Changing the change
DESIGN VISIONS PROPOSALS AND TOOLS

Rethinking the smart home:

An environmental perspective

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Abstract

In this paper, we propose a vision of the "smart home" that diverges from current trends in home automation and home-as-machine paradigms, where lights are dimmed and music is tuned on to suit one's mood or where one can set the Jacuzzi's temperature from the car while driving home.

In the future that we hope for, the "smart home" is about intelligent management of resources – for personal cost savings and for the benefit of the environment.

The notion of a "smart home" must change to match people's day-to-day realities, and technology companies must shift their understanding of the relationships between people, technology, and the environment, to identify solutions that enhance everyday life with minimized impact to our planet.

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1. Introduction

Over the past few years the severity of the issues that this planet is facing has become not only noticeable but something to be addressed promptly and cautiously – from global warming to environmental degradation and the depletion of natural resources. Growing concerns have pushed governments, NGOs, corporations, regulatory entities and individuals to take action. Among these groups, technology developers and the broad HCI community have a great responsibility.

As Blevis (2007, 511) reports, in the USA 567 million (1/3 of worldwide sales) new Windows-based computers have been purchased since 1981 and nearly half of them have been purchased in the last 5 years, meaning that "the number of computers purchased new in the US in the last 5 years is equal to nearly 90% of the number of people who actually live in the US". Clearly, this is not sustainable from an environmental perspective. However, if we look at the matter from a different perspective, the HCI community and technology developers can balance their responsibilities by playing lead roles.

Blevis (2007, 313) highlights a link between interactive technologies and the use of resources, stressing how "interactive technologies can be used to promote more sustainable behaviours" and how "sustainability can be applied as a critical lens to the design of interactive systems". Recent work by Jain & Wullert (2002), Wash et al (2005), Gustafsson and Gyllenswärd (2005), Bång, M., et al (2006), Stringer et al. (2007), Mankoff et al (2007), and Blevis (2007) demonstrate how technology can be adopted to motivate and enable people to have a more sustainable behaviour, by using social networks as motivational tools, reducing ride sharing's coordination costs, promoting awareness around energy consumption, or focussing on the impacts of interactive or pervasive technologies from a use, development and disposal perspective.

As part of the User Experience Group at Intel Corporation, we typically concentrate our efforts around the home environment and, when looking at domestic technologies, we believe that the concept of "smart home" needs to shift: from a place of seamless automation to one of empowerment. The User Experience Group at Intel uses a blend of ethnographic, human factor and design research skills to develop user-centric consumer electronics products and technology solutions that can genuinely support people's values and practices. Our user experience design enables Intel's Digital Home to start with people to then define the experiences that they want and enable platform designers to create more compelling solutions for a richer user experience.

In this paper, starting from a brief analysis of how the concept of "smart home" evolved through time, we put forward four key principles and metaphors that provide a philosophical foundation for what we believe a smart home should really be about:

- The "smart home" is about using technology to empower people to control and maintain waste and resources in their own domestic landscape;
- The "smart home" has to be a communicative entity – capable of equipping people with a clear and solid understanding of what is going on around them, in their own homes;
- The "smart home" must be accessible, transparent and easy to "read", mirroring how people live (versus how developers, technologists, designers and engineers believe people live); and
- The "smart home" means different things to different people, requiring personalizable, customisable, local practices aware, socio-culturally relevant, open and networked technologies.

The paper is divided into five sections. In the first part we introduce the paper themes while in the second we offer selected historical examples demonstrating the evolution of the ideas

behind the “smart home” as they have led to today’s notions of home automation that caters to an unscaleable and unsustainable lifestyle for the privileged. In the third section, we outline underlining principles and metaphors that should be taken into account when designing the so-called “home of the future”. In the fourth part of the paper, we discuss how companies like Intel can actively support and promote sustainable lifestyle changes by driving alternative visions of the smart home. In particular, we discuss current Digital Home prototyping efforts and the benefits of “smart homes” that enable intelligent resource management. In the final section of the paper, we offer a number of concluding remarks and an overview of next steps to be addressed.

