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Methodological and Ideological Options

Smarter than metering? Coupling smart meters and complementary currencies to reinforce the motivation of households for energy savings

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ABSTRACT

A crucial argument in the debate around smart meter deployment in the EU is the potential for households to save energy. One strand of research in this field has investigated the effects on household energy consumption of the feed-back provided by smart meters. However, another aspect that deserves attention is the motivation for households to use the feed-back to save energy. This paper explores how the emerging trend of using complementary currencies for sustainability policies could translate into new interventions adapted to the smart meter deployment and capable of promoting more autonomous forms of motivation compared to interventions using official currencies. Three systems designs (rewarding, regulatory and hybrid) are presented and discussed within the framework of self-determination theory. Because the rewarding system S1 can contribute positively people's basic needs for autonomy, competence and relatedness, it could lead to more autonomous forms of motivation. The conclusions regarding the regulatory system S2 are less clear, although the hybrid variant S3 that integrates mechanisms from the rewarding system into the regulatory system could be perceived as more consonant with people's basic need for autonomy.

1. Introduction

Household energy consumption and efficiency are important targets for policy makers. Households represent 25% of the European energy consumption (EEA, 2013) and are thus considered as a sector with high saving potential. The Building Performance Directive (2010/31/EU), the Energy Labelling Directive (2010/30/EU), the Energy Efficiency Directive (2012/27/EU), and even the Third Liberalisation Package (2009/72/EC) aim at achieving part of the potential savings by considering households as responsible consumers that ought to be committed to reducing their energy consumption. These Directives are based on the rationale that householders' behaviour will change if they are provided with additional information (energy labels, campaigns, etc.), energy tariff structures and additional feedback. Smart meters play an important role in this strategy as the technology that will provide feedback to households on their energy consumption. Indeed, it assumed that the additional feedback will lead to energy savings in the household sector. For this reason, the deployment of smart meters has been strongly promoted since 2009 and, following the recent estimation of the Joint Research Centre of the European Commission (JRC, 2013), at least 170–180 million smart meters will be installed by 2020 for a total cost of €30 billion.

Feedback on energy consumption can be direct, in which case the consumption information is immediately provided to the consumer, or indirect, if some processing is required before reaching the energy user. Direct feedback requires adding various types of real-time in-house displays, possibly linked to smart meters. Indirect feedback is more often implemented by the utility company that provides the customer with more detailed bills.

The effect of feedback on behaviour has been tested in many pilot projects and has given rise to an extensive literature (Abrahamse et al., 2005, 2007; Anderson and White, 2009; Darby, 2006; Fischer, 2008). Darby's (2006) review allowed her to estimate "Savings have been shown in the region of 5–15% and 0–10% for direct and indirect feedback respectively". Ehrhardt-Martinez et al. (2010) and Fischer (2008) stated figures of the same order. More recently, large scale research projects, such as the Energy Demand Response Project (Ofgem, 2011), the Smart Metering Project (CER, 2011) and Intelliekon (Schleich et al., 2011), conclude that potential energy saving through smart metering resides somewhere between 2 and 4%. These figures are well below those of prior studies and tend to indicate that the potential of smart meters *per se* to trigger energy savings in households is rather limited.

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This limited potential comes as no surprise, considering the fact that persistent efforts to move towards conservation-oriented behaviours require what Osbaldiston and Sheldon (2003, p. 349) have termed "high-quality" motivation. However, the role of motivation remains largely unexplored in these studies. To our knowledge, none of these surveys have, for instance, clearly evaluated the initial motivation of households to save energy as an explicative parameter on the effectiveness of feedback—just as if there was an implicit and widely accepted hypothesis that feedback alone can trigger behavioural changes. This weakness has not escaped the notice of prominent researchers in the field: "The installation of the enabling infrastructure (smart meters, in-home displays) and provision of detailed information alone will not be sufficient to involve consumers." (JRC, 2013 p.77), "Information on consumption will not work without a motivation to conserve, which may be provided by other instruments like financial incentives, goal setting or personal commitment" (Fischer, 2007), "Information without motivation goes nowhere" (Anderson and White, 2009). As more positively stated by Darby (2006), "using feedback in this way [regularly reading standard gas or electricity meters] requires a level of commitment to reading the meter regularly […]. The potential savings, with motivated participants, can be in the region of 10–20%".

Consequently, motivation—defined as what moves individuals to act towards an end—deserves much attention, especially when trying to link feed-back and energy savings. Besides, it is also a timely preoccupation, as linking motivational tools to the smart meter infrastructure is likely to imply specific technical standards and requirements regarding communication ports and data interoperability for instance. If those requirements are not taken into account before the massive deployment of smart meters takes place, it could hamper for decades the possibility to develop such motivational tools in the future.

