PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies

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Deliverable D3.2

Report on PAR Analysis

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Contents

Preface

This paper is the deliverable for task 3.2 in Work Package 3 (WP3) of the Pathways Project. Work Package 3 focuses on specific examples of transitions on the ground. I.e. real-life, real-world initiatives in sustainability transition processes.
Analysis in Work Package 3 is set into five tasks:

- Task 3.1: Further elaboration of case studies and participative action experiments;
- Task 3.2: Participative Action Research;
- Task 3.3: Analysis of case studies;
- Task 3.4: Meta-analysis of on-going (and past) projects in identified domains;
- Task 3.5: Collecting the results of the case studies, synthesising the findings of WP3 and preparing for feedback in WP1 and WP2.

Associated with these tasks are five deliverables:

- D 3.1: Further elaboration of case studies
- D 3.2: Report on the PAR-Analysis
- D 3.3: Comprehension of case studies for MLP transition analysis in WP2
- D 3.4: Operationalization of variables concerning niche-innovations, lifestyles and behaviour for integrated assessment in WP1
- D 3.5: Working paper on transition pathways in the making, its scaling-up and learning potentials

This paper contains deliverable 3.2 due in month 34 of the project. Its aim is to provide insight into the use and value of Participatory Action Research in the context of transitions towards low-carbon societies.

Introduction

This report is part of the PATHWAYS's project work package 3 concerns active research to foster initiative-base learning (IBL), i.e. the workings, processes and development of (local or regional) action towards sustainability transitions. It addresses the following questions: What enables or disables the implementation of innovative governance in the real life of individuals? How does governance need to be rearranged in order to get stakeholders on board at the local level? Following the hypothesis, that such governance will be shared efforts across society, we take a broad approach to the questions, concentrating on active and direct involvement of citizens, users and others in unfolding sustainable transitions. This paper will therefore illustrate the role, prospect and limitations of experimental Research to support and initialize sustainability transitions. Participation of (social) researchers towards the realization of sustainability-oriented transitions has come more and more to the fore over the last years. Such activities have also been labelled "Transformative Research" (e.g. Schneidewind 2013) in contrast to research that studies transitory phenomena but does not take an active part in them.

We derive implications based on two experiments pursued between 2014 and 2016. One was conducted as a real-world laboratory in a city quarter context, while the other concerned a LivingLab approach on heating behaviour in households. Both experiments are set in the area of PAR.

Experimental Transformative Research is able to connect to transitions very directly and very deeply. Working and learning with entrepreneurs of all sorts (social, economic, institutional as well as activists and researchers) enables us to gain profound insights into transition "in the making" and to uncover hidden or less obvious mechanisms unfolding "on the ground" of sustainability transitions.

The report proceeds as follows: Relying on a more theoretical basis set out in deliverable 3.3, in chapter 1 we develop the case for Transformative Research more deeply and describe the use and sense of the research and experiments conducted and described here. Chapter 2 depicts the two experiments and their findings in detail, while chapter 3 discusses these findings with regard to different objectives, including the prospect of Transformative Research, its chances and challenges, resulting implications as well as potential learnings for other research strands into sustainability transitions, i.e. quantitative modelling through Integrated Assessment Models and Socio-technical-Analysis in a Multi-Level Perspective. This paper is one of the last products of the project "PATHWAYS – Exploring transitions pathways to sustainable low-carbon society". It will thus refer to, draw from and reflect on earlier deliverables in this project.

1. Participatory Action Research as Transformative Research for Sustainability

1.1. Transformative research as a paradigmatic background

To understand the approach of initiative-based learning conducted here, it is important to point out the agenda of transformative research as a paradigmatic background, also described in deliverable 3.3 of this project.

The German Advisory Council on Global Change (WBGU) uses the expression transformative research to describe research that actively advances a transformation (WBGU 2011). Transformations can be defined as socio-economical, cultural and political changes that lead to new ways of thinking, producing and consuming. They imply a modification of the routinized behaviours and opinions of all major actors involved (Spaargaren et al. 2012). Sustainability transitions, in particular, are complex evolutionary phenomena likely to involve extensive changes in society, economy and technology (Fischer-Kowalski & Rotmans 2009, Shove & Walker 2010). Transformative research is interventionist research that explores and supports transformation processes in practical terms. It strives for technical as well as for social innovations, including their acceleration. In the words of Schneidewind et al. transformative research "*takes an active role in initiating and catalysing change processes. The aim of transformative science is to achieve a deeper understanding of on-going transformations and increased societal capacity for reflexivity with regard to these fundamental change processes*" (Schneidewind et al. 2016, 2). The authors hence define transformative science as "*a specific type of science that does not only observe and describe societal transformation processes, but rather initiates and catalyses them. Transformative science aims to improve our understanding of transformation processes and to simultaneously increase societal capacity to reflect on them* (ibid., 6). "

Due to its interventionist character, transformative research demands a systemic perspective as well as inter- and transdisciplinary methods (WBGU 2011). The approach is therefore rather widely conceptualized and may in itself contain numerous different methods and research goals. It encompasses, for example, consumer research, which is needed for the development of new business models such as the shared use of resource-intensive infrastructures, and also research for technological innovations like efficiency technologies. Two distinct methods are real-world-laboratories (RWL) and Sustainable Living Labs both of which represent different forms of Participatory Action Research that have been pursued here.

Transdisciplinarity plays a major role as transformative research includes the involvement of relevant stakeholders into the research process, for different purposes. It seeks to increase the social relevance of research questions through the involvement of stakeholders in setting research goals. Secondly, it also involves stakeholders in the actual research process, and thus aims for the combination of scientific and practical approaches (Talwar 2011, WBGU 2011, p. 22 and 322f).

This does not only have consequences for the concept of research but also for the methodologies to be chosen. Transformative research not only requires the involvement of actors of transition processes but also the creation of an environment in favour of a coproduction of knowledge between the sciences, politics and stakeholders. Therefore, it has to integrate the different forms of knowledge (for example local, traditional or indigenous knowledge), of the involved actors both scientific as well as non-academic. This process is reflexive, i.e. it cannot be implemented linearly, but rather through searching, learning and experimenting in iterative processes. The circular nature of this learning process is a crucial element of this approach (Figure 1).

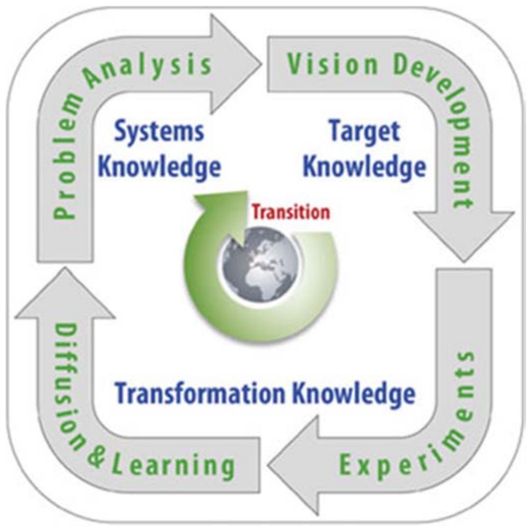

Figure 1: Forms of Knowledge and the Transition Cycle, Schneidewind/Singer-Brodowski, 2013, 72.

In this sense, Schneidewind (2013, p. 83) recently called for a transformative literacy, that is "the ability to read and utilize information about societal transformation processes, to accordingly interpret and get actively involved in these processes". He bases this postulation on Scholz (2011) who introduced environmental literacy that is „the ability to read and utilize environmental information appropriately, to anticipate rebound effects, and to adapt to changes in environmental resources and systems, and their dynamics". In order to do so, research needs to encompass a technological, economic, institutional and cultural dimension in a transformative and transdisciplinary design. The more interventionist approaches described here are set into this agenda. They refer to research settings that actively engage with "the real world" as a true transformative approach can only be an effective when conducted where transformation or transition, respectively, occurs.

Since a transformative approach hence implies direct and intended intervention by the researchers in order to create knowledge and direct effects it comes with both advantages and disadvantages. As it is developed – and ideally tested – "in situ", knowledge from transformative research seeks to be of direct relevance to a case and to a wider public beyond the scientific community. Results created should hence be more or less directly actionable, i.e. applicable to a given set of circumstances and/or goals. On the backside, the creation of knowledge within a specific background always faces the question as to what degree it is generalizable beyond its particular concern. Even products or services developed and tested in a LivingLab-approach (see below) with a wide range of stakeholders may be limited to a specific geographical, cultural, milieu- or environmental-specific context. Moreover such research may face distortionary effects like a Hawthorne-effect (i.e. individuals modifying their behaviour in response to their awareness of being observed; Wickström/Bendix, 2000) and thus be affected from e.g. perception of desirable behaviour on the side of the participants. The advantages and challenges of transformative research are discussed in more detail in chapter 4.1.

1.2. Transformative Research in WP 3: Real-world-laboratories and Sustainable LivingLabs

This chapter presents the participatory methodology pursued in WP 3 of the project. Next to "classic" analysis, efforts in participatory action research should develop, apply and derive lessons for transitions towards sustainability. They are designed to lead to more sustainable environments or technologies together with the actors on the ground: locals, companies, activists, etc. The approaches seek to draw advantages from involving different kinds of expertise (Kirchhoff et al. 2013, Ozanne/Saatcioglu 2008) in order to better capture and understand the mechanism and processes on the ground.

It is thus assumed that scientific findings in some social contexts can be better achieved if professional researchers involve 'laymen' into their research (Lewin 1997), in order to try and intervene in existing social structures. Here, non-researchers do provide their specific knowledge on the background or the specificities of a certain problem or sustainability context. Examples for integrated expertise may regard researchers' knowledge from a different discipline, experience from other cases and methodological abilities; market- and production-related knowledge of companies and their technical skills; awareness of local affairs, circumstances and specific motivation for change from locals and activists.

An important reason to pursue research and sustainability oriented experiments in the real world is to evade unwanted emergent phenomena or contra-productive practices that may lead to e.g. rebound effects (Liedtke et al. 2014), as such effects may not become apparent in more artificial laboratory or experimental settings. Experiments in transformative research may control the experimental settings in different levels of strictness, and strive to learn from them, potentially adapting the setting in the course of research. For the two different settings pursued and conducted here, the Real-world-laboratories (RWL) in a city quarter were designed with a high degree of openness. The specific aim was to include the needs of the involved groups, to cater for potential uncertainties and risks in a voluntary movement, and to gain more control over the experimental settings on the side of the researcher in the Sustainable Living Labs (SLL), which requires a more standardized methodology to achieve reliability and validity of implications. However both come with the common aim noted above: Advancing sustainability transitions. It is important for both approaches to create knowledge and practices that are actionable (Argyris 1996) and effective, i.e. sustainable – ideally without evoking rebound effects or harmful externalities.

2. Methodology: Two experiments in Transformative Research

2.1. Sustainable Living Labs

Living Lab concept can be understood as research designs and infrastructures, which jointly involve researchers, users and developers in an open innovative development process in more or less real life sustainable environments. The main emphasis is put on contributing to a culture of more resource efficiency in economy and lifestyles (Low Resource and Carbon Society). In this context, eco-innovations[1] play an important role. However, they often do not fully meet their engineered potential for resource and energy conservation due to a lack of diffusion, imperfect utilization or unintended side effects. Moreover, eco-innovations often do not perform in the intended way because of unexpected user behaviour – either because of low user acceptance, wrong implementation and application or economically, socially and psychologically motivated rebound effects.

