

User-integrated Innovations in Urban Areas for a Transition towards Sustainability¹

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Abstract

A continuing trend of global urbanization leads to a geographical concentration of population and social activities that causes a regional compression of concomitant resource and energy consumption. This paper argues that a Sustainable Living Lab infrastructure (SusLab) in urban areas facilitates a systematic integration of user's consideration in the design and development of Product-Service Systems (PSS) that enables changes of daily routines in favor of urban wealth development and conservation of ecosystem services. The authors build on the Sustainable Consumption and Production (SCP) Model of the Wuppertal Institute that provides a theoretical framework of sociotechnical rearrangements towards urban sustainability transition. Therefore, a reconfiguration of social practices and PSS in a desired direction according to social, ecological and economic concerns is reconsidered on the micro level in line with efficiency, consistency, and sufficiency strategies. The authors introduce an assessment framework for urban sustainable development and illustrate multifarious concepts of PSS that are aiming to decouple wealth development from resource and energy consumption in urban areas.

Keywords: Sustainable Consumption and Production (SCP); Urban sustainability transition; Product-Service Systems (PSS); Sustainability innovation; Sustainability strategies; Living Labs; SusLabs

Cities as a Transition Arena for Sustainable Innovations

The role of cities for a transition towards sustainability has become an emerging topic in scientific research, politics, and urban governance [1-5]. According to a survey of the United Nations in 2014, 54% of the world population is living in urban areas and it is estimated that around 66% of the world population will be urban in 2050 [6]. The trend of global urbanization leads to a geographical concentration of population and social activities and therefore causes a geographically centered allocation of energy and resource use. Consequently, cities and urban districts are a predestined area for the development and diffusion of user-integrated sociotechnical innovations that improve resource and energy conservation as well as overall cultural, social, and economic development [1]. In order to enable an urban transition towards sustainability and a low-resource culture [7], especially the fields of housing, mobility and food need to be considered [8].

In line with Schmidt-Bleek [9], the maintenance of global ecosystems² comprises the fundament of human living and business activities. Daily social practices of individuals and the corresponding consumption of products, services and infrastructures are always associated with the use of natural resources [10]. Nevertheless, available natural resources and landscapes are limited and human beings cannot reproduce them through technological innovations. Therefore, the availability of ecosystem services has direct impacts on economic development and societal wealth. Rising climate change and resource depletion can lead to economic and social conflicts and crisis

due to unequal opportunities of wealth development (e.g. regional droughts lead to irregular access to natural resources [11]). Henceforth, individual, societal and economic resource consumption patterns need to be designed in a way that allows an inter- and intragenerational satisfaction of human needs and well-being. If societies are willing to realize climate reversal and resource conservation, daily routines at home and at work need to be changed in favor of a low-resource and low-carbon culture [7]. Sustainability policies and strategies can provide a driving legal and institutional framework for social and technical innovations in order to change daily business routines and individual lifestyles. However, it needs to be considered that setting a focus on technical innovations is insufficient. Instead, social innovations should be additionally considered in urban governance strategies that facilitate a reconfiguration of daily routines towards a lower level of consumption, re-use or longer use of products and services without compromising well-being (see section 2.2).

In Germany, the total consumption of raw materials within the entire area of consumption and production accounts for around 73.3 tons per capita and year on average [12]. First estimations show that private households in Germany consume around 30 tons of primary resources per capita and year on average [13]. However, a sustainable target corridor of private households' resource consumption per capita and year would rather be around 8 tons on average [14]. Bearing in mind that around 60-80% of the world resource consumption is urban [6], a transition towards such a resource consumption level within the next decades requires the development and diffusion of innovative demand oriented low-resource Product-Service Systems (PSS) in urban areas

¹This paper is based on previous research considerations, in particular Baedeker and Liedtke [5], which has been translated and further developed.

²Systems can be differentiated between ecosystems (atmosphere, hydrosphere (oceans and water cycles on continents and atmosphere, biosphere (animals and plants), cryosphere (ice and snow), and pedosphere (soil)), and social systems, which include society (sum of all human beings), economies, and business organizations. Each social system has specific characteristics and is interconnected with other systems through the exchange of materials, energy, and information [10].

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which address consumption behavior of private households. In this regard, innovative PSS that are aiming to decouple resource and energy use from wealth development should be consistently incorporated in urban policies and strategies. Appropriate innovation spaces in terms of user-integrated real laboratories could facilitate the development of creative social and technological solutions in production and consumption that counteract the growing absolute resource and energy use and reduces underlying environmental pressure (see section 2.2) [8,12].

