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Framework for a Residential Energy Information System (REMIS) to Promote Energy Efficient Behaviour in Residential Energy End Users

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Framework for a Residential Energy Information System (REMIS) to Promote Energy Efficient Behaviour in Residential Energy End Users

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Abstract

Previous studies on residential energy end use behavior reported significant reduction in energy end use of 7% to 24% when feedback is used to modify behavior in an energy efficient manner. However, most feedback systems investigated in previous studies have not benefited from advanced information systems (IS). IS can shape energy efficiency behavior by providing real-time feedback on energy consumption, cost and environmental impact. Such systems represent a new and less-researched subfield of energy informatics. This paper provides a conceptual framework for showing the potential use of IS to modify residential energy use behavior towards better energy efficiency. The framework builds on research in residential energy end use, in particular energy end use behavioral model. It provides conceptual inputs for a blue-print to develop a residential energy management information system (REMIS) and also highlights the use of new information and communications technologies (ICT) that had not been widely used, setting the grounds for further research in this area.

Key Words

Residential energy, energy informatics, information systems, Green IS, Green IT, energy-behavior

1. INTRODUCTION

World-wide residential sector accounts for 14% of global total final energy consumption in 2008 and is predicted to increase by 1.1 percent per year (US EIA 2009). The breakdown of energy used by households varies widely. For example in Australia, the residential sector accounted for around 11% of final energy (Petchey 2010). In the USA, from the 2005 US Residential Energy Consumption Survey (RECS), the share of residential electricity used by appliances and electronics in US homes has nearly doubled from 17% to 31%, growing from 1.77 quadrillion Btu (quads) to 3.25 quads since 1978 (US EIA 2009).

Hirst, Goeltz, & Carney (1982) first proposed a relationship expressing energy use in the residential sector as: Energy Use = f (capital stock, technical efficiency, behavior). Other studies on residential energy consumption generally point out that residential energy consumption is a function of home structure, household profile, technical efficiency of the energy consuming systems and appliances, and energy use behavior. In Australia, a reduction in household occupancy and an increase in both house size and ownership of appliances (structural effect) are estimated to have led to an increase in energy consumption of 45 petajoules (Petchey 2010). Growth in electrical appliance energy consumption was the largest among major -uses which represents an increase of 4.7% per annum. Amongst appliances the highest growth was in standby power usage (about 17% per year) which is telling of the degree to which consumer behavior and increase in appliance population had impacted the composition of residential energy use (Petchey 2010). The shift in composition of household appliances to more life-style oriented appliances further increases the necessity for intervention as life-styles are behavioral in nature with potential for modification. This paper is therefore particularly concerned about energy end use behavior.

Research has shown that among the interventions that are aimed to improve residential energy efficiency, feedback offers a significant potential in amending the consciousness of energy end user and modifying energy use behavior (Darby 2006; Fischer 2008). A number of studies have shown that changes in behavior could contribute to efficient energy use. Experimental research on residential energy end use behavior had yielded significant reduction in energy end use when the behavior is modified in an energy efficient manner, demonstrating the potential returns in managing this factor. These include reduction of 7-13% (Winett et al. 1979), up to 20% (Darby 2006) and 5-12% (Fischer 2008). Unander et al. (2004) noted in their studies of residential energy use in Scandinavian countries that the decline in Denmark's heating intensity was not due to technology but due to a change in behavior. However, most of the feedback systems investigated in previous studies has not benefited from the new technologies, in particular information systems and technologies available now. What is lacking from feedback based energy efficiency studies is a tool that bridges the information gap to provide intervention such as timely feedback on energy use, advice on energy conservation and receipt of inputs from users on energy end use behavior as well as decision making. Although this tool could be found in the form of ICT available today, there is still no widely researched framework for such an IS based approach and what exactly are the functional affordances required of such an IS.

The use of information systems and technologies in energy management, which are now called energy informatics systems, could have resulted in further reduction by enhancing interactivity with the energy end-user and providing more effective feedback (Watson et al 2010). Energy informatics represents a new and less-researched subfield of information systems. The objectives of this paper are to introduce REMIS and propose a conceptual framework that shows how REMIS could facilitate energy efficient behavior. The paper contributes towards addressing one of the energy informatics questions proposed by Watson et al (2010), that is "how can an information systems be used to change social norms to increase energy efficiency". The framework lays the theoretical, conceptual and architectural foundation for the development of REMIS and for further field research on the optimal level and mix of intervention to promote energy efficient behavior.

The rest of the paper is organized as follows – review of relevant literature, description of the REMIS and REMIS framework and summary and conclusion.

2. LITERATURE REVIEW

Three areas of knowledge that needs to be established from a review of the literature are residential energy management IS (REMIS), behavioural approach to energy/environment management and energy informatics. Literature on REMIS, meagre as the set is, was reviewed to get a basic understanding of REMIS. Literature on energy/environment management via behavioural approach provided theoretical basis for the conceptualization of REMIS based on behavioural modifications. Literature on energy informatics were reviewed to provide the knowledge base for developing an IS based framework for REMIS. These literatures were reviewed along the lines of their methodology (conceptual or empirical), area of focus (humanity, process, general) and also the contributions (presenting or validating theory, framework or model).Some of the relevant literature are summarised in Table 1 and discussed in the ensuing paragraphs.

