LIVING LAB: RESEARCH AND DEVELOPMENT OF SUSTAINABLE PRODUCTS AND SERVICES THROUGH USER-DRIVEN INNOVATION IN EXPERIMENTAL-ORIENTED ENVIRONMENTS[1]

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[1]This paper is based on the outcomes of the project ***Design Study for the Living Lab Research Infrastructure to Research Human Interaction with, and Stimulate the Adoption of, Sustainable, Smart and Healthy Innovations around the Home*** 2008-2010) see: www.livinglabproject.org The project aims at developing a future European research infrastructure that researches the acceptance and the human interaction with, and stimulates the adoption of sustainable, smart and healthy innovations around the home. Project partners are: TU Delft, ETH Zürich, The Procter & Gamble Company, ACCIONA S.A. BASF SE, Universidad Politécnica de Madrid and the Wuppertal Institute. Within the European pool, the Wuppertal Institute represents the consumption and sustainability research and acts as moderator and integrator for the different participating expert disciplines. Based on a focused foresight process it has elaborated an intersectoral research profile and strategy.

Abstract

The LIVING LAB project is a design study within the 7th Framework Programme of the European Union. The aim of this project was to develop the conceptual design of the LIVING LAB Research Infrastructure that will be used to research human interaction with, and stimulate the adoption of, sustainable, smart and healthy innovations around the home.

LIVING LABs address some of the difficulties that occur in the course of an innovation process. Worldwide, 85% of development efforts are spent on products and services that never reach the market. At the same time, the experts often underestimate the market potential of many products and services. Living Labs are an approach to stimulate user-driven innovation, which can lead to a better understanding of customer needs and thus to more successful innovations.

LIVING LAB tries to utilize the advantages of a European research infrastructure to foster sustainable products and services. Sustainable products, or eco-innovations become more and more important in the face of the challenges as climate change and overuse and depletion of natural resources.

The LIVING LAB research infrastructure will explore the consumer's point of view of sustainable and quality-of-life-enhancing innovations. The project is supposed to gather insight in the consumer's motivations for using (or not using) these innovations, and work with the industry to develop alternatives with a better chance of succeeding in the market.
The paper will summarize and discuss the results from the LIVING LAB design study and will give an overview about the status of ongoing further European activities.

Keywords
User-driven innovation, sustainable products and services, sustainable innovation

1. Introduction: Sustainability as a prerequisite for any product or service

Numerous research and policy reports show that the present patterns of production and consumption in the industrialised countries are not sustainable (see e.g. IGES, 2010; Millennium Ecosystem Assessment Board, 2005; SERI, 2010; UNEP, 2010; WWF, 2009; WorldWatch Institute, 2009). An ever-increasing energy and resource consumption will disturb the Earth's sensitive biological eco-systems.

The lifestyle of the average population in industrialised economies is characterised by high levels of consumption and is, thus, responsible for an enormous increase of resource extraction and environmental problems. In most countries, household consumption determines 60% or more of all life cycle impacts of final consumption. For industrialised countries all studies indicate that housing, mobility, food and electrical appliances account for over 70% of the impact of household consumption.

Current trends in global consumption of natural resources are not only environmentally unsustainable, they are also socially unjust in a basic perspective. People in rich industrialised countries consume up to 10 times more resources than those in the poorest countries – whereas these resources are extracted to a large extent in the latter countries.

Therefore, industrialised countries in particular have a global responsibility in terms of sustainable development and are required to change their patterns of economic activity so as to decrease their resource use in absolute terms. OECD countries are global leaders in innovation and could switch to a stronger emphasis on green innovation; green ICT is a key element of global ecological progress. Sustainability - referring to the efficient use of energy and non-renewable resources and keeping the GHG emissions at the lowest possible level – has been integrated in the European ICT and e-business strategy (European Commission, 2010b; Welfens, 2010).

An absolute decoupling of economic growth from resource use is a precondition for sustainable production and consumption. Our welfare generation has to happen within the natural system boundaries. It must be sure that the ecosystem services provided by nature are not reduced. Currently we are consuming more ecosystem services and more natural resources than nature is providing on a sustainable basis.

The sustainability research shows the need for a holistic approach taking into account and optimizing the whole production-consumption-system. Only sustainability-oriented efficiency and sufficiency strategies will able to solve the future tasks, challenges and problems.

Thus the future potential for resource efficiency, climate change, poverty reduction and broadening welfare lies in the fields of individual deciding and behavioural processes combined with organizational learning processes recognizing the social context situations. Therefore we need more information and research results about these processes, we need more knowledge what people want and how they use products and frameworks in their living environment – at home, on the road and on their job. Such an interactive, sciences and stakeholder integrative research approach needs other test beds, kits and framework conditions.

