such as acknowledging the relative importance of doing something for the environment, financial aspects, and peer effects (distinguishing from others/following from others) which are prone to several biases such as social desirability. This will be faced in next steps of the WP4.

We will give a brief description of which ones apply to which citizenship action and what form they take in the energy citizenship actions catalogue chapter below.

4.3 Other analytical components

Aligned with Task 4.4 *Developing and testing non-energy related models at local level*, the identification of other analytical components that define the energy citizenship emergence is following a data-driven approach. This approach will allow the identification of those components/factors that, beyond technical and behavior components, are relevant to characterize energy citizenship emergence.

The data-driven approach, i.e., making decisions based on data analysis and interpretation, for finding patterns in data through clustering considers the collected GRETA data and complementary secondary data sources. The aim is to cluster and profile individuals and citizen groups based on the available GRETA data, i.e., creating the model based on the data (data-driven).. An important factor is the identification of the cluster-specific factors which provide information about the several types of groups as a whole and on the national/regional levels. This also applies to the determination of the other analytical components which will be part of the framework. These components include the following:

- **Social components:** Age, income, education, employment, gender, number of family members, wellbeing, energy justice, wellbeing, inclusivity.
- **Environmental components:** lifestyle, environmentally friendly actions (unplugging unused devices, turning off lights, not flying, walking, using public transport, participate in carpooling, etc.), heat/electricity load/saving, recycling, environmental awareness/consciousness, own assessment of environmental friendliness, climate change mitigation.
- **Regulatory components:** regulations, laws, taxes, policies, incentives.
- **Other components:** energy literacy/information literacy, energy knowledge, social networks, social activities, communities, outlook, political components.

The proposed data-driven approach visualized in Figure 12 includes; (1) GRETA data; (2) hierarchical clustering to form groups of similar energy citizens; (3) mapping of the clustering results/mapping the energy citizens into groups with different levels of engagement, such as, Forerunner, Unwilling, Indifferent [16]; (4) identifying the cluster-specific factors.

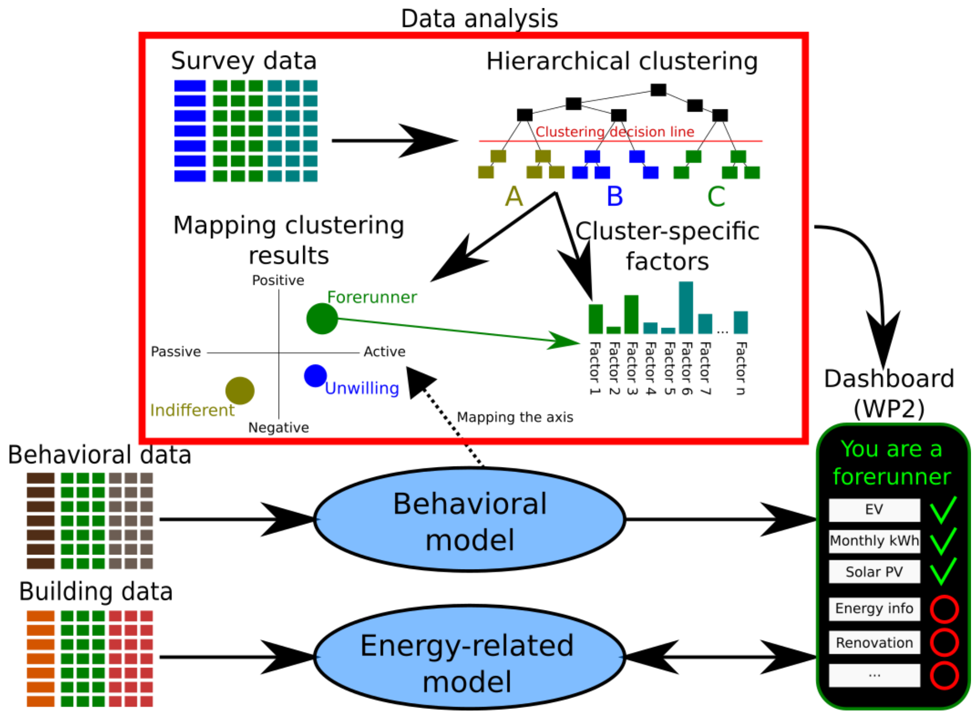

Figure 12 Data-driven model

First, the survey data is processed according to D4.1 [17]. In the second stage, the processed data is clustered with an explainable hierarchical clustering method, such as, Clustering of mixed-type data considering concept hierarchies (ClicoT) [18]. Utilizing explainable/interpretable clustering methods and statistical analysis allow the determination of the cluster-specific factors which can be used to determine the applicable components for energy citizenship actions. Moreover, the individuals are then mapped to positive/negative and passive/active axis according to their engagement levels [16]. Here the multinational survey includes questions that can be used to aid the mapping process. Furthermore, the mapping is learned by using answers to the subset of questions that were defined in D1.4 [19] identifying the citizens/communities' positive/negative stance or passive/active stance towards decarbonization and green transition.

It has to be noted that, the data-driven approach combined with the information from the behavioural and energy-related models will be used to form a user interface in WP2 *Information sensemaking and sharing within, between, and beyond energy communities* as well. For example, a dashboard that can be used by the stakeholders. Further development of the combined model allows individuals and communities to determine where they are situated in the green transition in relation to others, for example, by using energy personas (average energy citizens profiles locally/regionally/nationally).

5 Energy citizenship actions catalogue

The common modelling framework presented in section 3, it is adapted to each energy citizenship action in this section. Therefore, this section collects, classifies, and characterizes the actions that define an energy citizen. The energy citizenship action list has partially been defined according to different policy initiatives under the European Green Deal umbrella. The European Green Deal is a package of policy initiatives, which aims to set the EU on the path to a green transition, with the ultimate goal of reaching climate neutrality by 2050 [20].