In order to explore determinants of successful PSS innovations for an urban sustainability transition on both theoretical and practical basis, the paper is structured as followed. The next chapter two outlines the theoretical framework for the development and diffusion of demand driven sociotechnical innovations for urban transitions towards sustainability. In this regard, widespread sustainability strategies are outlined and a model of sustainable consumption and production is captured. In addition, the authors present a practical research approach for the development and diffusion of sustainable user-integrated PSS innovations and introduce an assessment framework for sustainable urban development. Chapter three illustrates three innovative PSS concepts that are assessed in chapter four according to the presented assessment framework. Finally, in chapter five the authors summarize key determinants for the development and diffusion of sustainable PSS in favor of an urban transition towards sustainability.

Theoretical Framework of Sustainable Urban Product-Service Innovations for a Sustainability Transition

The transition research approach [15-17] has evolved as a theoretical framework for research activities in sustainability science. Transition is characterized by “radical, structural change of a societal (sub)system that is the result of a co-evolution of economic, cultural, technological, ecological and institutional developments at different scale-levels” [18]. In the following, a theoretical framework for urban sustainability transition will be elaborated.

Integrating sustainability strategies of efficiency, consistency, and sufficiency in urban PSS innovations

The effects of urban consumption and production patterns on ecosystems are seldom causal and linear; instead, they are often non-linear with revisal and non-revisal patterns [19]. Urban PSS innovations as a driver for change in production and consumption have, therefore, socioeconomic and ecological effects along the entire value chain with specific differences in its lifecycle phases with regard to material and carbon footprints (e.g. due to additional resource extraction patterns, new transportation logistic) and shape behavioral change due to intended design arrangements [20]. The impact of urban innovations cannot be captured in its entirety due to the complexity of a globalized flow of materials and information [21] and multifaceted sociotechnical and socioecological interactions.

In this regard, a key challenge for a transition towards urban sustainability is to promote a low-resource and low-carbon society in line with an overall preventive strategy³, bearing in mind that every activity of consumption and production impacts its social and ecological environment and is impacted by the environment simultaneously [19]. One example for non-linear and unintended effects of production on

ecosystems (atmosphere) illustrates the use of Chlorofluorocarbon (CFC) in fridges. CFC was widely used in northern parts of the world for long time until scientific research investigations have revealed its disquieting ozone depletion impact on the South Pole. Even so, CFC is mostly prohibited internationally since many years; it is still floating in the atmosphere and causes further ozone depletion [22].

Moreover, it can be stated that structures, institutions and cultures in cities and urban districts are continuously changing over time due to intended and unintended interventions (e.g. political regulations, citizens' initiatives). Intervention effects are characterized by time lags [19]. Thus, transition processes should be set at the center of respective urban (political) intervention initiatives that account for specific qualities of change. The design and implementation of interventions should be in line with an internationally legitimized target corridor. The Sustainable Development Goals (SDGs) of the United Nations build a respective internationally legitimized sustainability agenda⁴.

Accordingly, an urban transition towards a sustainable development cannot be promoted solely by the development and diffusion of technological eco-innovations. Instead, an urban transition towards sustainability in line with the SDGs needs to consider the complexity of systems and their interconnections. Hence, citizens' lifestyles and production patterns need to be considered simultaneously. The same holds true for implementing political initiatives, for instance, new regulations for resource conservation. Therefore, transition processes and their required time, and possible unintended effects should be incorporated respectively [23]. A test period of implementation of urban policies for sustainable PSS is necessary in order to identify unintended side effects due to unpredictable sociopolitical and sociotechnical interactions (e.g. rebound effects [24]) that can be considered before the final binding implementation. In addition, Loorbach emphasizes that a key challenge of transition management for sustainability is (...) to create space for short-term innovation and develop long-term sustainability visions linked to desired societal transitions [25, p. 163].

In order to promote user-integrated innovations in urban areas for a transition towards decoupling wealth development from energy and resource use which account for complex interdependency of production and consumption patterns, the most popular kinds of sustainability strategies of efficiency, consistency, and sufficiency need to be integrated [26]. Firstly, efficiency strategies aim to decouple resource use from economic growth by improving productivity in particular of input factors (inclusive resource extraction) and production processes. Tischner [27] argues that product design accounts for 80% of resource use and production costs. Consequently, efficiency strategies should be already implemented in the products' design and development phase. Furthermore, efficiency strategies play a decisive role in the use phase due to changes of technical application (sociotechnical interactions).

