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Testing Scenarios to Achieve Workplace Sustainability Goals Using Backcasting and Agent-Based Modeling

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Abstract

Pro-environmental behaviors have been analyzed in the home, with little attention to other important contexts of everyday life, such as the workplace. The research reported here explored three categories of pro-environmental behavior (consumption of materials and energy, waste generation, and work-related commuting) in a public large-scale organization in Spain, with the aim of identifying the most effective policy options for a sustainable organization. Agent-based modeling was used to design a virtual simulation of the organization. Psychologically informed profiles of employees were defined using data gathered through a questionnaire, measuring knowledge, motivations, and ability. Future scenarios were developed using a participatory backcasting scenario development methodology, and policy tracks were derived. Dynamic simulations indicated that, to be effective, organizational policy should strengthen worker participation and autonomy,

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be sustained over time, and should combine different measures of medium intensity for behavior change, instead of isolated policies of high intensity.

Keywords
social simulation, pro-environmental behavior, workplace, agent-based modeling, policy pathways

Introduction

Large organizations are responsible for a significant amount of greenhouse gas (GHG) emissions (Emission Database for Global Atmospheric Research, 2000). Large organizations have been defined in the European Union (EU) as those employing 250 people or more, according to the Eurostat definition. The emissions generated by them result from their production processes as well as from the behavior of their employees. Besides their contributions to overall GHG emissions, large-scale organizations also hold a great potential for social influence, as they can reach large numbers of individuals and become spaces for social learning and behavioral change.

Although service-providing organizations have lower environmental impacts than industrial or manufacturing firms, changing the behavior of employees has the potential of achieving highly significant improvements in the overall environmental performance of the organization, including reductions in emissions. Research on the potential of organizational behavioral change policies to achieve significant emissions reductions is still scarce (Lo, Peters, & Kok, 2012), and the impact and contribution that individual workers can make in terms of improving an organization's environmental performance through engaging in environmentally sustainable workplace behavior have been underrepresented (Davis & Challenger, 2015).

Most environmental behavior research has looked at the domain of home and has ignored the importance of other sites of practice (Barr, Shaw, & Coles, 2011), in spite of existing evidence pointing to the fact that pro-environmental behaviors at work do not necessarily follow the same logic as behaviors at home, nor do they get easily carried over from one domain to the other (Tudor, Barr, & Gilg, 2008).

Furthermore, the types of policies required to steer behavior in a sustainable direction are still not clear, due to the complexity of factors influencing behavior change and their interactions, and the difficulty of mapping effects of policy combinations over time. Also, policy approaches are dominated by models of change that rely on evidence gathered in the home (Barr et al.,

2011), and the need remains to explore policy combinations in the workplace, and the emergent effects of different policy combinations over time (Jager & Mosler, 2007; Squazzoni, Jager, & Edmonds, 2013). Social simulation approaches hold promise for exploring these effects, through the modeling of heterogeneous individuals, the interactions among them, and between them, and the social structure in which they are embedded.

The research reported here used a social simulation approach and tests different policy options for pro-environmental behavior change in a large-scale public organization. The following research questions were formulated:

Research Question 1: What types of policies are likely to be more effective in transforming workplaces into low-carbon ones: one-time measures or consistent, stepwise policies?
Research Question 2: What are the effects of different combinations of policies?
Research Question 3: What is the required intensity of policy for a sufficiently fast-paced transition to a sustainable workplace in large scale-organizations?

This research is part of an EU-funded FP7 project aiming at identifying the barriers and drivers to sustainable everyday practices in organizations. The project used a multimethod empirical research design to explore the complex factors supporting or hindering sustainable practices in the workplace in three environmentally relevant domains: consumption of materials and energy, waste generation and management, and work-related mobility. The project explored microlevel internal factors with an influence on behavior in these three areas as well as structural/organizational factors that define the organizational and social context in which the individuals work and act. A participatory backcasting scenario development methodology was used with workers to define a common vision of a sustainable organization in the future and to develop appropriate pathways to reach it. Both the results of the empirical research carried out on the drivers of and barriers to sustainable behaviors in the organization, and the pathways formulated in the backcasting scenario development workshops were used to define policy recommendations that were then implemented in the agent-based simulations. We will focus here on the case of a public large-scale organization, the University of A Coruña in Spain, one of the six case study organizations in the project.

Agent-based modeling (ABM) was used to simulate workers in the organization and their interactions, as well as to formalize the interventions that aimed to reach sustainable targets by the year 2050. By realistically modeling individual profiles and forms of social interaction and influence within the

organization, we were able to analyze the effects of different policy interventions over time, thus showing how environmentally relevant behavior might change over a period of 40 years (2014-2050) and how emissions might drop and at what rate under different policy scenarios.

The article is organized as follows: We first provide a short overview of social simulation approaches to the study of environment–behavior interactions and of backcasting scenario methodologies, especially as they apply to organizations. We then describe the multimethod approach used in designing and testing different policy pathways to achieve reductions in organizational carbon emissions through employee behavior change, which included the following: a questionnaire to measure psychological factors that might play a role in different types of pro-environmental behavior, participatory backcasting scenario development to obtain realistic and stakeholder-endorsed policy pathways to a sustainable organization, and the design of an ABM where simulations of policy implementations were conducted. Next, we present the experiments performed within the ABM in which three types of interventions were tested, and results are discussed in terms of the long-term carbon-reduction effects of policy options. We conclude by providing a few recommendations on interventions for achieving sustainability in organizations.

Social Simulation and Environmental Psychology

Computer simulation has influenced most areas of science, especially the social and behavioral sciences (Gilbert, 2004). Social simulation, which entails the explicit representation of individuals and collectives and their interactions over time, is considered an outstanding method for modeling and building explanations of social processes, as it allows social phenomena to be investigated through the study of dynamic processes in computational models of populations (Salgado & Gilbert, 2012; Voss et al., 2010). Given the social embeddedness of human behavior and the importance of the social structure for human decision making, relatively detailed representations of social networks and groups are required (Edmonds, 2013). Social and environmental psychology provide important theoretical underpinnings for behavioral and cognitive dynamics of individuals, processes of interaction and social influence among individuals, and the description of feedback loops between individuals, groups, and the (simulated) natural and built environments (Li, Mao, Zeng, & Wang, 2008).