The Self-Determination Theory (SDT; Deci and Ryan, 2000; Ryan and Deci, 2000) provides an excellent model for understanding the different forms of motivation. In SDT, much attention is given to the orientation of motivation, or, put in other words, "the underlying attitudes and goals that give rise to action" (Ryan and Deci, 2000, p. 54). Besides, SDT also has an attested use in the field of pro-environmental behaviours and interventions (Koestner et al., 2001; Lavergne et al., 2010; Moller et al., 2006; Osbaldiston and Sheldon, 2003; Pelletier et al., 1998; Webb et al., 2013). Most importantly for this paper, SDT sheds a new light on the impact of different types of interventions on the quality of motivation (Moller et al., 2006; Webb et al., 2013). We have therefore chosen SDT as a theoretical framework to discuss policy interventions from the perspective of motivation in the context of smart meter deployment.

Indeed, for the massive deployment of smart meters to deliver important energy savings, we suggest that the related interventions should include provisions directly aiming at increasing consumer's motivation. Amongst the range of usual interventions, incentives (or penalties) are widely used interventions that can lead to desired behaviour changes in the short term (Abrahamse et al., 2005). However, seen from an SDT perspective, both incentives and penalties are controlling policy approaches that do not favour the kind of motivation necessary to internalise regulation and maintain behaviours over time (Moller et al., 2006). But can alternative incentives or penalties be designed in order to preserve the quality of motivation?

The underlying rationale of our research is that using complementary currencies instead of official currencies could provide the necessary alternative. This paper explores how the emerging trend of using complementary currencies for sustainability policies translates into new interventions adapted to the smart meter deployment and capable of promoting more autonomous forms of motivation compared to usual policies based on official currencies. After a short presentation of motivation seen in the light of SDT, Section 2 is dedicated to complementary currencies used for sustainability policies. Section 3 then presents three possible system designs to couple complementary currencies and smart meters. Based on those system designs, the impacts in terms of quality of motivation are then discussed in Section 4 before the paper concludes by highlighting implications for policy-makers, showing limitations and providing suggestions for further studies.

2. A Theoretical Framework and an Effective Tool to Tackle Motivation

2.1. Self-Determination Theory

Self-Determination Theory is a prominent theory of human motivation that gives much attention to the origins of motivation. Indeed, as is argued by Deci and Ryan (1985, p. 228) "In general, cognitive theories begin their analysis with what Kagan (1972) called a motive, which is a cognitive representation of some future desired state. What is missing, of course, is the consideration of the conditions of the organism that makes these future states desired." This consideration comes thus in contrast with cognitive theories, such as the Theory of Planned behaviour, (TPB, Ajzen, 1991) that are also used to explain pro-environment behaviours (Abrahamse and Steg, 2011; Bamberg and Schmidt, 2003). In the case of TPB, intentions are central and "are indications of how hard people are willing to try" (Ajzen, 1991, p.181), but SDT provides complementary insights by looking into the origins of this willingness to try. As suggested by Hagger and Chatzisarantis (2007) in their meta-analysis, SDT can offer complementary insights on the origins of beliefs and expectations that are used in cognitive theories.

Besides, SDT has also made a major contribution to understanding the quality of motivation that arises in different conditions. As underlined by Ryan and Deci, once early childhood is passed, most of our activities become extrinsically motivated (2000, p. 60). This means that they are performed for their instrumental value and not for the enjoyment of the activity itself. It is not difficult to argue that most activities aiming at energy savings fall into that category as it can hardly be expected that switching the light off or lowering the thermostat, for instance, will procure a true sense of enjoyment in itself.

SDT further differentiates extrinsically motivated action on the basis of the level of control vs. autonomy perceived by the individual. In the most controlled form of extrinsic motivation, the motives to act are perceived as being external to the self. This form of behavioural regulation is called "external regulation". Typically, behaviours that have been prompted by incentives (or penalties) fall into this category. But individuals have the potential to internalise values and regulations.

The first step in this internalisation process results in 'introjected regulation'. In this case, the values underlying the action have been introjected and contingent self-esteem is playing a major role. In the energy saving context of this paper, this would be typically the case when people feel an obligation to save energy and guilt when they forget to turn off the light.

The second step leads to 'identified regulation'. It corresponds to a more autonomous form of motivation when the activities start to be consciously valued and the individual can identify with them.

The third and final level of autonomy is called 'integrated regulation' and occurs when activity is fully integrated to the self and meaningful (Moller et al., 2006). This type of "integrated regulation" could be met, for instance with a person who has adopted a low-carbon lifestyle as one of his or her life goal. In this case, turning off the lights or lowering the thermostat is perceived as actions to reach a personal goal. Integrated motivation shares many similarities with intrinsic motivation. However, the main difference is that with integrated motivation, the action is still done for an instrumental value.

Individuals move along the continuum of increasing (or decreasing) autonomy/self-determination. As they internalise values and regulations, individuals can move in the direction of more self-determined/autonomous forms of motivation. But backward moves are also possible, for instance, when the external pressure is perceived as too controlling. In such a case, individuals no longer perceive their actions as being rooted in their own choice.

Deci and Ryan have come to the conclusion that autonomous forms of motivation (i.e. based on identified and integrated regulation) lead, amongst others, to better performance persistence of behaviours. This is to be explained by a higher fulfilment of the psychological needs for autonomy, competence and relatedness (Deci and Ryan, 2000, p. 247–248). In designing policy interventions, it is thus relevant for policy-makers to take into account ways to promote internalisation as it can lead to increased performances and persistence of the desired behaviours. The next section proposes complementary currencies as a possible tool for promoting this internalisation.