Consumption plays a crucial role in the development towards sustainability. The responsibility for sustainable development should be put not only on the shoulders of consumers. We need stakeholder approach where the activities of industry, retailers and political authorities are more important. The term sustainable consumption is defined along the lines of the Brundtland definition for sustainable development as the use of goods and services that respond to basic needs and bring a better quality of life, while minimizing the use of natural resources, toxic materials and emissions of waste and pollutants over the life-

cycle, so as not to jeopardize the needs of future generations. This definition has to be interpreted in a pragmatic way. The main points are: greater efficiency in the final consumption of energy and resources, minimization of waste, and more environmentally-sound consumption habits in households. It is important to understand, that sustainable consumption does not automatically means less consumption but rather more efficient, better informed and less resource and energy intensive consumption.

Since the industrialization, production systems have been focused as important part of the economy responsible for producing welfare and socio-economic progress. Households and the interaction of the production and consumption systems were only the "black box" on the demand side - the *Homo economicus* has been perceived as an actor with a high and well-known deciding and behavioural structure. However, the social sciences, the evolutionary economic and market research as well as the latest neuromedicine science have shown that the deciding and behavioural processes are relatively unknown. They are of high complexity and diversity.

Consumption is not primarily an individual activity, but framed by many cultural and social contexts. Individual behaviours are deeply embedded in cultural and institutional contexts (See e.g. Campbell, 1987; Douglas, 2003; Gronemeyer, 1993; Jackson, 2005, 2006, 2008; Sanford and Harris, 2006; Sanne, 2002; Schor, 2004; Shove, 2005; Spargaaren, 2004; Thøgersen, 2007; Warde, 2005). We are guided as much by what others around us say and do, and by the 'rules of the game' as we are by personal choice. So it is important to understand and influence the socio-cultural context within which consumer choice is negotiated. In these circumstances, the rhetoric of 'consumer sovereignty' and 'hands-off' governance is inaccurate and unhelpful (Jackson, 2005).

2. Eco-Design as a key precondition for sustainable development

"*Good design is sustainable design. It is a process joining creativity and innovation and delivering value. Good design is a quantifiable benefit, not a cost. Its value can be measured economically, socially and environmentally."* (UK Design Council 2008: The Good Design Plan)

Design is a driver for economic and socio-cultural innovation and communication processes in society; placed between companies and the society, between potentially eco-intelligent need satisfaction and eco-intelligent technical solutions. Design processes are reflecting socio-cultural, economic, and environmental trends and are thus integrated into such trends through a perpetual development process. A modern and innovative design connects the

consumer, who is increasingly involved in the design processes (user-oriented design) and the producer. According to a last years EU report, a modern design and innovation-oriented economy are strengthening the competitive advantage of its companies and economic systems (SEC(2009)501 final COMMISSION STAFF WORKING DOCUMENT: Design as a driver of user-centred innovation).

Sustainability research has shown that the development and implementation of ecological design is essential for a sustainable society. Design is a determining factor for ecological and social effects of products and their value chain in all life cycle phases: production, use, recycling, and disposal. Therefore, a sustainable design is a key for improving resource- and energy efficiency as well as environmental impacts of products and services (e.g. technologies such as Persuasive Technologies, Forced Functionalities etc.). Integrating users and all relevant stakeholders in the value chain into development processes can reveal both negative as well as positive human-technology-interactions and therefore reduce problems of acceptance in consumers. Such a systemic approach requires the development of new ecological services together with adequate business- and user models – they have to fit the following definition of eco-innovations, as written in the final report of the EU Sectoral Innovation Watch Panel on Eco-Innovation:

„Eco-innovation means the creation of novel and competitively priced goods, processes, systems, services, and procedures that can satisfy human needs and bring quality of life to all people with a life-cycle-wide minimal use of natural resources (material including energy carriers and surface area) per unit output, and a minimal release of toxic substances." (Reid *et al.,* 2008).

Based on this, the LIVING LAB approach is crucial for fostering eco-innovation as its perspective is different from the traditional 'eco-feedback' approaches. Instead of reducing the users' behavioural options to what product developers deem to be the most sustainable – or raising awareness that does not necessarily result in reduced resource consumption – LIVING LAB wants to explore an approach that should lead to long-term effective sustainable innovations in the home by engaging users rather than restricting them or designing around them. This fits the challenge for LIVING LAB to undertake new methods of user-oriented research in order to foster innovation in sustainable lifestyles and products.