In ABM, the agents can have a one-to-one correspondence with the individuals who exist in the real world, while the interactions between the agents can correspond to the interactions between the real-world individuals. As a result, these kinds of models are frequently used for applications where the

behavior and intentions of heterogeneous individuals and the interaction among them are key factors (Li et al., 2008). According to Jager and Mosler (2007), ABM offers a rich methodology that contributes significantly to the study of behavior–environment interactions and provides a valuable tool for exploring the effectiveness of policy measures in complex environments. However, agent-based social simulation models of real-world populations are still quite rare. To date, theirs (Jager & Mosler, 2007) is one of the most interesting and solid attempts to model the dynamics of decision making and behavior in the environmental domain by formalizing psychological theories within an ABM.

As mentioned earlier, research on pro-environmental behavior has focused mostly on the home as a site of practice (Barr et al., 2011), and this is also reflected in the social simulation literature with two recent studies, one exploring power generation from photovoltaic and renewable resources (Borghesi, Milano, Gavanelli, & Woods, 2013), and another exploring energy consumption and the possibility to influence consumption behavior through incentives in households (Amouroux, Huraux, Sempé, Sabouret, & Haradji, 2013).

Unlike classical modeling (in particular of physical systems), modeling social systems must be done with a sense of modesty: not only is it important to avoid the temptation to simulate everything (Hofstede, 1992), there is often more than one way to formalize and represent the qualitative information in the case studies (Polhill & Gotts, 2006; Polhill, Sutherland, & Gotts, 2010). The research presented here has taken up the challenge of representing psychological processes of individual decision making within the web of complex interactions in the workplace in three areas of environmentally relevant behavior, and tests a series of policy measures that would promote the sustainable behavior of workers (Andrews, Senick, & Wener, 2012; Andrews, Yi, Krogmann, Senick, & Wener, 2011), with the final aim of formulating recommendations for the support of organizational transitions to sustainability.

Backcasting Scenario Development in Organizations

Backcasting scenarios constitute a relatively new methodology in the field of sustainability and climate change (Dumitru et al., 2013; García-Mira, Dumitru, Vega-Marcote, & Alonso-Betanzos, 2012; Vergragt & Quist, 2011). In future and sustainability studies, backcasting scenarios allow us to envision and analyze different types of sustainable futures and develop agendas, strategies, and pathways to reach them (Vergragt & Quist, 2011). They have a strong normative component, as scenario development starts from desirable

future states or sets of objectives and then proceeds to the analysis of the steps and policies that are needed to get there, to design agendas that normally require cooperation and communication among different types of actors in complex socioeconomic and political environments. These types of scenarios are considered a useful tool in moving toward alternative climate futures (Giddens, 2009) and have the added advantage of promoting active commitment to goals, when a wide range of stakeholders participate. They are appropriate when there is a need to plan for long-term and novel goals in systems with high complexity and in which dominant trends are an important part of the problem (Broman & Robèrt, 2016). When applied to organizations, it has been argued that backcasting methodologies contribute to better managing complex problems in a systematic and coordinated way (Holmberg & Robèrt, 2000). Specific adaptations of backcasting methodologies in organizational settings have been initiated by proponents of the "natural step" approach which created practical tools for constructing future sustainable visions by taking into account the constrained characteristics of the environment and stakeholder base of particular organizations (Holmberg, 1998).

Method

Data Collection

We used a mixture of qualitative and quantitative data sources to build and configure an ABM. Specifically, a questionnaire was used as a basis for building decision-making algorithms for the agents for a number of different pro-environmental behaviors and for designing the social network. A backcasting scenario development workshop formed the basis for generating scenarios to explore within the model. The other data used pertain to the impacts of the behavioral choices agents make in terms of carbon emissions. The data used for this were obtained from the Environmental Office of the University.

Measuring Psychological Factors and Environmentally Relevant Behavior

The individual factors explored as determinants of pro-environmental behavior in organizations within this research belong to three categories, considered as the most relevant in previous research, and these are knowledge, motivations, and ability (Ajzen, 1987; Bamberg & Moser, 2007; Bonnes, Uzzell, Carrus, & Kelay 2007; de Groot & Steg, 2007; García-Mira, 2009; Stern, 2000; Stern & Dietz, 1994; Uzzell, Pol, & Badenas, 2002). A questionnaire was used to gather data on these psychological factors and to define the

individual profiles of the actors in the ABM. Answers were provided on a scale ranging from 1 (*totally disagree*) to 7 (*totally agree*), with the exception of the scale for values, which ranged from −1 (*opposed to my values*) to 7 (*supreme importance*). The questionnaire was filled in by employees on a voluntary basis using Qualtrics as a web platform. The online questionnaire was distributed to the whole university staff through an email asking for their collaboration in the research project. Almost 400 individual entries were counted (almost 20% of the University staff). In the final analysis and model, however, a sample of 255 complete questionnaires was considered, and the others were excluded due to incomplete data (11% of the total University staff), using the method of listwise deletion of cases.

Within the category of knowledge, we included worldviews; for motivation, both distant and more proximal antecedents were included, and these were values, identity, and personal and social norms. For ability, measures of both self-efficacy and outcome efficacy were selected.

Worldviews have been defined as a set of assumptions about the physical and social reality that may have powerful effects on cognition and behavior (Koltko-Rivera, 2004). *Worldviews* were measured with six items from the New Human Interdependence Paradigm (NHIP) scale (Corral-Verdugo, Carrus, Bonnes, Moser, & Sinha, 2008; $\alpha = .88$).

In terms of motivation, the first factor we considered were values, defined as a set of trans-situational goals that serves as a guiding principle in the life of a person or social entity (Schwartz, 1994). Four main types of values were measured through a 16-item scale: biospheric, altruistic, egoistic, and hedonic ($\alpha = .88, .69, .69, .76$; for example, de Groot & Steg, 2007, 2008; Steg, Perlaviciute, Van der Werff, & Lurvink, 2014).

