SMARTEES: Deliverable 6.2

Report on the updated theoretical framework for social innovation diffusion

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Executive summary

The SMARTEES project has adopted a multidisciplinary approach to research social innovations, starting with desk research, qualitative interviews, workshops, and surveys, culminating in agent-based model simulations.

In this deliverable D6.2 Report on the updated theoretical framework for social innovation diffusion, we aimed to update the theoretical stances elaborated in previous deliverables in the light of the simulations results more recently elaborated.

In section one, we have resumed discussing the theoretical framework to social innovations outlined in D6.1 while referring to the SMARTEES project research findings outlined in previous deliverables.

We adopt a multi-level perspective of socio-technical system change, which places social innovations at the 'niche' level where innovative sociotechnical arrangements are implemented. We further the theoretical analysis of this multilevel perspective detailing the dynamics of actors at the niche level, which are centred on the stance that actors act under the influence of motivations, deriving from their needs, while choosing from several alternative actions based on perceived costs and benefits, whose appraisal is related with their resources and attitudes. These variables and their effects are exemplified by referring to findings gathered from SMARTEES cases research.

In section two, selected dimensions (variables) are chosen for measuring their effects on modelled citizens in selected SMARTEES cases. We focus on the simulated implementation of communication and participatory strategies to measure their effect on social acceptance of social innovations' interventions. Further, we examine whether demographic variables such as gender, education, ethnicity and socioeconomic status influence the outcome of households' decision to join social innovations' projects. While the findings discussed do not appear conclusive, yet we argue that they offer some support for the stance outlined in the theoretical framework adopted, which emphasises how citizens would relate to social innovations through a perception of costs and benefits, influenced by their resources, that would translate in opposition seemingly perceived high-cost situations.

We conclude this deliverable with epistemological and methodological considerations highlighting the potential, the challenges, and the limits of agent-based modelling to contribute towards theories of social innovations.

1 Social innovation theory

1.1 Definition of SIs

In the SMARTEES project, social innovations (SIs) were defined through an ad hoc research workshop that resulted in the following definition:

"Social innovation is a process of change in social relationships, interactions, and/or the sharing of knowledge that broadens/deepens the engagement of individual stakeholders with energy topics and leads to, or is based on, new environmentally sustainable ways of producing, managing and consuming energy to meet societal challenges." (Villagarcia et al., 2021)

The definition sets aside energy SIs that are researched in this project from other types of SIs that have been investigated in other projects with inevitable implications for the definition of a theoretical framework of SIs that would suit the research aims of the SMARTEES project.

Despite this definition being specific for energy social innovations, it is worth mentioning that other researchers have defined energy social innovations before. Hoppe and de Vries (2019, p. 4) write: "we define social innovation in the realm of energy transitions as, innovations that are social in their means and contribute to low carbon energy transition, civic empowerment and social goals pertaining to the general wellbeing of communities", thereby stressing the two characteristics that these authors see as defining for energy social innovations: technical or techno-economic innovation and meeting social goals equitably. A literature review (Edwards-Schachter and Wallace, 2017) found 252 definitions of social innovation centred on three main clusters: 1, 'Processes of social change', 2, '(Sustainable) Development', 3, 'Services sector', respectively emphasising social aspects of the SI with its innovative sustainable features of the innovative provision of services but with considerable overlaps.

While it is not possible and perhaps not necessary to establish a single definition of social innovations, it appears that the many definitions that can be traced share some common elements characterising, with different words, SIs as socially innovative, sustainable, and equitable processes of change.

1.2 A theoretical framework of energy social innovations[1]

We discussed elsewhere (Pellegrini-Masini et al., 2019) that social innovations have attracted considerable attention with comprehensive reviews of SIs spanning several years or even decades (BEPA, 2014; Edwards-Schachter and Wallace, 2017; Moulaert et al., 2017). The complexity, diversity of nature, diversity of proposed definitions, and diverse historical and institutional contexts of SIs are compounded by a misuse of the SI label pointed by Moulaert et al. (2013, p. 13), who point out that: "…the lack of clarity about the term 'social innovation' can be attributed not only to its evolving analytical status but also to its over-simplistic use as a buzzword in a multiplicity of policy practices…".

[1] This section is a further development of the section bearing the same title presented original in deliverable D6.1.

This variety of definitions makes it more challenging to trace broad, overarching theoretical frameworks of social innovations in the literature that are not tailored to sector-specific and contextualised types of SIs cases (see, e.g. Bekkers et al., 2013).

One of the few traceable comprehensive theories of social innovations has been outlined in recent years (Haxeltine et al., 2017; Pel et al., 2020). It advocates for a relational theoretical approach grounded in empirical research in an iterative process of conceptual identification and testing. A relational theoretical approach signifies, in the words of Haxeltine et al. (2017, p. 6), that: "As articulated in relational approaches, agency in TSI (i.e., transformative social innovation) is more accurately understood as distributed across 'webs' or 'networks' of social and material relations." Furthermore: "We therefore approach social innovation (SI) as a process of introducing new social relations, involving the spread of new knowledge and new practices." (Haxeltine et al., 2017, p. 6). This theoretical perspective appears to be consistent with the research perspective of SMARTEES, which emphasises the importance of social networks and its chosen definition of SI (section 1.1).

Haxeltine et al. (2017, p.9) present their framework (fig.1) as a combination of four clusters of relational processes: a) relations in SI initiatives, b) relations in network formation, c) relations in institutional change, and d) relations in the social material context.

The first, relations in SI initiatives, accounts for the formation of relations within the SI and refers to a group of subjects who come together pulled by the dissatisfaction regarding a current state of affairs about a specific societal area of activities. These subjects would forge relations in response to this dissatisfaction and aim to establish an alternative set of activities seeking to replace the current ones based on new, different, or alternative values. This interaction between individuals at the core of the SI would be reinforced by their joint attempt at changing current institutional settings by pursuing shared goals and resulting in a process of empowerment (Table 1).

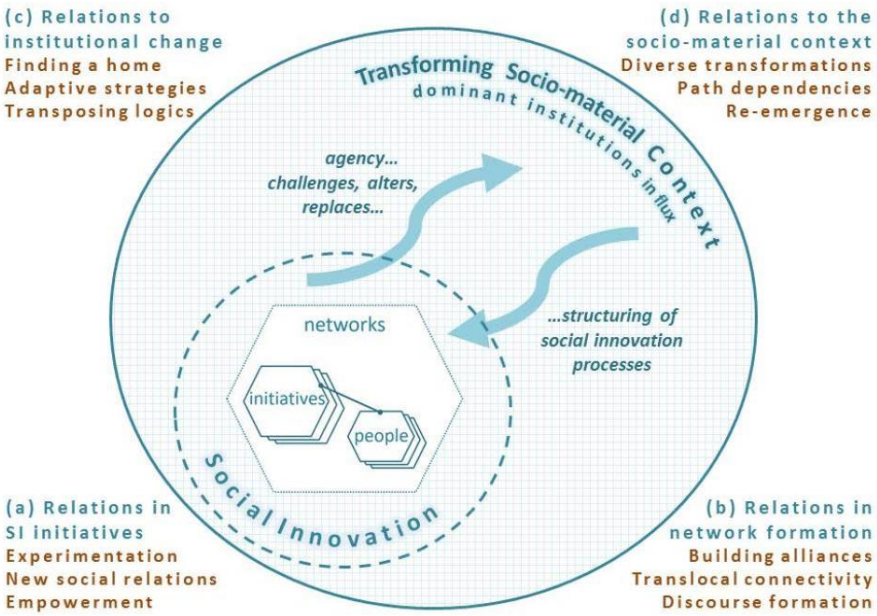

Figure 1 "A transformative social innovation process and its interlinked dynamics" (Haxeltine et al. 2017, p.9)

Relations in network formation instead refer to the forging of networks necessary for the SI initiators to sustain the process of SI. Networks are de facto alliances that help the initiators to overcome a lack of resources. However, networks are not only created locally, mainly when social initiatives try

to replicate successful models borrowed by other experiences in other countries, but they can also become transnational. Within these SI networks, new narratives and discourses that challenge established institutional settings are generated, reinforced, and developed, leading to a critical mass that is more apt at challenging established narratives of economic development usually upheld by neoliberal thinking. The third element of this framework (Haxeltine et al., 2017) refers to relations to institutional change, which affirms that SIs tend to find equilibrium within the institutional context, promoting institutional change while accepting and befitting from institutional recognition through a dialectic relational exchange that might lead to institutional hybrid arrangements. The fourth and final area of processes composing this theoretical framework of SIs regards relations to the socio-material context, i.e. the interplay between SIs and the socio-material context surrounding them. SIs attempt to replace established institutionalised socioeconomic relations but inevitably absorb from the context and occasionally reproduce at least some of the established socioeconomic relations that belong to the context. This process in itself is not a negative aspect of SIs as long as it reinforces SIs and allows them to bring change to specific contextual relations that are the main target of the SIs' actions.

Table 1 Twelve propositions for a SI theoretical framework (Haxeltine et al. 2017)

SI relational processes	**Propositions**
a) Relations in SI initiatives	1) "SI initiatives provide spaces in which new or alternative values can be promoted and aligned with new knowledge and practices—in a process of reflexive experimentation that supports both members´ motivations and moves towards collective 'success' and 'impact'." (Haxeltine et al., 2017, p. 10)
	2)"Manifesting new/alternative interpersonal relations is one pivotal way in which SI actors are able to create the right conditions to challenge, alter, or replace dominant institutions." (Haxeltine et al., 2017, p. 11)
	3) "People are empowered to persist in their efforts towards institutional change, to the extent that basic needs for relatedness, autonomy, and competence are satisfied, while at the same time experiencing an increased sense of impact, meaning, and resilience." (Haxeltine et al., 2017, p. 11)
B) Relations in network formation	4) "The transformative impacts of SI initiatives depend greatly on the changing tensions within and stability of the action field(s) that they operate in."(Haxeltine et al., 2017, p. 12)
	5) "Transnational networks are crucially empowering local SI initiatives." (Haxeltine et al., 2017, p. 13)
	6) "Discourse formation and its mediation through communication infrastructures crucially enhances the reach of SI network formation." (Haxeltine et al., 2017, p. 14)
c) Relations to institutional change	7) "SI initiatives need to find an institutional home in order to access vital resources; this often entails a balancing against the desire for independence from (critiqued) dominant institutions." (Haxeltine et al., 2017, p. 15)
	8) "SI initiatives employ a diverse range of strategies for bringing about institutional change; they must proactively adapt these strategies in response to changing circumstances, while navigating contestations with dominant institutions, and maintaining their original vision." (Haxeltine et al., 2017, p. 15)
	9) "One way in which SI initiatives engage with dominant institutions is by reconsidering the broader institutional logics in which those institutions are embedded; they do this by 'travelling' across different institutional logics, and by reinventing, recombining and transposing specific elements." (Haxeltine et al., 2017, p. 16)

d) Relations to the sociomaterial context	10) "The rise of SI initiatives and the particular transformative ambitions conveyed by them are strongly shaped by the historical development of the wider sociomaterial context." (Haxeltine et al., 2017, p. 17)
	11) "SI initiatives are only innovative against the background of an evolving sociomaterial context. Activities of innovating and invention present but one historical appearance of TSI, next to other less conspicuously innovative activities of re-invention, advocacy, and contextual adoption." (Haxeltine et al., 2017, p. 17)
	12) "Diversity is an integral element of TSI processes, reflecting the historical diversity of the people involved in them, who strive for diverse institutional forms that fit with their differing values, future visions, and present circumstances." (Haxeltine et al., 2017, p. 18)

1.3 The multi-level perspective of Social Innovations

Specific theories of energy social innovations (e.g. Hölsgens et al., 2018; Nogueira et al., 2019; Sung and Park, 2018; Terstriep et al., 2020) are developed making reference to multi-level perspective (MLP) based frameworks (Geels and Schot, 2010; Geels, 2005).

MLP (Geels and Schot, 2010) is built within theoretical constructs of sociotechnical systems. Sociotechnical systems are conceived (Geels, 2004, p. 900) as "encompassing production, diffusion and use of technologies" and are regulated by three types of rules: cognitive, regulative, and normative. They are resulting from the interaction of human actors configured into social groups, these groups create networks, and their members share agendas, perceptions, and norms.

Scholars (Geels, 2005, 2004; Geels and Schot, 2010) maintain that changing socio-technical landscapes create tensions in socio-technical regimes, allowing for niches to develop in which new sociotechnical practices can develop. The niches develop through "…three internal processes a) the building of social networks that carry, nurture and develop novelties; b) heterogeneous learning processes to improve performance and build a working socio-technical configuration; c) articulation of expectations and visions to guide learning processes and attract attention and funding" (Geels and Schot, 2010, pp. 22–23).

Niches serve as social experiments in which innovative technologies are tested through new socioeconomic arrangements, supported by individuals and groups organised in networks and coalitions able to benefit from public or private funding, aimed at experimenting with new solutions.

If the niche innovations are successful in proving their efficacy and sustainability (environmental, social, and economic), they tend to become long term institutionalised arrangements that establish networks with similar successful innovations; in this phase or level we would witness a "patchwork" of different sociotechnical regimes competing, in an evolutionary perspective, to succeed and grow. Whether the new socio-technical practices would prevail in the long term over the traditional ones, this would result in a permanent change resulting in a new socio-technical landscape (figure 2).

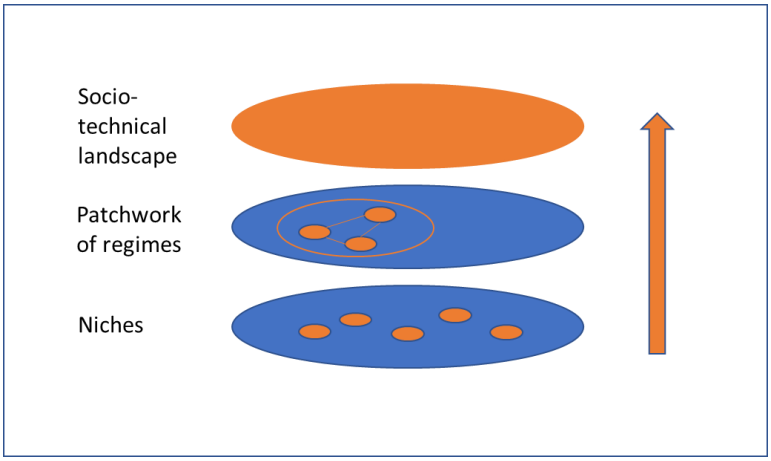

Figure 2 Multi-level perspective of socio-technical innovation (based on Geels 2002, 2004)

1.4 Integrating micro and macro levels towards a comprehensive theory of energy SIs

While the MLP and the relational framework of SIs presented in the previous sections help understanding how SIs develop in social and institutional contexts, their limit could be the lack of a focus on a microlevel of decisions and actions that regard individuals engaging as single actors or within groups and organisations in SIs.

This level has already been discussed in the deliverable D7.1 (Antosz et al., 2018, pp. 9–12), where the CONSUMAT model (Jager et al., 2000) has been described (figure 3) and in deliverable D7.2 where HUMAT, an updated version of the model was presented.

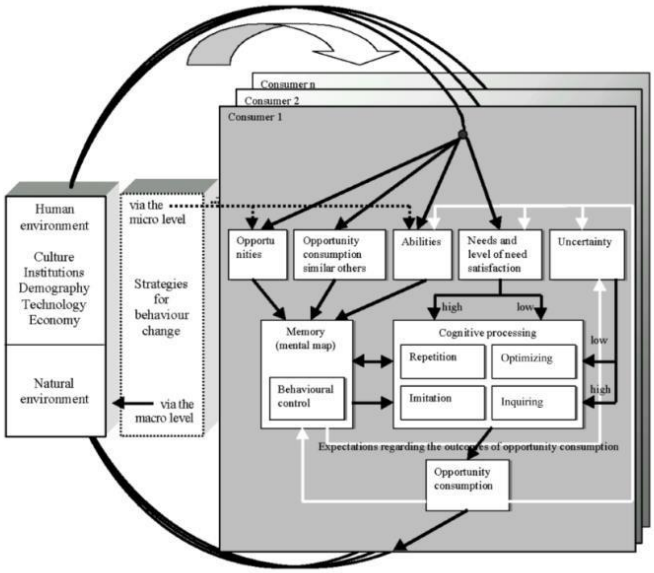

Figure 3 Overview of the CONSUMAT framework (Antosz et al. 2018, p.10)

The CONSUMAT model holds that three behaviour-driving forces (i.e. needs) interact 1) existence/sustenance, 2) social belonging and status, and 3) personal preferences (beliefs, attitudes). It has been proposed that different individuals might act under the influence of different motivational driving forces, which might be salient due to contextual circumstances (Lindenberg and Steg, 2007). Further, it was proposed (Kollmuss and Agyeman, 2002; Pellegrini-Masini, 2020, 2007) that motivational drivers regarding environmentally significant behaviours might shift with an individual's levels of satisfaction of needs, conceived in a hierarchy of motivations (Maslow, 1987). This motivational theory, albeit contested (Wahba and Bridwell, 1976), has received affirmative reconsideration and empirical validation in recent years (Oishi et al., 1999; Sheldon et al., 2001; Taormina and Gao, 2013).

Clearly, individuals may act in relation to SIs not only separately but, as often is the case, as part of organisations or groups; therefore, their subjective motivations might be overridden by the motivations created by the goals of their organisations, but this might not be the case when organisations do not hold strict rules of conduct or values that would address the appraisal of an environmental issue (Hemingway and Maclagan, 2004; Pellegrini-Masini and Leishman, 2011).

The CONSUMAT model holds that individuals would act under the three driving need sets of existence/sustenance (related to safety), social belonging and status (group position), and personal preferences (taste, beliefs) whilst using defined cognitive strategies (Antosz et al., 2018, p. 11):

1. *Low uncertainty and high satisfaction prompt agents to engage in repetition of previous behaviours, which is the script-based mechanism driving habitual behaviour.*
2. *High uncertainty and high satisfaction results in imitation of other people's behaviour, which is an important driver of fashion dynamics.*
3. *When satisfaction is low, the agents are more motivated to invest effort in improving their situation. Hence when they are certain but dissatisfied, they will engage in deliberation - an assessment of available options implemented as expected utility maximisation.*
4. *Low satisfaction and high uncertainty results in inquiring, where the behaviour of comparable/similar others is evaluated and copied if it increases expected satisfaction.*

While thinking of SIs development in niches, we could hypothesise that individuals would act using cognitive strategies 3 or 4, seeking new solutions for satisfying their individual and collective needs. At the same time, while waging different options through "deliberation" or "inquiry" they will be likely to evaluate different courses of potential action under the influence of resources or perceived costs and benefits often determined by contextual variables. It was pointed out that attitudes, resources (including personal capabilities) and contextual variables influence environmentally significant behaviours (Stern, 2000).

Specifically, holding resources, such as finances, time, knowledge and others, could alter perceptions of costs and benefits of different options or actions and therefore contribute to influencing the ultimate choice to engage in an action, both for individuals and organisations (Diekmann and Preisendörfer, 2003; Pellegrini-Masini and Leishman, 2011).

Inevitably, contextual variables themselves concur in shaping the perception of costs and benefits of specific actions for individuals (Corraliza and Berenguer, 2000; Pellegrini-Masini, 2007; Perlaviciute and Steg, 2014) and organisations (Bansal, 2005; Bowen, 2002; Leishman et al., 2012; Pellegrini-Masini and Leishman, 2011). Contextual variables could be immaterial like policies and regulations but could also include material circumstances influencing a specific (local or national) economy, such

as climatic conditions, relative scarcity or presence of natural resources, the density of population, location of energy sources and related energy infrastructure etc.

At niche level, the decision of SI actors, individuals or organisations, could therefore be represented as developing from A, motivations to act related to the level of satisfaction of the actor's needs, B inquiry and deliberation concerning different courses of action based on the relative perception of costs and benefits of such actions, influenced by C attitudes, contextual variables and actor's resources leading to D decisional outcome (figure 4)

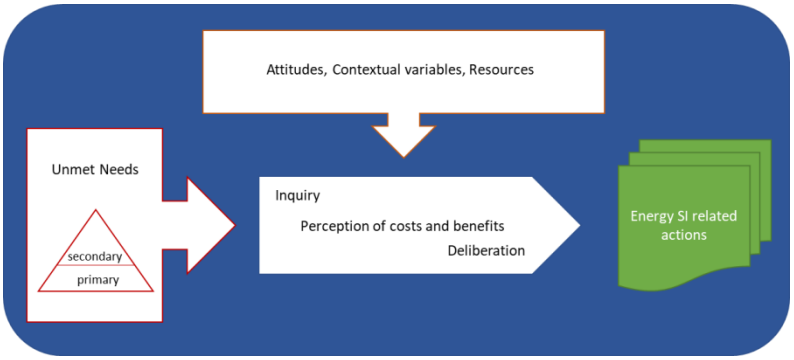

Figure 4 Groups of variables affecting the action of Energy SI actors

1.5 Variables influencing choices of SIs' actors: theoretical aspects and insights from the SMARTEES project

In the theoretical perspective that we have presented, drivers and barriers of SIs are those variables that we have indicated in the group C of variables, those influencing the perception of costs and benefits regarding the options of action that actors face. To have a common framework for identifying barriers and drivers in each SI case, we proposed four main categories of drivers and barriers variables to comprise them. The main four categories are attitudinal variables, capabilities and resources, contextual variables, and habits and routines. These four categories are based on the theory of 'environmentally significant behaviors' (Stern, 2000), which explains how different components influence environmentally significant behaviour and also the interactions between these components.

We have identified several variables from the literature and later from the research conducted in our cases. We can distinguish between variables that can function positively as drivers and negatively as barriers, which can thus either hinder or facilitate social innovations in the energy sector. A recent literature review on main barriers and drivers to solar power development in the European Union (del Río et al., 2018) refers to techno-economic issues (technological and economic characteristics of the innovation), policy and administrative issues, and social acceptability when discussing drivers and barriers for this type of energy innovation.

Analysing the drivers and bottlenecks for renewable energy technology projects, the following main barriers were identified: knowledge and skills (for example, awareness of renewable energy in public, industry, utility, and financial institutions), fit of the technology within the local implementation context (projects that have a technology-push character, which means technology is pushed onto the market without explicitly considering market demand, appear to be not successful), involvement of relevant stakeholders (important aspects here are explicit demand articulation and involvement of

local entrepreneurs, end-users, and local investors), market and financial mechanisms, and policies and procedures, thereby underling the varied nature of drivers and barriers affecting social innovations (Mondal, Kamp, Pachova, 2010).

SI processes also require forging new relationships with political, market, and social actors with different motivations and goals (Pel et al., 2017). A strong motivation of the involved actors or initiators to work on solutions for sustainable energy or related goals (i.e., pro-environmental attitudes) was identified as a key factor to starting an initiative and to keep pushing the development (Ooms et al, 2017). In the face of such changes, and the need to keep all the actors involved in the SI motivated and engaged, the concepts of empowerment and disempowerment become important variables in facilitating or hindering such initiatives. Haxeltine and colleagues (2016) conceptualise (dis)empowerment as the process through which human actors (individuals and groups) gain the capacity and willingness to mobilise resources to achieve their goals:

"People are empowered to persist in their efforts towards institutional change, to the extent that basic needs for relatedness, autonomy, and competence are satisfied, while at the same time experiencing an increased sense of impact, meaning, and resilience" (Haxeltine et al, 2017, pp.11).

In line with the SMARTEES empirical framework, which analysed a series of European cases of energy innovation clustered in five domains, corresponding to specific kinds of social innovation concerning the energy transition towards low-carbon societies, ten reference cases (two reference cities or islands per cluster) have been selected for the empirical analysis. For each cluster and each case, in particular, the drivers and barriers were identified and described in deliverable D6.1 related to actors' attitudes, capabilities and resources, contextual variables, and habits and routines. In addition to these categories, we have considered for this deliverable the influence of some demographic variables, which appeared to be relevant in influencing citizens' responses to SIs' interventions.

In the following paragraphs, besides a synthetic theoretical description of the variables, we recall the main findings of the analysis conducted in previous deliverables[2] for the variables discussed.

Categories of variables and findings from the researched cases

Attitudinal variables best predict individual pro-environmental behaviours when the context or personal capabilities do not constrain those behaviours. If the targeted or desired behaviours are considered expensive or difficult by the individual, then the context or the personal capabilities and resources have the best predictive value for the said behaviour (Corraliza and Berenguer, 2000; Diekmann and Preisendörfer, 2003).

The attitudinal variables regarding social innovation captured here are related to norms, beliefs and values. More specifically, we include here individual general environmentalist predisposition, behaviour-specific norms and beliefs, attitudes unrelated to the environment directly, and perceived costs and benefits of action.

In general, attitudes represent "relatively enduring organisation of beliefs, feelings, and behavioural tendencies towards socially significant objects, groups, events or symbols" (Hogg & Vaughan 2005), meaning that attitudes are the basis for future action (behaviour). In the case of social innovation, attitudes are therefore important in predicting specific pro-environmental or sustainability behaviours of the actors involved. Attitudes thus guide future behaviour, more so when they are

[2] We will refer mainly to deliverables D3.1, D6.1, D5.2

easy to recall (accessible) and stable over time (Glasman & Albarracín, 2006). Both direct experience and personal involvement induce individuals to think about their attitudes, which create the perfect conditions for these attitudes to be accessible for individuals, and to direct the future behaviour (Petty, Haugtvedt, & Smith, 1995). But the way attitudes influence the action or behaviour is just one of the components of attitudes. Schiffman and Kanuk (2004) suggest that attitudes are constructed around three components: (1) a cognitive component (beliefs); (2) an affective component (feelings); and (3) a conative component (behaviour) (Cognitive-Affective-Conative Model). More specifically, the affective component represents the emotional response (i.e., liking or disliking) towards an attitude object, or in other words, the feelings and emotions linked to an attitude object. The cognitive component refers to the thoughts and beliefs an individual has about an attitude object, representing the evaluation of the entity that constitutes an individual's opinion (belief/disbelief) about the object.

The general predisposition to act with pro-environmental intent can influence all behaviours an individual considers to be environmentally important, but on the other hand, the role of these predispositions can vary greatly with the behaviour, the actor, and the context.

