Energy End-Use Flexibility of the Next Generation of Decision-Makers in a Smart Grid Setting: An Exploratory Study

Inês F. G. Reis[1(✉)], Marta A. R. Lopes[1,2], Paula F. V. Ferreira[3], Carlos Henggeler Antunes[1,4], and Madalena Araújo[3]

[1] INESC Coimbra - Institute for Systems Engineering and Computers, DEEC, R. Sílvio Lima, 3030-290 Coimbra, Portugal
inesfreis@deec.uc.pt
[2] Department of Environment - ESAC, Polytechnic Institute of Coimbra, 3045-601 Coimbra, Portugal
[3] ALGORITMI Research Centre, University of Minho, Campus Azurém, 4800-058 Guimarães, Portugal
[4] Department of Electrical and Computer Engineering, University of Coimbra, Pólo II, R. Sílvio Lima, 3030-290 Coimbra, Portugal

Abstract. Demand Response (DR) mechanisms have been developed to reshape consumption patterns in face of price signals, enabling to deal with the increasing penetration of intermittent renewable resources and balance electricity demand and supply. Although DR mechanisms have been in place for some time, it is still unclear to what extent end-users are ready, or willing, to embrace DR programs that can be complex and imply adjustments of daily routines. This work aims to understand how the next generation of Portuguese decision makers, namely young adults in higher education, are prepared to deal with energy decisions in the context of the challenges brought by the smart grids. Results demonstrate that cost savings and the contribution to environmental protection are found to be important motivating factors to enroll into DR programs, which should be further exploited in future actions for the promotion of end-user engagement. Moreover, DR solutions are well-accepted by higher education students, although with limited flexibility levels. In addition, there is room to exploit the willingness to adopt time-differentiated tariffs, yet savings should be clearer and more attractive to end-users. Also, the framing effect should be considered when promoting this type of time-differentiated tariffs.

Keywords: Energy decision-makers · Smart grids · End-use flexibility · Smart technologies

1 Introduction

The process of decarbonizing the economy will depend, to some extent, on the demand-side flexibility, which may be fostered through the use of time-differentiated tariffs, either with static and dynamic options [1]. In these pricing schemes, end-users

J. L. Afonso et al. (Eds.): GreeNets 2018, LNICST 269, pp. 13–23, 2019.
https://doi.org/10.1007/978-3-030-12950-7_2

are encouraged to adopt more flexible consumption patterns, adjusting their demand profile by reducing or increasing consumption in different time periods, shifting load operation to cheaper time periods or redefining thermostat settings [2, 3]. According to [2] and [4], some factors may influence end-users' enrolment in DR programs, such as: end-user's energy literacy level; the complexity of DR programs and dynamic tariffs; technology costs (when compared to savings and incentives provided); the effort required to search for dynamic pricing information and adjust electrical appliances usage accordingly; risk/loss aversion; and the inertia associated with behavioral change. Moreover, in most European countries, time-differentiated tariffs are not provided to end-users as default, but as an option. Hence, it is relevant to assess end-users' motivations and preferences in what concerns the adoption of those tariffs, enrolment into DR schemes, level of flexibility and adoption of smart technologies, in the context of evolution of electrical networks to smart grids. This work aims to understand how the next generation of Portuguese decision makers, namely young adults in higher education, are prepared to deal with energy decisions in the context of the challenges brought by the smart grids. It presents the combination of two complementary exploratory surveys targeted at Portuguese higher education students exploring their motivations and concerns to be enrolled in DR programs and assessing factors influencing the adoption of time-differentiated tariffs.