For identity, we considered three dimensions within the workplace: environmental self-identity, environmental organizational identity, and organizational identification. Environmental self-identity reflects the extent to which you see yourself as a type of person who acts pro-environmentally (Van der Werff, Steg, & Keizer, 2014; Whitmarsh & O'Neill, 2010). Environmental self-identity ($\alpha = .90$) was measured with three items (adapted from Van der Werff et al., 2014). Environmental organizational identity refers to the degree to which the organization is perceived as defining itself as pro-environmental. Environmental organizational identity ($\alpha = .92$) and organizational identification ($\alpha = .86$), defined as the degree to which a worker identifies with the organization (Mael & Ashforth, 1992), were measured with six items each.

Norms have been found to be among the most relevant determinants of pro-environmental behavior (Carrus, Nenci, & Caddeo, 2009; Fornara, Carrus, Passafaro, & Bonnes, 2011; García-Mira, Real Deus, Durán, & Romay, 2003; Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008; Schultz, Khazian,

& Zaleski, 2008). Besides social norms, personal norms have also been found to be a predictor of pro-environmental behavior (Schwartz, 1992; Stern, 2000), and they have been defined as self-expectations regarding own behavior. More recently, local norms, derived from social interactions localized in specific places where the behaviors are performed, were also proposed as a relevant local predictor of pro-environmental intentions and behaviors (Fornara et al., 2011). Both descriptive and injunctive norms were included, at general and local levels.

General descriptive norms ($\alpha = .83$) and local descriptive norms ($\alpha = .81$) were measured with four items each reflecting to what extent respondents believed that a certain reference group acts pro-environmentally at work (cf. Ajzen, 2006). The same was done for general injunctive norms ($\alpha = .85$) and local injunctive norms ($\alpha = .79$). Personal norms ($\alpha = .83$) were measured with four items based on Steg and de Groot (2010).

Norms are transmitted through social networks. To serve the purposes of implementing a process of norm transmission within the ABM, we included a measurement of norm transmission, defined as the self-reported frequency with which workers encouraged others to act pro-environmentally in the workplace (the categories of "others" we included were co-workers, subordinates, supervisors, and the management team). The procedure for calculating rates of norm transmission and norm reception for workers and the description of the implementation of this process in the model have already been described elsewhere (Sánchez-Maroño et al., 2014).

Norm transmission ($\alpha = .91$) was measured by asking the following question: How often do you encourage the following people to act pro-environmentally at work? The respondents rated the frequency of this behavior on a scale from 1 (*never*) to 7 (*always*), for four categories of people: subordinates, co-workers, supervisors, and the management team. Also, a question was introduced on the perception of having an exemplary role within the organization, with two answer options (yes, no).

Finally, the ability to act pro-environmentally was conceptualized as efficacy in this study. We distinguished between self-efficacy, defined as the confidence and perceived control that people experience to execute sustainable behavior (Ajzen, 2006), and outcome efficacy, defined as the extent to which people think they can do something about environmental problems by acting pro-environmentally (Schwartz, 1977). Both self-efficacy ($\alpha = .85$) and outcome efficacy ($\alpha = .85$) were measured with three items each (cf. Steg & de Groot, 2012).

Finally, the questionnaire measured the frequency of a list of environmentally relevant behaviors at work. In total, 27 items were used to measure behaviors chosen from three categories of environmentally relevant

behavior: 11 items for consumption of materials and energy, eight items for waste generation and management, and eight for work-related mobility. Sociodemographic data were also collected.

Obtaining Different Policy Pathways Through the Use of Backcasting Scenario Development

To reach the objective of defining and testing several policy pathways to promote the adoption of pro-environmental behavior in the workplace, we used a methodology of backcasting scenario development, which allows options to be produced by real organizational actors.

A process-oriented, participative, and iterative backcasting scenario approach was used. Process-oriented scenarios (Quist & Vergragt, 2006; Robinson, 2003) are centered on ensuring effective participation of stakeholders and to produce, besides images of desired end-states, possible pathways to reach them and specific agendas for their implementation. It also used a stepwise approach to help participants generate the scenarios, guided by a series of structured questions (Dumitru et al., 2013). Formulations of the scenarios were narrative, as these are easier to handle by stakeholders than abstract representations.

Two workshops were carried out and a combined methodology was used, with mixed focus groups to develop the scenarios, inspired in part by the one used by Svenfelt, Engström, and Svane (2011) but significantly adapted to fit the objectives of this research, and the stepwise approach of Kok, Van Vliet, Bärlund, Dubel, and Sendzimir (2011), to orient the process and help stakeholders in getting disengaged with the present, which is considered to be one of the hardest aspects of backcasting scenarios both with stakeholders and experts (Svenfelt et al., 2011). As behavior change in organizations was a key aspect of this research, scenarios included a focus on who should change, which is often ignored in backcasting studies (Wangel, 2011).

The first workshop focused on the creation of the visions for the future of the organization and followed three steps: problem definition and establishment of targets, a brainstorming phase, and the final articulation of the main elements of the future images. Participants were provided with input on the specific country calendar for reducing emissions according to the Kyoto agreements, and these targets were established as system boundaries for the scenario development. The year 2050 was chosen as a target year, as it is the projection year most commonly used in the European Commission's policy documents due to the fact that it is relatively easy to envision and also far enough away as to allow for radical change to happen (Vergragt & Quist, 2011). Information was provided on the contribution of each area of practices

to overall emissions for the University, and this was used as a basis for deciding reduction targets in each of the areas of practice. This information is publicly available and provided by the organizational Environmental Office. Results of the questionnaire were not fed into the workshops, and these two methodologies were kept separate. Three future visions were produced, ranging from a more conservative to a more radical one.

The second workshop focused on defining the strategic pathways to reach sustainable future images and the social actors that should be involved. Participants were first reminded of the targets set in the first workshop and presented with the three narrative descriptions of the sustainable organization in 2050. Participants were then guided to reach a consensus on the most desirable future vision to work toward and set specific targets for emissions reduction in the three areas of interest. As mobility accounts for approximately 50% of all University emissions, a lot of the discussion focused on establishing targets for work-related mobility. A reduction of car use to 20% of university staff and students was considered worthwhile and feasible for 2050. This meant that 80% of the university population would use more sustainable means of transportation: 20% would come on foot, 30% would use bicycles, and another 30% would use public transportation. A stepwise approach was again used to define pathways, intermediary milestones, and actors involved at each stage.