Table 1. Selected research on REMIS, behavioral approach to energy/environment management and energy informatics

Review / Literature	Methodology[1]	Focus[2]	Contributions[3]
Abrahamse, W. Steg, L. Vlek, C. Rothengatter, T. 2005.	E	H	V
Chen, AJW. Boudreau, MC. Watson, RT. 2008	C	P	P
Darby, S. 2006.	E	H	V
Elliot, S. 2011.	C	P	P
Fischer, C. 2008	E	H	V
Hirst, Goeltz, & Carney. 1982.	E	P	P
Jenkin, T. A., Webster, J. & McShane, L. 2011	C	G	P
Lehman, PK. Geller, S. 2004.	C	H	P
Matthies, E. 2005.	C	H	P
Melville, N. 2010	C	P	P
Midden, CJH. Meter, JE. Mieneke, HW. Zieverink, HJA. 1983	E	H	V
Ueno, T. Sano, F. Saeki, O. Tsuji, K. 2005	E	H	V
Unander, F. Ettest, I. Ting, M. Schipper, L. 2004	E	H	V
Watson, R. Boudreau, M. & Chen, A. 2010	C	P	P
Watson, TW. Williamson, T. Boudreau, MC. Li, S. Zeng, Z. 2011	C	P	P
Winett, RA. Neale, NS. Grier, HC. 1979	E	H	V

2.1 Residential Energy Management IS (REMIS)

Actual implementation of residential energy management IS, which we will call REMIS, provides a glimpse of its functional affordance. Fujitsu (Straits Times. 2011.; Fujitsu. 2012.) collaborated with a governmental agency

[1] C = Conceptual; E = Empirical
[2] For Area of Focus, H = Humanity; P = Process; G = General
[3] For Contributions,, P = Presenting Theory, Framework, Model V = Validating Theoretical Model

for public apartment housing (Singapore) and a private residential apartment developer (Australia) to integrate their home automation technologies for a REMIS. The system monitors energy and water usage and displays these in real-time as well as provide historical trends. This provides residents with greater visibility of energy and environmental resource (water) consumption. It also integrates the building's video communication and energy/resource usage meters on their proprietary cloud infrastructure to track energy and water use in order to aid research on how to improve future apartment designs and deliver more efficient energy performance from residential buildings. Besides automation of energy and user information processing, the system was also used to monitor and control household systems (such as air-conditioning system) and appliances (smart appliances).
Two technology giants had over the past three years rolled out their cloud based REMIS in an effort to test the technology in the market. These were Microsoft Hohm (launched on 24 June 2009 by Microsoft) and Google Powermeter (launched on 5 October 2009 by Google) (Microsoft 2009; Google. 2011; Nader, W. 2011). In both cases, these were free energy monitoring tool to raise awareness about the importance of giving people access to their energy information. Google Powermeter included key features like visualizations of residential energy usage, the ability share information with others, and personalized recommendations to save energy. Microsoft Hohm went beyond energy usage reporting and provided savings recommendations, which can range from placing new caulking on windows to removing air leaks to installing a programmable thermostat. These recommendations are tailored based on specific circumstances in the consumer's home including house features, usage patterns and appliances. In addition, consumers were able to compare their energy usage with that of others in their area and connect with the Microsoft Hohm community to find referrals and exchange ideas. These implementation of REMIS somewhat widens REMIS's functional affordance beyond just monitoring and reporting energy use, but to include energy conservation knowledge and advice as well.

2.2. Residential Energy Use Behaviour

Behavioural approaches were found to be mainly based on socio-psychological discipline. Behavioural approaches to decision making have two main roles. The first is to help explain behaviour and identify important behavioural drivers for interventions to target. The second is to provide a framework for empirical research on the impact of these interventions. Elliot's (2011) conceptual model of the impact of human behavior on the environment demonstrates that monitoring and evaluating are key on-going activities affecting human behavior with regards to the environment with technology (including ICT) playing a lead role.

Matthies (2005) presented a heuristic model of environmental decision making, adapted by Fischer (2008), as shown in fig 1. In this model, behavioural outcome is seen as a result of both conscious and habitual behaviour. In conscious behaviour, norm activation precedes any motivation for action. Norm activation is made up of three areas of consciousness (environmental problem, relevance of one's behaviour and own sense of control). Only with this set of consciousness will the person reflect on changing his or her behaviour in order to solve the problem. Upon being conscious of the problem (norm activation completed) the next phase comprising of different motives (personal norms, social norms and "other motives" such as minimizing costs) for action follows. Norms may conflict with each other or with other motives, which brings the person to the next phase of evaluating costs and benefits (both in the tangible and intangible sense). During the evaluation phase, norms and motives may also be redefined in with the availability of new information. For example, in some cases marketing campaigns might trigger impulse action. Decisions on energy use can be categorized by:

- How energy is used (intensity, mode of usage). This relate to curtailment behaviour (repetitive efforts to reduce energy use) such as lowering thermostat settings (Abrahamse et al. 2005).
- What appliances to purchase or upgrade. This is a once-off behaviour that impacts efficiency of the equipment

Specific actions arise after evaluation phase and if such actions are performed regularly they could develop into new routines or habits. Habitual behaviour is therefore seen as a perpetual influence to day-to-day action affecting the outcome. Routinized or habitual behaviour that is not energy efficient leads to sub-optimal energy use (Fischer 2008). The only way to break out of habitual behaviour is to form new norms which is where the energy end user transits from subconscious (habitual) behaviour to conscious behaviour (norm activation).