2. A Brief History of the “Smart Home”

We can trace the concept of “smart home” to the early 1980s and that, more generally, of a technologically-enhanced “home of the future” much farther back in time. Alongside the evolution of these idealistic domestic visions, our understandings of ourselves as inhabitants of such futuristic, “smart” homes – and of technology’s role in our lives – has changed over time as well.

Hardyment (1988, 1) points out how the industrial revolution has “turned the home from a productive unit into a consuming maw, and from a nest and refuge to a ‘physical service station’, a battery of bought conveniences from which individuals recharge themselves with food and sleep”. Homes today appear to be more like *shop window*s, rather than a place for baking, brewing and making clothes (Hardyment 1988, 2) – shop windows that are the products of relatively fast paced changes brought about by technologies and how we conceptualized them over time.

In the next sessions we briefly overview some of these changes, to show how the notion of “smart home” developed over time and to support the view that today’s notion of home automation caters to an unscaleable and unsustainable lifestyle for the privileged.

Forty (1992) discusses the impacts of the 1920s labour shortage, related to the introduction of electrically powered machines in the home – machines that could enable one person alone to manage an entire household and still enjoy left over leisure time. Opposed to this idealistic view of technology, Vanek (1974) argues how time spent in housework has hardly changed since 1926, regardless of domestic appliances’ introduction. Vanek’s view has been challenged by many, including Gershuny and Robinson (1988) and their argument that between 1965 and 1985 domestic technology has considerably reduced women’s routine housework. Although the argument around these opposing perspectives appears to be still unresolved, Cowan (1983) and Hardyment (1988) noted how in the 1940s an emphasis on consumption and the introduction of more domestic technologies implied an increase in time spent on housework, paralleled by an increase in standards.

During this first part of the 20th century domestic technologies increasingly populated people’s homes and did so at a fast rate: as a symbol of freedom from everyday chores and the promise of newly discovered leisure time. Even if the notion of “smart home” per se did not exist as we understand it today, the escalating inclusion of new (smart?) technologies in everyday life dramatically changed the notion of home and people’s relationships with time and space. Interestingly however, during this first of part of the century many thinkers, architects, artists and inventors were exploring the relationships between home and technology, challenging the notion of modernity, exploring the benefits of new technologies or investigating future opportunities. Examples include Fuller’s *Dymaxion Dwelling Machine* (1927) and *Aluminaire House* (1932) and William and George Keck’s House of Tomorrow for the Chicago World Fair of 1932.

With the Second World War things evolved again and the depiction of women as technically competent figures capable of freeing men from work outside the home contributed to the post war uptake of domestic technologies. Many women liked outside-the-home roles and needed to be free from domestic chores (Harper 2003): technology was there to address such a need. However, as men started to return from the war, women started to be encouraged to go back in

the home through propaganda depicting ideal images such as waving wives on the doorstep, smiling at their husband about to go to work – just before immersing themselves into daily domestic chores. The below extract from a 1950 article in *The Atlantic Monthly* describes the kind of social sentiment that was at stake:

> Instead of apologizing for being a mere housewife, as many women do, women should make society realize that upon the housewife now fall the combined tasks of economist, nutrition expert, sociologist, psychiatrist, and educator. Then society would confer upon the status of housewife the honor, recognition, and acclaim it deserves. Today, however, the duties of the homemaker have become so depreciated that many women feel impelled to work outside the home in order to retain the respect of the community (Agnes E. Meyer in Plante 1995, 283).

During this time modern technology increasingly supported new ways of living, considerably changing home design: new kitchen styles emerged to accommodate refrigerators and washing machines and television lounges were introduced alongside a substantial increase in TV sales (Aldrich 2003). In brief, the latest home technologies functioned to demonstrate prosperity – as props for the perfect housewife in her display of domestic prowess. During this time the reality of domestic technologies as tools to enable new lifestyle were paralleled by a vast array of visionary and critical explorations of the home and its future.