2 Literature Review

The need to balance energy demand and supply has become more pressing due to the increasing penetration of renewable sources characterized by their intermittent nature. One of the approaches for bridging the demand-supply mismatch in the energy systems is using demand-side management (DSM) techniques to shape demand profiles [5]. DR mechanisms are relevant DSM tools, relying on price signals as the main incentives to change electricity consumption patterns [6]. Some works in the literature exploit end-users' responsiveness to DR programs. For instance, [7] and [8] modeled the influence of pricing in the adjustment of load operation. When comparing these results with a real world experiment conducted by [4], it turns out that simulation results are optimistic and that end-users only accept to change their daily behavior in response to price signals to a certain degree. Usually, end-users are interested in minimizing their energy bills by taking advantage of pricing conditions and transfer home appliance operation to off-peak hours [9]. However, end-users tend to organize their domestic activities based on their preferences; therefore, while some load operations are relatively easy to shift, to interrupt or to re-parameterize, others are more restricted [1]. For instance, a study developed in [10] revealed that residential users in The Netherlands are willing to postpone the start of dishwashers, washing machines, clothes dryers, irons, vacuum cleaners, heating systems and the charging of electric vehicles. Still, lower levels of flexibility were associated with the use of the electric oven. Also, the survey developed in [11] found that Portuguese end-users are more willing to shift the operation of the laundry machine and the dishwasher than of other appliances, identifying electricity savings, not compromising the energy service, and environmental benefits as the main decision factors. In addition, some level of end-users' commitment is required to

decode and process complex information on time-differentiated pricing mechanisms. Thus, according to [12] it should be expected that high-literate end-users are more likely to adopt time-differentiated rates since, in principle, people with higher levels of literacy should be more able to understand the advantages of this adoption. In addition, renters generally seek innovative solutions to minimize their costs and therefore are also expected to adopt some type of time-differentiated tariffs. Nevertheless, the literature suggests that end-users show adverse reactions to the adoption of these tariffs due to their complexity. For example, the study in [2] highlights that "*consumers are open to dynamic pricing but prefer simple to complex and highly dynamic programs*". These findings are in accordance with [13], who concluded that end-users are more willing to adopt simpler tariffs, with fixed tariffs being preferred to all others. Although there is a consensus on the preference for simpler tariffs, little is known about how end-users assess time-differentiated tariffs and what is the influence of varying price information presentation on commercial offers [12]. Moreover, no study was found on the preferences of the next generation of energy decision makers.

3 Objectives

In this setting, this work aims to understand how end-users perceive the complex energy decision context brought by smart grids, in particular, their preferences and willingness to enroll into DR programs and time-differentiated tariffs to support the design of future energy systems. This work presents the results of two complementary exploratory surveys performed within Portuguese higher education students. Young adults were the target of this work because they will soon be the next generation of energy bill payers and the main energy decision-makers in the context of future smart energy systems. In general, this age group is not in charge of making energy related decisions or paying the energy bill. Young adults are also generally seen as more environmentally and energy aware and driven by personal values, while more cautious about money and time management [14]. This age group is more aware of the advantages and constraints of smart grids, when compared to other segments of the population [10]. Thus, this work aims to contribute to understand how young adults perceive the technological opportunities offered by smart grids and what are their motivations to participate in DR actions and time-differentiated tariffs, which represents a contribution to the existing literature about the topic.

The motivation, context and objectives of this study have been provided in Sects. 1, 2 and 3. Section 4 presents the research methods used and the main results are reported in Sect. 5. Section 6 presents the main conclusions and recommendations for future work.

4 Research Methods

Two complementary approaches addressing the general objective of this work were developed using surveys made available through online platforms. The complexity of the topic created important challenges to the design of surveys, as these need to have

technical robustness while displaying the ability to be answered by non-experts. The surveys were made available to higher education students enrolled at Portuguese higher education institutions in undergraduate and postgraduate studies. This group was chosen as they are the next energy-related decision makers generation and to ensure higher literacy levels. Different academic backgrounds were included to guarantee diversity. Both approaches addressed the same target audience and the topic assessed, while having their own specificities.

4.1 Case Study 1

Case study 1 aims to exploit the motivations and concerns behind the willingness to enroll into DR programs. Table 1 summarizes the dimensions and variables included in the survey.

Table 1. Dimensions included in the case study 1 survey

Dimensions	Variables
Socio-demographic characterization	Gender, age, on-going level of studies and number of residents at home
Level of knowledge and participation in the energy management at home	Monitoring habits on reading the electricity meter, supplier switching rate, knowledge about time-differentiated tariff schemes and ownership of monitoring devices
Motivation for participating in DR programs	Main motivations for engaging in DR programs, including potential savings, environmental or other important concerns behind the willingness to enroll into DR programs and on the importance of feedback from peers
Flexibility and willingness to change electricity use habits	Willingness to participate in DR programs, delay consumption or change electricity use time, if they could benefit from a reduction on their electricity tariffs

This survey followed the following steps: first, it was designed and tested by a small group using a face-to-face approach and email; second, it was improved based on the feedback collected; and third, it was implemented through Google Surveys between February and April 2018.