To cope with these problems, a user-integrated action research methodology and research strategy are therefore needed (Liedtke et al. 2015). The Sustainable Living Lab (SLL) approach regards research to enable innovation processes, in which users and other stakeholders participate in the development, testing and diffusion of products, services and system solutions to make applications, technologies, practices etc. more sustainable. Through this the Living Lab approach offers two central benefits. Firstly, it helps to improve understanding of the behaviour and needs of users as well as of their habits and practices in terms of resource and energy consumption. Secondly, and even more important the Living Lab approach comes with transdisciplinary research that can develop possibilities to intervene on consumer practices and therewith change social practices more effectively through the insights mentioned in chapter 1).

Sustainability LivingLabs are reflexive infrastructures that respond to (technical or procedural) issues of eco-innovation such as imperfect utilization of technologies or products, unintended side effects or lack of diffusion. The objective is to early identify trends in the field of Sustainable Consumption and Production and to integrate relevant stakeholders (producers, handicraft, consumers, users) into the development of research strategies, the design and the testing process. Therein, the focus is set on resource and energy efficiency and sustainable lifestyles.

In such a setting users and other actors relevant to the context, actively participate in the development, testing and diffusion of products, services and system solutions, respectively.

SLL can be adapted flexibly according to a defined research question, but follow a clearly determined process logic: defining a problem, designing the research strategy, creating solutions and (iteratively) testing and applying the results. Dependent on the individual goals and circumstances, users and stakeholders can be involved in all or in specific stages of research (Talwar et al. 2011, Figure 3). Given the emphasis on pluralism in participatory action research, quantitative and qualitative methods are often integrated in a mixed methods

[1] Generally eco-innovations refer to new technologies that improve economic and environmental performance. Some definitions also include organizational and social changes for improving competitiveness and sustainability in its social, economic and environmental pillars (Carrillo-Hermosilla et al. 2009; see also Rennings 2000).

research design (see Liedtke et al. 2015). These more controllable experiments offer a lower degree of freedom without following a pure observe-and-monitor rationale (see Schneidewind and Scheck 2012, Talwar et al. 2011).

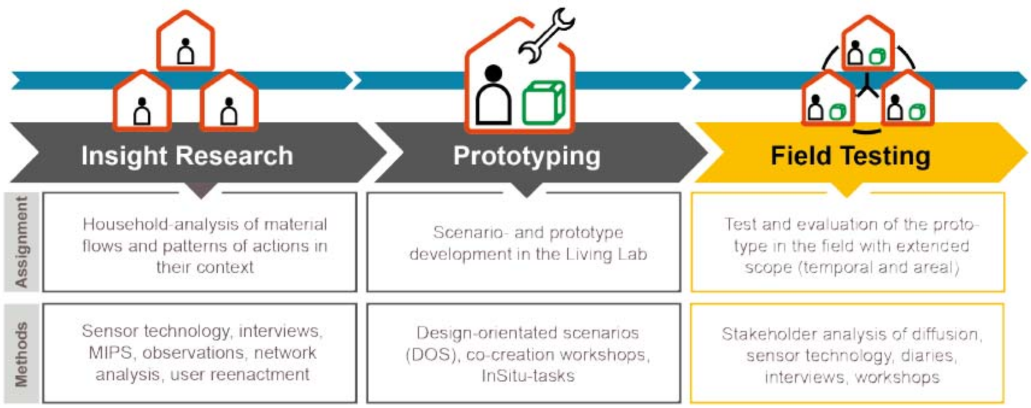

Figure 2: The Sustainable LivingLabs three-phase model of research, Liedtke et al. (2014), 111.

The Wuppertal Institute has advanced this research methodology in several related projects, focusing on sustainability innovations and integrating users and stakeholders (Liedtke et al. 2014). In principle, a LivingLab experimental setting can contain three phases (ibid., also Figure 2). In the first phase, *Insight Research*, the status quo in the field of interest is explored and the required/potential level of change in social practices of households is analysed. A second phase, Prototyping, prepares the user- and stakeholder-integrated development of a transformational design. Stakeholders along the value chain from designers, suppliers to end-users participate in the development phase. They often do so in efforts of Co-Creation where the insights of the different groups shall lead to enhanced designs in terms of applicability, acceptance and efficiency. The third phase *Field Testing* encompasses the implementation of the transformational design in a quasi-experimental setting that allows observing its effect by intervening with social practices of households. LivingLabs can be adapted flexibly in this framework according to a defined research design.

Thus, users and stakeholders can be involved at all or at specific stages of research, i.e. in the phases of defining a problem, designing the research strategy, creating results or in the (iterative) application of results. Living Lab research aims to foster broader behavioural and cultural changes that support B-pathways, i.e. broader regime transformation. We are specifically interested in behavioural change that may lead to significant savings in resource and energy consumption. We consider behavioural change to realize significant reduction of energy and resource flows cost-effectively. Furthermore, behavioural change does not require (major) capital investments and thus do not compensate energy and resource conservation in terms of embodied energy (see Berg et al. 2015, p. 25ff).

2.2. Real-World Experiments

Based on Groß und Krohn (2005) real world experiments are hybrid variants of experimentation. They oscillate between modes of knowledge production and knowledge application as well as between controlled and context specific conditions. Current real world experiments in transformative research are for example often set in transitions of cities and city quarters as loci of (social) innovation in an urbanizing world.

As such, real world laboratories can hence be seen as a field experiment conducted and iterated in specific areas confined by space, time and/or context. In the case of sustainability oriented real world experiments, a normative aspect is added, since the realization of a more sustainable condition at the end of the experiment when compared to its start is part of the design. The notion of "experiment" or "laboratory" suggests, that despite a given goal, the aspired improvement needs to be explored. The clarity of the given goals can therefore be more or less determined at the beginning of the experiment and range from quite precise aims (e.g. creation of a 100%-energy autarchic city quarter) to less well defined targets (e.g. improvement of well-being in a given region). However, due to this framing such experiments are often context-specific (Castree et al. 2014) and researchers have to deliberate carefully about generalizable implications of their efforts.

Real-world labs are mostly characterized by Participatory Action Research (PAR), i.e. " 'a participatory, democratic process concerned with developing practical knowing in the pursuit if worthwhile human purposes.' Simply stated, this is a systematic approach that seeks knowledge for social action." (Reason and Bradbury 2001, 1 cited in Ozanne and Saatcioglu 2008, 424 and Ozanne and Saatcioglu 2008, 424).

RWLs as PAR for sustainability transitions therefore pursue two distinct but interdependent targets: the generation of scientific knowledge and the deduction, development and application of actionable knowledge (Argyris, 1996) in this course. PAR is generally democratic, so that researchers and practitioners cooperate on "equal footing" (Berg et al., 2015; Gross & Krohn, 2005). Constituting a close entanglement with the field of study, PAR is able to detect, describe, foster and potentially counter unwanted emergent outcomes, such as rebound effects. Due to its experimental nature, PAR cannot completely control its settings: it rather seeks to learn from and improve the development of its area of interest and hence represents a hybrid mode of experimental research. In this hybridity, PAR thus needs to iterate between different ways of knowledge production and application as mentioned above (Schneidewind/Singer-Brodowski 2013, Berg et al., 2015; Groß & Krohn, 2005, see also Figure 1).

For participants' engagement, Talwar et al. (2011) have developed a typology consisting of the following, iterative four steps:

1. problem definition;
2. design of the research strategy;
3. creation of results;
4. application and testing of results.

Our PAR approach follows this four-step logic, and our research was developed along the four phases shown in Figure 3. The case is concerned with urban sustainability, nutrition and food waste. The findings are presented in chapter 3.1.3.

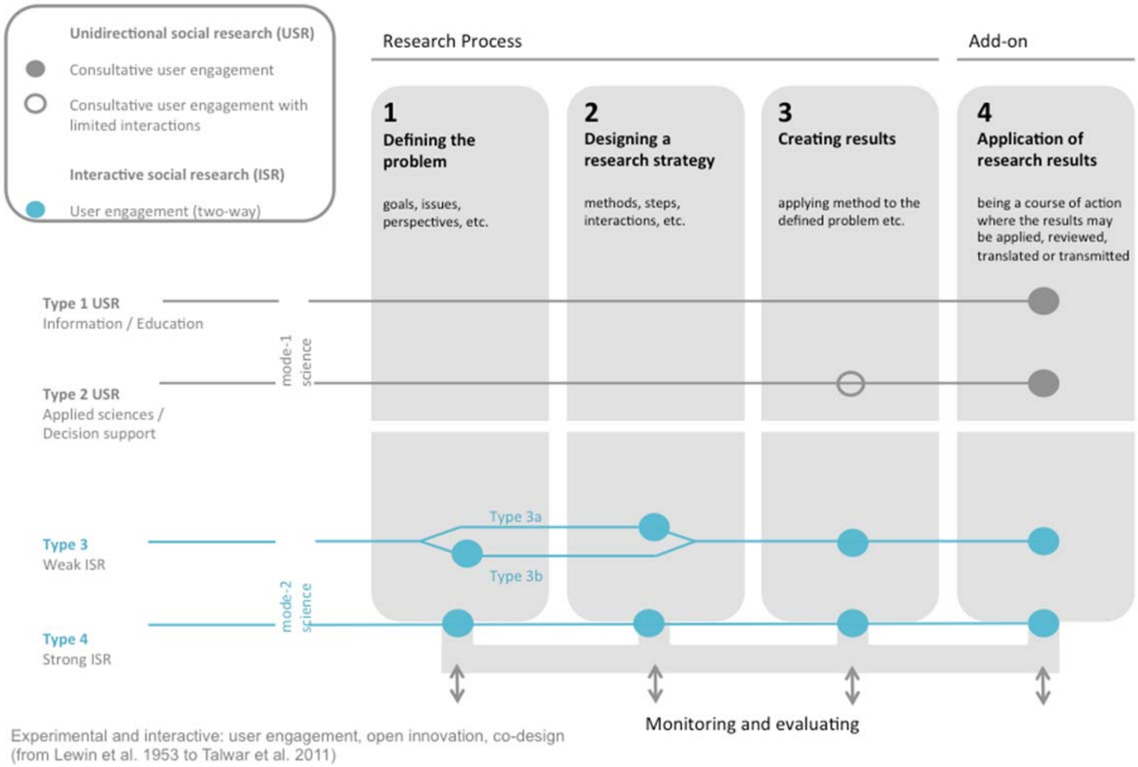

Figure 3: Process of participant engagement (cf. Talwar et al. 2011: 382).

3. Two Transformative Experiments

The current discussion about sustainability transitions generally highlights the need to act especially on mobility, housing, food production and consumption, and leisure-time activities (Leismann et al., 2013; Kotakorpi et al, 2008). These sectors represent high shares of total resource consumption, and changing them as necessary will probably lead to wider transformations of our economic system, culture and lifestyles (Rohn et al., 2014). At the same time, sustainability needs to be achieved in many different dimensions in these sectors, i.e. innovations regarding technical, socio-economic, cultural, spatial, etc. aspects (Elzen & Wieczorek, 2005). In this chapter we present two concrete experiments dealing with this challenge. We present their goals, processes, and outcomes to illustrate the chances, distinct problems and effects of transformative research.