Mon Uncle, a 1958 movie by Jacques Tati, ironically explores ultra-modernistic notions of the home, where everything is automated and gadget-like, including a candy-coloured space age home complete with neurotic houseboat and automated dogwalker. In Robin Boyd's *House of Tomorrow* (1949) – a two-storied home which included a lounge-room, a study, a dining room with kitchen and a bedroom – technology and the notion of *good taste* were mixed to illustrate modernist aesthetic ideals as well as a new and contemporary way of life. In this modernist proposal of the future, technology played a pivotal role and not only from a structural perspective. A good example was a mocked-up television which anticipated its introduction in 1956 (Serle 1996, 96).

As the 60s and 70s approached, new belief systems related to the role of women in society overturned the 50s ideals: more women had out-of-home occupations and technology was consequently needed to save time and effort within the household. During this time a vast array of domestic technologies emerged, from automated kitchen utensils (e.g. food processors) to personal care (e.g. electric razors) and cleaning devices (e.g. vacuum cleaners). The *house of the future* came to mean something more than simply a collection of futuristic looking technologies collected under one roof. During those decades our imaginary future homes edged ever closer to a vision of the home itself as a machine, capable of precise automation in the service of our human wants and demands for uninterrupted comfort.

During this time of socio-cultural shifts and positive appreciation of the future, new materials and technologies offered the opportunity to explore new options and, importantly: freedom. Consequently, many architects and designers explored the notion of the future home, exploring materials, new structural possibilities and futuristic technologies. Famous examples include Disneyland's Monsanto's *House of the Future* (1967), made almost entirely from the latest plastic technologies, and Matti Suuronen's *Futuro* (1968), a prefabricated space-age home made of fiberglass-reinforced polyester plastic that summarized the typical utopian architecture of the era: mobility, leisure and new materials. An increased interest in wiring homes to augment their functionality started during this time. America's Independent Electric Light and Power Companies for instance promoted during that time a home of the future where "electrically operated climate-conditioned extensions will permit *summer terraces* all at will by your electricity" (in Heimann 2005).

In the 1970s and 1980s colour TV set dramatically penetrated the market, together with video cassette recorders, compact disc players, microwave ovens and personal computers – these technologies considerably changed the home landscape as it was known. In many ways the two previous decades can be seen as preparatory for the 1980s trend toward "smart homes,"

where advanced control systems automate the domestic space in seamless ways that isolate inhabitants from the realities of their environment.

Following the *Cooperative Research and Development Act* passed in 1984 by the U.S. Congress, the National Association of Home Builders (NAHB) in Washington, D.C. formed the SMART HOUSE Limited Partnership with the aim of providing integrated wiring for all current home services and provisions for home automation technology. NAHB's vision was that of a computer-controlled home: a house, condominium, or apartment where people can spend more time pursuing life's rewards and less time performing routine household tasks (Howard and Wagoner 1991). The concept of the smart home was officially born.

Within this context people started integrating new technologies in their homes in different ways and similar technologies implied a variety of social changes in different parts of the world.

Ironmonger et al (2000) for instance describe how different types of Australian households adopted new technology at different rates, with higher technology adoption in households with children and slower in one-adult households. Trend analyses revealed that color television, cable television and the videocassette recorder collectively played a major role in expanding the share of disposable personal income devoted to mass media in Belgium between 1970 and 1991 (Dupagne 1997). In the US 95% of the households had a TV in 1972 (half of them in color), HBO opened its doors in 1975 and by 1987 half of U.S. TV households (about 55 million) subscribed to basic cable. Finally, the introduction of personal computing in the home opened up new opportunities for work, play, connecting, learning, and doing business, significantly impacting everyday life, from spatial, time and speed perspectives. Aldrich (2003, 20) highlights how through time different forms of domestic technologies have been adopted at different rates and how such a trend might have implications for how smart home technologies might be adopted in the future, reiterating Bowden and Offer (1994) a distinction between "time saving" goods (such as washing machines) and "time-using" goods (such as the television).

