

Article

# Office Occupants' Perspective Dealing with Energy Flexibility: A Large-Scale Survey in the Province of Bolzano

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**Abstract:** The current energy system is dealing with an increasing share of renewable energy that, because of its intermittent availability, can affect the effectiveness of the energy supply. To cope with the problem, buildings need to become energy flexible. According to the definition given by IEA EBC Annex 67, energy flexibility is the ability of a building to manage its demand and generation according to local climate conditions, user needs and grid requirements. Users of energy-flexible buildings play a crucial role for an effective implementation, thus user acceptance and proper behaviour are important factors. In order to understand the current level of awareness on the topic and the general acceptance of the users, this paper presents the results of a large-scale survey distributed in the office buildings of the Province of Bolzano (Italy). This study investigates the information, experience, beliefs, and desires of the building users (i.e., office employees) with concepts and technologies dealing with energy flexibility, such as smart grids, smart appliances, and smart meters. This study identifies (i) the main socio-demographic characteristics associated to the information and desires about energy flexibility in office buildings, and (ii) the main conditions of social acceptance of flexible energy usages. Although this work is focused on a specific user type (i.e., office workers in the Province of Bolzano) and the results cannot be generalized, the analysis offers an interesting insight on the user perspectives and acceptance on energy flexibility and can be easily replicated. The results can be used at local level to provide insights for policies and strategies to encourage building users to be more flexible.

**Keywords:** energy flexibility; user acceptance; office buildings; smart technologies

## 1. Introduction

In response to the urgent threat of climate change [1], decarbonizing energy systems has been progressively recognized as a priority in recent European energy policies [2,3]. Consequently, an exponential growth of different renewable energy sources penetration is occurring in parallel with the extensive electrification of the demand [4]. Conventional centralized energy systems based on fossil fuels are transforming into efficient decentralized systems supported by renewables [5,6] and stand-alone energy consumers are shifting towards interconnected energy communities of prosumers able to both consume, locally produce and store energy [7]. For maintaining grid stability and for managing grid congestions without an excessive cost for new infrastructures, increasing flexibility in the energy system becomes necessary [8–10].

Energy flexibility of a building represents ‘the ability of a building to manage its demand and generation according to local climate conditions, user needs and grid requirements. Energy flexibility of buildings allows for demand side management/load control and thereby demand response based on the requirement of the surrounding grids’ [11].

As buildings are the largest energy consumers in Europe, responsible for approximately 40% of energy consumption and 36% of CO<sub>2</sub> emissions [12], they play a key role towards energy flexibility target [13]. In the revised Energy Performance of Buildings Directive 2018/844/EU [12], the flexibility is introduced as fundamental pillar underlying the Smart Readiness Indicator (SRI). Such indicators should measure the capability of a building ‘to use information and communication technologies and electronic systems to adapt the operation of buildings to the needs of the occupants and the grid and to improve the energy efficiency and overall performance of buildings’.

In terms of ‘adaption’, buildings can contribute through demand response (DR) strategies to change consumption patterns to optimize the use of energy [14–16]. In buildings, several demand-side energy management strategies can be adopted: [17,18] have studied the flexibility potential of domestic appliances modulation, [19] have investigated the impact of the electric vehicles optimal charging on the residential distribution system, [20,21] have evaluated the effect of domestic hot-water storage tanks in balancing the renewable energy production. Furthermore, the storage potential in thermal mass embedded in building construction elements [22] offers a buffer role to enhance system stability, mitigating the fluctuations of variable renewable energy sources [23] and shifting demand from on-peak to off-peak periods.

Nevertheless, the implementation of energy-flexible control strategies [24,25] can affect building users, in terms of lifestyles, thermal comfort and potential increase in costs and energy consumption [26,27]. In parallel, since building users can affect the energy and flexibility performance of buildings through their energy uses [28,29], the identification of actual users’ beliefs and desires becomes crucial to investigate the actual and potential acceptance of energy flexible solutions.

Despite the high number of assumptions on how users might perceive smart technologies and smart grids [30–32], existing studies focusing on the field-investigation of stakeholders’ involvement in energy flexibility of buildings are limited. For retail stores, the questionnaire results of the research of Ma et al. [33] highlight that the smart control of lighting, heating, ventilation and air conditioning systems and refrigeration are the preferred options to provide energy flexibility; assuming the energy manager’s perspective, legislation and financial savings constitute the two main drivers of flexibility implementation but the direct involvement of employees in demand response strategies is not considered suitable. For residential buildings, the large-scale survey of Li et al. [34] brings out the important role of household for the adoption of energy flexible solutions and identifies the potential flexible building users by looking into their perspectives of smart grid technologies and their readiness to use energy flexible buildings. For office buildings, the study of Billanes et al. [35] provides insights on the main barriers to adopt energy flexibility; the results show that building owners/managers are more concerned with business operations and profit, while occupants give primary importance to indoor comfort and ease-of-use of technology; however, the hypothesis discussion is solely based on literature review and lacks a case study application.

This kind of analysis takes advantages from the social acceptance concept. The acceptance (or rejection) of energy technologies is the core of a deep debate in the scientific literature [36]. The acceptance is the response of several actors in front of energy interventions and it promotes or gets slower the change towards more sustainable (e.g., renewable, efficient, or flexible) energy systems [36]. This concept is one of the possible responses addressing the support, the adoption, the opposition, or the neutral reaction in front of an energy system change. Even if the concept of acceptance focused on energy flexibility is little discussed, it is recognized as critical to achieve user satisfaction [37] and correct use or high spread of a flexible solution.

This study intends to integrate this group of researches on buildings and end-users with a sociological perspective, using the framework of the Socially Embedded Unit Act [38]. The framework

focuses on two levels: the first level is individual and investigates desires, beliefs and choices of individuals; the second level is collective and focuses on meanings embedded in a cultural context, and on norms, forms, practices, motives, and experiences. In the decision-making process, the agent (e.g., the individual) has three features: it possesses desires (goals, purposes, or ends), beliefs (information and knowledge), and it makes choices (act, do, perform). ‘In sum, *at the individual level desires and beliefs direct action*’ [38]. Beliefs, desires, and choices create social norms and practices that are reproduced within social groups (e.g., family, entire society).

The applied framework supports the understanding of the actual and potential social norms—based on individual beliefs, desires, and choices of the public office occupants—favourable (or critical) for the spread of energy flexible solutions and an effective use of energy flexible technologies. This study investigates desires (e.g., willingness to use smart appliances in the office) and beliefs (e.g., information on smart energy appliances) of public office occupants for understanding which are the meanings and interpretive understanding of energy flexible solutions, within the specific culture of South Tyrol and public offices. This study is relevant for understanding which social norms, favourable to the spread of energy flexible solutions, could be promoted by the actual beliefs and desires of end-users. These aspects give us the opportunity to anticipate the potential acceptance of energy flexible solutions and technologies and investigate the creation of related social norms, within a cultural context.

Considering the great potential of office buildings to offer energy flexibility in the near term, due to the existing building management, control systems and large energy consumption [39,40], this work broadens previous researches and approaches the energy flexible topic from the perspective of end-users with a survey focusing on office buildings occupants, i.e., people who occupy and use the building technologies, and investigates the end-user beliefs and desires, according to sociological perspective and using the Socially Embedded Unit Act framework [38].