Behaviour-specific norms refer to specific personal moral norms, attitudes toward acts, and behaviour specific beliefs about the difficulty of taking certain actions or about their consequences for the self, others, or the environment. Personal norms and the predisposition to act in a certain way towards protecting the environment can be influenced by external variables or information that shapes the said beliefs, such as findings in environmental science (about consequences), publicity and commentary about those findings, and the actual and perceived openness of the political system to public influence (which may affect perceptions of personal responsibility) (Stern, 2000).

The personal norms in this context are nothing more than "expectations that people hold for themselves" (Schwartz, 1973), consisting of feelings of moral obligation or duty (Schwartz, 1970, 1975, 1977), which can be activated in order to behave in a pro-environmental manner. These personal norms are learned and modified through social interaction. According to Schwartz's Norm-activation Theory (NAT), the process of norm activation consists of four situational variables or activators (i.e., awareness of need, situational responsibility, efficacy and ability) and two personality trait activators (i.e., awareness of consequences and denial of responsibility). In other words, personal norms provide guidance on how to act sustainably or pro-environmentally in specific situations only if they are activated (if individuals are aware of conditions that entail adverse consequences for others and feel capable for averting these consequences) (Olbrich, Quaas, & Baumgärtner, 2011). However, the activation of personal norms is not sufficient for individuals to engage in pro-social behaviour, because they can be neutralised by denying the consequences of an individual's actions on others or by denying the responsibility to take action (Harland et al., 2007). Moreover, a sustainable or pro-environmental behaviour can be influenced not only by specific personal norms, but also by attitudes unrelated to the environment directly, such as those related to consumer products, saving money or other resources, luxury, waste, or the importance of social relationships (Stern, 2000).

Perceived costs and benefits of an action represent other social-psychological variables that influence the behaviour of an individual and they have been discussed specifically in research about social acceptance of renewable energy as variables influencing the acceptance of renewables' developments in local communities (Pellegrini-Masini, 2020; Perlaviciute and Steg, 2014).

Trust is another attitudinal variable whose importance cannot be underestimated when discussing social innovations. Trust towards the actors of community energy developments has been found to be a key variable influencing social acceptability, for example in wind farm local debates (Pellegrini-

Masini et al., 2020; Walker et al., 2010) and more broadly in other types of community energy projects (Aitken, 2010; Huijts et al., 2012; Koirala et al., 2018; Rand and Hoen, 2017).

In the SMARTEES project, as we reported in D6.1 (Pellegrini-Masini et al., 2019), attitudinal variables, and particularly pro-environmental attitudes (i.e., general environmental predisposition) played a significant role, influencing the engagement of several actors in different types of social innovations considered in the project. This was the case, for example, for cluster one "Holistic, Shared and Persistent Mobility Planning" and the cases of Zürich and Groningen where the institutional actors appeared to be motivated by an environmental concern and the desire to improve the quality of the urban environment. This is not to say that other attitudinal variables were not at play in the same cases, which might have acted instead as barriers, for example in the same cluster, in the case of Groningen, shopkeepers reacted negatively to the proposed mobility measures, chiefly out of concern for their perceived possible costs, i.e. loss of income for their businesses. Another example where pro-environmental attitudes played an important role is given by the cases of Samsø and El Hierro where a sustainable energy vision for the island was envisaged and acted upon by all the leading actors of the SIs, even though, also in these cases they were not the only attitudes at play, and in both cases the perception of significative benefits for the island economies and the future development of the islands played a role in strengthening the will to implement the SIs and to engage in them. Occasionally attitudinal variables were found to act as significative barriers, for some actors, besides the example of shopkeepers in Groningen, another one can be pointed at in the case of Järva, (Stockholm), were residents who were not thoroughly informed and sufficiently engaged at the start of the project had the perception that the interventions would have entailed significant costs for them both in terms of forced relocation and in increased rental rates.

Among the attitudinal variables, trust towards the proponents of SIs, appears relevant for social acceptance in SMARTEES cases (Lema-Blanco and Dumitru, 2019; Pellegrini-Masini et al., 2019). This appeared to be true in several instances, for example in the case of Augustenborg, Malmö, it an initial distrust was reported due to the cultural background of the residents involved; the same problem was found to be present in Järva, Stockholm, where residents displayed initially a low level of trust towards both the public housing company and the municipality and were protests erupted as a consequence of this and incomplete information received by the residents. Similarly, in another context, in Torry, Aberdeen, yet a neighbourhood relatively deprived, lack of trust by residents towards the municipality appeared to be a problem. Lack of trust towards the municipality was also cited as a barrier for the Timisoara case, another urban SI case placed in a deprived social context. This recurrence of trust as a barrier in low-income neighbourhoods is not surprising and it appears to be coherent with research on deprivation and institutional trust (Giustozzi and Gangl, 2021).

Personal capabilities and resources can play a significant role in the performance of environmentally relevant behaviour, because performing any behaviour requires finite tangible and intangible resources (Margetts & Kashima, 2016). It was found that even a temporary change in resources is associated with a change in environmentally significant behaviour (Fujii & Kitamura, 2003). Resources can be divided into two broad categories: economic and socio-emotional resources (Cropanzano & Mitchell, 2005). Because an economic resource, such as money, can be exchanged with most other resources it is perceived as being not very personal, whereas a socio-emotional resource, such as giving time, is more personal and signals a particularistic relationship between the giver and the receiver (Foa & Foa, 1974, 1980). The capabilities and resources included here are knowledge and skills required for particular actions (e.g., the skills of a movement organiser for activism, mechanical knowledge for energy-conserving home repairs), the availability of time to act, and general capabilities and resources such as literacy, money, social status and power (Stern, 2000).

Literacy is essential in helping us make sense of the world we are a part of, and is broadly considered as the ability to read and write. For now, there is no consensus of what exactly environmental literacy is, or one single, universal definition for this concept. Roth (1992) described environmental literacy as the outcome of a number of interplaying attributes: knowledge of ecological concepts, environmental issues and environmental action strategies; cognitive skills for analysing environmental problems, and skills in the use of environmental action strategies; and the individual's 'affects' (values, environmental sensitivity, environmental attitudes, locus of control). Thus, an environmentally literate individual possesses the values, attitudes, and skills that enable conversion of knowledge into action (Yavetz, Goldman, & Pe'er, 2009).

Social status was defined as "a person's relative position in a social hierarchy" (Swencionis & Fiske, 2018) and was related to the "respect, admiration, and importance in the eyes of others" one individual gets (Gregg, Mahadevan, & Sedikides, 2018).

Financial resources represent those material resources having the potential to support the development of ideas, actions, and projects.

Time is an asset from which benefit is produced. Time may be one of the most precious resources, as it expires every day. The existence of a time constraint and the time necessary for an activity to be performed can affect the individual actual behaviour (Becker, 1965). In other words, time is important for decision-making and subsequent actions of individuals: if activities are more time-consuming, then the less free time an individual has, the less of those activities he/she is likely to perform. Empirical evidence for this time component affecting the intentions of environmentally-minded individuals to behave pro-environmentally is mixed. For example, one study found that that increasing the free time is related to a significant reduction in the value-action gap (i.e., pro-environmental values are not necessarily conducive to pro-environmental behaviour) (Chai et al., 2015). Another study did not find support for the hypothesis that increased feelings of less time available and work-life imbalance affect the intentions of individuals to behave in a congruent way. However, the scholars found that for more demanding behaviours in terms of time, feeling more dissatisfied with the amount of time available for leisure (i.e., free time), negatively impacted the behaviour of individuals (Melo et al., 2018). Therefore, when there is already the perception of squeezing time for leisure, even if the issue is one of importance for the individual, then the actions will more likely not be of support for the said issue if the actions are time-demanding.

Knowledge is a body of information (factual or procedural) gathered by individuals through formal or informal (television, newspapers, family, friends, etc.) education and experiences.

In a review on the personal and social factors influencing pro-environmental behaviours (Gifford and Nilsson, 2014), it was found that both knowledge and education to an extent predict pro-environmental behaviours. Particularly, and unsurprisingly, knowledge that is correct (Levine and Strube, 2012) seems to predict pro-environmental behaviours. With regards to education, Gifford and Nilsson (2014) reference five studies providing evidence holding that more highly educated individuals are more concerned about the environment, although a single study (in Norway) contradicted this finding (Grendstad & Wollebaek, 1998).

Skill refers to the ability of using that information and applying it in a context. Similarly, environmental knowledge can be defined as one's ability to identify a number of symbols, concepts and behaviour patterns related to environmental protection (Laroche et al., 2001). Research shows that a deeper knowledge of environmental issues and how to solve them increases the likelihood of individuals taking action to protect the environment (Vicente-Molina, Fernández-Sáinz, & Izagirre-Olaizola, 2013; Mobley et al., 2010). Any project or any endeavour can be accomplished only with the support, effort, and expertise of the *human resources* involved in it.

Therefore, all these personal capabilities and resources are important for directing behaviour, more so when considering pro-environmental behaviour as goal-directed and resource-enabled.

Resources were evidently playing a role in the SMARTEES cases (for details please refer to D6.1, Pellegrini-Masini et al., 2019). In general, it is safe to say that financial resources played an important role in most of the cases researched in enabling the SIs that otherwise, without appropriate public funding would have not been started or implemented. This was particularly evident for cases of the island of Samsø, El Hierro and the urban cases of Stockholm, Malmö, Aberdeen and Timisoara, where significant investments were made in energy generation, energy infrastructure, building refurbishments, and improvements of public spaces. Financial resources were not the only type of resources at stake, in fact, human resources were also a relevant aspect capable of affecting the design and implementation of SIs in leading organisations in some cases. This was true in cases like Samsø and El Hierro where the presence of leading individuals allowed to generate a vision of the SI, which was eventually shared and supported by the municipality and other actors and succeeded in securing public funding. Human resources are often discussed in terms of knowledgeable individuals and skilled individuals available in organisations that lead the SI and this brings in the discussion the relevance of knowledge and skills as s resources for the development of the social innovation. For example, in Järva a pivotal role was played by an individual who was initially representing the tenants of the buildings undergoing refurbishment and later worked for the municipal housing company while continuing to engage residents thanks to her mediation skills and understanding of the diverse social and ethnic backgrounds of the neighbourhood. So essentially skills and knowledge are often identified with valuable human resources in leading organisations engaged in the SI but, in our cases, knowledge has been also indicated as an issue that might influence social acceptance by citizens, in this case, citizens might be seen, like in the case of Järva at the start of the project and to an extent El Hierro, where citizens lacking essential information about the SIs' projects protested or expressed their dissatisfaction.

The next category comprises external or **contextual variables,** including interpersonal influences (e.g., persuasion, modelling), community expectations, advertising, government regulations, other legal and institutional variables (e.g., contract restrictions on occupants of rental housing), *material costs and rewards,* the physical difficulty of specific actions, capabilities and constraints provided by technology and the built environment (e.g., building design, availability of bicycle paths, solar energy technology), the availability of public policies to support behaviour (e.g., curbside recycling programs), and various features of the broad social, economic, and political context (e.g., the price of oil, the sensitivity of government to public and interest group pressures, interest rates in financial markets) (Stern, 2000). It is worth mentioning that each individual can perceive these external variables in a different manner because these variables can be linked to different attitudes and beliefs. In other words, a contextual factor, such as the price of a product can be seen both as a driver and as a barrier as it could be linked to a positive attribute (higher quality, organic, etc.), or perceived as an economic barrier (Stern, 2000).

Within the group of contextual variables, the institutional (i.e., political, regulatory) context can hinder or support the successful implementation of social innovation projects. Particularly, legal frameworks and policy instruments can facilitate community energy projects to merge and mainstream (Elle et al., 2015; Hewitt, 2019). *Laws, regulations and supportive policies,* translated in economic incentives or favourable regulations, for example, can facilitate technological innovation, investment, knowledge building, networking activities and the strengthening of social innovations in the energy sector (Elle et al., 2015; Ooms et al., 2017).

Heiskala (2007) emphasise the importance of institutional environments for social innovations' development and proposes two meanings for institutional structures, a broad one based on three

institutional pillars that include also cultural structures, which are: regulative, normative and cultural-cognitive, and a narrower definition that is more relevant for our argument here and that includes "(a) public policies (public goods and services), (b) the regulatory framework (laws, regulations, collective agreements) and (c) organizational principles and arrangements." (Heiskala, 2007, p. 62). Also, Cattacin and Zimmer (2016, p. 22) emphasise the importance of the institutional and political context for social innovation: "We argue that social innovations have to be analysed against the background of their specific contexts or, to put it differently, that social innovations at the local level are the outcome of a political process and as such a reflection of city-specific (welfare) cultures—the institutional perspective—and local governance arrangements—the political perspective." This view is shared by Thompson (2019, p. 1178), who states that "institutional structures are fundamental for governance and social reproduction, and provide the essential material for social innovators to play with; but they can be more or less conducive to playful innovation for the production of more or less socially just outcomes." Cattacin and Zimmer (2016, p. 23) point out that urban governance is embedded in "multi-layered institutional settings" that comprise in their words (2016, p. 26): "The institutional context of administrative structures and state organisation, the welfare-regime context in which the local welfare regime is embedded, the local political culture as an expression or outcome of specific norms and values". Certainly, diverse administrative and regulatory levels might influence social innovations with their policies, laws and funding schemes. Particularly policies of funding schemes might be a crucial element for social innovations like we have pointed to in earlier deliverables (Pellegrini-Masini et al., 2019), as held by other scholars (Cattacin and Zimmer, 2016; Rentzsch, 2016).

Further in the group of contextual variables, because many of the SIs in energy community projects adopt public-private partnerships schemes, combined with a certain degree of involvement of citizens' groups in decision-making (Hewitt, 2019), low awareness of citizens around energy issues and low interest in energy for the general public may influence the implementation of such energy initiatives negatively (Ooms et al., 2017). In this context, the active engagement of citizens in the public arena becomes an important positive factor (Moulaert, 2017). To engage and empower citizens, it is important to design adequate framework conditions (Haxeltine et al., 2016) and establish participatory approaches that engage citizens in decision-making processes from the early stages of the initiative (Perlaviciute et al. 2018; Schuitema & Bergstad, 2012). Early-stage participation has proved to be an important variable in the SMARTEES project. As detailed in D6.1, D5.2 and other deliverables, it was found that in those cases where early-stage participation was present, the SI interventions were more accepted, and protests were limited.

In the SMARTEES cases, it is possible to trace several examples of contextual variables that have influenced the SIs researched. An important category would refer to what we have termed earlier in a broad sense the institutional context. This has played a major role in the SMARTEES cases because most of the SIs have benefited from substantial public funding that has been recruited to a considerable extent through public grants or anyway through public bodies involved in the development of the SIs, as detailed in D3.1 (Caiati et al., 2019). For example, in the island cases of El Hierro and Samsø, particularly in El Hierro, considerable public grants have allowed starting and sustaining the projects. The development of the heat network in Aberdeen, a central element of the SI, was carried out through the creation of a not-for-profit ESCO whose initial loans were underwritten by the municipality. In Järva Stockholm, substantial funding was provided by the municipality after the 2008 financial crisis (Stimulus of Stockholm), which benefited the public housing company Svenska Bostäder that sustained the investment for the interventions in Järva (Persson and Högdal, 2015).

Habits are both habits of doing (behaviours, actions, occupations), and habits of thought (tendencies to think in certain ways), which are performed repeatedly, relatively automatically, and with little variation, whereas **routines** are regular, more or less unvarying procedures, customary, prescribed, or habitual, as of business or daily life (Clark, 2000). Habits and routines are closely related to social innovation aims, in the sense that any social innovation is accompanied with changes at the level of social relationships and the 'playing rules' between the involved stakeholders (Bekkers, Tummers, & Voorberg, 2013). Through changes, social innovation challenges the existing personal habits and routines of all the individuals involved. Moreover, changes in behaviours often require breaking old habits and becoming established by creating new ones (Dahlstrand & Biel, 1997).

At the same time, a disruption in personal habits and routines cannot be taken lightly, because a disruption in a person's everyday "elemental" routines can have a profound effect on the person's overall social integration, as well as on the person's sense of who he or she is in the world (Clark, 2000). Not only do the consequences of changing habits and routines represent a challenge, but also the intrinsic characteristic of habits, as being persistent. Breaking a habit or a routine is not impossible, though, as they do interact with time, agency, and context (Clark, 2000). Habits and routines are valuable for social innovations in particular and creative endeavours in general, as they encompass important advantages at personal level: (a) increase skill in action or thought as they enable an individual to focus more on the elaboration and less on the given action or thought, (b) requiring low effort levels in thought or action they reduce fatigue and new learning could be superimposed, (c) free attention for the unpredictable, and (d) enable a person to exercise functions without having to recall and attend to specific elements of a given practice (Young, 1988).

In the SMARTEES cases, habits and routines did not play a major role for most of actors involved in the SIs investigated. Nevertheless, they were indicated occasionally as a barrier, particularly for the cases involving sustainable mobility interventions Zürich, Groningen, Vitoria-Gasteiz and Barcelona. For example, for Zürich and Groningen some citizens and shopkeepers were concerned with the changes introduced by the sustainable mobility plans, habits and routines were indicated as a weak barrier. Also, in Vitoria-Gasteiz, where superblocks were implemented, it appeared that cyclists struggled to abandon the habit of cycling through routes that now crossed pedestrian areas. In Barcelona instead, another superblocks case of SI, habits and routine showed to be a strong barrier for residents that used regularly their cars and therefore were reluctant to accept the new pedestrian areas. Aside from the mobility cases, habits and routines were seldom mentioned as a driver or barrier in other cases, an exception is the case of Samsø where there was an indication that habit and routine were a barrier in the municipality, which was not used to work with the type of sustainable energy projects that the SI promoters envisaged for the island.

Demographic variables were initially omitted in our previous theoretical framework outlined in D6.2, however, further research in our cases showed that some of these might play a role in shaping citizens' choices regarding SIs' actions.

Demographic variables were found to have a significant effect on individual environmental citizenship. Specifically, participation in demonstrations and protests was found to be negatively related to age (Stern et al., 1999). *Age*, amongst other demographic variables, was found to positively impact the adoption of sustainable consumption practices (Chai et al., 2015) and engagement in pro-environmental behaviours (Melo et al., 2018). In other words, as individuals grow older, their behaviour tends to become greener. This result is supported by other studies, in which pro-environmental behaviour positively correlates with age (older people score higher on measures of pro-environmental behaviour) (Longhi, 2013; Lynn & Longhi, 2011). When comparing different types of environmentally-friendly actions and behaviours at different age stages, it was noticed that although at-home behaviours (i.e., switch off lights in rooms that are not being used) increase with

age, this relationship becomes almost flat, however, above the age 65. Purchasing behaviour (i.e., take your own shopping bag when shopping) is increasing with age until around age 50, then decreases slightly as ageing. The association of transport-related behaviour with age is much different: young individuals are the most environmentally-friendly, but this behaviour is reduced with age, reaching a minimum in the late '50s, and then increasing again, so that 80-year-olds are similar in their transport-related behaviour to 35-year-olds (Lynn, 2014).

Regarding *gender*, research reports that women show stronger pro-environmental attitudes, concerns, and behaviours than men (Blocker & Eckberg, 1997; Gutteling & Wiegman, 1993; Luchs & Mooradian, 2012; Scannell & Gifford, 2013; Tikka et al., 2000; Zhang, 1993; Gifford & Nilsson, 2014). This difference has been found across 14 countries in Europe, Latin America, and the U.S. The gender difference was consistently stronger for behaviours than attitudes (Zelezny, Chua, & Aldrich, 2000). However, research across the world paints a more disparate picture. In China, similar patterns were observed in domestic environmental behaviours. However, there were no differences in behaviours outside the home, and women actually expressed lower levels of concern than men (Xiao & Hong, 2010, Gifford & Nilsson, 2014). In a study from Shanghai (Shen & Saijo, 2008), results instead suggests that men are more environmentally concerned than women with regards to global environmental problems and were more prone to pro-environmental behaviou. One explanation may be that in Shanghai, men have higher education levels and are likely to be more politically active than women (Shen, 2008). However, although there are clearly exceptions to this, women, in general, seem to be more environmentally concerned and show more pro-environmental behaviours. It has been suggested that personality may mediate the effect of gender on sustainable consumer behaviour; for instance, Luchs & Mooradian (2012, p 147) suggest that more agreeable consumers are more likely to show social and environmental concerns, a personality trait that is more prominent among women. It has also been suggested that females are more sociable other-oriented, which may influence pro-environmental behaviour (Zelezny et al., 2000).

It has also been claimed that women express more concern and intent to act upon these concerns, but that men are more knowledgeable (Arcury & Christianson, 1993; Gambro & Switzky, 1999; Gifford et al., 1982–83; Levine & Strube, 2012). This is a pattern that was confirmed in other studies (Arcury, Scollay, & Johnson, 1987; Grieve & Van Staden, 1985; Schahn & Holzer, 1990; Stern et al., 1993). Gifford and Nilsson (2014) suggest that this may be the result of school and social systems that discourage girls from an interest in science. If that is the case, the authors of that study strongly suggest that educators pay more attention to the environmental education of girls and women. Another explanation is that altruistic concerns are more important to women, especially those with children at home (Gifford & Nilsson, 2014; Davidson & Freudenburg, 1996; Dietz, Kalof, & Stern, 2002). With regards to gender and participation in social innovation in energy efficiency and the transition to a low-carbon society, this may indicate the importance to reach out to women particularly and having a plan for how to involve them in the processes in order to be able to successfully implement social innovations.

2 SMARTEES findings from ABM modelled cases and theory development

In this section, we present the results of the ABM modelling development for selected SMARTEES cases. In each case, the focus is placed on selected dimensions that will be used to discuss considerations of the theoretical contribution of the SMARTEES project for theories of social innovation.

2.1 The Groningen case. Case study cluster 1: Holistic, shared and persistent mobility plans.

Groningen is an old, compact city originating from the third century with around 200.000 inhabitants, including a student population of around 60.000. Since the early 1970s, city planning has focused on facilitating cyclists and pedestrians in the city, and de-intensifying car use in the city. The Traffic Circulation Plan, developed by the municipality, was implemented in 1977 and was the start of a social innovation process focusing on holistic traffic planning, and several developments and plans followed in the years after. We focus on a specific implementation of the social innovation, namely the case of the closure of the Noorderplantsoen park for cars starting in 1993. In this park, the traffic situation had become more problematic over the years. In particular, sharing of the road by cars and cyclists turned out to be unsafe. Moreover, the quality of the park decreased due to reduced air quality, sound emissions causing a nuisance, and lower safety, especially for playing children. The situation brought the local population and policymakers together in organizing a referendum on closing the Noorderplantsoen for car traffic. In October 1994, after a test closure of one year, a majority vote of 50.9% decided in favour of permanent closure.

Because of the interesting social dynamics that took place in this case, we focused on modelling this referendum for the Groningen case study. The agent-based model we developed for that focuses on the diffusion of acceptance of a new organization of traffic in one of the city's main arteries connecting the east to the west - – the Noorderplantsoen park. The theoretical and empirical foundations of the Groningen agent-based model and the calibration processes are described in deliverable 7.3 in section 1 (Antosz et al., 2020). The agent-based simulation starts with the idea of the referendum on a car-free park when Groningen residents exchange information with alters in their social networks on their preferred voting decision. The process from initiation of the referendum until the voting day is represented. In this period agents interact and obtain information and here is where attitudes are formed and information is exchanged. Based on acquired knowledge, those residents assess how satisfied they would be if the park was open for cars, compared to how satisfied they would be if the park was closed for cars. The simulated results of the baseline model for the Groningen case yield an average of 49.54%, (Standard Deviation = 0.73, N=1000 simulation repetitions) votes for closing the park for cars. The simulations were carried out in the BehaviorSpace of Netlogo 6.2.0 (Wilensky 1999). The specified simulation consisted of 1000 repeated runs. Results of simulations on the baseline model and simulations of counterfactual scenarios are described in deliverable 7.4 (Bouman et al, 2021). In the next section, we elaborate on selected dimensions of influence in social innovation in our model.

Description of the selected dimensions

Social demographics: age and education

The first set of social dimensions regard the role of social demographics of the Groningen population where we focus on age aspects and educational attainment level of residents. We select these dimensions as the city of Groningen is unique in its population for the relatively large proportion of young and specifically highly educated residents. This is mainly because Groningen is an established university city. In our simulation model, we replicate the referendum using an empirically calibrated model, using population statistics and information on the results of the referendum (Municipality of Groningen, 1994; Municipality of Groningen 1999). In the results section, we describe how social demographics age and education play a role in this social innovation case.

Municipality led vs community led campaigns on the project

The third selected dimension of influence on the social innovation regards municipality versus community-led campaigns promoting citizens to cast votes pro or against closing the park for cars. Initially, the traffic circulation plan and the closing of the Noorderplantsoen for car traffic were social innovations initiated and organized by the municipality with a strong top-down structure. However, citizens were involved, and various community organizations had opinions on the social innovation. These opinions were often voiced via various campaigns. In our simulations, we investigated both campaigns from the municipality focusing on affirmation on the benefits of having a park free of car traffic, and on a campaign where the shopkeepers' community focused on the convenience of traffic through the park both for more shopping and traveling convenience. In reality, both opinions were strong, and that is partially also why the real referendum yielded a borderline majority vote for closing the park for cars. In the results section, we discuss the models and simulation results for both campaigns.

Results of the model regarding the selected dimensions

Social demographics; age and education

We investigate the role of age and education by looking at differences between groups in simulated voting behaviour. In this set of simulations, the population is N=14094. In this simulation, the total turnout of artificial residents that cast a vote was 30.03%, where a minority of 49.92% voted to close the park for cars. The simulations show distinct differences between both selected demographic groups as follows:

The role of age

The simulations show that there are differences between age groups in voting behaviour. First, it is noticeable that individuals in older age groups are more likely to cast their votes. In particular, artificial residents from the Groningen model aged 25-64 are more likely to go and vote as they have a higher turnout (31%) than the other two age groups. However, the age group 65+ is slightly more prone to vote to keep the park open for through car traffic. Younger residents are more likely to vote to close the park for cars, whereas older age groups vote to keep the park open for car traffic (see Table 2).