1. Clean and Sustainable Mobility
2. Clean, affordable and secure energy
3. Circular economy action plan

These 3 initiatives have been transformed into action typologies and 2 more typologies have been added to organize the action list:

4. Sustainable consumers behaviour and diet habits
5. Sustainable habits and behaviour

The probability of occurrence of energy citizenship actions is evaluated in a specific way. This means that Lotka-Volterra equations are action-specific. The analytical components explained in section 4, characterize the actions and define the factors to be considered in Lotka-Volterra equations.

To facilitate the description of the energy citizenship actions calculation method, a catalogue is presented in the following sections. The description of the actions follows the template described in

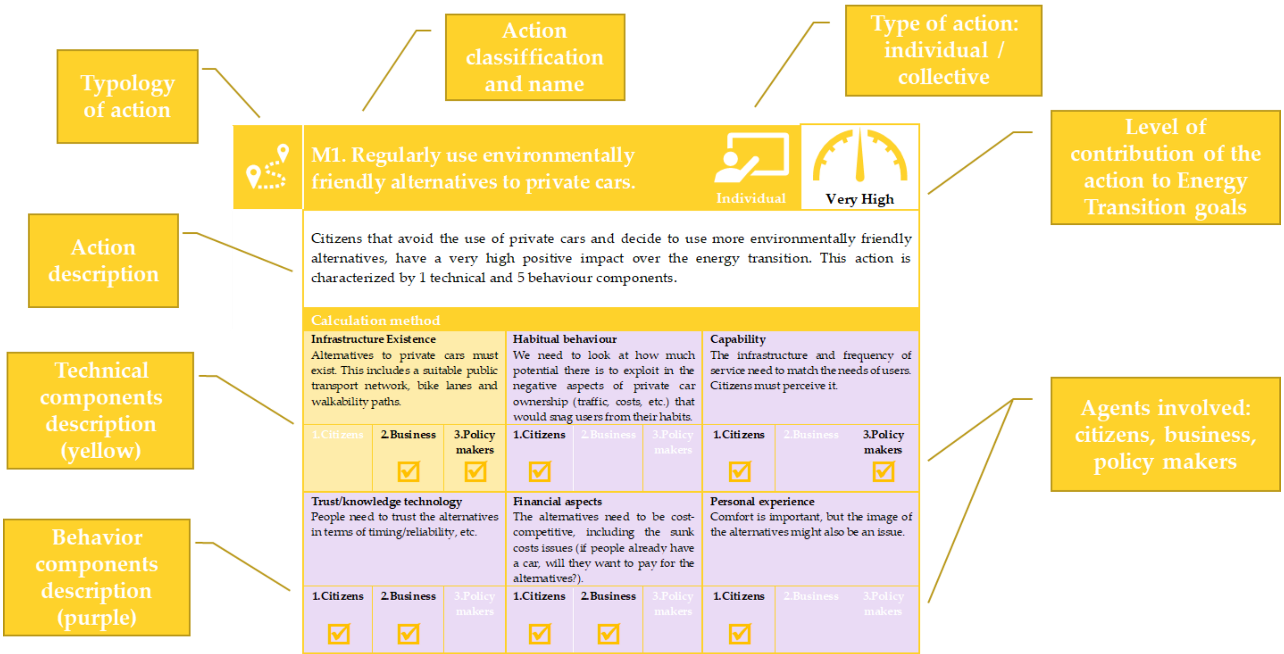

Figure 13. Each energy citizenship action has its own form.

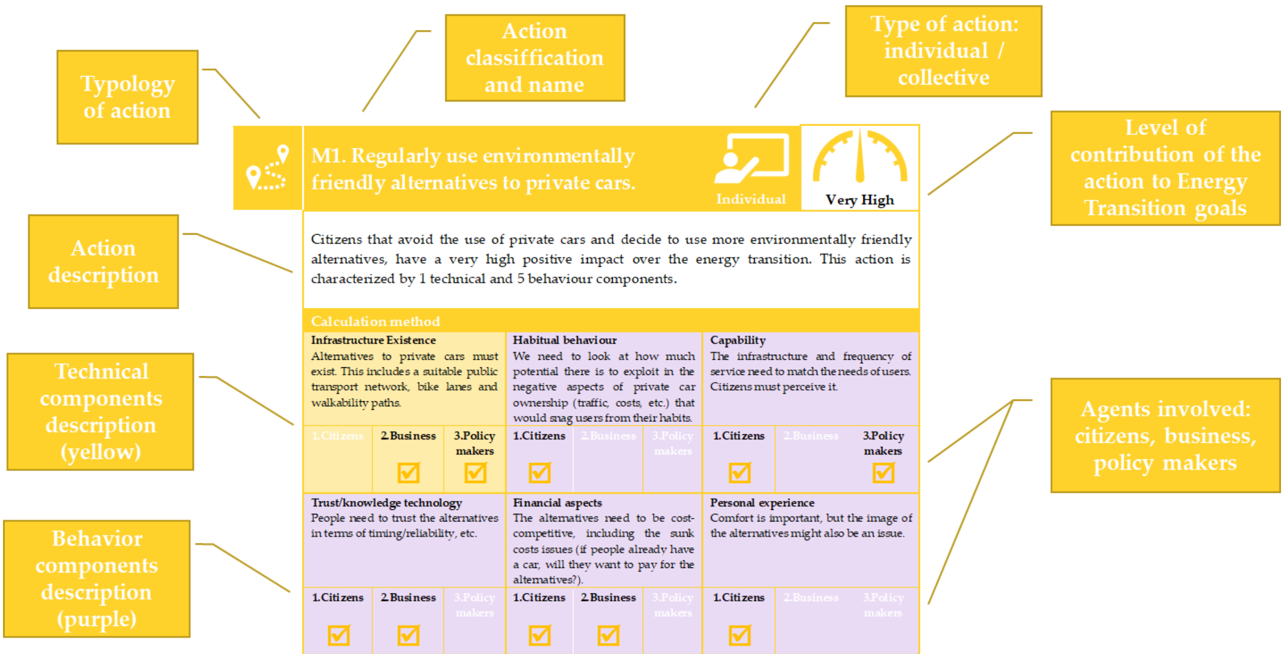

Figure 13 Energy citizenship action template

The action list comprises a total of 43 energy citizenship actions, divided by 1) Clean and sustainable mobility actions: 5; 2) Circular economy actions: 2; 3) Clean, affordable and secure energy: 10; 4) Sustainable consumers behaviour and diet habits: 5; 5) Sustainable habits and behaviour: 21. It has to be noted that actions under the umbrella of 5) Sustainable habits and behaviour have been listed but not fully characterize. As it will be described in section 5.5, these actions are mostly qualitative and have an indirect impact, making them more complex measuring the willingness of citizens to put them in place. Therefore, the template was applied to 22 energy citizenship actions.