2.2. Complementary Currencies for Sustainability Policies

From an SDT perspective, both incentives and penalties are controlling policy approaches that do not favour the kind of motivation necessary to internalise regulation and maintain behaviours over time. But are there alternative interventions that could have a more positive (or less thwarting) impact on motivation? The emerging trend of using complementary currencies as policy instruments for sustainability seems an avenue worth exploring (Joachain and Klopfert, 2012). The trend is embodied by pilot projects involving public authorities and based on the idea of rewarding specific sustainable behaviours with complementary currencies. In those systems, another standardised unit than official currencies is used to mediate exchanges. This standardised unit (e.g. points such as in loyalty schemes) is called a "complementary currency" in the sense that it is designed to serve specific sustainability objectives and complement thereby official currencies that serve more general purposes (Lietaer et al., 2010; Seyfang and Longhurst, 2013).

There is a variety of complementary currencies systems in the EU, ranging from grass-roots Local Exchange and Trading Systems (LETS) to more top-down, sustainability-oriented schemes (Blanc, 2011). Those systems have the common trait of using another standardised unit than the euro to mediate exchanges and "are designed to operate in parallel with, as complements to, conventional national moneys" Lietaer et al. (2010, p 99). This definition is broad and includes radically different types of systems that range from the "parallel sustainable monetary systems [that] are being developed by civil society groups and non-governmental organisations (NGOs), informed by ecological economics perspectives" (Seyfang and Longhurst, 2013, p.65), to commercial loyalty schemes such as Air Miles for instance.

However, the innovative interventions presented in this paper are building on yet another type of systems that is characterised by the importance of the role played by public authorities and by the choice of sustainability objectives.

The E-portemonnee project, which was initiated in 2005 in Overpelt, a municipality of the Province of Limburg (Belgium), is a leading experiment using complementary currencies as policy instrument for environmental sustainability. Participants obtain points by performing some sustainable actions, such as switching to green electricity or following a composting course, from a list established by the local municipality (Bond Beter Leefmilieu, 2006). Participants can later exchange the points they have obtained against products or services proposed in a list of rewards (e.g. entrance tickets for the municipal swimming pool or energy saving lamp bulbs). It is a project where the Intercommunale for waste management (Limburg.net) as well as the municipal authorities have the leading role (Joachain and Klopfert, 2012; Joachain et al., 2009). According to the published results for the trial phase in Overpelt (from November 2005 to 31st October 2006), one family out of 5 would have obtained / used E-portemonnee points (Bond Beter Leefmilieu, 2006). This project is still running, has grown to include 6 other municipalities and is now seeking ways to expand.

Another pilot project, the Torekes, was initiated at the end of 2010 in a deprived area of the City of Ghent (Belgium). Torekes has mixed social and environmental objectives and is designed to improve the quality of life in the area of Rabot-Blaisantvest. In a similar way to E-portemonnee, this project rewards specific actions, including pro-environmental actions (e.g. putting a plant tub on the window sill or placing a no junk mail sign on the letterbox). In turn, the complementary currencies obtained can be used for buying public transportation tickets for instance. They can also be spent in some shops in the area, which was not the case in E-portemonnee. However, the Torekes project proposes an even more innovative use for the currency which met with great success: it is accepted as the only means of payment for renting a small plot in community gardens that are participating to the project.

But why would those pilot projects based on "non-financial incentives", as we have called them, have a positive or at least less thwarting impact on motivation than their usual counterpart in official currencies? In this respect, two specific features of those systems are worth attention.

A first important feature is the decoupling of these non-financial incentives from the official currencies. Indeed, it will probably not have escaped the reader that the systems we have described here above share similarities—in their functioning though not in their objectives—with commercial loyalty schemes. Loyalty schemes are widely used to promote business. Supermarket loyalty schemes, for instance, often offer points in proportion to the amount spent in official currencies. The ratio in official currencies of what the customers have spent and what they have received is usually low but studies have shown that, in some cases, even a "little threat" can be valued by the customers (Demoulin and Zidda, 2008). Complementary currency systems can function like loyalty schemes and be linked to official currencies as well. For instance, in the project E-portemonnee, it is possible to obtain 5 points per euro spent buying goods in second-hand shops participating to the scheme. However, in complementary currency systems for sustainability, many of the actions that are rewarded are not linked to a value in official currencies. E-portemonnee offers, for instance, 500 points for participating in an activity organised by the Environmental Department of the municipality. The objective, in this case is to provide a "non-financial incentive" to overcome the hard part of taking the time, effort, and energy to attend to the (free of charge) activity. Complementary currency systems can thus be decoupled from official currencies. This allows those systems to propose a wide choice of actions that are meaningful in terms of sustainability objectives, regardless of the fact that those actions are linked, or not, to a value in official currencies. Besides, decoupling the complementary currency system from official currencies can lead to a different perception of the incentive. Rather than its value in terms of official currencies, it is its symbolic "green" value that is put forward. Obtaining complementary currency units will then attest of the efforts made towards saving useful resources and protecting the environment.