Table 2 Voting behaviour differences across age groups simulated population N=14094

	% votes to close the park for cars	*Turnout, % of age group that votes*	
Age 18-24	*54%*	*29%*	*n=2591*
Age 25-64	*49%*	*31%*	*n=9096*
Age 65+	*46%*	*27%*	*n=2406*

The role of education

The simulations show differences between groups with different educational levels in voting behaviour and preferences (Table 3). It seems that individuals belonging to the group with middle and higher educational levels are more likely to vote to close the park for car traffic. Lower educated groups display a marginally lower turnout and seem to prefer to keep the park open for cars.

Table 3 Voting behaviour differences across educational level groups simulated population N=14094

	% votes to close the park for cars	*Turnout, % of age group that votes*	
Educational level: lower	*42%*	*26%*	*n=5072*
Educational level: middle	*53%*	*34%*	*n=4388*
Educational level: higher	*53%*	*35%*	*n=4634*

Municipality led vs community organizations led organizations

In the original empirical case, citizens of Groningen city were rather divided in their opinions on whether the park should be closed for cars, and this division was clearly neighbourhood oriented. Figure 4 represents the original referendum votes cast in 1994, where 50.09% voted to close the park for cars. Noorderplantsoen is located in northwest central Groningen, marked as the black banana-shaped form. Areas with light-red shades indicate that most citizens in these neighbourhoods were against a car-free park, preferring car traffic convenience. Areas with green shades indicate a majority of supporters for a car-free park. This section discusses simulation results from both municipality-led and community-led campaigns regarding the referendum on closing the Noorderplantsoenpark for cars. In the artificial model of Groningen, we implement two different scenarios, namely version 1, where we discuss a scenario where the municipality holds an affirmative campaign on the benefits of having a car-free park. Next, in version 2, we discuss a scenario where the shopkeepers' community held a campaign to underline both shopping and traffic convenience if the park would be kept open for car-through traffic.

Figure 4 Division of preferences and voting results in 1994

Version 1: Municipal affirmative car-free park campaign

In this simulation (repeated 100 runs), we investigate how voting behaviour and results would change if the municipality actively campaigned to affirm the benefits of having a car-free park. Figure 5 depicts the results of the simulations on the affirmative car-free park campaign and shows a strong effect. In this simulated scenario, it can be observed that with this campaign, voters are strongly influenced and become more convinced that having a car-free park is an optimal outcome. The overall majority vote for closure of the park becomes 62.88%. We furthermore investigated whether the timing of such a campaign would influence voting results. In the simulations, we experimented with implementing the scenario in the onset of the social innovation, in the middle of the process, and right before the referendum. All simulations show that an affirmative campaign strongly impacts voting behaviour and that citizens more often vote to close the park for cars. If the campaign is cast in the beginning, 62.90% vote for closing, if in the middle 61.88% and right before the referendum 62.88%. So overall, it is noticeable that casting an affirmative campaign evokes a tipping point in preferences already at the onset of the social innovation. For more detailed results, see deliverable 7.4. The results are further summarized in table 3, 'synthetic description of selected dimensions'.

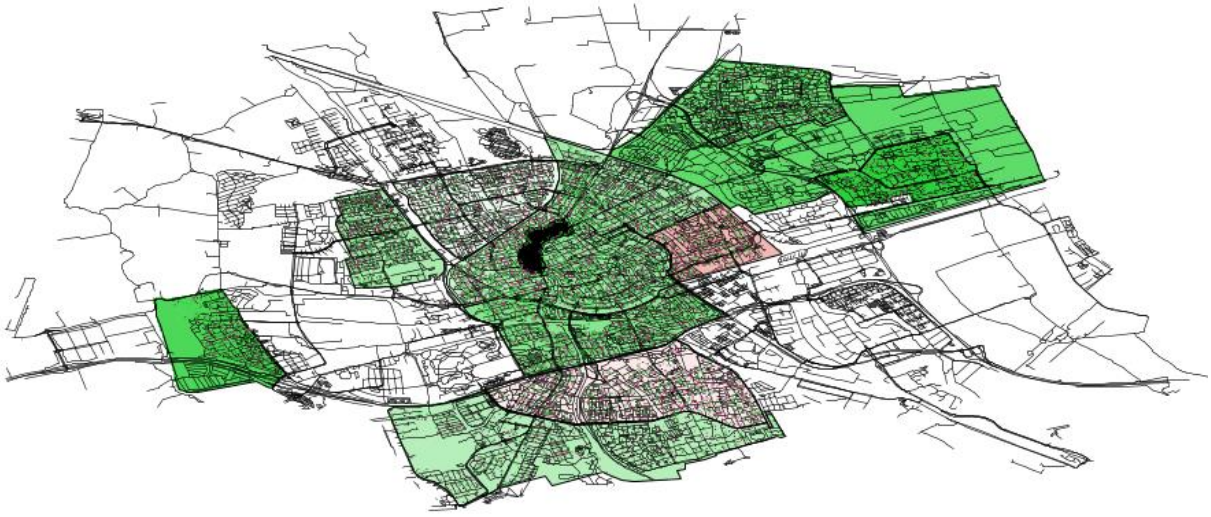

Figure 5 Map of Groningen showing voting results after implementing the affirmative municipality-led campaign

Version 2: Shopkeepers' campaign promoting park trough car-traffic for mobility and shopping conveniences

The shopkeepers' campaign promoting car traffic in the park shows a very different dynamic from the municipality's affirmation campaign. In this case, the effect seems less strong. However, slightly more citizens become more prone to vote to keep the park open for cars. In this set of simulations, only 49.57% of the artificial residents vote for closing the park for cars. We furthermore investigated whether the timing of such a campaign would influence voting results. In the simulations, we experimented with implementing the scenario in the onset of the social innovation, in the middle of the process, and right before the referendum. All simulations show that a shopkeepers' campaign has a limited impact on voting behaviour. If the campaign is cast in the beginning, 49.52% vote for closure, if in the middle 49.57% and right before the referendum 49.57%.

Recapitulating, the simulations show that casting a municipal-led affirmative campaign evokes a tipping point in preferences already at the onset of the social innovation and is effective at any time point. In contrast, the impact of the shopkeepers' community campaign is marginal at best, and differences between the campaign timing are marginal. For more detailed results of these scenarios, see deliverable 7.4. The results are further summarized in Table 4, 'synthetic description of selected dimensions'.

Figure 6 Map of Groningen showing voting results after implementing the shopkeepers smearing campaign

Final considerations

Looking at the results regarding social demographics as dimensions that could represent important drivers for social innovation, the model results indicate that both age and educational attainment play a role in voting behaviour. First of all, for age groups, there is a difference between turnout and also in preferences. The results indicate that age and educational attainment may influence the likelihood that an individual casts a vote, and to some extent, also what the individual will vote for. Social demographics thus should be regarded as potential important building blocks for citizens' behaviour in social innovation. The simulations on campaigns show that citizens can be influenced in their opinions and decisions and that when information is spread via a campaign by the municipality rather than a local community, this influence seems a bit stronger.

The results of our simulations (in this report and Deliverable 7.4) show that both social demographics and campaigns are important drivers of social innovation and can influence the extent to which an individual regards social innovation as important, forming an opinion, and contributes accordingly. The results indicate that policymakers could target groups with a lower turnout with campaigns led by the municipality to have a stronger impact on their attitudes. These results are completely in line with our reports on policy recommendations developed in the dedicated policy workshops held with various stakeholders (see deliverable 5.2). In sum, deliverable 5.2 reports in detail what makes individuals more likely to accept social innovation and to be involved in the innovation. Specifically, the more (positive) citizens are involved in a project, and the more they experience that their input is being appreciated and used, the more support there will be for developing plans. The bottom line for policy in the context of social innovation is involving people in the plans from early on and ensuring that the citizen population's heterogeneity is represented in the development of plans. Further, to ensure that these plans contribute as much as possible to the well-being of all citizens and that they feel that their perspective is considered relevant, even if the ultimate implementation still has some negative outcomes for a subgroup of citizens.

Table 4 Synthetic description of selected dimensions, results and their relevance for SIs' theory and policies

Dimensions selected	Description	Syntethic results	Theorethical and policy considerations
Social demographic characteristics			
Age	The voting population is categorized in 3 groups, namely; 18-24 25-64 65+	In the age group of 18-24, a majority of 54% prefers a car-free park; however, the turnout of this age group is much lower than the two older groups Age group 25-64 supporters of a car-free park in the minority with 49% Age 65+ supporters of a car-free park in the minority with 46%	Results show differences between age groups in voting behaviour and preferences that are important to consider in SI theory and policy development. Age groups should be targeted differently if one wants to increase or decrease their importance for voting. Policies could target younger age groups to increase turnout, whereas 65+ age groups could be targeted regarding their preferences for keeping the park open for cars
Education	The voting population is categorized in 3 groups, namely: Lower Middle Higher	In the lower educated group supporters of a car-free park in the minority with 42% and have a lower turnout than middle and higher educated groups Both middle and higher educated group	Results show that there are differences between different levels of educational attainment in voting behaviour and preferences and therefore important to

		supporters of a car-free park are in the majority with 53%	consider in SI theory and policy development. Theories on social innovation could acknowledge and underline differences between group in their level of educational attainment.
Municipality led vs community organizations led project			
Version 1: municipal led Affirmative campaign	The campaign held by the municipality to increase acceptance of a car-free park	These simulations show a strong effect across neighbourhoods, increase in votes to close the park for cars. The majority of 62% on average prefers a car-free park	Theories should further elaborate on the role of municipal and top-down organized campaigns and the impact on opinion formation and citizens active involvement in social Innovations, as these simulations imply a strong impact. Policies could recommend involving citizens in the community and municipal campaigns to reach stronger embeddedness and support of the social innovation

Version 2: shopkeepers community campaign	Campaign held by shopkeepers to convince citizens of the convenience in transport and convenience in reaching the shops quickly	Enough effect to get push votes for a car-free park into the minority. When this campaign is held, 49% of the citizens still prefer a car-free park	The investigations of municipal versus community-led campaigns show that it is important to further theorize on the impact that either entity has on social innovation. Specifically for our case, we further investigate and discuss theoretical considerations and simulation results in deliverable D7.4. Policies could recommend involving citizens in the community and municipal campaigns to reach stronger embeddedness and support of the social innovation

2.2 The El Hierro case. Case study cluster 2: Islands and renewable energy.

El Hierro is an island of the Canary archipelago in Spain, which covers an area of 278 km^2 and has a population of 10,679 inhabitants according to the ISTAC in 2017, which for several decades has been characterized by the search for a sustainable growth model, favouring the conservation of its environmental wealth and the use of its own resources in the framework of development actions.

Also known as the Meridian Island, El Hierro rises 1,500 meters above sea level, which results in a unique landscape with steep slopes permanently hit by the wind. This contributes to an annual average wind speed between 7.2 – 8.4 m/s and a maximum wind speed of 30.8 m/s.

El Hierro suffered from double isolation due to its small size, low level of economic development, and strong dependence on the primary sector. Also, the lack of natural resources like water (e.g., desalination plants consume more than 45% of the total energy of the island) historically caused dramatic periods of emigration, decreasing the number of inhabitants on the isle (in specific young generations that had to emigrate to the other Canary islands or other countries). In this context, it maintained a total external dependence on energy supply. Until the wind pumped hydropower station entered into operation in 2014, electricity generation was based on fossil fuels (diesel) with the consequent environmental and economic costs.

The challenges addressed throughout the project "El Hierro 100% renewable energy island" are twofold: (1) gaining resilience and autonomy in energy supply while (2) becoming a sustainable island substituting fossil fuel-based energy with renewable energy sources.

Selected dimensions for theory development

In this case, the model is aimed to simulate the temporal evolution of citizens' opinions about the project to answer the following question: Which percentage of citizens will be in favour and which percentage will be against the expansion of the 100% renewable El Hierro project based on a given political scenario? Therefore, the purpose of the model is to study the acceptability of the expansion of the Renewable El Hierro project, once the citizens have experienced the first phase of the project.

The HUMAT integrated framework was used to model the process of attitude formation among the residents of El Hierro Island. As described in Deliverable 7.3 (Antosz et al., 2020), the El Hierro agent-based model is very similar to the Vitoria-Gasteiz agent-based model concerning design and contents, with variations to account for differences in data sources, citizens' needs, entities, and actors involved in the model and their policy strategies.

The main entity (agent) of this model is the citizen, which has two behavioural alternatives: either to accept or to reject the expansion of the project. In this case, in the questionnaires, a high number of citizens stated that they were undecided in their position both concerning the initial project (around 30%) and in their support for the expansion of the project (50%). For this reason, a change was made to the HUMAT model. Although the agents continue to take a (binary) position for or against the project based on a threshold, a third internal state of indecision is introduced. This state influences the behaviour when interacting in the social network: both in the inquiring and the signalling processes (see Antosz et al., 2020, for details of these processes) as the agents tend to prioritize communication with other agents who are in the same state (in favour, undecided, or against).

The model also deals with several critical nodes that played a relevant role during the implementation of the project: the Cabildo (insular council), the opposition political parties, local media, Gorona del Viento (the company responsible for running the "Wind-Pumped Hydro Power Station") and other associations (environmental associations, tourism sector, etc.).

Different quantitative and qualitative procedures were used to collect relevant information to feed the system with case-specific data: analysis of the newspaper library, interviews with the promoters of the project, etc. Among them, a survey was conducted in 2020 to collect data from citizens. After the analysis of these data, six categories of citizens' needs (and their importance) were identified and included in the model concerning:

- Energy independence
- Environmental quality needs
- Economic sustainability
- Island prestige
- Participation needs, referring to the possibility of participating in city decisions, and
- Social needs, referring to belongingness, social safety, social status, etc.

Description of the selected dimensions

The main timeline implemented was:

1. 2002-2008 period in which the "100% renewable El Hierro" project was launched;
2. 2009-2014 period in which the execution works were carried out in Gorona del Viento; and
3. 2015-2020 period in which the project was put into operation.

Along this timeline, actors (critical nodes) influenced citizens for and against the project through various communicative acts that were extracted from the documentary analysis. Table 5 contains an example to show how this communication has been parameterized to be injected into the model: supporter or opponent indicates being for or against the SI; reach is the percentage of agents of the social network affected by the communication act; finally, some communications are made indirectly through other critical nodes, and this is indicated in the column Secondary Critical Node.

Table 5 Example of communication acts of critical nodes

Primary Critical Node	Behaviour	Starting Month	Starting Year	Ending Month	Ending Year	Frequency	Reach	Secondary Critical Node
Other Associations	opponent	10	2013	10	2013	1	0.2	Local Media
Gorona del Viento	supporter	11	2013	11	2013	1	0.2	Local Media
Local Media	supporter	12	2013	12	2013	1	0.2	Local Media
Gorona del Viento	supporter	12	2013	12	2013	1	0.1	Local Media

Cabildo	supporter	3	2014	3	2014	1	0.1	*Cabildo*
Cabildo	supporter	9	2014	9	2014	1	0.1	*Cabildo*
Political Opposition	opponent	12	2015	12	2015	1	0.3	Local Media

As already mentioned, the communication strategies applied by the critical nodes in this model are crucial for citizens to evolve and change their position. For the model to reflect reality, the communicative acts and their orientation in the three stages of the project were analyzed, and the following conclusions have been drawn:

1. In the first stage of the project (2002-2008), communications were mainly oriented to energy independence in the speech of the promoters and are present in 50-60% of the communications. Moreover, the frequency of communications between promoters and citizens is very low (around 2 per year).
2. In the second stage of the project (2009-2014), the orientation of the messages from the promoters was focused on more different aspects. Although energy independence continues to be present in 100% of the messages, other aspects are also present, such as prestige (50%), environmental quality (25%), and economic sustainability (25%). During this period, the frequency of messages launched by promoters also increases. The voices against (influencers, Ecologist Association) guide their communication to criticize the messages on energy independence (they deny the official message of being able to be 100% renewable), participation (they attribute a lack of transparency), and environmental quality (they denounce the impact plant/wind energy).
3. In the project's third stage (2015-2020), energy independence continues to be present in 100% of the promoters' messages. The presence of other aspects is also increased: environmental quality (50-100% depending on the year), prestige (50-100% depending on the year), and economic sustainability (50-100% depending on the year). It should be noted that in 2015, after the plant's start-up, communications were not focused on economic sustainability and that in 2017 communications were not oriented towards prestige. In this period, the frequency of communications from one of the main promoters (Gorona del Viento) increases, and, in addition, direct activities are carried out, such as the distribution of led bulbs, visits to the plant, etc.

The interface of the model is presented in Figure 7. In the centre, the map of El Hierro island is shown with citizen agents placed in their corresponding census section, those in favour of the SI coloured in green and those against in red. As mentioned, in this case, the model also deals with undecided citizens that are represented with blue colour. As the model evolves, the colour of any citizen can change.

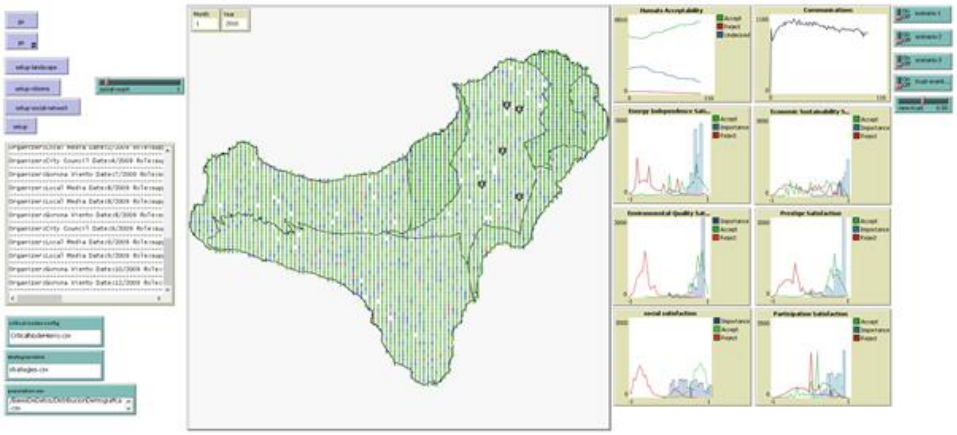

Figure 7 Interface of the model for the El Hierro social innovation case

On the left side, a text box is displayed showing information about the communication acts being launched by a critical node. On the right side, 8 graphics show a) the evolution of agents accepting (green)/rejecting (red) the SI or undecided about it (blue), b) the number of agents being communicating and c) the evolution of the satisfaction/dissatisfaction of the six specific needs together with the importance of each (histogram in blue).

This model has been designed to reproduce the basic timeline of several phases of the design and creation process, as previously described. To calibrate the model, field data from the case of El Hierro has been used (surveys, in-depth interviews with key informants, press releases, local media analysis) but also some relevant items that emerged in discussion with promoters and the stakeholders during the policy scenario workshops.

As stated in Deliverable 7.3 (Antosz et al., 2020), the data for the agents was fed directly from the questionnaires, and it was replicated proportionally to census and according to the population categories identified by using Decision Trees (see Figure 8) and following the procedure described in (Alonso-Betanzos et al., 2021).

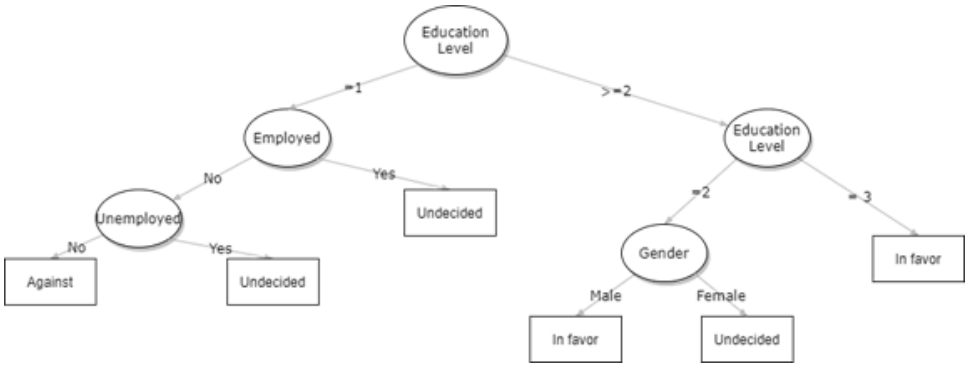

Figure 8 Population categories identified as relevant to the acceptance or rejection of the project

The model has several parameters, as listed in Deliverable 7.3 (Antosz et al., 2020). In the interest of model simplicity and to make it easier to use, the values of many of them have been derived by applying theoretical knowledge.

Results of the model regarding the selected dimensions

The model underwent a sensitivity analysis and calibration of the parameters to reproduce the basic timeline faithfully. In this section, we will show the results over this main timeline, considering that our desired outcome is to see how the number of agents who have accepted the SI project of El Hierro evolves.

Initially, the three stages of the project were implemented; however, as mentioned, in the first period, communicative acts are very scarce, especially during the first two years, and mostly in favour of the SI. Therefore, the influence on the population is very little or not significant, and there are no appreciable changes in the model's state. For this reason, we have focused the playback of the timeline on years 2006-2008 of stage 1, stages 2, and 3.

Table 6 shows the results at the end of the timeline, where it can be observed that the model ends in 2021 with a high percentage of the population undecided about the project, which is coherent with the data obtained with the surveys. Also, Figure 6 shows the evolution of the number of agents accepting the SI from 2006 to 2021, showing that the model correctly reproduces the ground truth. As can be observed, a decrease in acceptability began around 2016 that barely recovers in 2020. This circumstance coincides with the third stage of the project in which it was put into operation and was explained by the stakeholders. The main reason for the public's disenchantment with the project was a misunderstanding since most of the population assumed that the project would lead to a reduction in the electricity bill.

Table 6 Percentage of agents accepting, rejecting or undecided about the El Hierro SI after running the model (average results of 100 runs). Mean percentage of agents and standard deviation (SD)

Accept (%)	SD (%)	Reject (%)	SD (%)	Undecided	SD (%)
51.16	3.73	10.02	0.72	38.82	3.63

Policy scenario development

Two rounds of workshops were carried out involving the stakeholders of the projects. The second round was devoted to policy scenarios. There were two objectives during this workshop. The first one was to present the simulated timeline to ensure that it was faithfully reproduced (validation through experts). One issue addressed was the low presence of opposition to the project reflected in the timeline analysis and the bias of the survey results towards acceptability. In the discussion, some facts that generated the population's discontent during the project implementation process came to light (not previously reflected in the documentary analysis), which were incorporated into the model. The second objective was to define alternative hypothetical scenarios of interest to stakeholders. Several possible alternative scenarios were discussed, among which, finally, those for which it was possible to obtain all the necessary information to enter them into the system were chosen. Specifically, these were the considered scenarios:

SCENARIO 1	A) Change the **orientation** of communication: focus it on the

	dimension of **economic sustainability** B) **Increase** communications from promoters: new communicative actions focused on the dimension of **economic sustainability**
SCENARIO 2	Creation of a new event focused on satisfying the needs of **prestige and economic sustainability**
SCENARIO 3	A) Promote **meetings between *cabildo* and citizens** in census sections **in significant periods** of the project B) **Meetings between *cabildo* and citizens** in census sections **during the whole project** with an intensification of meetings in the definition phase of the project

Experimentation with policy scenarios

Description of experiments

All the simulated scenarios start from the project's original timeline as presented above and include new communication strategies from different critical nodes aiming to overcome conflictive situations. Analogously to the initial situation, 100 simulations have been carried out for all scenarios, and the average results will be shown.

Scenario 1: Changing the communication of the promoters towards the population's specific needs and adding new communications at key moments of the project

This scenario was already proposed in the 1st workshop, and during the 2nd part of the stakeholders insisted on the need of improving the communication carried out by the project promoters about the project with the goal of "ensuring that the citizens perceive the project's benefit, as this is the most effective in terms of their acceptance". The idea is to counteract the negative perception derived from the citizens' misunderstanding that the Gorona del Viento plant was to reduce the electricity bill, thus generating a high distrust in the project when citizens did not receive any direct economic benefit.

This participant's perception matches the survey results, as the factor that influences the most the decision of the citizens to vote in favour or against the project is its economic sustainability, followed by prestige, which is directly related (as the increase in the prestige of the island has a consequence in the number of visitors, tourists and income of residents).

Two different situations (1.A and 1.B) were tested in scenario 1, for which the frequency of communicative actions from promoters is increased, especially in the 2014-2020 period, in which a loss of support from citizenship to the project is identified. The difference among both situations is the focus of these communications:

A) The focus is economic sustainability;

B) The focus are economic sustainability, prestige, and environmental quality (the three more relevant needs for the inhabitants of El Hierro, according to the survey).

Table 7 illustrates the results of this Scenario. For the sake of comparison, the first row shows the base result obtained with the original timeline. Compared with the original situation, there is a notable increase in the number of agents who accept the innovation (from 51% to 71% in the best of the cases), mainly due to a notable decrease in the number of undecided (up to 19%). However, there is also a slight decrement in the number of agents who reject the social innovation (around 1%). This recovery of people's confidence in the project is also reflected in the acceptability curves in Figure 9.