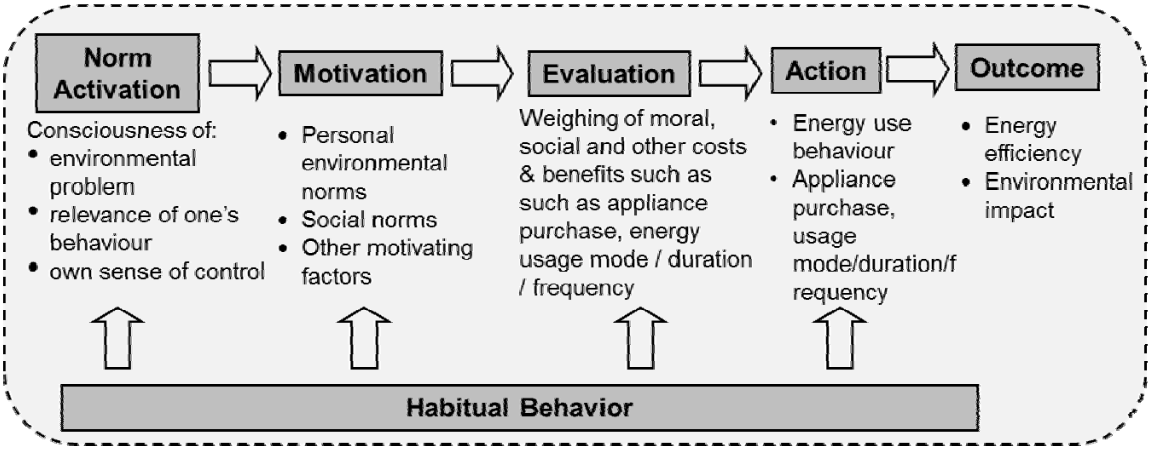

Figure 1. Heuristic model of environmentally relevant behavior. Adapted from Matthies (2005)

Matthies's (2005) heuristic model of environmental decision making relies on continuous and effective feedback for norm activation to take place. Fischer (2008) had also expounded on the value of effective feedback (right down to appliance level) for the household energy consumer. Darby (2006) views feedback as a learning tool, allowing energy users to teach themselves through experimentation. However, the heuristic model does not expand on the nature of this feedback which is vital for norm activation, making it necessary to further examine the nature of such feedback. From a behavioural science perspective, feedback is part of a collection of intervention steps taken to modify behaviour (Wilson & Dowlatabadi. 2007). Prior to feedback there is also a need to solicit inputs from the energy end user in order to determine the appropriate intervention strategy.

Via intervention targets and settings, behavioural scientists have successfully applied the principles of behaviour analysis to increase a variety of pro-environment behaviours and decrease a variety of behaviours that damage the environment (Lehman & Geller. 2004). Intervention strategies (Lehman & Geller. 2004) can be organized as follows:

- Antecedent Strategies
  - (a) information/education,
  - (b) verbal or written prompts
  - (c) modelling and demonstrations
  - (d) commitment
  - (e) environmental alterations
- Consequence Strategies
  - Rewards
  - feedback

What constitutes feedback varies from the perspective of different researchers. Lehman & Geller (2004) had scoped feedback as part of a consequent strategy, ie after the event or action, synonymous with performance appraisal. Other researchers (Midden et al 1983), however, look at feedback from both the antecedent and consequent perspective. Simple feedback comprising of general information to conserve energy by itself is not effective (Midden et al 1983). Giving people feedback on their own energy consumption leads to more significant drops in use, varying between 7% and 21% (Midden et al 1983). Regular feedback based on magnitude of energy use and financial consequences together with comparative feedback such as benchmarks against similar house structure or household profiles was found to be most effective.

2.3. Energy Informatics and Use of IS for Energy Management

In recent years, some research had allured to the need for IS in energy management. Fischer (2008) had concluded on the need for feedback on actual energy consumption with high level of frequency, interactivity and granularity extending to appliance-specific breakdown in applications such as smart metering, electronic data processing and communication. Watson et al. (2010) pondered on the type of and level of information granularity to optimize a given flow network. At that time, however, there was considerable constraint in adopting cost effective and widely available technologies for energy consumption feedback. Fischer (2008) had also allured to research gaps in studies on energy consumer feedback done concerning the small sample sizes of the studies and projects and timeliness of measurement and feedback. A possible reason for the small sample sizes could be the cost of carrying out field research where considerable hardware and software was required. Previous technologies relying on direct read-outs from meters or dedicated computer terminals / programs might still be too cumbersome for the average residential energy consumer to regularly check on.

Technology and IS aided experimental research on residential energy end use (Darby 2006; Fischer 2008) focussed mainly on feedback of energy use to the end user with little consideration on the other aspects of intervention. Even so, these research had still not been able to completely address the question on how best to provide feedback in order to influence the residential energy user towards energy efficient behaviour, having somewhat been constrained by widely available and suitable ICT for mass field studies. Convenient and inexpensive self-meter reading and appliance-specific breakdown would need sophisticated technology which Fischer (2008) had quoted as “unlikely to be installed widely” at the time of her research. The situation is now different with smart plugs/sockets costing less than AUD50 allowing consumers to self-monitor electrical energy usage at appliance level. In the following section we present the REMIS framework which is based on advanced information systems and technologies and relevant intervention and behavioural models. The review of energy informatics literature revealed that most of the approaches were conceptual in nature but provided also a guide for the functional affordance of REMIS. A key take-away is on the roles played by IS. This can be classified into: automate, informate, (informate up and informate down) and transform (Zuboff. 1985; Chen, Boudreau, & Watson, 2008). In the context of energy informatics, Watson el al (2010) described three types of technology are present, or should be present, in an intelligent energy system: flow networks, sensor networks, and sensitized objects, whereby IS plays a central role in integrating these three technologies

3. THE FRAMEWORK FOR RESIDENTIAL ENERGY MANAGEMENT INFORMATION SYSTEM (REMIS)

The REMIS framework (Figure 2) is developed by adapting and integrating (a) the role of information systems and green IS from Zuboff (1985) and Chen et al (2008); (b) Matthies’s (2005) Heuristic model of environmentally relevant behaviour and (c) Fischer (2008) and Lehman & Geller (2004) works on the role of feedback and intervention strategies respectively. The framework helps to explore and understand how information systems can be used to shape energy use behavior.