Modern sustainable homes are often rather high-tech environments. Heating, cooling, ventilation, lighting, communication and energy management systems are all connected and interact with each other and with the home occupants who need to monitor, manage, maintain and live with them. One of the research challenges is to explore to what extent

people can indeed successfully interact with the potentially complex range of in-house systems, and to what extent this interaction contributes to sustainable households over time. This leads to the following research objectives: To understand the relationships between home occupants' behaviour, domestic resource consumption and domestic systems (products and technologies), with the aim of minimizing the resource consumption and waste production, while optimizing user experience and comfort.

LIVING LAB is an integrated technological socio-economic approach to enable optimised interaction of production and consumption. Technological and social innovations can only be developed interactively by mirroring, explaining, and integrating emerging trends and consumer behaviour. This is and will be essential for companies and consumers because individual or social milieu oriented solutions are going to play a significant role in a continuously differentiating "World Society". For instance, the social phenomenon swarms exemplifies the difficulties and open questions about how to respond to new trends and behaviour. Swarms are family-like, mostly academic groups without kinsman like basis. They arrange a common family life and live in frequently temporal domestic partnerships and therefore are highly flexible in their careers (Surowiecki 2004; Couzin/Krause 2003). However, the product and service mix equivalent for swarms may be quite different to the one of traditional households. This kind of questions must be understood when developing products that shall be sustainable and accepted by new groups of consumers.

3. The LIVING LAB approach

Traditional methods for generating insights about consumers rarely make it possible to experience the full benefits of new or hypothetical products, and often fail to predict accurately whether consumers will understand the technologies that underpin truly innovative products. As a result, **new products and innovations often fail in the market**, and companies have increasingly poor returns on their investments in product innovation.
Thus, user centred research can have commercial value for companies by helping alleviate the risk involved when launching a new product, technology or service. At the same time, in designing such products more and more attention is given to improving environmental sustainability, while maintaining quality of life. A user-centred approach is needed here too, because all too often products, that were designed for environmental efficiency under given circumstances, are misused or overused, resulting in unintended and generally less sustainable outcomes ('the rebound effect'). There is a need for sustainability-oriented user insight to assess and improve the true impact of sustainable innovations around the home.

A Living Lab is a combined lab-/household system, analysing existing product-service-systems as well as technical and socioeconomic influences focused on the social needs of people, aiming at the development of integrated technical and social innovations – new product mixes, services and societal infrastructures – and simultaneously promoting the conditions of sustainable development (highest resource efficiency, highest user orientation, etc.) and respect the limited numbers of nature services we can use without destroying the ecological system. Therefore, this research approach is highly relevant for developing sustainable products and services as it allows the development and testing of sustainable domestic technologies, while putting the user (i.e., home occupant) on centre stage. Living Lab is an integrated technological-socioeconomic approach to enable optimized interaction of production and consumption; technological and social innovations can only be developed interactively by mirroring, explaining, and integrating emerging trends and consumer behaviour.

The two elements (real homes *and* living laboratories) are what make the Living Lab research infrastructure unique. The research conducted in Living Lab will be innovative in several respects. First, it will contribute to market innovation by producing breakthroughs in sustainable domestic technologies that will be easy to install, user friendly and that meet environmental performance standards *in real life*. Second, research from Living Lab will contribute to innovation in practice by pioneering new forms of in-context, user-centred research, including long-term and cross-cultural research.

Living Lab is a research infrastructure that focuses on research of user-integrated PSS-development. Its overall goals are

- to map resource consumption and user experiences of sustainable innovations in the home.
- to understand the discrepancy between people's awareness and actions concerning the use of sustainable innovations in the home.
- to model factors in the use phase of sustainable innovations in the home influencing adoption and resource consumption effects.

A second research goal for Living Lab is the development of new longitudinal methods of user-centred design, building on co-creation and open innovation approaches. As most research in this field is of an explorative, qualitative nature, one of the challenges Living Lab

will be facing is to come up with more robust approaches, addressing issues such as validity and generalization over larger user groups.

In order to integrate knowledge of the use of sustainable innovations in the product and service design, the Living Lab approach tries

- to develop methods for contextual, social, user centred design, early prototyping and testing.
- to explore open innovation processes for the development of sustainable solutions.
- to offer different standardised research protocols and data collection methods, hence to provide comparable results between the different Living Lab facilities as well as reliable and valid information according to scientific criteria.

Thirdly, the dissemination of knowledge across the Living Lab network and beyond is an important public function of Living Lab. To disseminate knowledge on user and design practices facing the sustainable challenges within the EU community the Living Lab approach tries

- to establish and maintain an expert centre on sustainable solutions.
- to manage databases (user studies, data analysis and collection etc.) which support knowledge development, transfer and application of sustainable solutions on the national and European level.