Secondly, sustainable business strategies of consistency are aiming to facilitate a circular flow of materials in economies and societies [28]. In other words, all input variables are entirely reused along the value chain. Therefore, no waste would occur if the entire raw materials extracted within the extraction process were used for the next production; however, currently only around a third of the extracted resources reaches the economic system, while two thirds persist undetected and unused [29]. In addition Schmidt-Bleek estimates that only 3% of raw materials in economies are recycled [29]. In this regard,

³A preventive strategy considers the uncertainty of destructive effects of human beings on the ecosystem. Reducing resource and energy consumption is, therefore, a central part for a sustainable urban development [9].

⁴Further information about the SDGs (<https://sustainabledevelopment.un.org/sdgs>).

innovative value chain management approaches of material flows need to be developed to promote a circular economy approach.

Thirdly, the sufficiency strategy follows the guiding idea of jointly increasing societal wealth and decreasing the overall level of resource and energy consumption through the evolvement of alternative lifestyles and corresponding low consumption levels in favor of the diffusion of a low-resource culture [7]. One obvious line of reasoning behind this strategy is that less resource consumption will lead also to financial savings due to less expansion. Liedtke et al. [26] argue that sufficiency can be considered a mediating strategy of efficiency and consistency that counteract rebound effects in the long run [24]. Schneidewind concludes that “[...] In order to sufficiently meet human needs without irreversibly overburdening global ecosystems, we require a producer and consumer culture that has learned to differentiate between the essential and the expendable combined with an economy that is under much less pressure to grow [...]” ([30], Foreword by Schneidewind).

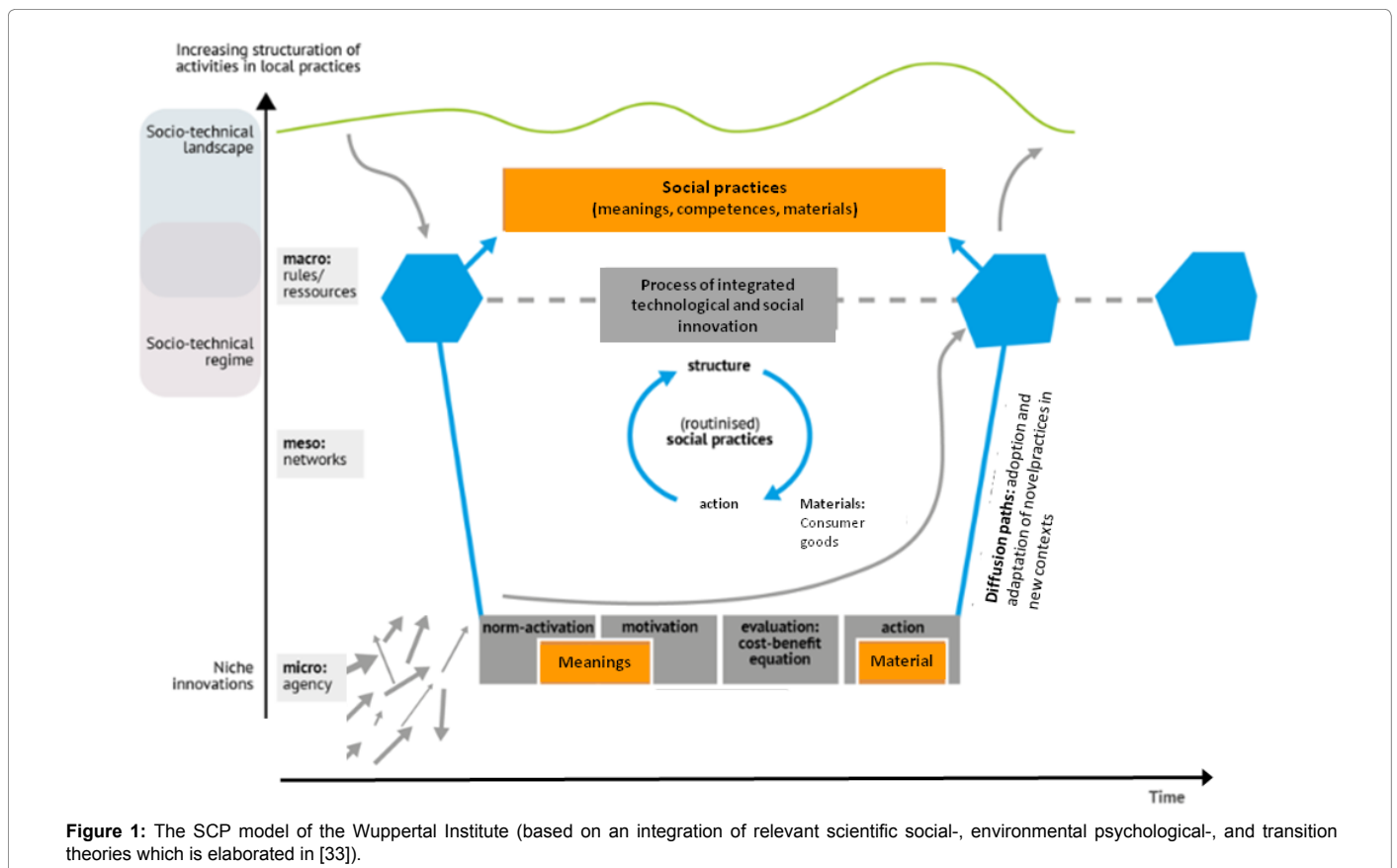
All three strategies can be considered as constitutive complements as they all have to be practiced simultaneously if production and consumption is to be designed sustainably. Sachs [31, p. 41] argues that “Efficiency without sufficiency is counterproductive; the latter must define the boundaries of the former”. In this regard, it is crucial that macro strategies regarding sustainable development such as the German Sustainability Strategy [32] are reconsidered on a micro level in a way that citizens and (business) organizations are able to experience a variety of possible implementation opportunities. The Sustainable Consumption and Production Model of the Wuppertal Institute build on this challenge of developing sustainable bottom-up PSS innovations.