The first version of the energy citizenship actions catalogue is presented in upcoming sections. It has to be noted that the catalogue includes technical and behaviour components, while other relevant components will be included once T4.4 is finished (expected to February 2023), as it is describe in section 6 Next steps.

5.1 Clean and Sustainable Mobility

The European Commission has pledged to become climate-neutral by 2050. To this end, the transport sector needs to undergo a transformation which will require a 90% reduction in greenhouse gas emissions, while ensuring affordable solutions to citizens [4]. Citizens play an important role in implementing clean and sustainable mobility solutions and can contribute strongly to achieve the objectives set by the European Commission.

Energy citizenship actions considered in GRETA under Clean and Sustainable Mobility are the following ones:

- M1. Regularly use environmentally friendly alternatives to private cars
- M2. Consider the Carbon Footprint of the transport when planning holiday and other longer distance travel and adapt their plans accordingly
- M3. Buy an electric car
- M4. Buy a new car and consider its low fuel consumption as an important factor in their choice
- M5. Participate in carpooling

Table 4: Action M1. Regularly use environmentally friendly alternatives to private cars

M1. Regularly use environmentally friendly alternatives to private cars.

Individual | Very High

Citizens that avoid the use of private cars and decide to use more environmentally friendly alternatives, have a very high positive impact over the energy transition. This action is characterized by 1 technical and 5 behaviour components.

Calculation method

Infrastructure Existence	Habitual behaviour	Capability
Alternatives to private cars must exist. This includes a suitable public transport network, bike lanes and walkability paths.	We need to look at how much potential there is to exploit in the negative aspects of private car ownership (traffic, costs, etc.) that would snag users from their habits.	The infrastructure and frequency of service need to match the needs of users. Citizens must perceive it.

1.Citizens	**2.Business** ☑	**3.Policy makers** ☑	**1.Citizens** ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	**3.Policy makers** ☑
Trust/knowledge technology People need to trust the alternatives in terms of timing/reliability, etc.			**Financial aspects** The alternatives need to be cost-competitive, including the sunk costs issues (if people already have a car, will they want to pay for the alternatives?).			**Personal experience** Comfort is important, but the image of the alternatives might also be an issue.		
1.Citizens ☑	**2.Business** ☑	3.Policy makers	**1.Citizens** ☑	**2.Business** ☑	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers

Table 5: Action M2. Consider the Carbon Footprint (CF) of the transport when planning holiday and other longer distance travel and adapt their plans accordingly

M2. Consider the CF of the transport when planning holiday and other longer distance travel and adapt their plans accordingly.

Individual

High

Citizens that plan the holidays or long-distance trips considering the carbon footprint of the transport have a positive impact. It includes flying less frequently, preferring trains over planes, chose to travel without car, plan holidays in closer destinations, etc. This action is characterized by 5 behaviour components.

Calculation method

Component	1.Citizens	2.Business	3.Policy makers
Habitual behaviour - People need to be more aware of the issues of their current choices (long queues at airports, hidden fees, need for travel to/from the airport, etc.) - They also need to know about the alternatives	☑		
Capability What is the degree of availability of the alternatives? How many people do they reach? Can these people reach their destinations? Can they bring everything they need? Can they do so fast enough?	☑		
Trust/knowledge technology Do people trust the alternatives to bring them to their destination without issues? Do they know about their existence (for the journeys they want)?	☑		
Financial aspects Are the alternatives cheaper? Both in terms of visible and invisible costs?	☑		
Personal experience Comfort aspects and ease of booking (such as the presence of a central point to book international routes)	☑		

Table 6: Action M3. Buy an electric car

M3. Buy an electric car.

Individual

Very High

Citizens that have to buy a car and decide buying an electric car instead a fuel-based car, have a very high positive impact over the energy transition. This action is characterized by 2 technical and 7 behaviour components.

Calculation method

Component	1.Citizens	2.Business	3.Policy makers
Technology availability (μ_{1_1}) Electric cars must be available at affordable price. Companies investing in creating, optimizing, and selling electric cars must exist. Policies encouraging the implementation of electric car will also contribute the implementation of electric cars in business.		☑	☑
Infrastructure Existence (μ_{1_2}) Charging points must exist or have to be planned at the sale point. Otherwise, more investments would be needed. Companies able to make the installations must exist. Policies can support the creation of Electric vehicle charging stations.		☑	☑
Habitual behaviour Buying frequency of cars, natural renewal times of production lines, dissatisfaction with gasoline cars.	☑	☑	
Capability Is the range enough? Do companies have the know-how to produce electric vehicles?	☑	☑	
Trust/knowledge technology Do people trust that they will find a charger when they need one?	☑		
Financial aspects Are the vehicles affordable in terms of purchase costs? Will the focus switch from purchase costs to Total Costs of Ownership	☑		
Personal experience Driving pleasure/experience, green image of electric vehicles	☑		
Distinguishing from others Until which point are electric vehicles a distinguishing factor?	☑	☑	
Following others At which point does it become wrong/abnormal to drive a gasoline car?	☑	☑	

Table 7: Action M4. Buy a new car and consider its low fuel consumption as an important factor in their choice

M4. Buy a new car and consider its low fuel consumption as an important factor in their choice.

Individual | High

Citizens that buy a new car and consider the low fuel consumption of it, have a high positive impact. It must be note, that this action and action M3 applied only for those cases where the citizens are obligated to buy a car. Action M3, related to buy an electric car, it is considered to have a higher positive impact than M4, as avoids the avoids the use of fossil based fuels. M4 is characterized by 1 technical and 5 behaviour components.

