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Single Use Goes Circular–An ICT Proto-Practice for a Sustainable Circular Economy Future

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ABSTRACT

Design research within information and communication technology and human-computer interaction is well poised to link relevant artefacts' lifecycle phases, such as the end-of-life with design. From a lifecycle thinking perspective, this paper investigates aspects of product longevity, interrogating what *sustainable* product lifetimes in a *sustainable* Circular Economy mean. The potential of the latter concepts has not yet been fully exploited. Also, the power of stakeholders, e.g., of designers and consumers, has not been synergistically combined. However, fulfilling this potential might facilitate a transition towards more sustainable future societies. The present work draws inspiration from an extreme case of "single use" cameras. In particular, it uses the notion of "practices" as a basic unit of design to articulate the desired linkages in lifecycles. "Single use" practices then serve as an epitome of a "borrowed for use" scenario, which—transferred to the mobile phone—results in a proto-practice. As outlined and argued in this paper, the proposed proto-practice might exact a more profound change compared to previous concepts or lived practices. It is a specific example of designing for the Circular Economy using the mobile phone, which also epitomises how designers and consumers collectively can address temporalities, rebound-effects and design trade-offs in general. Developing proto-practices and with them setting goals that might have been out of reach previously, is proposed as a central component for future design research. Proto-practices thus promote more provocative visions of transition towards sustainable societies.

KEYWORDS: product lifetimes; longevity; social practice theory; consumer behaviour; product attachment; responsible production and consumption; end-of-waste; transition design; sustainable HCI

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INTRODUCTION—DESIGNING FOR A SUSTAINABLE CIRCULAR ECONOMY

This study deals with the question of how to design for a sustainable Circular Economy (SCE). It proposes design strategies that facilitate prolonged consumption of digital artefacts used in everyday life. It also points to the roles that diverse stakeholders, such as consumers and designers, might hold in achieving sustainable product lifetimes.

In considering design for the SCE this work aligns with Transition Design (see next paragraph) and living within the “safe and just space for humanity” [1]. Represented by the Stockholm Resilience Centre’s planetary boundaries and economist Raworth’s social foundations, the two primary dimensions of sustainability considered here are “environmental” and “social”. Together they comprise that “safe and just space for humanity” [1]. Whereas the planetary boundaries “attempt to quantify the safe biophysical boundaries outside which the Earth System cannot function in a stable state”, “the social foundation [...] protects against critical human deprivations” [1]. This study’s specific products of concern are electronic consumer goods, such as the mobile phone. The contemporary mobile phone production and consumption is considered a key example in having experienced changes not drastic enough to cease its unsustainable practices, despite increased attention and efforts on how to beneficially combine forces of the involved stakeholders, particularly consumers and producers. The study focuses on how the lifetime of mobile phones might be prolonged and in which ways features like upgradability, reparability, reusability, shareability, multifunctionality, or emotional durability support longevity. A central research need is articulated as the question whether these features and corresponding activities make ‘end-of-waste’ conceivable. A first overview over consumer and producer influence points in lifecycles and thus on product lifetimes is established in the Section “**LIFECYCLE THINKING—LINKING INVENTION WITH DISPOSAL & CONSUMERS WITH DESIGNERS**”, which thereby elaborates the ways in which the phases “end-of-life” and “design”/“invention” can be linked. Both the concept of end-of-waste and its enabling activities, such as long use, shared use, reuse, remanufacturing, repair and recycling stem from conceptualisations of the Circular Economy (CE).

Design for the SCE includes not only technological artefacts but also humans using them, thus forming patterns of everyday practices. The implications of such practices for sustainable design have been considered in social practice theory, for example in [2]. Scholars from social research as well as from design research see a practice as “a constellation of devices, skills and meanings that coheres as an everyday only-ever semiconscious activity” [3]. Especially Transition Design, a new field of design research, study and practice, proposes design-led transition toward more sustainable futures (extensively described by Tonkinwise, Irwin and others [4–6]). The mechanism of transition often involves social practices as a carrier of change. Scholars from sociology and Transition Design propose that practices as entanglements of humans and technology in everyday life are to “be considered a basic unit of society [in transition]” [3]. Consequently, in this work practices are employed as a ‘basic unit of design’. Putting practices in the centre of design favourably connects the physical (when referring to ICT, or electronics, or industrial design) with intangible matters like the use itself or other interactions (when referring to HCI, or interaction design), as those two spheres should be seen as inseparable in designing for the SCE.

Given humanity's recent transition from the production age to the information age, consumers have found it increasingly difficult to determine, which use practices are, or would be, sustainable. During an earlier study of societal perspectives on the phenomenon "planned obsolescence", I became curious about the possibility that this shift may have had a more profound effect on consumer behaviours. In that study, we found that 'design as politics by other means' deserves far greater attention in the current discourse on design's role in transitioning towards more sustainable societies [7]. Part of such "politics by other means" is relieving the consumer from some of the imposed responsibility for major lifetime improvements by help of design affordances, i.e., the subtle power of design to regulate user behaviour. The present study more closely explores how to counter obsolescence, i.e., the premature end-of-use of technological artefacts, by help of design, thus, guiding consumers towards sustainable practices.

The paper is further structured as follows. After discussing lifecycle thinking, including the linkages between design and end-of-life, the remainder of the Section "**LIFECYCLE THINKING—LINKING INVENTION WITH DISPOSAL & CONSUMERS WITH DESIGNERS**" is devoted to design affordances. It is through the Sections "**SINGLE USE PRACTICES WITH "DISPOSABLE" CAMERAS**" and "**BORROWED FOR USE—A SPECULATIVE PROTO-PRACTICE IN ICT**" that the reader is introduced to the two cases employed for the aforementioned exploration, where both include a technological artefact and its use practices. The first case presents single use practices by help of a recent historical artefact, the single use camera (SUC), and serves as an epitome for the links between "end-of-life" and "design"/"invention". From the SUC's ostensible single use design, practices are deduced that resemble a "borrowed for use" scenario, which throughout the Section "**BORROWED FOR USE—A SPECULATIVE PROTO-PRACTICE IN ICT**" is applied onto the main case, the mobile phone, in order to speculate over, and propose, a proto-practice. In this proto-practice, the technical possibilities of repurposing products or parts are tied together with the potentials for personal bond or emotional attachment of users, on a scale with two opposing extremes: "built for longevity" and "built for adaptability". For to reveal the context the proto-practice enters and operates in, the Section "**BORROWED FOR USE—A SPECULATIVE PROTO-PRACTICE IN ICT**" eventually relates it to comparable concepts from research and to real-life practices.

Furthermore, this paper points out a research need connected to the regulatory character of design, i.e., how design affordances work, can be improved and favourably complement existing regulation in light of the SCE. A summative discussion of the transfer between the two detailed cases in the "**DISCUSSION**" Section evolves around temporalities, rebound effects, and design trade-offs, and can first initiate such investigation into complementing regulation. Sustainable product lifetimes are illustrated to be a wicked problem. With focus upon product service systems (PSS) and a model for overlap of product generations in the production, the Section "**DISCUSSION**" also illustrates, and the Section "**CONCLUDING REMARKS**" concludes upon, certain necessary and sufficient conditions to be met by the SCE. One of the paper's contributions is that it, with the proto-practice proposed, seeks to spark "new ways of designing" [6] in a research *through* design approach, departing from research *into* design (i.e., making connections to design history). Both these design research approaches facilitate theory building, here within Transition Design and its "visions of transition". Such facilitation, in form of a continuation with and abstraction of proto-practices developed *through* design, is also depicted as future research in the final Section "**CONCLUDING REMARKS**".