As an IS, REMIS use **enables** a critical and central role in the integration of intervention strategies (Lehman & Geller. 2004). The enablement is achieved in several ways – (a) providing effective feedback (b) automating energy use data collection including surveys to solicit inputs from energy end users and manage user learning (c) monitoring and controlling household systems and appliances and (d) informating (Zuboff 1985; Chen et al 2008) of the energy user (informate down) or utility company or energy policy maker (informate up)

The intervention strategies that REMIS enables would affect the outcome by steering the user (norm activation, motivation, evaluation and action/behaviour processes) towards energy efficient behaviour, consciously or sub consciously given a time period long enough for environmental detrimental habits to be broken. The outcome can be measured in terms of energy use (eg kWh)and translated into energy efficiency or environmental impact for feedback to the user. Positive outcome could create the conditions for continuous REMIS use and subsequently favourable energy use behaviour. The subsequent sections detail REMIS’s functional affordance when channelling intervention in each of the phases in the norm activation theory.

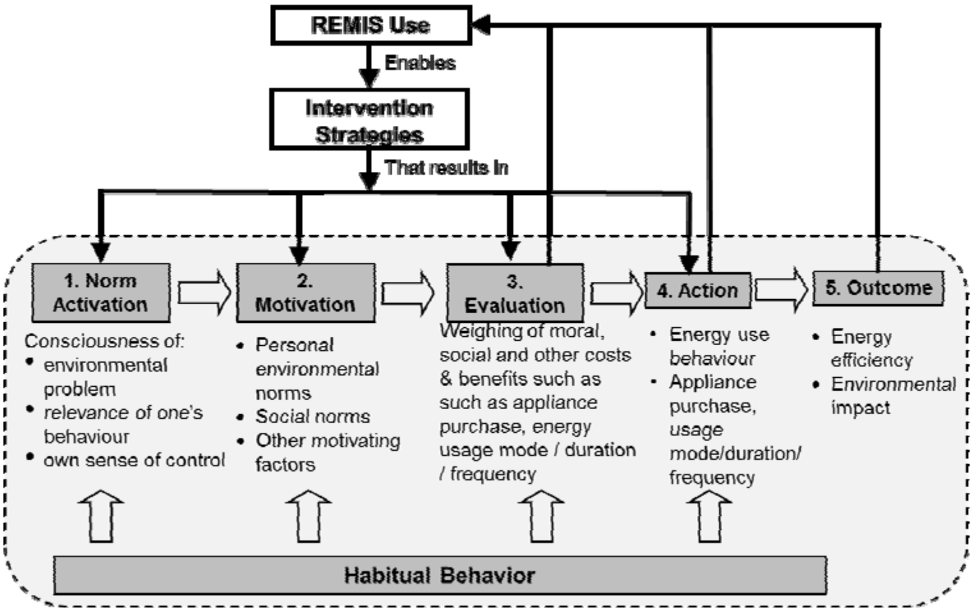

Figure 2. Residential energy management IS framework

3.1. REMIS and Energy Use Norm Activation

The key role of REMIS in norm activation (summarized in fig 3) is to **informate down** by channelling **intervention** to the energy user in order to bring about **consciousness** of the environmental problem due to inefficient energy use, relevance of his energy use behaviour and also to advise him on options to improve on energy efficiency, hence raising his consciousness of his sense of control.