3.1. The PATHWAYS LivingLab

Heating in residential buildings is a major factor for energy consumption in Germany and based on the current gas- and oil-driven regime also a major source for GHG emissions (Echternacht et al. 2015). Reducing the energy demand of heating could thus significantly contribute to a reduction of GHG-emissions. Currently, regime transition towards an overall more sustainable regime is significantly lagging behind the necessary cuts to reach the emission goals set for 2050. Causes for these observations are rooted in an extremely inert system. This inertia is driven through several factors: first of all and most important are long investment cycles on both supply side (applied heating technologies) and demand side (refurbishment rates and newly builds), secondly investments and innovation are hampered by strong interest groups lobbying against change as neither owners nor tenants are willing to bear the necessary monetary burden (split-incentive dilemma (Kumbaroğlu and Madlener 2012)). Moreover, policy is showing a mixed picture as there are significant drivers for change, e.g. in the form of subsidies for renewable installations and strong regulations for newly builds (ENEV) while at the same time fossil fuel-based appliances are also promoted if they provide to efficiency gains (Echternacht et al. 2015).

In this scenario of severe inertia, measures that trigger more efficient heating and ventilation behaviour require low amounts of investment. They commensurate with the regime and hence require few adaptions and do not demand rises in rents etc. They could therefore provide an important and easily accessible source of reducing resource use and GHG-emissions caused by heating (Jensen et al. 2015).

Contributing to a growing literature on the effects of eco-feedback, in the SLL we analysed and compared the effects of more automated, high- level technological driven smart home systems, promising a more energy efficient heating in private households, and a more informative, low-level technological feedback and behaviour driven CO_2 meters, helping to realise an improved management of indoor air quality and consequently, affecting indoor temperature management indirectly.

In this regard, we hypothesise that

1) smart home systems lead to a more energy efficient indoor room temperature management, i.e. lower average indoor room temperatures;
2) CO_2 meters lead to a better management of indoor air quality, i.e. lower average indoor CO_2 concentrations.

3.1.1. Rationale of the LivingLab

In the PATHWAYS project we focused on an experimental design within the field testing phase, based on extensive prior research by the Wuppertal Institut: Baedeker et al. (2016) highlight the influence of social norms and the importance of hospitality concerns for users when it comes to indoor temperatures. In this regard, Buhl et al. (2016) emphasize the importance of comfort concerns for users. With respect to promising interventions for the sake of more energy efficient heating practices, Bettin and Buhl (2016) find that motivating feedback interventions promise most effective incentives for behavioural change in terms of indoor room temperature (compared to strength of intervention). Jensen et al. 2015 highlight the potential of diffusing feedback devices and behavioural change among leading lifestyles for energy conservation on larger scale. Buhl and Acosta (2016) estimate non trivial rebound effects of behavioural change via turning down the thermostat and propose to consider socio-psychological dimensions of users in order to better understand and mitigate those unintended effects. In this regard, Liedtke et al. (2014, 2015) call for more user-integrated development of product and service innovations in the heat domain. Altogether, the findings from comprehensive insight research on heating behaviour do propose that innovative feedback technologies are supposed to address socio-psychological traits of users in order to foster behavioural change effectively. We hypothesise that innovative feedback designs are promising interventions into behavioural practices in the heat domain depending on how the feedback technology works. To this end, field experiments on innovative feedback designs, sensory data logging and interviews were conducted in order to investigate their potential for more resource and energy efficient heating and ventilation practices.

3.1.2. Method

Eight households in Wuppertal (Germany) participated in the Living Lab study. Prior to the experiment the households had to apply for participation. The households were then chosen with an aspiration for social variety. However, to eliminate technological influence based on resource use, all households had to use gas heating appliances. The participants were invited for a telephone interview in the course of the study. The interview comprised (1) standardised survey items on the households' situation and building characteristics, and (2) a qualitative semi-structured part using interview guidelines on heating and ventilation routines in interaction with the heating system and among the household members. Seven of the eight participating households also completed the interview. Table 1 provides an overview over the households that participated.

Standardised interview data was used to compile case descriptions (e.g. type of building and heating system installed) and put measurements of temperature, humidity and CO2 levels in relation to building characteristics.

The eight households participated in the field experiments for two periods: a baseline period to obtain control values and a test period to obtain treatment values, both lasted about two weeks each. Moreover, data logging continued after removing treatments such that the experimental period lasted between 16 November 2015 and 18th of January 2016.

Two different interventions were used: the 'CO2 meter' and a smart home system. The 'CO2 meter' uses a traffic light system to indicate air quality (CO2 concentration) and provides additional information for temperature, CO2 concentration or humidity on a small display. It is hence a low-level technology with a high level of behaviour dependency as the inhabitant is only directed by the appliance to act, but the system does not act by itself. This device primarily helps to improve the indoor air quality as the user easily recognise bad air quality by coloured lights (<1000 ppm green, >1000 ppm and < 1500 ppm orange, >1500 red). Additionally, the CO2 meter can help to regulate the ventilation duration as one can see when the CO2 level reached a healthy level again. Here lies the potential for energy savings, as it is important that ventilation is long enough to refresh the indoor air but should not be as long as to reduce the heat stored within the building itself significantly.

The smart home system allows users to control their radiators in a web-interface in addition to the normal regulation of the digital thermostat. Time profiles and automatic actions (turn off radiator if windows are open) for radiators can be implemented. Here, a high level of technology is combined with a medium level of behaviour dependency (still: if it is programmed 25°C and has significantly long ventilation periods energy consumption will be high). The potential for saving energy lies in the regular periods of a day where lower temperatures are sufficient, e.g. office and sleeping.

Case	Household situation	Interview partner	Dwelling	Heating system	Intervention
hid 1	2 adults (40, 42 years) 3 children (3, 7, 10 years)	Male	Semi-detached house, owners, 144 sqm, built 1966-1994	Underfloor heating; fireplace 23.000 kWh per anno	CO_2 meter
hid 2	2 adults (50, 60 years)	Female	Flat in apartment house, owners, 98 sqm, built 1929 or earlier	Single-storey heating system 13.300 kWh per anno	Smart Home System
hid 5*	2 adults (N.A.), 1 adolescent (19 years)	Female	Detached house, owners, 2x82 sqm, built 1930-1965	Central heating, controlled by smart home system 1.000-1.500 Euro (gas only) per anno	CO_2 meter
hid 22	2 adults (34, N.A. years), 3 children (0, 2, 4 years)	Male	Terraced house, owners, 140 sqm, built 1966-1994 Windows renovated 2014	Central heating, fire place 13.500 kWh per anno	Smart Home System
hid 25	2 adults (both 70 years)	Female	Flat in apartment house, owners, 120 sqm, built 1995 or later	Central heating, underfloor heating N.A. kWh per anno	CO_2 meter
hid 27	2 adults (32, 40 years)	Male	Flat in apartment house, for rent, 55 sqm, built 1929 or earlier	Single-storey heating system, 1.000-1.500 Euro (gas+electr.) per anno	CO_2 meter
hid 28	1 adult (36 years)	Male	Flat in apartment house, owner, 90 sqm, built 1929 or earlier	Single-storey heating system, N.A. kwH per anno	Smart Home System
hid 29	No interview data				Smart Home System

Table 1: Overview of test households.

As the essence of this investigation is the reduction of energy consumption for heating, the consumption of natural gas in the homes was captured for each period. These values were corrected due to changing weather conditions over time and hence different outdoor temperatures. According to the German directive VDI 3807 and Grinewitschus et al. (2014, p.

1096) as well as Lovric and Grinewitschus (2016), heating degree days have been utilised as follows:

$$GTZ_{t20°/15°} = \sum_{0}^{z}(t_i - t_a)$$

$GTZ_{t20°/15°}$: Heating degree days with heating limit temperature of 15°C
t_i : Mean indoor air temperature (set to 20°C)
t_a : Mean outdoor temperature on heating day in °C
z : Number of heating days
In the next step, the heating degree days of the specific period have to be divided by the long term average heating degree days of one year. In this case the mean value of the city Duesseldorf, close to Wuppertal, has been used.

$$k_p = \frac{GTZ_{t20°/15°}}{G_{m(Duesseldorf)}}$$

k_p : Percentage of heating degree days of specific period over long term heating degree days in %
The following equation forecasts the energy consumption for heating for the whole year:

$$E_{VgP} = \frac{E_p}{k_p}$$

E_{VgP} : Energy consumption for heating for the whole year in $\frac{\text{kWh}}{\text{a}}$
E_p : Energy consumption for heating for the specific period in kWh
We calculated the characteristic value of energy consumption by:

$$e_P = \frac{E_{VgP}}{A_{EP}}$$

e_P : Characteristic value of the energy consumption in $\frac{kWh}{m^2a}$
A_{EP} : Area of indoor heated space in m^2

3.1.3. Results

3.1.3.1. Quantitative Findings

When it comes to changes in temperature, we find significant level and trend effects for 4 out of 8 households. The relative average treatment effects range from -5.9 % for hid25, to +2.1 % for hid29, +2.8 % for hid28 and up to +4,8 % for hid2. In three of four households, we find positive trend effects, suggesting that the negative immediate level effects are cancelled out by behavioural relapse patterns with increasing time. The also significant removed treatment trend in hid29 underlines this finding. Only hid25 shows significant negative treatment effects. As hid25 reacted to the CO_2 meter, the smart home system shows only positive significant treatment effects in the remaining three households. Thus we cannot conclude that the smart home system enhances a more energy efficient indoor room temperature management.

When it comes to CO_2 concentrations, only 2 out of 8 households show significant level and trend effects pre and post intervention.

One household shows a negative average treatment effect of -18 % (hid28) and one household shows a positive average treatment effect of +13 % (hid29). The latter shows a significant negative level effect for the removed treatment measures. As both households have been equipped with a smart home system, the CO_2 meter does not perform any significant effect in any household.

In contrast to the data logging of CO_2 concentration and indoor room temperature every minute, the gas consumption was only captured before and after the reference and intervention period. Without the high resolution of quasi real time data logging, we are limited in drawing conclusions of the intervention on the energy consumption.

Four households show relevant changes in energy consumption for heating after implementing the interventional feedback devices. Three of these four households show a reduction of energy demand, while all of them got a CO_2 meter. The characteristic energy consumption decreases by 12 % (hid5), 13 % (hid27) and 51 % (hid25). The energy demand of one household (hid28) more than doubles after receiving a smart home system.

Our results show that the CO_2 meter as a low-level technological intervention may exhibit significant effects of indoor room temperature, but not for CO_2 concentrations. Thus, we do not give evidence in favour of hypothesis 2). The CO_2 meter did not intervene into heating practices in favour of lower CO_2 concentrations in living rooms.

The smart home system as a high-level technological intervention may exhibit both, significant changes in indoor room temperature and CO_2 concentrations. However, we refuse to accept hypothesis 1) as well, as we only identify positive treatment effects when it comes to indoor room temperature. The smart home systems did not intervene intro practices in favour of lower indoor room temperatures. Interestingly enough, the smart home system does exhibit significant changes in CO_2 concentrations, but in both ways, leaving the effect of smart home systems on indoor air quality inconclusive, too.

The measured changes in consumption of natural gas for heating do mirror the unanticipated findings from the time series analysis of logged data of indoor room temperature. Most relevantly, the smart home system is associated with increase in energy consumption (over 100 % in hid28) and the CO_2 meter is associated to a relevant decrease in energy consumption (over 50 % in hid25).

The results give rise to the question whether CO_2 meters may intervene into heating practices in favour of more energy and resource efficient indoor room temperatures, i.e. lower average indoor room temperatures and smaller temperature drops during ventilation. This may be the case because more regular but shorter ventilation is associated with a more energy efficient indoor temperature management.