LIFECYCLE THINKING—LINKING INVENTION WITH DISPOSAL & CONSUMERS WITH DESIGNERS

From Linear to Circular Thinking

Two concepts or approaches both attempt to exact a shift from linear to circular thinking in the contemplation of product lives and the CE. One approach is lifecycle thinking as described in [1]. Here, lifecycle thinking refers to a "holistic, systemic, and critical approach that guides the design, manufacture, transport, use, and end-of-life of product-systems". It concerns impacts from the whole lifecycle, not only particular stages, phases or materials, and considers a product system "sustainable when the lifecycle is located within the planetary and social boundaries" [1]. The other concept stems from the emergence of sustainable HCI as a field with Blevis' paper initiating to link invention with disposal in HCI [8–10]. Both approaches attribute the initial lifecycle phase "design" a decisive influence over other (later) lifecycle stages, such as production, use and end-of-life. Approximately 70% of the costs of a product are decided during this conceptual phase [11]. Similarly, scholars assume that, in the broadest sense, the majority of social and environmental impact lies within the design decisions made upon invention [1].

The move to circular thinking involves connecting all later phases back to the initial phase, or vice versa, while connecting is considered "applicable to all levels, from a single product-system, product sector or industrial sector, to that of an economy (e.g., circular economy)" [1]. One might assume this imperative to "close the loop" is everything design has to ensure for resisting the previously linear thinking (lifeline see Figure 1A). Yet, this leaves out the temporalities involved: both for the lifeline and for a closed-loop lifecycle we could examine the speed at which a life is passed through and whether there are "pauses". Hence, in addition to closing the loop (in all honour of the Closing-the-Loop initiative http://www.closingtheloop.eu/about-ctl/recovery-networks), circular thinking also entails: (i) not accelerating the circulation speed, but rather slowing it down (prolonging use and, perhaps, other phases, such as design); (ii) to be aware of possible stoppage, or leakages. Part (A) and (B) of Figure 1 depict the prolonging of a product's lifetime, i.e., the distance to the product's end-of-life. More loops (and runs through these loops) are created by branching out new paths, illustrating an extension of the lifecycle circle that is often, for the sake of simplicity, reduced to the recycling loop. For Figure 1B the product (re-)use loop has been unfolded from the recycling and the remanufacturing loop, transforming the loops' shape into a figure of eight. Within this figure of eight, temporalities are included taking the form of spirals "into the deep", which represent times of inactivity, i.e., hibernation or stockpiling. Product, parts and material hibernation are synonymous with leaks in this lifecycle model, as have been illustrated with dashed lines for raw material extraction and disposal. The open (re-pliable) curve from raw material extraction to disposal in Figure 1B therefore still depicts the linear lifeline model from Figure 1A. In general, any straight lines drawn inside the loops may resemble a shortcut and/or some form of leakage.

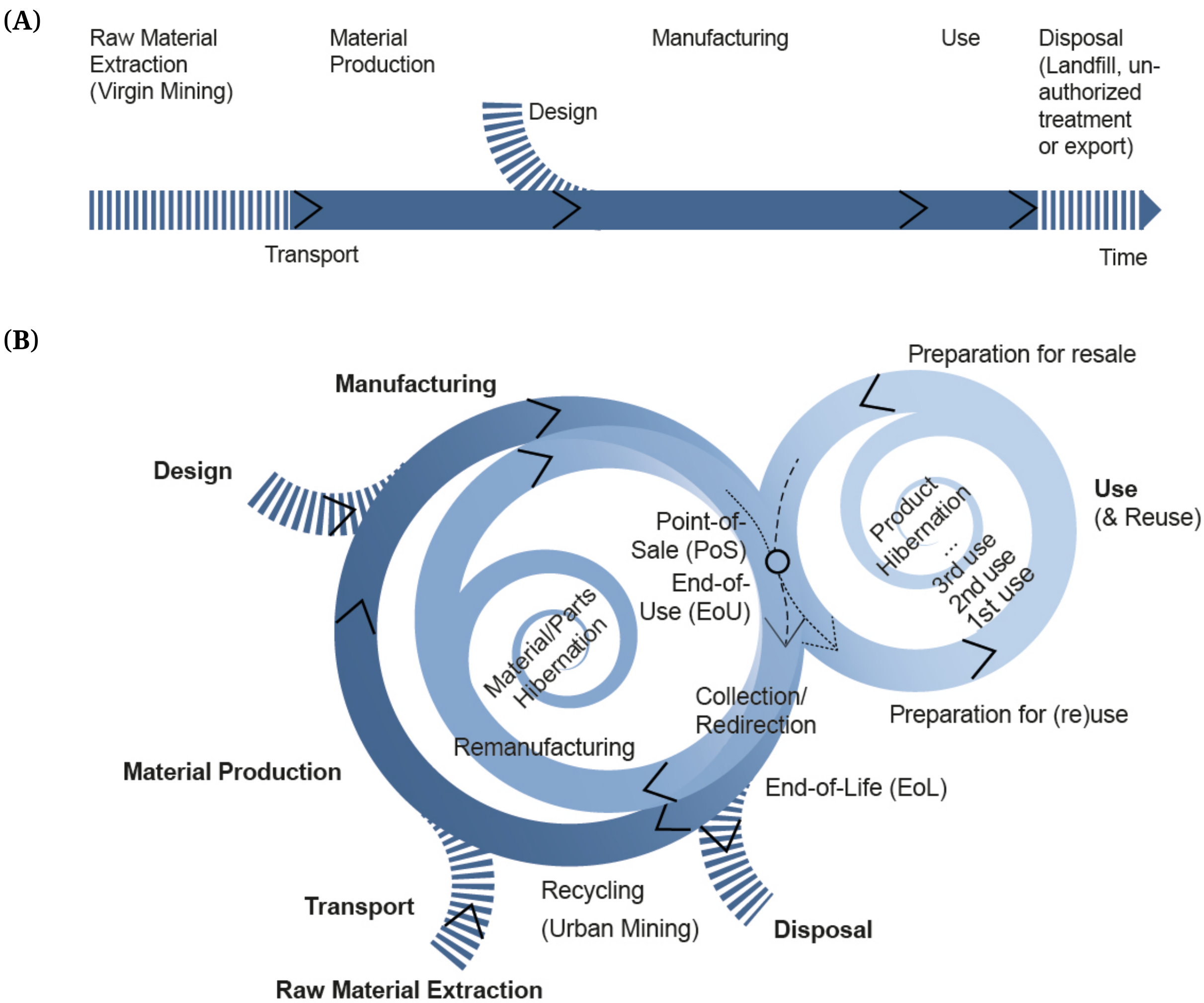

Figure 1. **(A)** Linear lifeline, **(B)** 8-shaped closed-loops lifecycle with hibernation spirals.