A group of 12 people participated in the two workshops. About half of the composition of the first workshop was maintained for the second, and additional members were then invited. An initial list of about 30 University staff members was drafted, belonging to different academic departments and whose work had an environmental aspect to it. They thus played the double role of university staff and experts. Both workshops lasted between 3 and 4 hr. Participants at the event were invited to attend via mail, and the invitation included a short description of the working technique.

Dynamic Simulations of Policy Implementation: Designing the Agent-Based Model

The profile of the agents was defined by using psychological variables that are known to influence pro-environmental behavior in the three areas of interest. Instead of using theoretically derived assumptions, we grounded the profiles in empirical data obtained through a questionnaire. Workers' decision-making processes were simulated using empirically grounded decision algorithms (for further information on the decision algorithms used, please refer to Online Appendix B and Figure S2), which gave us an opportunity to explore the relationship between individual trait factors such as values, or

identity, and the importance of social influence processes (e.g., social norms) on the direction of behavior. The theoretical model, used as indication in the preprocessing stages of setting up the ABM, was the Value-Belief-Norm (VBN) model of Stern (2000), adapted by de Groot and Steg (2009) to include other relevant variables such as identity. However, once the theoretical decision-making model has been designed, the results obtained were almost purely data-driven.

The interaction between workers was modeled by taking into account both the formal structures of the organization (a hierarchical structure) and the more informal connections among workers, which have proven to be significant as sources of influence in organizational psychology research (Mehra, Kilduff, & Brass, 2001; Oh, Chung, & Labianca, 2004; Sparrowe, Liden, Wayne, & Kraimer, 2001). To our knowledge, the combination of questionnaire-based methods for data collection, backcasting scenario development, and ABM is novel in the study of pro-environmental behavior.

Several policy tracks and interventions were developed from the scenario exercise data, to be implemented in the organizational simulations, using ABM (Matthews, Gilbert, Roach, Polhill, & Gotts, 2007; Sánchez-Maroño et al., 2012). These policies were tested in different combinations to see their effects on the performing of certain behaviors and related emissions levels. The ABM is a prototypical simulation which included different types of individuals with different organizational roles, their interactions—represented as a social network following rules of interaction that are based on both hierarchical and horizontal relationships—and the environment of the organization.

For the organization under study, the ABM had the following goals:

- To provide a formally represented model of the organization, the interactions within it and with its environment, for automatic forecasting and policy planning.
- To act as a test bed for formalized assumptions of the drivers of and barriers to everyday pro-environmental behavior in the workplace.
- To explore the logical consequences of accepting assumptions and evidence concerning the dynamics of everyday pro-environmental behavior.
- To allow the formalization of the backcasting scenarios and to test different policy tracks derived from them.

Formal representations of the organization provided a test bed with which to examine the various ways scenario-based interventions affect overall system behavior as an emergent property of interactions. These provide a "tool to think with" (see, for example, McIntosh, Jeffrey, Lemon, & Winder, 2005;

McIntosh, Seaton, & Jeffrey, 2007; Torrens, 2003), which may be used as part of wider discussions on the effectiveness of proposed measures. One advantage of ABM approaches in this regard is that it can be used to try out policy options that would be costly, or entail political risks if tried out in the real world. The results of such tests, if evaluated with respect to the assumptions embedded in the construction of the model, could be useful in determining whether real-world trials should be attempted, or whether the expected effect of the proposed measure is likely to be insufficient to merit exploration outside the domain of the simulation. Therefore, ABMs have been broadly used for sustainability research, with examples ranging from the exploration of the role of awareness in the consumption of a scarce resource (Sissa & Damiani, 2015) to the assessment of the performance of buildings given realistic occupants (see Andrews et al., 2011; Azar & Menassa, 2012). For more details on the implementation of the decision-making processes, how the ABM was validated, and how uncertainty was addressed, please refer to Online Appendix B.

As the theoretical model postulates that different value profiles will be associated with different behaviors, the 16 value items (refer to section "Measuring Psychological Factors and Environmentally Relevant Behavior") collected through the questionnaire were used to identify different profiles by using a clustering technique. Five different clusters were identified, three of them representing "pure" profiles—biospheric, altruistic, and hedonic—while the remaining two were hybrid clusters (biospheric–altruistic and hedonic–egoistic). For the sake of brevity, the details of how these clusters have been identified are discussed in Online Appendix A. All simulated university employees were distributed in one of these five groups, and each cluster would exhibit different behaviors in the model (please refer to Table S1 in Online Appendix A).

The other aspect to be designed in an ABM is the interaction among agents, as they interrelate and change their behavior over time based on the observation of the behavior of others and/or the environment. Therefore, a social network must be designed (Ronald, Dignum, Jonker, Arentze, & Timmermans, 2012). Social networks are an important quality of formal organizations, as previous research has shown that employees tend to be more cooperative and productive when their formal contacts are accompanied by informal ties (Mehra et al., 2001; Oh et al., 2004; Sparrowe & Liden, 1997; Sparrowe et al., 2001). Our empirical findings suggest that activity- and place-dependent social networks do have a role to play in influencing everyday pro-environmental practices in organizations (García-Mira & Dumitru, 2014), which is also coherent with the findings of Barr et al. (2011). Within this network, the dynamics can determine the way of thinking of the individuals and their behavior.

Due to the specific characteristics of the studied organization, in which individuals have more autonomy (understood as the degree of control over how to perform job-related tasks) than in other more "formal" or hierarchical organizations, two networks working in parallel were used. The vertical or hierarchical network is the one employed for modeling the transmission of rules and policies of the governing bodies of the organization at different levels (research groups, departments, etc.). The horizontal network is the one modeling the relationships of companionship and friendship, and thus the transmission of norms and behaviors through social relations beyond the hierarchical structure of the organization, that a priori seem of utmost importance, especially in the case of a university. The horizontal network is constructed from the vertical network, linking the individuals in the bottom part of the vertical network with their peers in the research group (if teaching/research personnel) or administration service (if administrative personnel), taking into account their reported number of interactions on average, which was reported in the questionnaire by respondents.

