Energy sufficiency in private households enabled by adequate appliances

Lars-Arvid Brischke
ifeu – Institute for Energy and Environmental Research Heidelberg
Reinhardtstr. 50
D-10117 Berlin
Germany
lars.brischke@ifeu.de

Leon Leuser
ifeu – Institute for Energy and Environmental Research Heidelberg
Wilckensstraße 3
D-69120 Heidelberg
Germany
leon.leuser@ifeu.de

Carolin Baedeker
Wuppertal Institute for Climate, Environment and Energy
Döppersberg 19
D-42103 Wuppertal
Germany
carolin.baedeker@wupperinst.org

Franziska Lehmann
ifeu – Institute for Energy and Environmental Research Heidelberg
Reinhardtstr. 50
D-10117 Berlin
Germany
franziska.lehmann@ifeu.de

Stefan Thomas
Wuppertal Institute for Climate, Environment and Energy
Döppersberg 19
D-42103 Wuppertal
Germany
stefan.thomas@wupperinst.org

Keywords

domestic energy efficiency, energy demand side, energy-using products, user perspective, sufficiency

Abstract

Energy efficiency of a range of domestic appliances covered by the labelling and ecodesign directives has improved significantly over the last 15 years. However, the power consumption of the German residential sector has remained relatively constant over this period. Besides other factors, such as decreasing average household size, the main reasons for this development were the increases of the types, features, size, equipment stock and usage times of appliances and devices in private households.

The project "Energy Sufficiency – strategies and instruments for a technical, systemic and cultural transformation towards sustainable restriction of energy demand in the field of construction and everyday life" investigates how the complementation of energy efficiency with energy sufficiency could lead to more user adequate domestic products and product-service systems and thereby result in an absolute reduction of power consumption.

In this project, energy sufficiency is defined as a strategy to reduce energy consumption by three approaches:

1. Quantitative reduction of sizes, features, usage times of devices etc.
2. Substitution of technical equipment in households by e.g. urban services.
3. Adjustment of technical services delivered by appliances to utility needed and desired by users.

The energy saving effects of an application of these approaches were modelled for different types of households and the energy saving potentials of energy sufficiency quantified. Innovative approaches for user adequate products and services were developed in open innovation workshops by the Design Thinking method. The paper summarizes some of the intermediate results of theoretical and transdisciplinary investigations of the project that runs until May 31, 2016. Furthermore, a first set of design criteria for user adequate appliances enabling energy sufficiency are developed based on these results. The paper concludes with suggestions for the future development of energy labelling and ecodesign derived from the design criteria and supplemented by examples of existing requirements according to the voluntary environmental label "Blauer Engel".

Introduction

In the last decade, energy efficiency has become an important pillar in the international and EU climate change mitigation policy (EC 2008, OECD 2014). The respective goals for increases in energy efficiency are linked with the assumption of a limitation or reduction of energy demand without disturbing economic growth (WCED 1987). The EU has established successful instruments such as energy labels and minimum efficiency performance standards for appliances. Energy efficiency of a range of domestic appliances covered by the labelling and ecodesign directives has improved significantly over the last 15 years, e.g. BSH (2013) indicates a reduction of power consumption of fridges and freezers by 75 %, of washing machines by 63 %, of laundry driers by 72 % and of dishwashers by 50 % between 1998 and 2013.

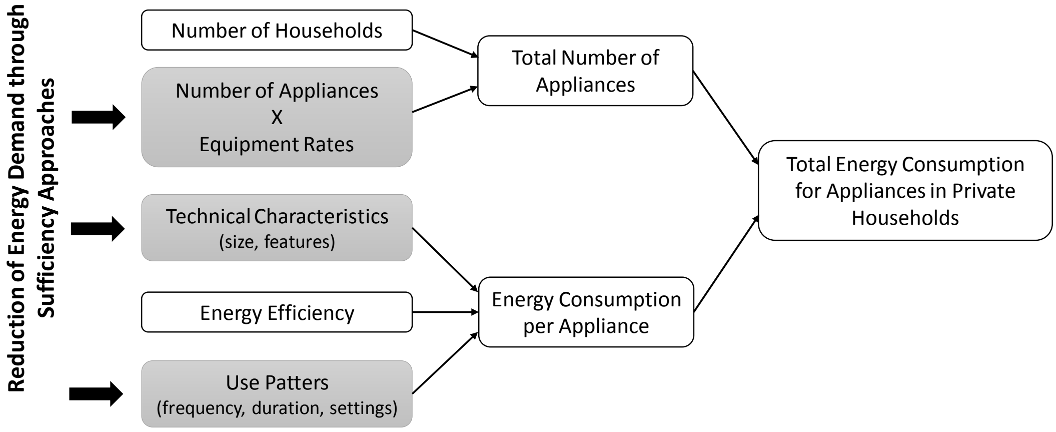


Figure 1. Determinants of appliance energy consumption (source: Siderius, Brischke 2011).

This remarkable development results in a broad supply of highly efficient products in the highest label categories (A++ and A+++) for five product groups (washing machines, fridge-freezer units, dishwashers, dryers, electric ovens and air conditioners). It proves the approach of the EU-efficiency label to be highly successful for the stimulation of energy efficiency improvements in the sector of household appliances. A recent example for the success is the introduction of the efficiency label for vacuum cleaners on the 1st of September 2014. As found by dena (2014), the introduction of ecodesign requirements and the label stimulated a strong dynamic in the market towards efficiency. This becomes evident by the increase in the market share of highly efficient vacuum cleaners with 1,200 Watt or less. The share quintupled from 5 % in August 2014 to 25 % in October 2014.

As shown, labelling and ecodesign brought about significant advances in the energy efficiency. However, as already found in previous eceee-papers, these efficiency improvements did not lead to significant absolute reductions of power demand in the residential sector (Darby 2007, Calwell 2010). A study, conducted by dena (2012), on the effects of the ecodesign directive of nine product groups[1] on energy demand in Germany estimates a relative conservation of 60 TWh/a in 2020 due to the EU regulation compared to baseline projections. However, the same study estimates a slight increase of 0.4 TWh/a in the total energy demand of these product groups in 2020 compared to 2008. This finding is consistent with the development of the total power consumption in the German residential sector: It has remained relatively constant over the last decade (see Brischke et al. 2015).