A second important feature is that the use of complementary currencies can be dedicated to a specific objective. In the example of E-portemonnee, the proposed items and services for using the complementary currency units are consistent with the sustainability objectives of the project. The obtained complementary currency units (CC units) can only be used to get a compost bin, items of FSC wood, gift vouchers for Oxfam shops, discount coupons for public transportations, water-saving shower heads, etc. The entire system is dedicated to sustainability objectives. It is not only in the way participants obtain the CC units but also in the way they use them that the system serves its sustainability objectives. Besides, the use of the CC units can also be decoupled from official currencies. For example, in the Torekes project, participants can use their CC units to rent a small plot in community gardens that are part of the project. What makes this use so interesting is that only CC units, and no official currencies are accepted as payment for renting the plots. Since growing their own vegetables is a meaningful and valued choice for the residents of the area, many of them complete the actions to obtain the CC units necessary to rent their small plot of land.

These two features of complementary currency systems (i.e. decoupled/symbolic value and dedicated use) allow us to expect that

they could play a different role on the quality of motivation than official currencies do. This question will be discussed in Section 4.

3. System Designs

This section describes three system designs coupling smart meters with complementary currencies, called S1, S2 and S3. In this coupling, smart meters provide the necessary data on household energy consumption and complementary currencies provide what we have called a "non-financial incentive" to save energy. The part of the energy consumption (i.e. electricity, gas, etc.) that is covered by the system depends on the available smart metering infrastructure. Those systems are still hypothetical at this stage as they have not yet been implemented.

These three systems are inspired from an initial research aiming at selecting complementary currency schemes benefitting from a strong implication from public authorities and supporting sustainability policies with a strong environmental dimension. Examples of those complementary currency schemes are provided in the previous section. The number of systems which qualified at the time of the research was small (i.e. 3 systems were selected) which is coherent with the literature on the subject (Kennedy and Lietaer, 2008; Seyfang and Longhurst, 2013). Besides, two proposals of systems not yet applied (i.e. Biwa Kippu: Lietaer et al., 2012 and Tradable Energy Quotas: Fleming and Chamberlin, 2011) were also selected for further analysis because they introduced very innovative elements that matched the research made on the possible architectures for the complementary currency systems.

The description of S1, S2 and S3 is done according to the taxonomy developed by Joachain and Klopfert (2012, 2013). This taxonomy of constitutive parameters for the selected complementary currency systems was developed taking into account the coupling with smart meter technology. The resulting hierarchical classification of parameters is used as a building tool for the design phase.

In this paper, we will concentrate on a limited set of key parameters summarised in Table 1.

The research on the taxonomy highlighted the importance of the 'model' in the design of a system. Indeed, the research revealed the main polarity between what we have called a rewarding model and a regulatory model.

The E-portemonnee project in Limburg is a good example of a rewarding model: CC units are given for specific sustainable behaviours detailed in a list set forth by each participating municipality. Such actions are thus "rewarded" by public authorities in the complementary currency system.

The Biwa Kippu and the Tradable Energy Quotas are examples of regulatory models. A regulatory model is based on mandatory participation and the willingness to comply with regulations put in place by public authorities.

As the choice between a rewarding and a regulatory model orients the systems on radically different paths, it was thus decided to explore both paths. This led to the design of two contrasted systems: S1 (rewarding system) and S2 (regulatory system). However, as a result of the analysis of the strengths and weaknesses of S1 and S2, a third system, called S3 (hybrid system) was later developed to integrate some of the flexibility provided by a rewarding system into a regulatory architecture. In the following paragraphs, we will compare the key parameters presented in Table 1 for S1 (rewarding system) and S2 (regulatory system).

3.1. Main Rules

In the architecture of S1 (rewarding system), CC units are given to households when they perform specific sustainable actions according to the rules defined in the 'obtaining' parameter. The terminology 'rewarding' was preferred to the terminology 'voluntary' because it is more consistent with the fact that the designed system is intending to create a policy instrument which promotes and rewards energy savings in the household sector.

In S2, the system is based on a model with mandatory participation of every household which is a much more radical option. The terminology 'regulatory' was however preferred to the terminology mandatory for this model because it underlines the fact that the energy saving objectives are regulated by public authorities.

3.2. Operational Aspects

Since S1 is a rewarding system, the obtaining–earning rules are based on the behaviours that the project wants to promote, keeping in mind the central objective of reducing households' final energy consumption. It follows that the difference in energy consumption for each participating household (Δ in consumption over a predefined period) is considered a key element for earning CC units.

On top of this central way of earning CC units, an obtaining list is added to the system to reward specific actions (e.g. investing into insulation, performing energy audits, buying a fridge with the best energy label on the market or following an energy education course). The next step is to define a "using-list" so that households can benefit from the CC units they have obtained. The following guidelines were proposed to build the lists: all actions that entitle to earn CC units are also eligible for using them. For example, if a household invests in double glazing, the earned units can be used for any actions of the obtaining list which the household wants to perform later (as in a loyalty scheme). Since the choices provided by the obtaining–earning and using lists are

Table 1
Key parameters of the taxonomy of complementary currencies used for sustainability policies.