A more detailed description of the ABM can be consulted in Online Appendix B, and the modeling of social networks is described in more detail in Sánchez-Maroño et al. (2015).

Experiments

Based on the results of the backcasting scenario development workshops, different interventions were tested for each of the three categories of behavior included in the study. Interventions to promote sustainable work-related mobility behavior were given priority. We will provide examples for three different types of interventions tested, with details on the experimentation included in the following section. The following types of interventions were tested: (a) targeting the increase in the proportion of University staff having a biospheric value profile; (b) targeting structural limitations for car use, thus using top-down "choice editing" strategies; and (c) targeting the increase in the use of alternative transportation means such as bicycle use.

Results and Discussion

Hiring Staff With a Biospheric Profile, Increasing It by 50% as Compared With Current Levels, in 2050

The first policy option we explored had to do with modifying the staff structure of the organization over time, by including a preference for biospheric values in the hiring policy of the university, ending in an increase of 100% in

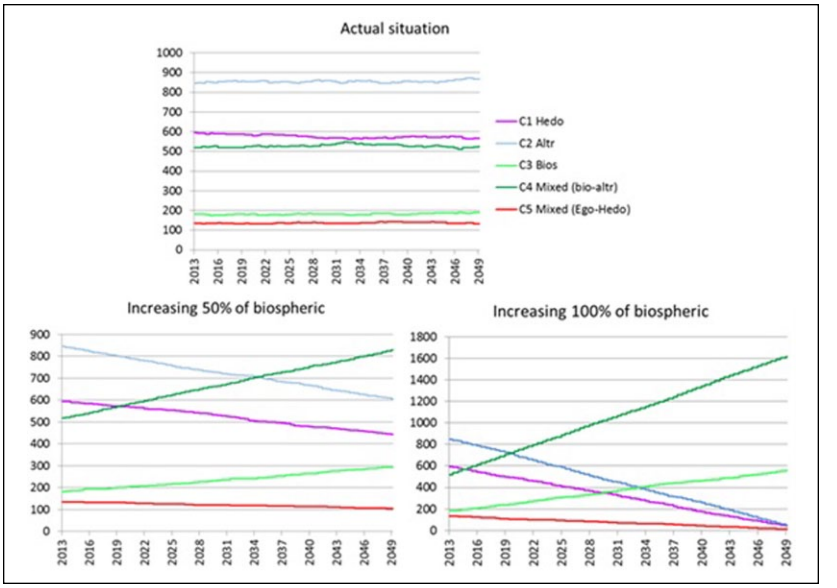

Figure 1. Number of agents per value profile in the present situation with no exogenous change (top center) and in the simulation of the increase of numbers of agents with a biospheric profile (50% of staff in the left and 100% on the right).

the clusters which contain this profile (pure and hybrid). It is clear how such a policy might be difficult to experiment with in a real setting, yet experimenting with it in a simulated environment can give us insight into its influence over behavior in the workplace. Also, it is conceivable, given educational efforts to instil pro-environmental values in young people, that future generations might lean more toward self-transcendent value profiles. Figure 1 shows a graph representing the agents per profile in the five profiles that were obtained for the organization. The subfigure on the center reflects the situation at present, and the resulting situation in 2050 if the present ratios are maintained. In the subfigure in the left, the ratio of biospheric personnel has been increased up to 50% as compared with the present situation, simulating new staff recruitment. Similarly, the figure on the right represents a situation in which the university staff is composed exclusively of staff with a biospheric value profile. The changes in the proportion of employees for each value profile are easily perceptible in the figure. For effects of interventions on carbon emissions, refer to Figures S4 and S5 in Online Appendix B.

In Figure 2, the number of agents using each transport type for commuting (car, bus, bicycle, train, motorcycle, walk) is shown. Similarly, the subfigure

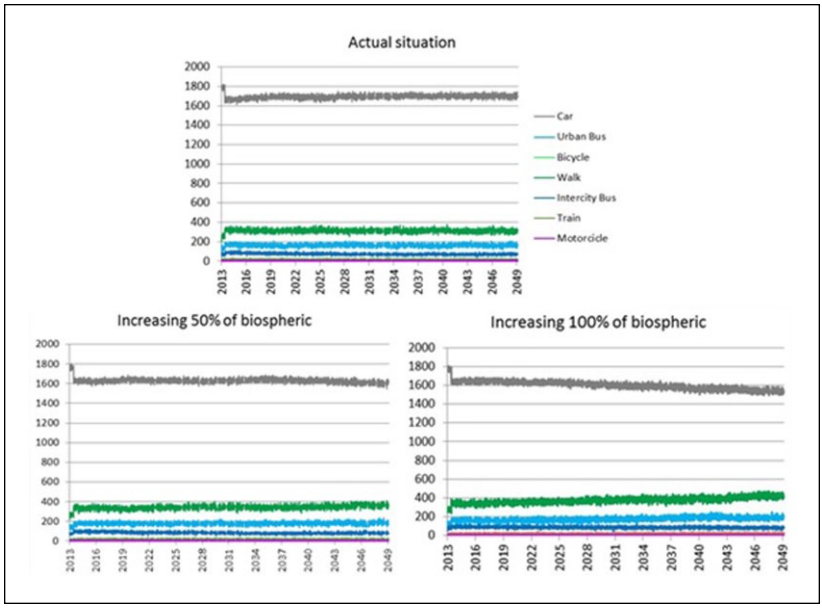

Figure 2. The number of agents using each type of transportation for the simulation of increasing recruitment of the biospheric profile.
Note. Present situation in the center, with no exogenous change to the biospheric profile in the upper part of the figure, 50% of biospheric personnel on the left, and 100% on the right.

on the center upper part represents the present situation in terms of number of agents using each transport type, whereas the left and right subfigures indicate how the number of agents using each transport type changes if the proportion of staff with a biospheric profile changes by 50% and 100%, respectively. In Online Appendix B, we have also included the effects of such a policy simulation on daily carbon emissions (please refer to Figures S4 and S5). Taken together, these results show a very interesting trend. In spite of the important changes in value profiles of the agents as well as those in the type of transport chosen to commute from home to work (notice that the number of agents commuting by car is reduced by more than a 100 individuals), changes in emissions are almost imperceptible. It thus seems that changes in the value profiles of employees by themselves would not achieve sustainability goals, which is consistent with previous research results in environmental psychology, indicating that values alone account for relatively low percentages of the variance of behavior (Bamberg & Moser, 2007). This is due to the fact that values are general antecedents of behavior, and this low influence is

even more prominent in organizational settings, where the autonomy to act on one's own values is relatively limited.