4.2 Case Study 2

Case study 2 exploited factors that, to some extent, influence the willingness of end-users to adopt a time-differentiated tariff. The survey included the dimensions and variables presented in Table 2.

Table 2. Dimensions included in the case study 2 survey

Dimensions	Variables
Socio-demographic characterization	Gender, age, academic background and housing situation
Enrollment in electricity management	Responsibility for the payment of the electricity bill; knowledge about contracted tariff and responsibility to choose the electricity tariff and supplier; monitoring habits of the electricity meter
Motivational factors to be flexible	Main motivations for engaging into time-differentiated pricing programs, including potential savings, savings-comfort trade-off and others considered relevant by respondents
Adoption of time-differentiated tariffs	Two exercises were designed to assess the willingness to participate in a time-differentiated scheme exploiting the format of the information provided (potential savings vs. increased costs). The way information about a tariff is presented triggering feelings of possible savings or potential losses, known as the framing effect, is presented as a feature to be taken into account in the promotion of those tariffs. In these exercises, respondents were asked to choose between maintaining a flat tariff or adopting a time-differentiated tariff. Graphical and numerical information was provided highlighting potential savings and increasing costs, distributed randomly in different versions among participants who were warned of potential changes to daily routines

The survey was made available through a LimeSurvey platform to higher education students all over the country between March and May 2018.

5 Results

5.1 Case Study 1

The sample composed by 125 respondents consisted mainly of men (61.6%), mostly aged 18–24 (84.8%), with 8.8% being between the ages of 25 and 29 and the remaining more than 30 years old (Table 3). 59.2% are undergraduate students from different training areas and 40.80% are Master students. The majority are Portuguese (94.4%) and full-time students (88%). As for the number of residents in the housing, 9.6% live with only 1 or 2 members; 30.4% with 3 members; 44.4% of respondents with 4 members and 16% with 5 or more members.

Table 3. Socio-demographic characterization of case 1 sample

Category	Variables	Level	Quantification
Personal	Gender	Female Male	38.40% 61.60%
	Age	Between 18 and 24	84.80%
		Between 25 and 29	8.80%
		More than 30	6.40%

(*continued*)

Table 3. (*continued*)

Category	Variables	Level	Quantification
	Nationality	Portuguese Other	99.40% 5.60%
	Course enrolment	Under-graduate Master	59.20% 40.80%
	Student status	Student-worker Full-time student	12% 88%
House	Number of residents	Between 1 and 2 members 3 members 4 members 5 members or more	9.60% 30.40% 44.40% 16.00%
Energy management at home	Familiarity with time-differentiated tariffs	Yes No	67% 33%
	Communicate energy consumption to supplier	Yes No	24% 76%
	Electricity supplier change in the last 2 years	Yes No	9% 91%

Regarding the level of knowledge and the dynamism for participating in the electricity market, results show that over 67% of respondents reported to be familiar with time-differentiated tariffs and 24% regularly communicate electricity consumption to the supplier. However, students showed to be much less proactive on changing supplier, as only 9% have done it in the last 2 years, and on owning and using an electricity monitoring device. Declared motivations to defer electricity use were tested by asking respondents to give their opinion about several statements concerning the contribution towards the environment, fuel imports and electricity bill. The results indicate that all these factors can be assumed as relevant for the engagement on a DR program. In fact, 95% of the students would be willing to defer their electricity consumption if that would have a positive environmental impact, 89% if that would have a have a positive impact on the fuel imports, and 90% if that would have a positive impact on the electricity bill.