The Living Lab research approach will not focus on one area exclusively, such as home automation or energy conservation. Instead, it takes a broader, more **holistic** perspective. Furthermore, it takes a **systemic approach** focused on **user practice**. It therefore can be a strategic research instrument for science, companies and society. It should help to generate competitive advantages matching sustainable requirements and contributions. It should give the possibility of arranging a competition of product-service systems for the highest resource efficiency solution (including benchmarking processes). For public awareness it is necessary to show the results and to position the product-service systems in a global economic system. Users should be actively integrated in research for the best sustainability solution.

4. The LIVING LAB research agenda

The research lines have been elaborated on the basis of a foresight process that started from a selection of global megatrends. An expert panel of the LIVING LAB project

consortium analysed these megatrends and ranked them according to their relevance in terms of sustainability and in terms of LIVING LAB.

Not all of the megatrends introduced are equally relevant for the research agenda of LIVING LAB. In order to define a selection of megatrends important for LIVING LAB, an expert panel was asked to assess the above-mentioned list. Megatrends were to be rated according to their relevance for sustainability and for LIVING LAB. As trends “relevant for Living Lab” were defined those related to areas and developments that affect innovation intensity, competitiveness and user orientation. The experts were supposed to place the megatrends on a ranking system from ‘0’ (not relevant at all) to ‘5’ (extremely relevant).

The expert’s assessment led to a choice of twelve megatrends that were rated relevant for both a sustainable development and for research in a LIVING LAB. Selection criterion was a rating above ‘3’ both in the megatrend’s relevance for sustainability and for Living Lab research on a scale from ´0´ (not relevant) to ´5´ (extremely relevant). Table 1 indicates the selected megatrends in order of ranked importance.

Table 1: Megatrends selected as relevant for LIVING LAB

Megatrend in order of importance	**Relevant aspects regarding LIVING LAB**
Resource scarcity and efficiency	This represents the most relevant trend for the idea of the LIVING LAB project. Again this factor underlies the basic concept of the LIVING LAB project.
Climate change and environmental threats	
Urbanisation	Fundamentally changes lifestyles and consumer behaviour. Increases the need to find solutions for space saving and sustainable living.
New consumption patterns	Creates new consumer groups with new demands. Important to research because of its close link to the question of how to create a sustainable market.
Ubiquitous intelligence	Immediate impact on product development. High market potential for future competitiveness.
Individualisation	Directly leads to an increase in resource consumption. Results in the diversification of lifestyles that increases the demand for tailor made products.
Digital Lifestyles	Potential for new forms of product systems with high resource efficiency. Facilitator for innovation, user central production and knowledge diffusion.
Knowledge based economy	Consequence of globalization and the relocation of manufacturing activities. Innovativeness which is the single most important factor for successful product development, becomes ever more important for European competitiveness. Generates opportunity for development of services that can substitute goods to save resources.

Cultural diversity	Creates the need for sensitivity towards multicultural consumers and constant changes of the composition of European populations. Increases the importance to consider differences in norms as a prerequisite for sustainable consumer behaviour.
Demographic change	Notably high impact on household size and composition. Fundamentally changes consumer patterns.
New mobility patterns	Induces one of the highest impacts on the environment by households. While mobility is external to LIVING Lab's central research site, the household domain creates the need for mobility, which means that diversification of household functions can potentially make mobility more sustainable.
Health thrives	Directly shapes product design and development. Goes hand in hand with resource conscious consumption and production.

(Source: LIVING LAB Grant Agreement no. 212498 Annex I – "Description of Work" [2007])

Relevant research questions and topics were elaborated in a matrix on the basis of a cross-impact analysis of the most relevant megatrends and the basic functions of homes. On the basis of a thematic analysis and clustering of these research questions, research lines were formulated in order to structure the potentially broad scope of LIVING LAB research into manageable foci.

The research lines aim at being innovative and explorative but also traceable in their development. Furthermore they were conceived to be related as closely as possible to current societal developments that influence questions of sustainability, innovation, competiveness and the project's focus area: the home.

The research agenda of LIVING LAB is based on five generic research lines. Each research line is accompanied by several specific research activities that have been proposed by LIVING LAB consortium partners. These are intended to illustrate the anticipated use of the research infrastructure.

4.1 Research line: Design, construction and maintenance of sustainable homes

The LIVING LAB facilities will serve as highly visible examples of sustainable homes. They will be designed to perform at the frontier of sustainable building systems: radically reducing emissions, materials consumption, energy and water use. The LIVING LAB facilities will be conceived and designed collaboratively with actors in the value chain and users as a 'process' rather than a 'product', allowing for the widest possible range of experimentation on the local scale.