Parameters for the main rules	
Parameters for participation	
Model	describes what kind of rationale is used for the system as a whole to motivate households to participate.
Parameters for the operational aspects	
Obtaining–Earning	describes the rules vis-à-vis households on how to earn CC units. It requires the definition of an "obtaining list"
Obtaining–Buying	describes the rules vis-à-vis households on how to buy CC units
Using	describes the mechanisms put in place to allow the circulation of the obtained CC units between participants to the system. It requires the definition of an "using list"
Using–Exiting	describes the mechanisms put in place for the use of CC units that involves their exiting of the system
Parameters for the currency	
Form	describes the vehicle chosen for circulation of the CC units (paper, electronic, etc.)
Value	describes the unit of account chosen for the CC as well as the standard(s) in relation to which the CC-units are evaluated. Those standards do not have to be unique and can be anchored in official currencies or not.
Convertibility-Buying	defines a formal convertibility rate for buying CC units
Convertibility-Selling	defines a formal convertibility rate for selling CC units

key for motivation, those aspects are further discussed in the light of self-determination theory in Section 4.

Regarding S2, the first option which was examined is similar to the mechanism of a civil service or 'tax-like' system (see Biwa Kippu proposal: Lietaer et al., 2012). According to this rationale, households have to provide a certain number of CC units on a defined time basis (ex: 100 CC units per year for each household). Households earn those CC units by reducing their energy consumption. This option is considered as unfair for the households which have already made the most efforts towards energy savings in the past. A second option for S2 is to base the regulation on energy targets. This type of model shares similarities with quota systems (see, for instance, TEQ's proposal, Fleming and Chamberlin, 2011). Indeed, energy targets are calculated for households, taking some elements of their profile into account. In this sense, the system can be considered as "fair" (households with similar profiles get similar targets) provided the parameters for profile computation are properly chosen and well accepted.

In the S2 system, each household obtains a number of CC units that corresponds to their energy targets. As a household consumes energy, it also "consumes" CC units accordingly. At the end of the period for which the target was set, a given household can either break even (energy targets are met, all CC units have been used) or it can have consumed more or less energy than its target. In the case the household has consumed more than its target, it needs to buy extra CC units (penalty). If, on the contrary, it has consumed less than its target, it can sell back its remaining CC units (reward).

3.3. Currency

For both systems, we recommend to opt for an electronic form for the currency and to forbid the transfer of units from one household to another as to guarantee the correct decoupling of the system from another currency. Indeed, authorising household-to-household transfers (either with printed notes or electronic transfer) can result in the creation of parallel markets (e.g. using eBay) that would give a market price to the units. Besides, and this is equally valid for S1 and S2, an electronic form enables the feature of directly providing information to the households on the number of CC units obtained and used via the smart meter (direct feedback).

Furthermore, in S1, the decoupling of the CC units from official currencies enables the policy-makers to decide how many points they intend to give for all the different actions they want to promote, regardless of the fact that this action is linked, or not to a value in euros. The same applies for the items on the using list. In S1, it is not foreseen that households can buy CC units and there is no convertibility-buying rate. However, if no other option proposed in the using list is meaningful to participants, they are allowed to sell their CC units. A convertibility-selling rate is thus foreseen but with a major discount to promote using CC units according to the using list.

For S2, the value of the currency is grounded in the kWh of primary energy. Primary energy was chosen in order to have a common unit for different sources of energy (e.g. oil, electricity, gas). Households which consume more energy than their target have to buy their missing CC units from public authorities at a given rate. This convertibility-buying rate is defined by public authorities and is not linked with suppliers' prices. Households which have consumed less energy than their target are rewarded, similarly to what is seen in S1, at a convertibility-selling rate which is also defined by public authorities.

3.4. A More Flexible Regulatory Architecture: The Hybrid Solution S3

Bearing the strengths and weaknesses of both systems in mind, a third design (S3) based on hybrid architecture is proposed. In this S3 system, some features of the rewarding model are integrated into the regulatory model. Energy targets are still set for households which receive a number of CC units accordingly, such as in S2. However, S3 foresees extra possibilities to obtain CC units by being rewarded for some specific actions (such as in the obtaining-earning list in S1). Compared to using targets exclusively, this offers more flexibility to earn extra CC units, an aspect which could help households that are high above target to stay in the system. The same rationale is applied to how the CC units can be used. With the similar objective of increasing the possibilities offered by the system, households with a consumption lower than their target would also have the opportunity to use their remaining CC units for goods or services (such as in the using list in S1).

4. Discussion

The underlying rationale of our research is that using complementary currencies instead of official currencies could provide alternatives to financial incentives and penalties with a positive impact on the quality of motivation. In the previous section, we have explored how the emerging trend of using complementary currencies for sustainability policies translates into new interventions adapted to the smart meter deployment. This has led to two radically different system designs: the rewarding system (S1) and the regulatory system (S2). A third system design, the hybrid system (S3) is a variant of the regulatory system S2. In this section, we will discuss whether those systems are capable of promoting more autonomous forms of motivation compared to usual policies based on official currencies.