The large majority of the sample shows a real concern about the environment. This is an expected result as the Eurobarometer on Attitudes of European citizens towards the environment showed those with a higher education degree tend more likely to agree that they can play a role in protecting the environment [15]. However, the possibility of the cost reduction is still the most often motivation mentioned, being classified as "totally agree". Pearson's chi-square statistic tests indicate that younger respondents are more motivated to shift their electricity usage driven by economic ($p < 0.001$) and environmental factors ($p < 0.001$) and energy dependence ($p < 0.001$). The majority of students, who attend engineering courses, tend to be more sensitive to environmental factors than those enrolled in other fields. Recognizing the importance of the cost factor, the flexibility to postpone electricity usage was tested against different potential cost savings and considering different deferral periods for using electricity appliances

such as the washing machine. Flexibility was assessed based on the respondents' willingness to defer the use of their domestic appliances for 1–2 h, 3–6 h or for more than 6 h. The results indicate that the willingness to defer electricity use tend to increase for higher potential cost savings (Fig. 1). However, flexibility is limited and the number of respondents willing to postpone their electricity use for more than 6 h (long-term) is considerably lower than the ones willing to delay it for 1–2 h (short-term), for all range of cost savings.

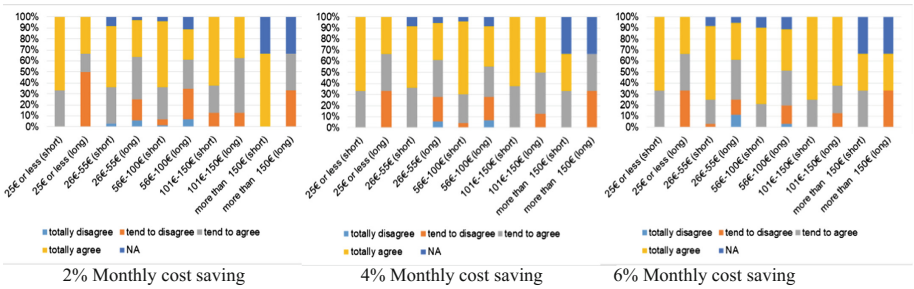

Fig. 1. Results regarding the willingness to defer electricity use according to potential monthly cost savings (2%, 4% and 6%, respectively)

The monthly electricity bill does not seem to play a major role on the overall assessment of the willingness to defer electricity use. Although the results indicate that consumers paying a high electricity bill (>150 €/month) tend to show a higher disagreement for both short-term and long-term flexibility, the number of participants included in this class is too low for considering the results as significant. As for consumers paying a low electricity bill (<25 €/month), the results also show a higher disagreement trend for long-term flexibility, comparatively to most of the other groups, for both the lowest and highest potential monthly cost saving cases. This can be explained by the lowest potential savings (in absolute terms) of respondents with lower electricity bills and by difficulties felt on changing electricity use patterns, or reduced interest on the topic in the case of respondents with higher electricity bills. It is worth noticing that this latter group is also the one showing more doubts for all the scenarios, as 33% of them selected the option "don't know". However, once more, this result must be looked with caution as the number of respondents in this group is very small. The middle groups (especially the ones 101–105 €/month) show a more stable pattern of responses with higher potential to participate in DR programs.

5.2 Case Study 2

Although case study 2 reached a total of 340 respondents, the sample was cut off at the age of 30 and the sample reduced to 270 respondents to ensure answers were only collected from the young adult segment. The sample is gender balanced (men 50%, women 50%) and respondents average age is around 22 years old (mean = 22.06; SD = 2.8) (Table 4). Most of them are students in Engineering and Exact Sciences (63.3%), while a small share is enrolled in Social Sciences and Humanities (28.9%),

Table 4. Socio-demographic characterization of case 2 sample

Category	Variables	Level	Quantification
Personal	Gender	Female	50%
		Male	50%
	Age		Mean = 22.6 SD = 2.8
	Academic background	Engineering Social Sciences and Humanities Life & Health Sciences Non-specified	63.3% 28.9% 6.3% 1.5%
House	Ownership	Own Owned by family Rented University facilities Other	6.3% 33.0% 56.7% 3.0% 1.1%
Energy management at home	Tariff	Flat Time-differentiated Unknown	37.8% 23.0% 39.3%
	[If answer time-differentiated] Frequency of electric appliances usage only in the cheapest periods of the tariff	Valid = 56.45% Non-answers = 43.54%	Mean = 5.69 SD = 0.796
	Responsibility for paying bills	Yes alone Yes with other people No	10.0% 51.1% 38.9%
	Responsibility for decide contracted power/tariff	Yes alone Yes with other people No one else has decided No, no one from the house decided	7.4% 11.5% 37.4% 43.7%

Health and Life Sciences (6.3%) and other non-specified academic areas. Regarding housing, most of the surveyed sample rents a house with colleagues (56.7%), while 33% live with their own family, which may disclose that they typically do not make direct energy-related decisions (beyond the usage dimension).