3.1.3.2. Qualitative Findings

Heating Behaviour

The research questions addressed in this part are: 1) In how far do comfort temperatures named by participants match with measured values? How do differences between the values resonate in heating and ventilation practices? 2) What do usual doings of being warm and comfortable at home look like and what role does the interaction with materials and technologies play in them? 3) How did participants feel about the interventions used?

These questions were addressed by the following research strategies:

1. Comparing what participants named as their usual comfort temperatures with actually measured values and searching for respective doings in the interviews that might explain differences.
2. Analysing the interview data using a guideline containing the categories of materials, meanings and competences in order to carve out what users describe as relevant in their heating and ventilation routines.[2]
3. Analysing the interview data using the guideline categories of 'previous experiences with smart home or feedback devices' and 'experiences with the intervention' in order to gain more insights into how participants changed routines or not.

As part of the interview participants were asked to name their usual comfort temperatures at home. The question in the guideline did not further specify this in order to leave room for the interview partners' interpretations. It showed that some participants gave reasons for different temperature levels and often differentiated between rooms, stating that bedrooms were not or minimally heated, while higher room temperatures were maintained in the other rooms (mostly the living room). Furthermore, some of the male interview partners expressed gender-based differences, explaining that their female partners would usually prefer higher room temperatures, leading to a kind of conflict about heating routines.

Despite these limitations, Table 22 summarises the comfort levels named by interview partners.

hid	1	2	22	24	25	27	28
Comfort temperatures named by interview participants							
LR	20°C	17°C-19°C	19°C-21°C	19°C-20°C	20°C-22°C	19.5°C-21°C	22°C-24°C
Excep-tions	//	19°C when sitting for longer	Wife prefers 21°C	//	Aiming at constant temp.	Evenings: 20°C-21°C (pref. girlfriend)	//
Mean temperature (SD) measured before intervention							
LR	25.6°C (0.7°C)	20.8°C (0.8°C)	23.5°C (0.9°C)	21.4°C (0.9°C)	24.8°C (0.9°C)	20.6°C (1.0°C)	19.9°C (1.4°C)

Table 2: Comparison between named comfort temperatures and mean temperatures (including standard deviations) measured in the living room (LR) before the intervention.

[2] In this we follow the theory of social practice, and the observation that "focusing on practices, their trajectories and their interconnections, obliges us to attend to processes of ongoing transformation, feedback and related circuits of reproduction" (Shove/Walker 2010, 476) thus improving our understanding of the real interrelations in heating behaviour.

Measurements show some relevant deviations between named preferences and actual temperature levels (e.g. hid1, hid2, hid22, hid25). In most cases the actual room temperature was higher, pointing to a gap which allows for different interpretations: there might be a gap between what participants assume to be their usual comfort levels, it could reflect an interview effect to state what is generally considered a societal „standard" of room temperature (as e.g. reflected in the media) or some kind of problem in set up or control of the heating system.

Meanings associated to heating routines were rated qualitatively regarding how important the dimensions costs, comfort and environmental concern are for the interview partners. Results are presented in the following Table 3. Note that the categories are based on a qualitative assessment and were not measured on a quantitative scale.

	Comfort	Costs	Environment
hid1	+++++	+++	+++++
hid22	++++++	++++++	+
hid25	++++++	+++	++
hid27	+++	++++++	+++

Table 3: Qualitative evaluation of categories of meanings in households.

Two interview partners associated their underfloor heating system (hid1, hid25) with ambiguous meanings, i.e. it provides a very comfortable kind of warmth but is also inflexible and participants wished for some kind of automation reacting to outdoor temperatures. Therefore, comfort is highly rated in both cases; costs also seem to play a minor role as especially hid25 stated:

> hid25: B: *"Yes, so if it [the heating bill] would become horrendously high/ but the older you get, the more sensitive to cold you become obviously. As long as we can bear it, we allow ourselves the luxury. To accomplish the FEEL-GOOD FACTOR is in first place. This is individual for everyone. Someone would say, I'm good with 18 degrees. But I know, that it is not."*

In hid27 costs are foregrounded and together with being aware of problems associated with the building envelope the interview partner is willing to accept some loss of comfort as reflected in this statement:

> B: *"Well in this case it's about the costs, because we know that we live in an old building, we know that we live on the ground floor and that is not going to change for us, I have lived my whole live on the ground floor, we have a cat and it has to walk in and out. And we have agreed/ or because we know we have to accept the constraints. [...] Hence we are aware of what we have and that we have to deal with constraints, it was very important to us to come down from that 110€."* (T27)

For hid1 the highest meaning connected to environment was found as this household stated to be willing to invest in future heating technologies (e.g. combined heat and power unit) for reasons of sustainability even if it would not pay off economically. The interview partner reflected on resource use of heating with natural gas and put it into perspective to his own personal interest in sustainable agriculture/food.

Ventilation

As introduced above, the CO_2 feedback was used as an intervention to test for changes in ventilation routines, which can influence air quality (health aspects, improved conditions against mould formation) and heating energy consumption.

Therefore, we here look at descriptions of usual doings of ventilation. Hid25 and hid22 were chosen for a deeper look into ventilation routines.

The interview partner in hid25 described her usual routine of very long ventilation periods. Despite of being aware that this kind of long ventilation is not optimal she states she sometimes forgets to close the window, but apparently this doing is also associated to feeling fresh air:

> hid25: B: *"Yes, yes. That is a (laugh) bad habit of myself. I always rip all of the windows OPEN; there is always ventilation in summer and whatever. And now, even if it's freezing, I KNOW for sure (coughs) [...] yes sometimes I forgot it, then I was away and had the window open and when I came back, everything was cold. Of course it is unhealthy. It is very different. Sometimes I had it open for an hour. It depends. Or sometimes for half an hour."*

She also describes conflicts with her husband about leaving the windows open for such long periods.

For hid22 comfort was foregrounded as a meaning since the interview partner stated he was unwilling to pay attention to turn down the heating every time during ventilation and expressed a strong wish for automation. While for this reason the case appeared interesting when just looking at interview data, measurement before, during and after the intervention (smart home system) does not allow to conclude any significant effects.

Experiences Regarding the Interventions

In this section we concentrate on experiences of users in interaction with materials specifically concerning the interventions and how they incorporated them into heating and ventilation practices.

We zoom in into results on the CO_2 meter in two households (hid 25 and hid27) in order to exemplify some of the implications.

> hid25: *" […] and because of that I am very/(coughs) very happy about this meter, this CO_2 meter. It shows, IF it is correct, I*

> *don't know, anyway THIS is an device, I directing myself to it, [...]. But only BRIEFLY and in the past, it had the window LONG open and my husband shouts hurrah, when I do that, he doesn't like it AT ALL and thinks it is complete paradoxical but I might have overkilled it. When I see now how FAST this meter, if it is the same situation again, it switches over to green so FAST. SO LONG as I had ventilated before, well obviously I don't have to do that again."*

These kinds of long ventilation periods can partly be shown in the corresponding CO_2 graph:

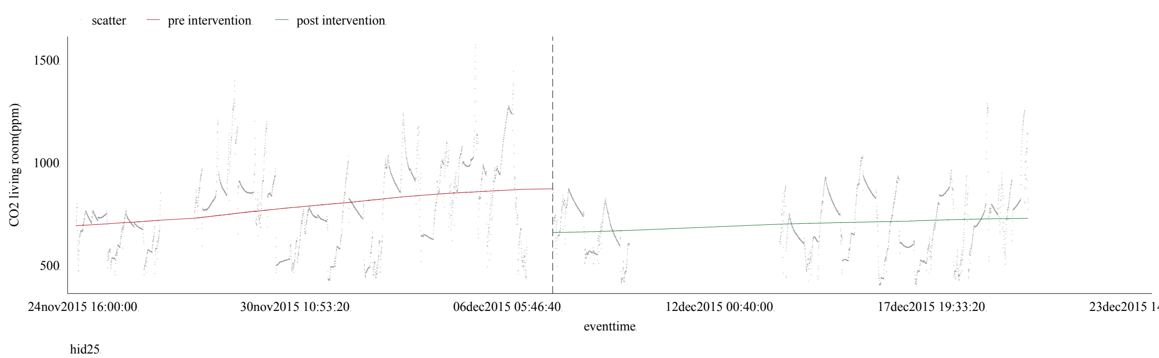

Figure 4: Single-group interrupted time series analysis of CO_2 change for hid25.
Note: ITSA with higher-order autoregressive models and Newey-West standard errors.

In the pre-intervention phase some peaks of CO_2 concentration above 1000ppm can be seen and longer periods of values around 500ppm, pointing to the long ventilation cycles. The corresponding temperature graph also shows drops of temperature in these phases from the usual ca. 24°C to around 20°C. Especially in the early intervention phase – except for one week of absence (no values) – peaks are much lower and ventilation periods also appear to be shorter. Drops of room temperature also appear to be less frequent, although still present.
In the case of hid27 especially in the early intervention phase ventilation was much more frequent and CO_2 concentration is much less. This behaviour is reflected in the following statement:

> hid27: *"[...] we look constantly on this display and I always say: Come on, let's open the window, it is yellow again. My girlfriend said: Now listen, when it's yellow you CAN open but you don't have to. Well from this on, we pay heed to it constantly. Every few minutes, we look at it if our carbon dioxide concentration is in the green zone."*

In hid28 we could observe constantly higher indoor temperatures because the participant did not set up a nocturnal fall in the smart home device.

> hid28: *„And now I did not yet make it to set up profiles in the new system. Your colleague explained to me but it unfortunately only works on the PC and I have it on my tablet and on the other thing, there you can turn it up and down but not set up profiles. […] I seriously thought about purchasing this system that I now got on a rental basis from you, so to speak. Because I really find it comfortable. A, because/ I did this two or three times, but I didn't know, I turned up the heating in the evening and then I forgot – because I haven't set up profiles yet – to turn it down again. And then in the morning on my way to work or so I really turned down the heating underway. And there I have the feeling that you are more sparing with it and also /not just financially but also not use energy unnecessarily."*

This aspect is very well reflected in the graph below where in the intervention the typical falls of the pre-intervention phase are suddenly absent, leading to a generally higher and very constant indoor temperature. This is clearly an effect of interaction with the new device, which was not yet incorporated into usual routines and led the participant to forget that the heating was still on. Furthermore, the interview partner described how he had turned down the heating remotely a couple of time, but as the temperature curve shows, apparently to a higher level compared to how the nocturnal fall was set up before the intervention.

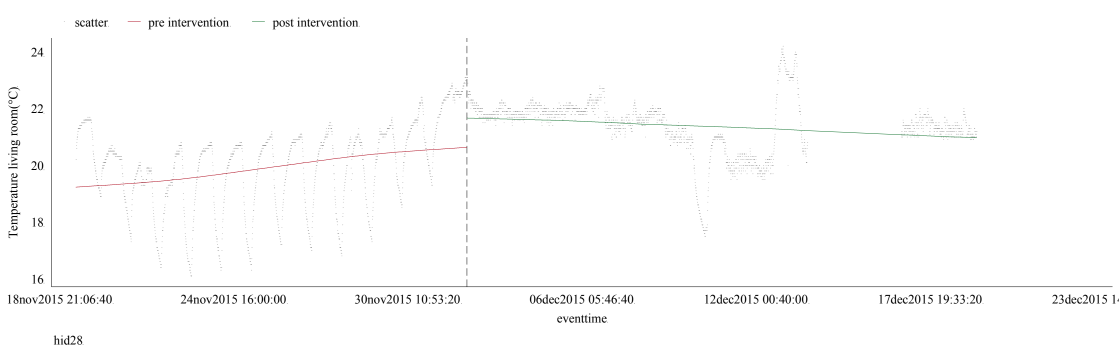

Figure 5: Single-group interrupted time series analysis of temperature change for hid28. Note: ITSA with higher-order autoregressive models and Newey-West standard errors.