Calculation method

Technology availability Low fuel consumption cars must be available at affordable price. Companies offering this type of cars must exist.			**Habitual behaviour** How many people consider fuel consumption when buying a car?			**Capability** Do people have access to consumption information? And the resulting cost savings?		
1.Citizens	**2.Business** ☑	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers
Trust/knowledge technology How much do people trust the advertised consumption (which is the info they have)?			**Financial aspects** How much will people actually save? How will they perceive this?			**Personal experience** How do people feel about having a lower-consumption car?		
1.Citizens ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers

Table 8: Action M5. Participate in carpooling

M5. Participate in carpooling.

Collective

High

Citizens that use carpooling services instead private cars when public transport or other transport modes are not suitable for them, have a high positive impact over the energy transition. This action is characterized by 1 technical and 6 behaviour components.

Calculation method

Infrastructure Existence (μ_{1_1}) Carpooling network must exist. Private car sharing companies exist. Citizens can also promote the creation of them. Policy makers must allow regulatory framework that supports its existence.	**Habitual behaviour** Do people know about carpools available to them? What frustrations do they have with their current situation?	**Capability** Will everyone be able to participate? Will the density be enough so that everyone can participate? Will organising pools be easy?
1.Citizens ☑ · **2.Business** ☑ · 3.Policy makers	**1.Citizens** ☑ · 2.Business · 3.Policy makers	**1.Citizens** ☑ · 2.Business · 3.Policy makers
Trust/knowledge of others Will users trust others to be on time?	**Financial aspects** How much will people save by doing this?	**Personal experience** How will the different personas see carpooling? Will some see that as a positive (having a good time with a friend, for example)?
1.Citizens ☑ · 2.Business · 3.Policy makers	**1.Citizens** ☑ · 2.Business · 3.Policy makers	**1.Citizens** ☑ · 2.Business · 3.Policy makers
Following others At which point does it become a norm?		
1.Citizens ☑ · 2.Business · 3.Policy makers		

5.2 Sustainable and efficient energy generation and consumption

Consumers have an essential role to play in achieving the flexibility necessary to adapt the electricity system to variable and distributed renewable electricity generation (EU, 2019). Empowering and providing consumers with the tools to participate more in the energy market, will help to achieve the EU renewable energy targets and enable EU citizens to benefit from the internal market for electricity (EU, 2019) [2]. Moreover, citizens can take other type of actions that will contribute to increase the share of renewables, to reduce the energy consumption and make it more efficient.

Energy citizenship actions considered in GRETA under Sustainable and efficient energy consumption are the following ones:

- E1. Considering a lower energy consumption as an important factor in the choice when buying a new household appliance
- E2. Better insulate their homes to reduce their energy consumption
- E3. Have switched to an energy supplier which offers a greater share of energy from renewable resources
- E4. Be member of an energy cooperative
- E5. Participate in energy community
- E6. Have installed equipment in their home to control and reduce their energy consumption (e.g., smart meter)
- E7. Install solar panels in their homes
- E8. Buy a low-energy home
- E9. Battery storage
- E10. Save energy in everyday life

Table 9: Action E1. Considering a lower energy consumption as an important factor in the choice when buying a new household appliance

E1. Considering a lower energy consumption as an important factor in the choice when buying a new household appliance.	Individual	Very High

Household appliances consumption can represent between 14% and 30% of the total household energy consumption[1]. Choosing a lower energy consumption appliance when buying a new one will have a very high positive impact in energy consumption reduction. This action is characterized by 1 technical and 3 behaviour components.

Calculation method

Resource availability			**Habitual behaviour**			**Trust/knowledge of technology**		
Are energy-saving devices available for purchase? Do companies have the tooling/knowledge/people/production lines necessary to produce energy-saving appliances? What will be the norms for appliance consumption?			Do people take energy consumption into account in their purchases? Do companies communicate about the consumption of their devices? How?			Do people know how much devices consume, what the differences are, and how significant this is? Do they trust the labelled value? How do companies communicate the consumption of their devices? Do they used independent/trusted methodologies? What are the legal requirements about consumption labelling (and related methodologies)?		
1.Citizens	**2.Business**	**3.Policy makers**	**1.Citizens**	**2.Business**	3.Policy makers	**1.Citizens**	**2.Business**	**3.Policy makers**
☑	☑	☑	☑	☑		☑	☑	☑

Financial aspects		
How much will consumers save? How will that be communicated? How do people balance purchase vs use costs? How will businesses price their devices/trickle down savings? How will they communicate the financial aspects? Will laws require financial information of some kind (e.g. displaying savings)?		
1.Citizens	**2.Business**	**3.Policy makers**
☑	☑	☑

[1] 20% in Spanish households for the year 2010 https://www.idae.es/uploads/documentos/documentos_Informe_SPAHOUSEC_ACC_f68291a3.pdf

Table 10: Action E2. Better insulate their homes to reduce their energy consumption

E2. Better insulate their homes to reduce their energy consumption.

Individual

Very High

Improve the isolation at homes can reduce the heat and air conditioner energy consumption in a 40% as an average. Therefore, citizens living in old building stock that implement this action will have a very high positive impact over the energy transition. This action is characterized by 1 technical and 5 behaviour components.

Calculation method

Resource availability (μ_{1_1}) What are the available improvements? There are funds that support this kind of actions?			**Habitual behaviour** At which frequency do citizens do major repairs? Is it more often than when moving into a new home? How often do the isolation solutions change?			**Capability** Can the citizens's homes accommodate the proposed isolation solutions? Are there enough qualified installers to insulate homes?		
1.Citizens	**2.Business**	3.Policy makers	**1.Citizens**	**2.Business**	3.Policy makers	**1.Citizens**	**2.Business**	3.Policy makers
	☑		☑	☑		☑	☑	
Trust/knowledge of technology Will the citizens see/accept the impact of insulation?			**Financial aspects** How do citizens treat investment versus later savings? How will policymakers stimulate attention to TCO?			**Personal experience** Do citizens get the desired temperature level?		
1.Citizens	2.Business	3.Policy makers	**1.Citizens**	2.Business	**3.Policy makers**	**1.Citizens**	2.Business	3.Policy makers
☑			☑		☑	☑		

Table 11: Action E3. Have switched to an energy supplier which offers a greater share of energy from renewable resources

E3. Have switched to an energy supplier which offers a greater share of energy from renewable resources.