Sustainable Consumption and Production Model of the Wuppertal Institute

The Sustainable Consumption and Production (SCP) model of the Wuppertal Institute integrates environmental resource strategies with social innovations in order to reconfigure social practices towards sustainable production and consumption patterns [33]. An analysis of mutual interactions between consumption and production patterns encompasses the research nucleus of the model (Figure 1).

The theoretical basis of the SCP model comprises an integration of social, environmental psychological and transition theories. Especially the integration of transition research and social practice theories has been proposed as a promising approach to further develop a theoretical framework of consumption and production research [34].

The SCP model captures and structures individual and social transition mechanisms (social practice theory [35]) in sociotechnical regimes with the corresponding resource consumption induced by the use of products, services and infrastructures. In this way, individuals’ social practices or daily recurring routines of activities at work and at home determine the resource and energy consumption. Social practices are proceeding mostly unconsciously and simplify complex daily procedures. The accomplishments of routines therefore illustrate the underlying product and service portfolio of each individual and the corresponding sociotechnical resource and energy consumption profiles. By implication, changes of social practices [36] have implications on individuals’ surrounding infrastructures and the underlying products and services. An illustrative example is our septic system; a change towards overall lower water consumption has led to



disturbance of water flows in sewer tunnels. The SCP model captures determinants of such individual and social practice evolvments in order to change those towards an overall low-energy and low-resource use [30,31]. The model reconsiders nationally and internationally legitimized sustainability target corridors (German Sustainability Strategy [32], SDGs) in order to counteract potential rebound effects [24]. Moreover, it considers a multi-level perspective (MLP) in line with the transition research approach by analyzing the interconnection between sociotechnical regimes, niches and landscapes in change processes [15,17]. Hence, the design of consumption and production system in sociotechnical regimes is closely linked to individuals' and societal routines of daily activities. As a result, a transition of sociotechnical regimes towards sustainability requires changes of daily routines of actions. In this manner, product and service innovations need to be designed in a way that facilitates a sustainable and low-resource culture [33,37].

In sum, a self-determined reconfiguration of unsustainable resource intensive social practices at work and at home towards sustainable daily routines of action remains the main research challenge [36,38]. Social and technical innovations can initiate such transition processes and facilitate the materialization of sustainable low-resource infrastructures. User-centered PSS innovations can support such a transition of daily routines towards sustainable urban development. The next section elaborates a respective practice oriented research approach that promotes the development and diffusion of PSS innovations.