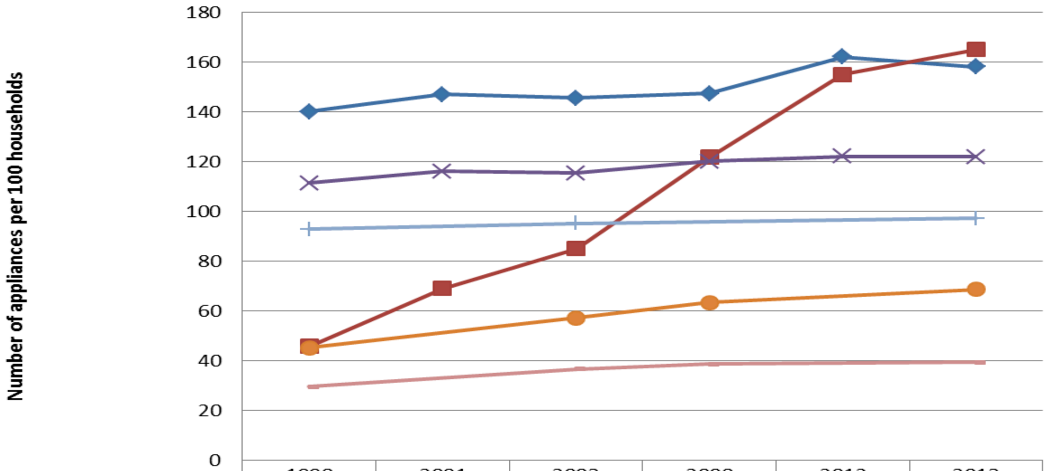
This shows that energy efficiency is only one of the main determinants of energy consumption of appliances (see also Figure 1), together with:

- The ***number*** of appliances: the number of appliances per household (number of different appliances times equipment rates) times the number of households;
- The ***use patterns*** of appliances: frequency of use (e.g. using the dishwasher 6 times a week), settings (e.g. 60 °C cotton cycle for washing) and duration (e.g. the television is on (on average) 4.5 hours per day);
- The ***technical characteristics*** of appliances: the capacity of the appliance, the efficiency of the power supply or the motor, etc.

Regarding the changes in the number and types of products, equipment stock, features of appliances and the use habits in private households over the last decades, we assume the following points as reasons for the almost unchanged power demand level are:

- Inadequate product design due to demographic development and consumer needs: increasing sizes of appliances, but decreasing number of persons per household.
- Trend of continuously growing technologization of leisure time, information and communication (e.g. Brischke 2010, p. 192).
- Increasing number of appliances per household as a result of a rising number of types of technology and functionality options and features (Prognos et al. 2014, p. 193).
- Equipment stock higher than 100 % (see Figure 2).
- Increasing usage times (trend to a 24/7-society: to be always accessible and available).
- Redundant technical features, functions and equipment of various product groups (e.g. computer, smart phones, smart TV, home cinema system): functional divergence instead of convergence.
- Product cycles shorter than product lifetimes leading to the addition of more efficient equipment instead of substitution of less efficient equipment.
- Energy efficiency classification partly based on measurement standards that are inadequate to usual practices of daily life and average consumer routines by the use of appliances, e.g. washing machines and dishwashers. One problem is that these inadequate standards may lead to over-estimating the energy consumption and thus create too high expectations in terms of energy savings.
- Misleading product design and marketing strategies of manufacturers and retailers optimized to meet purchase patterns

1. Standby and off-mode losses, simple set-top boxes, non-directional household lamps, tertiary sector lighting products, external power supplies, electric motors, circulators, televisions, domestic refrigerators and freezers.



	1998	2001	2003	2008	2012	2013
TV	140	147	145,5	147,4	162	158
PC	45,7	69	84,9	121,7	155	164,9
Refrigerator	111,4	116	115,3	120,1	122	121,9
Dishwasher	45,1		57,2	63,3		68,6
Washing machine	92,8		95,2			97,2
Dryer	29,5		36,7	38,7		39,4

Figure 2. Equipment stock for appliances in German households (source: Stat. Bundesamt 2013, bdew 2013).

of consumers, which are not suitable to satisfy adequately consumer wishes and needs by the usage of appliances, e.g. the increasing motor performance of vacuum cleaners does not correlate with an improved cleaning effect.

- More and more complex appliances require typically more instead of less attention and effort for energy saving usage by consumers. Examples include: a growing number of product features are in operating mode and often cannot be deactivated, even though they are not needed; the fridge or freezer part of fridge-freezers often cannot be deactivated separately; a range of consumer electronics devices have no hard-off switch.

These factors show that energy efficiency is only one parameter to achieve an absolute reduction of the domestic energy consumption, but efficiency alone does not necessarily lead to this reduction. For an effective policy approach, efficiency has to be complemented by a sufficiency strategy, which was also emphasized in former eceee and aceee papers (Wilhite, Norgard 2003; Harris 2006, Darby 2007, Calwell 2010, Müller 2009).

In the first study (Wilhite, Norgard 2003) it was found that efficiency was not sufficient enough for a significant reduction of energy demand. The focus on energy efficiency was claimed to be a "self-deception" in policy making, as thereby, the attention is shifted away from the important variable of energy service growth. Darby (2007) further specified this approach with the elaboration of three energy sufficiency definitions and outlined some policy options to address energy service growth (also see Section 2). While Müller (2009) started out with the question of whether energy consumption is becoming a moral issue, a rationale for energy sufficiency is developed in his contribution to eceee. The rationale for policy in this realm was first picked up by Darby, emphasizing the "normative nature of sufficiency": "To adopt sufficiency as a force in policy is to recognize boundaries to a social order and to make normative judgments" (Darby, 2007). However, Müller argues that sufficiency could be introduced in policy in liberal societies as a measure of "social justice", referring to the principle "not to harm others". In a study by the aceee (Harris et al. 2006), the idea of sufficiency is introduced at the appliance level – here termed "consumption-based energy efficiency" – and the implementation of variable efficiency in energy policy and labelling is discussed. Calwell (2010) examines this issue further, proposing progressive efficiency specifications and absolute sufficiency limits. In this paper, we take these subjects up and develop them further.

Based on the intermediate results of our research project "Energy Sufficiency – Strategies and Instruments for a technological, systemic and cultural Transformation towards a Limitation of Energy Demand in the Consumption Sector Construction and Living", we present suggestions on how energy sufficiency could be enabled by user-adequate appliances and how the introduction of such appliances could be supported by a further development of the EU labelling and ecodesign directives. Therefore, in the following sections our definition of energy sufficiency is presented first, followed by an estimation of the maximum effects of an application of sufficiency approaches on domestic power consumption. In the third section selected results of our empirical explorations for an application of energy sufficiency on appliances are presented. The next section gives an overview of a first set of design criteria for user adequate appliances enabling energy sufficiency. In the last section suggestions for the further development of the EU labelling policy are given.