In contrast to shortcuts, circular thinking promotes detours. More loops are passed through, and, at the shown junctions to alternative paths, the most preferred options are chosen. What "most preferred" is derives from the hierarchy of waste pyramid (see Figure 2), whose stages map approximately to the different repurpose loops of Figure 1B. A more detailed hierarchy of waste pyramid, deliberately transformed into a "sustainable use of resources" hierarchy can be found in [12].

Blevis describes the above through his principle of promoting renewal and reuse, stating that "design of [...] information technologies implies the need to first and foremost consider [...] renewal & reuse of existing objects or systems" [8]. Also across several lifecycles—on said single product-system, sector and economy levels—invention and disposal can, and shall be linked. In Blevis' words is "any design of new objects or systems [...] of information technologies [...] incomplete without a corresponding account of what will become of the objects or systems that are displaced or obsoleted by such inventions" [8].

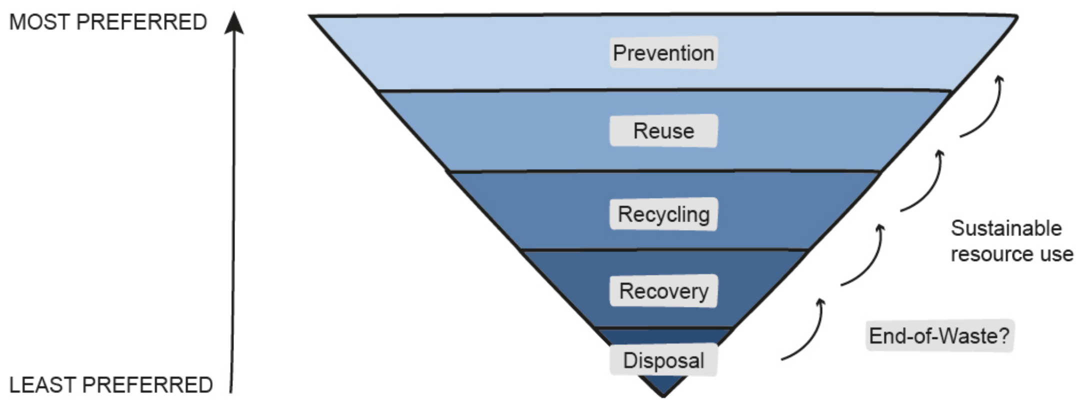

Figure 2. Hierarchy of "waste" pyramid, based on [12,13].

Given that mobile phones, in particular, engage users with many digital artefacts, such as different software/apps, documents, files, a (picture, video) library and personal data stored on the hardware, those "displaced or obsoleted [objects]" [8] are even not necessarily physical. To mirror the fate of such "soft matter" (preferably in the direction of reuse and remanufacturing), it is feasible to add small loops in every (re-)use or remanufacturing loop, graphically showing (desired) *detours*. At this point, it seems questionable whether the less preferred options, i.e., disposal and recycling of the soft matter—for example *code* as such matter—work at all. Nevertheless, this illustrates what can be called soft maintenance. It can concern: (i) software/data, (ii) interfaces that change with updates, (iii) learning/recalling interaction with a technology over time, and iv) repair of such soft matter [14]. Humans interact with technology in particular through interfaces, whose design significantly influences how likely the artefacts are used, how gladly and for how long [15,16]. The digital interface also stands for a gateway to the underlying "elements of the immaterial, the invisible and the non-sensual", which are "gain[ing] importance [in design and even] create a new culture of design" [17]. Since such invisible soft matter nevertheless "fundamentally structures the functions, usability and character of the object" [17], it plays a vital role in the use phase or for potential reuse: Well beyond the point of acquisition, the new matter of concern becomes whether, and how far, users manage to maintain use of, or to relove the object, its functions, usability and character (*Relove* is also the name for an initiative in Oslo, Norway to teach children how to repair clothes by sewing, mending, patch working, embellishing, redesigning, and this notion I am happy to transfer to ICT here).

With Figure 1, a certain imperative towards longevity and attachment has been established, which may be equally called "Resisting Throwaway Culture". The figure introduced and named certain influence points for the consumer or user, often located at paths branching off to the inner, more preferred loops of the lifecycle. These points are (not limited to): point of sale (acquisition for the consumer); (1st, 2nd, 3rd... n-th) use; preparation for reuse (including repair, maintenance, purchase of spare parts, accessories, etc.); end of use; product or parts hibernation; redirection towards reuse of product or parts (resale, second hand market); redirection towards remanufacturing, recycling or disposal of product or parts at end of life. The consumers' influence primarily resides in the upper-right section of the eight-shaped lifecycle in Figure 1B, indicating that consumer influence over earlier phases (raw material extraction, material production, design and manufacturing) is limited or merely *indirect*.

Responsibility for Sustainable Product Lifetimes

Although said to be in its infancy, studies of consumer influences on product longevity do focus on "the impact [...] of [...] use-related behaviour" [18], in particular on emotional bonds with, and personalisation of, the product [19], but also on topics such as pleasure-in-use and meaningfulness. The impression from this stream of research is that consumer influence pairs with design's influence on an equal footing, as Cooper expresses "appliance life spans are determined by consumer behaviour as much as by design specification" [20]. Strategies towards product longevity may thus translate to two categories already touched upon above, which are related to technical durability strategies on the one hand and user behaviour strategies such as "relove" on the other.

This equal influence assumption often leads to consumers being rendered responsible for major lifetime improvements. However, considering the indication of indirectness from above, the influence of consumers might be somewhat overestimated, not necessarily understudied. An assumed great consumer influence is likely subject to the myth, that "[c]onsumers should lead the shift to sustainability" [21]. Arguments, that dispel this myth, largely assert that, against common assumptions, spillover effects (where habituating one pro-environmental behaviour promotes another) rarely occur. Moreover, the pro-environmental behavioural change of the individual consumer does unfortunately not “result in large environmental improvements” [21]. As the premise is that “many [if not all] people join in” [21], a scaling barrier occurs, which even provides moral license for (barely noticeable) inaction of individuals [21,22]. On top of that, the idea that consumers simply have to abstain from consumption is to be challenged, as Chapman and Gant argue “the desire to consume is not necessarily *our fault*”. Thus, they deem “not accommodat[ing] human desire” in favour only of environmental benefit, *counterproductive* [23].