Sustainable living labs as a user-centered method for developing sustainable PSS in urban areas⁵

User-integrated innovations of products and services can facilitate the desired application of technological and social innovations in line with efficiency, consistency and sufficiency strategies (see section 2.1). Living Labs are a strategic research instrument for science, business, and society for the development and diffusion of sustainable sociotechnical innovations [39-41]. They are designed to promote user-centered and economically competitive PSS that facilitate a broad set of sustainability potentials. The sustainable living lab approach, also called SusLab [39], has three main characteristics; it should create space to develop and test innovative user-centered PSS, further develop existing PSS towards sustainability, and improve the development and diffusion of sustainable business models [42,43]. In this manner, SusLabs contribute to the development and diffusion of sustainable sociotechnical solutions in value chains in line with national and international legitimized sustainability goals and strategies (e.g. German Sustainable Development Strategy [32], SDGs) by integrating

stakeholders of production, consumption, research, and local communities [39,44]. Such SusLabs therefore proactively integrate user and local citizens as experts of their social systems in the research and design process in order to elaborate sophisticated sustainability solutions. The SusLab method encompasses three consecutive steps:

- Insight research: user observation, analyzing the actual needs in social systems together with relevant stakeholders.
- Prototyping/Co-creation: joint and iterative development of new PSS.
- Field tests: Application, evaluation, and optimizing PSS in reality test [39,44,45].

The SusLab method allows the development and diffusion of highly valuable services for users and at the same time promotes a lifecycle wide low resource and low energy use, including resource extraction, production, trade, usage, and disposal or recycling/reuse. In line with Schmidt-Bleek and Tischner [46] and Liedtke et al. [20] environmental effects of PSS along the entire value chain need to be considered already in the development and design phase. Urban governance strategies could facilitate the evolvment of SusLab research infrastructures combined with market based environmental policies, such as promoting approaches of ecological true prizes [47,48] and resource and energy tax systems. In this way incentives for the development of low-resource and low-energy PSS innovations could be encouraged due to increasing prizes of natural resources and Greenhouse Gas (GHS) emission. However, an evaluation of progress towards sustainability requires an assessment framework that indicates, if impacts of a reconfiguration of social practices and PSS evolving in a desired direction according to social, ecological and economic considerations. In this regard, assessment criteria for sustainable urban development will be presented in the next section.

Assessment framework for sustainable urban development: from individuals via PSS to cities⁶

The following assessment approach of sustainable urban development set a focus on the impact and transition dynamics of PSS in cities. Therefore, a set of assessment criteria is proposed which are categorized in six categorical fields (Table 1). The assessment integrates the individual household/lifestyle perspective with urban governance, global responsibility, social inclusion/participation, and sustainable economic development.

According to the assessment criteria it is crucial that PSS are differentiating a core service on the basis of specific lifestyle and cultural

⁵This section is based on and has been partly translated from Baedeker and Liedtke [5].

⁶The following sections are based on and have been partly translated from Baedeker and Liedtke [5].

Category (intervention level)	Assessment criteria
Households/lifestyle	Participation/security, identity/status, competence/education, resilience/low resource and energy use
City/district	Urban wealth development/quality of life, urban culture, townscape strategies/guiding principles, ecosystem resilience, communication/information, participation
Global responsibility	Decoupling resource use from wealth development, diversity, urban-rural interaction, circular resource flow
Social inclusion	Equality, integration/inclusion, diversity
Sustainable economic development	Guiding principles (Socio-ecological market economy), innovation dynamics
Urban life	Townscape, urban culture (cultural diversity)

Table 1: Assessment criteria for sustainable urban development (translated from [5], based on [26], OECD Better Life Index (Further information about the OECD Better Life Index, see <http://www.oecdbetterlifeindex.org/de> (accessed on May 2017)), and the SDGs).

determinants in urban areas. Furthermore, a sustainable business model [42] of the PSS needs to be developed that focuses on the service for the user (e.g. comfortable and enjoyable room climate) instead of the product itself (e.g. heating system hardware). The systemic deliberation of consumer requirements, strategic partnerships, investor relations, competitors and further stakeholder need to be incorporated in the business model in line with hybrid value creation approaches. A sophisticated research and development infrastructure, such as the SusLabs approach illustrates, enables cooperation on a par with relevant system actors that can enable mutual learning outcomes [39,44,45]. As illustrated in section 2.1, sustainability strategies of efficiency, consistency, and sufficiency need to be considered in the PSS and business model creation in order to emerge new markets and foster urban sustainability transitions.