Research involving construction industry, craftspeople and other building experts is dedicated to construction related topics before, during and after the occupation of a LIVING LAB facility. Research topics may for instance include:

- The development and application of easy to install systems, technologies and materials with a high user acceptance, high sustainability performance and market success. This refers to technologies for both new construction as well as refurbishment.
- The development and application of user-friendly systems, technologies and materials that can easily be dismantled, separated and reused or recycled.
- Monitoring and management of communication processes and feedback loops between actors and decision makers in the planning and construction process.

4.2 Research line: Integrated approaches to home energy management

LIVING LAB can provide a unique opportunity to study the integration of demand based energy offerings and related services in combination with smart appliances and low-energy heating and lighting solutions. Complex home control technologies, computers and internet are becoming an integral part of the home environment. The focus in this research line will be on developing interaction designs and smart systems (smart meters, smart grids) that can encourage and support home dwellers in saving resources.

The influence of information technology on user practices at home is strongly increasing. Complex home control technologies, computers and internet are becoming an integral part of the home environment. Much research is conducted on adaptive and intelligent systems that can on the one hand improve the dweller's well-being, but also have a strong influence of the sustainability aspects being studied in the first research area. Similarly, the digital user environment can be adapted to accommodate and support users at home. A known solution to achieve better energy-efficiency is the influence of energy efficiency awareness through smart metering. This will allow dwellers to actively keep track of their energy consumption, in order to adapt their energy-consuming behaviour if necessary. Insights in psychology, semiotics and sociology can be used to experiment with techniques such as practice theory, context-sensitive prompting, persuasive interfaces and compare their effectiveness and suitability for motivating learning and behaviour change in the home.

Given the upcoming deployment of Smart Metering and Smart Grids, whereby two-way communication between householders and utility companies will be possible, new

opportunities towards designing interactive systems for energy savings have arisen. Furthermore, products linked to Smart Metering may provide utility companies with unique value added services.

The focus will be on developing interaction designs and smart systems that can encourage and support home dwellers in saving energy. Techniques from persuasive technology could be further developed and applied by considering how the product interacts with the user in terms of:

1. The physical design of the product, including perceived physical affordances, ease of use, and pleasure in use.
2. Social interaction issues, including perceived social norms, for example how much energy is being consumed by an equivalent household in a similar sized house.
3. The perceived environment as recognized by the energy savings system, including issues such as amount of daylight, outdoor temperature, or detected user activities.
4. Financial and environmental incentives, for indicating what time of the day is there a grid surplus of green energy.

In addition to energy savings displays, the design of new user-centred products, such as context aware smart controls that can help the user to save water, centrally switch electric devices on or off, or localize heating-cooling energy should be considered.

An important aspect is the saving of resources as by-product of the use of intelligent systems. If the latter not only improve resource utilization but also e.g. personal safety (against theft etc.), health (warning in case of an accident, etc.) and (combined) communication via TV, mobile phone, and internet, a high preference of users for the core performance of the product will benefit resource efficiency.

Central to testing and developing interactive products and displays for energy savings is the notion of user-centred design, whereby users can be directly involved in the development and testing of the product. Given the complexity of user and environmental factors which may influence energy savings behaviour, working prototypes should be placed in a real-world context, involving actual consumers. This should facilitate an iterative design process.

Table 2 shows an example research project in the context of this research line:

Table 2: Example research project

Open Innovation Session (OIS): Improving energy awareness and efficiency in households by means of smart metering and smart grids – A user-centred perspective
Countries: Switzerland, Germany, Netherlands, Spain

Project goals and background

Goal: Improving energy awareness and efficiency in households by means of smart metering and smart grids with focus on the user.

Background: Conduction of Open Innovation Sessions with the same set-up in four different countries. Comparison of all four sessions and identification of cross-cultural differences. Using these findings for the development of customized products and services.

Problem: Smart meters are not implemented in households to improve energy efficiency.

Research questions

Topic 1: User acceptance and adoption of energy-awareness devices

- How can you overcome these obstacles? (fear of unauthorized access, high costs, …)
- How can you make households (singles, couples, parents, children, …) understand energy consumption & and where and how it can be saved?
- How can you promote something new?

Topic 2: User involvement in energy saving & consolidation

- How can you visualise energy consumption?
- How can you keep users involved in energy saving on the long run?
- How and what kind of energy-feedback solutions can you use to motivate the different people (singles, couples, children, visitors, …) in a household or even a whole neighbourhood to save energy?

Topic 3: The Future - Smart grids, smart metering, sensors, internet…and their possibilities for energy saving

- How can you communicate (energy-feedback)?
- How can you use real-time energy-cost-feedback and price predictions to adjust behaviour?
- How and what kind of energy-feedback solutions can you use in public buildings, offices, schools to save energy?