3.1.4. Conclusion

The results from rigorous experimental testing revealed no significant level effects (that is the overall behavioural change after introducing the intervention) and trend effect (that is the marginal behavioural change over time after introducing the intervention, i.e. slope effect) of the CO_2 meter in terms of CO_2 concentrations at the same time (both effects constitute the average treatment effect). Our results do not support our hypotheses, that a CO_2 meter changes the households of CO_2 concentrations significantly. The same accounts for the smart home intervention. We find only positive significant changes in terms of indoor room temperature. Thus our results do not support the hypotheses that a smart home system leads to more energy efficient management of indoor room temperature. The identified changes in energy consumption in terms of natural gas do underline this finding. Those overall results are in line with previous research on this matter. Bettin and Buhl (2016) find that motivating feedback designs do intervene more effectively than harshly intervening devices, which rather strive to automate and thus eliminate the influence of user behaviour eventually. Too coercive interventions into user behaviour designs may even lead to counterproductive effects with respect to changing indoor room temperatures.

At the same time, the CO_2 meters *do* affect indoor room temperature while the smart home system affects CO_2 concentrations significantly in both directions - positively as well as negatively. Again, the changes in consumption of natural gas for heating do underline the finding, that a CO_2 meter may as well affect energy consumption (in the desired direction, i.e. negatively). Therefore, we do support the findings from previous studies, that eco-feedback affects behaviour significantly, but remain rather inconclusive when it comes to specifying the direction of the effects. In this regard and as presented in the method section, the study would have benefitted from larger sample sizes and a control group.

The results suggest that smart home systems as well as CO_2 meters may lead to changing airing and heating behaviour for some households, however, we only find significant effects in 4 out of 8 households, leading to rather inconclusive and ambiguous results that give rise to new hypotheses for future research. Our findings lead to the question whether CO_2 meters may intervene more effectively into heating practices in favour of lower indoor room temperatures due to more energy efficient, i.e. more regular but short ventilation. In turn, smart home systems may exhibit less energy efficient heating practices, due to flawed human-technology-interaction, i.e. false applications and set-ups of the smart home systems. Further research should focus on those hypotheses and realise test settings that allow conducting research in relation to a control group and larger samples in order to provide more concise and representative conclusions.

In this respect, our qualitative interviews revealed that those ambiguous effects may result from various reasons stemming from competences of users and their meanings behind heating practices. We identified two main reasons with respect to heating practices. First, the smart home system calls for enhancing the competences of users in order to set up the systems properly and truly help users to manage their energy consumption more energy efficiently. Second, comfort may trump energy and resource efficiency concerns which leads to inertial behavioural changes. Comfort is the most important meaning behind heating practices for interviewees. At the same time, measured temperatures are usually above perceived and preferred (stated) comfort indoor room temperatures. The positive trend effects after intervening in heating practice may support the qualitative findings and hint the problem concerned with initial comfort temperatures that users desire to meet despite technological interventions into energy behaviour or energy and resource efficiency concerns. In this respect, our results support previous findings on the issues and problems of changing heating practices in favour of more sustainable behavioural pathway: We propose that high-level technological interventions like smart home systems need to address problems linked to human technology interaction. A more deliberately user-integrated design of high-level technology driven feedback may overcome shortcomings in terms of technology handling. In addition, high as well as low-level technology interventions into heating behaviour need to tackle meanings of users that address comfort rather than energy or resource efficiency at home in order to support more sustainable pathways of behavioural change.

3.2. Real-World Experiment

In this section we present the processes, results and learnings from a RWL on food waste reduction in a city quarter of Wuppertal, Germany. The initiative that was the focus of our research concerned voluntary workers and the participants of a local food sharing activity. We investigated the potential of this grassroots movement implementing sustainable food consumption transitions by presenting the experience of this citizen initiative. We provide in-depth insights into our empirical work with the social movement “Essbarer Arrenberg”, which we supported and worked with from February 2015 to January 2016. The experiment started on February 2015, and was accompanied by the Wuppertal Institute since the first orientation-founding phase – on-site research was carried out from April until December 2015. The food sharing initiative saves and distributes food collected from supermarkets and shops (and occasionally also provided by private people) that, otherwise, would be thrown away – and thus wasted – in spite of being still edible.

3.2.1. Background: Sustainability in the Food Domain, Food Waste and Food Sharing

A peculiarity of the food sector is that food, contrary to other consumption areas such as mobility or leisure time activities, is a basic human need, and also plays a very important role in people’s social life and welfare (Tischner et al., 2010). Conventional food production, retail and consumption processes and patterns have manifold negative impacts on environment, human and animal health – including: soil, water and air pollution, soil erosion and degradation, eutrophication, deforestation, climate change, animal welfare issues, loss of genetic and cultural diversity, etc. (Tubiello et al., 2014; Pimentel, 2006; Steinfeld, 2006; Foley, 2005). Over recent years, a series of initiatives to promote sustainable food production and consumption at the local community level have emerged, such as farmers’ markets or the Italian “Solidarity Purchasing Groups” (GAS), aiming at (re-)connecting primary producers with final consumers. Different practices have been extensively analysed, and the findings have originated a fairly wide literature generally labelled as “alternative food networks” (Sage, 2014). The role of social movements and grassroots innovations in the food domain is increasing, contributing to a shift of power from the producer to the consumer within the food supply chain (Oosterveer, 2012: 155). Consumers have an active role to play in (re-)shaping the food system: in sustainability transitions, indeed, change first takes place within individual communities (niches) and might then diffuse to other communities as a social movement – potentially leading, in the end, to socio-technical changes in the mainstream institutions (Seyfang & Haxeltine, 2012)[3].

In this regard, the historical development of the role of the consumer over the last 50 years is significant. Consumers’ power, sensibility and awareness about environmental and social issues related to food production and consumption have increased, and they have become able to take a more active role in change processes (Oosterveer, 2012). For example, a growing

[3] This concept of “green consumerism” has also been criticised and accused of only providing an illusion of sustainability (Akenji, 2014): rebound effects, in fact, can potentially nullify the improvements (see e.g. Santarius, 2012; Jackson, 2009). Moreover, replacing conventional goods with ethically produced ones does not automatically reduce resource consumption (Akenji, 2014).

number of independent social movements has started to emerge, producing or procuring food in regional and urban contexts with the aim also of changing agri-food networks structures (see e.g. Sage, 2014; Brunori et al., 2012). However, their effectiveness in terms of real resource saving and GHG-reduction is as of yet unclear. More over the broader public is not always aware of actions that potentially could make a significant difference. Improving the application of manure or the efficiency of crops could be more influential than focussing on urban farming or the so-called "super foods". Besides, the existing niches need to develop the critical mass for providing a complete alternative for food provisioning, and to directly target sustainability (Balázs, 2015).

In addition, wide-ranged food losses and waste reduce resource efficiency. Studies suggest that as much as one-third of food produced for human consumption is lost or wasted globally – that is, about 1.3 billion tons per year (FAO, 2011). Food is lost or wasted throughout the whole supply chain, from field to fork – i.e. from the agricultural production to the final private consumer. In medium- and high-income countries food is mainly wasted in the last stages, meaning that it is thrown away even if it would still be suitable for human consumption.

According to FAO (2011), on a per-capita basis much more food is wasted in the industrialized world than in developing countries. They estimate the per capita food waste by consumers in Europe and North America to amount to some 95-115 kg/year, and to only 6-11 kg/year in sub-Saharan Africa and South/Southeast Asia.

In Germany, food waste occurs during production, post-harvest and processing, as well as at the stage of final consumption. Every year, German private households throw away food worth about 22 billion Euro – that means about 260 Euro/person/year, and round 1,000 Euro per year in a family of four people (10-14% of the total expenditures for food and non-alcoholic beverages; Kranert et al., 2012). At the level of retail and consumption, households are the biggest food waster (61%), followed by restaurants and out-of-home catering facilities (17%) and industry (17%), and shops (5%) (ibid.). About 82 kg of food pro capita are wasted every year: mostly fruits and vegetables (44%), but also bread and backed goods (20%), leftovers (12%), milk products (8%), drinks (7%), meat and fish (6%). 47% of food waste, i.e. 2.37 million tons (29 kg/person/year), is avoidable (ibid.). Governmental and political initiatives, such as the national campaign "Zu gut für die Tonne!" ("Too good for the garbage can!"), address this concern and try to raise awareness. In addition, individuals and non-governmental organisations also try to reduce food waste. One of the food movements tackling the issue is that of Food Sharing[4].

The organisation has been active since 2012 and it resulted from independent initiatives to address food waste. At the end of 2011, the documentary-film by Valentin Thurn "Taste the Waste" fostered a popularisation of the issue and debate. In March 2012, a first collaboration with an organic supermarket chain was initiated in Berlin. In summer, the newly formed Foodsharing Association started a crowdfunding campaign in Germany, collecting enough money for developing an online platform – showing that there were already many people sensible to the issue and ready to invest money in the idea. *Foodsharing.de* was released on December 12th, 2012. Started between Berlin, Hamburg and Cologne, the Association's activities involve now people from all over Germany: thanks to the website, food sharing can take place wherever people are interested in it (foodsharing.de, 2015; Rombach & Bitsch, 2015; Ganglbauer et al., 2014). Different kinds of initiatives are present within the organisation: private people exchanging food (the so-called "food baskets") among them and organising their cooperation through the online platform, but also the organised collection of food by volunteers in shops. These volunteers, who have to become "official" foodsavers by

[4] www.foodsharing.de

passing an online test and being instructed by a more experienced foodsaver, arrange also the food distribution for free in a defined place (a so-called "Fair-Teiler"). There are strict rules governing for example the cleaning of such distribution points, as well as a sort of "code of conduct" for the volunteers. All such initiatives in Germany are coordinated by the foodsharing.de network, which is organised in a highly hierarchically form. First, there are the so-called "foodsavers": they are allowed to go to supermarkets and shops, and ask for leftovers. Ranked above the foodsavers are the so-called "ambassadors". Every city has an ambassador, who is responsible for discussing the eventual problems of the different foodsharing locations and who is the only one allowed to speak to supermarket chains. The network is a very professionalized initiative and is active in all parts of Germany, the Netherlands, Luxembourg, Austria and Switzerland.

3.2.2. The Food Sharing RWL in the Arrenberg Quarter

As stated above, we investigated a foodsharing initiative developed in the framework of a city quarter movement called "Essbarer Arrenberg" ("Edible Arrenberg"). Arrenberg is a neighbourhood of Wuppertal, an industrial city south of the Ruhr area, North Rhine-Westphalia (NRW), in the western part of Germany. With its nearly 350,000 inhabitants, Wuppertal is the 17th largest city of the country. It is the industrial, economic, educational and cultural centre of the area called "Bergisches Land". Some 5,550 people live in the Arrenberg neighbourhood. The district is multicultural, shaped by different ethnicities and voluntary engagement (see http://www.aufbruch-am-arrenberg.de/index.php/de/)
Our RWL approach follows the four-step logic of Talwar et al., and our research was developed along the four phases shown in Figure 3:

1. Phase 1: Problem definition. Starting from a first assumption we investigate the establishment of the foodsharing initiative at the city district Arrenberg in Wuppertal.
2. Phase 2: Development of the research strategy. We designed a mixed-method approach based on both observations and qualitative interviews, to directly and iteratively exchange with the persons involved.
3. Phase 3: Creation of results using co-design. After informing the activists about our preliminary findings in the research process solutions for present and emerging in the initiative were developed in workshop settings.
4. Phase 4: First application of the results obtained, by creating experimental interventions for all participants. The interventions were carried out within the last three months of 2015[5].