The following examples illustrate concepts that have been developed or will be further developed in line with the SusLab approach and conceptual considerations of the SCP model outlined above.

Examples of Innovative Urban Bottom-Up Concepts⁷

In order to facilitate the broad possibilities of user-integrated transition processes towards sustainability, a high variety of PSS innovations need to be developed and spread. The implementation of urban sustainability innovations should be developed from the bottom up if it is to be successful and applicable.

Daily life and working, and the related consumption of existing service systems, are multifaceted; consequently, the approaches to finding solutions for a sustainable culture need to reflect this diversity in an approach that is relevant for a variety of business and sociotechnical fields [47-50]. The three following examples, which follow the SusLab three-step process by focusing on different aspects of it, broach the topics of heating/venting ("Heating Plus" [39]), eating as a community ("Wuppertal isst fremd" [51]), and the use of electronic devices in the neighborhood ("Cycle Genossenschaft" [52]).

Energy intelligent districts: 'Heating Plus'-the individualized user-integrated energy consultation concept

The concept 'Heating Plus'⁸ is based on the idea that a well-founded and individualized energy consultation is possible when utilizing the support of individualized measuring of room climate conditions [39].

A central component of the PSS "Heating Plus" is that not only technical details and technical comprehension of the system "heating" are foregrounded in the consultation of and interaction with clients; instead, the focus lies much more on changing daily routines of action related to heating and venting with simple and inexpensive non-technical support. Therefore, routines in connection to heating and venting can be newly established or permanently changed in favor of less energy consumption.

An analysis of room climate data such as temperature, carbon dioxide, and humidity conducted by an energy consultant offers an

initial impression of user behavior and social practices as well as of the functionality of the heating system and the influence of the building envelope. Based on the results of an initial analysis [40], the energy consultant can devise an individualized, economically optimized product-service package for the household, one that increases energy efficiency and actively changes the personal usage behavior towards less energy consumption.

The focus of the PSS "Heating Plus" lies on the activation of energy efficiency potentials in private households through customized, low-investment measures: Besides, the concept builds on a compilation of product arrangements, e.g. smart home systems or simple feedback systems, such as traffic light labeling for room climate. Moreover, the PSS facilitate an optimized and individualized heating and venting behavior in favor of both comfortable room climate and energy conservation.

To provide an individualized energy consultation of this kind, it is important to sufficiently train the consultants as well as other specialists (e.g. fitters) in the value chain. The PSS "Heating Plus" encompass five consecutive steps:

- Initial consultation: Inquiry about technical data of the heating system as well as about yearly energy consumption and energy costs.
- Data collection: Measuring the indoor climate of households.
- Intensive consulting: Optimized, household specific consultation with choice of suitable product-service solutions (technical and non-technical).
- Implementation of user-centered products and services.
- Evaluation consulting: examination of the compiled energy efficiency potential based on usage data and costs.

The innovative characteristic of this consultancy system lies in the strong involvement of the household and stakeholders in the value chain "Heating" during the development and implementation process of a sound PSS as well as in the individualized and fact-based consultation. It can address individual households as well as merged households.

"Wuppertal isst fremd", an innovative approach for out of home nutrition and social integration in urban areas

Nutrition is one of the most resource and energy-consuming sector in Germany [8]. The value chain of nutrition, including farming, production, transport and disposal, causes around 13% of CO₂ emissions per person and is the fourth greatest economic factor in Germany [50]. Moreover, logistic and mobility related to nutrition has a large ecological footprint.

The concept "Wuppertal isst fremd", developed by Annika Greven and Sophia Kahl [51], focuses on rearranging nutrition and social interaction patterns in urban districts. They have developed an interaction- and communication approach based on the concept "Rudi rockt"⁹ that encourage citizens to explore new cultures and meet people around their district through a so called 'running dinner'. In this manner, students, as the initial target group, enjoy a starter, main course and dessert each at different households with different participants. At the end, all participants get together at one place where partner associations of the district can present their work and

⁷The following sections are based on and have been partly translated from Baedeker and Liedtke [5].