Table 7 Number of agents accepting, rejecting or undecided about the El Hierro SI after running the model for Scenario 1 (average results of 100 runs). Mean percentage of agents and standard deviation (SD)

Scenario	Accept (%)	SD (%)	Reject (%)	SD (%)	Undecided	SD (%)
Base	51.16	3.73	10.02	0.72	38.82	3.63
1A	64.48	2.48	9.28	0.85	26.04	2.17
1B	71.45	2.28	8.91	0.79	19.64	1.80

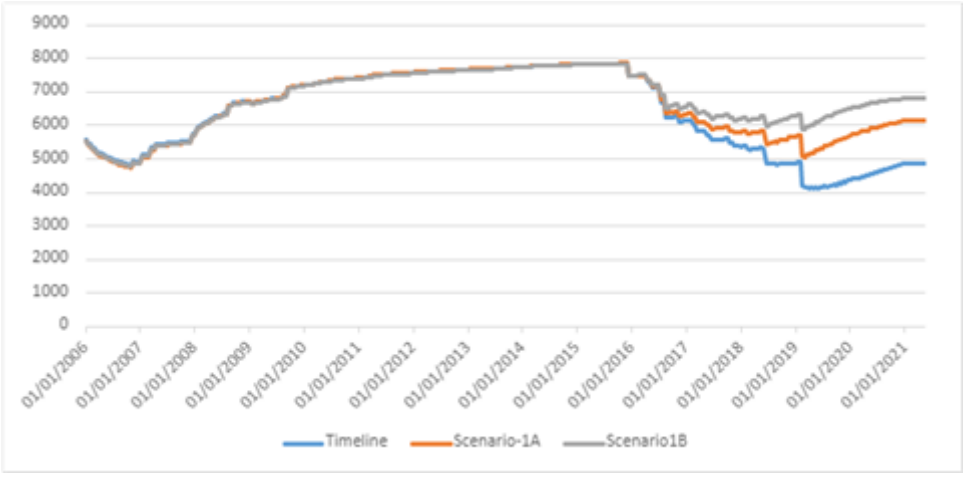

Figure 9 Evolution of the number of agents accepting the SI from 2006 to 2021. Comparison between the basic Timeline and scenarios 1A and 1B

Scenario 2: A new event satisfying the needs of prestige and economic sustainability

This scenario is based on a proposal of the 1st workshop, and it is focused on promoting a divulgation event on the island, a fair on renewable energy, in January 2015. The fair is a relevant showcase that contributes to enhancing the reputation of El Hierro as a sustainable island with an added economic benefit. The fair in January 2015 is a strategy to counteract the negative effect of the plant opening in June 2014, and especially the article that was published in the local press by two Gorona del Viento ex-engineers. The model showed that this event is a tipping point in the plant's perception by the citizenship; from that moment on, the acceptability of the project descents. This scenario was implemented in two versions.

Scenario 2 A include the following actions:

- A specific communication campaign of the promoter (Gorona del Viento) focused on the needs of prestige, economic sustainability, and environmental quality (mind that they were the three most relevant according to the survey), maintaining economic independence. The campaign's duration is four months, with different communicative actions before, during, and after the fair.
- The press will be a relevant critical node, reinforcing Gorona´s message (as usual in El Hierro); therefore, it will carry out one communicative act before, during, and after the fair.
- The Cabildo will be another relevant critical node reinforcing Gorona's message (as usual in El Hierro). Similarly, they will generate communicative acts: two instead of only one, again before, during, and after the fair.
- Attendance to the fair: due to the attendance at this event, HUMATS, i.e. simulated residents, exchange opinions about the social innovation for 1-3 months.

Scenario 2B: This scenario is aimed to test the effectiveness (if influence in social acceptance is achieved or not) of repeating the fair event in the following years. So, instead of having the fair just in 2015, this scenario considers three fairs, one per year, 2015, 2016, and 2017.

Table 8 shows the results obtained in this case. Similar to the previous scenario, this scenario also significantly increases the acceptability in the social innovation (more than 16%) compared to the original situation, although it does not reach levels as high as scenario 1. Again, this difference is due to a relevant percentage of undecided agents who are convinced by the actions and change to accept the social innovation in this scenario. Figure 10 shows the evolution of the level of acceptability. It is important to note that Scenario 2B achieves better results than 2A, which emphasizes the importance of holding communicative acts for a longer time.

Table 8 Number of agents accepting, rejecting or undecided about the El Hierro SI after running the model for Scenario 2 (average results of 100 runs). Mean percentage of agents and standard deviation (SD)

Scenario	Accept (%)	SD (%)	Reject (%)	SD (%)	Undecided	SD (%)
Base	51.16	3.73	10.02	0.72	38.82	3.63
2A	54.47	3.59	9,82	0.87	35.71	3.43
2B	68,97	2,41	8.76	0.72	22.27	2,08

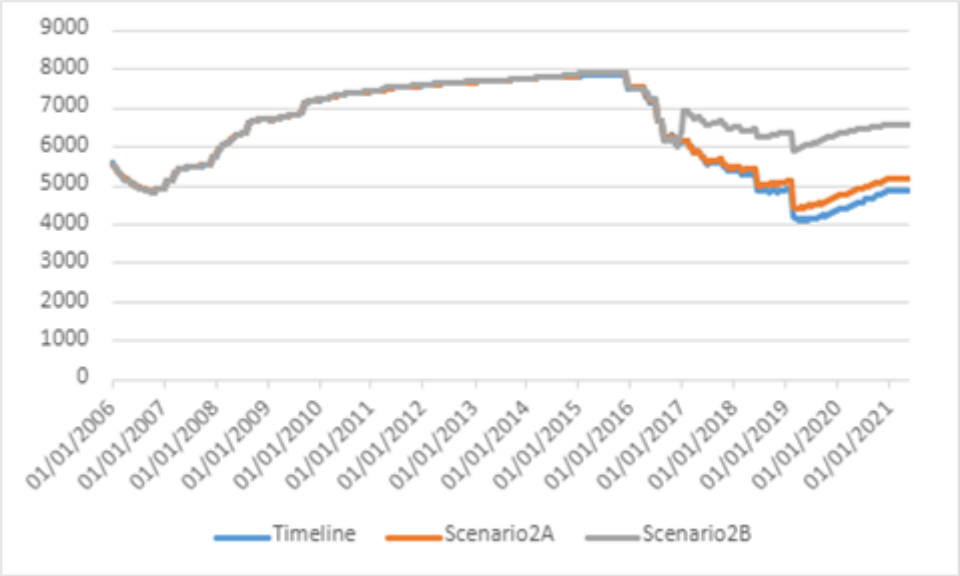

Figure 10 Evolution of the number of agents accepting the SI from 2006 to 2021. Comparison between the basic Timeline and scenarios 2A and 2B

Scenario 3: Intensification of communication between the *Cabildo* and the citizens

This scenario was proposed at the 2nd workshop on political scenarios in El Hierro, but it was not debated because it was pointed out that the organization of meetings in different municipalities was avoided at the time “so as not to have to explain certain things in a certain degree of detail until the objectives were achieved, which were to start up the plant and get a retribution, etc.”. However, other participants in the workshops acknowledge that at one point, the *Cabildo* stopped actively informing residents about the evolution of the plant, especially when the money had already been obtained and the work was underway.

Again, this scenario was implemented in two versions.

Scenario 3A. Face-to-face meetings in census sections in significant project periods (January 2007, April 2014, January 2015, June 2018). Given that the promoters (cabildo) initially ruled out this scenario for anticipating social unrest, it might be of interest for them to know what would have happened if meetings had been promoted at the municipality (or census district) level in significant stages of the project. At different stages, the cabildo sends a call (1 communicative act) to the HUMATS to present some relevant aspects of the project; due to these acts, HUMATS then hold face-to-face meetings whit their social networks, more actively, for 1-3 months.

Scenario 3B. Intensification of the meetings in census sections in significant phases of the project. The scenario consists of the intensification of the participatory strategy at the beginning of the project and throughout its development to promote a shared vision about the energy transition of El Hierro and the appropriation of the project "100% renewable El Hierro" by the citizens of the island (strategy: co-definition of a shared vision for El Hierro). In this case, the communication strategy of the cabildo is to reach all the inhabitants of the island through "face to face" meetings with citizens to inform them about the project and address all needs.

Table 9 shows the number of agents accepting the innovation once the model is run under approaches 3A and 3B of this scenario. Similarly, Figure 8 displays agents accepting the SI in executing these scenarios from the period of the basic timeline. Both Table 9 and Figure 11 reveal the same conclusion, scenario 3B leads to more agents accepting the project, resulting in the idea that providing more information to the public will result not only in better acceptance at the end of the project but also in less controversy during its development. In Figure 11 (see scenario 3A), we can appreciate the impact of the meetings in 2007 and 2018.

Table 9 Number of agents accepting, rejecting or undecided about the El Hierro SI after running the model for Scenario 3 (average results of 100 runs). Mean percentage of agents and standard deviation (SD)

Scenario	Accept (%)	SD (%)	Reject (%)	SD (%)	Undecided	SD (%)
Base	51.16	3.73	10.02	0.72	38.82	3.63
3A	62.40	2.38	9,88	0.76	27.72	2.13
3B	71.24	2.88	9.24	0.88	19.52	2.39

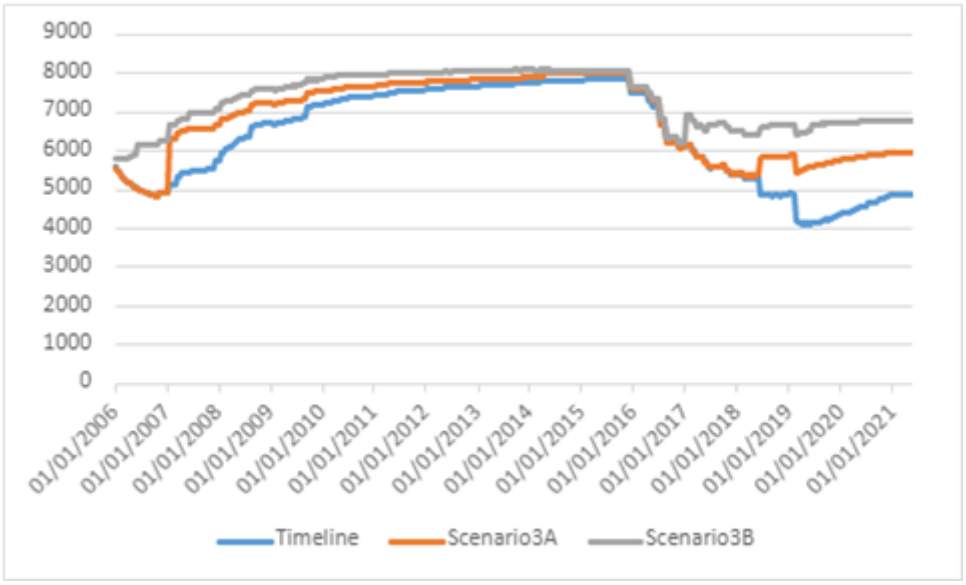

Figure 11 Evolution of the number of agents accepting the SI from 2006 to 2021. Comparison between the basic Timeline and scenarios 3A and 3B

Final considerations

The El Hierro model aimed to study the project's "El Hierro 100% renewable energy island" acceptability by citizens once they have experienced the first phase. In order to reach this purpose, in the model, the main agent is the citizen, who has two behavioural alternatives: to accept or reject the expansion of the model. Three alternative strategies put in motion by the island council were tested, considering targeted communication addressing the needs of economic sustainability, prestige and environmental quality.

The results of the model suggest that focusing on the need for economic sustainability, increasing communication from promoters, creation of a new event directed at satisfying citizen's needs of sustainability and prestige, as well as intensifying meetings between the island council and citizens at key points in project development do have the potential to influence citizen's attitudes towards the social innovation, increasing the number of agents accepting the expansion of the project, mainly by decreasing the number of undecided individuals. Thus, these results move forward the notion that targeted communication strategies on relevant needs of citizens, coupled with providing more relevant information through meetings, can lead to a better acceptance of the project and less controversy during its development. In sum, strategies targeted at citizens' needs can influence their attitudes towards the SI, from undecided to acceptance of the project. These results complement the policy recommendations developed based on workshops held with stakeholders and reported in deliverable 5.2 (Dumitru et al., 2021), underlining the importance of implementing strategies for promoting acceptance from the beginning and maintaining them across the project. Thus, developing targeted communication strategies addressing the needs of the citizens, in combination with participatory approaches implemented with high frequency and sustained over time, can increase the citizen acceptability of the SI by changing the attitudes from undecided to acceptance.

2.3 Samsø case. Case study cluster 2: Islands and renewable energy.

Samsø is a Danish island in the Kattegat 15 km off the Jutland Peninsula. The community has 3,724 inhabitants and is 114 km^2 in area. Samsø is in the Central Denmark Region. Agriculture has been the primary occupation on Samsø for millennia, and nearly the entire island comprises cultured landscapes. Ecological agriculture and production are growing in Samsø, with a broad network of cooperating associations. It comprises farming of a large variety of vegetables, grains, and fruits, livestock meat and products, a dairy, a brewery, restaurants and cafés, candy production, permaculture, and forest garden experiments. Three hundred years ago, the island of Samsø had hundreds of operating windmills (therefore, there is a long tradition of using wind energy on the Island).

On Samsø, three successive projects involved the establishment of district heating plants, two of which were straw-fired (same as Samsø's original plant, which preceded the REI project) and one powered by wood chips and solar panels (2500 m2 solar panel system).

The Samsø model has been described in SMARTEES Deliverable 7.3 (Antosz et al., 2020). The agent-based model focuses on mobilizing residents of the Samsø town of Onsbjerg to participate in a district heating network project implemented in their neighbourhood. This was one example of district heating implemented on the island, along with the Nordby-Maarup and Ballen-Brundby cases. The main elements of the heat network project, also characteristic for the entire social innovation (Caiati et al. 2019), and reflected in the agent-based model include:

- A bottom-up approach, driven by a small number of active members of the local community building an alliance with expert organization of Samsø Energy Academy (Energiakademiet),
- Progressive character of the consensus-building through negotiation and dialogue to overcome conflicts and resistance,
- Credible and transparent communication (e.g., open minutes from the meetings and open budget documents),
- Resident co-ownership of the district heating infrastructure and the related economic gains,

- Energy Academy's capitalization on the experience (and lessons learned) through the set-up of three district heating networks in different parts of the Island.

Typical nodes/agents present in the model are residents of Samsø, divided into two groups. Residents of the Onsbjerg district where the heat network is installed, and residents of other districts. Individual residents have a set of needs that includes the motives of:

- Affordability (experiential need),
- High air quality (experiential need),
- Safety (experiential need)
- Renovation inconvenience (experiential need),
- Social need,
- Ecological values,
- Islander identity (value),
- Aesthetics (value).

Moreover, Islanders have a set of beliefs (cognitions) about how their current heating system and the new district heating satisfies those needs. For example, a resident might believe that the new district heating will be more affordable than the old system and that it will be less polluting for the air. Agents residing on the virtual version of the Samsø island differ for the degree to which these needs are important to them, and concerning beliefs about how satisfying it is to continue to use the default heating mode and how satisfying it will be to switch to the district heating network. Residents also have their individual cognitive dissonance tolerance threshold, which, if exceeded by the preferred alternative, requires them to take action to reduce it. Moreover, residents are characterized by gender, age group, education, and income levels. Individual residents form households.

The key findings of Samsø are drawn mainly from the analysis conducted in D6.1 (Pellegrini-Masini et al., 2019) of the interviews and from the research previously conducted on secondary data and reported in deliverables D3.1 and D3.4. Furthermore, simulations and policy experiments are described in D7.4

Description of the selected dimensions

Social demographics; age and socioeconomic status

The first set of social dimensions regard the role of social demographics of the Samsø population where we focus on age aspects and Socioeconomic status (SES) of the level of residents. Under SES, we capture educational attainment, occupational attainment, and household income. We select these dimensions as we expect that these aspects are important in one's decision to join the heat network.

The results section describes how social demographics, age and SES, play a role in this social innovation case.

Public grants and investment, The impact of pricing

The financial costs associated with joining the heat network are related to investment costs and operational costs. It is first possible to change the costs of joining the heat network, for example, by subsidizing the costs of joining a heat network. Also, of interest from a time-discounting perspective is the policy scenario where the fuel prices are expected to rise in the future. The more the agents perceive that fuel prices may rise considerably in the future, the more they may be motivated to join the heat network and invest now to save money in the long run.

Results of the model regarding the selected dimensions

Social demographics; age and socioeconomic status

We investigate the role of age and socioeconomic status by looking at differences between groups in deciding to join the heating network. In this set of simulations (10 repetitions), the population is N=15301. A majority of 50.03% (Standard deviation = 5.20) joined the heat network (see Figure 12).

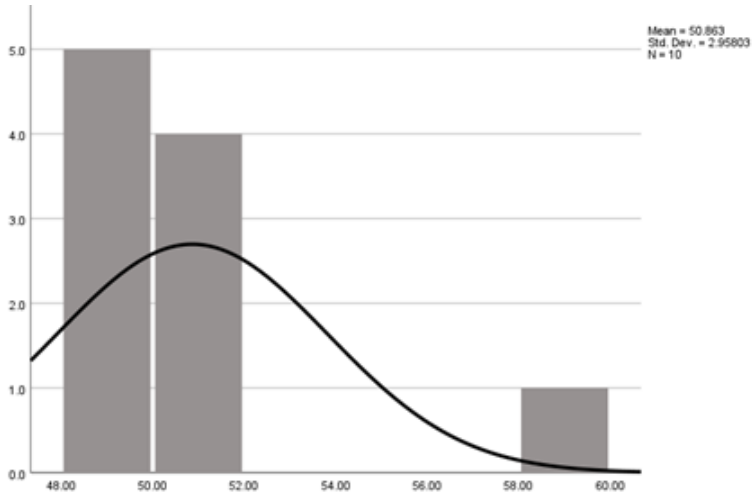

Figure 12 Average of citizens joining the heating network

The simulations show clear differences between both selected demographic groups as follows:

The role of age

The simulations show that there are differences between age groups in social innovation adaptation of joining the heat network. In particular artificial residents from the Samsø model belonging to the age group, 25-69 are more likely to adopt the social innovation and join the heating network (see Table 10).

Table 10 Joining the heating network across age groups

	% joins the heating network
Age 15-24	*10%*
Age 25-69	*54%*
Age 70+	*6%*

The role of socioeconomic status

The simulations show differences between groups with different SES in adopting the heat network (Table 11). It seems that individuals belonging to the group with higher SES are more likely to join the heating network.

Table 11 Joining the heating network across Ses

	% joins the heating network
SES: lower	*12%*
SES: middle	*16%*
SES: higher	*53%*

Public grants and investment, The impact of pricing

In this scenario, we explore to what extent the financial costs associated with joining the heat network are related to investment costs and operational costs. We implemented a case where the local government subsidizes the whole of installation costs; thereby, the weight of pricing on agents' motives is lowered, as the costs may become a smaller issue for some households.

The experimental simulations show that averaged over ten runs, in this scenario, a majority of 53.50% (Standard Deviation = 5.20) joins the heating network (Figure 13) with an increment of 3.47% compared to the baseline scenario where 50.3% of citizens join. Also, here we see that the policy does not affect the willingness to join for a small proportion of citizens as they were already convinced to join.

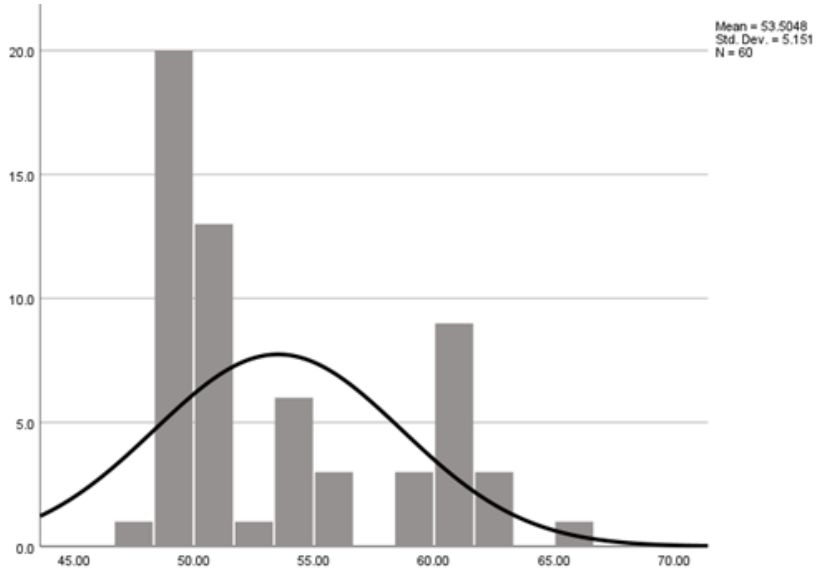

Figure 13 Distribution of citizens joining the heat network

Municipality Information campaigns

In this scenario, we explore how an informational campaign led by the municipality can be implemented by making certain needs more important in the agents. We focused on a case where an information campaign emphasizes (1) the improvement of the air quality when the heat network is implemented (experiential outcome), (2) the value of being independent of the mainland (value outcome), and (3) how the plant promotes sustainability as it decreases carbon emissions (experiential outcome).

This experiment shows that in this policy intervention scenario, 61,65% (Standard Deviation = 1.78) of the citizens would join the heating network after being exposed to the municipal information campaign (Figure 14). Compared to the baseline model without any policy scenario, the informational campaign mobilizes 11,3% agents more to join the heating network

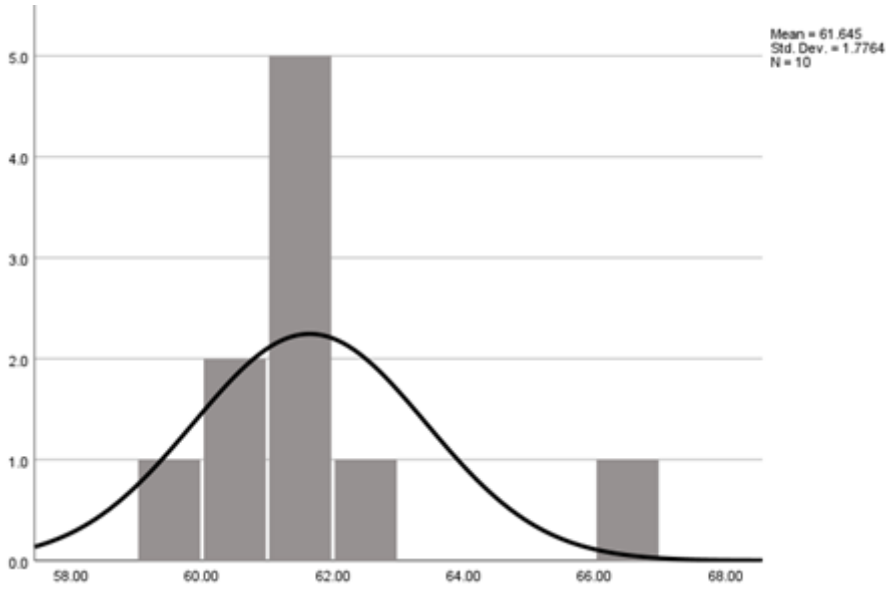

Figure 14 Distribution of citizens joining the heat network

Comments and considerations regarding selected dimensions and theory development of social innovations

Looking at the results regarding social demographics as dimensions that could represent important drivers for social innovation, the model results indicate that both age and socioeconomic status play a role in one's decision to join the heating network. Citizens of middle age and higher socioeconomic status are most likely to join, and elderly citizens with low socioeconomic status are least likely to adopt the social innovation.

However, in case of a price reduction, for instance, if the local government subsidises installation costs, more individuals would join the district heating, thereby making a difference for those interested but financially constrained households. The simulations on campaigns show that citizens can be further influenced in their opinions and decisions when information is spread via a campaign by the municipality.

Final considerations

The results of our simulations (in this report and Deliverable 7.4) show that both social demographics, local governmental subsidies, and information campaigns are important drivers of a social innovation and have the potential to influence the extent to which an individual regards the social innovation as important, forms an opinion and contributes accordingly. The results indicate that policymakers could focus on groups with financial constraints and see if there are ways to support citizens who have the willingness but not the resources to join. These results are completely in line with our reports on policy recommendations developed in the dedicated policy workshops held with various stakeholders (see deliverable 5.2). The bottom line for policy in the context of social innovation is involving people in the plans from early on, and making sure that the heterogeneity in the citizen population is represented in the development of plans to make sure that the plan is contributing as much as possible to the wellbeing of all citizens, and that the citizens have the experience that their perspective is considered to be relevant, even if the ultimate implementation still has some negative outcomes for a subgroup of citizens.

Table 12 Synthetic description of selected dimensions, results and their relevance for SIs' theory and policies

Dimensions selected	Description	Syntethic results	Theorethical and policy considerations
Social demographic characteristics			
Age	Age is categorized in 3 groups, namely; 15-24 25-69 70+	Citizens of middle age and higher social economic status are most likely to join, and elderly citizens with a low social economic status are least likely to adopt the social innovation.	Develop campaigns to target households that may not have the financial capability of joining the heating network to mobilize more households to join the heating network
SES	SES, consists of educational attainment, occupational attainment and income, categorized in 3 groups, namely: Lower Middle Higher	Citizens of middle age and higher socioeconomic status are most likely to join, and elderly citizens with low socioeconomic status are least likely to adopt the social innovation.	Develop campaigns to target households that may not have the financial capability of joining the heating network to mobilize more households to join the heating network
Public grants and investment, the impact	Joining the heating network has a cost for installation, in this	The majority joins the heating network (Figure 13). Also, here	Local governments can support and influence

of pricing	scenario in the ABM of Samsø, the local government subsidizes installation costs.	we see that for a small proportion of citizens, the policy does not affect their willingness to join as they were already very convinced that they wanted to join	households with financial constraints successfully by subsidizing installation costs.
Municipality led informational campaigns	a case where an information campaign emphasises experiential needs, personal values and social values, Specifically, on the topics of the improvement of the air quality, the value of being independent and sustainability	The overwhelming majority is influenced by being informed that social innovation may account for many of their needs and values. Informational campaigns mobilize citizens who were uncertain and significantly increase acceptability of the social innovation and willingness to join the heating network	The bottom line for policy in the context of social innovation is involving people in the plans from early on, and making sure that the heterogeneity in the citizen population is represented in the development of plans to make sure that the plan is contributing as much as possible to the wellbeing of all citizens, and that the citizens have the experience that their perspective is considered to be relevant, even if the ultimate implementation still has some negative outcomes for a subgroup of citizens.

2.4 The Vitoria-Gasteiz case. Case study cluster 4: Mobility in superblocks.

Vitoria-Gasteiz is a city with an extension of 276 km^2 and a population of close to 250,000 inhabitants in northern Spain. Some of its streets date from the 12th century, and it preserves much of its medieval layout intact. Some two decades ago, the city proposed a Sustainable Mobility and Public Space Plan partially based on a superblock model that reserves the space inside a part of the city (a block) for pedestrians and cyclists, with the final objective of recovering space for citizen´s use.

A superblock is an area of the city free from passing traffic. It is surrounded by roads where perimeter traffic is allowed, while inside, it is only allowed in the form of loops so that the cars that enter are again expelled to the perimeter roads. They also have some other internal restrictions like the type of parking allowed or a low-speed limit.