As for electricity costs, 61.1% of the respondents are responsible for paying the electricity bills by themselves or with other people. Moreover, 30.7% of the respondents admit never, or very rarely, reading the invoice or online monitoring electricity consumption, but 61% state to know the contracted tariff. 37.8% still have a flat rate and, of these, 57.8% state that it is still the most advantageous solution given their consumption profile. However, respondents also presented other reasons to maintain this tariff, such as the landlord being the main energy decision maker. Similar results were found in the choice of the electricity supplier (81.1% of the respondents indicate that this choice lies on other residents or on the landlord). Respondents who already have a time-differentiated tariff (23%) were asked how often they turn on electric appliances only in the cheapest periods of the tariff. Most respondents seem to have adopted this practice and use some appliances at night when the price is cheaper

(mean = 5.69, SD = 0.769). However, the high rate of non-responses to this question (43.5%) may indicate that even having a time-differentiated pricing mechanism some people do not take advantage of the lower priced periods. When asked about the likelihood of switching to a time-differentiated tariff (given a certain financial return), respondents were willing to adopt that type of tariff (Mean = 66.28, SD = 28.840). No statistically significant differences between information provided in the versions 'savings' and 'increased costs' were found ($t = 0.443$ $p > 0.05$), which means that, contrary to the framing effect theory, presenting information in terms of savings or increased costs seems not to be relevant to this population. When increasing the complexity of the time-differentiated tariff presented (from a daily to a weekly and monthly variation), results showed that the respondents' willingness to adopt the new tariff is affected by the framing formulation: 57.84% of the respondents who received the 'savings' version would be willing to adopt this rate (SD = 30.185) which is significantly different from the 37.23% of respondents who received the 'increased costs' version (SD = 31.057) ($t = 0.000$ $p < 0.001$). This result contradicts what has been reported in the literature and requires further attention [16, 17]. This outcome may have been generated by a respondents' misinterpretation of the question. While 30% of respondents who received the 'savings' version state that savings are attractive enough to change, 12.6% state they already turn on some appliances in cheaper periods. However, still 4.1% state that savings do not compensate the effort, 5.6% indicate day-to-day routine limitations do not enable taking advantage of a tariff with variable prices and 6.7% consider that the information presented during the survey was insufficient to decide. In the group of respondents that received the 'increased cost' version, 18.9% revealed that the added cost is significant and therefore the switch to the new pricing scheme is advantageous; 12.6% stated that daily routine requirements do not allow end-users to take advantage of a tariff with hourly price differentiations and 14.4% complained of insufficient information to decide. Respondents also pointed out other possible motives for not switching to the time-differentiated tariff, such as the fact that they are not responsible for this decision; the complexity of calculations to determine whether or not the change really pays off and the fact that the proposed tariff had higher prices during winter, when perceived heating needs are higher.

Results also showed correlations between age and the willingness to adopt the proposed tariffs ($rho = 0.258$ $p < 0.001$ and $rho = 0.253$ $p < 0.001$, respectively). However, contrary to what was initially expected, results did not confirm the influence of the academic background on the adoption of time-differentiated tariffs, which is generally associated with energy literacy. Moreover, those respondents already experiencing this type of tariff showed greater willingness to adopt the proposed one, thus indicating that experiencing different tariffs may be a positive decision factor.

6 Conclusions and Future Work

The results of both case studies showed that the next generation of Portuguese decision makers, namely young adults in higher education, are familiar with electricity tariffs and understand the implications and advantages of adopting DR schemes associated with time-differentiated tariffs. This segment of the population is available to adopt DR

programs involving shifting the operation of some appliances such as the laundry machine and the dishwasher. However, this flexibility is limited to short-time shifting actions and influenced by sufficient, clear and attractive financial incentives and should not compromise the household activities. Cost savings and the contribution to environmental protection were found to be important motivating factors to enroll into DR programs. Moreover, the framing effect was also found to be a relevant feature to be considered when promoting time-differentiated tariffs and designing DR programs.