The existing sociological literature on energy focuses on different topics related to end-users—such as energy efficiency, consumptions, and saving [29], smart energy monitor use [41], and social acceptance of energy technologies [36]. Among the most interesting investigations into the interaction among sociology and the energy field is related to the link between the energy beliefs, desires, and choices and the socio-demographic characteristics of end-users [41,42]. This kind of research (i) investigates differences within a population and promotes the development or the creation of ad hoc actions for enhancing an effective energy transition and (ii) is able to address the relevant gap between expected and actual energy consumptions or the energy flexibility of buildings, due to the end-users [43].

One of the most studied and influencing socio-demographic characteristic is the gender. Existing scientific literature observes differences based on gender linked to the desires, beliefs, and use of a technology (e.g., thermostat [44]), to the energy finance-related literacy [42], or to the change in energy behaviours after a building retrofit [45]. The gender is relevant to explain the level of energy finance related-knowledge, underlining that the knowledge (based on information) is a more available resource for males than females [42]. The gender often explains differences in individual choices as well as in collective choices or practices reproduced within a group (e.g., family practices). Indeed, the gender is a variable approximating social dynamics and relationships within a group (e.g., household or office colleagues) [46,47]. Therefore, it is not a simple matter of gender, but the analysis of the association between gender and the energy topics is relevant for starting to investigate how people perceive and use energy and technology, based on choices made within a group. Beyond the socio-demographic characteristics of gender, the education level is affecting some end-user choices, such as the ventilation habits in houses [45].

This paper, focusing on the perspectives of users and on possible factors contributing to or inhibiting the use of flexible energy solutions, discusses issues often overlooked in the research on energy flexibility. Using the insights from the existing literature on several energy topics (e.g., energy efficiency, energy saving behaviour) and the framework of Socially Embedded Unit Act, this research investigates the association among socio-demographic characteristics and the perspectives of users about energy flexible interventions in workplaces, in terms of desires, beliefs, and experiences.

The actual research is mainly focused on residential buildings [41,47], while the workplaces—having the same gap—are less investigated [43,48]. The flexibility that office employees are asked for is referred to their capability to adapt their everyday routine in the office to fit in their energy use with the renewable energy production. To improve the energy flexibility and the efficient use of energy in office buildings, the office occupants should rely on smart controls and be willing to accept for example a shift in the timing operation of office appliances (e.g., dishwasher, printer/copier), a modulation of the indoor temperature within the comfort range, or the use of electrical vehicles to store energy.

Within the Italian context, the Province of Bolzano represents a frontrunner in the field of building energy efficiency and smartness. It worked as a pioneer for the introduction of energy labelling and high-performance buildings, with the close collaboration between public institutions, research centers and local energy agencies. In recent years, an increasing focus has been devoted towards the introduction of smart technologies, especially in public buildings and infrastructures. Although the share of smart electricity metering in Italy is more than 95% from several years [49], the legislative framework was not adequate to enable the introduction of energy flexibility and smart grids. Nevertheless, in 2018 at the NOI Tech Park the first Energy Community of South Tyrol has been released, with the collaboration of the local energy distributor and a team of technology companies. The case represents a prototype of energy community of a public office building and has been also analyzed in terms of smart readiness by [50]. Another example is the Smart city project FP7 SINFONIA [51], where Eurac research worked with the local institutions to increase the level of efficiency of social housing and the penetration of renewable sources, introducing smart technologies both at building and at city infrastructure level. There are also several local projects focused on the topic, and in particular, the ERDF (European Regional Development Fund) INTEGRIDS (Integrated Energy Grids) [52] aimed to develop energy flexible strategies for buildings in Province of Bolzano in order to foster the efficient use of renewable energies within thermal and electrical grids. Moreover, also the management of the Province of Bolzano is interested in increasing the energy efficiency and introducing innovative smart technologies within the public office buildings, and started to plan awareness programs for employees of public buildings [53].

According to these premises, a large-scale survey is conducted in the framework of the IEA EBC Annex 67 project [11] on the end-users of the office buildings of the Province of Bolzano, Italy. The case study results aim to preliminary understand office occupants' perception of renewable energy usage and their perspectives towards smart grids, smart appliances and smart meters in office buildings.

In the following sections, the methods for designing the questionnaire and conducting the survey are presented (Section 2), and the survey data are provided in figures and tables to give an overview of the results (Section 3). Finally, the main conclusions are outlined in Section 4.

## 2. Materials and Methods

### 2.1. Questionnaire Design

This study aimed to survey office building end-users. Based on the work of Li et al. [34], an online questionnaire was prepared in two languages, Italian and German, consisting of 16 multiple-choice questions organized in three main parts, as presented in Table 1:

(1) *Socio-demographic characteristics*: in the first section of the survey, a set of questions were raised about socio-demographic characteristics of the respondents, in terms of gender, age, educational level, position and office typology.

(2) *Beliefs and desires about renewable energy usage*: the second section dealt with the perception of renewable energy usage and was developed through different questions aimed at understanding the office end-user's information on renewable energy sources and the importance attached to the use of renewable energy.

(3) *User perspectives about smart grids, smart appliances and smart meters*: the third section was about office occupants' perspective on smart grids, smart appliances and smart meters. This last section was introduced by a short description (both in Italian and German) of smart grids and their functioning principles, in order to give an overview to the respondents about this topic. Then, the survey participants were asked to answer questions about their experiences with the smart grid concept, their beliefs, desires, feelings, and motives to use smart grid products and services, investigating the meanings attributed to energy flexible solutions and technologies.

