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Helping consumers to reduce their energy consumption and greenhouse gases emissions: what tool to develop?

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4.1 Introduction

Facing climate change, caused by human activities largely through the combustion of fossil fuels which releases large quantities of greenhouse gases into the atmosphere, we need to transform our energy systems. Energy saving is an essential condition for this transformation. Indeed, intermittent renewable energies cannot replace fossil fuels to meet the current energy demand yet without developing expensive and polluting storage infrastructures. These objectives are included in the agenda of the European Union. This agenda is declined in France with the law of 17 August 2015 on the energy transition for green growth (LTECV Loi relative à la Transition Énergétique pour la Croissance Verte). Participation of all territorial stakeholders is expected to foster less energy-intensive practices and, in general, more sustainable behaviors to reduce impacts on the biosphere over the long term (Lutzenhisser and Gossard, 2000; Brisepierre, 2011; Brounen et al., 2012).

Numerous tools are proposed to foster this energy and ecological transition: investments in renewable energy production, clean transport, low-energy building conception and renovation, sustainable agriculture, tax incentives, new norms and advice on energy efficiency in all sectors, and communication campaigns to promote eco-friendly behavior, etc. Among them, smart meters and associated applications are spread out to help households to better control their energy consumption. Despite their importance for energy management and saving, smart meters aren't

well accepted. The reasons are to be found in many obstacles such as knowledge, values, norms, or beliefs (Schweitzer & Simon, 2021). Moreover, the expected change in users' consumption behavior is not guaranteed (Zélem, 2010): Although consumers seem to be aware of the necessity and the urgency to reinforce the energy and ecological transition, they do not engage in real transformations of their consumption mechanisms, which are too strongly linked to their habits. Finding issues to faster the transformations need more focused attention and research.

Several applications linked to smart meters are currently available and may guide the consumers in reducing their energy consumption. They take many forms but are mostly underused. We hypothesize that these applications are not enough identified as important instruments for the energy and ecological transition. They are rather seen as spyware-like tools controlled by political and economic processes. The lack of transparency of the tools and their providers is probably an important issue.

The objective of this chapter is first to analyze such applications made available to consumers. Since the latter's degree of awareness of energy and ecological issues may influence their decision to use or not to use these applications, a more in-depth analysis of consumers' representations of the energy and ecological issues, as well as the energy planning/policies/tools is proposed based on outcomes of both qualitative and quantitative surveys. These representations are confronted with overall energy consumption behaviors.

We state that citizens must no longer be considered simple consumers whose energy consumption only responds to technical and economic logic. Their energy needs are controlled by their environment and their lifestyle, which influence is important to be highlighted to make citizens aware of their potential to reduce their footprints. Individual lifestyles and practices are essential factors to consider in the energy-saving policies and associated tools. Developing the ecological awareness of individuals is an essential step to motivate their energy-saving for environmental reasons and not only for financial ones (cost saving can have direct and indirect rebound effects). In this way, the chapter also discusses the structural implementation of the SMI web interface, designed to help users in their energy savings along with several steps of ecological awareness. The tool aims at fostering the overall "ecological reflexivity" of energy consumers, defined as the degree of an individual's awareness of his or her consumption practices and their impact on the environment.

Section 2 presents the analytical framework for our study. Section 3 discusses the results of an analysis of the energy management tools, and the main findings of two qualitative and quantitative surveys on the representation of energy management. Section 4 presents the structuration of an SMI web interface. The section concludes with the work carried out.

4.2 Practices and control of energy consumption

The individual practices, inducing energy consumption, are influenced by several factors which are detailed according to socio-demographic, geographical, and technical dimensions in the scientific literature depending on the approach, discipline, and issue. This section presents the cross-cutting 'lifestyle' approach that describes such individual practices bringing together all the propositions. This lifestyle approach is guiding our analyzes as well as the SMI web interface development oriented to make the households aware of the role of their practices in their energy consumption patterns and contribute to favor their energy savings.

4.2.1 Analysis of energy consumption by lifestyle

The study of energy consumption through "lifestyle" consists in considering all the individual and social factors that influence citizens' practices. Herpin and Verger (2008) define the lifestyle 'as a matrix that creates needs': individuals take positions and decisions concerning themselves and/or their family (professional choices, residential location, choice of activities, etc.) that condition their practices and thus their energy consumption.

Most of the studies based on the lifestyle approach link the lifestyles and energy consumption through the household composition, the description of the owned equipment, their use frequencies, their time of use, and the individual beliefs (Lutzenhiser, 1993). Some authors highlight that income is a good indicator of energy consumption: Alexis Roy (2007) shows that the higher the consumer's income, the more he consumes, even though the consumer remains sensitive to ecological discourse and in favor of energy savings. Consumption is then mainly identified as a social indicator. Druckman and Jackson (2008), Brisepierre (2011), Sahakian (2011) show that the household energy consumption also depends on the type and location of the inhabitants in addition to social and cultural factors. According to Gram-Hanssen and Bech-Danielsen (2004), lifestyles influence the choice of dwelling. Sanquist et al (2012) explain that households are positioned in a socio-spatial living space: This position changes when they marry and have children when they move to another location; these life modifications induce changes in the intensity and frequency of their energy consumption.

A sample of more than 300,000 Dutch households was studied by Brounen et al (2012). They show that gas consumption is mainly controlled by the structural characteristics of the dwelling (age, type of building), while electricity consumption varies more according to the composition of the household (especially income and family structure). The EDF R&D (Electricité De France Research and Development) team states that technical and structural factors are responsible for 2/3 of the

explained variance of the heating energy consumption while 1/3 of the variance is explained by household socio-demographic variables (Cayla et al., 2010). Tabbone (2017) studied the life cycle of households during the time, their lifestyle (social dispositions and practices), and the links with their living environment (characteristics of the dwelling and its surroundings). He concluded that lifestyle guides the individuals towards the desired living environment and in return, this residential choice, associated with the technical offer of the chosen territory, influences their lifestyle. Indeed, individuals have activities according to the possibilities territory offers.