Since the 1990s the concept of smart home has permeated popular culture (Aldrich 2003, 22): from publications in popular magazines such as Vanity Fair to television programs such as BBC's *Dream House,* the idea of inhabiting a smart home has become of public domain, together with related fears, uncertainties, concerns and dreams.

The uptake of home automation and control technologies has however been slower than predicted; many of the ideas behind these homes of the future and the associated promises of housework-free living do not match people's day-to-day reality. Gann et al (1999 in Aldrich 2003, 22-3) suggest a number of reasons for such a slow uptake, including: relationship between the required high initial investment and the its benefits; the costs associated with "retrofitting" old homes versus wiring new homes; a lack of common protocols and the consequent focus on on/off switching systems for single applications; suppliers narrow "technology push" approach and lack of users' needs; and little usability evaluation by suppliers.

Nonetheless, the dream of a technology-enhanced home of the future continues to permeate current thinking around smart homes and domotics. Technology companies are equally caught up in this dream, which isolates them as well from the realities of domestic living and from the impact that their home technologies have on people's aspirations and expectations and, in the end, on the environment.

At the 2008 Consumer Electronics Show (CES) Bill Gates described a home of the future in which computing power will be available in every room, through embedded-in-furniture touchscreens. To have a clearer understanding of such view of the future home one can refer to what is called *Microsoft Home*, modeled on Bill Gates' own Seattle mansion.

Microsoft Home, powered by four PCs running Windows XP, features dozens of networked monitors, Xboxes, appliances, and consumer electronics devices scattered everywhere: security and entry to the future home is enabled through an electronic kiosk with a touchscreen, a biometric scanner, and a smartcard reader; as one enters lights and heat automatically fine-tune to one's preference and a screen on the wall reads emails aloud; in the kitchen one can run a pot

beneath the barcode reader on the microwave and automatically set time and temperature or get help with cooking by scanning RFID tags on specific ingredients; digital media is everywhere and accessible from any room, on every device, thanks to a central media server which supplies entertainment throughout, seamlessly streaming content where is needed (O'Brien 2003).

Microsoft does not stand alone, of course, as the source of our collective vision of a future smart home. It is precisely this type of vision of embodies in our view the type of future home that should be re-considered: it represents a concept of home automation that caters to an unscaleable and unsustainable lifestyle for the privileged. In the following sections, we propose alternatives to this lifestyle and discuss how companies like Intel can actively support and promote sustainable lifestyle changes by driving alternative visions of the smart home.

3. Smart homes for the rest of us

Blevis (2007, 503-4) overviews five principles that set sustainability as the focus in the context of interaction design: linking invention & disposal; promoting renewal & reuse; promoting quality & equality; de-coupling ownership & identity; and using natural models & reflection.

Gann and Barlow (1998, 13) discuss how the smart home industry must "motivate consumers to buy its products" and therefore develop "solutions that satisfy real user needs" – solutions that have to "operate as (1) *generic technologies*, providing the basic, standard compatible building blocks for (2) *context-specific systems*, adaptable to a wide variety of dwelling types, and (3) *personalised systems*, tailored to specific individual and household requirements". The authors (Gann and Barlow 1998, 13) also highlight how smart home solutions must satisfy a number of conditions:

- Functionality – the equipment/system must have clear and unambiguous functions;
- Ease of use – clear and simple user interfaces, interactivity and connectivity;
- Affordability – for individuals and housing providers;
- Reliability and maintainability;
- Flexibility, adaptability and upgradability – systems need to develop as user needs change; and
- Replicability and ease of installation – systems need to be available as a standard, reproducible product.