Set-up of the OIS:

- Questionnaire ‘expectations’
- Basics” presentation smart metering
- Several input presentations by guest speakers
- Discussion of three central topics
- Mind mapping
- Creative workshop (generating ideas & solutions in groups)
- Concept development
- Presenting and discussing of the ideas & concept
- Evaluation of the session (questionnaire)

Wrap-up:

1.Evaluation of each session concerning

- content smart metering
- use for LIVING LAB (method Open Innovation Session)
- Comparison of results from all four sessions.

Included LIVING LAB phase(s) Prototyping, co-creation and validation of sustainable innovations (in dedicated modular LIVINGLAB test houses).
Added value of LIVING LAB **Users are considered a source of inspiration** and innovation in order to co-develop and validate innovative solutions for sustainable households. Simultaneous **cross-cultural research**, evaluating use and acceptance of sustainable innovations in different countries.

4.3 Research line: The connected home

Virtual services (such as tele-working, teleshopping and social connectedness) have the potential to radically change habits, develop new market opportunities and foster resource efficiency at the same time. The main research focus here is to what extent and in which way living in a connected home can promote sustainability, beginning at the level of the single dwelling and extending outwards from the local neighbourhood and beyond.

Even if LIVING LAB focuses on the home environment, events that occur outside the home may not be neglected. This is illustrated by the fact, that activities connected to the home heavily interact with activities in other places. These activities refer to many daily-life areas:

- Consumption needs
- Professional
- Education
- Entertainment
- Health services

Certain activities, which need interaction with exterior elements, can be fulfilled without leaving the home. In such a case, the activity could possibly be fulfilled virtually. Some examples of these activities could be:

- Online health services and Telemedicine. Include all type of physical and psychological measurements that do not require a patient to travel to a specialist.
- Virtual relationships and entertainment. Social networking websites are used to communicate with other people, send messages, share photos and videos, make new relationships… in short, to connect people.

- Virtual learning and advice communities. In these online communities people can share personal stories of specific issues (medical, social, professional…), find similar experiences and offer useful and practical advice to others in similar situations.
- Web shopping. Booking, buying and selling products or services over electronic systems such as Internet allows the user to save a considerable amount of time and make much easier all these processes.
- Comfort, easiness and privacy are the reasons why virtual worlds are so successful nowadays.

4.4 Research line: Resource efficient lifestyles and social networks

This research line studies lifestyles and consumption patterns. That is to gain insight in the role of the user regarding efficient resource consumption and waste streams. Included here is gas, water, electricity, but also use and disposal of packaging materials. While much data is available from research on existing residential settings, further studies will facilitate the introduction of complex system interventions while simultaneously monitoring the effects in terms of acceptance and resource use. Such research will be based around studies on specific user practices, such as personal hygiene (e.g., bathing, washing and showering), and consider resource use (e.g., water, gas, electricity, etc.) and waste streams, including grey and black water, and garbage.

Many consumption decisions are taken in a group or network context. LIVING LAB infrastructures are a unique research ground to explore those networks and the manifold interactions between members of a social network and its influence on the acceptance of more resource efficient products.
This research line studies lifestyles and consumption patterns. That is to gain insight in the role of the user regarding efficient resource consumption and waste streams. This includes gas, water, electricity, but also use and disposal of packaging materials. While much research data is available from research on existing residential settings, research will facilitate introducing complex system interventions while simultaneously monitoring the effects in terms of acceptance and resource use.

The use of resources is dependent on age, education and socio-economic situation of the user. LIVING LAB is the place to research not only those parameters and their mutual effects but also the resulting lifestyles of people. Studies (e.g. Kotakorpi *et al.* 2008) have

shown that even within groups that are rather similar regarding the characteristics mentioned above, individual consumption patterns lead to vast differences in the amount of energy and resources used in a household. Those varying consumption patterns may be connected to different recognizable consumption decisions or overall lifestyles.

The impact of training sessions for end consumers (incl. dwellers) to reduce their consumption (energy, water) as well as consumption awareness tools (e.g. smart metering) is a central point to study within this research line, but also within the research line "Intelligent Systems". Are users changing their behaviour because of teaching or awareness instruments? Are energy savings achieved? What kind of instruments or methods are adequate (visualisation with colours, graphs or figures)? Is it necessary to fresh up training sessions regularly?

Consumption of products and services is not an exclusively individual affair. Family, friends and the respective peer group form the individual's image of products and services as well as the overall picture of "a good life". Furthermore, many consumption decisions are taken in a group or network context e.g. the planning of a family holiday. LIVING LAB infrastructures are a unique research ground to explore those networks and the manifold interactions between members of a social network and its influence on the acceptance of more resource efficient products.
This is the social influence of improving energy efficiency awareness. The effects of community participation, for instance by playing energy games in neighbourhoods, to further awareness has been studied by Wenger (2007). This may involve lead users who take up the challenge of setting up active communities within neighbourhoods as joint effort to rethink consumption routines and boost innovations that reduce resource consumption. Up till now, those communities are mostly characterized by extreme users who are devoted to resource consumption.