The analysis of practices inducing energy consumption is usually complex as it depends on many individual and social factors for which there is a lack of data. Moreover, diverse fields of expertise (sociology, geography, engineering, etc.) are necessary to study the same time the legislation, the technical offer of the territory, the housing, the behavior, the energy consumption, etc. Ideally, it would be useful to provide tools that would provide the consumers or the stakeholders a direct comparison of the energy consumption with explanatory factors, including information on the lifestyles and environments, and a proposition of adapted solutions for energy savings.

4.2.2 Framework for analyzing practices and representations of energy demand management (EDM)

To analyze the practices of the individuals, and the related energy consumption, explanatory factors are derived from previous studies, classified according to two dimensions, the social dispositions, and the living environment.

- **The social dispositions** of an individual refer to his or her values, habits, attitudes - opinions/biases/beliefs. They are strongly dependent on the social capital (social environment of the individual, access to networks, etc.), the economic capital (incomes), and the cultural capital (knowledge, culture, etc.). Social dispositions are built gradually over time and are strongly influenced by the individual's network (family, friends, etc.). They are internalized by the individual throughout his or her life. Although they are not fixed, they remain difficult to change.
- **The living environment** describes the individual's environment, including his or her dwelling (house/apartment, rural/urban, old/new) and all the related equipment, the socio-technical offer of the inhabited territory (housing offer, heating system, competence of professionals, costs of what is offered), public policies (disincentives, obligations/prohibitions, etc.), the local climate.

The social dispositions and the living environment of an individual co-evolve during his or her life cycle (change his or her professional and family context: getting married, having children, separating, or divorcing, etc.) modifying his or her practices, and the related energy consumption (Figure 1).

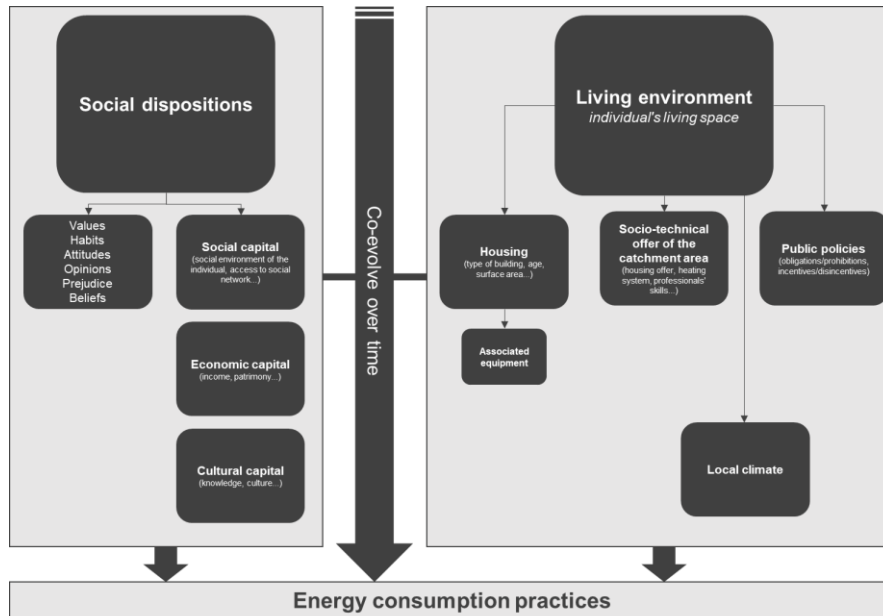


Fig . Figure 1: Representative diagram of the link between social dispositions and the living environment and its effect on energy consumption practices (Source: Authors)

Energy Demand Management (EDM) refers to a set of measures aimed at saving energy. These measures can be implemented by various actors to limit the energy demand, i.e. all energy consumption. Consumers themselves are targeted by these measures to limit their energy demand. EDM measures aim at modifying the energy consumption trajectory and the practices of individuals towards greater energy savings. Christine Zélem (2010) shows that today's regulatory and technical measures are still limited and should better consider the uses, practices, and representations of these different actors.

4.2.3 Energy demand management (EDM) measures

Energy demand management (EDM) includes communication campaigns, challenges, financial incentives such as off-peak/peak hours, and applications (websites,

mobile phone applications, etc.) enabling consumers to analyze their energy consumption. Smart meters and their associated web applications are EDM tools deployed in the territories to organize automatic monitoring of household electricity consumption and more efficient energy planning strategies. Schweitzer & Simon (2021, task 2 of the Interreg SMI project) show that such tools are not well accepted because of many obstacles related to the social dispositions of individuals: knowledge, attitudes, norms, values, and beliefs of consumers. They explain that fostering the contribution of the users in the development and the implementation of the tool would favor the use of the smart meter, especially if positive symbolic representations are associated with it. This would help the user to understand its functioning and would limit the "privacy paradox", which refers to the existing "gap between stated privacy preferences and actual usage behavior given the identified benefits".

AlSkaif & al (2018) explain that consumer acceptance and use of such tools follow several steps. They proposed the 'transtheoretical model of change' (TTM) (Prochaska & Velicer, 1997) that they adapted to the study of energy consumption behavior (Fig. Figure 2). Five steps describe the intellectual processes occurring when using an EDM tool. The pathway is full of obstacles that the tool may help to overcome to orient the user on an energy-saving trajectory.