4.1. Contributing Positively to People's Need for Autonomy, Competence and Relatedness

Studies grounded in SDT have tested empirically the relationship between different forms of motivation and environmentally responsible behaviours.

Autonomous forms of motivation for the environment (i.e. identified or integrated regulation) were found to be good predictors of environmentally responsible behaviours in studies using different predictive models based on SDT (Lavergne et al., 2010; Séguin et al., 1999). In Lavergne et al. (2010), for instance, autonomous motivation was found to be predictive of a higher frequency of environmentally responsible behaviours whereas external motivation and introjected motivation did not predict frequency. Amotivation was found to be predictive of a lower frequency.

In their 1998 study, Pelletier et al. found that the correlation between autonomous forms of motivation and environmental behaviours was generally significant, which was not the case for the non-autonomous forms of motivation. Osbaldiston and Sheldon (2003, p. 355) tested a 3-step path model based on a goal approach and concluded that "the results of this study support our assumption that internalised (or self-determined) motivation can promote sustained environmental behavior change. Participants who initially identified with their environmental goals and/or anticipated enjoying them performed considerably better than participants who felt put-upon by their goals or complied out of a sense of guilt." Finally, in their study on household energy-saving behaviour, Webb et al. (2013) used a goal-directed behaviour model that they extended by adding self-determination as a predictor of intentions and behaviours. They also found a positive relationship between autonomous motivation and energy-saving intentions and behaviours. Besides, adding autonomous motivation enhanced the predictability of the goal-directed behaviour model.

The literature grounded in SDT provides thus theoretical ground and empirical support to suggest the existence of a positive link between autonomous forms of motivation and higher frequencies and persistence of environmentally responsible behaviours.

According to SDT, as individuals internalise behavioural regulation, the forces that are driving them to act become more and more grounded in their own personal goals and values. Besides, as explained in Deci and Ryan (2000, p. 262–263), "[…] a consideration of basic psychological needs provides a basis for predicting when the efficient pursuit and

attainment of goals will be associated with more positive versus more negative performance and well-being outcomes." Most importantly, when the basic needs for autonomy, competence and relatedness are perceived as being thwarted, it is associated with non-autonomous forms of motivation (including amotivation), more extrinsic aspirations, and adverse effects in terms of performance and well-being. Conversely, interventions that contribute positively people's basic need for autonomy, competence and relatedness have the potential to facilitate the internalisation process.

4.1.1. Need for Autonomy in the Rewarding System S1: The Positive Contribution of Decoupled/Symbolic Value and Dedicated Use

To support the need for autonomy, salient recommendations relate to offering choices that can reflect people's own interest and values, and providing a meaningful rationale for the desired behaviour (Moller et al., 2006). In the following paragraphs, we argue that the rewarding system S1, because it uses complementary currencies, could offer more meaningful choices than its counterpart in official currencies (i.e. subsidy).

Subsidies mostly provide financial incentives aiming at changing "efficiency behaviour", typically for promoting investments in new technologies such as photovoltaic, efficient appliances, insulation, etc. However, subsidies can hardly be used for promoting curtailment behaviours or incentivising behaviour changes aiming at increasing awareness, knowledge or user engagement. This is explained by high transaction costs and the low economic value (in official currencies) of the promoted actions. As an example, recent studies conclude that potential energy saving through smart metering resides somewhere between 2 and 4%. According to Klopfert and Wallenborn (2011, p. 21), regarding electricity, a consumption reduction of 2–4% per year would lead to "around 15 to 30 euro saved per year for an average Belgian household (3,500 kWh at 0.20€ per kWh)". The value of the action promoted is thus relatively low and the transaction costs (e.g. processing the demands for subsidies, etc.) would be higher than the value of the savings. The problem of the economic value in official currencies is even more acute for incentivising behaviour changes aiming at increasing awareness, knowledge or user engagement as the link between these actions and a value in official currencies is not always straightforward.

Conversely, one of the specific features of CC is that it can be decoupled from official currencies. As seen in the system design section, policy-makers can decide how many units they want to give for each actions they intend to promote, regardless of the fact that the actions are linked, or not, to a value in official currencies. S1 can thus be used not only to promote investments, but also to promote actions that have a low value in official currencies, such as lowering energy consumption. In the design of S1, lowering one's energy consumption is a central way of obtaining complementary currencies units. Besides, CC units could also be granted for households attending discussion groups, making a commitment on a web site, setting a goal, or reading historical of comparative feedback, etc., which are, according to Abrahamse et al. (2005), useful actions to promote lowering energy consumption.

S1 is thus able to offer a wide choice of actions that are meaningful in the context of energy savings. But it is not only on the 'obtaining side' that CC can positively contribute to the perception of S1 as a system offering meaningful choices. Indeed, a second specific feature of the CC systems S1 is, as we have seen, its dedicated use. This means that the choices offered for using the CC units can also be meaningful and inline with the sustainability objectives of the system. In the system design section, we gave the example of a household investing in double glazing. The CC units obtained thereby could be used for further investments in energy efficiency, or to perform an energy audit, for instance. More generally, all measures that entitle to obtain CC units can also be (partially) paid for with the same CC units (as in a loyalty scheme).