Table 3: Example research project

Multi-market insight generation for less resource intensive bathing practices, different European countries

Project goals and background

The goals of the project can be divided into two categories, a theoretical goal and a practical goal. The theoretical goal is testing the applicability and effectiveness of a novel approach to Design for Sustainability (DfS). The practical goal is generating insights and early product ideas for the reduction of household resource consumption through design.

Practice theory applied to Design for Sustainability

Household appliances have become more energy efficient through eco-design strategies; however the desired effect of reduced household resource consumption has not been reached. On the contrary, household resource consumption in the Netherlands has increased 24% in the past twenty years (MilieuCentraal). Research into this discrepancy points out two important factors that are currently underexposed in DfS methods. They are (1) integration of a use perspective and (2) a viewpoint beyond single products. Based on these recommendations the proposed DfS method integrates principles from practice theory into a co-design method. Cross cultural analysis was included to gain practice level insights.

According to practice theory, focusing on technical solutions and individual behaviour while assuming peoples' 'needs' as fixed entities, not only disregards the dynamics of everyday life in which technologies create needs and conventions constantly change. It also stands in the way of the more radical change needed to reach sustainability goals. On the other hand, an often heard criticism on practice theory is its lingering in the theoretical arena and lack of practical applications.

Using the example of bathing, this project aims to create, test and illustrate a practical application of practice theory with the goal of reaching reduced resource consumption in the field of product design.

The focus of the method is on the early phases of product development, generating insights and early product ideas without working towards fully developed products.

The proposed design method currently focuses on the generative phases of the product development process. It consists of two steps. In the first step a group of users is asked to come up with and experiment with less resource intensive ways of doing in the context of their own home. They are asked to describe their current practice and reflect on their experiments. A workbook (cultural probe) with assignments and reflexive questions loosely guides them in this process. The second step is a group session in which the experiments and experiences of the participants are used to generate product ideas to support the less resource intensive ways of doing.

Cross-cultural approach

Furthermore, this study takes the assumption that looking at cultural diversity can widen the variety of insights which can be used as a source of inspiration for designing sustainable practices. However, there is a lack of clear-cut approaches for collecting

information on sustainable everyday practices from multiple cultures. The research therefore addresses two needs:

- To increase the variety of insights on possible less resource-intensive practice
- To improve the precision of data on resource consumption

Therefore, this study explores what kinds of insights can be gained through comparing bathing practices between groups in different markets and how this information is taken up in co-design efforts.

Research questions

- Is the proposed practice oriented co-design method applicable for the generation of product ideas? If not, how can it be improved?
- How does cross-cultural information influence product idea generation?
- Do the ideas generated have potential to (radically) reduce household resource consumption? If not, why?

Content, Methodology, Outcomes

The project will start with a preparation phase in which the workbook and other materials are prepared and participants are recruited. Then the participants (between 10 and 15) will work on the workbooks, including the design, execution and reflection of bathing experiments for a period of two weeks. Insights from the cross-cultural analysis will be used as input to inspire participants. At the end of the two weeks the participants will come together in a group session led by a professional facilitator.

Participants will be selected through the European 'LIVING LAB user network'. The workbooks will be prepared using the principles of cultural probes, including insights from other creative techniques developed in co-design (see example in figure). The content and assignments in the probes will be inspired by practice theory (for example asking a parent about their childhood bathing memories). Two weeks before and during the two weeks of experimenting, water consumption of the participants will be measured with equipment from the mobile LIVING LAB 'suitcases'. The group session will use familiar brainstorming techniques, again complemented with principles of practice theory.

Outcomes can be divided into two groups: (1) information about the applicability and correspondence of practice and theory of the method and (2) ideas and insights related to bathing. Both will be qualitative data gathered through interviews, the workbooks, online blogs and material and video from the session.

Included LIVING LAB phase(s)

Insight generation (phase 1)

Added value of LIVING LAB

The LIVING LAB research infrastructure is relevant for this research project for a number of reasons:

- Mobile research equipment 'suitcases' to measure water consumption of the participants in their own homes
- Europe wide LIVING LAB database of users and companies interested to take part in such studies

- Expertise present in scientists and practitioners connected to LIVING LAB on making cultural probes, leading sessions, qualitative data analysis

4.5 Research line: New product and service development

Products with dominant environmental effects in the use phase should be developed in LIVING LAB with a clear focus on the user context to prevent unwanted side effects. Looking at the increasing percentage of electronic devices used at home in all domestic areas, furthered by the growing trend of working at home, the possibilities of creating new sustainable practices around such activities seem endless, especially at this early stage. Within this research line, we are aiming for user-centred research around complete product-service systems, e.g. “sustainable washing” could research the usage and behaviour system of clothes, washing machine, laundry detergent, ironing, but also washing services or shared facilities.