Individual

Medium

The share of renewables in the European countries electricity mix is being increased. Moreover, there are companies offering a greater share of energy from renewable resources. Citizens demanding this type of services contribute to the incrementation of them. This action is considered to have a medium impact over the energy transition. This action is characterized by 2 technical and 5 behaviour components.

Calculation method

Component	Description	1.Citizens	2.Business	3.Policy makers
Renewable resource availability	Renewable resources must be available, regulations must allow taking advantage of them and promoters of the technology must exist.	☑	☑	☑
Resource availability	Existence of energy suppliers.		☑	
Habitual behaviour	At which moments do citizens naturally look at changing their energy contracts? What incentives would work to accelerate this? What sign-up incentives will companies offer? What contract lengths do they offer? Rules about switching providers.	☑	☑	☑
Capability	What levels of renewables can they provide?		☑	
Trust/knowledge of technology	Do the providers have the capacity to provide the contracted percentages?		☑	
Trust/knowledge of others	How do consumers perceive the claims about renewable percentages?	☑		
Financial aspects	What is the price impact of higher renewables percentages?	☑	☑	

Table 12: Action E4. Be member of an energy cooperative

E4. Be member of an energy cooperative.

Individual

High

This action refers to citizens that join renewable energy cooperatives and contribute to the deployment of renewable based energy. The impact of this kind of actions it is considered to be high. This action is characterized by 1 technical and 8 behaviour components.

Calculation method

Resource availability The existence of renewable energy cooperatives will contribute to the emergence of this action. Suitable regulatory framework it is needed.			**Habitual behaviour** At which frequency do citizens consider joining similar services? What triggers this search?			**Capability** How many new members can be accommodated each year?		
1.Citizens	**2.Business**	**3.Policy makers**	**1.Citizens**	**2.Business**	**3.Policy makers**	**1.Citizens**	**2.Business**	**3.Policy makers**
	✓	✓	✓				✓	
Trust/knowledge of technology What kind of information do participants get? Can they easily process it?			**Trust/knowledge of others** How do the various citizen groups perceive energy cooperatives?			**Financial aspects** What will the financial costs and benefits be?		
1.Citizens	**2.Business**	**3.Policy makers**	**1.Citizens**	**2.Business**	**3.Policy makers**	**1.Citizens**	**2.Business**	**3.Policy makers**
✓			✓			✓		
Personal experience What will be the (non-financial) advantages and obligations they get?			**Distinguishing from others** What kind of citizens will use this as a social distinction?			**Following others** What kind of citizens will follow their peers?		
1.Citizens	**2.Business**	**3.Policy makers**	**1.Citizens**	**2.Business**	**3.Policy makers**	**1.Citizens**	**2.Business**	**3.Policy makers**
✓			✓			✓		

Table 13: Action E5. Participate in energy community

E5. Participate in energy community.

Collective

Very High

Being part of an energy community could imply putting in place one or several energy citizenship actions in a collective way. Because of that, the impact of this action could be very high. This action is characterized by 1 technical and 8 behaviour components.

Calculation method

Component	Description	1.Citizens	2.Business	3.Policy makers
Resource availability	Potential to put in place in an specific location several energy citizenship actions. Suitable regulatory framework.	✓	✓	✓
Habitual behaviour	At which frequency do citizens consider joining similar services? What triggers this search?	✓		
Capability	How many new members can be accommodated each year?		✓	
Trust/knowledge of technology	What kind of information do participants get? Can they easily process it?	✓		
Trust/knowledge of others	How do the various citizen groups perceive energy communities?	✓		
Financial aspects	What will the financial costs and benefits be?	✓		
Personal experience	What will be the (non-financial) advantages and obligations they get?	✓		
Distinguishing from others	What kind of citizens will use this as a social distinction?	✓		
Following others	What kind of citizens will follow their peers?	✓		

Table 14: Action E6. Have installed equipment in their home to control and reduce their energy consumption.

E6. Have installed equipment in their home to control and reduce their energy consumption.

Individual

High

Citizens that have installed equipment in their home to control and reduce their energy consumption (e.g., smart meter) and/or citizens that use of apps to track their energy consumption, contribute to the energy transition. This action is characterized by 1 technical and 5 behaviour components.

Calculation method

Infrastructure existence The existence of a suitable infrastructure must exist. Regulations allowing its deployment must exist as well.			**Habitual behaviour** At which moments do citizens install similar equipment?			**Capability** How easy is it to understand the output of such devices and to take actions reducing energy consumption?		
1.Citizens	**2.Business** ☑	**3.Policy makers** ☑	**1.Citizens** ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers
Trust/knowledge of technology Will users believe the energy-saving claims? What kind of claims will the providers make?			**Financial aspects** How much will the installation cost? How much will users save? How will they balance the two?			**Personal experience** Will citizens be able to keep their level of activities/comfort?		
1.Citizens ☑	**2.Business** ☑	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers

Table 15: Action E7. Install solar panels in their homes.

E7. Install solar panels in their homes.

Individual | Very high

Citizens deciding to install solar panels to produce and consume renewable energy will contribute in a very high way to energy transition. This action is characterized by 3 technical and 7 behaviour components.

Calculation method

Space availability
In order to make the installation, space must be available. Owners have to decide if they want to dedicate space for the installation.

1.Citizens	2.Business	3.Policy makers
☑		

Renewable resource availability
Even if space is available, it has to be suitable to make the installation. The production will depend on the radiation. Technology suppliers make the studies to determine if is worth it.

1.Citizens	2.Business	3.Policy makers
	☑	

Resource availability
Technology suppliers must be available at affordable price. Regulatory framework must be suitable as well.