**Table 1.** Content of the survey.

Survey Section	Questions
Socio-demographic characteristics	Gender, age, education level (high school or lower, university/PhD), position (employee, manager, team leader, team member, other), office typology (single office, shared office with another colleague, shared office with two other colleagues, shared office with three or more other colleagues, open space, other).
Beliefs and desires about renewable energy usage	<p><i>Information on renewable energy sources</i> Do you know about renewable energy sources? (no, a little bit, yes).</p> <p><i>Importance of using renewable energy</i> How important, do you think, is using renewable energy instead of fossil fuels? (1 not at all important–5 very important); How important, do you think, is using renewable energy in your office? (1 not at all important–5 very important).</p>
User perspectives about smart grids, smart appliances and smart meters	<p><i>Experience with smart grid technologies</i> How familiar were you with the smart grid concept or technologies before this questionnaire? (1 I didn't know about it–5 I already knew a lot about it).</p> <p><i>Willingness or desire to use smart appliances in the office</i> Would you be willing to let the following smart appliances be remotely controlled by your electricity utility?—dishwasher, printer/copier (ensuring urgent jobs will be done right away), air conditioning system (ensuring comfort temperature), smart heating system (ensuring comfort temperature), electric vehicle—(1 not willing at all–5 really willing); Would you be willing to follow the messages shown on your office energy display or your smart phone to manually turn on the following smart appliances at the recommended time?—dishwasher, printer/copier (ensuring urgent jobs will be done right away), air conditioning system (ensuring comfort temperature), smart heating system (ensuring comfort temperature), electric vehicle—(1 not willing at all–5 really willing).</p> <p><i>Motivation to accept a flexible energy usage</i> What would be the conditions for you to ACCEPT the direct control of some appliances by your electricity utility? Choose as many as apply. <i>-not compromising privacy, possibility to override at any time that control, not interfering with the work activities, only if needed to ensure electricity supply, environmental advantages, effective electricity bill savings, be informed of the control actions and savings generated, other-;</i> What would be the conditions for you to FOLLOW the recommendations from your electricity utility and manual control your appliances? Choose as many as apply. <i>-not compromising privacy, possibility to override at any time that control, not interfering with the work activities, only if needed to ensure electricity supply, environmental advantages, effective electricity bill savings, be informed of the control actions and savings generated, other-;</i> What would be the reason for you to NOT ACCEPT the control of some appliances by your electricity utility? Choose as many as apply. <i>-interference with privacy, no override function, risk of inference with the work activities, mistrust in the electricity utility, unawareness on the motive requiring that action, risk of damaging equipment, lack of contractual legitimacy, unawareness on the control actions, might be too complex to operate, other-;</i> What would be the reason for you to NOT FOLLOW the recommendations from your electricity utility? Choose as many as apply. <i>-interference with privacy, no override function, risk of inference with the work activities, mistrust in the electricity utility, unawareness on the motive requiring that action, risk of damaging equipment, lack of contractual legitimacy, unawareness on the control actions, might be too complex to operate, other-;</i> How motivating do you think you will be from the following things?—<i>seeing how much you are minimizing your electricity usage, seeing how sustainable you are, seeing how much money you are saving, seeing how you are doing compared to your colleagues, seeing how flexible your energy consumption is</i>—(1 not motivated at all–5 really motivated); What information would you want to see on your building energy display? Choose as many as apply. <i>-the amount of CO<sub>2</sub> reduction, the amount of saved money, the amount of saved energy, the influence of your energy usage on the environment, other-</i> How do you think smart grids will influence your work? (1 in a bad way–5 in a good way).</p>

The quantitative survey was chosen for some of its specificities. The goal of this survey was to investigate some of the socio-demographic characteristics, desire, beliefs, and more general perspectives of end-users about smart grids, meters and flexible energy solutions, starting from a set of factors already relevant for other energy topics [47]. This study needed a standardized tool for collecting data about some known factors related to the acceptance of energy solutions and reaching a high percentage of people working in the public offices in South Tyrol. The survey is the tool that, according to our knowledge, fixes better these research needs: standardized questions on known relevant factors, potential spread to a large sample, possibility to analyse results investigating the associations among factors [54]. However, the survey needs to be careful in some aspects.

Social scientists agree on the existence of the problem of social desirability in answering to surveys. As [54] reports, 'social desirability regards the commonly held evaluation of a certain attitude or behaviour of the individual within a given culture. ( . . . ) If an attitude (or behaviour) has a strong positive or negative connotation in a certain culture, questions concerning such an issue may elicit a biased response'. In our case, social desirability could exist regarding the renewable energies (therefore the 'importance of using renewable energy') and the willingness to use smart appliances in the office. The social desirability bias is a relevant issue to deal with and quite complicated to overtake. However, this survey tried to avoid—at least partially—the social desirability bias through its anonymity, and it considered the cultural context as creating social norms that could be somehow transformed in social desirability bias [38]. The used survey did not want to be exhaustive and empty of social desirability, but it was a relevant opportunity to collect information and data from a large population of workers in public offices.

## 2.2. Survey and Response

The questionnaire was distributed through CAWI (Computer Assisted Web Interviewing) technique. The questionnaire link was circulated in the offices of the Province of Bolzano during the period February–June 2017 and was addressed to all categories of employees. In total, we sent the document to 10,000 collaborators of the Province of Bolzano and the survey was closed collecting 922 completed questionnaires, resulting in a response rate of 9.2%. No partially filled-in questionnaires were received, since it had been required that respondents answered all the questions.

## 2.3. Data Analysis

Statistical analysis was conducted using the statistical analysis software SPSS to understand the possible connections of social-demographic data of the respondents (gender, age, educational level, position, office typology) with their perception of renewables and perception and attitude towards smart grids. In order to explore the distributions of variables of interests, absolute and relative frequencies were calculated. The existence of associations between qualitative variables (nominal variables or ordinal variables treated as nominal) was tested through the independent chi-squared test ( $\chi^2$ ). Furthermore, in order to explore the differences between the groups of variables expressed in ordinal scale, either the Mann–Whitney U test (in the case of two groups,  $Z$  statistics were reported) or the Kruskal–Wallis test (in the case of three or more groups,  $K-W H$  statistics were reported) were applied, in accordance to the distribution of the data. In this case study, the use of non-parametric tests gave the possibility to provide quantitative evidence of the existing differences among the considered groups, e.g., based on gender. The values of the mean ranks ( $MR$ ) resulting from the non-parametric tests, identified the degree of association to surveyed items and were indicated in brackets after the respective sample groups of reference.  $p < 0.05$  was considered significant in all the analysis.

### 3. Results and Discussion

#### 3.1. Socio-Demographic Characteristics

The group characteristics of the survey respondents are shown in Table 2. They consisted of 61% women and 39% men, mostly within the age category 40–59 years old and with a high school or lower educational level (56%). Most of the respondents had a position of either ‘employee’ (77%) or ‘manager’ (13%) and worked in a ‘single office’ (42%) or ‘office shared with one colleague’ (40%).

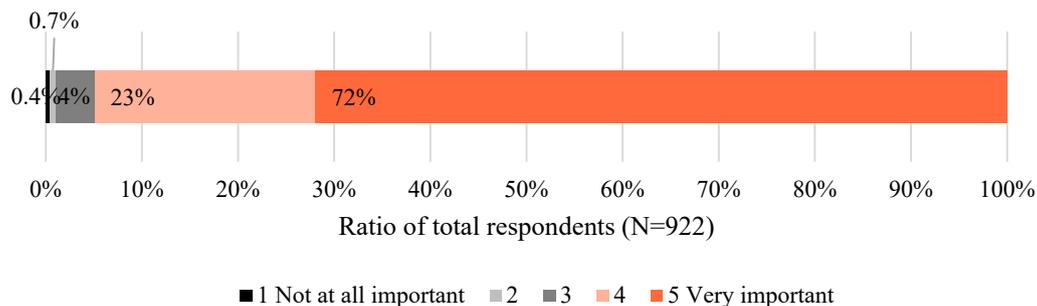
**Table 2.** Respondents’ characteristics (N = 922).