The first step is a pre-contemplation phase describing a consumer with no intention of changing his or her consumption behavior. The tool must provide information to the user for him or her to identify the mechanism of his or her actions and their consequences on his or her energy consumption, whatever are the results. The second step considers a behavior change. The EDM tool must display the data collected in a fully transparent way to the consumer, protecting his or her privacy (transparency and privacy protection are two essential steps in the individual's acceptance of the tool).

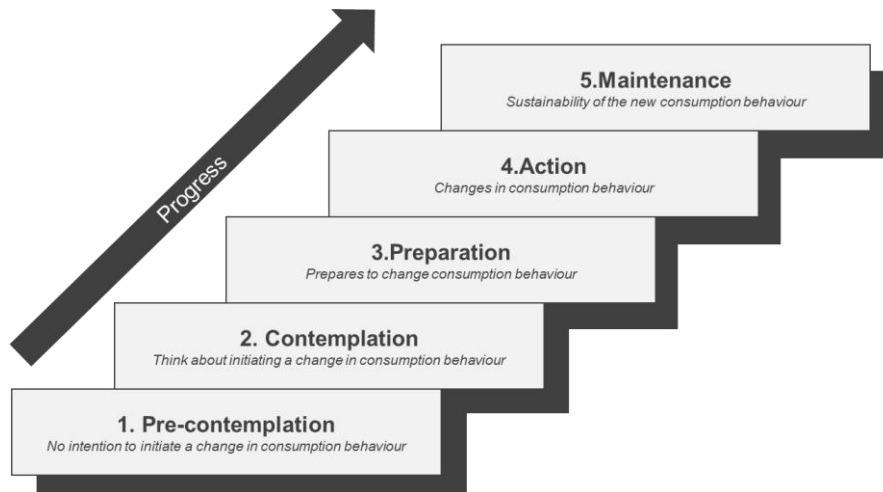


Fig . Figure 2: Diagram illustrating the stages of the Transtheoretical Model of Change (TTM) (Source: Authors via Prochaska & Velicer, 1997)

The third step consists of preparing the action. The individuals must use their knowledge and experiment with the EDM tool. The tool must be fun, easy to access, and must allow the consumer to quickly observe the results of some actions. The next step is to implement a new behavior, while the final step is to maintain this new behavior. It is important then to motivate the consumers and prevent possible backtracking by providing evidence of the benefits of their efforts. Beck & al (2019) list ten mechanisms that are thought to facilitate user motivation: point system, ranking, badge, level, presence of a story, clear goals, feedback, reward, progress, and challenge. Cost indicators are discussed by various authors (Ehrhardt-Martinez, Laitner, 2010; Kendel, 2015; Zelem, 2018) who explain that the financial gains are usually quickly absorbed by greater use of electrical appliances (this is called the direct rebound effect), or the acquisition of new consumer goods (indirect rebound effect).

4.3 Analysis of the tools and the representations of the EDM

We hypothesize that the EDM tools currently available are not sufficiently used also because consumers are not enough identifying those tools as important for the energy and ecological transition. Personal dispositions are certainly key factors of explanation. Energy and ecological issues are not priorities for everyone and are not yet sufficiently integrated into the individual daily agenda. They are not enough explained by the energy suppliers through the EDM tools while adopting habits for

energy saving is certainly a long process that must be supported by an awareness of the underlying issues.

Task 3.5 of the SMI project has several objectives:

- Analyze the web applications/tools provided to individuals to help them to reduce their energy consumption;
- Characterize the individuals' representation of the energy management and the associated tools;
- Propose a web interface to the SMI, developed in Task 3, that can foster the degree of an individual's awareness of his or her consumption practices and the impact of the latter on the environment (ecological reflexivity).

4.3.1 Analysis of EDM tools

Applications were extracted from the Google Play platform using several keywords relating to energy-saving & planning. We note, as well as Beck & al (2019) for other platforms, that no specific category was created for EDM tools. Most applications are proposed by electricity suppliers through a contract that allows the user to have access to an account. Whether issued from the private market sphere (such as Ecojoko) or by public providers (EcoWatt, Enedis, EDF & Moi, etc.), addressed to an "individual" - a single household/user, or a "collective" - open to all, applications were analyzed. In the text presenting each application, we detail the provider, the feedback (individual or collective), and the presence or absence of references to the energy underlying issues (climate change, energy planning, technical issues related to the occurrence of "blackouts", etc.), the indicators used to describe the household (kWh, Watt, Euro, grams of CO₂, etc.), the type of actions proposed to save energy, the presence or absence of games.

The analysis shows that arguments in favor of ecology and carbon footprint are mostly absent from individual applications or mentioned as secondary information. On the other hand, the collective applications focus on collective contribution: "Let's act together for the planet", "Let's act against climate change", and "Change our habits to protect the planet". A "community" section lists various objectives related to climate risk ("Reduce CO₂") and technical risks ("Reduce nuclear waste", "Reduce peak demand"). Individual action is transposed into global objectives, with no direct benefit to the user.

Individual applications generally show cost indicators (in euros) and to a lesser extent the energy consumption in kWh. Some applications even promote the change of equipment and offer discounts to buy them. Collective devices present direct information on energy consumption (in watts, "mini watts"), or other indicators such as the quantity of uranium consumed (in micrograms), or the quantity of CO₂

emitted (in grams) and its equivalence in terms of activity, such as the number of kilometers traveled by a vehicle.