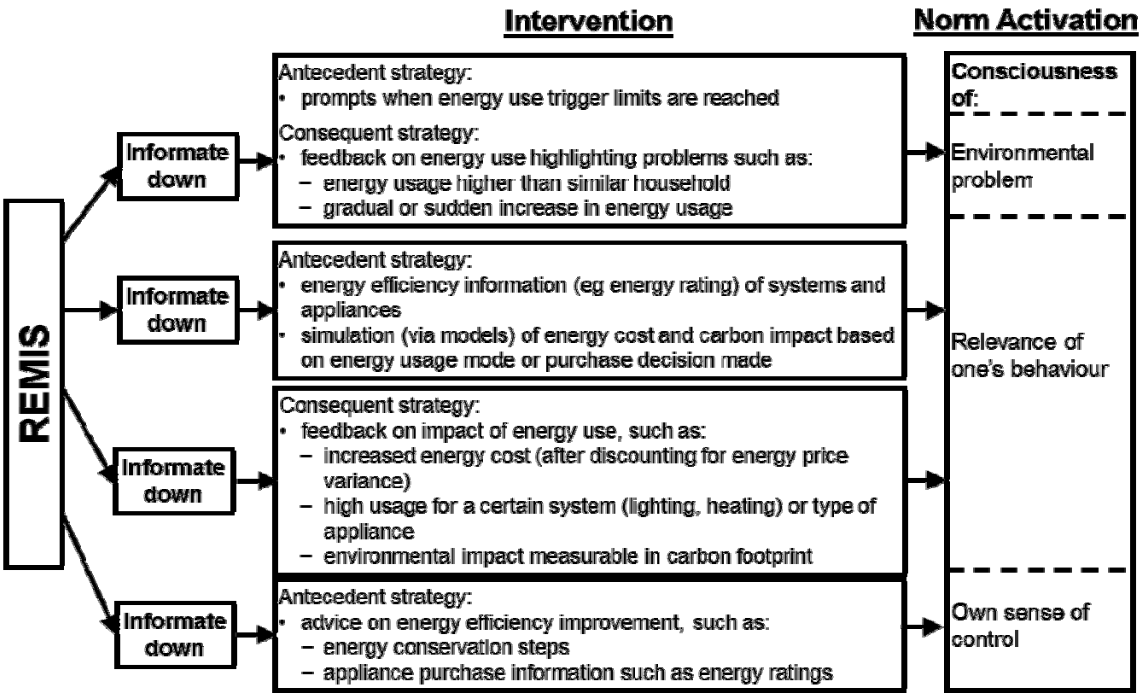

Figure 3. REMIS and energy use norm activation

As an example of a use of antecedent intervention (as defined by Lehman & Geller (2004)), REMIS could informate down by prompting the user (in real-time) when a pre-determined limit for energy use of a system (say air conditioning) is triggered. As a consequent intervention, REMIS could also informate down by prompting the energy user when certain energy use trends warrants attention, such as higher energy usage than a similar household or gradual or sudden increase in energy use. A series of such prompts then brings about consciousness of the environmental problem. By providing appliance energy efficiency information via REMIS or simulation of energy cost and carbon impact (antecedent intervention by informating down) before a purchase decision, the energy user could reflect on the relevance of purchase decisions (behaviour). As a consequent strategy, REMIS could informate down feedback on the impact of energy use (cost, environmental impact), raising consciousness of the relevance of the energy user's behaviour. Finally, REMIS could informate down and provide advice (antecedent strategy) to improve energy efficiency by way of energy conservation steps or during appliance purchase in terms of energy rating, hence providing a sense of control to the energy user.

3.2. REMIS and Energy Use Motivation

An individual is motivated by both personal and social norms as well as other motives such as cost (eg possible discounts). REMIS hence needs to educate, inform and provide feedback to induce such motivation. As it is not practical to provide a scope of all motivating factors, it would not be too far if monetary incentives are assumed to be a major other motivating factor. The flow of information due to REMIS in modifying motivation can be seen in fig 4.

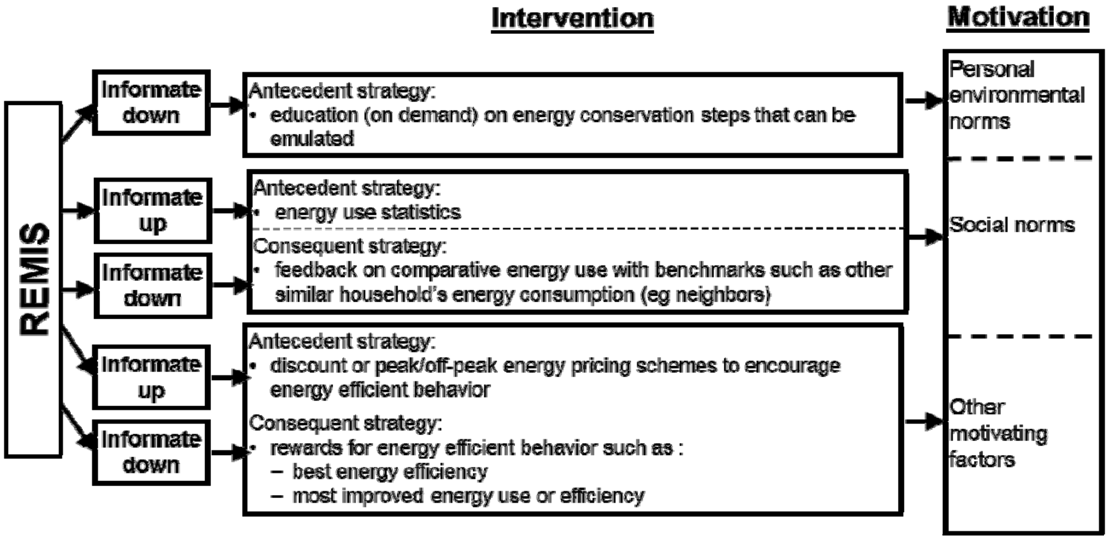

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Figure 4. REMIS and energy use motivation

As an antecedent strategy REMIS could provide education on improving energy efficiency (informating down) which transforms personal environmental norms. By collating energy consumption statistics for utility companies or energy policy makers (antecedent strategy informating up) and by providing feedback on comparative energy use (consequent strategy informating down) REMIS can intervene to modify social norms.

REMIS can informate down (antecedent strategy) to inform the energy end user of discounts for a certain energy use pattern such as off-peak usage. As a consequent strategy REMIS could provide information on rewards (informate down) when the energy user had successfully modified a certain aspect of energy use behavior towards energy efficiency, such as most improved energy efficiency. The discounts and rewards then represent factors that provide motivation.

3.3. REMIS and Energy Use Evaluation

The evaluation stage is the most information intensive as the residential energy end user would typically be seeking as much information as possible before making a decision. This is where support, by way of provision of information and assistance in evaluation would help steer the decision maker towards more energy efficient decisions. Information provided before the decision (to facilitate it) is mainly antecedent in nature.