Different simulations were tested varying the percentage of staff with a biospheric value profile; 10%, 20%, 50%, and 100% were considered, although only the most significant results were included in the previous figures. Experiments targeting a proportion of 10% or 20% of staff with biospheric profiles show a similar evolution to the ones presented here. Also, although results are slightly better for the 50% and 100% hiring rate, the difference in carbon emissions with lower rates diminishes over time (see Figures S4 and S5 in Online Appendix B).

A few important conclusions can be drawn from the simulations above. First, we can see that hiring more staff with a specific value profile that is more likely to carry out pro-environmental practices in the workplace does not significantly modify the number of agents using the different transport means. This is most likely due to the fact that acting upon one's values is significantly limited by other personal, social, and structural factors in the organization (Ruepert et al., 2013). Further simulations support this reasoning in a dynamically simulated evolution over time. Emissions would be slightly reduced, but further simulations holding technological improvements constant have shown that these reductions disappear almost entirely when considering only the hiring of biospheric staff in isolation, which means that they are rather due to expected technological improvements of the environmental performance of vehicles. Finally, we can see in the last figure that an increase in the hiring of staff strongly endorsing biospheric values when replacing retiring staff by 100% gives slightly better results, yet the achieved reduction of GHG emissions diminishes over time, and are overall low (refer to Figures S4 and S5 in Online Appendix B for daily emissions reductions in the different scenarios). Simulations thus help us conclude that a hiring policy based on selecting staff with a pro-environmental value profile (the biospheric) would not achieve significant results in isolation, in spite of this profile being more motivated to act pro-environmentally. However, decision algorithms differ according to the value profile of the individual, suggesting that segmenting sustainability interventions by relevant traits of population clusters is a worthwhile avenue for policy, as previous research has also suggested (Abrahamse, Steg, Vlek, & Rothengatter, 2007).

Testing Both One-Off and Sustained Over-Time Policies for Reductions of Car Use for Commuting

Backcasting scenarios have also included restrictive measures for the use of cars, such as controlled reductions in parking space, or fees for parking that make commuting between home and work by car more costly. The effects of

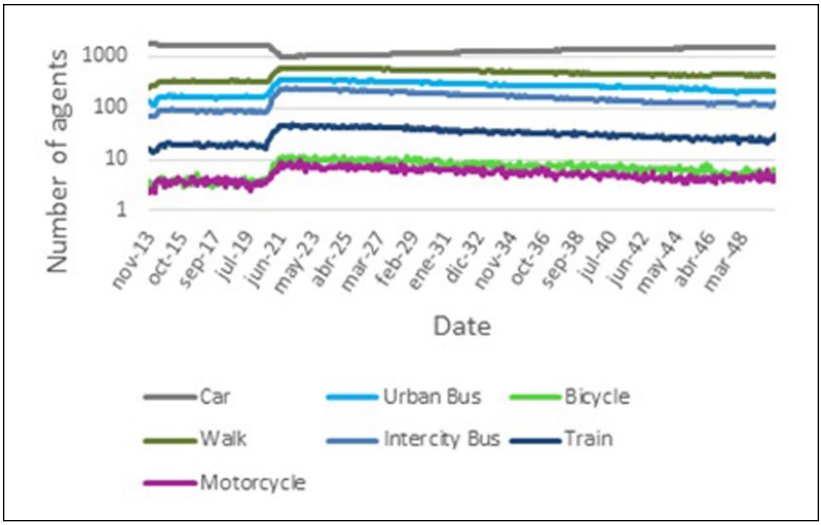

Figure 3. Effects of one-off policy interventions either restricting or making car use less attractive on the number of agents using a certain transport mode.
Note. *y*-axis is in a logarithmic scale for a better visualization of the results.

policies for the restrictions of car use were tested. These experiments affect the conditions of the environment in which the agents live. Experiments were run both for one-off policy measures, which would restrict the use of the car, and for stepwise, incremental policies that would be maintained over time up to the target year. One-off policies are common in organizations and social systems that rely on a democratic governance system, which includes limited terms of office. However, incremental policies have fewer political and psychological costs (in terms of citizen support, and adaptation) and have the advantage of creating an environment in which a culture favoring sustainable practices is likely to be created, as people start assuming the new conditions as part of their everyday life.

Simulations for the effects of restrictive policies of car-use reduction have taken into consideration of several scenarios: policies implemented at one point in time; policies being maintained over time with progressive interventions targeting reductions of 10%, 30%, or 50% of car use (in number of users) as compared with baseline numbers; and resulting emissions estimations for the three targets, with comparison among them.

When confronted with one-off restrictive policies targeting reductions in car use for home-work commuting, specifically 50% reduction (see Figure 3), agents are forced to adapt by choosing alternative transportation means.

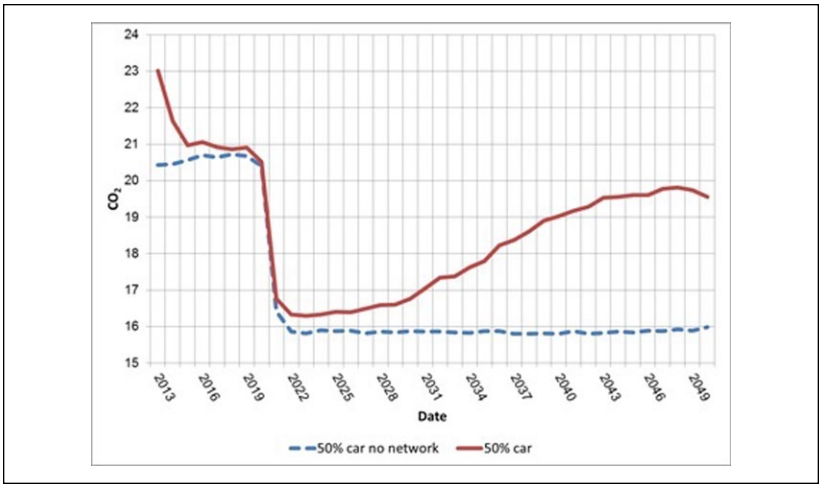

Figure 4. Influence of the social network.