All the applications claim the non-degradation of the lifestyles ("while preserving your comfort", "without impacting your comfort") or refer to an environmental impact reduction "without effort". Such energy transition representation was supported by Mr. Maroš Šefčovič, Vice-President in charge of the Energy Union portfolio, who stated in 2018: "*We cannot safely live on a planet with a climate that is out of control. But that does not mean that to reduce emissions, we should sacrifice the livelihoods of Europeans.*" On the contrary, Carbone 4 explains that "*the impact of individual actions is far from negligible*" and the individual efforts "*cannot by themselves enable us to achieve the -80% reduction in the personal carbon footprint compatible with the Paris Agreement*" without a great loss of comfort (doing without meat, cars, planes, etc.).

Like Becket al., 2019, we noted that only a few applications, issued from the public sphere, use games to encourage consumers to reduce their energy consumption. Nevertheless, the role of games is still questionable since games may reinforce the idea that the energy transition can be easy.

Other questions arise from this work regarding the understanding of non-economic indicators (is everyone able to understand what do a *Wh*, a *gram* of uranium, or *CO₂* mean?) and the ambiguous position of energy suppliers who are expected to contribute to the reduction of the energy consumptions while their profits depend on them.

4.3.2 What social representations of energy management?

Since the analysis of the relationship of individuals with the energy management, in general, may help to investigate the reasons why the EDM tools are not used, qualitative and quantity surveys were performed. The surveys aimed to detail the individuals' representations of climate change and energy issues, as well as of the energy management, and related tools. The main questions are: How do users associate the EDM tools with the energy and ecological transition? Can we distinguish several types of representations? Are political conceptions influencing the use of the EDM tools? Answers were expected to be useful elements to develop the web interface of the SMI.

Qualitative survey

Thirteen qualitative interviews were first conducted in May and June 2020. This period corresponds to the first wave of the COVID-19 crisis during which the French population was locked in. The interviews were therefore conducted remotely

by telephone. The impact of such interviewing conditions cannot be discussed at this stage. The table below (**Erreur ! Source du renvoi introuvable.**) lists the respondents, their gender, age, occupational category (OC), whether they live in a house or a flat, and whether they have a smart meter or not.

Table . Table 1: Characteristics of the thirteen individuals interviewed for the qualitative survey.

Respondent no.	Gender	Age group	OC	Housing	Linky (SM)
1	M	50-60	Executives and higher intellectual professions	Flat	No
2	F	60+	Retired	Flat	Yes
3	M	30-40	Executives and higher intellectual professions	Flat	Yes
4	F	40-50	Intermediate occupations	Flat	Yes
5	M	20-30	Unemployed	Flat	Yes
6	F	40-50	Intermediate occupations	Flat	No
7	F	20-40	Tradesperson, shop, or business owner	House	No
8	M	40-50	Executives and higher intellectual professions	House	No
9	F	40-50	Executives and higher intellectual professions	House	No
10	M	50-60	Intermediate occupations	House	Yes
11	M	50-60	Executives and higher intellectual professions	House	Yes
12	F	40-50	Intermediate occupations	House	No
13	M	60+	Retired	Flat	Yes

The questions aimed at detailing the interviewee's lifestyle and his or her relationship with the EDM tools and policies concerning the climate and energy issues. To be able to describe the overall state of the ecological reflexivity of the interviewees, several questions were asked concerning their practices in activities inducing a product or energy consumption (shopping, transportation, and use of any kind of energy at home). This enabled us to know whether or not the individual makes an effort to reduce his or her carbon footprint, and if any, in which sector of activity and with which strategy (e.g. take into off-peak hours, buy energy-efficient devices, contract with green electricity provider, etc.). The EDM tools were discussed in terms of use, individual and societal impacts, or representations. The interest in the new offers of the energy market, which become more flexible in terms of the supply and distribution of the renewable energies, was evaluated. Few questions concerned the building characteristics (location, age, surface area, etc.), and the energy housing costs of the households to evaluate if the costs are "*constrained expenditure*" (Maresca and Dujin, 2009). Do individuals make energy-saving efforts with re-gaaboutsts? or their benefits for the environmeQuestttthe ions were asked to understand the relationship of interviewees with the risks. Have users integrated the

precautionary principle or the “foresight norm” (Comby & Grossetête, 2012), which requires awareness of the repercussions of our actions environment? Since the underlying moral injunction is influenced by the relationship of individuals with governing bodies, we asked questions concerning evidence in policies and voting practices. Confidence in the future was also discussed.

Several types of behaviors were observed among the interviewees while no real categories could be distinguished. Some interviewees expressed doubts regarding the efforts to develop when others do not: *“We are a bit helpless. Well, I feel a bit helpless because I think that if we are the only ones doing something, nothing will change”* (Léo). The respondents feel disarmed in the face of climate change and realize that only a minority of people are aware of the ecological issues. Such interviewees showed different levels of ecological reflexivity and contrasting opinions on energy saving.

We observe that most of the behaviors are not guided by environmental concerns but much more by financial ones. Economic links to social conditions are discussed: *“Even for me, honestly, it's marginal, the optimization of electricity consumption isn't necessarily driven solely by ecological concerns, there's also the financial aspect...”* (Léo) *“I'm trying to adapt, especially since I'm on my own now, so there are no longer two incomes... I indeed try to be prudent”* (Anaïs). The interest in the energy topic and the contribution to energy saving is often linked with the representation of the energy cost weight in the global household budget. Sometimes these costs are considered too low to justify energy saving and behavior change. One example concerns the use of the off-peak system *“No, no, no, the off-peak rates, according to the literature I had read here and there, correspond to a few cents of savings, so no, we're not into that”* (Victor); *“but then, you shouldn't be a slave of the system either... I know some people who do laundry at night, to earn a few cents, but you shouldn't – well... come on! (laughs)”* (Grégoire)