For this case, the agent-based model devised simulates citizen acceptance of the superblock project and how this acceptance is influenced by the actions and communications of relevant entities, such as the City Council, the press and other media, citizen's associations, and some others.

The Superblock "Sancho El Sabio" project had two phases, a preliminary one (from October 2006 until April 2007), and an implementation phase (from the end of the previous phase until 2012). Although there have been controversies and debates among the population, in a survey carried out in 2020 as part of the SMARTEES project, only about 15% of respondents of the questionnaires indicated to be against the superblocks social innovation. To date, three superblocks (Central, Sancho el Sabio, and Médico Tornay-Judimendi superblocks) have been completed, and actions have been implemented in 20 of the 77 superblocks scheduled in the Plan. Five more interventions are planned to be implemented in the period 2021-2023. Our objective in modelling the development process of this first superblock is to reproduce the evolution, over the years that this process lasted, of the levels of citizen acceptance to help determine which factors influence the population the most. And thus, be able to smooth the rejection curve in future similar projects.

Selected dimensions for theory development

The purpose of the model is to simulate the temporal evolution of citizens' opinions about the superblocks project and how it changes as policy actions take place. The model investigates which percentage of citizens will be both against or in favour of the superblock project based on different policy scenarios.

The model follows the general HUMAT architecture presented in Section 3 of Deliverable 7.2 (Antosz et col., 2019). The foundations of the Vitoria-Gasteiz agent-based model are described in detail in Deliverable 7.3 in Section 3 (Antosz et col., 2020), and results of simulations in different alternative policy scenarios are presented in Deliverable 7.4.

The main entity of the model is the citizen agent which has two behavioural alternatives: accept or reject the superblocks innovation. In addition, four critical nodes known for their relevance have been included after an exhaustive documentary analysis of the case: the city council, merchants' associations, other associations (grouping neighbours, cyclists, pedestrians, etc.) and local media.

Description of the selected dimensions

Different quantitative and qualitative procedures were used to collect relevant information to feed the system with case-specific data. A survey was conducted in Vitoria-Gasteiz in November 2020 to collect data from citizens about their needs, trust, and other socio-demographic aspects. After the

analysis of these data, it was decided that the citizen agents would be motivated to choose one or another alternative motivated by six types of needs:

- *Wellness* needs, which, among others, refer to health and security,
- *Environmental quality* needs, referring to air and noise pollution,
- *Comfort,* which, among others, refer to parking availability and price,
- *City prestige*,
- *Participation* needs, referring to the possibility of participating in city decisions, and
- *Social* needs, referring to belongingness, social safety, social status, etc.

The interface of the model is presented in Figure 15. In the centre, the map of Vitoria-Gasteiz is shown with citizen agents placed in their corresponding census section, those in favour of the SI coloured in green and those against in red. As the model evolves and citizen agents change their position, their colour is appropriately varied. On the left side, in addition to configuration options, a text box shows information about the communication acts being launched by a critical node to influence citizens. On the right side, there are eight graphics. The one on the upper left side shows the evolution of agents accepting (green) or rejecting (red) the SI (see Figure 16 for details) along the years. The one on the upper right side shows the number of agents being communicating. The remaining graphs show data for each of the six specific groups of needs (see Figure 17 for details): the satisfaction achieved on that need for the agents accepting or rejecting the SI (using the same colour pattern) and the importance of the need for the population (histogram in blue).

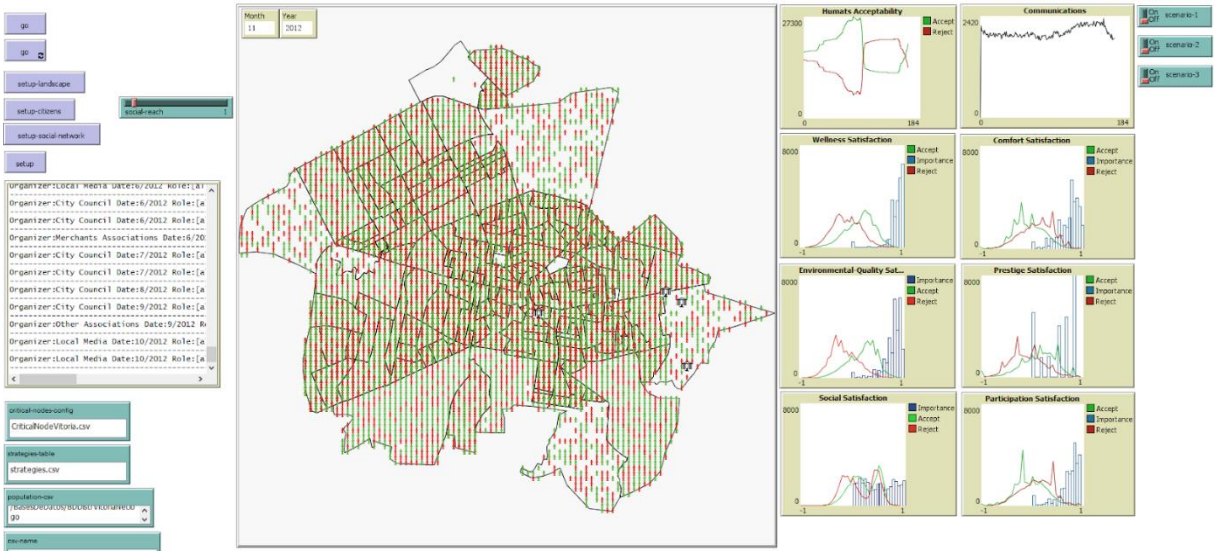

Figure 15 Interface of the mode for the Vitoria-Gasteiz social innovation case

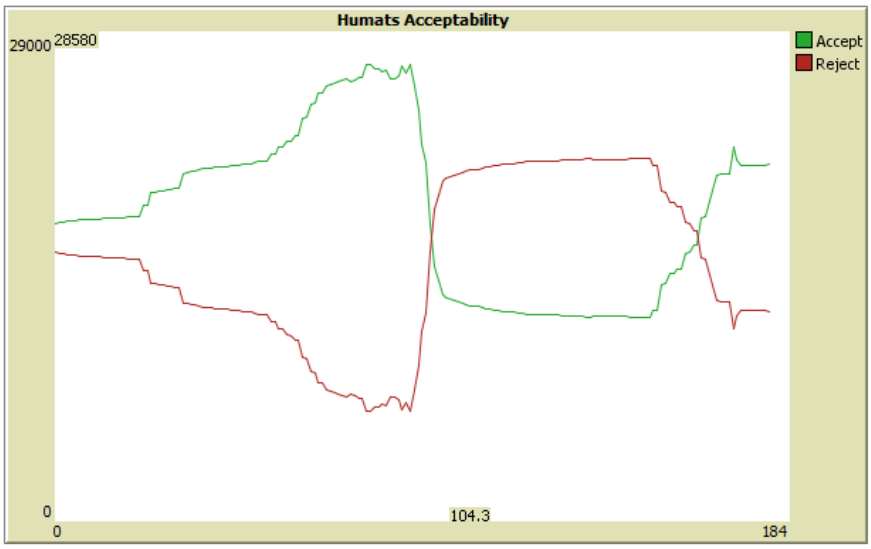

Figure 16 Graph of the evolutions of the global acceptance (green) and rejection (red) levels of the project among the population of agents. The curves correspond to the basic timeline of the project, through years 2006 to 2013 (equivalent to 180 ticks of model r

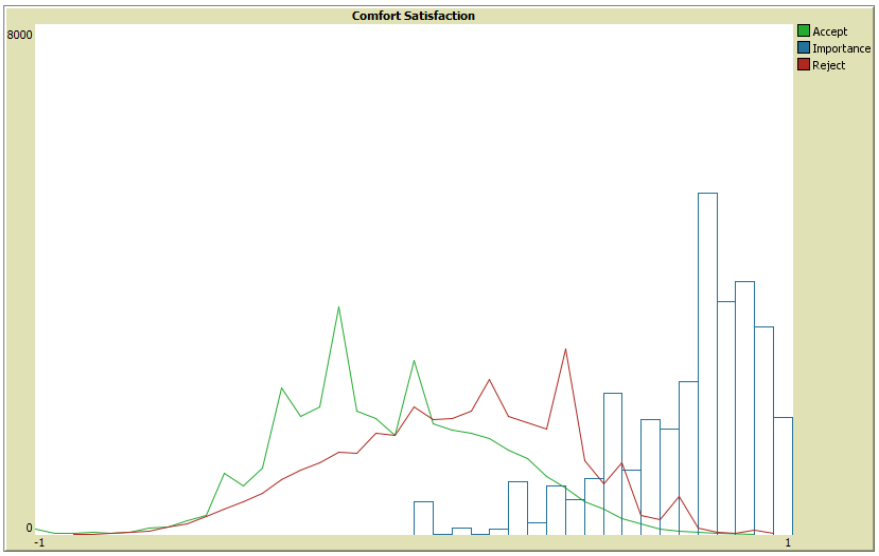

Figure 17 Graph of the evolution of global satisfaction levels in one of the needs produced by the acceptance (green) or rejection (red) of the superblocks project. The histogram (blue) refers to the importance of that need in the population of agents

This model has been designed and calibrated to reproduce the basic timeline of several phases of the design and creation process of three different superblocks in the city (covering from the presentation of the plan in 2006 to the implementation stage that lasted till 2012). In addition, the period from 2012 to the present (2021) has been added. To calibrate the model, field data from the case of Vitoria-Gasteiz has been used (surveys, in-depth interviews with key informants, press releases, local media analysis), but also the analysis carried out by the promoters and the stakeholders during the policy scenario workshops have been taken into account.

According to the survey carried out in Vitoria-Gasteiz in 2020, most citizens report having a favourable initial position concerning the superblocks project. Consequently, the ABM reached high

levels of acceptability of this social innovation in a very short period. This was consulted with the interested parties during the second policy scenario workshop, who identified memory and sample biases as factors to explain the high number of positive responses obtained from the survey since, after several years of successful implementation of the superblock, citizens would tend to raise their initial support for it. They also confirmed the significant opposition around 2010 due to changes in parking regulation and car restrictions policies in the pilot and central superblock.

The communication strategies applied by the critical nodes are crucial to allow citizens to evolve and change their position. As mentioned, for the model to reflect reality, the communicative acts for these two periods were extracted from documentary analysis. Given their relevance, they were analysed in the workshop with stakeholders. A problem found was the low frequency of negative opponent messages (with a very reduced number of communicative acts), which again causes fast acceptability of superblocks. According to one of the participants, since a certain consensus had been reached with the Citizen Pact for Sustainable Mobility, which obtained the support of political groups, relevant social groups and the local media, the opposite positions were little represented in the media discourse. In conclusion, the ABM accurately represents the communicative acts that took place in the modelled period.

Finally, the model was evaluated positively, as the stakeholders confirmed during the workshop that it could correctly reproduce the pattern of acceptability under the scenario representing the history of the case.

Results of the model regarding the selected dimensions

In this section, we will show the results of the model over the main timeline, taking into account that our desired outcome is to see how the number of agents who have accepted the superblocks SI is modified, although we will have a look also at the satisfaction achieved in the different groups of needs. We have run two different timelines for the model: the first one addresses the actual stages of the model (from 2006 to 2013, as described), while the other extends the run of the model to the present (2021). As mentioned, the communicative acts for these two periods were extracted from documentary analysis. It must be considered that 1) in the latter period, communicative acts are very scarce and mostly in favour of the SI, and 2) many citizens are in favour at the end of 2013. These conditions cause that almost the entire population is convinced of the superblocks' project with the progress of time, as illustrated in Table 13. As can be observed, the stability of the model is high, shown by its very low standard deviation. Additionally, Figure 18 shows the evolution of citizenry accepting the SI over time. Note that the alternative scenarios will try to increase the number of agents in favour of innovation where their needs are satisfied and correct the remarkable fall of the period 2010-2012.

Table 13 Number of agents accepting the superblocks' SI after running the model (average results of 10 runs)

TimeLine	Average number of agents in favour (%)	Standard deviation (%)
2006-2013	66.3	0.32
2006-2021	85.3	0.26

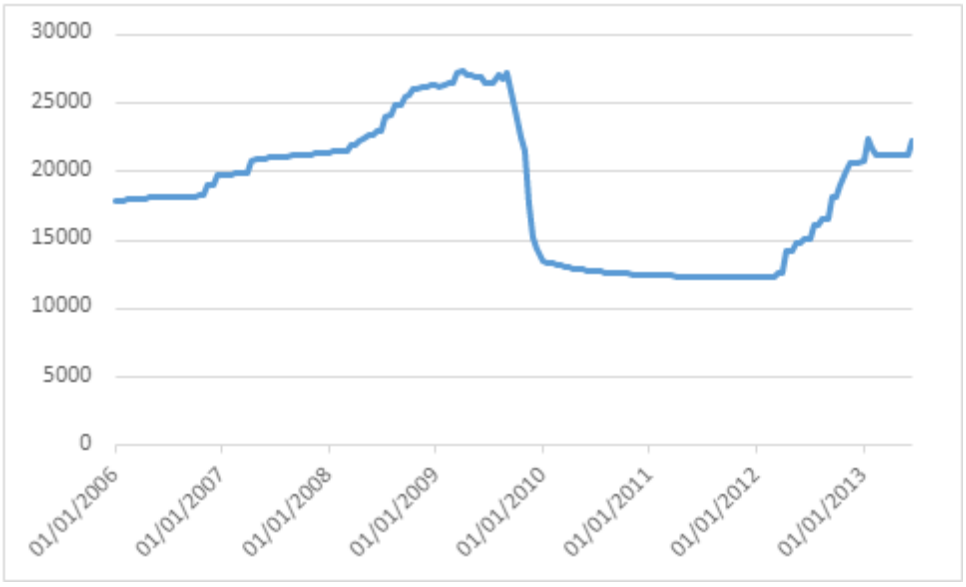

Figure 18 Number of agents accepting the SI from 2006 to 2013

Deliverable 7.4 can be consulted for the level of satisfaction of needs of the population of agents when accepting or rejecting the superblocks project: for the first timeline (ending 2013), comfort and participation needs, both accepting or rejecting the SI, carries the same level of satisfaction, however, the rest of the needs are better satisfied when the superblocks' project is accepted. Moreover, prolonging the execution in time (until 2021) causes the differences between accepting or rejecting to be more pronounced.

Overview policy scenario workshops

After two rounds of workshops with stakeholders, three possible alternative scenarios of interest were implemented in the model:

1. Modification in the strategy of the critical nodes: a new communication campaign would be conducted in the first stages of the project focusing on making citizens become more familiar with superblocks and increasing their level of support.
2. Addressing specific needs (e.g., comfort, that enhances the positive benefits of the superblocks model). It was argued that the communication concerning the changes the City Council implemented in parking space in 2010 could be improved, as the local media informed more about the negative reactions of citizens and merchants than the positive aspects of the measure. This negative information could be counted by increasing communications or providing alternative messages specifically oriented to groups of the population directly affected by these measures.
3. Involvement of a large number of citizens and local actors in the co-definition of the mobility policies. It was argued that a "top-down" approach was followed in defining the sustainable mobility and public space plan. Contrary to that approach, an alternative policy scenario would include "rethinking the participatory model" and articulating new formulas for citizens' participation at the neighbourhood scale. This scenario could be implemented in the model by testing the impact of meetings with citizens in specific neighbourhoods, enhancing communication among them.

Experimentation with policy scenarios

Description of experiments

All the simulated scenarios start from the project's original timeline as presented in Figure 18 and include new communication strategies from different critical nodes aiming to overcome conflictive situations or increase the acceptability of superblocks.

The simulated scenarios were extended until 2013 to see the effects of the alternative policies implemented (extending the timeline further will show the natural evolution of citizen's agents as they experiment with the superblock, but will not reflect the influence of the new policy. For a detailed explanation, see Deliverable 7.4).

Again, ten executions of the model have been carried out for each alternative scenario, and the average results will be shown in the following sections.

Scenario 1: Intensification of communication by promoters and supporters

In November 2009, a new parking policy was introduced in the city centre to dissuade using private cars. The measures taken consisted of increasing the on-street parking prices three-fold. Also, residents, who benefited from free parking before, should pay for parking in the centre. This policy was accompanied by a communication strategy that aimed to increase citizens' environmental awareness, focusing on the benefits of the Sustainable Mobility Plan and the superblocks model.

However, the measure was very unpopular, and the City Council had to deal with the strong resistance of the city centre residents and the retail sector. The residents' associations gathered about 13,000 signatures against the measure. This conflictive situation can be seen in the model (see the marked decay in acceptability in Figure 18).

This first alternative scenario tries to overcome this situation by using a more intense communication campaign, promoted mainly by the city council. The promoter's discourse will address the satisfaction of the need for comfort to anticipate the residents' discontent as they feel that their previous right to park is restricted.

To represent it, new communications emphasizing the benefits of superblocks for comfort (noise reduction, more free space for public use, and so on) are added to those already included in the original timeline (for specific details, please consult Deliverable 7.4). This alternative scenario was approached in different ways, trying to achieve a more significant impact on reducing the decrease in acceptability along years 2010 to 2012:

- Scenario 1.A. Orientation of new communications towards only comfort needs.
- Scenario 1.B. Orientation of new communications towards all needs. Although this approach is slightly different from the initial proposal, for the sake of comparison, it tries to see if the impact of communications to comfort is not diluted among the other citizen's needs.
- Scenario 1.C. Orientation of new communications towards only comfort needs but increasing the reach of the campaign.
- Scenario 1.D. Orientation of new communications towards only comfort needs but expanding the communication period. The communications started earlier (in 2007), trying to prevent the rejection of superblocks, and the number of communications was also increased.
- Scenario 1.E. Orientation of new communications towards only comfort needs, increasing reach and expanding the communication period. This approach combines both previous scenarios 1.C and 1.D.

Results from experiments from Scenario 1

As all approaches in Scenario 1 gave similar results, we will show the results of the base scenario (1A) and the one that leads to better results (1E). Table 14 illustrates the number of agents accepting the superblocks innovation once the model is run under approaches 1A and 1E of this scenario. Figure 19 displays the evolutions of agents accepting the SI in executing these scenarios from 2006 to 2013. Both Table 14 and Figure 19 reveal the same conclusion: scenario 1E leads to more agents accepting the project. Focusing on how the citizen's needs are satisfied, Figure 21 shows the results of the most moderate approach (1A), where only comfort-oriented communications are increased, while the results of the approach with more changes (1E) are shown in Figure 22. Both can be compared to the original situation depicted in Figure 20. It can be appreciated that, in the last scenario, there are more agents with a higher satisfaction value (above 0.3) in comfort needs.

Table 14 Number of agents accepting the superblocks' SI after running the model under different approaches of Scenario 1 (average results of 10 runs)

Scenario	Mean number of agents in favour (%)	Standard deviation (%)
Timeline 2006-2013	66.3	0.32
Scenario 1A	66.86	0.32
Scenario 1E	70.59	0.33

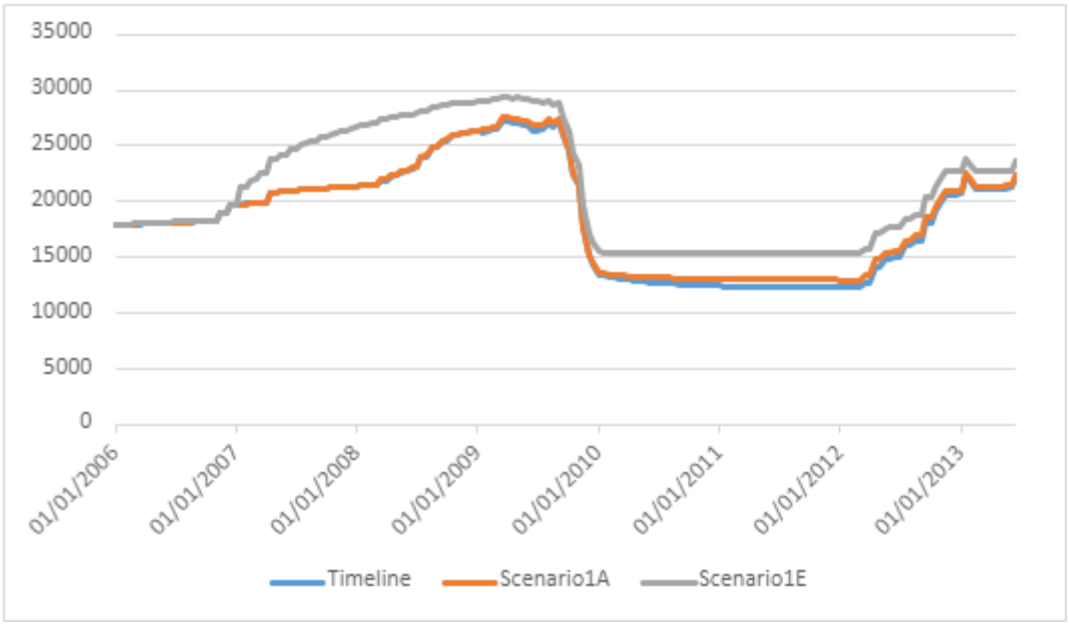

Figure 19 Number of agents accepting the SI from 2006 to 2013 in two different approaches of Scenario 1 (1A and 1E)

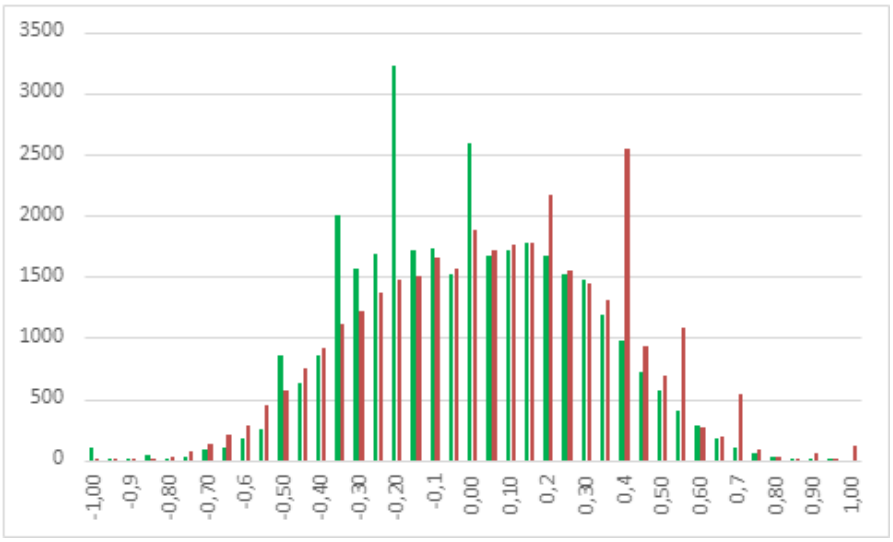

Figure 20 Original timeline (2013). Mean satisfaction for Wellness needs (from 10 different runs). The X-axis represents the level of satisfaction (from -1 to 1), whereas the Y-axis indicates the number of agents that accept (green) or reject (red) the superblock

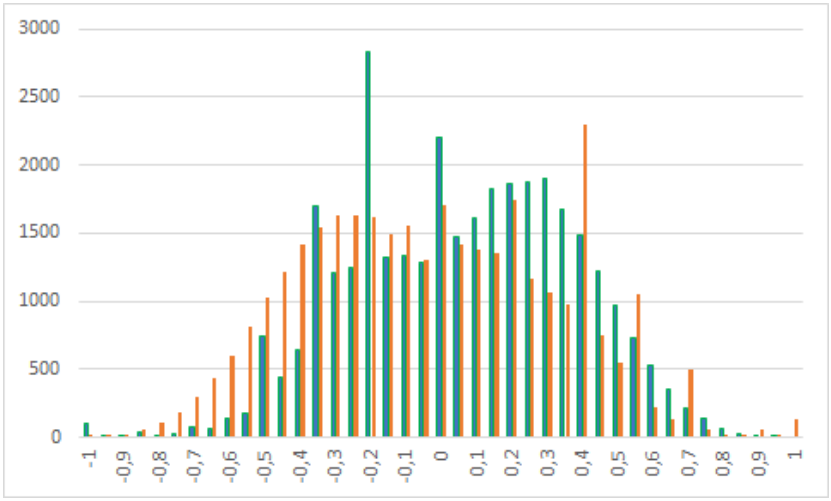

Figure 21 Scenario 1A. Mean satisfaction for Comfort needs (from 10 different runs). The X-axis represents the level of satisfaction (from -1 to 1), whereas the Y-axis indicates the number of agents that accept (green) or reject (red) the superblock project

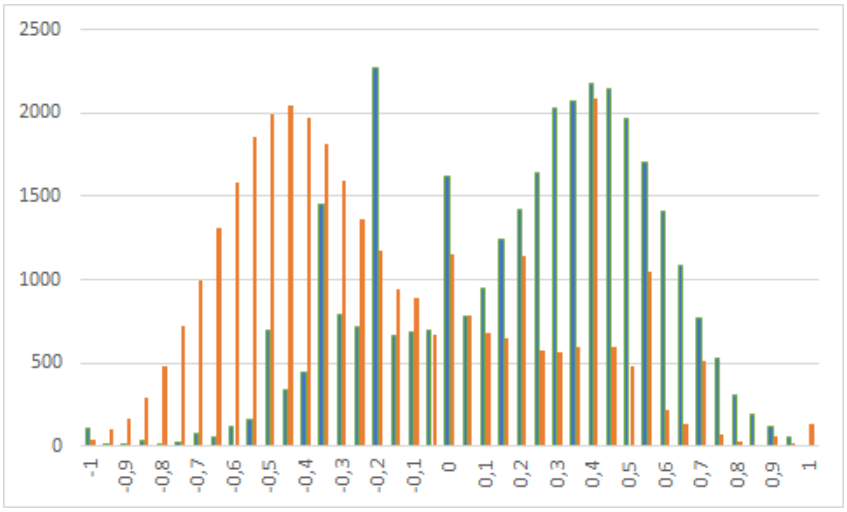

Figure 22 Scenario 1E. Mean satisfaction for Comfort needs (from 10 different runs). The X-axis represents the level of satisfaction (from -1 to 1), whereas the Y-axis indicates the number of agents that accept (green) or reject (red) the superblock project

Scenario 2: Meetings between citizens of the same census section

This alternative policy scenario consists of "rethinking the participatory model", trying to answer the question: If people have spaces to communicate among them and discuss the new policy, would the acceptability of the superblocks project improve?