Energy Sufficiency – Definition

To date, the most specific definitions of energy sufficiency were developed by Darby (2007). Three definitions of the concept of energy sufficiency are proposed with ecological sufficiency beyond all three:

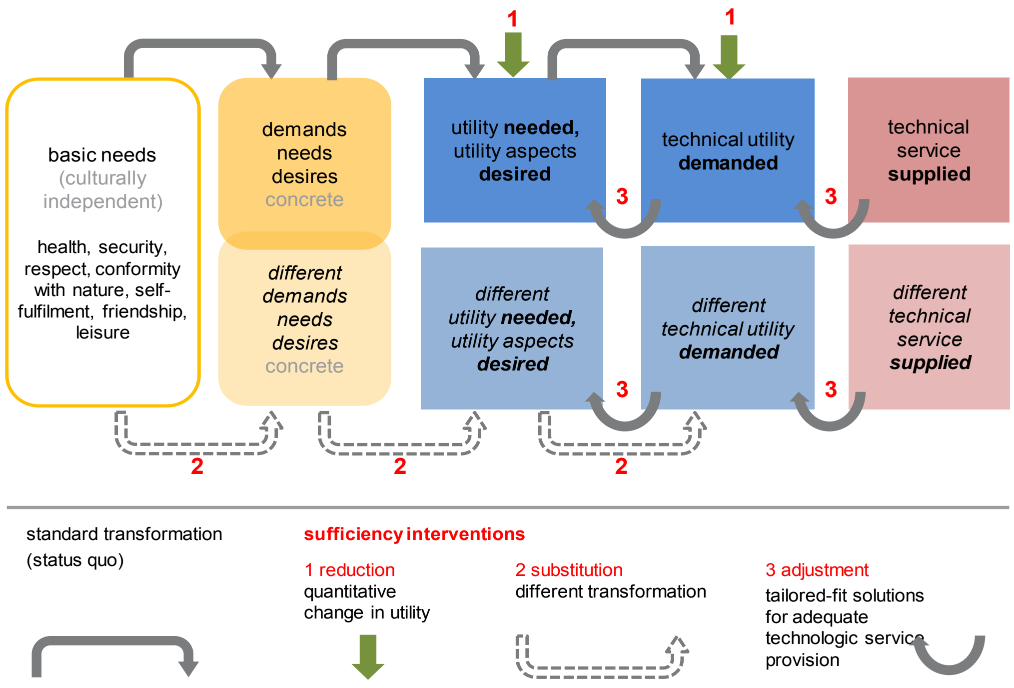


Figure 3. Causal chain of transformation from basic needs to technical service supplied, energy sufficiency approaches and points of interventions (Brischke, Thomas 2014).

1. Carbon sufficiency, as a quantitative approach, is focused on greenhouse gas emissions. Within such a framework, an equitable amount of permissible emissions would be allocated per capita.
2. Energy consumption sufficiency is a more localized approach with the focus on energy security.
3. Energy service sufficiency focuses on the service provided by technical equipment requiring energy input.

This growth in energy services (e.g. duration and space lighted (see Fouquet and Pearson 2006)) driven by consumptive lifestyles and the emphasis on economic growth is one explaining (see Leuser 2014) but in politics widely neglected factor for the considerable advances in efficiency not resulting in a reduction of energy consumption (Brischke et al. 2015).

The concept of energy service sufficiency was further developed within the research project "Energy Sufficiency" and Brischke et al. (2015) elaborated a definition of energy sufficiency. In our definition, energy sufficiency is a strategy that aims to limit and reduce the input of technically supplied energy by a quantitative or qualitative change of utility demanded and / or technical service delivered. According to this definition the main characteristic of energy sufficiency is a quantitative and/ or qualitative change in the demanded main utility (e.g. clean clothes, clean dishes, keeping foodstuffs fresh) and further utility aspects[2], and thereby, the delivered technical services (e.g. washing performance of washing machines and dishwashers, cooling volume and temperature of a fridge) by practising energy sufficiency (see also Fischer et al. 2013). Energy efficiency, by contrast, aims to increase the ratio of service output to energy input while holding the output at least constant.

Sufficiency as a strategy needs to be in line with the requirements of sustainable development. This means that it has to take into account the complete resource input, effects of temporal and spatial shifts and ecological and social impacts. This holistic approach goes far beyond measures that solely aim at energy conservation behaviour, which focus on a demand reduction without taking into consideration the wider perspective of sustainable development. Therefore, energy sufficiency aims at energy-relevant consumption and household production decisions as well as decisions concerning the use of equipment. It also takes into account fundamental changes of energy-relevant aspects of lifestyles and social practices[3].

The technical utility ultimately demanded by consumers and the technical service supplied by the appliance depend on a causal chain of transformation steps that starts with basic needs independently from cultural factors[4] (see Figure 3[5]). In each step, the basic needs are transformed and concretised. Step

2. We understand utility aspects as such aspects that are minor compared to the main utility. They comprise aspects such as comfort, self-expression, status symbol, social affiliation or differentiation, physical activity, health, aesthetics. For example, while a side-by-side refrigerator still has the main utility that food is cooled, it has further utility aspects such as status symbol, an ice dispenser and maybe even internet access.

3. The research field on lifestyles, practices and energy is large but limited length does not allow us to expand on it here. Sources for more information are many papers in the Panel on Dynamics of Consumption in this and previous eceee Summer Studies.

4. As basic needs independently from cultural factors we define similar to the basic goods of Skidelsky and Skidelsky (2012): health, security, respect, personality, harmony with nature, friendship, and leisure.

5. Within our project, technical service is defined as the properties and functions of the technical equipment of a household, which may be potentially useful for household members and made available by energy, regardless of whether this utility is actually demanded or needed by consumers. It is therefore different from the technical utility that is demanded, because the service provided by the equipment could for example be overprovided.

one to three are from the perspective of the consumer, which is highlighted with the terms "needs" and "utility". In contrast, in the fourth step the demanded technical utility is satisfied more or less adequately by the technical service supplied by appliance. The service and related service aspects depend on the characteristics and features of the appliance.

- Step 1: Basic needs (e.g. health) are transformed into concrete, culturally influenced demands, needs, and desires (e.g. fresh food). Both demands and needs often related to the reliefs that are needed for the care economy.
- Step 2: Demands, needs, and desires are transformed and concretised into utility needed (e.g. chilled food) and utility aspects desired (e.g. certain amount of chilled food at home).
- Step 3: The aspects are then transformed into the demanded technical utility (e.g. a refrigerator).
- Step 4: The demanded technical utility is (more or less adequately) met by the service supplied by the respective appliance (e.g. fridge volume, cooling temperature).

The demanded technical utility (step 3) depends on the user, whereas the delivered technical service (step 4) depends on the appliance.

Within the energy sufficiency strategy, we distinguish between the three approaches: **reduction, substitution** and **adjustment**:

- **Reduction** of utility needed, utility aspects desired and thereby the technical utility demanded is a consumer decision. Reduction can be achieved by changes in purchase decisions (e.g. smaller appliance) or in decisions concerning the use of appliances (e.g. watching less TV). The technical service supplied by the appliance is still available in principle and in the same form, but the consumption is reduced. In order to motivate and enable consumers for reduction information on adequate sizes and service levels to avoid oversizing of technical household equipment as well as smaller, flexible and detachable appliances have to be available. These preconditions should be supported by labelling and ecodesign.
- **Substitution** applies to decisions related to consumption (e.g. purchasing a bicycle instead of a car), technology use (e.g. using clothes line instead of tumble dryer), aspects of the provision (e.g. buying more fresh food instead of frozen food), and lifestyle (e.g. veganism). Substitution is characterized by a qualitative change in demands, utility aspects or technical aspects without or with minor quantitative changes. Nevertheless, these qualitative changes still lead to a reduction in energy consumption.
- **Adjustment** relates, firstly, to consumption through adjusting the type of appliances, the size and the functions to the demanded utility and utility aspects. Potential options for realization are for example sensors or the option to switch off features. Secondly, relating to the use of technology, adjustment means both a qualitative adjustment (e.g. features that are always switched on but seldom used) and quantitative adjustment (e.g. the cooling volume) to the demanded utility, either by a conscious user or by the appliance.