Three exemplifying occasions where consumers basically try to exert influence on earlier lifecycle phases could be called “Do not buy”, “Repair-it-yourself” and “Design-it-together”, which fairly correspond to the principles “prevention” and “reuse” in Figure 2. The first example, consumers not buying, so demanders not asking for anything from the supply-side, has unfortunately a poor voice or a deficient say in supposedly balanced “demand-regulates-supply” economies. Firms happened to destroy their products’ integrity even before the point of sale, skipping the usage phase and taking shortcuts in the lifecycle. Such scrapping of new(!) surplus products [24] is an unethical but legal industry practice, despite that society at large agrees that options higher up the pyramid, i.e., “reuse and parts harvesting[,] are much more valuable than recycling” [25]. Repair is another such valuable option, with the DIY repair model [25] seeking to bring repair closer to the average consumer, e.g., promoted by modular-repairable Fairphone and Shiftphone. All its drawbacks, issues of repair-*ability* or with consumers’ capabilities within self-repair, we can find subsumed under design for- and right to repair research [1,12,26–28] and debate [29]. In the debate, repair is remarkably described as a “product right” (as exhibited during the PLATE 2019 conference). The whole movement brings much-needed changes in social norms, yet bigger shifts appear to be required in industry, towards repairable products and reliable professional servicing and maintenance. A step up from DIY repair would be consumers influencing “design” through participating in that phase. Through including them, for example by means of surveys (like here for electric appliances [30]), their appreciation of or preference for given (hypothetical) design features is taken into account, albeit first after the fact that these features were designed/invented. Users, designers, or researchers influencing exactly those features, could be achieved through direct user participation as in the Participatory Design (PD) tradition, prevalent in Northern Europe [31]. However, it is not likely that many users get involved in such cases. Either way, it means that the depth of user influence (onto design features) or its breadth (the level of diversity and the number of participants) is limited.

The Power of Design to Afford Consumer Behaviour

Several scholars, including myself, think that along with the impact that design has on all other lifecycle phases comes a significant regulatory power [1,7]. The regulatory power of design lies in the ability to provide affordances for a specific use behaviour. A closer look at this ability, held by designers and mediated by the designed object is considered to be key in "design as politics by other means" [7,32]. With this, the system's designers (meaning *all* involved design, engineering and decision-making disciplines), are understood as mediators of afforded consumer behaviour or use practices, who may bring along a whole spectrum of intentionality. In other words, the "designers' implicit or explicit assumptions about how individuals make use of […] objects […] are inscribed onto the material world" with "[s]uch "scripts" […] influenc[ing] practices by facilitating or impeding certain of their forms" [33]. Close to understanding designed objects' scripts and affordances [1], and consequences towards practices of consumption and use is also research on consumers' appreciation of products [34]. Often noticeably affected by knowing of and about the designers' intentions [34], appreciation seems to increase once those scripts have been deciphered. As earlier mentioned, product life spans may be in part determined by consumer behaviour, and in part by design specification. However, taking into account the regulatory power of design, consumer behaviour can in turn be mediated by design specification and thus subtly shift the assumed balance in favour of design.

Most scholars agree that "the boundaries between designers, engineers, users, the natural sciences, the social sciences and the humanities" are effectively blurred, as we in this age "create not just products and technologies, but also […] appropriation, new processes and services" [35]. Consequently, the role of consumers in achieving sustainable product lifetimes, discussed here, is taken as the role of this blurred persona, rather than human individuals. This resonates well with understandings of social practice theory. Firstly, if one shares the view of "distributed agency", causal influences on practices would be ascribed not only to human individuals but also to material objects [33]. The distribution of agency over both consumers and designers—via the material objects—appears to be the next logical step. Secondly, practice theories situate practices on a meso-level, between consumers on the micro-level and authorities on the macro-level. I agree with Mylan arguing for "a deeper understanding of the demand side, drawing on the sociology of consumption and practice theory" [36]. While Mylan juxtaposes that with the otherwise prevailing focus "on questions of design and management in the realm of "production" [36], I prefer to connect these realms, as it is a strength of practice theory to "integrate processes of technological and social change in a comprehensive sociotechnical perspective" [33]. The design(er)'s immersion into demand side considerations is part of the effort to answer those questions of design, by *informing* design(ers) about which affordances towards consumer behaviour the designed has or could have. With inscribing affordances into the designed it might be reached "beyond the usual recommendations of both technology-centred supply side [and demand side] governance approaches" [33], thus bridging between macro- and micro-level. Certainly, the power and ability of such governance to regulate consumer behaviour (as apparent in research within lifecycle thinking in policymaking [37]) has to be acknowledged and integrated. The rationale with that is to have "design as regulation" *complement*, not confront, the ordinary regulation (by law, but also by social norms, and market [1]).

SINGLE USE PRACTICES WITH "DISPOSABLE" CAMERAS

This section introduces the case of the "disposable" camera that motivates the case discussed further in the paper. The epitomising function derives from being a somewhat atypical or extreme case, as such producing insight that "random [cases] emphasizing representativeness will seldom be able to" [38]. Due to this atypicality, the almost ancient artefact under investigation, the single use camera (SUC), remained present and memorable for the author. I had been part of a group of international and interdisciplinary students in 2008, who had an SUC on exhibition during the Environmental Adapted Product Development & Manufacturing (EAPD&M) course, at Chalmers University of Technology, Gothenburg. The SUC was disassembled (as in Figure 3) and attached to an explanatory poster. The underlying assignment work had been on the lifecycle assessment (LCA) of a product that the group surprisingly found to be a circular product service system (PSS, discussed in the Section "**DISCUSSION**") already. This kind of camera and its parts is far from being used only once and then disposed of. So, despite the name(s) it is not nearly "single use" or easily "disposable". The system of SUCs bought and sold through photo shops, department stores, pharmacies, etc., has been highly circular from its height of popularity before the rise of the digital camera to today. Simply put, successfully extracting one's pictures from the device provides incentive to bring the physical object back to the issuer. Once returned, producers facilitate for (i) reuse of the whole camera with just the film-roll, battery and paper-cover replaced for the next customer, (ii) reuse of dismantled parts up to 10 times, (iii) parts material recycling up to 100 times, and iv) eventual thermal recycling. The incentive to bring the object back, and these manifold, iterative uses are all reasons for the SUC being such an affordable system of "single use", mass-produced items.

As surprising as the circularity of the SUC may have been, it is no secret there had been a process towards achieving this during the 1990s. Goldstein, and Nagel [39,40] have illustrated that evolution, from SUCs not being initially circular to a rather matured circular production and sales model, with a balanced supply and demand for its reusable components. The subsequent SUC model will be referred to in the later comparative discussion of two cases. First, however, the main case is introduced in the following section.