Some users express distrust in politicians and their way to address climate change, while they have little knowledge of the energy efficiency and energy transition objectives: *“It's all very well to have agendas, but with all the lobbyists, once again in politics, all the agendas are either distorted or modified and, in the end, it's only 50% of the initial agenda that comes to fruition, which makes no sense.”* (Grégoire); *“Politically, we're going to say 'yes, but jobs depend on it!' We have jobs, we support jobs through consumption, and consumption, whatever we say, has a carbon footprint. [...] Overall, the political actions are not strong enough to support all this”* (Elsa); *“Overall, there is a will but it's still a bit lukewarm, even at European level I don't have the impression that they have... well I don't feel that they have the desire to go into that”* (Léo)

Many respondents do not see how the EDM tools will help the energy transition. While understanding the efforts that they must develop to reduce their carbon footprint (mainly concerning transport and food), people with higher cultural capital do not perceive the solutions provided to reach energy efficiency as sufficient. The technological solutions are found useless to support the energy transition. Green technologies and energies are often pointed out: *“As soon as there is a solution that seems good, we immediately realize that there are important counterparts, in*

particular making cars run on electricity. "(Victor); "And there is no green energy and so on, I mean, there are things that make you wonder, today solar panels are made from rare metals and you have to go and find them in Chile, China and so on, and that the recycling of these things is not very well organized and that solar panels are not managed today, we hear about wind turbines but it's the same thing, so today we build wind turbines, and nobody asks what we're going to do with them afterward." (Elsa); "Because between running a 10,000 euro car on diesel and running a 30,000 euro car on electric power, you have to have the money in the first place, and then the batteries of an electric car also pollute, so it would just be a problem that would be displaced" (Christian). "I don't see the point of wind power now from an energy point of view, it has been proposed to me to put some on my house, and on my neighbor's house" (Vincent); "oil, it's not ready to stop with shale gas, and after, etc., etc. we'll find something else, look at all the crops, which are also biofuel, from plants... who's going to settle again, so we'll deforest to make biofuel, then we'll put pesticides so that it grows better". (Karen).

Distrust of politicians is notably observed according to the sociological profiles of the interviewees. This result is coherent with the national observations of the CEVIPOF polling institute which qualifies the 2009-2019 decade as a *'black decade for political confidence in France'*. This lack of trust in politicians and also in companies disfavor changes in energy suppliers and contracts despite the gradual liberalization of the electricity market. Far from making their choice according to a cost-benefit trade-off, individuals prefer to follow the advice of trusty third parties in their close network relations: *"so I do it and if one day in a debate with one of them [anti-nuclear activists], well at least I'll be blameless and I'll have something to talk about... that's it"*.

The comparisons of energy consumption between similar households offered by a few EDM tools appear as a limitation to the energy savings, the interviewees felt to be within the norm. The interviewees also raise concerns about the security of smart meters, their applications, and the protection of personal privacy: *"There are all these debates today about global warming and what we need to do, and I find that these systems [EDM tools] are very opaque, in the end, we all sign "accepted conditions" agreements, without reading them because they are three pages long and boring, but I'm still very dubious about what they are going to do with our data..." (Elsa).*

The interviews finally revealed that smart meters and their applications help to reinforce existing energy-saving behaviors. These tools are usually used only by one member of the household, who finds satisfaction in a better understanding of energy consumption (understanding peaks, awareness of energy costs, and their lifestyles compared to others). Some users expect more information to understand how they can reduce their consumption and increase their energy production (when existing) while less active users see the energy monitoring as an additional mental burden.

Quantitative survey

To complete the previous analysis, a quantitative survey focused on studying the representation of energy management and smart meters. The sample consisted of 164 people (90 were women and 74 were men) of whom 104 declared themselves to be executives and higher intellectual professions, 20 employees issued from administrations & services activities, 12 students, 12 with intermediate employment, 9 tradespersons, business or shop owners, 1 farmer, and the rest with non-response. The respondents answered questions designed to capture their feelings about the environment and energy issues, their belief in climate change, confidence in technology, and their representation of the EDM and associated tools. Responses to the questions are classified following a Likert scale (sometimes called a satisfaction scale) ranging from "strongly disagree" to "strongly agree". The results are presented as the number of responses as proposed by Boone (2012).

Our results show that climate change is well identified as an established process assuming that the topic is not controversial among the respondents (Fig . Figure 3).

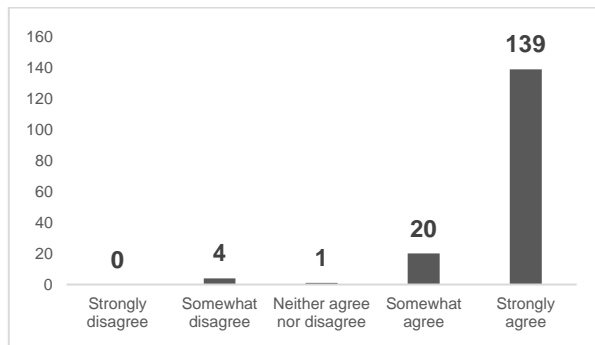


Fig . Figure 3: Frequencies of responses to question 1 "Climate change is a well- fact" in the quantitative questionnaire on representations of EDM and smart meters

We note that 152 of the 164 respondents take daily energy-saving measures indicating an action-oriented attitude (Fig . Figure 4).