The application of these three approaches is based on the individuals' conscious decisions in their daily practices, consumption, type of leisure and lifestyle. Important factors, however, are political and technological framework conditions that limit the effects of drivers for higher energy demand, and enable and empower citizens to apply energy sufficiency approaches. Additionally, services and infrastructures provided by companies and municipalities can influence energy related decisions of households as they facilitate and enable citizens to choose other options.

However, it needs to be taken into account that resources freed-up when practicing energy sufficient options – e.g. time and financial resources – could lead to sufficiency rebound effects (Alcott 2008). To close this gap, energy sufficiency requires modifications in the (legislative) framework conditions that influence energy relevant decisions of households (Leuser 2014, Thomas et al. 2015). Additionally, changes in the esteem of these alternatives and respective cultural changes need to be stimulated. We are aware of these additional requirements and structural changes, but concentrate in this paper on the potentials and energy sufficiency on the level of appliances.

In Figure 3, the points of sufficiency interventions with these three approaches in the causal chain are illustrated. For example, in the case of reduction this could mean that at 1) the desired indoor temperature is reduced (different utility needed) due to the insight that a lower temperature is still sufficient. This would result in a decrease in the demand of space heating (and different technical utility demanded). In the case of substitution, the desired utility (thermal comfort) is unchanged quantitatively while the qualitative aspects are changed and the thermal comfort is achieved by using other clothes indoors (chain 2). In both cases, an adjustment 3) of the technical service supplied (space heating delivered) is necessary. Thereby the supplied technical service (space heating) can be reduced. To illustrate the application of these strategies further, in the following, we present the convergence of appliances and exnovation[6] as exemplary approaches.

Convergence of Appliances as an Approach for Reduction and Adjustment

Reduction may further be comprehended as a reduction of redundant features and functionalities. An example is the provision of adequate input and output devices for smartphones such as displays, keyboards, and CD/DVD/Blu-ray-drives. Thereby, tablets, laptops and other devices would become obsolete – devices that are often used in parallel. This would result in a high-quality but at the same time resource-conserving satisfaction of information-, communication- and entertainment needs of households.

Ex-novation as an Approach for Reduction

The increasingly shorter innovation cycles and respective marketing strategies lead to the "need" (more adequately, the desire or wish) to own the newest device or appliance. The result of this development is an increased number of still functioning devices owned by households. These are not discarded but used

6. Exnovation means the process of eliminating existing (unsustainable) practices and products by innovative solutions. Thereby, it is ensured that the innovation is substitutive and not additional (Sveiby et al. 2012, p. 157).

Table 1. Assumed parameters for modelling of efficiency and sufficiency in a two-person household without electrical water heating and circulation pumps (Source: Lehmann 2013).

	average	efficiency	sufficiency in equipment	sufficiency in use patterns	combination
cooling + freezing	2 separate devices 190(+5)l/30l efficiency class B 5°C (-12°C)/-22°C	2 separate devices 190(+5)l/30l A+++ 5°C (-12°C)/-22°C	1 combination unit 100l/15l A+++ 5°C/-22°C	2 separate devices 190(+5)l/30l A+++ 7°C (-10°C)/-20°C 1 month off	1 device 100l A+++ 7°C 1 month off
washing machine	7 kg efficiency class A 2,25 uses/week 60°C	7 kg A+++ 2,25 uses/week 60°C	6 kg A+++ 2,25 uses/week 60°C	7 kg A+++ 1 use/week 40°C	6 kg A+++ 1 use/week 40°C
tumble dryer	efficiency class A 1,3 uses/week	A++ 1,3 uses/week	-	A++ 1 use/week 3 months off	-
dish washer	efficiency class B 12 place setting 2 uses/week	A+++ 12 place setting 2 uses/week	A+++ 8 place setting 2 uses/week	A+++ 12 place setting 1 use/week	A+++ 8 place setting 1 use/week
cooker + oven	2,5 h/week	2,5 h/week	2,5 h/week	1 h/week	1 h/week
lighting	incandescent bulbs, energy saving bulbs 1,7 h/day 80 lx	LED 1,7 h/day 80 lx	LED 1,5 h/day 75 lx	LED 1,5 h/day 75 lx	LED 1,25 h/day 70 lx
television	flatscreen 80 cm + hard disk efficiency class B 2 h/day	flatscreen 80 cm + hard disk A+ 2 h/day	flatscreen 60 cm + hard disk A+ 2 h/day	flatscreen 80 cm + hard disk A+ 1,5 h/day	flatscreen 60 cm + hard disk A+ 1,5 h/day
	tube TV set-top-box 0,5 h/day	flatscreen 51 cm A+++ 0,5 h/day	-	flatscreen 51 cm A+++ 0,5 h/day	-
	standby mode	standby mode	standby mode	disconnected	disconnected
audio	stereo system 1,5 h/day standby mode	stereo system 1,5 h/day standby mode	-	stereo system 1 h/day disconnected	-
ICT	1 PC, 1 laptop 1 monitor each 3 h/day 1 smartphone standby mode	1 PC, 1 laptop 1 monitor each 3 h/day 1 smartphone standby mode	1 laptop 4 h/day 2 smartphones incl. dockingstation standby mode	1 PC, 1 laptop 1 monitor each 2 h/day 1 smartphone disconnected	1 laptop 2 h/day 2 smartphone incl. dockingstation disconnected
other	…	…	…	…	…

additionally or in parallel to new devices. Adequate design of appliances and services would therefore allow the replacement of outdated appliances or functions by new ones without leading to the necessity to own more appliances. This could be realized for example by a modular product design or the compulsory collection of old devices by retailers or manufacturers when purchasing a new product.

Modelling of Energy Savings Potentials

Caused by the necessity of quantifying possible energy saving potentials and also investigating and comparing their impact, a tool was created for modelling a household's equipment and use patterns and calculating the annual electricity consumption of each device. An exemplary, two-person household was modelled. By varying parameters of household equipment and use patterns, different approaches of efficiency and sufficiency were mapped and the resulting energy saving potentials were calculated (Lehmann 2013). A caveat needs to be stated: these potentials do not take into account the many restrictions households may face when they try to live more energy-sufficient (cf. Thomas et al. 2015). Therefore, the potentials presented below should be understood as maximum theoretical potentials assuming, that all of the main electrical applications must remain available.

The initial household was based on average power consumption data for the different types of power applications in households from STROM.check of Energieagentur NRW (see Lehmann 2013). In the next step, we assumed that the model household is completely equipped by the most energy efficient appliances, but equal in terms of sizes, functions and use patterns. The results are therefore maximum theoretical efficiency potentials. We assumed that the three energy sufficiency approaches (reduction, substitution and adjustment) were implemented consequently in the particular types of power applications by transforming the parameters of equipment (volume, size, device properties, equipment stock) and use patterns (term, frequency and type of usage). Examples are: reduction by decreasing the size of TV; substitution by shared community cooking that reduces the frequency and thereby the term of usage of stove and oven; and adjustment by switching off features not used or required. **Table 1** gives an overview of the parameter assumptions, more detailed in Lehmann (2013).