Characteristics	Categories	Survey Answers (%)
Gender	Male	39
	Female	61
Age (years old)	<30	4
	30–39	17
	40–49	37
	50–59	35
	≥60	7
Educational level	High school or lower	56
	University/PhD	44
Position	Employee	77
	Manager	13
	Team leader	6
	Team member	2
	Other	2
Office typology	Single office	42
	Shared office with another colleague	40
	Shared office with two other colleagues	7
	Shared office with 3 or more other colleagues	6
	Open space	2
	Other	2

#### 3.2. Desires and Beliefs about Renewable Energy Usage

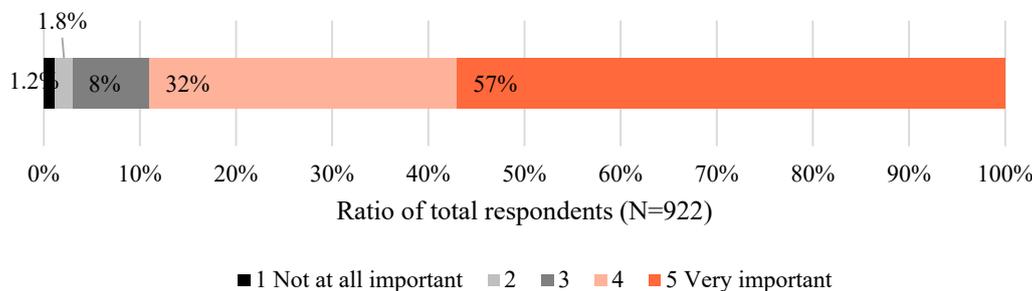
The first question was related to the level of information about the renewable energy sources. Three options were presented: ‘no’, ‘a little bit’ and ‘yes’. The survey results showed that 65% of the respondents was aware of renewable energy sources, whereas 33% admitted knowing ‘a little bit’ about the topic and only 2% stated to be unaware.

Concerning the general question related to the importance of using renewables instead of fossil fuels (Figure 1), a Likert scale (from ‘1-not at all important’ to ‘5-very important’) was used. A percentage of 72% of the respondents voted the option ‘5-very important’ (against 0.4% for the option ‘1-not at all important’).



**Figure 1.** Importance of using renewables instead of fossil fuels.

Similarly, for the question related to the importance of using renewables specifically in the context of the offices (Figure 2), 57% of respondents chose as top option ‘5-very important’ compared to the 1.2% obtained for the option ‘1-not at all important’.



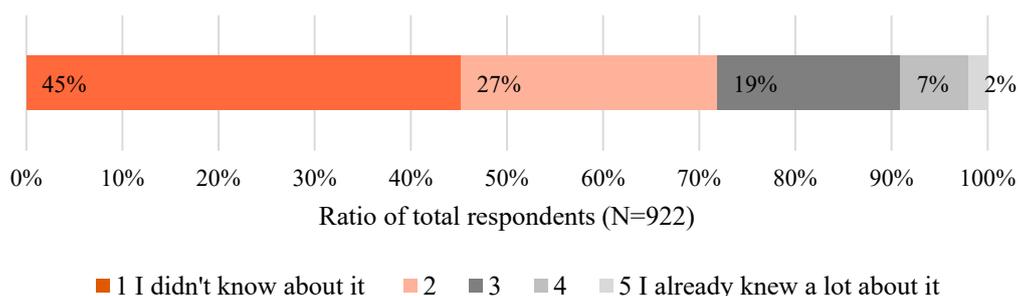
**Figure 2.** Importance of using renewables in office buildings.

The independent chi-squared test confirmed the existence of association for both gender and information about renewable energy sources ( $\chi^2(2) = 27.75, p = 0.000$ ), and gender and importance of using renewable energy in the office ( $\chi^2(4) = 14.01, p = 0.007$ ). Statistically significant differences among groups existed ( $Z = -5.17, p = 0.000$ ), indicating that the information on renewable energy sources in the case of men ( $MR = 508.74$ ) was higher than in the case of women ( $MR = 431.52$ ). These results confirmed the gender gap about energy literacy—or energy-related beliefs (e.g., information)—cited by [42]. Regarding the importance of using renewable energy instead of fossil fuels and the importance of using renewable energy in the office, the same test did not highlight any significant differences in the distributions among males and females. Moreover, there were no differences between different groups of age variable and employee position with respect to the information and importance of using renewable energy instead of fossil fuels (in fact, all tests show  $p > 0.05$ ).

The chi-squared test verified that there was an association between educational level and information on renewable energy sources ( $\chi^2(2) = 13.86, p = 0.001$ ) and educational level and importance of using renewable energy instead of fossil fuels ( $\chi^2(4) = 11.17, p = 0.025$ ). There were differences in information on renewable energy sources between educational levels ( $Z = -3.40, p = 0.001$ ), indicating that the information on renewable energy sources was higher for respondents with ‘university/PhD’ level ( $MR = 489.22$ ) than for respondents with ‘high school or lower’ level ( $MR = 439.30$ ). There were also differences in the importance of using renewable energy sources instead of fossil fuels ( $Z = -2.23, p = 0.026$ ), indicating that using renewable energy was more important for respondent with ‘University/PhD’ level ( $MR = 478.57$ ) than for respondent with lower education level ( $MR = 447.83$ ). In [45], it was stated that the education level affects the energy technology use and the results of this survey confirmed the association among educational levels and preferences towards renewable energy.

### 3.3. User Perspectives on Smart Grid Technologies

After providing a brief introduction on the concept of smart grids, the respondents were asked about their previous beliefs or information on the topic. Five options were presented from ‘never heard of it’ to ‘know a lot about the concept’. As shown in Figure 3, and in agreement with the results of [34], 45% of the respondents did not know about the concept and only a small number of them (2%) stated to already know a lot about it. Therefore, according to the answers, we could state that most of the respondents were not or little aware of smart grid features, nor about the potential benefits of its application.



**Figure 3.** Experience with smart grid concept.

After the analysis of the frequency distribution of the variable experience with smart grid technology or concept, a new variable with three categories was created. Values equal to 3 or higher were combined in one modality (3); the modalities 1 and 2 remained without any changes.

The independent chi-squared test acknowledged the existence of association between gender and experience with smart grids ( $\chi^2(2) = 34.22, p = 0.000$ ). There were statistically significant differences between males and females ( $Z = -5.21, p = 0.000$ ), where men showed higher experience with smart grid technologies ( $MR = 514.93$ ) than women ( $MR = 427.59$ ). There were no differences between different groups of age variable and employee's position regarding the experience with smart grids (all tests showed  $p > 0.05$ ). Once more, the energy literacy—or the energy-related knowledge or information—was different based on gender [42] and education level [45]. These results confirmed the association among gender and energy flexibility literacy, in addition to the already cited association among gender and other energy topics [42]. This research also has opened new questions on the association between education level and the use of energy flexible technologies.

The chi-squared test confirmed that there was an association between educational level and experience with smart grid ( $\chi^2(2) = 8.26, p = 0.016$ ). There were differences in experience with the smart grid ( $Z = -2.71, p = 0.007$ ) indicating that the experience with the smart grid was higher for respondents with 'university/PhD' level ( $MR = 486.26$ ) than for respondents with 'high school or lower' level ( $MR = 441.67$ ).

The existence of association between information on renewable energy sources and experience with smart grid was affirmed by the chi-squared test ( $\chi^2(4) = 54.78, p = 0.000$ ). There were statistically significant differences in experience with smart grid between different levels of renewable energy sources information ( $K-W H = 47.36, p = 0.000$ ): the test indicated the highest value of experience with smart grid concept for the respondents declaring to have information on renewable energy sources ( $MR = 499.96$ ), followed by the users with partial information (a little bit) ( $MR = 399.03$ ) and by the respondents declaring to be unaware of renewable energy sources ( $MR = 264.45$ ).