Nevertheless, after this initial change in behavior, the influence of the social network results in a progressive increase in car use, which over time would tend to reach baseline levels again (note that there are free parking areas near the campus). In Figure 4, we can see the effects of this policy when the social network (i.e., interactions between agents) is eliminated. We can observe that when controlling for the social network, or, said differently, if workers were isolated and not exposed to the influence of others in the organization, their choices of alternative transportation means would be maintained constant. The influence of the social network is thus very important in the final outcome, rendering one-off car-reduction policies inefficient.

When policies are maintained over time, and include progressive interventions at certain intervals, results are far more promising, as agents start taking up other modes of transportation and adapt to the new reality, with the social network working in favor of sustainable goals. Figure 5 shows the results obtained in the case of maintained reduction policies aiming at a final reduction of 10%, 30%, and 50% of car use, respectively, by 2050. The model considered policy interventions working toward the final reduction target at 4-year intervals. Two important conclusions can be drawn from these simulations: (a) carbon emissions are considerably lower than in the isolated application of policy and (b) comparisons between the different reduction targets show that applying a more aggressive reduction target of 50% does not obtain significantly better results than for the less aggressive one of 30%, which

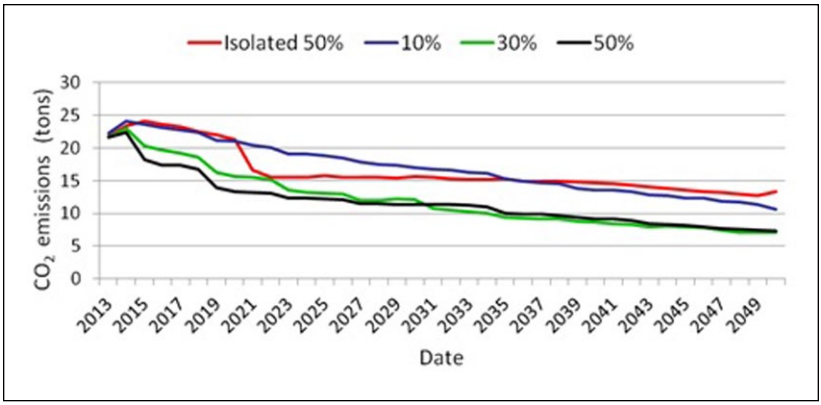

Figure 5. Comparative effects on emissions of car-reduction policies isolated in time (50%) and maintained over time, with targets of 10%, 30%, and 50% reductions by 2050 (tons of CO_2).

indicates that milder policies can be sufficient for the emissions reduction targets of European organizations. Figure 5 shows that carbon emissions in the long term are almost the same for both reduction targets of 30% and 50%, which both obtained better results than the lowest percentage tested (10%), which in turn is better than the isolated application of the policy even when the influence of the social network is eliminated (see Figure 4).

Testing Combined Policies for Transitions to Sustainable Commuting

Policy makers often find it appealing to combine policies targeting behavior change. This is especially so for commuting behaviors where policies tend to be unpopular due to the entrenched habits of car use and status and identity functions car use plays (Griskevicius, Van den Bergh, & Tybur, 2010). Testing and determining the effects of combined policies was thus a relevant objective of the present study. We tested combinations of policies targeting both car-use reduction and promoting the use of the bicycle (see Figure 6). The targets set were of a 100% increase in the number of bicycle users among university staff (a doubling of present-day numbers) and of 10% reduction in the number of car users. In the figure, it is visible that both policies maintain their desired effect in the long term and that the total emissions reduction obtained is similar to the situation in which the car-use reduction target is set to 30%. Thus, similar emissions reduction effects can be obtained by

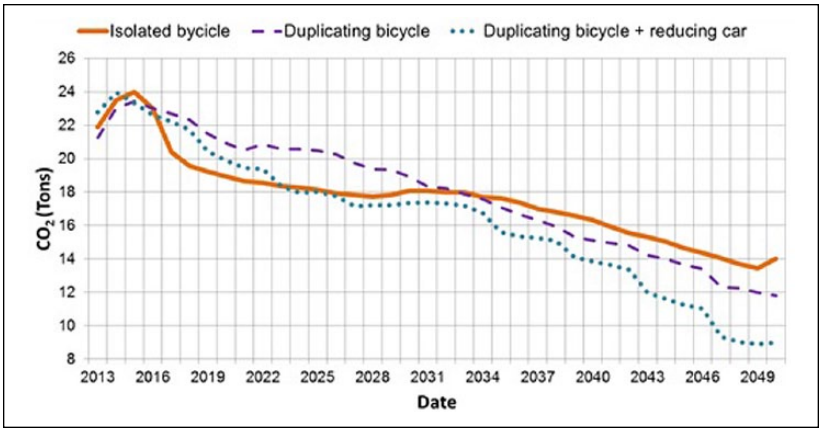

Figure 6. Testing combined policies for transitions to sustainable mobility.

targeting a milder reduction in car use and combining it with other mobility policies such as the increase of the use of bicycles among workers to commute between home and work. Such policies are also less politically costly and thus easier to be adopted and implemented. They are also more likely to receive support from workers in an organization, as the measures targeting car-use reductions would be complemented with behavioral alternatives. Furthermore, such combinations of policies are likely to be especially effective in behavioral areas that have been notoriously difficult to change, such as commuting.

Restrictive policies need to be combined with the provision of alternatives for behavior in order for them to be effective in bringing about behavior change over time. Applying restrictive policies only, either one time or incrementally, might generate negative reactions, and more so in democratically governed public organizations. Furthermore, restrictive policies that only change the environment in which behavior takes place are likely to have only short-term effects as they do not affect the psychological antecedents of behavior such as personal norms or our identities, which have proven significant as determinants of pro-environmental behavior change (Bamberg & Moser, 2007; Steg & Vlek, 2009; Turaga, Howarth, & Borsuk, 2010; Whitmarsh & O'Neill, 2010).