While we agree with Blevis' and Gann & Barlow's views, we would like to add a set of nested underlying principles and metaphors that provide a philosophical foundation for what we believe the smart home should be.

First of all, we believe that on a conceptual level the notion of "smart home" has little to do with that of automation, where technologies in the home can predict one's mood and reconcile one's preferences, seamlessly and automatically. We indeed believe that the "smart home" needs to be about using technology to *empower people to control and maintain waste and resources in their own domestic landscape*. To do this it is crucial we conceptualize the home as an ecosystem that generates waste and consumes resources. In such a paradigm, "smart" means capable of helping people manage their resources and waste.

An ethnographic study conducted by colleagues at Intel in 2006 and 2007 (Woodruff et al. 2008) reported how for participants the notion of living in a "green home" meant "constant activity to keep it in tune with nature's changing state and rhythms", to minimize energy use and maximize comfort "by constantly reconfiguring windows, doors, skylights, solar panels, etc". The metaphor of *living on a ship* was often used by participants to refer to this ongoing configuration and maintenance, embedded in their experiences of living in a "green home". This "living on a ship" metaphor comes directly from everyday practices around the use of technologies to live in a

“greener home” and it mirrors our proposition that a “smart home” is about the capacity of controlling and maintaining waste and resources, instead of spectable and the seamless automation of multiple “intelligent devices”.

Within this paradigm, we secondly propose that the “smart home” needs to be about information, not spectacle. We believe that the smart home has to be a *communicative entity* – capable of equipping people with a clear and solid understanding of what is going on around them, in their own homes. Within this paradigm, “smart” means practical, everyday, accessible, and, more importantly, in touch with the relationships between house and household – place and inhabitants.

If we accept the above notion of the mart home as a communicative entity, it is clear that today’s smart homes often do not allow people to be smart. Today the home is indeed un-transparent about what it does, when and why. This generates a situation where its inhabitants cannot clearly and easily see what is occurring and what would enable them to make smart decisions. We consequently propose that a home is smart when it is *accessible, transparent and easy to “read”*.

These features align themselves with the conditions proposed by Gann and Barlow (1998, 13) overviewed at the start of this section. This notion of accessible, transparent and easy to “read” smart home is fundamentally about developing technologies that mirror how people live, versus how developers, technologists, designers and engineers believe people live. To gain such deep understandings and embed them into the design of new home technologies, developers must ensure ethnography and design research efforts are natural components of the development cycle and that such insights are truly embedded in it – from its start to the end.

Only by gaining a rich understanding of what, how and why people use the world around them the way they do, we can find ways to design accessible, transparent and easy to “read” smart home technologies.

Finally, while for some (like Bill Gates) “smart” means one thing with one solution, we believe that for the rest of us *smart home means several things*, as the home is a complex, multi-layered and multi-faced entity where new technologies increase complexity, generate possibilities and potentially create unnecessary and un-transparent layers. Different geographical location and socio-cultural environments call for technology solutions that take such differences into account and that stay away for *one-size-fits-all*. Personalization, customization, local practice awareness, socio-cultural relevance, open platforms and local networks all play a crucial role in the development of home technologies we believe can make our homes smart.

To summarize, we propose that a paradigm shift must occur and that we must reconceptualise the idea of “smart home” as a *communicative entity* that employs *accessible, transparent and easy to “read”* technology which empower people to *control and maintain waste and resources* in their own domestic landscape in a manner that is *personalizable, customisable, local practices aware, socio-culturally relevant, open and networked*.

4. Changing the Change from Within: a Corporate Credo

The perspective we represent in this paper, and to this community of researchers, is squarely rooted in the authors’ collective backgrounds as design academics and, now, as corporate practitioners of design research. We are not so naïve as to believe that corporations might altruistically lead the charge toward a sustainable future – not until there is clear evidence of profit in that direction. On the other hand, we know that large corporations can instigate widespread change: their weight may make steering them an unwieldy operation, but, when they decide where they are going to land, their impact can be mighty powerful. And it is ultimately the individuals working within corporations who set the company’s direction and decide its goals.