In addition to the possibility of communicating with their social networks to solve HUMATS dissonances, the model includes the possibility of having random conversations between citizen agents (see section 4.1.3 in deliverable 7.3). This scenario increases these random and spontaneous conversations in controversial stages of social innovation dramatically. Specifically, each of the citizens that belong to a given census section will have a probability of 0.05% (a model parameter) of communicating with others in the same census section. Note that we are mentioning a percentage for each citizen, thus, in a census section with 100 inhabitants, each neighbour could talk to five of their neighbours, which significantly increases the total number of communications. The probability of having these conversations will progressively decrease (20% every 15 days), and so after three months, the conversations will resume their usual course. The conflictive stages that are taken into account and the actions carried out in the model are:

- July 2006. Meetings in all census sections when the Sustainable Mobility Plan is proposed.
- September 2009. Meetings in the census sections (46 of 188) affected by the increase in the price of outdoor parking.
- January 2012. Meetings in all census sections once the discrepancies regarding the outdoor parking issue have subsided.

5.3.1 Results from experiments for Scenario 2

Figure 23 shows the large increase in citizen agents communicating (both in favour and against the SI) at specified times (note that in a normal situation, around 2000 agents are communicating). However, this communicative overload barely affects acceptability, as can be seen in Table 15. The

differences with the original situation slightly exceed 1%, which, considering the city's current population, would mean an increase of around 2,500 more inhabitants in favour of the SI.

Figure 23 Scenario 2: Mean number of citizen agents communicating (average of 10 runs). The X-axis represents the temporal line, whereas Y-axis indicates the number of agents

Table 15 Mean number of citizen agents communicating after running the model for Scenario 2 (average results of 10 runs)

Scenario	Mean number of agents in favour (%)	Standard deviation (%)
Timeline 2006-2013	66.3	0.32
Scenario 2	67.4	0.36

Scenario 3: Citizen meetings and campaign to increase citizens' environmental awareness

The goal of this scenario is to change the orientation of the new communications to increase the importance of environmental quality and wellbeing so that the global satisfaction of the agents is also increased if they give more importance to those needs. Although it was initially treated separately, applying just an awareness campaign, better results were achieved by incorporating the previous scenario (including meetings between citizens). Thus, starting from scenario 2, this 3rd scenario incorporates an environmental awareness campaign for citizens from 2008 until 2010. Therefore, the city council will send information to all citizens regarding well-being and environmental quality to increase the importance of both needs for the citizens. We considered a high scope assuming that the campaign reaches 30% of the population. These communicative acts take place once a month, from January 2008 to June 2010.

It is important to note that this scenario aims to modify the importance the citizens give to those needs (not the satisfaction of those needs).

Results from experiments for Scenario 3

Similar to the previous scenario, there were hardly any differences between the baseline and the new scenario in this situation. Table 16 reports a 1.2% increase in acceptability at the end of the model execution. Figure 24 shows the evolution of this model that clearly overlaps with the original (and with scenario 2).

Table 16 Number of agents accepting the superblocks' SI after running the model for Scenario 3 (average results of 10 runs)

Scenario	Mean number of agents in favour (%)	Standard deviation (%)
Timeline 2006-2013	66.3	0.32
Scenario 3	67.5	0.34

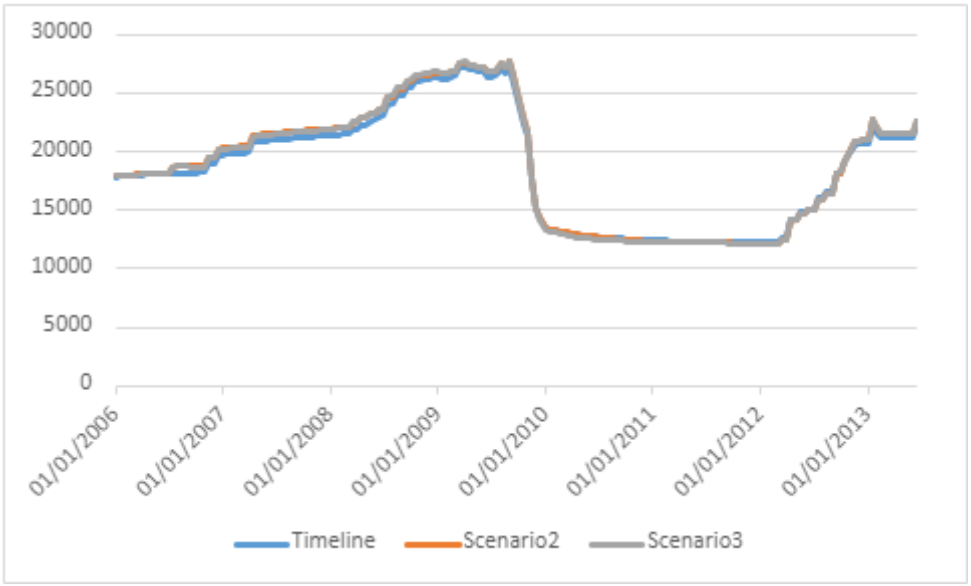

Figure 24 Number of agents accepting the SI from 2006 to 2013 for both Scenario 2 and Scenario 3

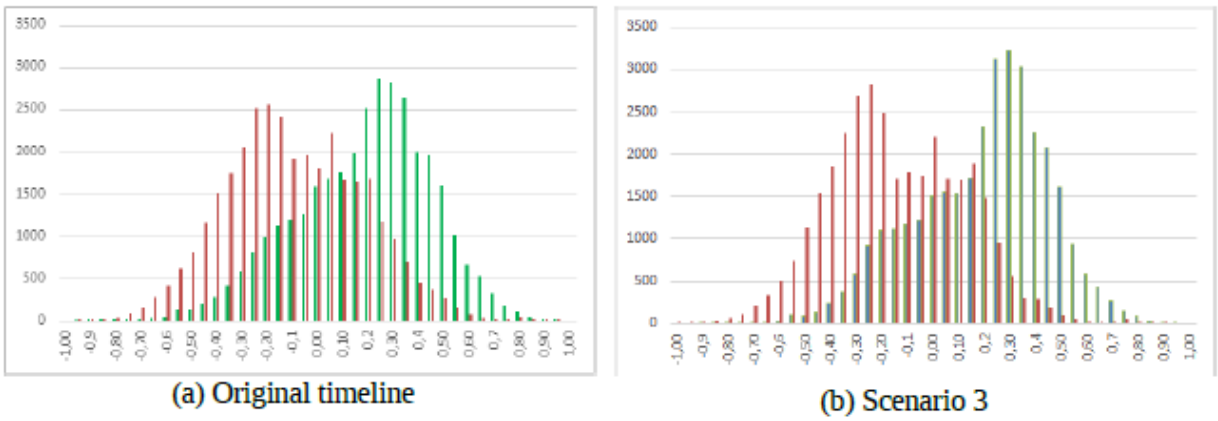

Figure 25 Scenario 3. Mean satisfaction for Wellness needs (from 10 different runs). The X axis represents the level of satisfaction (from -1 to 1), whereas the Y axis indicates the number of agents that accept (green) or reject (red) the superblock project

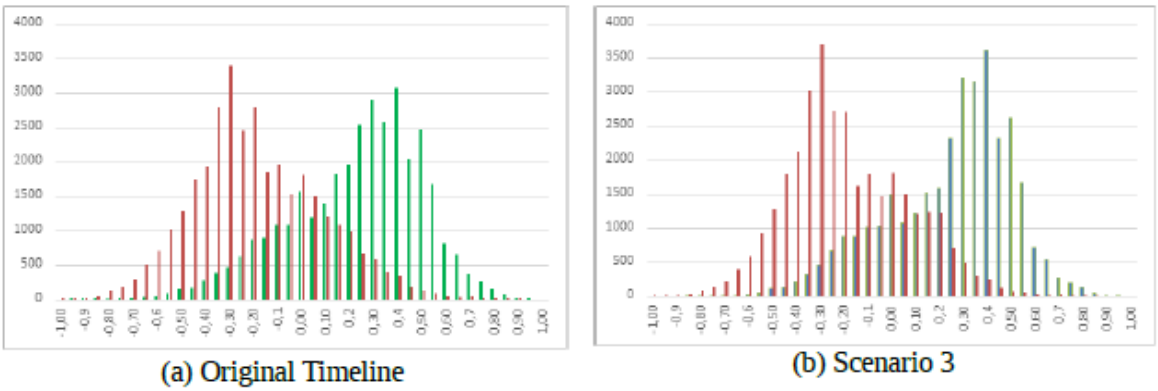

Figure 26 Scenario 3. Mean satisfaction for Environmental Quality needs (from 10 different runs). The X axis represents the level of satisfaction (from -1 to 1), whereas the Y axis indicates the number of agents that accept (green) or reject (red) the superblock

Figure 25 and Figure 26 display the final satisfaction experienced by citizens for Wellness and Environmental Quality needs in the original timeline versus the third scenario. Although the difference is not very relevant, if we focus on the peak of the curves where the density of agents is higher, we can observe a slight increase in the number of agents who experience an acceptable level of satisfaction supporting the project when communication is focused on emphasizing the importance of these aspects. Reciprocally, the number of agents who experience a level of dissatisfaction when rejecting the project also increases.

Final considerations

Communication campaigns targeting comfort needs achieve a limited increase in consensus towards the SI project, thereby not reversing the deep drop of consensus registered due to the three-fold increase of parking fees in the city centre and the institution of parking fees for residents. The most successful communication campaign modelled achieved a 4% improvement in consensus: this suggests that in perceived high-cost situations, campaigns have a limited impact on citizens' responses towards an implemented policy.

Increasing citizens' meetings, i.e. their interactions, did not significantly affect the SI's interventions' consensus. This seems to suggest that while providing meeting opportunities for citizens could have a value in itself, this would not change their perception of locally implemented policies; this is clearly a

different situation from having meetings between citizens and representatives of the actors leading the SI's project, in this latter case, like shown in other cases' simulations, the social acceptance might rise.

Even when communication campaigns stressing the SI's intervention benefits about environmental quality and wellbeing are added to citizens' meetings in simulations, the results do not change with a very modest increase in acceptance of the SI's interventions. Again, this appears to confirm that if residents perceive the SI's interventions to generate a high cost for them, communication strategies to raise consensus based on altering citizens' attitudes are likely to fail.

2.5 The Barcelona case. Case study cluster 4: Mobility in superblocks.

Barcelona is a pioneer city in establishing superblocks areas, with the first superblocks created in the El Born and Gràcia districts in 1993 and 2006, respectively. Inspired by these positive experiences, in September 2016, the City Council extended the superblock management model throughout the city, responding to the city's scarcity of green spaces, high levels of pollution, environmental noise, accident rates, and unhealthy lifestyles. Superblocks are implemented to enhance the habitability of public spaces, increase urban greenery and biodiversity, and promote low carbon mobility.

Barcelona city is planned to be organized into 503 superblocks through the Urban Mobility Plan, as approved in the 'Let's fill the streets with life' superblock program (2016). The plan is being implemented by the Municipality of Barcelona, also receiving technical support from other municipal areas. Superblocks in Barcelona have received social support and acceptance in certain areas (e.g., Sant Antoni, Horta) and high levels of protests and contestation in others (e.g., pilot superblock in Poblenou) that have been reduced over time. Social contestation was motivated by the lack of information and social participation before starting the urban interventions. Changes in the pilot project were made after, following the suggestions of residents and the citizens' associations in the area. In the succeeding superblocks, public participatory processes have been launched. The outcomes of the superblocks program have been assessed in three pilot interventions, measuring positive outcomes in the following dimensions: improvement of environmental and public space conditions, increase in green areas, enhancement of social activity, and social interaction in neighbourhoods. El Poblenou's Superblock received a "special mention" at the 2018 European Prize for Urban Public Space.

Selected dimensions for theory development

In this case, the model is aimed to simulate the temporal evolution of citizens' opinions about the project to answer the following question: which percentage of citizens will be both against and in favour of the superblock project based on different policy scenarios?

For this case, and considering that Barcelona is a city with more than a million and a half inhabitants, data acquisition (from surveys to documentary analysis) was centred on two superblocks areas: Sant Antoni and Poblenou. As previously commented, there was hardly any public opposition at Sant Antoni, and the superblocks project was usually accepted. However, the case of Poblenou was the opposite, and there was a strong social protest, so the latter is the case modelled and thus able to simulate alternative policy scenarios that try to minimize social opposition.

The HUMAT integrated framework was used to model the process of attitude formation among the residents of Poblenou (Barcelona). As described in Deliverable 7.3 (Antosz et al., 2020), the Poblenou agent-based model is very similar to the Vitoria-Gasteiz agent-based model concerning design and contents, with variations to account for differences in data sources, citizens' needs, entities, and actors involved in the model and their policy strategies.

The main entity (agent) of this model is the citizen, which has two behavioural alternatives: either to accept or to reject the expansion of the project. As the agents tend to prioritize communication with other agents who are in their same state, this state influences their behaviour when interacting in their social network: both in the inquiring process, to know the opinion of others, and in the signalling process, for the agents to disseminate their opinion (see Antosz et al., 2020, for details of these processes).

The model also deals with several critical nodes that played a relevant role during the implementation of the project: the city council, the opposition political parties, local media, and other associations. In this model, associations play an important role and will be very active in their communicative acts. In addition, there are associations both in favour of the social innovation (for example, CSP9, collective Poblenou superblock) and against (PASP, acronym in Catalan for platform of those affected by the Poblenou Superblock).

Different quantitative and qualitative procedures were used to collect relevant information to feed the system with case-specific data: analysis of the newspaper library, interviews with the project's promoters, etc. Among them, a survey was conducted in 2020 to collect data from citizens. After the analysis of these data, six categories of citizens' needs (and the relative importance they give to each one) were identified and included in the model concerning:

- *Wellness* needs, which, among others, refer to health and security,
- *Environmental quality* needs, referring to air and noise pollution,
- *Comfort,* which, among others, refer to parking availability and price,
- *City prestige*,
- *Participation* needs, referring to the possibility of participating in city decisions, and
- *Social* needs, referring to belongingness, social safety, social status, etc.

Description of the selected dimensions

The main timeline implemented was:

1. May - September 2016, this period is considered the start-up of the pilot superblock.
2. September 2016, a period of citizenry information and participation is launched.
3. October 2016 - January 2017, a period in which the promoters maintain meetings with the associations of residents and those affected by the final design of the superblock.
4. March - September 2017, a period in which the final design of the superblock is implemented.

Along this timeline, critical nodes (actors) influenced citizens for and against the project through various communicative acts extracted from the documentary analysis. Table 17 contains an example showing how this communication has been parameterized to be injected into the model: supporter or opponent indicates being for or against the project; reach is the percentage of agents of the social network affected by the communication act; finally, some communications are made indirectly through other critical nodes, and this is indicated in the column Secondary Critical Node.

Table 17 Example of communication acts of critical nodes (Freq. stands for Frequency)

Primary Critical Node	Behaviour	Starting Month	Starting Year	Ending Month	Ending Year	Freq.	Reach	Secondary Critical Node
City council	Supporter	8	2016	8	2016	1	0.1	City council
Local media	Supporter	8	2016	8	2016	1	0.1	Local media
City council	Opponent	9	2016	9	2016	1	0.1	City council
Political opposition	Opponent	9	2016	9	2016	1	0.1	Local media
Other Associations	Opponent	9	2016	11	2016	1	0.3	Local Media
Other Associations	Supporter	9	2016	9	2016	1	0.3	Local Media
Local Media	Opponent	9	2016	9	2016	1	0.1	Local Media
Other Associations	Supporter	9	2016	9	2016	2	0.1	Other associations

As already mentioned, the communication strategies applied by the critical nodes in this model are crucial for citizens to evolve and change their position. For the model to reflect reality, the communicative acts and their orientation in the four phases of the project were analysed, and the following conclusions have been drawn:

1. The first phase of the project (May-September 2016) is just an experimentation period, with the start-up of the Poblenou superblock pilot. In this period, mainly the city council sends communications to the citizenry, and the local media publishes some news about it.

2. The project's second phase (during September 2016) is an information and public participation phase with debates in the street, sector meetings, information points, and an open day to assess the superblock proposal. The local government, as promoter, carries out many communicative acts, although so do associations both in favour (CSP9) and against (PASP) social innovation.

3. The third phase of the project (October 2016-January 2017) starts the final design of the superblock area, so the local authorities have meetings with the associations of residents and those affected for discussing this final design. There is a strong mobilization of both supporters and opponents associations at this period, and the local media take a relevant role.

4. The last phase of the project (March-September 2017) corresponds to the implementation of the final design of the superblock. Again, as the main promoter, the city council takes an active communication role, and there are some protests from associations against the

project (PASP), also supported by political opposition. However, other associations continue to express their support to the superblocks project (CSP9).

The interface of the model is presented in Figure 27. In the centre of the map, the area of Poblenou is shown with citizen agents placed in their corresponding census section, those in favour of the superblocks project coloured in green and those against in red. As the model evolves, the colour of any citizen may change.

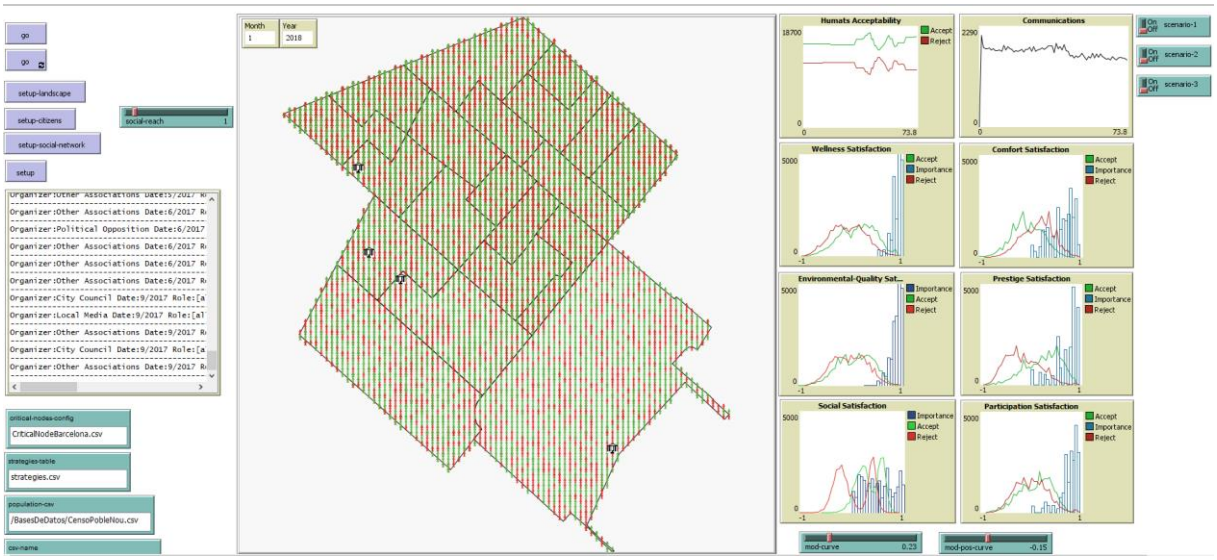

Figure 27 Interface of the model for Poblenou social innovation case

On the left side, a text box shows information about the communication acts being launched by a critical node. On the right side, eight graphics show a) the evolution of agents accepting (green)/rejecting (red) the SI, b) the number of agents being communicating and c) the evolution of the satisfaction/dissatisfaction on the six specific needs together with the importance of each (histogram in blue).

As previously described, this model has been designed to reproduce the basic timeline of the several phases of the design and creation process. To calibrate the model, field data from the case of Poblenou has been used (surveys, in-depth interviews with key informants, press releases, local media analysis) but also some relevant items that emerged in discussion with promoters and the stakeholders during the policy scenario workshops.

As stated in Deliverable 7.3 (Antosz et al., 2020), the data for the agents was fed directly from the questionnaires that was replicated proportionally to census and according to the main population categories identified by using Decision Trees (see Figure 28) and following the procedure described in (Alonso-Betanzos et al., 2021).

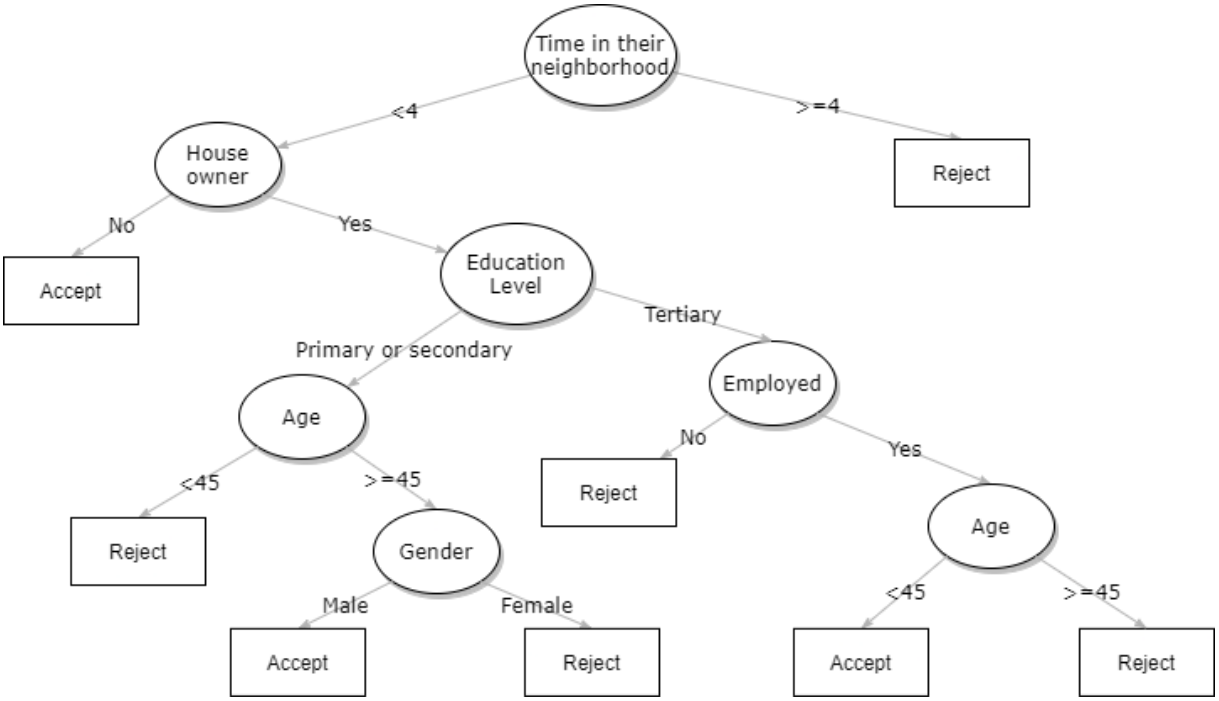

Figure 28 Population categories identified as relevant to the acceptance or rejection of the project

The model has several parameters as listed in Deliverable 7.3 (Antosz et al., 2020). In the interest of model simplicity and to make it easier to use, the values of many of them have been derived by applying theoretical knowledge.

Results of the model regarding the selected dimensions

The model underwent a sensitivity analysis and calibration of the parameters to reproduce the basic timeline faithfully. In this section, we will show the results over this main timeline, considering that our desired outcome is to see how the number of agents who have accepted the superblocks project of Poblenou evolves.

As in some of the alternative scenarios that will be described later, we wanted to include more communicative acts before the start of the project, the basic model starts in 2015 even though the first phase of the project starts in September 2016, so that the comparison between the real timeline and the alternative scenarios is clearer.

Table 18 shows the results at the end of the timeline, where it can be observed that the model ends in 2018 with 60% of the population in favour of the project, which is coherent with the data obtained with the surveys. Also, Figure 29 shows the evolution of the number of agents accepting the project from 2015 to 2018; as can be observed, a decrease in the acceptability begins around October 2016 that corresponds to the third phase (with social mobilization) and starts to increase again once the final project starts its implementation (March 2017) although it slightly decreases during this last phase.

Table 18 Percentage of agents accepting or rejecting Barcelona project after running the model (average results of 10 runs). Mean percentage of agents and standard deviation (SD)

Accept (%)	SD (%)	Reject (%)	SD (%)
60.9	0.31	39.1	0.31

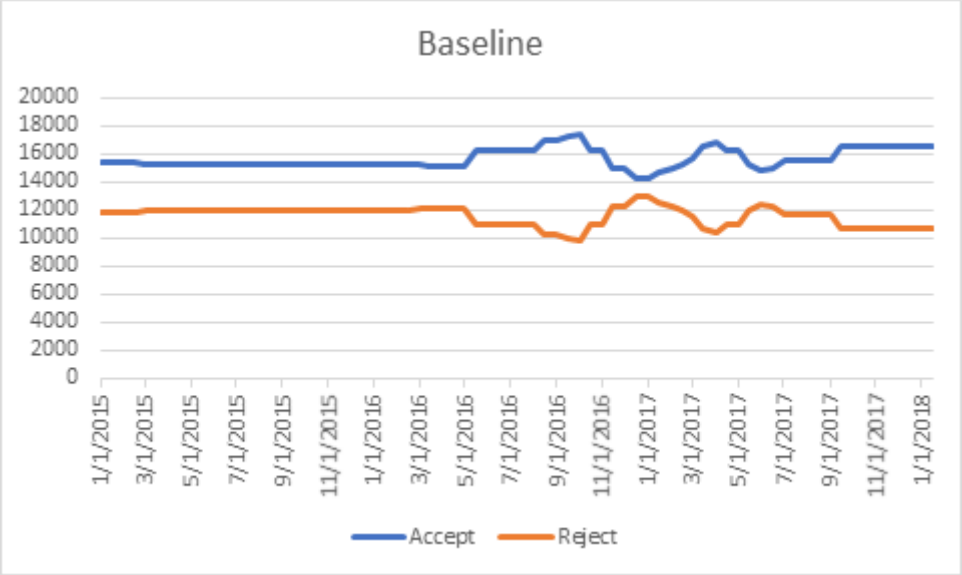

Figure 29 Evolution of the number of agents accepting the SI from 2015 to 2018

Development of Alternative Policy scenarios

The urban mobility case considers two different cities in Spain: Vitoria-Gasteiz and Barcelona. The first round of policy scenario workshops was organized in both cities in two different sessions. The first session was conducted separately in Vitoria-Gasteiz and Barcelona. The second session was conducted simultaneously to facilitate the participants in both cities to engage in joint discussions and interchange experiences and lessons about implementing superblocks in their respective contexts. Following a participatory and interactive methodology, a diversity of participants reflected jointly on the experiences and lessons learned during the implementation of the superblocks program in the city, discussed the most relevant dimensions (barriers and facilitators), as well as suggested alternative measures and communication strategies to increase citizens' acceptability of the superblocks model and so the following alternative scenarios, were considered:

SCENARIO 1	A) Organize participatory meetings B) Organize participatory meetings over a longer period
SCENARIO 2	Run a communication campaign focused on different needs: A) comfort and participation B) Wellness, comfort and city prestige

SCENARIO 3	A) Run an awareness campaign aimed at increasing the concern of Poblenou residents for well-being and environmental quality B) Include the awareness campaign of scenario 3A) and incorporate self-organized meetings between neighbours C) Starting from scenario 3B, add new communications from local media and associations supporting the social innovation project D) Starting from scenario 3B, add new communications from local media supporting the social innovation project

Experimentation with policy scenarios

Description of experiments

All the simulated scenarios start from the project's original timeline as presented in the section above related to the main model results and include new communication strategies from different critical nodes to overcome conflictive situations. Analogously to the basic timeline analysis, ten simulations have been carried out for all scenarios, and the average results will be shown.