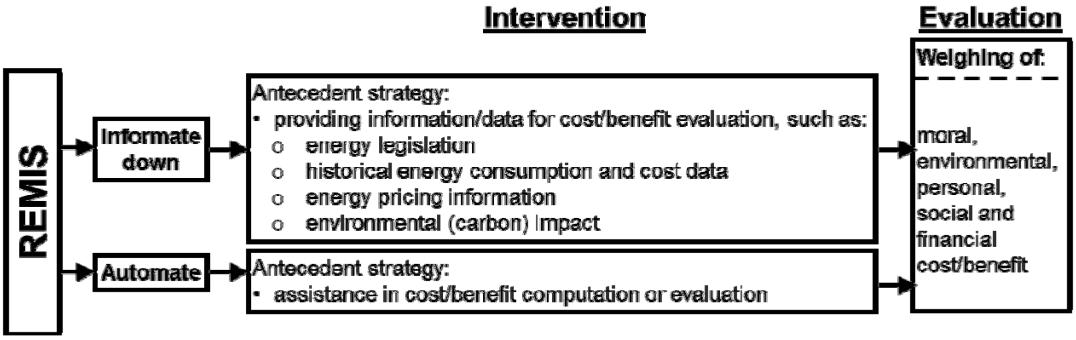

Figure 5. REMIS and energy use evaluation

As illustrated in fig 5, REMIS can informate down by providing information for cost/benefit evaluation as part of an antecedent strategy. As an IS it could also automate the information processing by performing the cost/benefit computation or assist in the evaluation process.

3.4. REMIS and Energy Use Action

Energy use action could take the form of system and appliance purchase as well as manner of usage and intensity.

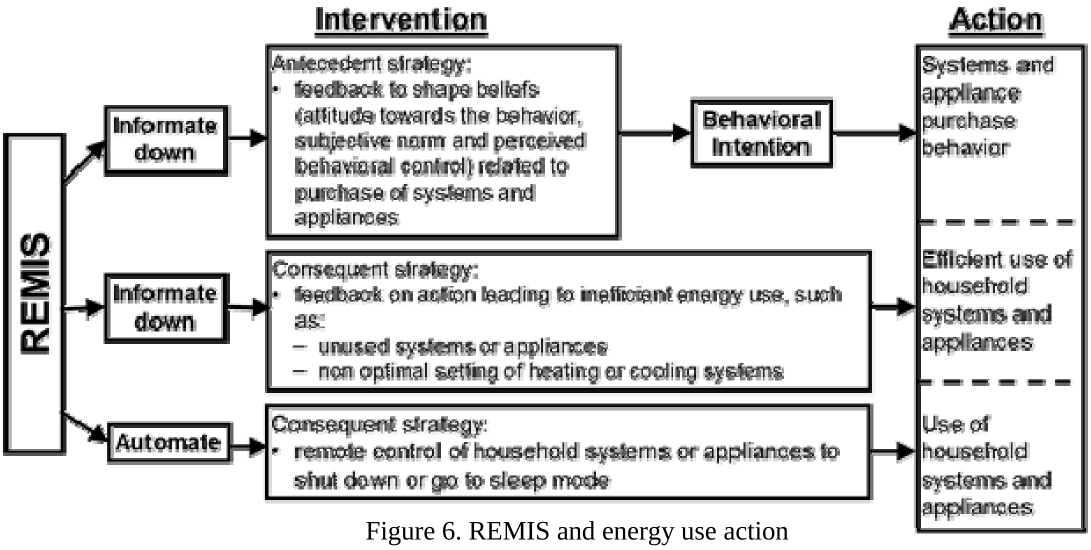

Figure 6. REMIS and energy use action

System and appliance purchase is a planned behavior where, based on the theory of planned behavior (Ajzen, I, 1991), can be measured by intention to behave which in turn is subject to the three factors of attitude towards the behavior, subjective norm and perceived behavioral control. These three factors are driven by beliefs held by the individual which can be shaped by antecedent intervention channeled by REMIS (informate down role).

At the same time, the manner of usage and intensity are actions which can be further guided via interventions brought by REMIS. The heuristic model of environmentally relevant behavior (Matthies 2005, Fischer 2008) suggests that environmentally detrimental habits directly influence the energy user, leading to a habitual way of energy use. For instance, some energy users might be in the habit of turning on the TV in the lounge when they return home from work, even when they are not in the lounge to watch the program on TV.As part of a consequent strategy, REMIS could monitor and informate down to the user of any actions that results in inefficient energy use.

In an automate role REMIS can allow user control over household systems or appliances remotely thereby extending the scope of his actions. As an example, the energy user who had left his air-conditioning on while he is out of his house for an extended period of time, would be able to switch it off via REMIS. To allow for this systems and appliances need to have remote control capabilities built in. Some plugs or sockets have built in remotely controlled relays to turn on or off power to the appliance it is connected to. This opens up possibilities of controlling appliance remotely, although it needs to be done carefully as some appliance should only be shut down with proper shutdown procedures. With more such devises being used, an additional evaluation consideration should include the additional energy consumption due to the built-in "smartness" in order not to significantly increase the energy consumption overheads. This automate role also has to be in conjunction with intervention strategies (ie effective feedback) to guide the energy user towards efficient energy use.

3.5. REMIS and Energy Use Outcome

Energy use outcome are measurable in terms of energy efficiency and environmental impact. Although Watson el al (2010) described sensitized objects as having the capability to sense and report data about its use, for REMIS such objects would be either smart appliances (that has these capabilities) or adaptor technologies such as smart sockets or smart plugs that provide reporting capabilities to the appliances they are connected to. Hence the automate role of REMIS here is to measure (automate) and report (informate down) energy use at appliance level.