1.Citizens	2.Business	3.Policy makers
	☑	

Habitual behaviour
At which frequency do home owners consider major upgrades to their homes?

1.Citizens	2.Business	3.Policy makers
☑		

Capability
Do home owners have access to an appropriate roof space (enough surface, right orientation)? Do businesses have enough employees to manufacture and install the solar panels?

1.Citizens	2.Business	3.Policy makers
☑	☑	

Trust/knowledge of technology
Do citizens trust solar panels to provide them enough electricity at the moments they need it?

1.Citizens	2.Business	3.Policy makers
☑		

Financial aspects
What is the payback time?

1.Citizens	2.Business	3.Policy makers
☑		

Personal experience
How do people feel about having solar panels? Do they change their consumption behaviour (e.g. charging their car when the suns shines)

1.Citizens	2.Business	3.Policy makers
☑		

Distinguishing from others
What kind of people will see solar panels as a way to distinguish themselves?

1.Citizens	2.Business	3.Policy makers
☑		

Following others
What kind of people will feel the obligation to follow others? When will that happen?

1.Citizens	2.Business	3.Policy makers
☑		

Table 16: Action E8. Buy a low-energy home.

E8. Buy a low-energy home.	Individual	High

Citizens taking into account the energy consumption of their homes as a criteria to buy them, have a high positive impact over the energy transition. This action is characterized by 1 technical and 4 behaviour components.

Calculation method

Component	Description	1.Citizens	2.Business	3.Policy makers
Infrastructure existence (μ_{1_1})	Low energy homes must be available at affordable price.		☑	
Habitual behaviour	At which frequency do people buy a new home? Do they habitually consider its energy consumption?	☑		
Capability	Will companies be able to provide enough such homes to cover demand?		☑	
Trust/knowledge of technology	Will home owners believe the low-energy claims?	☑		
Financial aspects	How will home owners balance the extra purchase costs and the lower energy costs?	☑		

Table 17: Action E9. Battery storage.

E9. Battery storage.

Individual

Medium

By storing the excess electricity produced for example, by solar panels, battery storage increases renewable energy self-consumption. As the battery has necessarily accompany renewable energy generation installation, this action by itself it is considered to have a medium positive impact over the energy transition. This action is characterized by 2 technical and 4 behaviour components.

Calculation method

Resource availability Technology providers must be available.			**Infrastructure existence (μ_{1_1})** Renewable energy installation must exist.			**Habitual behaviour** What is the frequency of purchase of similar reference devices (and what are these)?		
1.Citizens	**2.Business** ☑	3.Policy makers	**1.Citizens** ☑	**2.Business** ☑	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers
Capability How much of the extra production of solar panels can the battery absorb? How much can they provide during excess demand times?			**Trust/knowledge of technology** How will users perceive the batteries? Will there be usability issues?			**Financial aspects** How will users balance purchase costs versus electricity savings? What will the policy regarding metering be (in some cases, policies are such that batteries do not provide any financial savings).		
1.Citizens ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers	**1.Citizens** ☑	2.Business	**3.Policy makers** ☑

Table 18: Action E10. Save energy in everyday life.

E10. Save energy in everyday life.

Individual

High

There are different ways to reduce the energy use and save energy in everyday life. For example, actions like heat one's home less in winter and use air conditioning less in summer or turn off electrical appliances rather than put them on standby mode, have a high positive impact over the energy transition. This action is characterized by 7 behaviour components.

Calculation method

Component	1.Citizens	2.Business	3.Policy makers
Habitual behaviour What are the decision/action moments (and their frequency) energy saving actions could latch on?	☑		☑
Capability What level of control do users have on their devices?	☑	☑	
Trust/knowledge of technology What kind of feedback users get on the actions they would take?	☑	☑	
Financial aspects What kind of rewards do users get for performing the energy-saving actions?	☑		☑
Personal experience How complex is it to perform the actions? Do they lose any comfort?	☑		
Distinguishing from others Will there be ways for users to show off how great they preform (such as a ranking of best energy savers in a given group_?	☑		
Following others Will the users know what others do?	☑		☑

5.3 Circular economy

Decoupling economic growth from resource use and shifting to circular systems in production and consumption is key to achieving EU climate neutrality by 2050. Among the 30 action points on the circular economy action plan, there are actions to empower consumers and public buyers. Within those actions, 2 were selected to be part of the energy citizenship actions catalogue:

- W1. Tray to reduce the waste.
- W2. Regularly separate waste for recycling.

Table 19: Action W1. Try to reduce the waste

W1. Try to reduce the waste.

individual

High

4.8 tonnes of waste were generated per EU inhabitant in 2020 [21]. Reducing the amount of waste generated has a very high positive impact both over the waste management and transport needs and the generation of resources. Reducing the waste can be done in different ways, for example, trying to cut down on the consumption of disposable items or using items as much as possible. The action is defined according to 5 behaviour components as it is described below.

Calculation method

Habitual behaviour What are they key moments in waste disposal (getting waste into bins, and emptying these)?			**Capability** Do citizens know how they can reduce waste?			**Trust/knowledge of others** Will the users trust that new packaging actually reduces the general impact? Or will they think it's just hiding it elsewhere in the chain?		
1.Citizens ☑	2.Business	3.Policy makers	1.Citizens	**2.Business** ☑	**3.Policy makers** ☑	1.Citizens	**2.Business** ☑	3.Policy makers
Financial aspects Would citizens (or companies) get information about how much money they save by reducing waste?			**Personal experience** How easy is it to reduce waste/how much extra work does it cost? Will reduced packaging/avoiding disposable items still allow to keep the same user experience/product quality?					
1.Citizens	2.Business	**3.Policy makers** ☑	1.Citizens	**2.Business** ☑	3.Policy makers			

Table 20: Action W2. Regularly separate waste for recycling

W2. Regularly separate waste for recycling.

individual

Low

Contributing to facilitate waste recycling it is considered to have a low positive impact over the energy transition. The action is defined according to 1 technical and 5 behaviour components as it is defined below.