The "Foodsharing am Arrenberg" is embedded into a larger context of food oriented activities, although it is not directly affiliated with them. It is one of three foodsharing initiatives in Wuppertal, which are located in different city districts. The other two had started their foodsharing activity before, and were therefore larger successful in terms of number of participants, number of voluntary helpers and range of products offered when the experiment started. The initiatives operate rather freely and independently based on the voluntary engagement of the activists.
The "Foodsharing am Arrenberg" involves the organised collection of food from supermarkets, bakeries or other shops and restaurants by volunteers. These volunteers – who, to become "official" *foodsavers*[6], have to be instructed by a more experienced *foodsaver* and

[5] A few more results are going to be applied in the year 2016, e.g. suggestions based on resource use calculation.
[6] All foodsharing initiatives in Germany are coordinated by the foodsharing.de network, which is organised in a highly hierarchical form. The bottom rank is constituted by the so-called *foodsavers* on the local level, who are allowed to enlist for the collection of food at participating shops as well as for asking owner-operated ones to join the network. Ranked above the *foodsavers* are the so-called *ambassadors*, who are present in every city.

to pass an online test – also arrange distribution these foodd in a defined place – the office of the "Aufbruch am Arrenberg" Association, which promotes cultural activities in the neghborhood. Within some limits related to decent behaviour, food is distributed unconditionally to anyone showing up. There are strict rules about food and health issues, e.g. regulating the cleaning of the distribution point, and there is a sort of "code of conduct" for the volunteers.

The whole observation phase was supported by participatory observation, qualitative interviews using a problem-focussed survey to interview participants to the foodsharing (n=54) and workshops with foodsavers using the methodology of future workshops (n=3). A researcher attended all the foodsharing activities, to observe the unfolding events and note down all occurrences into a research protocol. The foodsharing office is hosted in the office of the Arrenberg city quarter initiative. The food to be shared is firstly prepared for distribution (for example, foodstuff already gone bad is sorted out) and then handed out by two to four official foodsavers. The food products that were offered were recorded by the attending researchers in an observation protocol (inspired by traditional household protocols), together with information about provenience, delivery and other observations. During the openings, it was observed how the foodsavers interacted with the participants, how the visitors reacted to the offered products, which foods were preferred and how many products every participant took. Also, data about gender and (assumed) age of all the participants were recorded. Almost all the visitors capable of speaking the German language good enough to answer a few questions (some of the participants with an immigration background barely spoke German) were asked for participation in the standardized interview; up to December 15th, 2015, 54 participants had been interviewed (each one only once). The number of interviewees each Thursday was very variable: at foodsharing-days with a high number of "new faces", up to 5 people were interviewed for about 10-15 min; during events in which all the participants had already been asked, no interview could be conducted.

The workshops with the foodsavers took place at the Wuppertal Institute for Climate, Environment, Energy GmbH. They were conducted before the starting of the foodsharing in Arrenberg and then periodically, to reflect with the foodsavers on the development of the initiative and discuss their impressions, the eventual difficulties encountered (for example in the food provisioning) and how to overcome them.

To facilitate a proper understanding of the foodsharing in Arrenberg, some information about the participants is also necessary. During the first part of the observation period, their number remained constant around 20-25. At the end of June and in August 2015 the number of visitors dropped noticeably, mostly because of difficulties in food provisioning – in those months the initiative could not continuously provide enough food and sometimes it did not even take place because of this (see chapter 4.1.1)[7]. The initiative started to recover from October 2015 on, when food products were again reliably provided. Nonetheless, in that phase the number of visits remained very fluctuating and unpredictable. At the last opening in September, for example, the participants were only 4 – despite plenty of food on offer and

They are responsible for discussing the eventual problems encountered by the local initiative and are the ones allowed to speak to chains of supermarkets or retailers.

[7] As mentioned in chapter XXX, the development phase was stimulated by procurement insecurities, which lead to a change in food provision activities in the middle of the year. In this phase, the numbers of visitors became unstable and decreased for a few weeks. After a short re-evaluation, food products started being supplied again by a company-based network that included smaller shops and an organic supermarket. Furthermore, the cooperation with a foodsharing initiative in another quarter of Wuppertal was intensified. Thus, by the end of summer, the new partnerships made it possible to ensure a better quality and a quite high variety of food offered – particularly bread, dairy products such as yogurt, cream and fresh cheese, vegan products such as soya yogurt and tofu, and lots of varying seasonal vegetables and fruits.

good weather conditions. During the first nine months of the initiative, such patterns seemed to be difficult to comprehend and foresee (see Fig. 6).

Fig. 6. Visitor development between May 21st, 2015, and December 17th, 2015.

Some tentatively explaining factors might be represented by personal occurrences or social events on the side of the habitual visitors, school holidays and also weather conditions (less participants showing up when it rained).
However, a much higher number of participants could have potentially become a difficulty in this phase: the initiative, in fact, is hosted in the limited spaces of the "Aufbruch am Arrenberg" Association, where the foodsharing is carried out parallel to the habitual office activities of the organisation. The limited size of the room could hence become an element of difficulty, especially during the autumnal and winter months that do not allow carrying out activities outside as in summer (see Fig. 7). The food savers, however, do not have the possibility to pay a rent for a new space. This is an issue that emerged already during the first months, and alternative solutions are being searched since then.

Fig. 7. In summer and spring, people can gather outside the Aufbruch am Arrenberg Association's office.

The great majority of the visitors were women, and the gender ratio averaged around slightly more than two female per male participant. Until the middle of December 2015, the foodsharing had been visited more than 400 times (excluding children): of these, about 70% of the visitors were by women, and 30% by men. Also more than 120 visits of children were counted within the observation phase. Most adult visitors belonged to the age group between 30 and 50 years. About half of the participants had become aware of the initiative either through the foodsavers, family, friends or neighbours. Personal relations and word of mouth thus played an important role in the process. A significant part of the visitors consisted of single mothers and unemployed people, as well as of people working in the social and health-care sector. Also, a high share of the visitors had a migration background. Apart from a few exceptions, all participants lived in the neighbourhood (all lived in Wuppertal), and most of them walked to the foodsharing; only a few came by public transport or by bike.

Two actions were reported by the participants to be most associated with taking part in the initiative: either meeting other people, or being already en route to/from other activities such as coming from work or the university, taking a walk with the dog or going with kids to the nearby park.

Although most of the visitors claimed to take part in the foodsharing to avoid wasting food and to support the initiative, only few of them explained this in terms of sustainability or as part of particularly environmental-friendly lifestyles. Only two people showed deliberately ecological motivations. Saving money appears to be linked to the social background of the visitors. It was especially – but not solely – found amongst participants with a migration background and a limited command of the German language as well as amongst the youngest visitors – who just quickly came in, took some products and left.

It is noteworthy that, overall, the concept of foodsharing was very positively considered. Almost all visitors claimed that food that is still edible should by no means be wasted and that such initiatives should be strongly supported and further developed also in other districts and cities. Some participants were very surprised that so much food in good conditions would have been simply thrown away. Almost no one reported to have ever thrown away products taken at the foodsharing, apart from a few cases where the food had already gone bad. Interviewees stated also that the main reasons for them to take part consisted in the appreciation of foodstuff, i.e. wanting to contribute to reducing the waste of still edible foods, and in saving money but supporting the initiative and meeting other people were also mentioned often. The initiative appears to have developed an important social attraction and function in the neighbourhood – in this way fitting into the concept of reducing individual consumption's ecological impacts by promoting local points for interaction (Speck, 2016).

The interviews and the observations showed that the initiative's social dimension was an important motivation for people to attend the foodsharing and became a strong positive and unexpected emergent effect. The possibility to meet (new) people, chat with the foodsavers, and the overall open and pleasant atmosphere – was one of the important reasons why the initiative was appreciated. In this context, the initiative seems to have developed an important social sustainable aspect, in the sense of providing an answer to "social" (e.g. communicative) needs present in the neighbourhood. One exemplary case of such needs is represented by those district's inhabitants who live alone and are glad to have a possibility of meeting other people through participating in foodsharing.

Food-related practices are embedded into habits, time regimes and lifestyles, e.g. related to mobility and working/studying or leisure times. Within that, the ecological potential of the foodsharing initiative seems to be high, if the framework as it is now is promoted in the future. However, it was also shown that foodsharing can involve rebound effects when the consumers employ the money saved for buying e.g. animal products, exotic foods or other resource intensive goods. Some visitors also claimed that foodsharing gave them the opportunity to consume more expensive food products, such as organic fruits and vegetables, that otherwise they would have been too expensive for them. The money saved was reinvested for buying other foods (e.g. meat, not very present at the foodsharing) or schoolbooks for the children. Other participants explained that the foodsharing had partly modified their shopping and eating habits, allowing them to consume more fresh products more often, as well as leading them to try new recipes. To scientifically deal with this problem was seen another open issue for further research. Therefore one of our aims was to identify the resource use and saving potentials of foodsharing activities. We therefore calculated the average material footprint (Lettenmeier et al. 2009) per person/week taking into account the average amount of food products distributed at “Essbarer Arrenberg”. The calculation of the saving potential was based on the assumption that participants substitute some of their “normal” shopping behaviour with the participation in foodsharing events. The result of our calculation was an average material footprint of 10,31 kg per person at a weekly foodsharing event. This corresponds to an average material footprint of 536 kg per person in a year. Visitors who regularly get food products at Arrenberg foodsharing events have therefore the potential to save up to 536 kg resources per person in a year, based on the assumption that the “non-wasted food” substitutes that usually bought. When calculating these results it is important to keep in mind another important factor for the evaluation of foodsharing: the possibility of rebound effects, for example because of resource-intensive transportation. If visitors drive to the foodsharing by car (with an assumed travel distance of 5 km and a car from 2004 with an average fuel consumption of 8.4 liters/100 km), they “use up” almost 25% of the saved material footprint[8]. However, in the case of “Essbarer Arrenberg”, most of the visitors lived in the neighborhood and come by foot, bike or public transportation, rendering this weak spot unimportant in this case. Other rebound effects could derive from an increased purchasing of animal-origin foods, which are particularly resource-intensive, made possible by the money saved thanks to the foodsharing. Also, money saved through participating in the foodsharing may be used to obtain other, more resource-intensive products. In this case, participating in foodsharing may even increase a person’s or household’s footprint. The interviews with participants indeed show, that this can be the case.

The insights validated our hypotheses that grassroots initiatives can indeed stimulate new consumption practices and allow consumers-citizens to take a new, more active role. Consumer-citizens can indeed become agents of change towards sustainability by adopting/introducing new (sustainable) lifestyles, practices and consumption habits as well as new products and services (Grabs et al. 2015). By doing so, they can both raise awareness about sustainability-related issues and offer potential solutions for the group members and the community in which they operate. Consumer-citizens could therefore play a key role in fostering sustainable consumption and sustainability transitions. On the other side, to our surprise, we found that many consumers – especially non-German speaking participants – did not know or understand what foodsharing was really about, nor did they care: for them, it was just a way to obtain food for free.