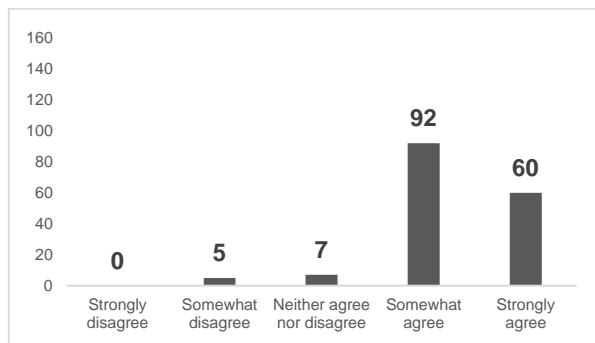


Fig . Figure 4: Frequencies of responses to question 10 "**I practice eco-gestures in my daily life**" in the quantitative questionnaire on representations of EDM and smart meters.

These daily energy measures are certainly not impacting their comfort since they mostly do not find it normal to reduce comfort to reduce greenhouse gas emissions (Fig . Figure 5). Shove (2013) explains the constant search for comfort is "*not only based on rational behaviors, but also depends on traditions, the internal management of the home, the relationship between sexes, and power relations within the family, which influence the environment differently*".

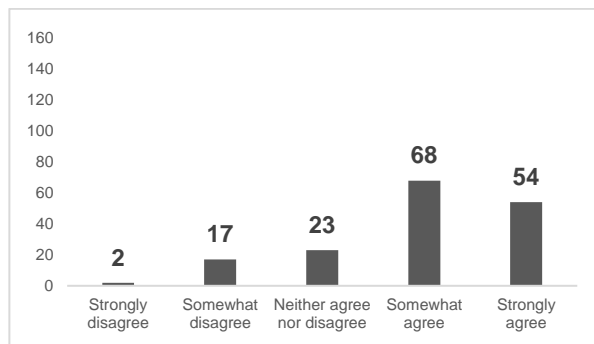


Fig . Figure 5: Frequencies of responses to question 22 "**It is not normal to reduce comfort to reduce greenhouse gas emissions**" in the quantitative questionnaire on representations of EDM and smart meters

People are generally aware of the efforts needed to reduce the causes and effects of climate change. Unlike the results of the qualitative survey, the respondents trust technology to achieve energy targets (e.g. Figure 6; 107 out of 164 respondents are in favor of technology as a solution to reduce energy consumption).

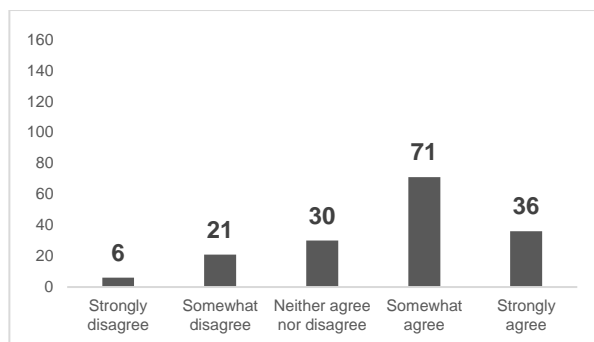


Fig . Figure 6: Frequencies of answers to question 11 "**Technology will help us find solutions for the reduction of energy consumption**" in the quantitative questionnaire on representations of EDM and smart meters.

Respondents expect efficient EDM tools, easy to use. A predictor of the acceptance of such a technical tool is the perceived usefulness. Data privacy is still an obstacle, and control over personal data remains a controversial topic (Figure 7).

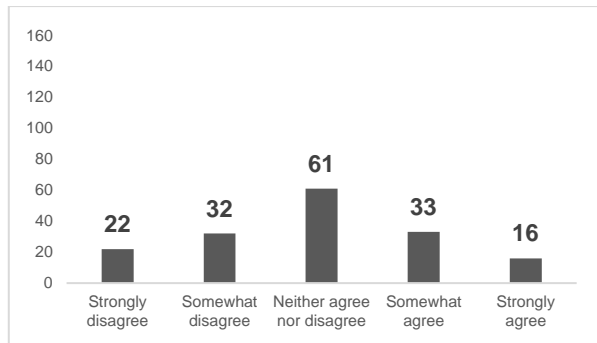


Fig . Figure 7: Frequencies of responses to question 19 "**Smart meters infringe on privacy**" in the quantitative questionnaire on representations of the EDM and smart meters

While 78 respondents felt that they do not have time to review their energy choices (Figure 8), 118 respondents said that they would also like to have more information on the evolution of the energy market (Figure 9).

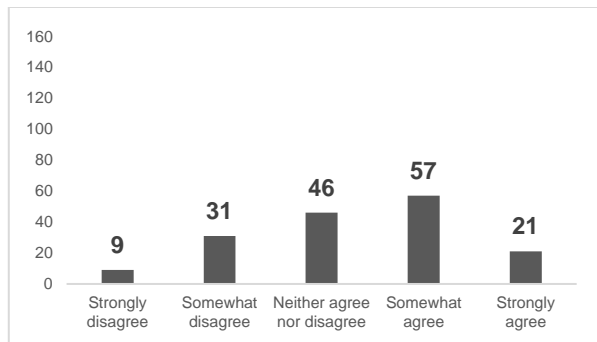


Fig . Figure 8: Frequencies of responses to question 14 "**I don't have time to be an actor in my energy choices**" in the quantitative questionnaire on representations of DSM and smart meters

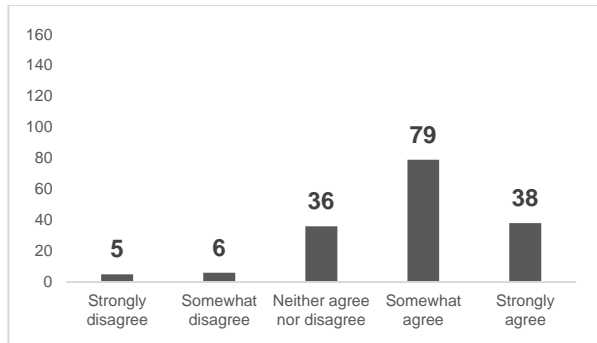


Fig . Figure 9: Frequencies of responses to question 13 **"I would like to have more information on the evolution of the energy market"** in the quantitative questionnaire on representations of DSM and smart meters

We note that the economic factor would not be a determining factor in their energy choice: 96 respondents are ready to pay more to benefit from renewable alternative energy (Fig . Figure 8).