In this section of the paper, we discuss how companies like Intel can actively support and promote sustainable lifestyle changes by driving alternative visions of the smart home. In particular, we discuss current research and prototyping efforts within Intel's Digital Home Group, and, in as much as we feel we have achieved some success in shifting the corporate conversation at Intel in a positive direction, we offer these thoughts on what we might have done well when we were most successful. Every organization will be different, of course. Accordingly, we submit the following principles as our own credo, in which others may find helpful guidance when it comes to rethinking their visions of a sustainable, technological future from within a corporation.

Change the conversation. That would have to be the first principle and the cornerstone of our approach as outlined in this paper. As designers working in the high-tech industry, we are responsible for communicating back to the company – and eventually back to the many other companies we work with, and to the end consumers of their products – a coherent vision of the integration of the industry's technological advancements in people's everyday lives. We do not work alone in that endeavor: we would not get very far if we tried. But by joining our voices with those of like-minded individuals throughout the company – in corporate strategic planning, in public relations, in sales and marketing – a growing group of committed individuals has been successful in shifting internal conversations about Intel's sustainability initiatives: away from a singular focus on producing ever more energy efficient products and toward a broader conversation that encompasses not only the corporation's responsibility to maintain greener office buildings and production facilities, but increasingly to one that highlights new business opportunities in enabling eco-technologies[3].

We could consider the glut of electronic gadgets to which we contribute simply part of the world's problem, or we could rethink our products and the services they enable in ways that will best support sustainable end-user practices (by promoting telecommuting over air travel, to give an obvious example). In Intel's Digital Home Group, we have begun to talk more frequently about home electronics not only as devices that draw power in order to provide us with entertainment, but also as devices with which we may outfit homes of the future so as to empower their inhabitants to intelligently manage home systems and the consumption of non-renewable resources. Our challenge to ourselves has become: "How can we leverage the 2% of overall household energy typically used to power the home PC, to significantly curtail the remain 98% of residential energy consumption?" (US DoE, 2001).

These conversations have been heavily – if second-handedly – influenced by the rhetoric and ideas of *bright green environmentalism*, championed at Intel by our colleague Jay Hasbrouck (Hasbrouck and Woodruff, 2008)[4]. "[B]right green environmentalism," according to writer Ross Robertson, "is less about the problems and limitations we need to overcome than the 'tools, models, and ideas' that already exist for overcoming them. It forgoes the bleakness of protest and dissent for the energizing confidence of constructive solutions" (Robertson, 2007). Its proponents tend to look optimistically toward human innovation, smart design, and new technologies to provide answers to the human-made problems of our environment (Wikipedia, 2008).

As such, it can be an extremely empowering force in a culture of solution-driven engineers. Nonetheless, that change in the corporate conversation has not happened quickly. Convergence on the talking points that have now begun to take hold has been the hard-won product of many conversations and much repetition. And it has been aided by the rhetorical value of prototyping and simple mock-ups – by our ability to show our colleagues what it might look like to provide end-users with the capability to measure and then to model their homes' inner workings, to set rules for heating, cooling, and appliance use that respond to real-time fluctuations in energy

[3] We should note that Intel has a long history of working with the U.S. Environmental Protection Agency on a range of environmental initiatives, including Climate Savers (http://www.climatesaverscomputing.org), and is consistently recognized for its efforts to improve sustainability of its operations (http://www.intel.com/intel/environment).

[4] The term "bright green" was first coined by American blogger and author Alex Steffen in 2003 to characterize an emerging, more technology-friendly school of environmentalism, in contrast to the traditional, "dark green" environmentalism which, to over-simplify, advocates the return to simpler ways of living and radical political change as the path to a sustainable future (Wikipedia, 2008).

costs, and to monitor real-time feedback on their energy consumption from the computing and display devices distributed throughout their homes.