In the application field of washing, drying and dish washing, we found an additional energy saving potential of up to 80 % generated by sufficiency in comparison with pure efficiency (Table 2), based on the assumptions in Table 1. Therefore, the energy saving potential of sufficiency is two times higher than the potential of efficiency. Similar results were

Table 2. Percentage energy savings of different strategies in particular product groups. (Source: Lehmann 2013, own assumptions.)

	average	Efficiency savings in relation to average		sufficiency savings in addition to efficiency	
	kWh/a	kWh/a	%	kWh/a	%
cooling + freezing	513	363	71	102	68
clothes + dish washing	412	138	34	219	80
cooking + baking	340	47	14	209	71
lighting	270	226	84	16	36
ICT + consumer electronics	745	175	23	445	78
others	235	38	16	149	76
total	3,574	986	28	1,906	74

identified in the application fields of cooking and baking as well as ICT and consumer electronics. In the application field of cooling and freezing, it is possible to generate the same energy saving potential of 70 % by both sufficiency and efficiency.

As a result, Figure 4 shows the possibility of realizing further significant energy saving potential by sufficiency in excess of the efficiency potentials. Based on the annual electricity consumption of an average two-person household in Germany (3,600 kWh/a), the model quantified a total reduction potential of up to 75 %, reducing electricity consumption to 680 kWh/a in case of maximum efficiency and consequent sufficiency in terms of equipment and use patterns of appliances.

This conclusion, however, is not generalizable to all households. This is because sufficiency approaches are characterized by a high degree of sociocultural boundary conditions, such as care economy duties, comfort requirements, financial capabilities, or attendance times. This restricts the actual implementation of the modelled sufficiency options, thus leading to a reduction of the quantified potential.

Transdisciplinary Elements of the Project and Selected Results from two Open Innovation Workshops

Within the research project, we carried out different empirical investigations in combination with creative approaches in order to recognize and to describe energy sufficiency solutions for a wide range of appliances, households and urban infrastructure and services. An important aim is to find out where and which energy sufficiency approaches are already being applied or acceptable and to develop new options jointly with consumers and experts in a transdisciplinary research process. We carried out five interviews with stakeholders on local and communal level. Three one-day workshops held with three groups, which were identified as so-called Neighbourhood Labs (see Unteidig et al. 2013). Within the workshops, the transdisciplinary method termed Cultural Probe was applied for the field of energy sufficiency. Based on these results, twelve qualitative interviews complemented by Cultural Probes with household members were carried out. Furthermore, two one-day Open Innovation Workshops[7] were organized in order to get an idea about how energy sufficiency could be implemented on appliance level. In these workshops, the first four steps of the Design Thinking Method (Definition – Research – Ideation – Prototyping) were used for the two focus cases of the research project: information- and communication devices and white goods. Two examples of this work are presented below: the combination of laptop and smartphone and the cleaning of clothes.

The last step of empirical investigations within the research project will be a representative survey by personal interviews based on hypotheses derived from the empirical investigations.

EXAMPLE 1: CONVERGENT INFORMATION AND COMMUNICATION DEVICE (COMBINATION OF LAPTOP AND SMARTPHONE)

The smartphone currently provides all technological features for typical information and communication activities in the form of a mobile device. It is today permanently accompanying many people and for most of them indispensable. Because of varying tariffs, some have multiple phones for different countries and/or different purposes (private, work). Compared to the smartphone, laptops entail several advantages such as a more comfortable in- and output, better computational performance for demanding tasks and higher processing speed. Increasingly people desire and facilitate the access to their own data at any place and any time. Still, for many, data protection is an important issue, as the data handled on smartphones and laptops are part of their own privacy.

Based on these initial conditions, participants of the workshops were asked to think about and work out desires and wants not fulfilled by modern technology. Further, they were asked to address problems they perceive concerning the current state of technology development in this sector. These were:

- The long-term availability of the familiar and well-tried design, features and software. With product cycles becoming

7. In these one-day-workshops, 10–15 participants were present. Participants were product designers, representatives of manufacturers, consumer advocates, citizens, journalists, scientists, marketing psychologists and a representative of an energy company.

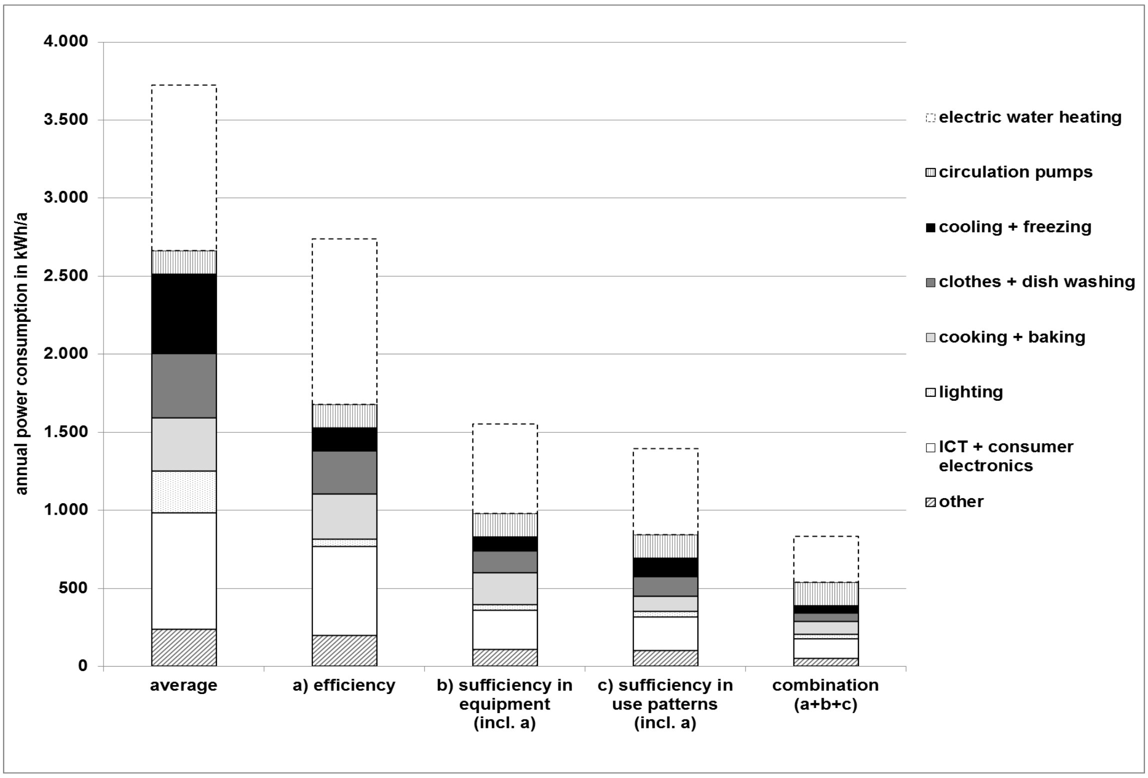


Figure 4. Modelled annual electricity consumption of a two-person household according to particular product groups for different energy saving approaches (source: Lehmann 2013, own assumptions).

ever shorter, new features and software are added. People are curious and want to use these new options. This, however, often requires the adoption to new hard- and software, which is time-consuming and tires users.