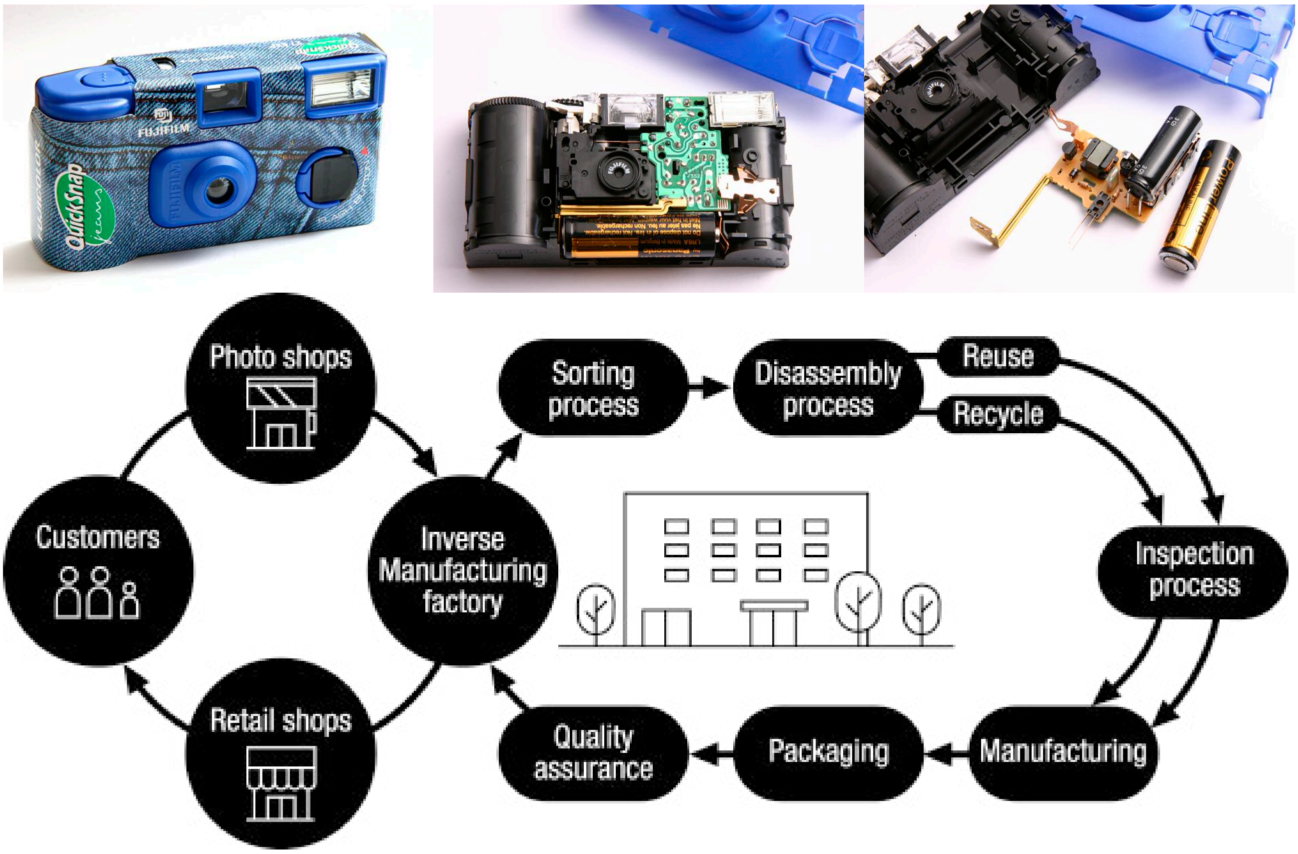

Figure 3. Single use camera and its disassembly for reuse as a whole, reuse of parts, parts material recycling and thermal recycling in Fujifilm's "Inverse Manufacturing System" (©Fujifilm Holdings Corporation, [41]).

BORROWED FOR USE—A SPECULATIVE PROTO-PRACTICE IN ICT

A Mobile Phone Borrowed for Use

The main case is that of the mobile phone as the most prominent representative of ICT. It is intended to create another extreme, speculative case by transferring the circular system of the SUC, and its atypical single use practices, onto mobile phone usage. Well aware of the multi-times higher functionality of the smartphone against an SUC, the analogy in bring-back incentive shall stimulate discussion about the soft matter connected to mobile phones. Soft matter, besides pictures, includes personal data, information, and configurations. Separating this soft matter whenever needed, would enable phone hardware to be "borrowed for use" instead of being sold to the user. Thus, in promoting sustainable future(s), I propose a speculative, "borrowed for use" mobile phone design. At the same time, this proposal resembles a *proto-practice:* a not-yet-existent, but desirable, future (best) practice [3].

Scholars describe practices as consisting of three elements: devices, skills and meanings [2]. Other terms are in use, such as stuff, skills and images or materials, meanings and competences [42,43]. Primarily, it is the devices (stuff, materials) being replaced, exchanged or envisioned to form a proto-practice. Such new devices could be denoted as proto-*types*, not-yet-existent, but desirable, future products. In the case of the mobile phone it is here envisioned that the prototype would require an SUC-like device: Just as described for the SUC parts (see above and Figure 3), certain parts and sub-assemblies would be good for "reuse-as-is" in a single-digit range, good for "refurbishment" in the double-digit range and "recycling" (melting down) in the triple-digit range. At best, the parts and sub-assemblies can be raised in their preference for reuse, all at once in a concerted effort, as depicted with arrows in the sustainable use of resources hierarchy (pyramid see Figure 2/Section "**LIFECYCLE THINKING—LINKING INVENTION WITH DISPOSAL & CONSUMERS WITH DESIGNERS**"). This lift requires corresponding material choices, depending on how frequent the reuse, refurbishment and recycling of parts and sub-assemblies shall happen, so, for instance twice, 20 times and 200 times, as well as depending on where they rank in said hierarchy (Figure 2). It poses also a desire for easy (dis)assembly in favour of detachable connections. Ease of disassembly can be achieved by a shallow disassembly depth, as with a sequence-independent disassembly [44,45], meaning it is not important what to disassemble first and last. Otherwise, it could be achieved by simple and few tools to open devices. This suggests that (hand) force to click something open is preferred over techniques like (un)screwing (similar to the informal recycling of ICT [46]). One-screw approaches [47] are preferred over many or several types of screws. When understood in Active Disassembly (AD) terms, a mechanism, such as a snap-fit release, a triggered unfolding, or similar, that can be executed in a matter of seconds [48,49] is preferred over applying electrical or magnetic forces or heat. "Microwaving" a whole assembly apart, as in [50], or in an AD example by The Agency of Design [51], seems too much of an effort. This is also the case for using costly, complex machines for recycling, because they are time consuming due to their small, batchwise handling opportunity (see for example the barely used cable stripping machines in places of informal recycling [52]). Since manifold solutions are available, where "describing the design problem more thoroughly" seems necessary, the proto-*type* features remain conceptual and are consciously rendered unfinished until the whole proto-practice is conceived and ready for real life testing.

Of similar importance as the described features of a device prototype are corresponding skills and meanings, which consider the practices that would or should emerge in use of the prototype. Here, the physical, and soft matter, especially the use and user behaviour, are taken into account simultaneously, in order to build a coherent proto-practice. The design approach taken here—inventing and recombining practice features that, in turn, can affect the prototype features—can be denoted as design interventions, meaning they are only tentative solutions. Framing the old but relapsing "problems-need-solutions" perspective into a new view as "situations that need interventions", as HCI researchers Baumer and Silberman [53] suggest to do, here means, we urge design(ers) to not "rush for solutions". As a result from this desired patience we would arrive at "innovations-in-waiting" as Shove and Pantzar also describe proto-practices [54]. Consequently, the following practice features are to be considered as design material in such iterative, patient treatment.

Practice features in the case of the mobile phone involve, first and foremost, a point of contact for consumers, i.e., "shops" that offer hardware to be "borrowed for use", rather than sold. It is likely that larger producers deliver to distributed, local partners (previously referred to as issuers). These promote a come-and-go model of acquisition, repair, upgrade, replacement, and take-back, as well as backup, transfer and erasure of the described soft matter, for their customers. It may be to everyone's advantage that customers resemble a *local* community—in a sharing economy environment, such as a transition town as promoted through Transition Design. The producer-customer relationship in such practices is much closer, of low threshold, more open, and frequent. As with other industries, such as car maintenance and repair [55], maintaining one's device(s) is made easier by distributed professional maintainers.