Behavior change strategies that target the use of alternative means of transportation have the advantage of encouraging alternative choices without imposing them, thus reducing negative reactions to these policies. Also, such policy options (e.g., awareness-raising campaigns, bicycle use-day, etc.) target

changes in personal factors (such as attitudes) or encourage experimentation with a new behavior, thus supporting the processes of habit-breaking (Verplanken & Wood, 2006) and pro-environmental identity formation, as mentioned earlier.

The main results of the agent-based simulation experiments demonstrated are summarized as follows:

- Hiring staff with high levels of biospheric values does not significantly modify the commuting behavior of agents, in spite of the fact that agents belonging to this category are more likely to act pro-environmentally.
- Mild-intensity restrictive policies maintained in time obtain better long-term results than more aggressive isolated interventions, in terms of overall emissions reductions. An aggressive policy seems to be very effective initially, and CO_2 emissions may be drastically reduced; however, the emissions increase again over time and they tend to reach the initial values. Nevertheless, maintaining a mild-intensity policy over time impedes emissions increasing again to starting levels.
- When applying restrictive policies targeting car-use reductions (e.g., reducing parking space at the university), better results are achieved when providing an alternative simultaneously (e.g., facilities for bicycle use) than when applying these policies separately.
- In the simulations tested, social networks are very influential in the long term and considerably affect the results of policy interventions.

Conclusion

The research reported here has used a combination of questionnaire-based empirical research, backcasting scenario development and ABM to investigate the effects of different policy interventions over time to promote pro-environmental behavior in a higher education organization. To achieve this, a realistic empirically grounded model of the organization was built and psychological theory was used to model the profiles of the agents representing workers in the organization, to define human decision-making algorithms for environmentally relevant behavior and to model processes of norm transmission and reception.

Policy tracks targeting organizational sustainability were defined within participatory backcasting scenario development workshops, and our analyses have demonstrated that to be successful, University policy should define tracks that are sustained over time, should combine different policies of medium intensity for changing worker behavior in a pro-environmental direction, instead of isolated policies of high intensity, and should take into

account the high influence of social networks and social norms in the workplace. Sustaining a certain policy track over time requires broad consensus in organizations with relatively flat hierarchies, and this can only be achieved through wide stakeholder participation in policy processes (García-Mira, 2009). Furthermore, the high influence of social networks and social norms suggests that bottom-up participatory processes should be put in place. Bringing a diverse range of actors such as workers, unions, and managers together can support consensus and commitment to sustainability goals, stimulate creative worker input, and possibly lower costs for behavioral compliance with organizational sustainability policies.

The use of social simulation methodologies such as ABM in the study of pro-environmental behavior change has proven worthwhile for several reasons. First, designing ABMs requires clear formalization of concepts and results of psychological research. Second, empirically grounded simulations provide valid models of dynamic interactions and processes which evolve over time and have emergent properties. Complex dynamic processes and testing the impact of complex feedback loops between contextual elements and psychological characteristics of individuals over time can instead be captured by agent-based social simulation methodologies, and thus create realistic models of everyday life contexts in which policies can be implemented and tested. The effects of different policies over time can also be apprehended through this methodology, thus making simulations a test bed for policy experiments and an important tool that can support policy making. The conceptualization and formalization of mechanisms of norm transmission and their influence in the simulation of a realistic organizational environment including a hierarchical and a peer/informal network is a novelty of this study.

The use of ABM together with backcasting exercises is also relatively new. Van Berkel and Verburg (2012) consider the use of ABMs as tools to evaluate the solutions backcasting exercises produce. Although in their exercise the advantages were derived chiefly from the ability to provide spatially explicit maps of the heterogeneous impacts of proposed policies (Van Berkel & Verburg, 2012), we have found utility in the approach of combining suitably designed questionnaires with data mining, backcasting, and ABM to explore scenarios using empirically configured agents. We hope to further test and refine this methodology in other contexts.

Organizations and policy makers have long been interested in knowing what determines whether certain policies are successful or unsuccessful. The present study has assessed the combined effects of vertical and horizontal relationships in the final effectiveness of policies, and has provided useful recommendations for the calibration of policy intensity and the types of policy combinations that are likely to work. This study has shown that combinations

of policies that provide adequate behavioral options in a particular domain and are of medium intensity can be as effective as policies of higher intensity. More detailed policy options can be tested in future research, and well-designed graphical user interfaces could eventually make these models interactive and possible to use by non-experts, thus also facilitating the dialogue between policy makers and scientists on complex problems.

Finally, the present research has demonstrated that organizations should be mindful of the importance of involving workers in designing sustainability-oriented policy measures as a necessary element in the effectiveness of organizational social responsibility plans. The contribution that individual workers can make through engaging in environmentally sustainable workplace behavior has been underrepresented (Davis & Challenger, 2015), and employees perceive their suggestions for environmental improvement to be insufficiently considered (Dumitru et al., 2016). While individual behavior is constrained by organizational structures and formal and informal rules, it is still the case that people bring with them their values, identities, personal norms, and patterns of behavior, which have an influence on their interactions with others and their adaptation at the organizational structures and culture they find in place. Organizations also differ in the degree of freedom and autonomy (understood as the degree of control over how to perform job-related tasks) workers are allowed, with universities being a type of organization where such autonomy is higher compared with, say, assembly-line workers in a factory producing trucks (see García-Mira & Dumitru, 2014). Participation could range from incentives to provide suggestions for the increase in the pro-environmental performance of daily tasks and routines to the continuous involvement of employees in the design and implementation of strategies to reduce the ecological footprint of the University.

Research undertaken in a different part of this project has shown that even in corporations in which autonomy and participation are much more restricted than in the present case, sustainable organizational change geared toward lower environmental impact would be considerably more effective if it included strategies for the facilitation of worker participation (Uzzell, Räthzel, García-Mira, & Dumitru, 2017). Organizations are key actors in climate change mitigation, and arguably, universities can also act as multipliers of virtuous behavioral change in their role as educators of future generations. They can act as good practice examples in the implementation of organizational governance models that can then be transferred to other societal contexts.

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