Change the metaphor. In short, this is the single, simple point we would like to make with this paper. The biggest roadblock we have encountered in introducing design concepts for computer-supported sustainable living has not been our colleagues' resistance to acknowledge that human impact on the environment is indeed a real problem, nor has it been failure to recognize a potential business opportunity in home automation and control: it has been fatigue. Any mention of "smart homes" within the organization is likely to draw a familiar, frustrated response from our well-seasoned technologists: "We've been down that path before". It is this frustration and disillusionment with the technological dreams of the past which has made it so important for us to redefine what it might mean for homes to be "smart".

Our "smart home" is a response to a new set of technological and social circumstances: a widespread and growing base of installed home networks that allow for the piecemeal introduction of networked devices and distributed sensors on the one hand, and the rise in consumers' awareness of the impact of their aggregate personal actions at a global level on the other. The "smart home" for us is now inextricably linked to both a negative (the old, unrealistic vision of a domicile designed to pamper its inhabitants while minimizing the need for human effort or imput) and a positive (the "smart home for the rest of us" described in this paper).

Persist in taking on the tough, small problems. While it can be helpful to sketch "the big picture" in explaining our particular ideas to others, it is often necessary that we tackle big problems from many fronts simultaneously. That means taking on small, but very tough, design challenges. Here we offer a concrete example in the user-interface problems associated with home energy management devices. Early in our explorations for smart homes equipped with whole-home energy management solutions, design team members installed in their own homes devices currently available on the market for monitoring and controlling home energy consumption. The results of those studies remain unpublished, as we are unable to put ourselves in the position of critiquing other companies' products, but we can report that there are many shortcomings associated with the available consumer solutions (this is a product category that would benefit greatly from the attention of a few concerned interaction and experience designers). Home energy monitoring devices were found to be difficult to install and set-up, often requiring the assistance of a professional electrician and labelled to warn consumers of the potential for death in the case of mishandling at instsallation (not generally considered the hallmark of a user-friendly product). While all the devices our collegues tested provided them with data, none but the most elaborate systems currently available (and generally installed only in newly constructed homes) provide information that suggest to users actions they might take to improve their current energy comsuption patterns. Providing actional information on the operation of home systems has become one of our driving objectives.

Even more discouraging were the findings of scientists who have determined that programmable thermostats – perhaps the simplest and certainly the most widely adopted of efficiency-oriented smart home appliances – may actually decrease the energy efficiency of home heating and cooling systems. In 2005, Energy Star endorsed a number of commercially available programmable thermostats, but by 2006 was forced to rescind that endorsement in the face of mounting evidence that homes equipped with programmable thermostats were not more efficient and were, in some cases in fact, less energy efficient than the same size homes using standard mechanical thermostats (Meier, 2007)[5]. The empirical findings at first seem implausible. How could a programmable thermostat, which is "smart" enough to automatically adjust the temperature in my home to optimal levels for every hour of the day, regardless of whether or not I remember it, be less efficient than the old-fashioned human-operated switch? Most of the blame has fallen on the user interface. Many users, it turns out, never properly learned to program their thermostats. Others used theirs just as they would use a mechanical thermostat – as a switch to

[5] Energy Star is the US Government program that promotes energy efficiency products and practices, in part by setting standard, energy-efficient performance requirements and endorsing products that achieve those standards (http://www.energystar.gov).

turn up the heat or cooling fans, regularly over-riding the programmed climate controls (Meier, 2007).