- In many cases, useful software does not work correctly on new devices.
- Short product cycles force even mindful people to waste resources.
- Redundancy of features of different devices.
- Increasing complexity due to the large variety of apps, software and features. These are often active in the background while not being used and with the user not being aware of the activity.

To address these issues, workshop participants developed the following ideas:

- Reduce redundancy by designing devices complementarily and with the option to combine various devices.
- Only software, features and apps that are often used shall be prioritized. Features that are not used shall be switched off in the background. However, it shall be guaranteed that the previous state can be restored.
- For interested users, there should be the option to keep control. Therefore, an easily understandable overview of which software features and apps are active is necessary.

With these criteria, the participants developed the idea of a "Fab LabTop". The "Fab LabTop" looks like a laptop consisting of its input and output units only, e.g. keyboard, display, speakers, interfaces and power storage (ideally power is generated by energy harvesting technologies), which are demountable separately. By docking a smartphone, the "Fab Lab Top" becomes a modular built laptop whose computer functions are provided by the smartphone. This device would combine the advantages of the smartphone and the laptop without redundancies and therefore reduce significantly both energy and material consumption. The smartphone operating system deactivates software that is not used, but keeps it available. The product can be manufactured, individually designed and finally recycled with 3D-printers.

EXAMPLE 2: SUFFICIENT PRODUCT SERVICE SYSTEM FOR HYGIENIC CLOTHES (COMBINATION OF HOUSEHOLD CLOTHES REFRESHING CABINET AND LOCAL LAUNDRY SERVICE)

In German households, clothes are washed frequently, without the clothes being dirty. The decision is based on social norms and routines. As a result, clothes are washed after a certain time span of wearing and not because the clothes are deemed impure. However, the resource-intensive cleaning process in a washing machine is designed for (heavily) soiled laundry. Due to labelling, manufacturers are stimulated to reduce water- and energy use of the washing program. However, the frequency of cycles is not addressed with these labels. The idea of sufficiency tries to find approaches for these still unaddressed use patterns.

The participants developed ideas on what an approach of reduction would mean in this case. The changes comprise washing less frequently and wearing the clothes longer in between the washing cycles. High profile role models, such as the CEO of Levi Straus & Co announcing that he had not washed his trouser for a year, help to raise awareness and stimulate changes in social practices and norms (Yates, Evans 2014). It is, however, difficult to find ways to stimulate this kind of cultural change and daily routines of citizens

Staying with the contemporary desire and concept of clean clothes leads to a search for ways of substitution. Two main approaches were identified for this strategy. The first one is the idea of a new household appliance termed "refreshing cabinet", replacing the washing machine at home when combined with a laundry service (see below). This device allows to refresh clothes perceived to be not hygienic enough anymore but that are still not soiled. In the box, the clothing is ventilated and maybe a bacterial and odour treatment is performed. This process reduces the frequency of laundry and related pre- and post-processing efforts (sorting, drying, ironing, folding and stowing the laundry). The cleaning frequency of clothes can remain the same, whereas the amount of laundry to be cleaned by washing machines and thereby the related energy and water demand can be significantly reduced. At the same time, the desire of reducing the time requirements for the laundry process would be satisfied. This idea is a substitution approach, because the cleaning cycles stay the same, while the hygiene of the clothing is accomplished by another procedure with possibly less energy consumption. The net environmental impact, however, would need further research.

For the substitution of the complete laundry with a household washing machine, the idea of a new service – a local laundry shop – was developed. The service is performed by a neighbourhood laundry and could include a pickup and delivery service (e.g. in combination with the postal service that picks up the laundry, when delivering parcels).

A first set of design criteria for appliances enabling energy sufficiency

Based on the results of the above mentioned, empirical investigations, as well as from other research projects and suggestions from the project team, a design guide for domestic products is planned. It will be presented to the participants of the manager and produce designer target groups. The design guide will present and explain criteria for the design of domestic appliances enabling energy sufficiency. In this section, we provide the first collection for potential design criteria, which are to be elaborated and partly to be tested by the survey, which will be carried out this spring, in terms of consumer acceptance.

We assume the following general preferences of users for household appliances partly derived from statements of the workshop participants, partly from own experiences, other research projects and literature.

Assumptions about the equipment with appliances:

- The idea of and need for buying a new appliance arises from a new want or desire that shall be satisfied.
- To satisfy this want or desire, the individual begins to inform him-/herself about the technological services supplied. Today, these options often entail a wide range of alternative products and a variety with regard to different features, sizes and functions.
- The individual tries to find the option with the maximum main utility and further utility aspects provided by the product. This utility comprises the satisfaction of the original want or desire and preferred side-features such as size and variety of functions.

Assumptions about the use patterns:

- The handling should be simple.
- Minimum time requirements for the operation of the device.
- Preference for a maximum flexibility in size and functionality in order to fit for temporally changing desires and wants. Only a small share of all features and functions is used often or regularly.
- Users want to keep what is familiar and to try out what is new, without forgoing what is familiar to them.
- Users do not want to practice actively new energy saving options when using an appliance, but want information about energy demand and respective costs.
- Disempowerment by technology is rejected. The users want to keep control and to be able to intervene.

A necessary precondition for an adequate use of appliances is information and transparency. As shown elsewhere (Leuser 2014; Darby 2001), information and transparency do not yet lead to a change in demand but are important factors that still need to be fostered. To enable users to make conscious decisions about the programmes and appliances they use, the power demand of appliances should be made present in the daily lives of users. This would mean displaying the energy demand for the program chosen (e.g. washing machine, dishwasher). Furthermore, concrete facts need to be presented instead of meaningful scales (e.g. a temperature scale for refrigerators and freezers instead of a numbered scale with which no clear decision can be taken). Additionally, handling could be facilitated by showing current energy demand (to identify changes) and possibly warning signals when energy demand of the appliances is unusually high (i.e. when the refrigerator is left open).

DESIGN CRITERIA FOR ADEQUATE EQUIPMENT OF HOUSEHOLDS FOR ENERGY SUFFICIENCY

Design criteria to realize Reduction

To design appliances ready for the reduction strategy, two important aspects need to be taken into account: (1) The avoidance of super-sizing and (2) of functional redundancies. For the implementation of the first aspect, energy-related features and characteristics of appliances should be designed in a way to facilitate the flexible customization to desired reliefs and needs of households. As the decision for the reduction approach is taken and performed by the user, appliances need to be designed in a way that allows users to take this option. Hence, the design should allow a maximum of flexibility to fit to the currently desired function and feature (e.g. size of white good appliances).

To avoid redundancies due to the design of an appliance, devices should have a modular structure and should converge in their functions. The modular structure has the added benefit that each module can be repaired or replaced when unrepairable. For other product groups, which cannot or only hardly be designed in a modular way, small and simple devices, which can be combined, could be a solution.