4. Conclusion

This research has shown how a conceptual framework for REMIS was developed from socio-psychological theories such as the heuristic model of environmentally relevant behaviour (Matthies 2005; Fischer 2008) and interventions as defined by Lehman & Geller (2004), in the process fulfilling roles of IS as defined by Zuboff (1985) and Chen et al (2008). Two areas for further research would be to instantiate an instance of REMIS to empirically validate it, and with this carry out research on acceptance of such an IS by the residential energy user.

4.1. Architectural Concept for the Design and Development of REMIS

A functional goal in the design and development of REMIS is to provide the energy user with information real-time, making input/output (I/O) technology crucial. Darby (2006) compared effectiveness of feedback via a selection of I/O available at that time, namely basic metering, key/keypad meters, dedicated/ambient displays or TV/PC as displays but was constrained by availability of mobile display technologies at that time. For instantaneous feedback to the energy user, it is essential to leverage from mobile computing. With a large section of the urban population having internet enabled smart phones or devices which can be installed with software applications that interacts with smart meters/sockets/plugs directly or via a remote server channelling feedback interactively to these devices would do away with additional display technologies, at the same time reducing cost. Given today's pervasive culture of glancing at our mobile devices every so often, interactivity via smart mobile devices has the advantage of timeliness in feedback in order to continuously modify energy use behaviour while the energy use event is still fresh in the energy user's mind. These mobile devices could also provide a means for control of systems and appliances (automate role). Backend computing could leverage on cloud based servers which fulfils also the automate role of REMIS, ie information processing. The functional components of REMIS are hence metering devices, I/O devices, data consolidation and communication gateway and cloud based server.

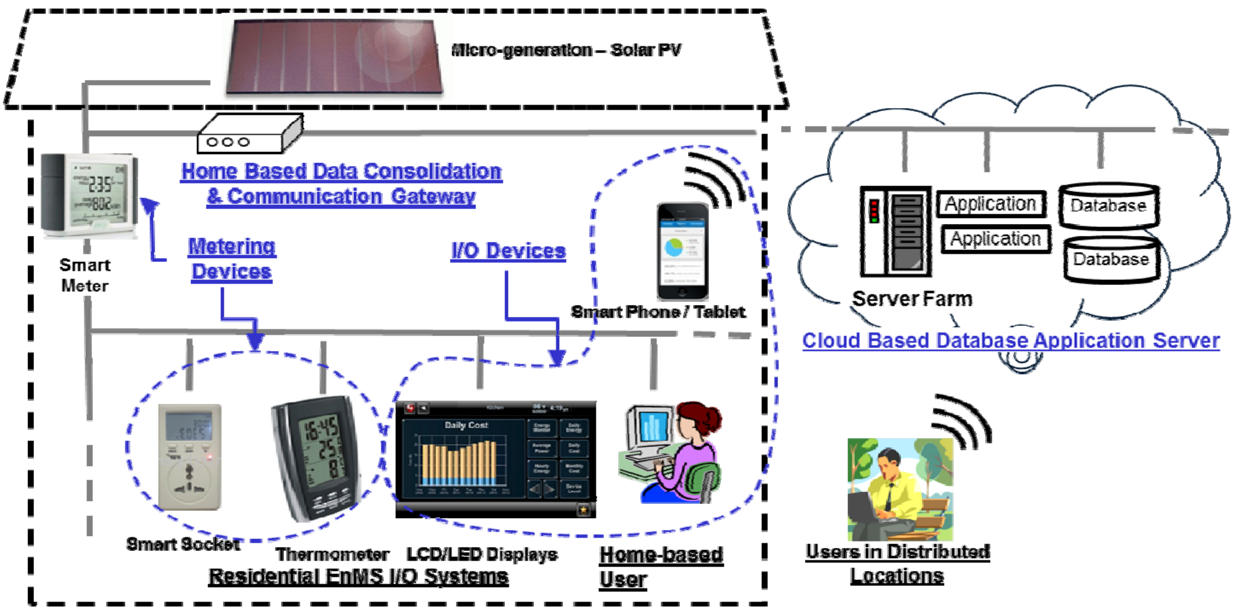

Figure 7. Architectural Concept of REMIS

4.2. Acceptance of REMIS

After a period of less than 3 years both Microsoft Hohm and Google Powermeter were subsequently withdrawn from the market (Google. 2011; Kirmse, A 2012; CBS Interactive. 2012). Reasons cited by industry analysts vary but the main contentions were:

- Lack of acceptance by consumers (Kirmse, A 2012)
- Too early for the market (Fehrenbacher, K. 2011)
- Perceived resistance from utilities (Fehrenbacher, K. 2011; Troast, P 2011)

It is clear from these implementations of REMIS by two of the world's major technology companies that withdrawal of such a major and world-wide IS implementation begs the question on acceptance by users which makes it important for further research to be done on the likelihood of acceptance for REMIS. Arising from the theory of planned behaviour, further theories on adoption of technology (Davis, F. D. 1980, 1989; Venkatesh, V. & Brown, S. A. 2001; Venkatesh, V. Morris, M. G., Davis, G. B. & Davis, F. D. 2003; Brown, S. A. & Venkatesh, V. 2005; Brown, S.A. Venkatesch, V. Bala, H. 2006; Brown, S. A. 2008.; Venkatesh, V. & Bala, H. 2008) could be leveraged on to shed more light into the factors that influence behavioral intention to adopt REMIS.