#### 3.4. Willingness to Use Smart Appliances in the Office

The scope of this section was to investigate the perspectives of the end-users concerning the smart appliances. The first question was related to the willingness of enabling some smart appliances to be remotely managed by the utility and building automatic control via building energy management systems (Figure 4). A Likert scale was provided from '1-not willing at all' to '5-really willing' as choices. Most of the respondents would be positive to allow remote control for all the appliances and especially the heating system (42.5%) and the air conditioning (41.8%), with respect to thermal comfort conditions. The willingness or desire to use an electric vehicle with a smart charging and discharging system obtained promising results too (39.5% stated the 'really willing' option).

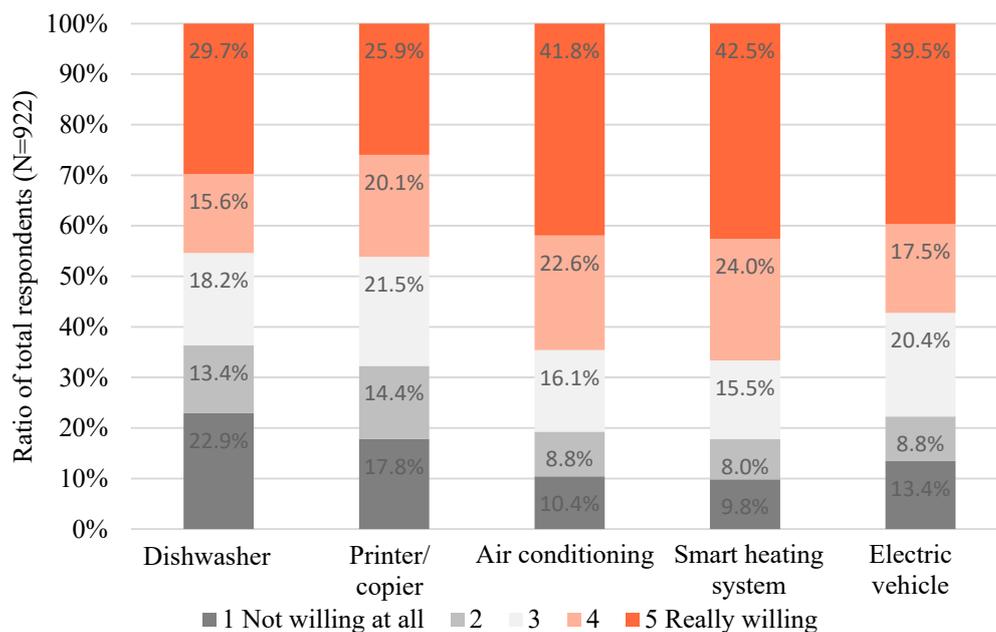


Figure 4. Willingness to let some smart appliances be remotely controlled by the electricity utility.

The second question was related to the willingness to follow the messages shown on the office energy display or a smartphone to let the user manually turn on some smart appliances at the recommended time (Figure 5). A Likert scale was provided from ‘1-not willing at all’ to ‘5-really willing’ as choices. The level of willingness was comparable with the results of the previous questions, in fact the majority of the respondents was ‘really willing’ to follow the messages shown on the building energy display or smartphone to manually change the energy use behaviour, especially acting on the regulation of the temperature settings acting on the heating system (40%) and the air conditioning system (40%) and on the smart control of electric vehicles (38.3%).

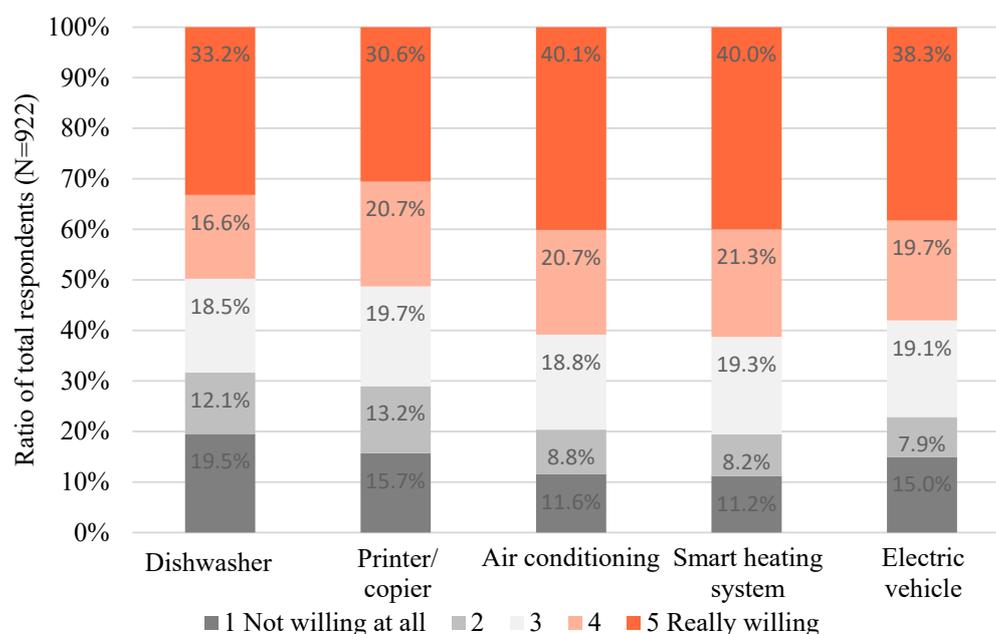


Figure 5. Willingness to follow the messages shown on the office energy display to manually turn on some smart appliances at the recommended time.

As noticed for the household case study [34], the office occupants were willing to remotely/manually control the heating or air-conditioning system in their office but, differently from the residential building users, they demonstrated a positive willingness respect to the electric vehicle. This outcome is in line with the smart grid development scheme published by the International Energy Agency [55].

Comparing the option of remote-automatic control and user manual control of smart appliances, the results indicated that office end-user's preferences for control option did not differ and they seem positively willing to accept also non-manual control. Moreover, there were no statistically significant differences related to different employees' positions and office typologies (all tests showed  $p > 0.05$ ). Compared to different levels of familiarity with smart grid, no differences on willingness in the use of smart appliances was detected (all tests showed  $p > 0.05$ ). Thus, multiple control options should be taken into account in the deployment of smart technologies.

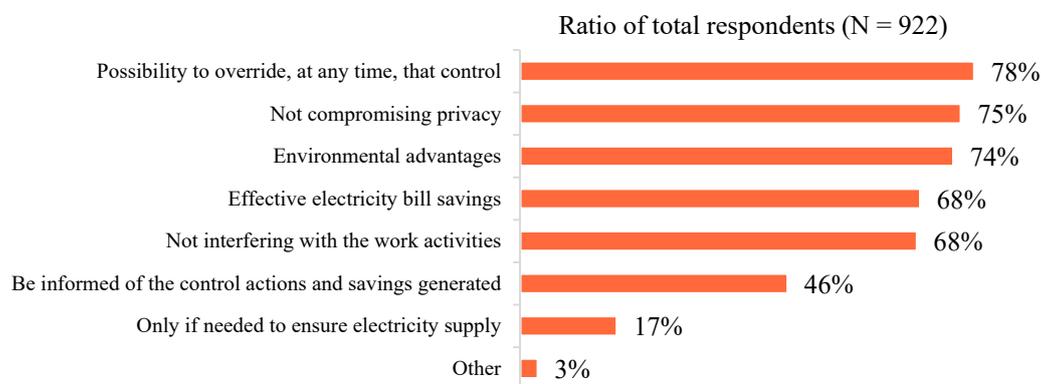
The lack of diversity in willingness to use remote-manual control options for smart appliances was a key difference compared to the residential users' case study [34], in which, on average for all the technologies, half of the respondents indicated their preference for grid remote control or home automatic control compared to the manual or no control options.