Scenario 1: Participatory meetings

This scenario tries to reflect the development of a neighbourhood participation strategy before executing the Poblenou pilot superblock, involving citizens in developing the Superblock Action Plan.

Two different situations (1A and 1B) were tested in this scenario. The first situation (scenario 1A) consists of organising meetings between the local government and citizens in the census sections affected by the Poblenou superblock a year before the start-up of the pilot superblock. Therefore, these meetings begin in September 2015 and are held monthly in all census sections affected for a year. The second situation (scenario 1B) reinforces scenario 1A by increasing and prolonging meetings. To do this, beyond the monthly meetings of scenario 1A, quarterly follow-up meetings are held during the year 2017.

Table 19 illustrates the results of this Scenario. For the sake of comparison, the first row shows the base result obtained with the original Timeline. Both scenarios increase acceptance compared to the base situation, although scenario 1B does so to a greater extent (almost 10% more of acceptability), which indicates the convenience of maintaining and reinforcing the meetings for a longer period. It is also important to note that in September 2016, when the start-up pilot is launched, the acceptability is very high (see Figure 30).

Table 19 Number of agents accepting or rejecting the Barcelona SI after running the model for Scenario 1 (average results of 10 runs). Mean percentage of agents and standard deviation (SD)

Scenario	Accept (%)	SD (%)	Reject (%)	SD (%)
Base	60.9	0.31	39.1	0.31
1A	66.54	0.32	33.46	0.32
1B	70.35	0.36	29.65	0.36

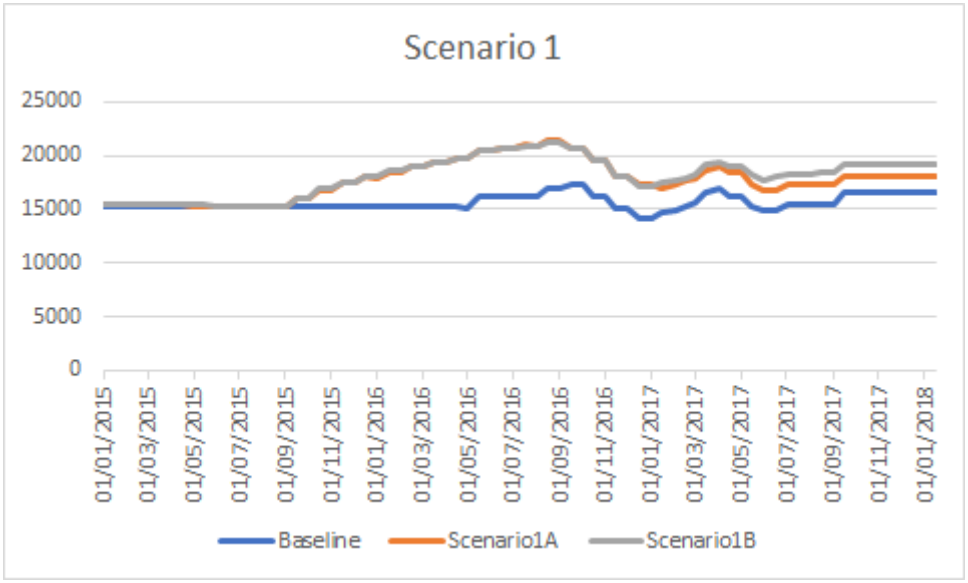

Figure 30 Evolution of the number of agents accepting the SI from 2015 to 2018. Comparison between the basic Timeline and scenarios 1A and 1B

Scenario 2: Communication strategy focused on specific needs

During the policy scenario workshop, stakeholders indicated the importance of identifying the needs of different groups living or working in the neighbourhood, so it would be recommended to align the superblock preparatory activities (information, communication) with the satisfaction of these social needs. Then, this second alternative scenario consists of a new communication strategy for the promoters addressing the satisfaction of the specific needs of the residents.

Analogously to scenario 1, two different situations were considered: scenario 2A and 2B. Note that these

- Scenario 2A represents a communication campaign of the Barcelona City Council, addressing the dimension of comfort and participation (similarly to an alternative scenario of Vitoria-Gasteiz). This campaign consists of 12 communications made for two years (bi-monthly communication): September 2015 to September 2017. Furthermore, local media support this campaign and publish a news item for each communicative act.

- Scenario 2B reproduces the same strategy as scenario 2A but addressing the needs of well-being (health, safety), comfort and prestige (recognition as an innovative city). Again, local media support this campaign.

Table 20 shows the results obtained in this case. Similar to the previous scenario, this scenario also significantly increases the acceptability in the social innovation project (more than 15%) compared to the original situation, reaching higher levels than Scenario 1. Moreover, the difference between Scenarios 2A and 2B is significant (more than 5%), denoting the relative importance of the tackled needs (well-being, comfort, and prestige). Figure 31 shows the evolution of the level of acceptability.

Table 20 Number of agents accepting or rejecting Barcelona SI after running the model for Scenario 2 (average results of 10 runs). Mean percentage of agents and standard deviation (SD)

Scenario	Accept (%)	SD (%)	Reject (%)	SD (%)
Base	60.90	0.31	39.10	0.31
2A	70.86	0.33	29.19	0.33
2B	76.59	0.30	23.41	0.30

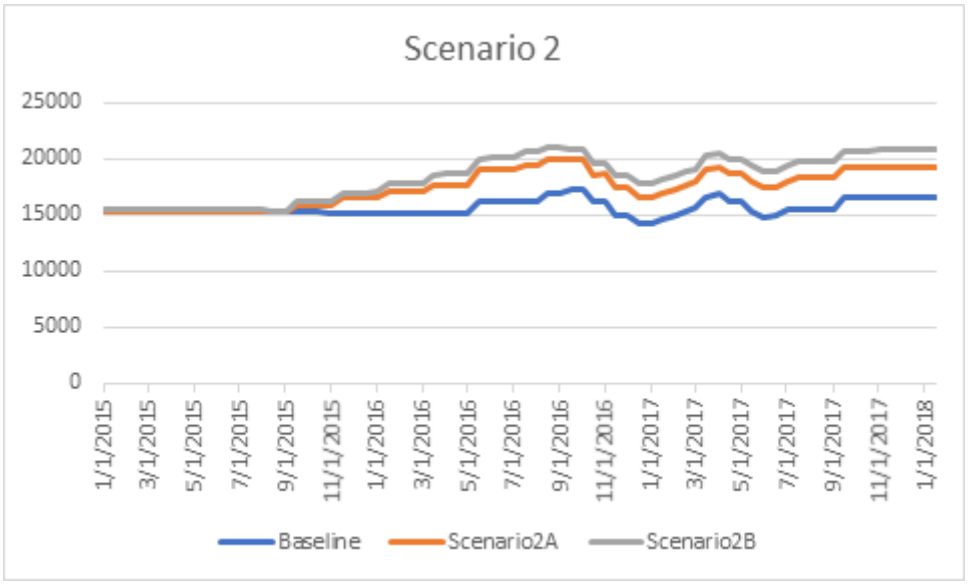

Figure 31 Evolution of the number of agents accepting the SI from 2015 to 2018. Comparison between the basic Timeline and scenarios 2A and 2B

Scenario 3: Environmental awareness campaign

This scenario tries to represent an environmental awareness campaign to increase the concern of the residents of Poblenou for well-being and environmental quality, focusing the discourse on the relationship between environmental quality, health, and safety. As in the previous scenarios, several situations were contemplated:

- Scenario 3A consists of an environmental awareness campaign promoted by the Barcelona City Council from September 2015 to September 2016 with 12 communications in 1 year

(one per month). The communication strategy focuses on increasing the importance of citizens on environmental quality and well-being (health, safety).

- Scenario 3B combines the previous campaign of scenario 3A with self-organized meetings between residents of the same census sections (neighbours), fostering citizen debate about superblocks. These communications between citizens will occur in 3 periods: September 2015, March 2016 and September 2016.
- Scenario 3C reproduces the previous one (scenario 3B) but adds new communications from local actors that support the campaign: media and associations. Thus, we added three new communications from the local media (in favour of SI) and another three communications from local associations during the same period that the conversations between citizens (and their social networks) occur.
- Finally, scenario 3D reproduces 3B but only adds new communications from the local media supporting the campaign and ignores the communication of the local associations considered in scenario 3C. Specifically, three communications are made by local media during the same period that the conversations between citizens occur.

Table 21 shows the number of agents accepting the superblocks innovation once the model is run under the different approaches of scenario 3. Similarly, Figure 32 displays agents accepting the project in the execution of these scenarios from the period of the basic timeline. Both Table 21 and Figure 32 show that scenario 3 slightly overcomes the base timeline (in some cases), being the scenario with the least promising results. Scenario 3C turns to be the best of this series, denoting the importance of the support of local actors.

Table 21 Number of agents accepting or rejecting Barcelona SI after running the model for Scenario 3 (average results of 10 runs). Mean percentage of agents and standard deviation (SD)

Scenario	Accept (%)	SD (%)	Reject (%)	SD (%)
Base	60.90	0.31	39.10	0.31
3A	60.92	0.29	39.08	0.29
3B	59.57	0.29	40.43	0.29
3C	61.44	0.42	38.56	0.42
3D	61.27	0.33	38.75	0.33

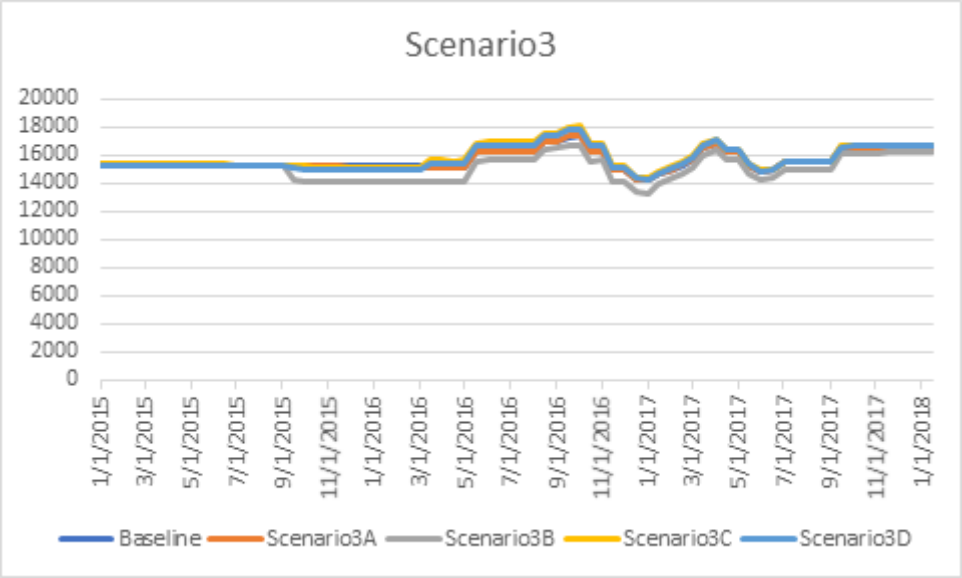

Figure 32 Evolution of the number of agents accepting the SI from 2015 to 2018. Comparison between the basic Timeline and scenarios 3A and 3B

Final considerations

The superblocks model enhances the habitability of public spaces, increases urban greenery and biodiversity, and promotes low carbon mobility. Superblocks in Barcelona have received support and social acceptance in some areas and protests and contestation in others. Learning from the early mistakes, public participatory processes have been launched in three pilot interventions, measuring positive outcomes in the following dimensions: improvement of environmental and public space conditions, increase in green areas, enhancement of social activity, and social interaction in neighbourhoods. Here, the model simulates the temporal evolution of citizens' opinions about the project using different policy scenarios. The modelled case, Poblenou had strong opposition and is used to simulate alternative policy scenarios to minimize social opposition. The agent (citizen) has two behavioural alternatives: to accept or reject the project's expansion. Agents prioritize communication with other agents who are in their same state, and this influences their standpoint. The model deals with several critical nodes that play a relevant role during the implementation (the city council, the opposition political parties, local media, and other associations). Here, associations play an important role in influencing agents standpoint. The model uses six categories of citizens' needs, including wellness, comfort, prestige, participation needs, and social needs, it demonstrates how critical nodes along a specified timeline influenced citizens for and against the project through various communicative acts. Further, the scenarios show how different critical nodes help overcome conflictive situations in these specific states/phases. Results show that communication strategies are crucial to allow citizens to evolve and change their position and that the focus of communication is crucial. The most successful scenarios worked with participatory meetings and a communication strategy that focused on specific needs identified amongst the agents (citizens). The least successful scenario included an environmental awareness campaign. The results indicate that an inclusive and listening approach is preferable when trying to achieve acceptance for implementing superblocks.

2.6 The Aberdeen case. Case study cluster 5: Energy efficiency against fuel poverty.

Selected dimensions for theory development

The dimensions selected for the study of social innovation in the Aberdeen agent-based model, ACSHIUM, were as follows:

- Gender effect on the selection of installation of district heating;
- Ethnicity effect on the selection of installation of district heating, and
- Profit limiting on the section of installation of district heating.

The dimensions above were simulated using the ACHSIUM model using parameter settings and configuration options as described in more detail in the next section. The simulation involved many hundreds of runs of the model to cover various combinations of parameters.

ACHSIUM features options to simulate one agent per household or one agent per citizen. In the latter case, agents are connected by the household they belong to as well as any other social network. The inclusion of gender as a scenario variable of interest led to us choosing the one-agent-per-citizen model configuration option. Since this leads to a larger number of agents, we constrained simulations to the Torry area of Aberdeen rather than simulating the whole of Aberdeen. We believe the outcome variables of interest would not be significantly altered by a whole-of-Aberdeen simulation, though this would need to be confirmed by a future study.

Description of the selected dimensions

Gender

A household is considered to be a group of individuals networked by family membership living in the same place. Multiple households may share the same spatial location through living in the same building. It is at the household level that the decision is made to install district heating. Thus, the decision to join the district heating may be down to an individual with this household, a collective decision, or somewhere in between. One of the properties of individual agents was their gender. In the model, gender was a simple binary allocation between males and females. Thus, there were household organizations where a single person made the decision, and this decision-maker had a gender.

To determine whether setting the gender of the decision-maker within a household would affect the adoption and installation of the district heating network, we varied the internal organization of households within the model. The organizational structure of the households could be one of the following:

- matriarchal – in which the eldest female made the decision as to whether to install the district heating or not.
- patriarchal – in which the eldest male made the decision as to whether to install the district heating or not.
- all-adults – in which the adults over a parameterized age (18 in this case) voted on the decision as to whether to install district heating.

- whole-family – in which all members of the family voted on whether to install district heating or not.
- random – one member of the family decided to vote on whether the district heating should be installed or not.

Each of these family organization types could be enabled or disabled over the range of the runs, and hence there are $2^5 - 1 = 31$ possible combinations of at least one organization type.

Ethnicity

Ethnicity has been shown to strongly correlate with homophily in social networks (McPherson et al., 2001). Social networks in this model were simulated by network connections between agents. Agents then used these networks to obtain advice about the installation of district heating. In order to do so, each agent was assigned an ethnicity. Each of the social networks in the model could be optionally configured to create links only between agents of the same ethnicity. We used this property to introduce very clear-cut homophily in the model, as detailed below.

We defined five ethnicities. A recent analysis of Aberdeen showed the following distribution of ethnicities[3].

1. White 92.0%
2. Chinese 1.0%
3. Indian 1.5%
4. Asian Other 2.8%
5. Afro-Caribbean 2.6%

We, therefore, allowed for the presence of five ethnicities in the model. The first ethnicity was weighted between 50-100. The remaining weights were varied between 0-10. Every agent was assigned an ethnicity using these weights.

The ethnicities were important from the point of view of the social networks. These networks were used to get advice when installing the district heating network. Homophily dictated connections made in the following networks.

- Social media
- Neighbourhood network
- Network due to employment
- Network due to schools
- Network due to community organizations

The above ethnicities were used to enforce homophily on these networks. The enforcement of the homophily was either strict or not present.

Profit for Aberdeen Heat and Power (AHP)

[3] Aberdeen: https://worldpopulationreview.com/world-cities/aberdeen-population, 2021-10-08

The model allows the simulation of implementing additional district heating installations beyond those specifically planned by the Council. We were informed that if a neighbourhood demonstrated sufficient interest in having district heating, then the installation of district heating would likely be considered for that location. In order to simulate this, we allowed people in streets, neighbouring a street with heat pipe installed, to vote on whether they would like to join the district heating network. Residents of public housing were assumed to have voted in favour of installation, reflecting the desire of the Aberdeen council to further advance the installation of district heating.

A key social innovation for the Aberdeen case study is the institutionalization of Aberdeen Heat and Power (AHP) as a not-for-profit, meaning the annual return on investment they seek from installations is around 0.5% rather than 10-20%, as would more typically be the case in a for-profit company. In the model, we allowed the return-on-investment sought by AHP to be varied. The results of the votes of the residents of a street were used to estimate the revenue returned from the cost of installation, assuming that those who voted in favour would connect. If the revenue returned exceeded that sought, then the district heating network would be extended into the neighbouring street.

Results of the model regarding the selected dimensions

The results were analyzed using the number of adopters of the district heating network as the outcome variable of interest. As well as visual inspection of the results, the Kruskal-Wallis rank-sum test (Vargha et al., 1998) was used to check for statistical significance. Using statistical significance tests with outputs from simulation models has been criticized (White et al., 2013). Typically, it is the magnitude of effect that is of primary interest when comparing scenarios using model runs. If the effect is large enough to be of interest on visual inspection, it is generally the case that the statistical test will be significant. If visual inspection suggests little difference in magnitude, then a statistically significant result does not alter the fact that the difference in magnitude is too small to be of interest. Therefore, the value of significance testing is to chiefly confirm that the eye has not been deceived when detecting an interesting difference in magnitude between scenarios simulated.

The results, detailed below, show no significant effect arising from the configurations of the model concerning gender or ethnicity, but it does appear that limiting profit does have some little effect when compared to the effect of altering installation and unit price for district heating. When scenarios comparing these were run, there was a noticeable increase in the adoption of district heating when compared with varying the cost of installation and ongoing payments.

Gender

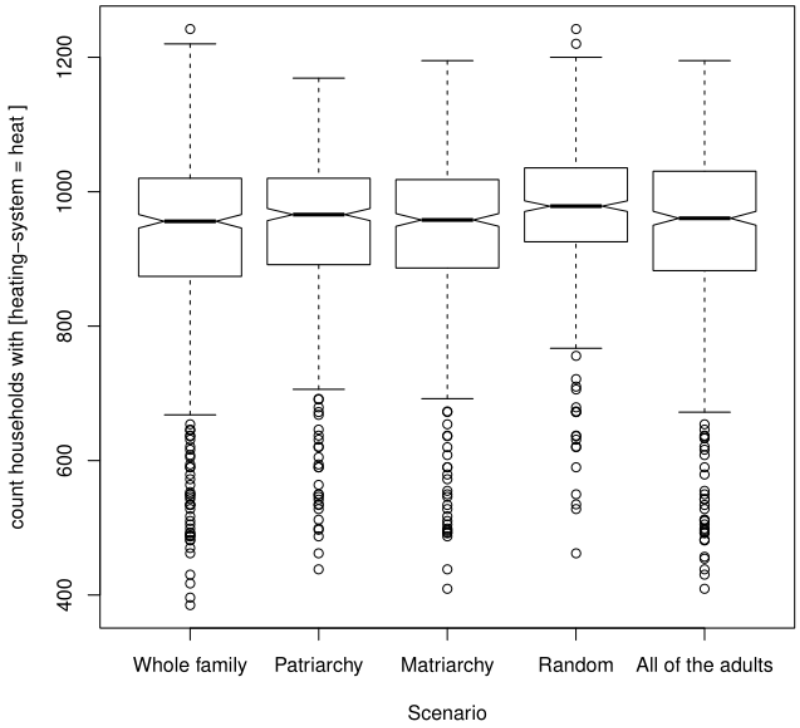

Figure 33: Family organization against district heating installations

The results not being significant is unsurprising as the model contains no mechanism to differentiate gender, other than the contexts in which different genders make their decisions. The decision-making process in this context is based on innovation diffusion theory, in which psycho-demographic profiles of individuals determine the means by which a decision to adopt is reached. To show an effect, we would need data on any gendered disproportionality in psycho-demographic profile (innovator, early adopter, majority or laggard), and/or in the social networks in which each gender participates (early adopters need to know an innovator; the majority need to know enough other adopters). To further verify this, we analyzed the results based on such family structures and tried to see if there were any differences when examined at this level of detail. As expected, no significant differences were observed, confirming that as currently configured and with the kind of decision-making we have in place, then such family organizations currently have no effect on the model. This result is shown in figure 33.

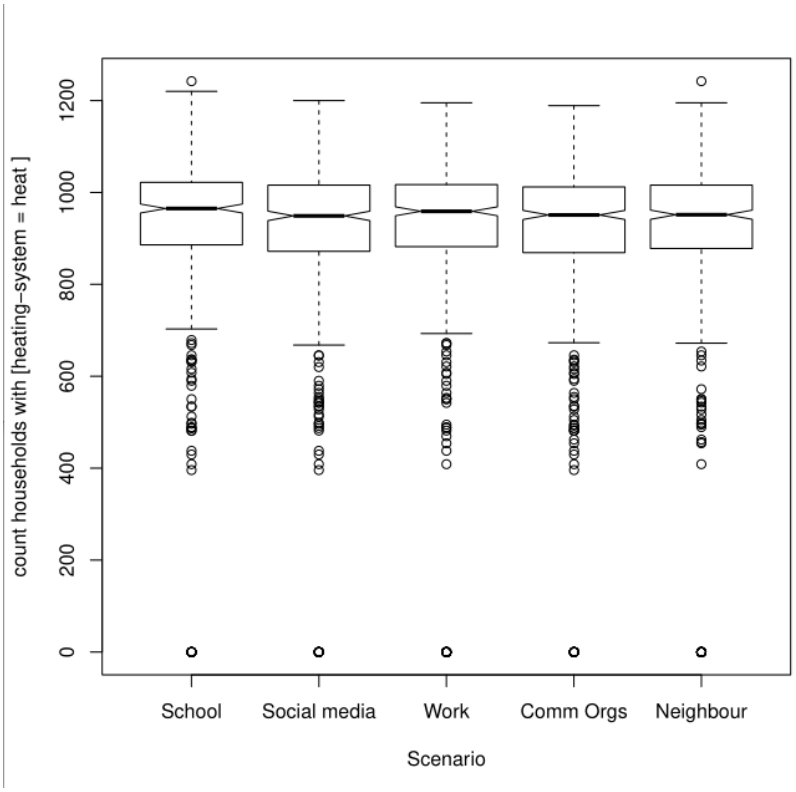

Figure 34: Number of installations by network

Ethnicity

As for varying the ethnicity homophily with the various social networks on and off, no effect was noticed due to the nature of saturation of the social networks. Dunbar's number is built into the model in such a way that it limits the maximum size of the social network for the purposes of gathering advice. If homophily is introduced in order to limit these networks, they are still only limited in size by Dunbar's number (Dunbar, 2010). Hence any shortfall caused by homophily is replaced by the surfeit of potential connections in other social networks. Consequently, the varying social networks based on ethnicity had no effect. This seems to be verified by the box plots above showing that the various changes in differing types of homophily led show very little variation between them. This is shown in Figure 34 above.

Profit for Aberdeen Heat and Power (AHP)

Lastly, we discuss the results of the issue of varying the economics of the district heating network. To investigate this we conducted two experiments. In the first experiment, a street would adopt the heat network if a simple majority of its households were in favour, and we varied the installation price and the ongoing costs. The rules of the agents mean that they do not particularly respond to pricing, and we found no effect. Besides the pricing, agents not in social housing will only adopt district heating if they have a reason: failure or replacement due for the existing heating system, or moving in to a property and reviewing the heating system. With the average lifetime of a boiler set to 12 years, chances of a boiler failing were relatively low. The circumstances leading to a majority of households in favour of adopting the heat network were therefore small.

In the second experiment, we used the current pricing regime of Aberdeen Heat and Power, but adjusted the return-on-investment sought from installing in a street. Rather than requiring a simple majority of agents in favour, the heat network would be installed if the expected return-on-investment from installation reached a specified target. The lower the target, the fewer households in a street needed to justify installation. The result is shown in the plot in Figure 35. Visually, this appears to show higher profits more often being associated with lower numbers of installations (the bottom-left-corner of the plot is less densely populated). This tentative result is subject to confirmation from a larger sample of runs.