However, only a couple of visitors reported to think that such a micro-level initiative could also have systemic effects. The results of the interviews show that the project modified the food provisioning habits of a significant share of the users: about 68% of the interviewed participants (n=34) explained to have already taken part in a foodsharing initiative. Of these, nearly a half stated that taking part in such initiatives had influenced their purchasing behaviour, and 13 people reported to buy less when shopping. A conscious ecological impetus of food saving therefore appears to be a fundamental concern only for a few participants and the foodsavers. Within the examined case, the engagement of the consumers towards the foodsharing initiative was extremely limited and mostly “passive”: in general, the majority just took the food and chatted a bit, but they did not see themselves as an active part. Nevertheless, a broad audience that is often not reached by sustainability communication campaigns, such as people with immigration background and a poor command of the German language, can be reached through such initiatives and therefore potentially be sensitized for and contribute to a sustainable cause through their behaviour.

[8] Assumption: private car (2004 with 8,4 l/100km) – travel distance 5km.

A broader community (or community of practice) around the initiative and triggered by its activities therefore seems to be lacking, as well as the development of visible and important social learning processes spilling over into the quarter or the city. Successful innovations presuppose rather wide-ranging learning processes (Beers et al. 2014); thus, the overall potential of this foodsharing initiative as a system innovation appears to be currently strongly limited. Further research about this quite unexplored potential and its leveraging for sustainability transitions in food consumption is needed.

Important interventions regarded regular and spontaneous workshops with the activists. These took place at the Wuppertal Institute for Climate, Environment and and Energy They were conducted before the starting of the foodsharing in Arrenberg commenced and then periodically. We reflected with the foodsavers on initiative's development, discussed their impressions, the eventual difficulties encountered and how to deal with them. Overall these meetings were felt to be effective as the parties could learn and discuss first hand. Moreover, observation by one party or person could be discussed, verified (or falsified), and acted upon. Spontaneous workshops concerned immediate problems (for example in food provisioning), necessities to act, and the identification or development of solutions. Through this e.g. new sources of food waste and an understanding for the regional meaning and boundaries of the initiative were derived.

Another field for intervention regarded knowledge and skills to use and cook specific foodstuff. It was for example observed that some, especially more traditional vegetables (e.g. mangel) were initially not taken because the participants did not know how to prepare them. It was thus decided that the promotion of private cooking skills could form an important action to support the participants and to foster a sustainable nutrition strategy through taking part in foodsharing. In this way it was sought to enable participants to actually utilize less well-known food on offer. To this avail we created a recipe collection to support the visitors and to stimulate a practical and healthy use of the food.

With concern for the heterogeneous and in some cases not well-educated or well-German-speaking target group, simple recipes were provided by the Wuppertal Institute. Some of them included pictures, cooking advice and additional information, e.g. on why certain ingredients are particularly healthy. Recipes were prepared following criteria of simplicity, availability of ingredients and seasonality. In order not to overwhelm the visitors, two or three new recipes were made available every two weeks during the foodsharing event by the researchers and the foodsavers. However, it was found that only few of the participants actually made use of them, which led to further simplification. Even then interest was low. We attribute this to the interest of the participants in obtaining food rather than in sustainability criteria, as it were the more educated, sustainability-contious participants who were interested in and using the recipes. The findings on this intervention show how RWL also have to be seen as experiments, which may (in part) fail. However, significant learnings were obtained on the different target groups and their (communicative) need, so that the process delivered interesting research results, while the outcomes were less significant. We will discuss this in more detail in the concluding section of this paper.

3.2.3. Conclusion

The food sector is formed by several different components, and consumers play an important role. Many incremental changes are occurring, partly as a result of technological innovations, partly because of pressure from society. The outcome is a partial, gradual adaptation of current regimes, in which also minor changes can have an impact on the environment (Zwartkruis et al., 2015).

Our research provided deeper insight into the importance of involving social aspects when addressing ecological sustainability, as the socio-economic motivation for participation (being part of the community, a forum for exchange and meeting, saving through sharing and the ability to obtain food at all) played a major role in peoples' motivation to take part, while the ecological motivation was more of a side or emergent effect. Foodsharing thus plays an important role in the social dimension of sustainability, e.g. by answering a series of needs of the neighbourhood's inhabitants and potentially contributing to the development of forms of well-being beyond mere material consumption. On the other side, however, its contribution in terms of increased awareness about issues related to food waste, ecological sustainability and healthy nutrition appears to be limited. This however, shows a broad gap between the interests and aims of the activists and the participants.

A better comprehension of foodsharing's potential to increase public awareness about sustainability-related issues – not only food waste but also issues of sustainable consumption and healthy nutrition – is required, too. Further research should therefore be conducted to better understand whether the predominant motivations for taking part in such initiatives are related either to ecological or social values, or to economic or social needs, and if these could be harnessed to improve ecological consciousness. Future research should also try to comprehend the role that might be played by potentially subconscious environmental values or related beliefs. Lastly, another aspect requiring further analysis regards the economic and ecologic rebound effects. It is not clear how people use the money they save thanks to foodsharing: are these economic resources used e.g. for buying green food products, for less environmental-friendly activities such as buying more meat or exotic fruits, or does any other rebound effect appear?

Finally, regarding the methodological lessons we were able to draw about RWL, we could validate the general usefulness of the approach, but we also found that the high degree of scientists' involvement requires guardrails to ensure their objectivity and therefore the study's validity. Moreover, we suggest that effective PAR may need time-spans that are longer than usual third-party funded research projects. Overall, since niche innovations and social learning processes develop over medium-to-long time periods, there is also a need for more longitudinal studies, to better assess the potential of such initiatives especially with regard to their ecological impact and contribution to sustainability transitions. More detail on the limits and barriers to transformative experimental research can be found in chapter 4.1.1.

4. Discussion

In this part of the discussion we want to address some of the challenges and open questions that transformative research may be faced with. After this, some solutions and preventive measures to ensure the quality of research are suggested in the following section.

4.1. Transformative Research

The two experiments presented and discussed above feature rather different approaches on the continuum of experimental research towards a transformation to sustainability. However, both have the commonality of actively interfering with existing systems to explore and – more or less – directly transform these into more efficient, more sustainable "entities". They hence show the bandwidth transformative research may take (see also Talwar et al. 2011, Figure 3). Also, both experiments provide very different insights into the unfolding and influence of

research on sustainability transitions. However, both have proven effective in either finding hints towards the applicability, effectiveness and room for improvement of certain interventions (SLL) or understanding, involving, coaching and consulting initiatives (RWL). Both RWL and SLL may hence be adequate tools within a transformation.
From this we may already deduct that it is a) difficult to speak of transformative research for specific applications and b) that this transformative research hence needs tailoring to the specific needs involved with a certain research question or transformative purpose. The concept by Talwar et. al. can provide a heuristic for this but may not be sufficient. In the following sections we will address the conditions under which these suggestions may actually be realized and what advantages, barriers and challenges may exist for transformative research.

4.1.1. Imponderability and Challenges of Transformative Research

In their process, both experiments exhibited some of the non-predictable uncertainties that may come with less controllable experimental environments. These will shortly be presented and discussed here. In SLLs this referred for example to the reliability of the players involved. In our case, one company, whose products we were originally meant to be subject of the Lab, decided to quit the experiment. The reason behind this was a change in corporate strategy and resulting adjustment in the relevant department's innovation budget. The SLL was significantly delayed and affected by the decision until an alternative solution was found. In the case of the foodsharing real-world laboratory, uncertainty did not affect the research cooperation but the development of the initiative. During the research process the behaviour of the initial food supplying company led to the need to completely readjust the food procurement by the initiative. Moreover, from February 2016 on, and thus directly after the intervention was finalized, a significant change in the visitor structure occurred. Suddenly, a specific group of migrants who were only partly living in the quarter became the largest group of participants. This eventually resulted in a clash of different habits, culture and expectations that in turn led to absence by the original participants who felt alienated. Subsequently, new regulations for participation had to be introduced e.g. concerning the quantity of foodstuff each participant was allowed to take or regulation on the number of participants allowed to be in the (small) office at a given point of time.
Especially the real-world labs are also dependent on the motivation of the initiative's activists to a) keep their initiative going, and b) to keep cooperation with the researchers alive and going throughout the projected time of the experiment (and the researchers' willingness to adhere to the goals and limitations of the activists). In the face of failure, stress and uncertainty, private voluntary workers cannot be (and should not be) coerced by researchers, to keep a failing project going. On the other hand, researchers active on third party funding are in dire problems when a project fails amid project time. We will come to the implications of this problem later in this chapter.
Another challenge certainly arises from the normativity of transformative sustainability oriented research. Aiming to improve a given situation towards another, more sustainable state requires judgement on what exactly qualifies such an improvement. While this may be rather obvious in some circumstances (e.g. reduction of carbon or material footprint through improved process efficiency) especially socially oriented RWLs may be faced with some dilemmas. Transformative research towards city quarter improvement for example may face different, legitimate but conflicting interests (e.g. between owners and tenants for fears of rising costs, gentrification, etc., cf. Echternacht et al. 2015 for more detail). Solving these conflicts may then become a task for the researcher. However, the decision on what is right or

wrong may not be that obvious, and notions of transformation towards a “good life” may be ambivalent in such a case.

Similarly, the future orientation of both SLLs and RWLs can be a challenge as the uncertainties of future development leads to risks in decision making, e.g. regarding wrong decisions and sunk costs, which is specifically relevant in third-party-funding situations. However, transformative research based on an iterative, learning-oriented and reflexive model may counter such effects given that enough time and resources are in place. Hope is indeed that transformative research through directly linking science and practice leads to more robust and resilient results in less time than the conventional separation between research, innovation, and practice does. However, one also has to consider that research maybe also bound by its own paradigms (Kuhn 1972) which may directly influence the choices, decisions and solutions found by the researchers and always requires them to second-guess their assumptions. While the latter may lead to second-loop learning and hence improvement in science, it may confront the researchers with problems of credibility and practicability (a conceived and suggested solution becoming invaluable) in a real-world experiment.

Another challenge is rooted in the interdisciplinarity and transdisciplinarity, which are hallmarks and utter necessities of transformative research (Schneidewind/Singer-Brodowski 2013). However, most researchers are neither trained nor experienced in this somewhat new research paradigm, which brings about a number of issues that need to be dealt with. One lies in ensuring the classic quality criteria for methodological scientific research in the more volatile and less reliable environment of transformative research (see e.g. Yin 2003), specifically in RWL. Transformative research must not only be meaningful for those people and groups affected by it, but also for the researchers themselves. In this, it should also support them in pursuing a scientific career and to perform research within acceptable standards. Hence, RWL should constitute a win-win situation for researchers and those, which are part of a transformative experiment.

Time and timing of transformative research may also become a challenge. While conventional research can often be conducted under time frames known from long time experience, especially the environmental uncertainties of RWL may require totally different approaches. For example change created by an experiment may unfold much slower in a real world experiment than under “normal” research circumstances. This can often be the case in initiatives dependent on voluntary workers that are limited in the time they can allocate. Also e.g. permissions from local authorities required to conduct and pursue an experiment (e.g. construction of buildings etc.) may take much longer than expected. Such everyday occurrences may however either delay the process or require a change in the experiments design. It is hence not only up to the researchers to decide on the speed of an experiment nor may it be in their hands at all. However, this may be in conflict with plans and projected time of a third party-funded project where the scientists have to adhere to the – also legitimate – expectations and reporting requirements of the funding party, resulting in a conflict of interest.