### 3.5. Motivation to Accept a Flexible Energy Usage

The respondents were questioned about a list of motivations for accepting a flexible energy usage. The motivating factors used in the questionnaire were selected based on previous research:

- Privacy issues and interference with users' activities were mentioned as main barriers to accept automatic control and smart grid technologies [56];
- Financial motives, such as reduction in and control over the electricity bill, and environmental motives were recognised as the main motivating factors for consumers' engagement in smart grids [57–59];
- The increase in acceptance due to the perception of smart meters was considered as helpful in giving feedbacks on how much electricity was used [60,61].

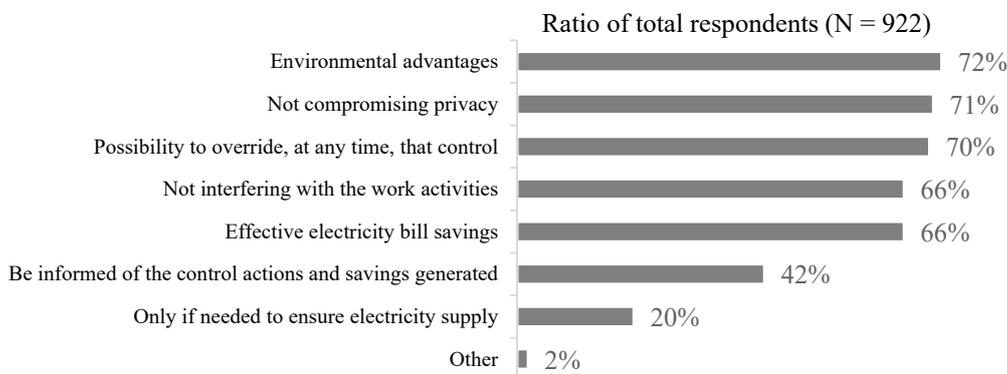
Figure 6 is related to the conditions for respondents to accept the remote control of some appliances by the electricity utility. The top three conditions chosen by the highest percentage of respondents were: (i) 'possibility to override, at any time, that control' (78%), meaning that the users, even if motivated in accepting a remote and flexible control, were not willing to give away the possibility to manage the operation of the building themselves; (ii) 'not compromising privacy', stated by 75% of the respondents and (iii) providing 'environmental advantages' (74% of respondents).



**Figure 6.** Conditions to accept the remote control of some appliances by the electricity utility.

Then, the questionnaire asked about the specific requirements respondents felt they needed to follow the recommendations from the electricity utility and manually control the appliances (Figure 7). The top three conditions indicated by the highest percentage of respondents were the same of the

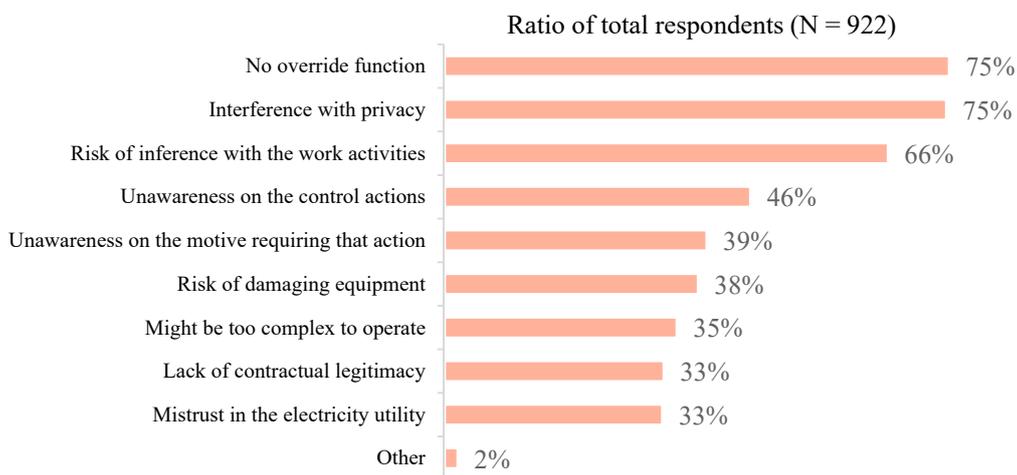
previous questions, but in a different order: ‘environmental advantages’ (72%), ‘not compromising privacy’ (71%) and ‘possibility to override, at any time, that control’ (70%).



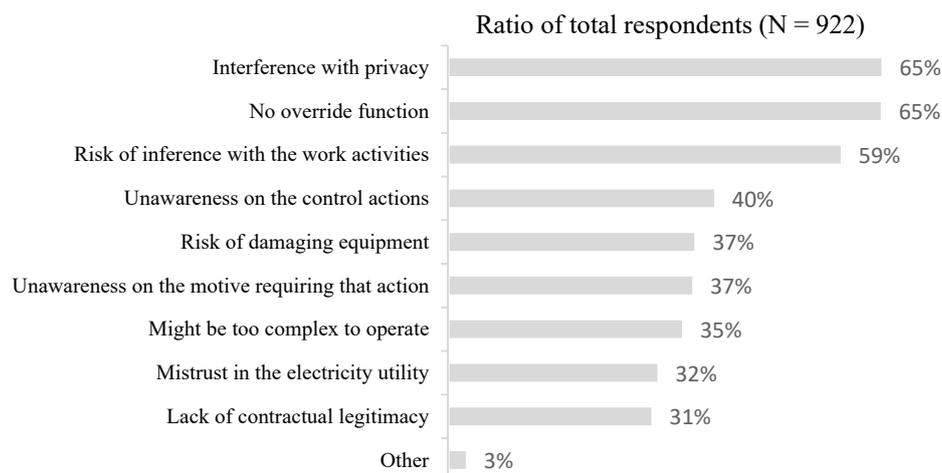
**Figure 7.** Conditions to follow the recommendations from the electricity utility and manually control the appliances.

It is interesting to see that environmental advantages were considered more important than electricity bill savings for motivating respondents in cases of both the remote control and the manual control of smart appliances. A possible explanation could be the fact that the respondents were all employees and so did not pay the bills.

Figure 8 refers to the reasons for the respondents for not accepting the remote control of some appliances—based on their beliefs (information and knowledge)—by the electricity utility, and Figure 9 refers to the reasons for the respondents to not follow the recommendations from the electricity utility and manually control the appliances. In both cases, the top three barriers were the ‘interference with privacy’, the ‘absence of an override function’ and the ‘risk of interference with other activities’. In the case of remote control, we noticed higher percentages for these three conditions compared to the manual control option.