Design criteria to realize Substitution

There is a need for the development, introduction and marketing of products and features that change daily routines and social practices towards energy sufficiency and resource conservation. An example is the refreshing box presented above. Clothes that were worn only briefly and are only slightly dirty could then be refreshed by ventilation, or odour and bacterial treatment instead of being washed. Thereby, the clothing is cleaned according to consumer wishes, but in alternative, probably more resource-conserving way.

Design criteria to realize Adjustment

For the design of appliances that are compatible with the adjustment strategy, it is important to implement features that adjust the operation mode automatically to the actual needs, wants and routines of users. Additionally, users could be relieved of explicit energy saving. This means, for example, the automatic adjustment to the desired level of service, such as the identification of the pot size, the amount of clothes or dishes in respective appliances, the identification or programmable deactivation of features or the whole appliance in times when they are not used.

Only a few frequently used standard programs and functions should be pre-programmed, and they should be energy- and resource-saving. Nevertheless, the variety of options should be kept available, but deactivated in order not to waste resources. The handling needs to be simple.

In some cases, it might even be reasonable to set this deactivation as a default, as with routers during the night, for example, when most households do not demand internet services. In case deactivation is not possible due to user demands, a sleep mode (e.g. for printers), or the turn down of performance levels should be activated after a certain timespan or after reaching a certain event. Features that are rarely or not used at all should be automatically deactivated. Another aspect of adjustment is the automatic avoidance of improper and resource-wasting use, which may be achieved through features such as a closing-mechanism of refrigerator and freezer doors, an automatic dosing of detergents or defrost function.

Suggestions for the future development of energy labelling and ecodesign

GENERAL SUGGESTIONS FOR THE DEVELOPMENT OF THE ENERGY LABEL AND ECODESIGN REGULATIONS

The future energy label and ecodesign requirements should focus on informing, supporting and enabling consumers in order to realise absolute reductions of energy consumption. Future preparatory studies should investigate the product characteristics in terms of their effect on absolute energy consumption. Additionally, an investigation of common use patterns of appliances should be carried out. Furthermore, the analysis has to be carried out from the perspective of sustainability. This means that the starting point of the analysis is to assume the reduction goals as set. This would lead to posing the question of "which equipment, use patterns, social practices and everyday routines are necessary from the perspective of sustainability?" The results of this investigation would then influence the definition of future targets for labelling and ecodesign regulations. Our suggestion is that typical use patterns, frequently used programmes, features and functions have to be integrated into the measurement standards and methods.

SUGGESTIONS FOR THE DEVELOPMENT OF ENERGY LABELLING

To date, the efficiency class is the main information of the energy label, while the annual energy consumption is only given along with other information. The quantitative differences in the efficiency classes of white goods are very small and reach already the limits of measurement tolerances. Thus, the efficiency class as a purchase decision criterion is almost ineffective to differentiate appliances with regard to absolute energy consumption. A new labeling approach is needed in order to establish absolute energy consumption as a purchase decision criterion. The absolute energy consumption (e.g. per year) should be the main information of the label. The efficiency could be indicated as background information. This approach is comparable to the current system of food pricing in supermarkets: the price of the product is the central indication and the specific price per volume or mass unit is given as background information. The absolute energy consumption, for example of programs and its dependence on device configuration and usage patterns should be made transparent by the label information requirements (e.g. in the product fiche). This information would be appropriate to motivate and enable consumers to look for adequate features, sizes and technical services delivered by the appliance and thus, to adjust the technical utility demanded to the utility needed.

Furthermore, it is time to make other, now more crucial factors transparent with the label. These factors include technical characteristics, functions and use patterns (see Figure 1) in order to achieve a steering effect in equipment and, if necessary, use patterns. This is illustrated by the new energy label for vacuum cleaners, with the obligation to include the following information in addition to efficiency class and average annual energy consumption: Dust re-emission class, carpet cleaning performance class, hard floor cleaning performance class, sound power level. The introduction of such a label in 2014 made these characteristics of vacuum cleaners transparent for customers. Thus, these characteristics depicted on the label became purchase decision criteria instead of electrical performance. This performance is inappropriate to assess the quality of cleaning service delivered compared to the main utility demanded (cleaning performance) and further utility aspects (e.g. low dust re-emission, low sound power level) that should be satisfied.

In order to keep the pull effect of the label, the requirements for the highest efficiency class are the most important. Siderius and Brischke (2011) therefore propose to reserve the A-Class for devices that achieve a yearly net end energy consumption of zero or nearly zero, comparable to Passive Houses, or Plus-Energy-Houses. The energy required by these appliances could be extracted from the immediate environment, such as by photovoltaic or by new energy harvesting technologies that are integrated into the device, and should not be counted as end energy consumption. This approach is different to the one of the EU labels for boilers. In case of the boiler the optimization of the actual utilization system (the building) is not the subject of the label. The proposed A-Class labelling for net zero end energy using appliances would result in an optimized device design, stimulating efficiency, sufficiency as well as consistency approaches at the same time, because the labelled unit is as well the utilization system.

Finally, we propose that those device features, which enable users to reduce and adjust (both are in the proposals for the highest efficiency classes inherently) should be made transparent on the label to stimulate interest in and innovation of such features.

SUGGESTIONS FOR THE DEVELOPMENT OF ECODESIGN REQUIREMENTS

Requirements related to the design of appliances to motivate, enable and support reduction

The appliance design should ensure the flexibility of the appliances in terms of energy-related functions and features in order to enable consumers to apply the reduction approach:

- Mandatory display and manual adjustability of user-relevant sizes and values, e.g. display and adjustability of cooling temperature, instead of an abstract scale in refrigerators and freezers. An existing example is the basic award criteria of the voluntary environmental label "Blauer Engel" for refrigerators and freezers, which requires the appliance to provide temperature display instead of an abstract scale and degree-by-degree temperature setting (RAL 2013b).
- For appliances that are operated via a program selection, a display should provide information on the associated energy consumption in program menu. The user is then able to compare the programs with consideration for energy consumption.
- Appliances should be size-flexible or built modularly and the energy consuming modules should be detachable.
- Energy consuming functions of an appliance (except safety-related functions) should be detachable.
- Appliances should enable users to configure the technical service supplied according to their individual utility needed, utility aspects desired and hence, the adequate technical utility demanded. The default setting at delivery should be that only frequently used or main features and functions are activated. Rarely used or additional features and functions can be activated by the users themselves as needed or desired at a later time.
- Additional energy consumption caused by extra functions could be avoided by progressive requirements in terms of total electrical connected load of the appliance.

Requirements related to the design of appliances to motivate, enable and support substitution

- A new type of ecodesign requirement, which supports the change of social practices and everyday routines towards energy and resource conservation by the design of the appliances (e.g. washing with low temperatures, help in correct dosing), should be developed.