Additional product/services could be considered as well, such as paying green electricity bills with CC units or converting to other CC systems that share compatible objectives. Offering the CC units to charities is another choice that could improve the perception of S1, in particular for those who don't want to be "bribed" with money to save energy. Those examples shed light on the importance of two specific features of S1 (i.e. decoupled/symbolic value and dedicated use) to offer a range of "rewards" that are meaningful in the context of energy saving and coherent with the sustainability objectives of the system.

Another recommendation provided by studies grounded in SDT relates to the importance of using a meaningful rationale, rather than pressuring people to act out of fear or guilt (Moller et al., 2006). Besides, when the desired behaviour is presented as instrumental to intrinsic values, it is more reinforcing to autonomous forms of motivation than when extrinsic values are used. (Moller et al., 2006; Vansteenkiste et al., 2004). Subsidies in official currencies appeal to financial savings. This is problematic as Sheldon et al. (2011, p 97) remind us that "extrinsic values for money, image, and status are known to be associated with less sustainable ecological attitudes." In their study, Sheldon et al. (2011, p. 102) primed American college students with either intrinsic or extrinsic values and concluded that "it seems wise to rethink many aspects of current environmental education, communication, campaigning, and policy so that instead of focusing on appeals to money, economic growth, and the like, intrinsic values are activated and encouraged."

Existing systems of complementary currencies used for sustainability rely on a meaningful rationale grounded in intrinsic values. Sentences such as "a viable and healthy environment is everyone's concern" or "everyone can contribute in his/her everyday life" are central to the message delivered about E-portemonnee for instance (www.e-portemonnee.be). This could easily be adapted for the rewarding system S1. The rationale to participate could be based on saving resources and protecting the environment and grounded in intrinsic values such as caring for the world to be a better place or taking care of future generations. The dedicated use of the complementary currencies for sustainable "rewards" increases the coherence of this message, which is not the case for subsidies that can be used for any kind of purchase.

4.1.2. Need for Autonomy in the Regulatory System S2: The More Ambivalent Effect of Setting a Target

In contrast to rewarding systems, the regulatory system S2 is based on mandatory participation. In theory, all households should thus participate to this system. The willingness to comply with the regulation (and to escape the foreseen penalty) is likely to be one of the main forces driving households to meet their energy targets in an S2 type scheme. As explained in Moller et al. (2006), a regulatory system such as S2 can provoke reactance, and clearly requires a control mechanism to penalise/reward households according to how well they performed their targets.

The principle of S2 is that each household receives a number of CC units, representing their energy target. As a household consumes energy, it also "consumes" CC units accordingly. At the end of the period for which the target was set, a household can have exactly met its energy target and used up all its CC units. However, it is more likely that the household will have consumed less energy than its target or more energy than its target.

In the first case, the household that has consumed less energy than its target can sell back its remaining CC units to the public authority (reward).

In the second case, the household will have to buy extra CC units from the public authority (penalty) in official currencies. This is close to the mechanism of a progressive tariff as the penalty is only due on the energy consumption that exceeds the target, and not on the total energy consumption. The rate at which households have to buy their extra CC units is defined by public authorities and is not linked with suppliers' prices. Considering this, although S2 is not decoupled from the official currency, it is totally decoupled from the energy market price.

Due to the obligation to participate to the scheme, it is difficult to imagine that S2 could not be perceived as a controlling intervention. The question is, however, to which extent S2 could be perceived as less controlling than its counterpart in official currencies (i.e. progressive tariff).

It can be argued that receiving a target could be perceived not only as more controlling than a progressive tariff but also as a breach of privacy. Besides, households always have the possibility not to take into account the target they have received. If they do so and consume more than their energy target, there is little chance that S2 could be perceived differently than a progressive tariff. Even if participants take their target into account, the motivation to save energy is likely to be perceived as externally regulated, as the targets were decided upon by public authorities.

However, the energy target could also set a sort of "standard" for reasonable energy consumption. If people perceive their target as a fair objective for their energy consumption, they could start internalising their target. This could lead first to introjected regulation. People would then save energy out of a sense of guilt. As Koestner et al. pointed out in their study on recycling (2001), introjected regulation still results in a fragility of behaviours and attitudes. However, if people internalise their target as a personal objective and commit to it, they would then have the kind of autonomous motivation that is more likely to be sustained over time.

The hybrid variant S3 includes alternative ways to earn CC units. It would thus offer more flexibility to the regulatory system, thereby increasing the sense of choice and autonomy. For both S2 and S3, the fact that everyone has to participate, that energy saving is a common goal, could facilitate the internalisation process in making the external target become one's own contribution to a sustainable energy future.

4.1.3. Need for Competence: The Coupling of Complementary Currencies and Smart Meters for Feed-back and Advice

All three system designs could also contribute positively to the participant's need for competence. Indeed, those system designs are conceived as fully integrating CC to the smart meter infrastructure. It is strongly recommended that households are equipped with in-house displays that provide regular feed-back and practical advice. Besides getting feed-back on their consumption, households would also receive specific feed-back. In the rewarding system S1, they would be informed on the number of CC units they have earned and on the possible actions they could take to obtain more. In the regulatory system S2, they would be informed on how much CC units they still have and how this matches their energy target. In the hybrid system S3, they would get information on how well they are doing compared to their target and on possible ways to obtain more CC units. Besides, households would also receive practical advice on how to reach their targets.