The simple residential programmable thermostat may be the example that best demonstrates the shift in metaphorical thinking proposed here in this paper; given a bit more thought up front, we may even have predicted such an outcome. Thermostats, for most of us in the US anyway, generally include a single temperature sensor integrated (and located together) with a wall-mounted control unit. The programmable thermostat adds to that configuration the ability to set rules for high and low temperatures and, often, accommodates alternate schedules for weekends and weekdays. We might have predicted that, as humans, we are unfortunately unskilled when it comes to predicting exactly how warm or cold we might be on any given Sunday or Monday of the year; whether we are likely to appreciate a warmed home when we return, on schedule, at 7:00 each evening, or if we might not have thought to turn the heat until several hours later when temperatures outside had reached much more uncomfortable lows. It might just be that "comfort" is more difficult than we had expected to peg to a specific measure of Celsius or Fahrenheit. Today's programmable thermostats may be too "smart" for their own good. Then we must account for the thermostat's singularity of placement. It may be a minor inconvenience that at the moment I recognize my slight discomfort of having just barely over-heated (or over-cooled) my home, I am not in the same room as my thermostat control. It may add only a few minutes to the time it takes me to adjust that control (probably the next time I happen to pass by the thermostat). But cumulatively, each of those hesitations might be just enough to make a big difference in my energy bill. Add all those factors to the simple usability problems of most commercially available programmable thermostats, and the findings which led to Energy Star's retraction of its original endorsement seen much less a puzzle, and much more a hairy UI design problem. At Intel, it has signaled the opening of an opportunity to employ some of the company's research in distributed sensor technologies and to establish a guiding vision of how mobile and embedded displays that have spread throughout our homes might be thought of as useful components in a system of home controls which empowers people to be smart about their own home energy use.

Demonstrate viability by demonstrating resonance. We rest assured that we will eventually be called upon to answer the question: "but how big is the market?". In many ways a focus on "green" solutions can make it too easy for executives to dismiss sustainability-minded initiatives as catering to a niche – a negligibly small group of left-over hippies who have taken up residence in the American Pacific Northwest. Executives need to see the numbers that affirm a concept's viability by confirming the size of the available market. In early 2008, we had an opportunity to conduct a six-country, 2400-person survey with the Nielsen Company. Our aim was to evaluate the appeal of some of our smart home product concepts and, more broadly, to understand people's (consumers') level of commitment to, and motivations for, engaging in sustainable practices at home. Much of the existing research in this area is limited to a specific market or region of the world, so we were very fortunate to have this opportunity to survey a large, international sample. While it is beyond the scope of this paper to report the results of that survey here, we can report that we were surprised – perhaps because of our own cultural prejudices – by our survey respondents' consistent sensitivity to the impact of personal choices on global conditions, and by the willingness, even eagerness, to invest personal energy – time, and even money – in smarter solutions and individual actions that might reduce their environmental impact. Across the six countries surveyed (US, Australia, Germany, Italy, China, and South Korea) we found the most enthusiasm from our Chinese respondents, 66% of whom said they would be willing to spend both more time and more money if it meant being environmentally responsible[6]. It is in research findings like these that we find the data we need to respond to critics who continue to believe that people are unwilling to participate in the intelligent management of their own resource consumption, and to win the continued support of the companies we work in our pursuit of smart home solutions for the rest of us.

[6] Findings of a survey conducted by the Nielsen Company for Intel Corporation, March 2008.

5. Conclusions

In this paper we briefly reviewed how the notion of “smart home” evolved till today’s concept of smart home as a place of seamless automation: a concept that in our perspective caters to an unscaleable and unsustainable lifestyle for the privileged. We then counter-proposed alternatives to this lifestyle by overviewing a set of four nested underlining principles and metaphors that provide a philosophical foundation for what we believe the smart home should be about. We finally discussed how companies like Intel can actively support and promote sustainable lifestyle changes by driving alternative visions of the smart home, offering insights on the principles that we adopted as our own corporate credo.

Within the paradigm we just offered, the future “smart home” that we hope for is related more closely to the intelligent management of resources – for personal cost savings and for the benefit of the environment. To achieve this result, the notion of a “smart home” must change to better match people’s day-to-day realities – technology companies must shift their understanding of the relationships between people, technology, and the environment in order to identify solutions that enhance everyday life with minimized impact to the planet on which we live.

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