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Several strategies for user centred sustainable innovation have been developed and reported on (Bakker et al., 2008). The strategies can be categorized according to their level of intrusion on user behaviour: from those, which design technologies around current user behaviour to those, which design products to promote certain behaviour in users. However, here we seek to understand how we can look beyond the product or technology level and study current behaviour and develop new ways of doing, including products/technologies, that are more resource efficient while optimizing the user experience.

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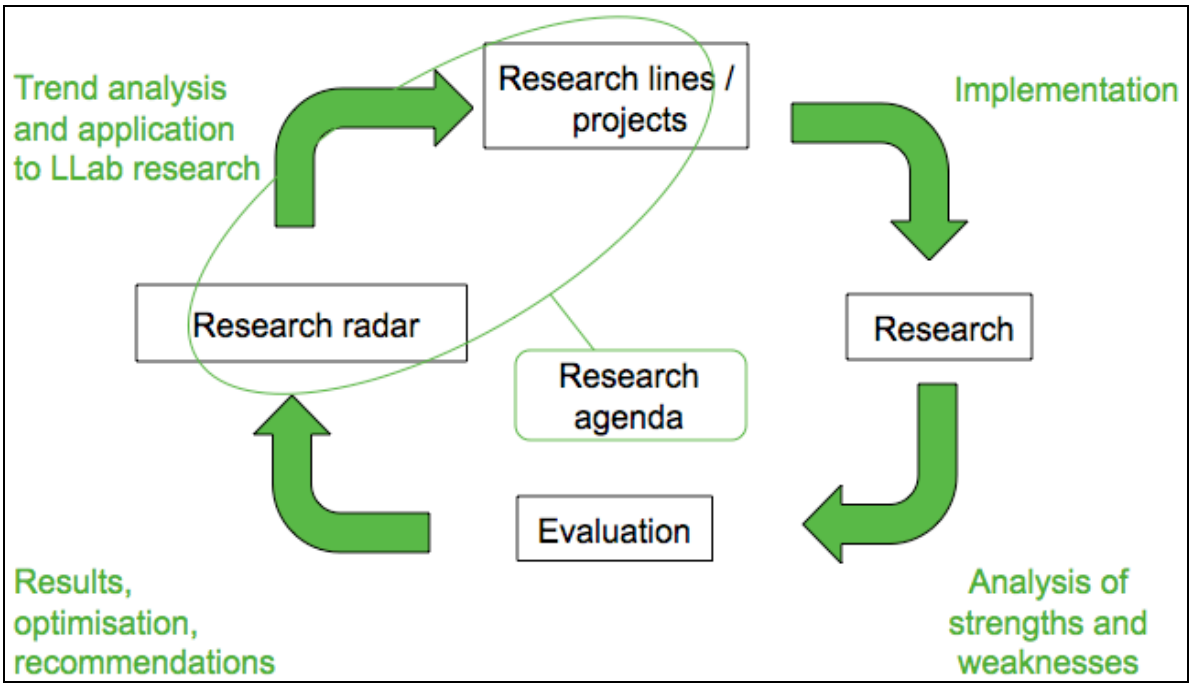
5. Conclusions

The LIVING LAB research agenda is supposed to be a part of a whole management cycle. That is the research agenda is not a terminal document but rather opens up an iterative process. As stated in the introduction, the agenda at hand was produced as research radar. Building upon deliverables already elaborated during the LIVING LAB project and using trend analysis, a potential research field was spanned. Out of this research field as shown in the LIVING LAB research map (see figure 2) several research lines were developed. Clearly, the next step is the implementation of projects - based on the research lines and in a LIVING LAB research infrastructure. Once the first projects are conducted, evaluation will be necessary in order to analyse strengths and weaknesses that appeared. This evaluation again will be point of departure for a new research agenda, adjusting research infrastructure and projects. Processing new societal, technological developments not yet on the horizon, a continuously updated research agenda is a prerequisite for successful, i.e. relevant research at LIVING LAB.

Figure 2: The LIVING LAB research agenda as a continuous technology platform and research radar process



Depending on the extent and shape of LIVING LAB in future, the need for a research agenda on the national level or for a single part of the research infrastructure may arise. In this case, nevertheless, an overall agenda is necessary in order to coordinate LIVING LABs on a European level, safeguarding the advantages of a European network, e.g. mutual learning, economies of scale and flexibility in the light of fast changing requirements in user-centred innovation research.

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