The current average mobile phone customer behaviour looks different. Hitherto, users who buy a piece of technology usually own it, owning also the right to keep it, unused "in the drawer", as long as they want. For instance, as many as four devices sit unused for every in-use phone in the UK [25]. (This is also represented by the hibernation spirals in Figure 1.) The owner is usually also free to resell or donate, or, in worst-case scenarios, to dispose of phones in household waste bins, despite prohibitive regulation, in Europe the Waste Electrical & Electronic Equipment (WEEE) Directive [56]. Most consumer electronics, due to their relatively small size, "afford" to fit in a bin: 89% of 141 million discarded mobile devices in the US went to landfill in 2010 [25], and only 19 states of the US have laws banning electronics from the regular trash [57].

If, however, consumers were to no longer own their devices, they might need a transition phase to get used to borrowing, just as SUC consumers had been used to unhand the camera after use. In contrast to the days or weeks an SUC is used, we anticipate usage of borrowed mobile phone hardware lasting as long as several years, due to the phone's higher functional complexity. For particular functions, long-time or systemic hardware borrowing has previously been considered, e.g., regarding the power supply of electric vehicle fleets. There, standardised battery swapping has been introduced, opposing the otherwise necessary charging stops. In the extreme, this would mean using a full-charge service instead of owning a battery. Some consumer electronics, like digital cameras and semi-modular phones, allow for such quick-swaps of the battery [58]. Yet, this often means each user owns several of them instead of "sharing" with others in the community or in this kind of "fleet", which then could manage to reduce the amount of batteries that are used and produced. Transferred to the case of "borrowed for use" mobile phones it is perhaps a question of becoming used to appreciating the affordances the hardware mediates, like having enough available charge for phone use and not being figuratively tied to the outlet (for charging practices, read further in [59]). Admiring the parts and materials per se (e.g., being possessive about the battery) should be avoided and converted into admiring the device as a whole, its affordances and the very personal constellation of information on it that—often underestimated in its importance—makes it our own.

Non-possession on the part of the user brings us over to the realm of production, where we can reconsider the SUC as a technology exemplar like Umeda et al. did [60]. I wish to apply their "marginal reuse rate" concept, as, with "borrowed for use", we intend to ensure reuse beyond item and time boundaries, on both product and parts level. Depending on how a product's (or part's) respective Production Distribution and Disposal Distribution overlap, this marginal reuse rate concept highlights and triggers implications for design. Umeda et al. categorise such implications along technologies with different lifetimes—short-lived (as the SUC), semi-long (as a photocopier) and long-lived (as an ATM) [60]. If a large overlap of the two distributions had been in place, or, in other words, an advanced producer liability achieved, producers immediately had to consider the material that already exists and is brought back to them (e.g., obsolete phone parts). The producers or, on their behalf, the system's designers, would be prompted to create new parts from the old parts or materials. For the lifecycles illustrated in Figure 1, it would mean trying to cut off or close the leakages from and to the circle. At the disposal stage, this denotes end-of-waste, but also at the design stage, it could close a leakage, if we see the varying amounts of energy and materials invested into the design phase like any virgin raw material input. Reconnecting design phases would denote ending the ignorance of the former, i.e., of design history. We assume that in contrast to the SUC's past, the mobile phone will continue to change significantly in the future. A proactive practice for design would be to smoothly integrate any novel technological developments into the "borrowed for use" mobile phone system in this overlap, exactly when engaging with the (material from the) past. It is easy to imagine to swap out parts for newer technologies (what we would call innovation, or forward compatibility), but here it is about establishing continuity (backward compatibility) alongside innovation.

All former aspects of practices, i.e., the distributed maintenance, non-possession, and the advanced producer liability are mainly thought to bring forth more durable artefacts that are kept for longer because the material stays a particular user's for longer. For instance, the storage, computing and charge capacity of a personal device can be kept high, the use be kept dependent on the installed parts. Even though repairs, updates and upgrades might be necessary, (which can cause partial take-back, obsolete material and minor waste), the user's personal bond will be strong, and, therefore, a long product life can be achieved. As proposed through the concept of Slow Tech [7,61], *the lifecycle pace is lowered,* *technology built for attachment, the use(r) bound to materiality.* On the other hand, that same "borrowed for use" practice allows users to upgrade and exchange parts as if they were modules. To this understanding of modularity as "everything is modular", I have carried out research on the topic presented at the PLATE 2019 conference [62]. Not least it has been shown, how well established the smartphone parts base is, with even laymen being able to build an (unofficial) smartphone [63–65]. Such a parts base for the "borrowed for use" scenario, which then would be an official one, would enable technology to adapt to future advancements or even to daily preferences. The said storage, computing and charge capacity of a personal device could increase or decrease at times. The material would not remain a particular user's for long, but in the system, constituted of many users. Nevertheless, the personal device stays its user's, because its use is unique, like the user herself, and can be kept independent of installed parts. *The lifecycle pace is accelerated, but more loops created and closed, technology built for adaptation, the use(r) rather detached from materiality*.

The latter part relates to accommodating to the human desire to consume: In product development, both the urge for the new as in "same, but different" and as in "never seen before" are at play and can be described through recent socio-economical examples of accelerating design cycles. Unikia, an online and local concept store [66], made design cycles more open and faster by demonstrating the design process in public and letting consumers vote on concepts to be developed and manufactured. While serving consumer's urge for the new the newcomer products suffered from immaturity and let Unikia go bankrupt eventually [67]. Another contemporary phenomenon concerns crowdfunding campaigns, which tie manufacturing to consumers' demand, while shortening so called lead-time (as with Unikia). Alternative mobile phones have been subject to such campaigns, but often to no avail, despite existing consumer demand (as in case of the Puzzlephone [68] or Turing/Hubble phone [69,70]). More of "manufacturing on demand" in the mobile phone production is nevertheless one of several valuable product regulation proposals, as have been published in the completed SMART project [12]. The accommodation to the human desire to consume and adapt can mean an acceleration, which seems to necessitate balancing decelerating measures *along with* it.