Future work should also address the integration of further issues arising in the realm of smart grid (e.g., willingness to accept automated decisions by energy management systems), as well as its adaptation to more representative target audiences.

Acknowledgement. This work was partially supported by project grants UID/MULTI/00308/2019 and UID/CEC/00319/2019 and by the European Regional Development Fund through the COMPETE 2020 Programme, FCT—Portuguese Foundation for Science and Technology within projects ESGRIDS (POCI-01-0145-FEDER-016434), Learn2Behave (02/SAICT/2016-023651), MAnAGER (POCI-01-0145-FEDER-028040), and POCI-01-0145-FEDER-007043, as well as by the Energy for Sustainability Initiative of the University of Coimbra.

References

1. Ozaki, R.: Follow the price signal: people's willingness to shift household practices in a dynamic time-of-use tariff trial in the United Kingdom. Energy Res. Soc. Sci. **46**, 10–18 (2018)
2. Dütschke, E., Paetz, A.G.: Dynamic electricity pricing - which programs do consumers prefer? Energy Policy **59**, 226–234 (2013)
3. Herrmann, M.R., Brumby, D.P., Oreszczyn, T.: Watts your usage? A field study of householders' literacy for residential electricity data. Energy Effi. **11**, 1703–1719 (2017)
4. Faruqui, A., Sergici, S.: Household response to dynamic pricing of electricity: a survey of 15 experiments. J. Regul. Econ. **38**, 193–225 (2010)
5. Rae, C., Bradley, F.: Energy autonomy in sustainable communities - a review of key issues. Renew. Sustain. Energy Rev. **16**, 6497–6506 (2012)
6. Kessels, K., Kraan, C., Karg, L., Maggiore, S., Valkering, P., Laes, E.: Fostering residential demand response through dynamic pricing schemes: a behavioural review of smart grid pilots in Europe. Sustainability **8**, 1–21 (2016)
7. Yoon, J.H., Bladick, R., Novoselac, A.: Demand response for residential buildings based on dynamic price of electricity. Energy Build. **80**, 531–541 (2014)
8. Moghaddam, M.P., Abdollahi, A., Rashidinejad, M.: Flexible demand response programs modeling in competitive electricity markets. Appl. Energy **88**, 3257–3269 (2011)
9. Steriotis, K., Tsaousoglou, G., Efthymiopoulos, N., Makris, P., Varvarigos, E.: A novel behavioral real time pricing scheme for the active energy consumers' participation in emerging flexibility markets. Sustain. Energy Grids Netw. **16**, 14–27 (2018)
10. Li, R., Dane, G., Finck, C., Zeiler, W.: Are building users prepared for energy flexible buildings?—A large-scale survey in the Netherlands. Appl. Energy **203**, 623–634 (2017)
11. Lopes, M.A.R., Antunes, C.H., Janda, K.B., Peixoto, P., Martins, N.: The potential of energy behaviours in a smart(er) grid: policy implications from a Portuguese exploratory study. Energy Policy **90**, 233–245 (2016)

12. Layer, P., Feurer, S., Jochem, P.: Perceived price complexity of dynamic energy tariffs: an investigation of antecedents and consequences. Energy Policy **106**, 244–254 (2017)
13. Frederiks, E.R., Stenner, K., Hobman, E.V.: Household energy use: applying behavioural economics to understand consumer decision-making and behaviour. Renew. Sustain. Energy Rev. **41**, 1385–1394 (2015)
14. Darcy, S., Dudeney, C.: Tomorrow's world for energy and water - what will consumers and citizens want in 2030? A check-list for change. Sustainability first - Workshop report, United Kingdom (2017)
15. EC: Attitudes of European Citizens towards the Environment. Special Eurobarometer 416, European Commission (2014)
16. Thaler, R.H., Sunstein, C.R.: Nudge - Improving Decisions about Health, Wealth, and Happiness, 2nd edn. Yale University Press, London (2008)
17. Kahneman, D.: Thinking, Fast and Slow, 4th edn. Círculo de Leitores, Lisboa (2014)