The dynamic nature of the means by which streets are invited to join means that a major predictor of installation is proximity of the street to existing infrastructure. Further experiments will be conducted with ACHSIUM to confirm this matter.

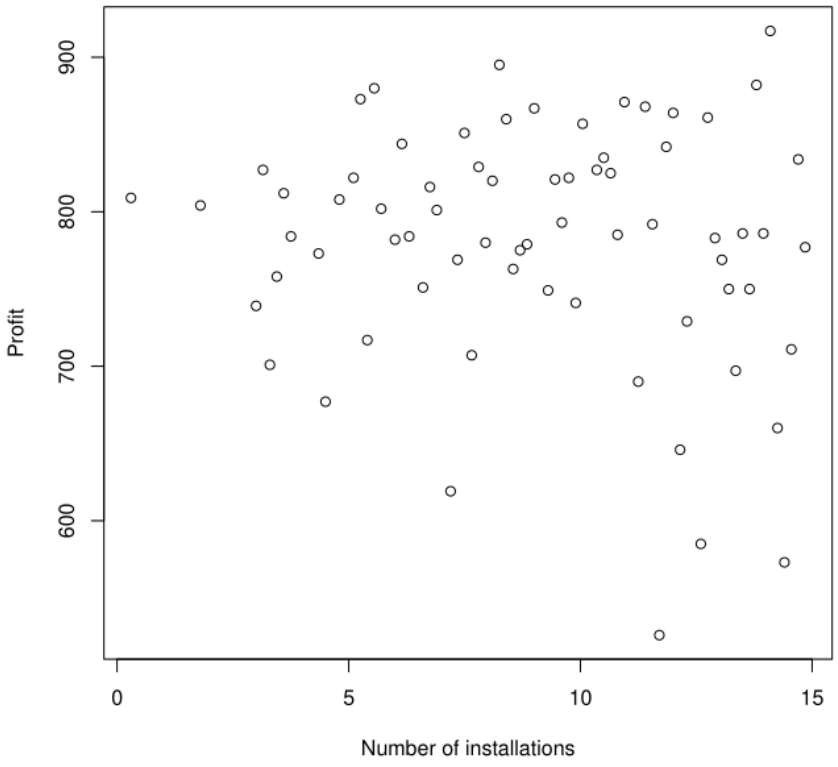

Figure 35 Profit against number of district heating installations

Final considerations

As simulated, it appears that targeting social networks through ethnicity may be ineffective in encouraging the adoption of the heat network if the average size of a person's advice network is sufficiently rich in potential connections. Anecdotally, however, it was the case that in Torry, it was found useful to attend meetings (such as English-language lessons) to discuss district heating with minority ethnicities who would not otherwise have had access to information. This subtlety is a matter that would be difficult to capture in the model without detailed social network data.

Targeting gender to influence the uptake of district heating also appears to be inconclusive based on the results from this model. The decision-making process is gender-neutral concerning the basis of this model, although it might not be in reality. Although there is no emergent behaviour arising from the model concerning different household organizations as it stands, it is worth noting that this is a matter over which policymakers would typically have little or no influence: these are details that households typically determine for themselves.

Limiting profit on the expected revenue from those who have pledged to install the district heating network seems to have clear advantages in principle, and there is a suggestion that results from the model support this. However, we would be hesitant about drawing any conclusions from this, as the pricing experiments where the district heating provider installed and continued to maintain a low price showed no discernible effect on uptake over the ten years that the model was run for. This is because very little economic sensitivity has been programmed into the agents.

Table 22 Synthetic description of selected dimensions, results and their relevance for SIs' theory and policies

Dimensions selected	Description	Syntethic results	Teorethical and policy considerations
Ethnicity homophily in social networks	Percentage of a particular ethnicity in a given population and which social networks were affected by homophily	None	It appears that ethnicity and homophily in social networks for the distribution of information affecting the adoption of the district heating network are unimportant.
Varying the gender or distribution of the decision-maker in the household	Each household could be of the following organization.	None	Again, using gender targeting to encourage the adoption of district heating does not appear to be effective in this model. This is

			because there is no mechanism to distinguish between genders
Varying the profit of the district heating provider taking into account prospective customers	Streets get to vote on joining the district heating network. If positive, then the expected revenue is factored into the cost of installation	None	This affects the adoption of district heating overall in comparison to other mechanisms but showed little sensitivity to actual magnitude.

3 Discussion

This section discusses how the ABM simulations carried out in SMARTEES and presented in section two contribute to refining the theoretical framework of social innovations outlined in section one. Further, we develop a general argument for the role of ABM in contributing to social innovations' theory development.

3.1 SMARTEES ABM simulations and their relevance for social innovations' theory development

In the following paragraphs, the main results for the simulated variables regarding the cases presented in section two are synthesised and discussed within the context of the theoretical framework presented in section one.

3.1.1 Education

In the case of Groningen, presented in section 2, the agent-based model simulated the voting behaviours of citizens living in the city of Groningen, called to vote about the closure of an urban park to car traffic.

The variable regarding the level of education of simulated citizens appears to influence their vote to an extent, showing that individuals with a higher level of education favoured removing car traffic from an urban park. This finding supports previous research showing that higher education levels predict pro-environmental behaviours (Gifford and Nilsson, 2014; Meyer, 2015), but it has to be emphasised that the only difference was between modelled citizens who had a lower educational level and those who had either middle or higher level. Nevertheless, this result suggests a role of formal education in influencing the acceptability of those social innovations characterised by a pro-environmental intervention that implies anticipated positive effects on the lives of residents. It has been argued (Meyer, 2015) that higher educated individuals might also be more concerned with social welfare, and pro-environmental and prosocial behaviours are considered by several scholars (Kollmuss and Agyeman, 2002, Neaman et al., 2018) as closely related. This stance would suggest that in the context of social innovations' acceptability, where often the aim of the interventions implemented is directed at delivering environmental and social co-benefits, education might positively encourage social acceptance or acceptability.

3.1.2 Communication strategies

Communication strategies have the potential of influencing pro-environmental behaviours, particularly for those types of behaviours that do not present significant barriers (Klöckner, 2015) or it could be said that do not present high costs (Diekmann and Preisendörfer, 2003).

Communication campaigns can influence the perception of costs and benefits of behaviours by creating awareness, conveying information, or influencing motivations, values, and social norms (Klöckner, 2015). In the case of social innovations, it is easy to see the potential of communication to influence acceptability before an intervention has been implemented or acceptance after. Communication can influence the acceptability of projects and interventions, even those that entail the perception of risks, by changing the perception of costs and building trust (Song et al., 2013; Guo and Wei, 2019).

Trust is a variable that might also play an essential role in the efficacy of communication campaigns because trusted actors might be able to generate more effective communication campaigns; in fact,

trust in policy actors is consistently associated with higher support of climate policies (Drews and van den Berg, 2016)

In the simulated case of Groningen (paragraph 2.1), campaigns either led by the municipality or by local shopkeepers show different levels of efficacy in swaying the voters towards the desired aim of supporting or opposing the closure of an urban park to car traffic. The municipality-led campaign appears more successful than the shopkeepers' in moving the voters, regardless of the temporal stage of the campaign. This result suggests that different actors engaged in social innovations' actions might achieve different results with their communication strategies, arguably depending on how the public perceives them and presumably on the level of trust that they elicit. These results appear coherent with the view that the opinion towards a pro-environmental intervention or policy might be influenced by the level of trust perceived towards their proponents (Pellegrini-Masini, 2020; Drews and van den Berg, 2016).

As earlier pointed in section one (paragraph 1.4), it has been argued that individuals might be influenced in choosing to adopt a behaviour based on motivations (originated by needs), attitudes and perception of implied costs and benefits; therefore, it is fair to assume that attempting to shift the perception of such costs and benefits by communication campaigns, paying attention at the perceived needs of citizens, might result in a higher level of support of SI's interventions.

In the simulations carried out for the cases of El Hierro, Samsø, Vitoria-Gasteiz, and Barcelona, campaigns were tuned in topics' content and intensity to magnify the perception of benefits delivered by the interventions. In El Hierro's simulations, two simulated communications interventions focusing on economic sustainability in one case and on economic sustainability, prestige and environmental quality in another showed that in both cases, the simulated baseline support would increase dramatically, however in the second case, which was targeting multiple needs the increment was larger (see paragraph 2.2). In Samsø, another island case like El Hierro, simulated communication strategies targeted several benefits of joining the network simultaneously: improved environmental quality, reduced carbon emissions and energy independence from the mainland. The results show that the communication strategies improved the rate of adhesion to the heating network, reaching about 62% of citizens joining, thereby achieving about 11% adhesions than in the baseline scenario.

In the case of Vitoria-Gasteiz (see paragraph 2.4), five communication strategies were simulated to gauge the improvement of the support of citizens towards the interventions, particularly emphasizing the comfort benefits that would have been generated. The results, specifically for the fifth option, which simulated an extended and far-reaching campaign, showed that the baseline consensus increased, although in the measure of only 4% compared to the baseline. This result suggests that when contextual factors perceived as high-cost are at stake, i.e. in the case of Vitoria-Gasteiz, parking restrictions, even extended and far-reaching campaigns magnifying the benefits of the interventions might generate only mild effects on support.

In Barcelona, where like in Vitoria-Gasteiz, the social innovation of superblocks was simulated, communication campaigns (scenario 2, paragraph 2.5) are successful in significantly shifting the consensus upwards of respectively 10% when comfort and participation needs are targeted and of 15% when well-being, comfort and prestige needs are the object of the campaign. These different simulated results reflect the varying relative importance of different classes of needs in the resident population and are consistent with the literature discussed in section one, which highlights the importance of hierarchies of needs in shaping the behavioural choices of agents. It has to be borne in mind that these are modelled results based on assumptions coherent with the theoretical stance that individuals are influenced in their decision-making by hierarchies of needs that they experience;

therefore, the simulated results reflect this assumption while adding in the modelled choices the influence of a large variety of variables that are grounded in the qualitative and quantitative data collected to build the models. In that regard, it is interesting to stress the difference in efficacy of simulated communication campaigns between Vitoria-Gasteiz and Barcelona: in Vitoria-Gasteiz, where a major drop in consensus happened because of the restrictions on car parking implemented in 2010, the campaigns were less efficacious in raising support, while in Barcelona where the consensus was relatively stable during the project, the campaigns showed to be more effective, thereby suggesting that the perception of costs and benefits might indeed be significant and hard to change in perceived high-cost situations.

3.1.3 Participatory processes

As pointed out in section one, participatory processes can be useful in social innovation design and implementation stages to gather citizens' opinions and allow them to express preferences regarding the implementable actions; further, participation facilitates the perception of a fair process and the growth of trust towards the leading actors of the SIs.

In the simulations carried out, several participatory activities were simulated to gauge the influence on citizens' support towards the SIs' interventions.

In the case of El Hierro (paragraph 2.2), participation was simulated in two versions of interventions, one consisting of fairs showcasing the SI's projects and their benefits, accompanied by communication campaigns, and another consisting of meetings with the local authority (cabildo). In both cases, the simulated participatory interventions dramatically improved the acceptance compared with the baseline, 18% in the first and 20% in the second. The best results were achieved in both types of interventions when the events were repeated, suggesting that their frequency also contributed to their effect.

In the case of Barcelona (Poblenou, paragraph 2.5), two participatory interventions were simulated, one consisting of monthly meetings held between citizens and the local government promoting the SI for a year, another added on top quarterly meetings the second year. The second simulated intervention generated a 10% rise in consensus towards the SI, while the first only 6% rise compared to the baseline. In this case, the results were more modest compared to El Hierro, although this might be attributable to different types of SIs' projects, in Barcelona's case, the superblock, which caused significant restrictions to car usage, while in El Hierro was a wind-hydro power station, whose impact on the living population would have been mainly on the landscape. Therefore, a hypothetical explanation for this difference could rest in the level of perceived costs generated by the SIs, with those generating locally perceived higher costs that meet a stronger resistance, less susceptible to being softened by, in this case, participatory strategies.

Nevertheless, the cases simulated show that participatory strategies are generally effective in raising consensus, thereby confirming the qualitative analysis' findings regarding other SMARTEES cases like Samsø, Malmö and Stockholm[4] and appearing consistent with the literature on social acceptance of renewable energy projects that suggests that participation can positively influence social acceptability (Perlaviciute et al., 2018; Perlaviciute and Steg, 2014).

3.1.4 Age

Age is another social demographic variable that was included for simulations in the case of Groningen and Samsø. In the ABM model (see section 2 of the present document for more details),

[4] For further details on these cases, refer to D3.1, D5.2, D6.1 and D6.3.

the role of age was considered to simulate voting behaviours related to the closure of a park for car traffic (Groningen) and the adoption of the social innovation by joining the district heat network (Samsø).

Simulation results show that the age variable has a differentiated effect on voting behaviour, both turnout (vote casting) and preferences. The results suggest that whereas the younger group of simulated residents is more likely to vote to close the park, the older age groups vote predominantly to keep the park open for car traffic. Also, the results show that age influences the behaviour of joining the district heat network. The simulated agents in the group age of 25-69 were most likely to join the heating network, compared with their younger (age 15-24) and older counterparts (age 70+). The simulation results are in line with previous findings that age does influence individual environmental relevant behaviours (Chai et al., 2015; Melo et al., 2018) and that there is a variable effect across different age stages (i.e., this does not increase or decrease linearly with age) (Longhi, 2013; Lynn, 2014). Thus, the age groups of the citizens should be considered for the acceptability of SIs' projects, promoting targeted communication and participation strategies addressing the different needs of citizens belonging to different age groups.

3.1.5 Ethnicity

Variation in environmental concern related to dissimilarities regarding attitudes, behaviours and decision-making was found among ethnic groups (Gifford & Nilsson, 2014). It was also showed that when societal decision-making authorities treat ethnic minority members in a procedurally fair way, giving a symbolic message that these groups are respected and valued, this enhances feelings of belongingness, more social trust and positive feelings (Valcke, Hiel, Onraet, & Dierckx, 2020).

In the case of Aberdeen (paragraph 2.6), the ABM was used to simulate the effect of ethnicity on a specific behaviour, namely the adherence to the installation of district heating. The model results showed no significant effect of ethnicity in the case of Aberdeen, namely, that targeting social networks through ethnicity for the distribution of information may be an ineffective strategy for the adoption of the district heat network. However, understanding the specific needs of diverse ethnic groups to offer solutions to meet these needs and create tailored communication strategies can prove valuable. For example, in the cases of Järva, Stockholm, and Augustenborg, Malmö, with a significant presence of an ethnically mixed population, stakeholders noticed that special attention was needed in dealing with communication and recruitment efforts for consultation and co-creation processes. Tailored communication approaches and participation strategies were regarded as more efficient in liaising with these groups, as they might not respond to traditional ways of soliciting participation. Some suggestions were made, such as on-the-ground resourceful individuals, with immigrant cultural backgrounds to liaise with these diverse groups, or active recruitment targeting community organisations' representatives (for more details, see Deliverable 5.2). Also, the usual recruitment channels might not work, as they could not be used and the information cannot reach these ethnic groups. This was the case in Torry (Aberdeen), where it was useful to reach to these populations through meetings such as English-language lessons to discuss district heating which otherwise could not have had access to this information.

3.1.6 Gender

Gender appears to influence pro-environmental attitudes and behaviours, with several studies reviewed (Gifford and Nilsson, 2014) pointing that women are generally more inclined to hold pro-environmental attitudes and to carry out pro-environmental behaviours.

In the simulations of the Aberdeen case, gender did not appear to make any difference with regard to joining the district heating network. As pointed in section 2.6, the reasons might be related to the

current model design, which is not sufficiently elaborated to account for psychological and behavioural differences across genders, if nothing for lack of sufficient data. Another explanation could be instead related to the type of action modelled (i.e., joining the district network appear like a long-lasting consumption choice with economic implications for the whole household for many years to come); therefore, it might be the case that in such a context of decision-making, perceived economic costs and benefits might trump gender differences related with environmental inclinations. An indication of the importance of economic factors for this modelled behaviour might come from the following variable discussed: economic convenience.

3.1.7 Economic variables

In section one, we pointed out that perceived costs and benefits might address the choice of individuals to engage in behaviours related to SIs' interventions.

In the case of Aberdeen (paragraph 2.6), the simulated behaviour is joining the district heating network; in this case, the simulation attempted to verify how various aspects of the economics of the heat network affected potential users' decision to join. The results are not conclusive due in part to the model attributing significant importance to the actual need to replace the households' current heating systems through failure or obsolescence. Nevertheless, a limited analysis focusing on the profitability sought by Aberdeen Heat and Power rather than the upfront and ongoing costs to households, suggests that more households will join when the profitability target is lower.

While, for the case of Samsø, an intervention consisting of subsidies paid by the municipality to cover the whole cost of fees to join the district heating network was simulated. The results show a modest increase in citizens joining of only 3.5% and that some individuals are not sensitive at all to this intervention, having already decided to join. The modest increase in the number of citizens who joined in the simulated case of Samsø might be due to the originally relatively modest fees that were required to join the project when this was announced and in its pre-construction phase.

3.1.8 Socioeconomic status of citizens

Section one discussed that resources might play a role in enabling citizens and other actors to participate in SIs or choose a response to specific SIs' interventions.

In the case of Samsø, socioeconomic status was simulated to understand its effect on joining a local district heating network. SES was calculated based on the variables of educational attainment, occupational attainment, and household income. The results show that individuals with higher SES, have considerably higher rates of adhesion to the district heating network: 53% of higher SES individuals in the model join the network versus 16% of those belonging to the middle SES group and 13% of those in the lower SES group. This result is coherent with research stressing the importance of resources for carrying out some behaviours (Margettes and Kashima, 2017); in this specific case, higher household income could reduce the perception of the initial cost of joining the network, although we have seen that this was not likely an obstacle, as the discussed simulation of the cancellation of the joining fee shows. Further, higher education might lead to a higher awareness of the environmental (Gifford and Nilsson, 2014; Meyer, 2015) and financial long-term benefits of joining, while higher occupational attainment might result in a higher sense of control of behavioural intentions, which has been argued to facilitate the translation of pro-environmental beliefs in actual behaviours (Eom et al., 2018).

3.1.9 Final considerations on SMARTEES' simulations and their relevance for social innovations' theory development

SMARTEES models are still undergoing some final tuning, and they are still running simulations at the time of writing this report. While the work so far conducted presents worthy insights on the role of several variables influencing actors' behavioural choices in the context of social innovation projects, they currently offer limited scope to enhance theories of social innovations, both because the simulations are still in progress and because the nature of agent-based modelling requires the understanding of several epistemological considerations that we leave to the next and final paragraph of this report.

In this paragraph, we limit to point out that several of the variables considered in section one and later explored through simulations appeared to be relevant for the behavioural choices of citizens. Perhaps more interestingly, it could be said that the simulations seemed to support the core idea outlined in our theoretical framework, that citizens would choose a course of action that best serves the satisfaction of their needs, after having considered their perception of costs and benefits of several behavioural options. Hence communication strategies that might magnify the benefits of the SIs' actions concerning perceived needs could improve the acceptability of the SIs, although these results might be limited in situations perceived as high-cost. Equally, in such high-cost situations, trust-building strategies based on participatory actions appear to improve acceptability limitedly, while their results are significantly better in situations where the perception of high costs is missing. Coherent with this view is the finding that higher socioeconomic status and lower costs to join heating networks would favour the adhesion of citizens: although in this latter case, the evidence is weaker, and further simulations would be needed.

3.2 Conclusive remarks: the contribution of ABM to theory on social innovation

A key question is to what extend agent-based modelling contributes to theory development on social innovation. For answering that question, we first have to reflect on the unique contribution of agent-based modelling. And that is their capacity to grow the dynamics taking place in social systems using computer simulations. Moreover, many simulation runs can be computed, and systematic variations allow for experimenting with population characteristics and policy interventions. Hence, in the context of climate adaptation of communities, the potential of ABM is significant.

Concerning the development of the theory of social innovation, the trustworthiness of the ABM's is essential. How do we know that the computer-simulated scenarios are a valid representation of real-world processes of social innovation? The bottom line here is how well the ABMs are capable of representing basic principles of human behaviour into simulated community behaviour. This defines the potential theoretical contribution to understanding the processes of social innovation. Theory development thus necessitates a valid representation of behaviour.

To begin with a discussion on validation, our ABMs provide causal connections between different relevant components. For example, existing (and hence validated) theories related to needs, decision-making, persuasion, and social networks can be formally connected. Combining them in a computational framework adds a dynamical dimension of process-growth to these simplified theories, thus producing "generative social science", as Epstein (2006) stated. The question on the theory of social innovation development is if these simulated dynamics are explanatory for real-world phenomena. How then should empirical data be used to test the explanatory power of the simulated social innovation processes?

The crux of the answer resides in the complexity inherent to social systems, which implies that social dynamics can be in a state of turbulence. As Lorenz (1963) demonstrated for meteorology, small causes may have large effects in such systems. This certainly applies to social innovation, and our simulations, for example, show that the outcome of a referendum can be very sensitive for relatively small events. The principles of complexity and uncertainty are being explained in deliverable 7.3, section 2 on p. 6 (Antosz et al., 2019).

Whereas social systems are usually in a more stable state, where prediction of behaviour and the impact of policies is predictable using statistical analysis (i.e., marketing research), it is precisely at moments of turbulence and structural change, which is so typical for social innovations, where the future may go in different directions, and small events may cause the difference between success and failure. Moreover, cascading effects may happen, as the successful implementation of a social innovation may create favourable conditions for additional developments.

It is the turbulences in social innovations that impose a challenge for validating ABMs simulating them. Within the "regular" social sciences, much attention in research and validating theories focuses on the predictive capacity of theoretical models. Given the often stable state a social system is in, this predictive approach works very well under many conditions. However, this predictive approach loses its power the more turbulent a social system behaves (e.g., approaching a tipping point). Because the more traditional social sciences are grounded on a Laplacian determinism (LaPlace, 1902), when the predictive capacity of a model drops, the proposed answer is usually adding variables and collecting more data to improve predictive power. And when a social system is in a relatively stable state, indeed, this will result in more accurate predictions.

However, when a social system is entering a more turbulent stage, different future scenarios become possible. For example, the referendum on a car-free park may result in a car-free park or not. Relatively small coincidental events may determine the outcome of such a referendum. In modelling terms, this means that adding more variables and data will not result in more accurate predictions. Yet, turbulences in social innovation are of great interest to study because this is where their future emerges and where policy may impact what future scenario is likely to become a reality. Therefore, accurate models of such social dynamics will produce different scenarios, logically meaning that their predictive capacity will be low from a deterministic perspective.

How then can we build trust in a model that identifies different future scenarios and the impacts of policy? From a deterministic social science perspective, the answer would be "replicating the past", hence using historical data is often perceived as the gold standard for evaluating a model's predictive capacity. However, when the future in a complex social system can be understood as being composed of several potential scenarios, this logically also holds for historical data, as the past once was future. And if different futures can be imagined, the past developments *could* have been different, too. The successful cases we study in SMARTEES could have been failures, and possibly small coincidental causes could have been triggering an alternative development.

While we may have expectations about the future, and even think of policies to reach utopias and avoid dystopias, the past is perceived as set in stone and history. Therefore, we are less imaginative concerning alternative histories that could have happened. It seems especially difficult to accept that large historical events could have been set in motion due to relatively small events. For example, the assassination of Archduke Franz Ferdinand of Austria by the Bosnian Serb nationalist Gavrilo Princip was a matter of chance but served as an important trigger in cascading into the first world war. In many social innovation projects, such chance events may prove to be critical in determining their success or failure.

Next to the difficulty of imagining an alternative past, a further issue is that the only data available is from the single scenario that made it to an empirical reality. In SMARTEES, we only have data from the case how it actually happened, not of how it could have happened. Combining this with the deterministic perspective of much social science research is understandable, but it is incorrect to build trust in a model only on its capability to replicate the past from a complexity science point of view. Moreover, it is relatively easy to parameterise a model to fit historical data, even when based on false assumptions.

Hence, due to a deterministic perspective, replicating the data from this single realisation of our current reality is often the dominating principle in evaluating how well a model performs. On top of that, the only data that we have is from the reality that emerged. Understandably, the validity question "Does it replicate past events" is often the gold standard against which a model's accuracy is being evaluated. Such a replication would create trust in our ABM's capacity to predict the future, at least in users not acquainted with the fundamental complexity of many social phenomena

Replicating the past as a litmus test for validity loses legitimacy because the past could have been different, as complexity theory emphasises. However, we usually do not know how likely other historic scenarios would have been, nor if our current reality was very likely to happen or not. Hence, instead of replicating the past only, a model should be capable of replicating it as part of a compilation of multiple cases of historical developments. One could even start thinking the other way around, using simulations to identify the distribution of possible alternative pasts. Yet, a simulation model should be capable of replicating the past as a possible scenario. The real case should fit in the distribution of simulated scenario outcomes. As a consequence, the question if our simulations contribute to theory development, or beyond that, if the ABMs themselves compose dynamical theories of social innovation raises a number of important philosophy of science questions. So, we do not claim that our models should be considered as theories of social innovation, we do not exclude the possibility that they can be used to develop theories, and we certainly think they outperform the "rational actor" in terms of accuracy.

Validating our models as a theory might require developing a process validation approach, where the behaviour of the agents is being tracked over time, and the processes and events happening being compared against theoretical knowledge from the social sciences, and empirical knowledge from case experts. When, for example, a certain implementation of attitude change results in unrealistic processes of opinion change in the model, improvements should be made. For example, when we observe that agents are repeatedly switching (oscillating pattern) between two really different opinions, we have theoretical and empirical arguments to improve the rules determining the agents' attitude change. This clearly resembles the process of theory building, and both qualitative and quantitative data will be needed to support this testing of process validity rather than outcome validity. If a model demonstrates to be capable of mimicking the behaviour of a variety of people in different cases in a theoretically and empirical convincing way, we may start thinking about a solid dynamical theory of social innovation.

In the meantime, simulations should be considered scientific attempts to produce plausible outcomes of social reality, based on behavioural assumptions founded on pre-existing empirical research and known contextual data. Their results can contribute with further knowledge, along with that produced by established qualitative and quantitative social research methods, to corroborate the relevance and effects of variables conceptualised in theoretical frameworks of social innovations, such as the one that we have presented in section one.

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