These two extremes—adaptation versus attachment—that the "borrowed for use" scenario brings forth can be tied together through incentivising the return of materials to the issuer. Be it from time to time, or only once at end-of-use, the bring-back simultaneously increases the focus placed on service in the scenario. So far, there have been monetary incentives in the form of deposits as on the Shiftphone, or, on modules as in the Fonkraft concept [62]. Other incentives have been servicing alongside worthwhile repair, and software solutions for backup and factory reset for resale, donation, etc. Rooted in the SUC's idea of returning the material to the issuer in order to print/develop the photographs, the picture taking function of the phone initiated a comparable, not primarily monetary, smartphone service incentive. This smartphone service could consist of software-enabled, automatic sorting of pictures into folders or around themes on the device (similar to prompts to save into pre-defined categorical folders on certain Social Media), and backup and clean-up of all pictures. This, for instance, could happen on the occasion of creating a photo-calendar, -book or other presentation at the end of the year. It would help the user in balancing out the available storage space on the device, or in extending storage in a module-switch fashion. This way, care can be given to the user's device(s) every year, providing the user with a "feeling of the new" and also an idea of what to give as a gift in times of when time (purposeful service, care) is considered more "giving" than money (things, materialistic status). Once, the borrowed material reaches the point of end-of-use (or is beyond repair or reuse), the same bring back incentive applies and the customer(s) might be reimbursed for the materials' remaining value. Diverse suggestions how a proper divestment, i.e., the off-boarding from use of a smartphone, could unfold, are applicable here, as have been described by Poppelaars et al. [71]. The proper redirection of values at the end-of-use is assured through exploiting the proto-practice's previously established bring-back function, be it for values like "platform-modular" and/or "urban mined" materials, or even the intangible previous design knowledge. Take-back on module level is with advantage tied to maintenance events, where the producer, repairer or maintainer gets the chance to get hold of the valuable old before installing the new. The latter is then an essential element of the proto-practice, which—originating from a low-threshold incentive—can even be enhanced through regulation by law later on. All the freed value can provide a starting point for material-led design that seeks to "bind" it again for years to come. The values "feed" into other resource-demanding products and practices of the time (depicting a future of platform-technology practices), should for example entire communities shift towards a lesser/different mobile phone use, which would mean there is a declining consumer demand.

Related Concepts in Research and Development

Several proposals in design and consumption research come close to the described proto-practice, as during the last decade researchers have notably suggested, examined or compared concepts for the ultimate reuse of mobile phones and their parts [72–74]. Two of them are presented in extracts here, where the first refers to the paper "Towards a sustainable business model for smartphones: Combining product-service systems with modularity" [72]. Its authors examined the environmental impact of comparable phone models through lifecycle assessments (LCA). They detailed why the Fairphone 2 is more sustainable in terms of CO_2-equivalents than a non-modular smartphone, assuming a five-year use period. Their presented approach builds forth on the modularity as for the

Fairphone 2 sold as a product, while pairing it with a PSS model to a phone sold as a (subscription) service. At best, this approach enhances sustainable production in terms of CO_2-equivalents through an advanced repair scheme, supposedly raising serviceability of the else 40% hibernating replaced phones at people's homes. Even phones with damages may, through an according less extensive subscription, be brought back into use.

Similarly, the Ecom phone concept by Joel Baumgartner, described in [74], claims to provide an extended use phase of devices without compromising competitiveness. It also combines the phone with a PSS, via subscription to a communication service and borrowed device until termination of the service. It features a modular construction via slots on the PCB for standardised components whose exchange and upgrade allows for a "soft evolution" [74]. It includes energy-efficient e-ink screen technology, a no-stand-by energy charger and docking station, an OLED lighting unit etc. The PCB, as the most energy-intensive, and other components of the devices return to the provider who later issues remanufactured ones to new customers. "An energy balance of the scenarios "business as usual" with yearly exchange and disposal of mobile phones, versus re-use and remanufacturing of the Ecom phones showed that the Ecom system consumes only about half the energy of the business-as-usual system" [74].

Researchers have also witnessed and described the ultimate reuse of mobile phones and their parts in developing countries throughout the last two decades. The informal recycling and reuse, which is often collocated with second hand trade and repair markets in the developing world, has been subject of many scholars' work, e.g., [46,52,75]. In the Global South, despite the adverse circumstances surrounding informal recycling, philanthropic habits appear to be in place. These are habits that the whole of humanity might have to acquire in order to make full use of the finite resources on Earth. The reference to such "endless reuse and repair" practices is offered here to emphasise the global effect changes could have. Introducing or "retracting" such practices to the Global North has definitely to be considered in tandem with, or in the light of, other rights and development goals, most notably the right to decent work.

DISCUSSION

Product Service Systems in an SCE

Essentially, both the proposed proto-practice and the related concepts are a critique of the prevailing unsustainable industry practices within mobile phone production and consumption. All of them ask for a new, or at least different, production process. This request has been answered with comparable examples of product-service-systems that demonstrate the "hardware-as-a-service" (HaaS) idea, yet with either less complex hardware, such as carpets, or bigger, immobile appliances, such as washing machines [72]. Here, the extreme case of the SUC has been employed, because of its high potential to lateral transfer onto what we would call a "mobile phone as a service", not least due to its more obvious comparability in terms of a bring-back incentive. The key difference in this circular phone proposal lies in designing new habits, in the form of a proto-practice. Only by envisioning such "a practice that has yet to be realized" [54], the mutually influential lifecycle phases become linked as desired. Not only a different production process but also a different design process had been provoked through taking practice as a basic unit of design. As such, a proto-practice is both a critique and a way of empowering designer and consumer alike to influence both creation, use and end-of-use of ICT.

We have seen that at creation, an abundance of thoughts, reasoning, how-to knowledge, traditions, or concepts of being-in-the-world manifests, and greatly determines future environmental, social, and economic impact. Especially when extending the term "product" to product service systems (PSS) [76], which the proto-practice and the other concepts allude to, the designed outcome is considered inclusive of "all physical and non-physical matter". Yet, we could extend our understanding even further, beyond the PSS, to a spatio-social, or a socio-technical system level [4]. On the system level we may, like Tonkinwise, consider "[t]he invention of new devices" as "only ever one-third of the problem of sociotechnical change." [3]. It indicates that the other two thirds, changing "traditions" (history), "cultures" and "concepts of being-in-the-world" deserve more emphasis. If we intend that design assumes the role of futuring afforded (i.e., mediated) consumer behaviour in pursuit of a sustainable CE, it means that the profession itself and its ethos (have to) change, not least in educating future generations.

Sociotechnical change might involve turning a proto-practice into a viable business, yet this appears to be problematic. Envisioning and putting a proto-practice into practice (i.e., making the proto-practice the present practice and unsustainable former ones to ex-practices [43]) is here considered a societal effort, as environmental and social costs and responsibilities are distributed over whole markets or economies. It stands in contrast to classical business founding, where an individual business enters a competitive marked. Proto-practices seem more appealing to the younger fields of social entrepreneurship, ecopreneurship, or these two collapsed to sustainopreneurship [77]. The sought-after production and business model within an SCE is subject of ongoing research, affiliated with the UiO:Norden project "Futuring Nordics" [78]. A part of that is a further inquiry into sustainable production and business models that would fit the developed proto-practice(s). The inquiry is based on a narrow body of literature, e.g., around the EU-Circular Business Innovation kit [79], around effectuation vs. causation business literature, the lean startup method, social entrepreneurship and similar, in order to determine an integrated, societal-scale business model, that hitherto seems non-existent.

The described societal effort is certainly geared towards achieving the 12th Sustainable Development Goal "Responsible Consumption and Production" through Designing for an SCE. The PSS model can be seen as the necessary condition to form a CE. The proto-practice described so far has incorporated closed loop(s) principles in the form of take back schemes for repair, reuse, remanufacturing and recycling, enhancing suppliers' product responsibility. We thus consider these, among several facilitating and enabling features a PSS has [80], necessary conditions. A decision as to whether they can be deemed sufficient conditions, to comprise a *sustainable* CE, can only be arrived at by conducting a temporal assessment of the phone PSS as a whole. The following argumentation revolves in large part around temporalities found in production models and product lives, before elaborating further both rebound effects and design trade-offs.