4.1.4. Need for Relatedness: Sense of Belonging and Networks

Parents and peers seem to have a great influence on the perception of the interventions. In their 2010 study, Lavergne et al. conclude that the influence of other contextual factors (parent, peers, etc.) seems to influence the perception of the interventions more than what they call "government style", meaning the way public authorities are perceived. Here again, it is interesting to turn to the specific features of CC compared to subsidies. Indeed, by adhering to a rewarding scheme, such as S1, participants could get a sense of choosing and belonging to a group, most probably not a real sense of community, but a bit of a taste of it (McMillan and Chavis, 1986; Seyfang and Longhurst, 2013). This would contribute positively to the need for relatedness, one of the three basic needs identified by Deci and Ryan as having the potential, when they are met, to facilitate the internalisation process. Even if households have different reasons to get aboard a rewarding system (including free-riding), as the community of participants expands, it could lead to group effects and network creation, thereby increasing the potential in terms of social practice evolution. This could also happen with the regulatory system S2, and its hybrid variant S3, especially if the interactions are facilitated with information technologies (websites, forums, etc.).

As Warde (2005, p. 141) reminds us, practices are "[…] dynamic by virtue of their own internal logic of operation, as people in myriad situations adapt, improvise and experiment". Especially in the case of S2 and S3, a great number of households would have to deal with their energy target and, indeed "adapt, improvise and experiment". This could lead to the emergence of more sustainable practices, which, in turn, could influence the perception of the S2 and S3 systems themselves.

4.2. Limitations and Further Studies

The research presented in this paper is still exploratory at this stage. It is focused on designing systems that combine complementary currencies and smart meters to promote more autonomous forms of motivations for energy saving in the households. Based on specific features of complementary currencies used in the system design, we have developed arguments supporting the idea that a rewarding system such as S1 could positively contribute to the needs for autonomy, competence and relatedness. The link between S2 and more autonomous forms of motivation is less salient. However, beyond the question of promoting more autonomous forms of motivation that we have focused on, many other aspects should be taken into account. Fairness, social acceptability, practical and legal aspects, effectiveness as well as privacy, to name only a few of those aspects, should be investigated. This could be grounded in the existing literature on complementary currency and on personal carbon trading (Fawcett, 2010; Starkey, 2012a, 2012b).

Further empirical studies should test if the hypothesis of a positive relation between using CC as incentives in the rewarding system S1 and more autonomous forms of motivations is confirmed. They should allow comparing the effect and the persistence of energy saving behaviours between unrewarded households, households rewarded with CC and households rewarded with subsidies. Persistence of energy saving behaviours should be checked after the interventions have ceased. Regarding S2, it should be reminded that no regulatory CC system has been applied yet. It is thus less straightforward to suggest trials to test such a regulatory system empirically. A more promising path for pursuing the research on S2 regarding motivation would be to use qualitative research to understand how people perceive and react to it.

5. Conclusions

Energy saving policies for households are focussed on providing consumption related information and financial incentives for investing in energy-efficient equipment. The massive deployment of smart meters—providing energy consumption feedback—promoted by the European Commission goes in the same direction. But is energy consumption feedback sufficient to influence behaviour? We suggest that interventions should include provisions directly aiming at increasing consumer's motivation.

Self-Determination Theory (SDT) shows the limits of financial incentives and penalties, and advocates interventions that promote the internalising process of external regulation towards more autonomous forms of regulation (Osbaldiston and Sheldon, 2003). Interventions that contribute positively people's basic need for autonomy, competence and relatedness have the potential to facilitate the internalisation process.

In this paper we have presented new—though still hypothetical—interventions based on the coupling of smart meters and complementary currencies. In the light of the SDT; we have discussed their potential in terms of promoting more autonomous forms of motivation than interventions based on financial incentives for both a rewarding system (S1) and a regulatory system (S2).

Because the S1 system can contribute positively to the basic needs for autonomy, competence and relatedness, we suggest that it helps the internalising process. In our view, S1 would be especially relevant

to promote curtailment behaviours and to increase awareness, knowledge, and user engagement. The conclusions regarding the S2 system are less clear but could reinforce the feeling of competence of the households. A final hybrid variant S3, mixing regulation and rewards mechanisms, is expected to be perceived as less thwarting to the basic need for autonomy than S2.

The discussion pointed out that for all the presented systems, many more aspects should be further investigated and empirical studies are essential to pursue the research on those hypothetical interventions.

However, we argued that the new proposed interventions can contribute to environmentally responsible behaviours [ERB] and, as Osbaldiston and Sheldon (2003, p356) remind us "[…] inducing even slightly more ERB may be seen as a significant accomplishment."

The paper shows the importance of linking motivational tools to feedback devices, such as smart meters. In the context of massive deployment of smart meters that is taking place in the EU, it is especially important for policy-makers to take motivation into account, and more specifically their practical implications. Not doing so could hamper for decades the possibility to develop such motivational tools.

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