Requirements related to the design of appliances to handle adjustment

- Equipment should be designed such that functions and features only consume energy, when they are in use. Functions and features not used should never cause energy consumption. An existing example are refrigerators and freezers that have to turn off the express freezing function automatically either when a maximum temperature of -32 °C is reached or after 65 hours at the latest according to the label "Blauer Engel" (RAL 2013b).
- It should be required that only a few of frequently used energy and resource optimized standard programs and functions should be pre-programmed.
- Requirements should contribute to the development of resource-intelligent appliances, i.e. appliances that recognize the routines and use patterns of its users and the conditions of the usage environment. Based on this information, their services delivered are optimized under the premise of a minimal use of resources automatically (e.g. automatic brightness adjustment of monitors). The requirement for washing machines to include an "auto half load" feature that automatically reduces water and energy consumption when it is not fully loaded by the label "Blauer Engel" is an example for this kind of requirement.
- It should be obligatory to equip appliances with functions for automatic detection and correction of improper use, which leads to significant increase in energy consumption (e.g. automatic closing of a refrigerator door when not closed properly). If this is impossible, they should have at least corresponding warning systems.

The suggestions summarized here are based on the intermediate findings of the project for a complementation of the already achieved advances by energy efficiency increases. The aim should be an absolute reduction of power demand in the residential sector to a sustainable level.

References

Alcott, B. (2007), The sufficiency strategy: Would rich-world frugality lower environmental impact? Ecological Economics 64 (2008), p. 770–786.

bdew (2013), Stromverbrauch im Haushalt, Berlin: Bundesverband der Energie- und Wasserwirtschaft e.V.

BSH (2013), Transparenz schaffen. Nachhaltigkeitsbericht BSH Bosch und Siemens Hausgeräte GmbH, p. 32.

Brischke, L.-A. (2010), Rationelle Energienutzung in elektrischen Anwendungen, In Pehnt, M. (ed), Energieeffizienz. Ein Lehr- und Handbuch, Springer: Berlin, Heidelberg.

Brischke, L.-A. (2014), Energiesuffizienz – Strategie zur absoluten Senkung des Energieverbrauchs, In Energiewirtschaftliche Tagesfragen. 64. Jg. 10/2014, p. 13–15.

Brischke, L.-A., Leuser, L., Thomas, S., Spitzner, M., Thema, J., Ekardt, F., Kopatz, M., Duscha, M. (2015), Energiesuffizienz, AP1 Rahmenanalyse, IFEU, Wuppertal Institut: Berlin, Heidelberg, Wuppertal.

Calwell, C. (2010), Is Efficient Sufficient? The Case for Shifting Our Emphasis in Energy Specifications to Progressive Efficiency and Sufficiency, eceee: Stockholm.

Darby, S. (2001): Making It Obvious: Designing Feedback into Energy Consumption. In: Energy Efficiency in Household Appliances and Lighting, edited by Paolo Bertoldi, Andrea Ricci, and Anibal de Almeida, 685–96. Springer: Berlin, Heidelberg.

Darby, S. (2007), Enough Is as Good as a Feast–sufficiency as Policy, Proceedings of eceee Summer Study 2007.

dena (2012), Kurzstudie zur Wirkung der europäischen Top-Runner-Strategie. Methodik und Zusammenfassung, Deutsche Energie-Agentur GmbH (dena): Berlin.

dena (2014), Dena-Marktanalyse zur Effizienzentwicklung in der Produktgruppe Staubsauger (ENER Los 17), Deutsche Energie-Agentur GmbH (dena): Berlin.

EC – European Commission (2008), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – 20 20 by 2020 – Europe's Climate Change Opportunity.

Fischer, C., Grießhammer, R., Barth, R., Brohmann, B., Brunn, C., Heyen, D., Keimeyer, F., Wolff, F. (2013), Mehr als nur weniger – Suffizienz: Begriff, Begründung und Potentiale, Öko-Institut: Berlin, Freiburg.

Fouquet, R., P. Pearson (2006), Seven centuries of energy services: the price and use of light in the United Kingdom (1300–2000), In: The Energy Journal 27(1), p. 139–77.

Harris, J., Diamond, R., Iyer, M., Payne, C., Blumstein, C. (2006), Don't Supersize Me! Toward a Policy of Consumption-Based Energy Efficiency, Procedings of the ACEEE Summer Study 2006.

Lehmann, F. (2013), Modellierung von Suffizienzstrategien zur Verringerung des Stromverbrauchs in Haushalten, Bachelor Thesis, Hochschule für Technik und Wirtschaft (HTW): Berlin.

Leuser, L. (2014), Municipal Support-Options for Energy Sufficiency by the Formation of Framework Conditions, Master Thesis, University of Business and Economics Vienna: Wien.

Müller, A. (2009), Sufficiency – Does Energy Consumption Become a Moral Issue? Proceedings of eceee Summer Study 2009.

OECD (2014), World Energy Outlook 2014, OECD-Organization for Economic Cooperation and Development.

Prognos, EWI, GWS (2014), Entwicklung der Energiemärkte – Energiereferenzprognose. Im Auftrag des Bundesministeriums für Wirtschaft und Technologie, Prognos: Basel, Köln, Osnabrück.

RAL (2013a): Basic Criteria for Award of the Environmental Label – Blauer Engel, Household Washing Machines, RAL-UZ 137; Edition January 2013, RAL: Sankt Augustin.

RAL (2013b), Basic Criteria for Award of the Environmental Label – Blauer Engel, Refrigerators and Freezers, RAL-UZ 138; Edition February 2013, RAL: Sankt Augustin.

Siderius, H.-P., Brischke, L.-A. (2011), The future of appliance efficiency policy: net zero energy using appliances, EEDAL – Energy Efficiency in Domestic Appliances and Lighting Conference 2011.

Skidelsky, R., Skidelsky, E. (2012), How Much is Enough? The Love of Money, and the Case for the Good Life. Allen Lane/Penguin Books.

Statistisches Bundesamt (2013), Wirtschaftsrechnung – Einkommens- und Verbrauchsstichprobe Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern 2013, Fachserie 15, Heft 1, Statistisches Bundesamt: Wiesbaden.

Sveiby, K. E., Gripenberg, P., Segercrantz, B. (2012), Challenging the Innovation Paradigm. Routledge Studies in Technology, Work and Organizations 9. New York: Routledge.

Thomas, S; Brischke, L.-A.; Thema, J.; Kopatz, M. (2015), Energy Sufficiency Policy: An evolution of energy efficiency policy or radically new approaches? eceee 2015 Summer Study paper No. 1-060-15.

Unteidig, A., Sametinger, F., Schubert, J., Joost, G. (2013), Neighborhood Labs: Building Urban Communities through Civic Engagement. Proceedings of the Participatory Innovation Conference 2013 in Lahti.

Wilhite, H., Norgard, J.S. (2003), A case for self-deception in energy policy, Proceedings of the eceee Summer Study 2003.

WCED – World Commission on Environment and Development (1987), Our common future, Oxford University Press: Oxford.

Yates, L., Evans, D. (2014), Eco Laundry Habits Are about More than Sustainable Washing Machines, The Guardian, October 9. http://www.theguardian.com/sustainable-business/behavioural-insights/2014/oct/09/eco-laundry-sustainable-washing-machines.

Acknowledgements

The authors wish to thank the German Federal Ministry for Education and Science for financially supporting this work.