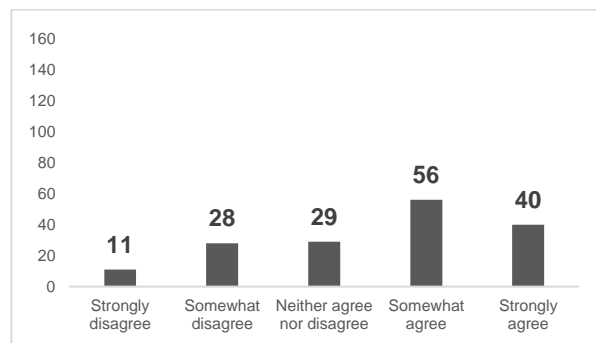


Fig . Figure 8: Frequencies of responses to question 7 **"I am willing to pay more for alternative renewable energy"** in the quantitative questionnaire on representations of DSM and smart meters.

However, fewer respondents (54, mostly managers) say that they do not pay attention to their energy consumption for financial reasons (Fig . Figure 9). These quantitative results corroborate the results of the qualitative survey. The 50 respondents who say that they pay attention to energy mainly for economic reasons have lower ecological reflexivity.

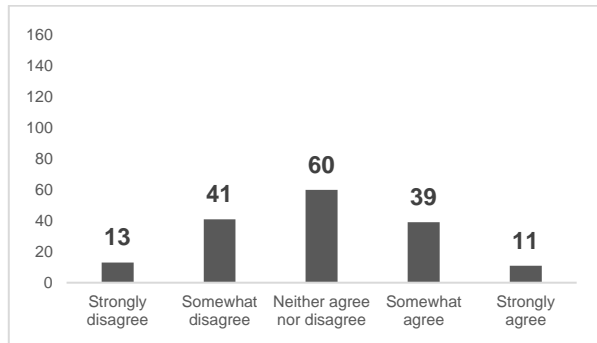


Fig . Figure 9: Frequencies of answers to question 12 "If I pay attention to electricity expenses at home, it is mainly for financial reasons" in the quantitative questionnaire on representations of DSM and smart meters.

4.4 A new tool for ecological reflexivity

The surveys carried out highlight a certain mismatch between the EDM tools offered and the consumers' expectations. The consumer is aware of the efforts to produce to reduce the causes and effects of climate change and is ready to act. They are quite confident in technologies, even if they have doubts about their efficiency. The doubts are reinforced by distrust in politicians and energy companies. On the other hand, actual EDM tools do not provide a comprehensive view of the objectives followed in the context of the energy and ecological transitions.

Providing consumers with better information on the overall societal issues and objectives, highlighting their lifestyle impacts on their energy consumption, and guiding them towards the most energy-efficient and ecological strategies would engage more and more people towards energy savings with increasing ecological reflexivity. Transparent information is needed to prevent consumers from elaborating false theories leading to a distorted representation of how they consume and how they could reduce their energy consumption (Kempton 1986, Kempton and Montgomery 1982, Krishnamurti & al 2013). Vedran Lesic & al (2018) analyzed 39 studies focusing mainly on individuals with higher ecological reflexivity to draw out insights into individuals' perceptions of energy consumption and savings. They show that individuals tend to overestimate the electricity consumption of low-energy devices, that they frequently use, and underestimate the high-energy devices that they use less frequently. The authors explain that these observations fluctuate with the unit used: overestimates are greater when using data in kWh rather than Wh. This unit effect has been observed in research on fuel by Allcott et al. 2011, Larrick and Soll, 2008; and water by Attari, 2014. They also show that energy consumption reductions are generally preferred to energy efficiency strategies: consumers with the lowest ecological reflexivity found energy-saving measures, such

as turning off lights and lowering the thermostat in winter, more effective than measures leading to improve the insulation of their home. Schwarz & al (1991) explains that individuals judge the probability of an event according to the speed of emergence of an example in mind.

To facilitate individuals' access to information and improve their ecological reflexivity (a determining factor in decisions and action), a web interface is developed for the SMI tool. This development is being conducted in such a way as to overcome the obstacles that have been highlighted by our surveys. It must meet four main objectives:

- Promote awareness of energy and ecological issues (increase the level of ecological reflexivity);
- Engage users in monitoring energy consumption daily;
- Engage users in reducing their energy consumption with an ecological and not necessarily economic goal;
- Move towards sustainable behavior.

To encompass these objectives, the interface developed for the SMI tool is composed of three main modules (Figure 12).