References

Abrahamse, W. Steg, L. Vlek, C. Rothengatter, T. 2005. A review of intervention studies aimed at household energy conservation. Journal of Environmental Psychology 25 (2005) 273–291

Brown, S. A. & Venkatesh, V. 2005. Model of adoption of technology in households: A baseline model test and extension incorporating household life cycle. MIS quarterly, 399-426

Brown, S.A. Venkatesch, V. Bala, H. 2006. Household Technology Use - Integrating Household Life Cycle and the Model of Adoption of Technology in Households

Brown, S. A. 2008. Household technology adoption, use, and impacts - Past, present and future

CBS Interactive. 2012.. Microsoft kills Hohm energy app. http://news.cnet.com/8301-11128_3-20075829-54/microsoft-kills-hohm-energy-app/. Accessed 24-9-2012

Chen, AJW. Boudreau, MC. Watson, RT. 2008. Information systems and ecological sustainability. Journal of Systems and Information Technology Vol. 10 No. 3, 2008 pp. 186-201

Darby, S. 2006. The effectiveness of feedback on energy consumption. Environment Change Institute, University of Oxford

Davis, F. D. 1980. A technology acceptance model for empirically testing new end-user information systems: Theory and results

Davis, F. D. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, 319-340

Elliot, S. 2011. Transdisciplinary Perspectives on Environmental Sustainability: A Resource Base and Framework for IT-Enabled Business Transformation. Management Information Systems Quarterly, 35, 197-236

Fehrenbacher, K. 2011. 5 reasons Google Powermeter didn't take off. http://gigaom.com/cleantech/5-reasons-google-powermeter-didnt-take-off. Accessed 20-8-2012

Fischer, C. 2008. Feedback on household electricity consumption: a tool for saving energy?

Fujitsu. 2012. Sustainability Case Study. Lend Lease – Convesso Concavo Project.

Geller, ES. 1981. Evaluating Energy Conservation Programs: Is Verbal Report Enough? Journal of Consumer Research, Vol. 8, No. 3 (Dec., 1981), pp. 331-335

Google. 2011. Google Powermeter: A Google.org Project. http://www.google.com/powermeter/about/. Accessed 24-9-12

Hirst, Goeltz, & Carney. 1982. Residential energy use: Analysis of disaggregate data. Office of Conservation and Solar Energy and the Energy Information Administration (EIA), USA.

Jenkin, T. A., Webster, J. & McShane, L. 2011. An agenda for Green information technology and systems research. Information and Organization, 21, 17-40

Kirmse, A. 2012. Privacy in Smart Homes. ComSys Seminar: Advanced Internet Technology SS2012

Lehman, PK. Geller, S. 2004. Behaviour analysis and environmental protection: Accomplishments and potential for more. Behaviour and Social Issues, 13, 13-32 (2004).

Matthies, E. 2005. Application of a new integrative influence model of pro-environmental behaviour to promote energy efficient behaviour. Conference Energy Efficiency and Behaviour, 2009

Melville, N. 2010. Information systems innovation for environmental sustainability. Management Information Systems Quarterly, 34, 3

Microsoft. 2009. Microsoft Hohm Helps Consumers Save Money and Energy. http://www.microsoft.com/en-us/news/press/2009/jun09/06-24EnergyUsagePR.aspx. Accessed on 20-8-2012.

Midden, CJH. Meter, JE. Mieneke, HW. Zieverink, HJA. 1983. Using feedback, reinforcement and information to reduce energy consumption in households: a field-experiment. Journal of Economic Psychology 3 (1983) 65-86

Nader, W. 2011. Real-time Power Monitoring, Home Automation and Sustainability. Architectural Engineering -- Dissertations and Student Research. University of Nebraska.

Petchey, R. 2010. End use energy intensity in the Australian economy. Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences

Straits Times. 2011. Energy-saving features for Punggol flats in pilot project. Straits Times, Singapore 2 August 2011

Troast, P. 2011. Google Powermeter: Smothered by Utilities? http://theenergycollective.com/petertroast/60281/google-powermeter-smothered-utilities. Accessed on 20-8-2012

Ueno, T. Sano, F. Saeki, O. Tsuji, K. 2005. Effectiveness of an energy-consumption information system on energy savings in residential houses based on monitored data. Applied Energy 83 (2006) 166–183.

Unander, F. Ettest, I. Ting, M. Schipper, L. 2004. Residential energy use: an international perspective on long-term trends in Denmark, Norway and Sweden. Energy Policy 32 (2004) 1395–1404.

US Energy Information Administration (EIA). 2009. Residential Energy Consumption Survey (RECS).

Venkatesh, V. & Brown, S. A. 2001. A longitudinal investigation of personal computers in homes: Adoption determinants and emerging challenges. MIS quarterly, 71-102.

Venkatesh, V. Morris, M. G., Davis, G. B. & Davis, F. D. 2003. User acceptance of information technology: Toward a unified view. MIS quarterly, 425-478

Venkatesh, V. & Bala, H. 2008. Technology acceptance model 3 and a research agenda on interventions. Decision Sciences, 39, 273-315.

Watson, RT. Boudreau, MC. Chen, AJ. 2010. Information Systems and Environmentally sustainable development: Energy Informatics and new directions for the IS community. MIS Quarterly Vol. 34 No. 1, pp. 23-38/March 2010

Watson, TW. Williamson, T. Boudreau, MC. Li, S. Zeng, Z. 2011. Energy Informatics and Business Model Generation. Proceedings of SIG Green Workshop . Sprouts: Working Papers on Information Systems, 11(6)

Wilson, C, Dowlatabadi, H 2007. Models of Decision Making and Residential Energy Use, Institute for Resources, Environment and Sustainability, University of British Columbia

Winett, RA. Neale, NS. Grier, HC. 1979. Effects of self-monitoring and feedback on residential electricity consumption

Zuboff, S. 1985. Automate, Informate – The Two Faces of Intelligent Technology. Organizational Dynamics

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