⁸The concept "Heating plus" has been developed by the Wuppertal Institute, the University Ruhr West und the InnovationCity Management GmbH. within the EU-project "SusLabNWE-Creation of a Networked Infrastructure for Innovation on Sustainability in the Home Environment (2012-2015)", financed by the European Territorial Cooperation (Interreg) and co-financed by the Ministry of Innovation, Science and Research of the State of North Rhine-Westphalia, Germany (MIWF NRW) ". For further information see www.suslab.edu (accessed on May 2017) and [40].

⁹www.rudirockt.de (accessed on May 2017).

participants are able to provide donations. In addition, the initiators are planning to incorporate motto-evenings that promote consciousness of the value and environmental effects of food. International and national sustainability goals have been applied as a guidance to facilitate positive impact of the PSS on social and ecological urban district development.

“Cycle Genossenschaft”, redesigning the value chain of electronic devices in urban districts

The concept “Cycle Genossenschaft” [52,20] illustrates a PSS that is aiming to reduce negative ecological effects of the commercialization of electronic devices by redesigning the value chain and promoting social interactions in urban districts simultaneously. Bearing in mind that the current value chain of electronic devices, especially in the information and communication sector, is characterized by a huge consumption of rare and highly valuable natural resources on the one hand and a low rate of recycling or reuse on the other hand [53], the concept of Jonas Michels aims to improve the value chain management of electronic devices in line with consistency, efficiency and sufficiency strategies illustrated above. In this regard, the concept pools the demand of electronic devices in urban districts with a legal form of a cooperative [54]¹⁰ that combines the supply of high quality products with product recycling and reuse and financing models that are designed for low, middle and high income households in order to improve urban wealth development. Members of the cooperative can choose whether to purchase, lend or share products according to their individual preferences. Therefore, members might prefer to purchase electronic hygiene devices, such as electronic toothbrush, but prefer to share an electronic window cleaner which might be used once in a few month. The cooperative organizes the exchange of electronic products, including negotiations with suppliers and the overall management of purchasing, lending, sharing electronic devices. Pooling the demand of products increases the negotiation power regarding prizes, quality and features. The representatives of the cooperative manage repairing, recycling and reusing with relevant (partner) institutions. Lending and sharing is organized in a way that promotes social interactions between members of the urban district.

In sum, the “Cycle Genossenschaft” concept sets a focus on the design of social arrangements rather than focusing only on the design of single products itself [26].

Assessment¹¹

The following qualitative assessment approach for sustainable urban development outlined in section 2.4 will be applied on the three PSS examples illustrated above¹. The overall aim is to illustrate which criteria of sustainable urban PSS are addressed more specifically in relation to each other and therefore raises diverse sustainability potentials. In this manner, it is crucial to consider that concepts of sustainable PSS do not need to fulfill all aspects equally. Instead, the authors argue that a combination of multifarious concepts of PSS facilitate a decoupling of wealth development and resource and energy use in urban areas. A portfolio of diverse PSS can promote a cultural attitude of a sustainable consumption and social integration. The assessment provides an orientation of how explicitly each PSS fit to the

¹⁰According to Walk and Schröder [54, p. 302] a cooperative can be defined (...) as a specific form of collective organization that is based on a set of principles valuing self-help, collective responsibility, democracy and solidarity. In addition cooperatives promote voluntary, self-determined and equal membership (one member: one vote) in order to achieve shared goals.

¹¹Assessment is based on and has been partly translated from Baedeker and Liedtke [5].

sustainability requirements of cities and reconsiders a combination of the PPS examples, including didactical and communicational aspects.

“Cycle Genossenschaft” addresses household’s equipment of electronic devices and its way of utilization in urban districts. “Heating Plus” set a focus on household internal heating energy management. With regard to the electricity consumption a combination of both PSS concepts could address behavioral structures in favor of the development and diffusion of a low-resource culture in urban districts. Therefore, the concept “Cycle Genossenschaft” could include the development of sustainable urban-district energy solutions (e.g. allocating and managing renewable energy consumption and promoting efficient and sufficient energy use). In this regard, “Cycle Genossenschaft could build an anchor point of urban district energy arrangements and sustainable electronic device management (Table 2).

“Wuppertal ist fremd” addresses different user requirements specifications as the PSS concept set a focus on the integration of services related to nutrition, including logistic and mobility in cities and urban districts. The PPS aims to address multifarious lifestyles and social interactions in urban districts through the incorporation of specific communication styles, including syntactic linguistic aspects and choice of communication channels. In this regard, a wide range of living situations can be addressed for a transition towards urban sustainable development.