The potentially normative character of transformative research may also result in less clear roles for the researchers who may become personally involved and hence alternate between the role of researcher and activists. This however, may lead to less clear and concise research results.

The aforementioned circumstances can imply that the requirements of a research question and design may conflict with the purpose in the mind of activists and other parties involved. E.g. an SLL may take longer than a company would allocate to an innovation process or the activists could feel constricted by the quality criteria researchers need to adhere to. Also, changes or adaptations of purpose undertaken by persons e.g. involved in a RWL may be in conflict with the research design leading again to needs of adaptations or even abortion of the research project if both sides cannot be brought to unison.

4.1.2. Chances of Transformative Research

Several chances and advantages are connected with transformative research and were revealed in this work. Firstly, transformative research ideally allows a real-time and on-time translation of research into practice and vice versa. Secondly, this research is closer connected to empirical development which may cater for more realistic and meaningful applied research. In turn, activities for sustainability may profit from state-of-the-art research directly. Through its context relatedness RWL may attribute their work with more meaning for research and researchers directly working with and for a sustainable cause; results of research and the direct interaction with people on the ground as well as immediate responses create a stronger knowledge and consciousness for opportunities, chances, barriers, etc. that can be utilized or need to be overcome in a transition towards sustainability.

The democratic nature of RWL allows concentrating on pressing problems identified by people "in the field". Common consultations on what is required, which foci need to be set, and what actions and goals might make sense from a scientific viewpoint can make transformative research more useful and again more meaningful to researchers, practitioners and also third-party funders. Both SLL and RWL provide intricate and direct insight into the development and growth or demise of niche developments directly. Through this new developments and their related chances and necessities can be identified as they unfold. This may shorten reaction time and improve effectiveness between research, practice and policy. Through this communication, reflexivity, learning and action towards sustainable development can be improved.

For researchers these more intricate insights can create a higher transparency and allow for knowledge creation within the cases in real-time. However, the specificity and transferability of knowledge gained from each case will need to be scrutinized, as false transfers may be harmful.

Transformative research as an iterated reflexive process can also help to identify, circumvent or prevent rebound effects through direct intervention in development processes. E.g. the RWL on Foodsharing identified a potential rebound effect from savings allowed by sharing while the SLL could show shortcomings of smart meters and longer term behavioural effects of the CO_2-lights.

Likewise externalities – both positive or negative – may be detected earlier. The importance that the foodsharing initiative developed for social cohesion in its city quarter is one point in case here.

Lastly, transformative research is inclusive. It brings together – ideally – all those connected with a certain issue in sustainability and jointly creates solutions that can be accepted by everyone involved. In this, it can ensure to make those heard that are normally not part of a development process (SLLs) or that lack the power or voice to make themselves heard in a transition (especially in case of RWLs).

4.1.3. Lessons Learned and Solutions Proposed

While the experiments undertaken and described here are certainly not the first of their kind, especially RWL for sustainability transitions and the affiliated transformative research is certainly in its infancy. Therefore, and due to its goals and partial normativity transformative research requires some specific solutions some of which may be provided here. For this, it can certainly also profit and learn from related strands of (participatory) action research, ethnography, participatory observation and others (see e.g. Yin 2003, Ozanne&Saatcioglu 2008).

One challenge encountered and described is that of personal involvement of the researchers and a potential loss of professional distance or a blurring of roles specifically in RWLs. To prevent this from happening and to ensure a certain level of distance, we created two distinct solutions. Firstly, we installed three layers of contact between the initiative and the researchers. One researcher was in constant contact with the foodsharing initiative and present at (almost) every activity taken. Two other researchers worked in less proximity. One in an observing role with a more traditional distance to the case, and the other in an intermediary position, visiting the initiative in regular cycles to see the developments first-hand but to remain less engaged. All researchers took part in workshops and regularly reflected on the initiative's development, successes, setbacks, etc. with and without the activists. While we made sure that all researchers directly involved were known to the initiative, so that trust could be ensured, we could thus also create a certain level of control over the involved researchers' personal involvement. Moreover, and to the same avail, the observing researcher was replaced after some time, again to make involvement less likely. Every time a new person became active on site one of the more detached researchers made sure he or she was properly introduced.

Related to this we found it useful to have as much clarity and transparency between the parties involved as possible. In SLL it was important to let the participants know how the experiments worked, what was required from them, and what they might expect from them. In RWL we made sure the activists knew and understood our own work and the limitations of a project, e.g. that our cooperation would be limited to about a year, and that there were also limits in time and capacity. We hence took care that a clear framing and mutual understanding of rules, settings, etc. was established, so that we could all work within shared expectations.

As a next point, it has to be made sure that learning can take place in both directions, i.e. while the persons active on the ground need to be open to suggestions from the researchers, the latter must also be willing to accept the (non-scientific) insights from members of an initiative whose knowledge on specific problems may exceed that of the scientists.

From these cases and others we also learned that transformative research may need a longer time frame than the conventional three project years to become effective. This is grounded in the imponderability and challenges of these strands of experimental research. For example SLLs may need a careful setup and may have to tolerate setbacks in cooperation and trust. Especially the duration of a starting phase of such experiments may require a considerable amount of time until trust is generated.[9] This implies that researchers but potentially also the providers of funds may have to work with more flexibility in terms of processes, outcomes and expectations while not leaving the appropriate rules of efficiency and effectiveness behind.

While in social experiments outcomes cannot be set as clearly as in conventional research settings, the process reveals a lot about the problems at hand, potential solutions, and specifically arriving at them. Therefore the process of research, that is the experiment itself, becomes much more important. In its effects and learnings it may potentially offer deep insights into the problems, chances barriers on the ground. It is hence essential to take as much learning from and to concentrate research as much on the process as on the outcomes.

[9] The FP7-sister projects Pathways, ARTS, TESS and GLAMURS conducted a workshop on this problem at the 2016 IST conference. A documentation of the results will be handed over.

4.2. Links between experimental Transformative Research with Quantitative Modelling and Socio-technical Analysis

This section will discuss potential points for insight and implications provided by experimental Transformative Research to quantitative modelling and socio-technical analysis (STA), and vice versa. We start with offers from IBL to the other methodological disciplines and discuss them in the order mentioned. After that we concentrate on points of interest where IBL can profit or needs information from the other approaches. Based on earlier work (Berg et al. 2015) and deliberations on collaborative attempts between the methods (Turnheim et al. 2015) we propose connecting points based on the findings of the experiments both with respect to outcome and process.

With regard to Quantitative Modelling SLLs may contribute by offering the data measured, found in real-life households under different technological or behavioural conditions for example with or without intervention, e.g. in our case that of heating behaviour. This data may be used to calibrate the models, calculate alternative scenarios or judge interventions' outcomes by simulating the integrated impact on a larger scale. Through integration models may then potentially uncover feedback effects on the experiments from other parts of the systems, which may or may not interfere with the effectiveness of an intervention. Moreover, insight on behaviour gained in SLL may be used to qualify and assess a model's underlying assumptions e.g. on cause-effect ratios, learning curves (DeCian et al. 2016) etc. Finally, these statistics may be used for an improvement in forecasting by e.g. entering effects from a new technology into the model.

RWLs may contribute to modelling by improved insights into behaviour observed and developed within an experiment. Again, this may help to test, improve or adapt a model's assumption. Moreover, RWL may offer 'other' or new perspectives to modelling such as new scenarios based on the individual experiments, their outcomes, impact, findings and processes. In our case for example, different rates of food waste or efficiency in food consumption can be derived. Even more interesting different and realistic narratives could be developed leading to new scenarios and hence outcomes.

However, based on the reasoning of Berg et al. (2015) and Turnheim et al. (2015), respectively one has to observe the limitations in translating results, assumption and observations directly between the approaches. As illustrated by the case of social learning in different time scales (see De Cian et al. 2016), granularity, etc. may hamper such translations considerably. Also, not every model is as susceptible to adopting such external data.

For socio-technical analysis, transformative research may provide insights into emerging niches, their specificities, and implications based on a more intricate perspective than "conventional" research e.g. in the form of case study research. Moreover, STA and MLP have often been concentrated on case studies of past transitions. Due its present-/future orientation transformative research may specifically add an understanding of future processes or the here-and-now, providing STA with hints for starting points of present or future transitions. Therein SLL may provide specific hints on emerging technologies and practices, their prospect and effects. SLL may also distil typical factors of success (and failure) of technologies and appliances, their likeliness of upscaling and potential pathways within a given regime. From this, governance implications for regime change or control may be deducted in the broader picture of STA in a multi-level perspective (MLP). Also SLLs may provide STA with insights in "real time" into unfolding transition processes, not only from an observer's perspective but also based on technological and behavioural insights gained directly in the research and development process directly linked to the transition.

Real-world laboratories may provide narratives for coming transitions based on the grass-roots initiatives analysed. As the transition logic sees such niche innovations as a powerful root for transitions, this research may thus have strong implications for portraying and understanding niches, their diffusion, limitations and subsequent impact. In this it may help to direct, amplify or add to the somewhat stylized assumptions on niche emergence and effects in MLP. One problem that will manifest itself between transformative research and MLP however, lies in a lack of operationalization in the MLP ontology. While there is a clear setting of processes for interaction between niches, regime and landscape, the MLP to date is not capable of providing definitions that can be directly operationalized, hence, what is seen as part of a regime, landscape and or niche is at least never quite clear so that direct lessons with regard to a specific case will require a concrete understanding of entities for any given analysis.

There are also a number of takeaways for IBL from quantitative modelling and STA. From modelling SLL specifically profits from the broad implications that models deliver through their future scenarios. These can help Living Lab-oriented research to identify hotspots and needs where innovations may be meaningful to test and develop and hence provide a focus for work. Moreover, the models' results provide a context and strong framing for SLL-work. They motivate researchers, technologists and users/consumers to deal with the challenges of e.g. climate change.

Likewise, real-world laboratories can derive focus, context and motivation from quantitative modelling. However, specifically when working with new initiatives, RWL in these settings will focus more on the social side of a transition and the interplay between economy, ecology and the social realm rather than the more technology and efficiency-oriented SLL's.

Input from STA can have a similar, however more qualitative meaning for SLLs and RWLs. Both may derive a specific context and narrative from STA as this line of research provides quite detailed input regarding the earlier and present unfolding of transitions of regime states (cf. e.g. Geels 2002). Due to its research focus the information obtained lies in the socio-economic and socio-technical than in the quantitative forecasts and more stylized facts of the models. Through this, STA provides a broader context perspective of space and time, specifically for SLLs, as it enables these to understand into which regime and/or transitory movements a certain technology, innovation or practice is rooted in. From this researchers may derive hints to the market and political environment a development is being brought into, what effects it may have therein and what challenges it may have to face in terms of barriers, competition, lock-ins etc. For real-world laboratories the narrative may be even more important. It provides knowledge and feeling for the role of an experiment in a larger framework and can hence offer not only a sense but also a more certain knowledge of cause and meaning. Potentially, real-world labs may hence also profit by finding a focus for work – the weaknesses and shortcomings of a given regime and the necessities of a transition – and also insights into cause-and-effect structures within a regime. The latter may originate from the dependencies and relations within a regime structure (technologies, institutions, policy, etc.), which STA unveils.

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