Calculation method

Infrastructure existence (μ_{1_1}) Adequate waste management system must exist.			**Habitual behaviour** What are they key moments in waste disposal (getting waste into bins, and emptying these)?			**Capability** Do people have separate bins at home? Are there recycling facilities nearby? How are these split? Is it clear how waste can be sorted (i.e. what goes where)?		
1.Citizens	**2.Business** ☑	**3.Policy makers** ☑	**1.Citizens** ☑	2.Business	3.Policy makers	**1.Citizens** ☑	**2.Business** ☑	**3.Policy makers** ☑
Trust/knowledge of others Do citizens believe their recycling actions will have an actual impact? Do they trust recycling will actually happen or do they see it as a scam?			**Personal experience** How easy is it to recycle/how much extra work does it cost?			**Financial aspects** Are there any financial incentives to recycle?		
1.Citizens	2.Business	**3.Policy makers** ☑	**1.Citizens** ☑	2.Business	**3.Policy makers** ☑	1.Citizens	2.Business	**3.Policy makers** ☑

5.4 Sustainable consumers behaviour and diet habits

Sustainable consumer behaviour is behaviour that attempts to satisfy present needs while simultaneously benefiting or limiting environmental impact [22]. In general terms, avoiding and reducing the consumption of goods and services will promote the reduction of environmental impacts. In GRETA context the actions under the sustainable consumers behaviour umbrella have been connected with sustainable diet habits. In total, 5 actions define the sustainable consumers behaviour and diet habits in GRETA:

- C1. Buy and eat more organic food
- C2. Buy and eat less meat
- C3. Consider the carbon footprint of the food purchases and sometimes adapt shopping accordingly
- C4. Buy local and seasonal food
- C5. Electricity consumption shifting according to peak renewable energy generation (or based on electricity spot price)

Table 21: Action C1. Buy and eat more organic food

C1. Buy and eat more organic food.	individual	Low

There are a lot of benefits over the environment and the health associated to follow a organic food based diet. However, when talking in energy terms, the impact of this action is positive but low. The action is defined according to 1 technical and 4 behaviour components as it is defined below.

Calculation method

Resources availability Organic food must be available at affordable price.			**Habitual behaviour** At what moment(s) do people make decisions about their groceries (e.g. at moment of purchase, when making a list, or on rare occasions, with the actual choice of products in a category set)			**Capability** Can the food suppliers produce the food according to organic requirements?		
1.Citizens	**2.Business** ☑	3.Policy makers	**1.Citizens** ☑	2.Business	3.Policy makers	1.Citizens	**2.Business** ☑	**3.Policy makers** ☑
Trust/knowledge of others How reliable/trusted are organic labels on food items?			**Financial aspects** How much more does organic food cost?					
1.Citizens	**2.Business** ☑	**3.Policy makers** ☑	**1.Citizens** ☑	**2.Business** ☑	3.Policy makers			

Table 22: Action C2. Buy and eat less meat

C2. Buy and eat less meat.

individual

Medium

Considering all the value chain, the production of meat has a bigger impact than the production of vegetables. Therefore, a plant-based diet has less impact than other type of diets. The action is defined according to 4 behaviour components.

Calculation method

Habitual behaviour At what moment(s) do people make decisions about their groceries (e.g. at moment of purchase, when making a list, or on rare occasions, with the actual choice of products in a category set)? How often do they eat out?			**Capability** Will food producers have the resources and knowledge to produce enough alternatives to satisfy consumer demand?			**Trust/knowledge of others** Will consumers trust the lower environmental impacts of meat alternatives?		
1.Citizens ☑	**2.Business** ☑	3.Policy makers	1.Citizens	**2.Business** ☑	3.Policy makers	1.Citizens	**2.Business** ☑	**3.Policy makers** ☑
Financial aspects How do the prices of alternatives compare to meat?								
1.Citizens ☑	**2.Business** ☑	3.Policy makers						

Table 23: Action C3. Consider the carbon footprint of the food purchases and sometimes adapt shopping accordingly

C3. Consider the carbon footprint of the food purchases and sometimes adapt shopping accordingly.

individual

Medium

This action can comprise other actions like buying and eating less meat and buying local (C2) and seasonal food (C4). It is considered that it can have a medium impact because it is not clearly defined that considering the carbon footprint is a criterion to make a choice, it is more related of being aware of it than to take action. It is defined by 5 behaviour components.

Calculation method

Habitual behaviour At what moment(s) do people make decisions about their groceries (e.g. at moment of purchase, when making a list, or on rare occasions, with the actual choice of products in a category set)?	**1.Citizens** ☑	2.Business	**3.Policy makers**
Capability How much information is available on packaging? How easy is it to understand?	1.Citizens	**2.Business** ☑	3.Policy makers
Trust/knowledge of others Will customers trust the accuracy of the provided information?	1.Citizens	**2.Business** ☑	**3.Policy makers** ☑
Financial aspects Will there be financial incentives related to reduced footprints?	1.Citizens	**2.Business** ☑	**3.Policy makers** ☑
Personal experience What kind of feeling will buyers associate to reducing their footprint? How tedious will they find looking at footprints?	**1.Citizens** ☑	2.Business	3.Policy makers

Table 24: Action C4. Buy local and seasonal food.

C4. Buy local and seasonal food.

individual

Very high

Mostly because of the reduction of transport needs, buying local and seasonal food has a very high positive impact on energy consumption reduction. It is defined by 5 behaviour components.

Calculation method

Component	1.Citizens	2.Business	3.Policy makers
Habitual behaviour Do people consider locality/seasonality in their habitual purchases? (The timing issue of other food actions also applies here)	☑		
Capability Can food providers supply local/seasonal foods that satisfy the needs and tastes of consumers?		☑	
Trust/knowledge of others Will consumers trust the locality/seasonality claims of food producers?	☑	☑	
Financial aspects How much more will local/seasonal products cost?	☑	☑	
Personal experience How important/big will be the feeling of eating local/seasonal foods? How much will people feel restricted by eating local/seasonal?	☑		☑

Table 25: Action C5. Electricity consumption shifting according to peak renewable energy generation (or based on electricity spot price)

C5. Electricity consumption shifting according to peak renewable energy generation.	individual	Very high
Trying to consume electricity at the peak moment of renewable generation will avoid the consumption of non-renewable energy. Therefore, this action has a very high contribution to energy transition goals. The action is defined according to 1 technical and 4 behaviour components as it is defined below.		