**Figure 8.** Reasons to not accept the remote control of some appliances by the electricity utility.



**Figure 9.** Reasons to not follow the recommendations from the electricity utility and manually control the appliances.

Thus, the results related to the motivation to accept a flexible energy usage showed that the privacy was judged as really important by the case study office's occupants and could represent a relevant barrier for the adoption of smart controls and smart appliances. Conversely, the interference with privacy did not seem to have much impact for Dutch residents in the study of [34].

Moreover, in contrast to the results arisen for the willingness to use smart appliances in the office (Section 3.4), the 'absence of an override function' was perceived as an obstacle and it implies that office occupants' respondents were not ready to completely accept whichever control and that they wanted to always be able to override the operation according to their personal preferences.

To understand the respondents' preferences to accept a flexible energy usage, a list of motivating information was provided using a Likert scale with from '1-not motivated at all' to '5-really motivated' as choices. The results are shown in Figure 10. The top three preferences were 'seeing how much money you are saving' (45.8% stated preference '5-really motivated'), 'seeing how much you are minimizing your electricity usage' (45.3% stated preference '5-really motivated') and 'seeing how sustainable you are' (38.6% stated preference '5-really motivated'). The option 'seeing how you are doing compared to your colleagues' resulted as the least interesting for most of the respondents (37.1% stated preference '1-not motivated at all'). These results were consistent with the findings in the research related to households in the Netherlands [34], in which the most motivating factors were financial benefits (reduced energy bills and financial rewards from the energy supplier), followed by seeing the effects of their energy use actions, reducing CO<sub>2</sub> emissions, and being acknowledged, while sharing the results on social media was a clearly not motivating factor.

Performing a statistical analysis on office occupants' survey results, the motivations for which some differences were detected resulted as follows:

- For the motivation 'seeing how sustainable you are':
  - Gender ( $Z = -2.79$ ,  $p = 0.005$ ), females ( $MR = 480.08$ ) were more motivated than males ( $MR = 432.22$ );
  - Educational level ( $Z = 2.94$ ,  $p = 0.003$ ), respondents with 'University/PhD' title ( $MR = 488.92$ ) were more motivated than people with 'high school or lower' level ( $MR = 439.54$ ).
- For the motivation 'seeing how much money you are saving':
  - Gender ( $Z = -2.77$ ,  $p = 0.006$ ), females ( $MR = 479.65$ ) were more motivated than males ( $MR = 432.90$ ).
- For the motivation 'seeing how you are doing compared to your colleagues':

- Age ( $K-W H = 13.75, p = 0.008$ ), motivation (expressed in mean rank) was decreasing among age levels as follows: respondents' age <30 ( $MR = 604.71$ ), respondents' age >= 60 ( $MR = 484.41$ ), respondents' age 50–59 ( $MR = 460.80$ ), respondents' age 30–39 ( $MR = 451.71$ ), respondents' age 40–49 ( $MR = 446.38$ ).

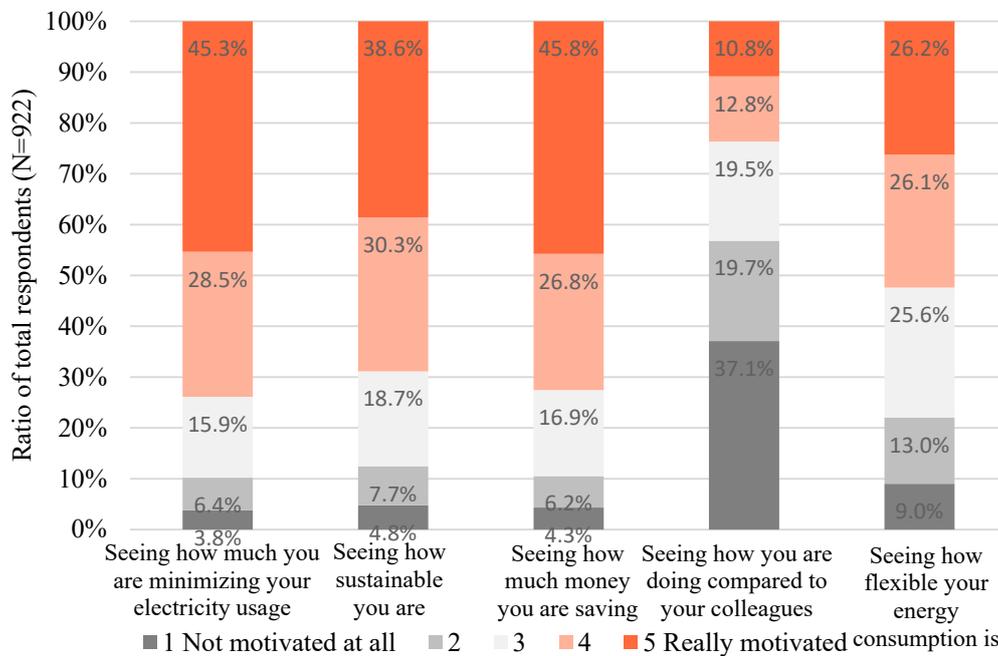


Figure 10. List of motivating information to accept flexible energy usage.

A further question was provided to understand which kind of information the end-users would like to see on a building office energy display (Figure 11). In total, 81% of the respondents recognised as main motivating factor being acknowledged on the amount of saved energy followed by financial benefits (recognised by 67% of the respondents). The influences of the energy usage on the environment and the amount of CO<sub>2</sub> emissions reduction were both chosen by around 63% of the respondents.

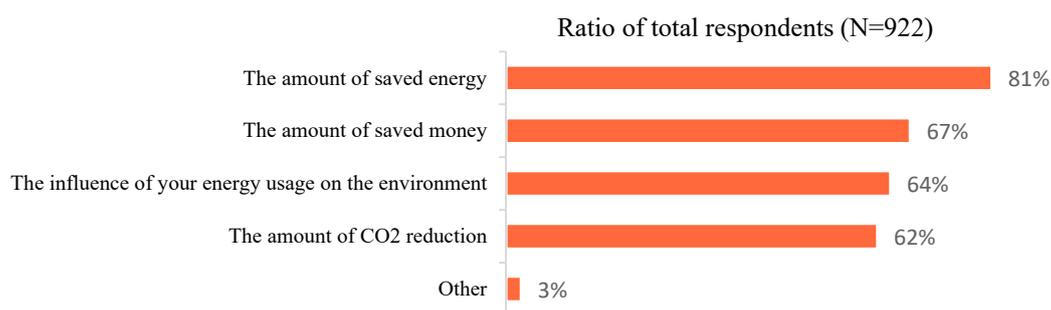
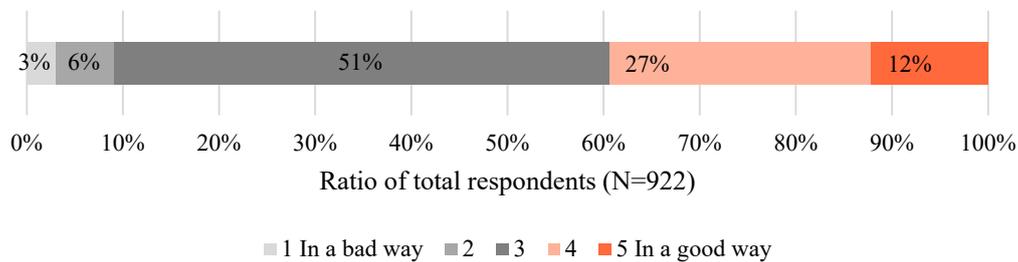


Figure 11. List of possible information to see on the display of the office energy monitor.