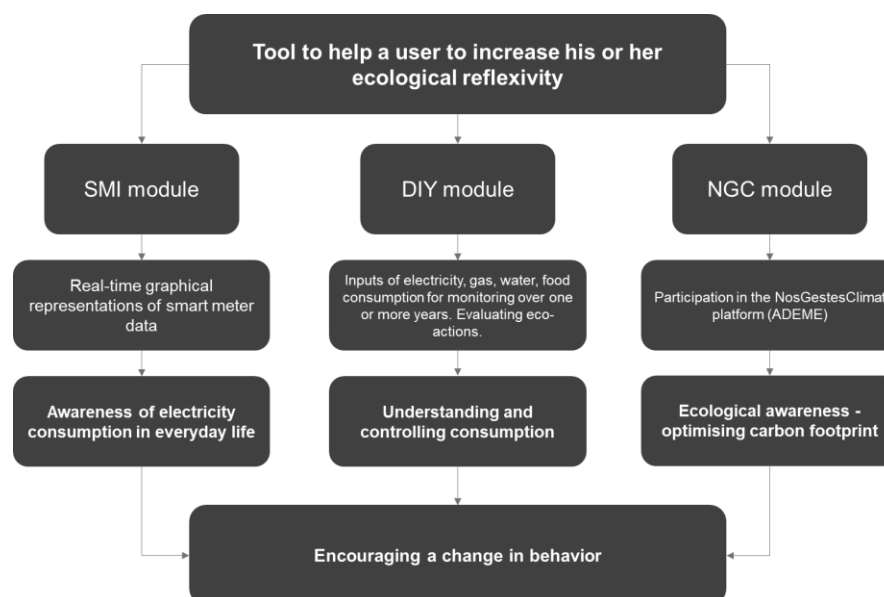


Fig . Figure 12: Programmatic diagram of the web interface for the SMI project (Source: Authors)

The first module (SMI) is dedicated to the analysis of data directly received from the SMI tool. This module gives the user the possibility to follow his electricity consumption (Which intensity? When do peaks in consumption occur? Which appliances consume the most? etc.) in several time slots. Several types of dynamic and easy-to-access displays are proposed. An "expert" display details the load curve, power peaks, daily consumption variations, average daily consumption curves by equipment, etc. Concerning the TTM model (section 2.3; Figure 2), this module provides the consumer with elements that must make him aware of the consequences of his energy consumption (upwards or downwards) of his or her practices. Consumption per equipment allows the user to identify equipment consuming more energy. The interface displays the data collected transparently, as trusting the tool and accepting to participate in reducing his/her consumption is an important outcome for the consumer.

The second "Do It Yourself" module is open to any user (whether they have the SMI tool or not). Users register their electricity consumptions (if they do not have an SMI) and other consumptions (gas, petrol/diesel, water, etc.) whenever they wish. About the TTM model, this second module allows users to act and collect their data. Making the consumer actively participate by mobilizing his knowledge and producing effort should favor the control of their consumption.

The third and final module uses the free and open access module "Our Climate Gestures" (Nos Gestes Climat - NGC) available *via* the website of the same name. This NGC tool provides an example of an easy-to-use application, associated with transparent documentation of the underlying methodology. It also facilitates the transmission of data and the sharing of experiences between users. The module is based on an analysis of the user's annual carbon footprint, both overall and detailed by activity (food, transport, housing, digital, public services, others). It allows users to evaluate their carbon footprint and compare them to climate objectives. Ecological actions are proposed. Concerning the TTM model, this module mobilizes game elements motivating efforts towards new energy-saving and greenhouse gas emission reduction.

The three modules together allow users to analyze the data associated with their practices, using the simplest possible graphical representations, to test strategies for reducing their footprint, and share their data or experiences with other households. The display of economic gains associated with a reduction in energy demand and carbon emissions recontextualizes the participation of the users in the resolution of major global issues.

4.5 Conclusion

The combined analysis of the EDM tools and the relationship of users with these tools, and the EDM in general, allows us to identify a few obstacles.

According to our analysis, the actual EDM tools do not yet offer users to understand that their lifestyle influences a lot of their energy consumption and footprint. Respondents are mostly aware of the efforts to develop to succeed in the energy and ecological transitions and are ready to act. It should be noted that they have the most confidence in the technology, despite concerns about the security of the tools and the protection of privacy. Dobré (2003) and Subrémon (2013) mention a "*voluntary and thoughtful*" resistance, which refers to a desire for non-conformity on the part of users who do not want to be trapped in a harmful system that restricts part of their freedom. Taking back control of one's actions by putting up resistance against the automation of the home is also put forward by De Certeau, who evokes the act of 'doing oneself' (De Certeau, reed. 1998). Subrémon (2009) explains that a set of practices implemented in the home would make it possible to promote 'energetic intelligence'.

EDM users monitor and save energy much more for economic reasons than for environmental protection. They weakly associate the EDM tools with the energy and ecological transition objectives. They are waiting for actions from the politicians and energy suppliers to progress in the energy and ecological transitions but do not trust their decision-making. They feel mostly disarmed face climate change (that is not here considered a controversial topic). Subrémon (2013) explains that the discourse on the ecological transition questions our lifestyles while a series of economic crises already generate fears and numerous other doubts among the households (work, family). In 1987, Bovay *et al.* mentions that the social discomfort caused by all these uncertainties led households to favor family comfort. Our surveys highlighted that energy-saving measures are also not a priority in front of future uncertainty and may be neglected due to lack of time, disinterest, skepticism or even more general mistrust of policies.

The analysis of existing tools showed that energy and environmental issues are also poorly explained upstream of incentives to reduce energy consumption. This is perhaps a consequence of the ambiguous position of energy suppliers who are supposed to participate in the reduction of energy consumption while their profits depend on it.

Based on a literature review and surveys, we presented a web interface to the SMI tool. The aim is to propose an interface that can help users to understand the challenges of the energy and ecological transition and their consumption by associating it with the influence of their environment and lifestyle. As the analysis of surveys did not reveal specific consumer representation profiles, which could have been used to adapt the interface according to the user, the interface is one addressed to all users. The intention is to guide the evolution of users towards sustainable practices in different stages, and gradually increase their ecological reflexivity (i.e. to engage them more generally and in a sustainable manner in an awareness of the impact of their practices on the environment).

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