Calculation method

Component	Description	1.Citizens	2.Business	3.Policy makers
Infrastructure existence	This option does not exist in all the countries. The possibility of doing it must exist and citizens need to have real time information.		☑	☑
Habitual behaviour	When do consumers renew/change their energy consumption contracts? How receptive are they to news/information campaigns? Do people know about the possibility of shifting? Do they have issues with their current consumption?	☑	☑	☑
Capability	Are there enough supporting devices to enable consumption shifting? Will charge shifting restrict some activities (at certain moments)?		☑	
Trust/knowledge of others	Do users know enough about charge shifting and its consequences?	☑		☑
Financial aspects	What will be the incentives for shifting consumption?	☑		☑

5.5 Sustainable habits and behaviour

Beyond the sustainable consumer behaviour of citizens, the sustainable habits and behaviour comprises other type of actions that citizens can take to promote the energy transition. However, putting in place several of the following actions does not have a direct impact over the energy transition and the indirect impact is very difficult to measure. Therefore, even the following actions characterize an energy citizen won't be part of the modelling framework in GRETA at this stage of the project.

- S1. Talk with friends and family about the energy transition and encourage them to be more efficient.
- S2. Demonstrate against climate change and for climate justice
- S3. Engagement with energy policy in climate activist groups

- S4. Join forces to on-site renewable energy generation
- S5. Engagement in local energy projects
- S6. Belong to voluntary organisations in conservation, environment, ecology or animal rights
- S7. Signing a petition
- S8. Joining in boycotts
- S9. Attending lawful demonstrations
- S10. Joining unofficial strikes
- S11. Took part in a demonstration
- S12. Attended a political meeting or rally
- S13. Contacted, or attempted to contact, a politician or a civil servant to express your views
- S14. Donated money or raised funds for a social or political activity
- S15. Contacted or appeared in the media to express your views
- S16. Expressed political views on the internet
- S17. Do unpaid voluntary work through social movements or charities in the last 12 months
- S18. Petition your government to do more to tackle climate change
- S19. Take part in a protest or march related to tackling climate change
- S20. Invest your savings or your pension in green funds
- S21. Increasing energy literacy

In next steps of the WP4, it will be studied if measuring any of these actions could be possible and, therefore, if they have to be included in the catalogue.

6 Next steps

The Energy Citizenship Actions Catalogue presented in this deliverable is the first version of how to model each energy citizenship action. The catalogue will be alive until the end of the WP4 and the work carried out in Tasks 4.3 to 4.6 will serve both to enrich the catalogue and to validate/test the developments.

In the context of Task 4.3 *Developing and testing energy-related base models at local level*, the consideration of energy and technical factors is being validated according to their relevance to analyse the technical capability of the action for citizen emergence. Moreover, once the factors will be validated, the normalization of each of them will be done. The normalization process consists in defining the method that will allow the transformation of the factors into a range between 0 and 1.

On the other hand, Task 4.4 *Developing and testing non-energy-related base models at local level*, is following a data-driven approach to make the selection of other relevant components beyond the technical and the behavioural ones, as it is explained in section 4.3. Following a similar approach to T4.3, once the non-energy factors, meaning the behaviour and other factors, will be selected, the normalization of them will be done.

Remaining work to finalise the catalogue will be done in the context of T4.5 *Predictive modelling and scenario definition at local level* and, overall, in T4.6 *Developing and testing models and scenarios for spatial analysis at regional, national and supranational levels.* Firstly, Lotka-Volterra equations per energy citizenship action will be defined according to validated factors of the different disciplines. This will allow to update the catalogue and create a second version of it. Secondly, the energy citizenship actions related to at least one case study will be tested in a real application. The application of the method will allow to validate the proposal and to identify potential modification/adjustment needs.

As a result, WP4 *Data processing and explicit modelling* will provide a solid base of analysis to GRETA project. The models produced will be used to perform the analysis outlined in WP5, aimed at identifying where energy citizenship is more likely to emerge.

7 Conclusions

This deliverable has described the analytical and operationalization approach adopted for energy citizenship modelling and has collected and characterized a complete list of energy citizenship actions for modelling purposes.

According to the literature review conducted, there are a lot of references describing various types of models with different objectives and focused on different fields of interest for GRETA. However, there is no specific evidence for models which target the emergence of energy citizenship behaviour in a holistic way. The lack of precedents in energy citizenship modelling offers opportunities as well as risks to GRETA. An opportunity in terms of being able to design a genuine model considering the objectives of GRETA. A risk because there are no studies which can provide the basis for our proposal. Experts from different fields of knowledge have participated in the modelling framework definition, promoting the adoption of a transdisciplinary approach.

Adopting a transdisciplinary approach has been one of the main challenges of the modelling framework definition. Most of existing approaches are focused on one perspective and, in case they integrate other perspectives, those are included as complements (informative, different degree of consideration, indicators, etc.) and not at the same level of the assessment. The specific requirements of GRETA modelling have been answered by adopting an analytical approach based on Lotka-Volterra equations, which were originally created in ecology to explain the interactions between preys and predators. These equations have been applied more recently in other fields, like in the development planning of a new product to understand the interaction between a product (system technology) and the components and elements (component technologies) that are combined to form the product. Adopted approach allows to consider technical, behavioural, social, economical, etc., factors at the level of importance that the action requires.

When modelling, energy citizenship comprises a wide variability of actions that demand a certain treatment. The analytical components are specific for each action and, as a result, Lotka-Volterra equations that characterize each of energy citizenship action are particular.

The Energy citizenship Actions Catalogue presented in this deliverable allows to comprehensively capture the modelling framework. The catalogue will be further developed until the end of WP4 and contributes to the creation of a solid base for the project by providing the approach to model energy citizenship emergence.

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