The last question of the survey was aimed at investigating how the respondents thought that smart grids would influence their activities. The 5-point Likert scale from '0-in a bad way' to '5-in a good way' was provided and the results are shown in Figure 12. It is visible that less than 10% of the sample perceived a negative influence of the smart grid on their work (point 1 and point 2 of the Likert scale), while the majority of the respondents had a positive perception of the smart grid on work activities. Particularly, 51% of the occupants chose the point '3' of the Likert scale expressing that smart grids would have a neutral influence on their work and therefore, implicitly, proving to be willing to accept a change in their routine due to smart controls. A percentage of 27% of the occupants selected

the point '4' and 12% the point '5' of the Likert scale, presuming that smart grids would influence their activities in a good way and probably taking also into account the positive effects of the smart grid, in a larger scale perspective, on the environment and on the reduction in carbon emissions.



**Figure 12.** Possibility of influence on work activities of smart grids.

Considering the very low frequencies of the modalities (1) 'in a bad way' (3%) and (2) (6%) for the variable influence of smart grid on work, these two modalities were grouped and a new variable with four categories was created (2), (3), (4), (5). The independent chi-squared test confirmed the existence of an association between experience with smart grid and the perception of smart grid influence on work ( $\chi^2(6) = 15.08, p = 0.02$ ). There were statistically significant differences in perception of the influence of smart grid on work between different levels of smart grid experience ( $K-W H = 6.64, p = 0.036$ ): the test indicated the highest positive perception of influence on the work for the respondents declaring medium/high smart grid experience (MR = 490.91), followed by the users with low experience (MR = 463.98) and respondents who did not have any experience (MR = 441.40).

#### 4. Conclusions

This research investigated the office occupants' perspective dealing with energy flexibility and related technologies. A questionnaire was designed and distributed as an online survey in the office buildings of the Province of Bolzano. The survey included a set of questions about socio-demographic characteristics of the respondents, perspectives of office end-users on renewable energy and beliefs and desires about smart grids, smart appliances and smart meters. The survey was completed by 922 respondents, corresponding to a response rate of 9.2%. Given the limited representativeness of the sample, it was not possible to make generalization of the results, but the outcomes of this analysis allowed for making preliminary considerations regarding office end-user's perspective on energy flexibility.

According to a descriptive analysis, more than 65% of the sample was aware of renewable energy sources and the related importance of fostering their use in building energy supply instead of fossil fuels. Nevertheless, the smart grid concept was unfamiliar to most of the respondents: in fact, 45% never heard about it and 27% was very little previously aware of smart grid concept, while only a small number of respondents (2%) stated that they perfectly understood the concept and its consequences.

Considering the willingness to change the energy use behaviour, most of the respondents accepted both grid remote and manual control of smart appliances. The most suitable smart appliances accepted to be controlled were the heating system and the air conditioning systems, with respect to the thermal comfort conditions. The level of acceptance did not change significantly for the different control options, hence multiple control options should be considered in smart technologies development to achieve high user acceptance and realize the energy flexibility in buildings.

The top three motivating factors to accept energy flexible usage in buildings for office end-users adopting smart technologies were found to be: economic savings, reduction in energy consumptions, and contribution in sustainability. On the other hand, the main barriers to energy flexible office buildings seemed to be concerns about smart control (in terms of interference with other occupants' activities) and privacy issues.

The most effective information to be displayed on the office energy monitor was the amount of saved energy and, in regards to the possible influence of smart grids on users' routine, 12% of the respondents believed in its really good impact, 3% of the respondents perceived the risk of a bad impact, and half of the respondents thought that smart grids would have a neutral influence on their everyday energy use, probably due to their unawareness of the smart grid functioning principles and possible effects.

The statistical analysis of the results showed the existence of an association between the high educational level (university/PhD) of the respondents and (i) high information on renewable energy sources, (ii) high acknowledgement of the importance of using renewable energy instead of fossil fuels, and (iii) high experience with the smart grid. Moreover, the highest value of experience with smart grid concept was expressed by respondents declaring the highest information on renewable energy sources, and the highest positive perception of influence of smart grid on the work was declared by the respondents with medium/high smart grid familiarity. This study confirmed that socio-demographic characteristics of gender and education level are associated to several aspects related to beliefs and desires of flexible solutions (e.g., information on renewable energy sources, experience with smart grids).

These results obtained from the study provide first important insights for future developments of smart grids according to office end-user perspective:

- It is necessary to boost office end-user's awareness towards the smart grid concept;
- High educational levels and high information on renewables may positively lead to higher experience with smart grids;
- Research on office end-user's preferences about control options for smart appliances should be investigated in the future development of smart technologies;
- The privacy issue can represent an important barrier in the control of smart appliances, thus adequate information about cyber security must be provided to future 'energy flexible end-users';
- Economic savings and the reduction in energy consumption are important motivating factors to adopt smart technologies, and can be shown as valuable information on building energy displays and considered into smart grid business development.

Thus, since social acceptance is an important requirement for the successful implementation and adoption of energy flexibility, policy should strengthen and promote organizational and communicative instruments to boost office end-users' awareness towards smart grid and energy flexibility concepts, both in terms of benefits and technical aspects, and considering the socio-demographic characteristics of the end users.

In doing this, policy should consider the result of this sociological study. According to the findings, the beliefs and desires about renewable energies were positive and spread for the majority of the interviewed end-users. Beliefs, desires, and experiences about smart grids and energy flexible solutions were quite different within the group of the interviewed end-users. The respondents were differently available to use energy flexible technologies, according to different motivations (e.g., interference with privacy). The list of motivations and the observed frequencies support the understanding of the cultural context of South Tyrol and public offices, linked to energy flexible solutions. These beliefs, desires, and experiences are associated with socio-demographic characteristics, especially in terms of gender.

Collecting data on beliefs, desires, and experiences about energy flexible solutions and technologies, this study is relevant for understanding which social norms, favourable to the spread of energy flexible solutions, could be promoted by the actual beliefs (e.g., conditions to accept the remote control of some appliances by the electricity utility) and desires of end-users. The strong associations related to the socio-demographic characteristic of gender add information on the cultural context and social norms that will be considered in the planning or implementation of energy flexible solutions in public offices of South Tyrol.

The work was intended to be a starting point for future research on the investigation of the energy flexibility related to the office occupants' perception and attitude towards renewable energy usage and smart grid. Nevertheless, the practical application of the questionnaire should be strengthened to reach a wider number of respondents and make the results representative for the country. Thus, to provide important insights for policies and strategies to encourage building users to be more flexible, follow-up end-user research is needed in multiple regions and covering multiple types of stakeholder.

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