“Heating Plus” does not primarily aim to contribute to social urban interactions but promotes new social interactions in the value chain of heating which lead to new business and service arrangements. The interaction between producer, fitter, and households is the main characteristic of the PSS in order to save energy. Individual determinants, such as development of competences of all involved individuals play a decisive role. Nevertheless, an overarching urban interaction structure has not been considered in the concept so far. The authors rate the

Participation/security	+	++	+++
Identity/status	+	+++	+++
Competence/education	++	+++	++
Resilience/low resource and energy use	+++	+++	++
Urban strategies/guiding principles	+++	+++	+++
Resilience of ecosystems	+	++	++
Urban wealth development/quality of life	++	+++	++
Communication/information	++	+++	+++
Global responsibility			
Decoupling resource and energy use from wealth development	++	+++	++
Urban-rural interaction	n/a	+++	+
Circular resource flow (consistency)	n/a	++	+++
Social inclusion			
Equality	+	+	++
Integration/inclusion	+	+++	+++
Diversity	+	+++	+++
Sustainable Economic Development			
Innovation dynamics	++	++	+++
Guiding principles (Socio-ecological market economy)	+++	++	+++
Urban life			
Townscape	n/a	++	+++
Urban culture (cultural diversity)	+	++	+++

Table 2: Assessment of PSS concepts according to sustainability criteria in urban development (own description: +++: Stronger fitness, ++: Medium fitness, +: Weaker fitness, n/a: No answer, Based on and translated from Baedeker and Liedtke [5]).

contribution to decoupling resource and energy use from wealth development as relative high as well as the development of guiding principles as a basic stimulus for a low resource culture is given. After initial implementation of the PSS further integration in urban district development could be a valuable next step. A respective sociotechnical and communication design can further the implementation of energy saving in urban areas through a structural coupling of citizens heating and venting preferences with urban heating systems (smart homes – smart cities) in order to reconsider additional aspects of sustainable urban and energy system development.

The concepts “Wuppertal ist fremd” and “Cycle Genossenschaft” address citizens’ opportunities of participation, competency improvements, and development of identity as well as social status in urban life. Moreover, both PSS facilitate progress of urban structures and cultural life. In this regard, the concepts comprehensively vitalize social urban integration in combination with ecological considerations. It can be stated that an integration of social and ecological transition aspects is crucial in order to counteract the mainstream perception that both dimension are standing in competition with each other.

As a result, the PSS examples illustrate multifaceted user-centered concepts in line with the production and consumption model of the Wuppertal Institute and guiding ideas of the SusLab approach.

Conclusion

The ongoing trend of global urbanization [1] leads to an increasing geographical allocation of population and social activities and therefore a high density of energy and resource use. In this regard, cities and urban districts offer significant opportunities for improvements in resource and energy conservation as well as in overall cultural, social, and economic development [1]. In order to promote sustainable urban transitions, the development and diffusion of user-integrated sociotechnical PSS innovations are required, especially related to housing, mobility, and food [8].

This paper reveals that a rearrangement of sociotechnical regimes [7,26] towards urban sustainability should be realized on the micro level of consumption and production. The development and diffusion of user-centered PSS and innovative business models [20,43] can be reached through an integration of users and further stakeholders of production, consumption, research, and urban districts in the design and development phase as they are the experts of their own social systems. In this way, a desired application of technological innovations can be realized that foster efficiency, consistency and sufficiency and consider possible rebound effects. However, instead of focusing predominantly on technological innovations, a reinforced consideration of social innovations in urban governance strategies facilitate a reconfiguration of daily routines towards a lower level of consumption, re-use or longer use of products and services. Therefore, PSS set a focus on a service instead of the products itself.

This paper has illustrated multifaceted PSS concepts that facilitate a broad range of sustainability potentials in order to decouple resource and energy use from urban wealth development. In order to evaluate the contribution towards urban sustainability transition, an assessment approach has been introduced that integrates the individual household/lifestyle perspective with urban governance, global responsibility, social inclusion/participation, and sustainable economic development.

In sum, it can be stated that SusLabs as a strategic sustainability research and development infrastructure enable a development and diffusion of sociotechnical PSS innovations that change citizens’ social practices in urban districts towards resource and energy conservation

[33]. The elucidated SCP model provides a sound theoretical framework of reconfigurations of social practices at home and at work in favor of an urban transition towards sustainability [33].

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