Temporalities in Circularity

The average useful lifetime of mobile phones has been shown to lie somewhere between 18 and 26 months [61,81], not regarded their potentially long "afterlife" in second hand markets in the developing world. Similar numbers occur for the production period for the range of phone models available in the world (refer to the "world's largest smartphone, tablet, PDA and mobile device database" PhoneDB for individual model's intended presence [82]). Third, numbers indicating the length of software support for these models [25] suggest time frames between 7 and 56 months. Based on Umeda et al.'s categorisation into short-lived, semi-long and long-lived products, introduced in the Section "**BORROWED FOR USE—A SPECULATIVE PROTO-PRACTICE IN ICT**", we thus consider the mobile phone a semi-long-lived product, "of which lifetime is comparatively same as length of production period" [60]. The previously introduced concept of "marginal reuse rate", shall here be discussed as uniquely applicable: The short-lived product's model, remarkably already exemplified using the SUC lifecycle, achieves a good marginal reuse rate of 85% and a high usability rate of collected products of about 98%. Its Production Distribution and Disposal Distribution overlap largely, so that components are commonly usable between product items or batches. These features might be scalable from short-lived to semi-long and long-lived products. In a more dynamic sense, they could even scale to the two extremes described in the proto-practice, which were building phone components to last and for attachment on the one hand, and to adapt, with more frequent circulation, on the other. What is essential, is to create a high overlap of the disposal (or then end-of-use) distribution of the first life and the production (or then remanufacturing) distribution of a new generation product or component (second life). Therefore, designing components commonly usable between product generations becomes key, and it means connecting every planned production with the past, i.e., disposed-of or non-used technology. The other implication for design would be that the longer the end-of-use distribution lasts, the longer the production period would have to stretch. This would entail keeping the design phase open, slowing down new development cycles, as proposed through the Slow Tech movement [7,61], in order to become comparably longer than a product's or component's first life. Furthermore, the high overlap is not dependent on absolute time spans, so how "slowly" designing takes place can mean something different on the component level (acceleration) than on the PSS level (deceleration).

Having disposal and production of product generations overlap and exploiting (component) reuse in a practical and idea-historical sense is currently lacking for the mobile phone. In contrast, all main, and even alternative, mobile phone producers, and software developers remain creating numbered versions of their technology. Version numbering stands then as a figurehead for unconverted backward compatibility. For users of almost all past middle-life mobile phone models this has meant a foreseeable end to spare parts and/or software support [25]. Even with more "fluent" versioning, as for the Librem phone ("lifetime updates extending phone's life" [83]), and within open software development (see case of developing Linux [84]) designing or knowing-how to design both hard and soft components commonly usable between product generations remains non-existent. When versioning of operating systems gives rise to software/hardware obsolescence, as described for iPhones and versions of iOS by Farman [85], then numbering hardware generations, e.g., 'TheMoreSustainablePhone 3.2', tells much about the past cut-off and 'new beginning' for each prior version, from 1.1 and throughout 3.1, causing premature obsolescence through a lack of compatibility. In order to emphasise compatibility and still keep track of the PSS's evolution, 'generations' is the more meaningful term to use, not least due to its allusion to inheritance. Versioning that implies cut-offs should be dispelled from designers' and consumers' minds in order to achieve the hitherto lacking overlap of product generations.

Aside from the relative overlap of product generations, we can of course ask ourselves how absolute numbers of lifetimes might look. Are we seeking for five-year long mobile phone lifetimes as of before the smartphone's rise [47] or in nowadays strive for longer smartphone lives [72]? Do we follow the software-side initiatives of creating a sustainable mobile operating system aiming for a ten-year lifecycle [86]? Or do we first regard society as being on the right track when adhering to the EU's guiding calculation of a minimum optimal lifetime of 25 years for a smartphone to be climate neutral [87]? Can we even imagine using existing phones for over 200 years in the case that prevailing unsustainable production and exploited resources force us to [87]? In response to this latter question, everybody would reply with 'No, we cannot', and highlight design's advocacy to change the technology over such a long period. Assuming a period between 10 and 25 years is, roughly, what humans still consider a foreseeable future, the presented proto-practice could aim for a future 10–25 year long lifespan. We see consumers and designers as having the responsibility to ask for, and make possible, such a long period of take-back and support, while simultaneously engaging with current and old (phone) technology to devise ways to create backwards compatibility. Moreover, in an attempt to accommodate to consumer behaviours on a continuum between longest-possible and shortest-affordable use, a flexible system is needed. The latter tackles the end of use rather than disposal, and makes sure unused items are reconstituted into new product or parts generations. In conclusion, the absolute numbers of product life lengths are somewhat diluted, yet we adhere to the desire that the circulation of both hard and soft matter in the system should be enabled for up to 25 years. The proto-practice serves the needs of both sides, whether the material is bound to one device for 25 years, or exchanged and rearranged multiple times serving different users, yet with a total service life of 25 years.

Rebound Effects and Design Trade-offs in Circularity

Adopting the PSS concept, as a "necessary condition" for the CE, has drawbacks, i.e., rebound effects that denote unsustainable outcomes, despite having reached circularity [80]. One such consumer-side phenomenon is "careless consumption". It is often related to a lack of ownership [80] or a detachment process in the prospect of a new purchase that consumers "excuse" by citing the "imperfections" of the currently used item [88]. With the "borrowed for use" proto-practice proposing both attachment and detachment strategies, for reasons of accommodating the human desire to consume, there is seemingly a thin line between the careless consumption rebound effect to appear or not. Here, the imperative, in that the (modular) material is only borrowed for use, which already implies a subtle bring-back dynamic, helps afford at least minor careless consumption occasions, certainly from a system's perspective.

Another consumer rebound effect relates to the increased accessibility [80] of devices and use of them on a "pay per use" basis. More people may be enabled to make (temporary) use of mobile phone functions, e.g., hitherto "unconnected" communities or individuals, such as ever younger children or technology inexperienced elderly. More devices could be made multiple use of and subjected to constant use, e.g., by adults and children time-sharing a device for work and entertainment. The induced effect is a more rapid wear and decay of devices. More people could afford to run several devices in parallel, with the effect of slower decay but also more resource use and inevitable decay, even in times of non-use. The "borrowed for use" proto-practice helps to make meaningful adjustments to such consumer needs and can, by help of the PSS's flexibility, pave the way for dealing with and reacting to occurring rebound effects. Such measures, possibly called troubleshooting and redesign, can only be taken after-the-fact, i.e., when rebound effects occur to some extent. Yet, they make an earlier reaction possible, thereby preventing greater harm. These measures render the bring- or take-back incentives outlined in the proto-practice very essential.

The same PSS's flexibility and ability to adjust is meant to support the system's designers when it comes to design-side rebound effects. Designers need to be able to foresee possible rebound effects, at least to some extent. When, for instance, proposing for ICT products to be built in a modular fashion, it was readily acknowledged that modularised technology demands "more material in the first place", which has potential for a rebound [62]. This may imply that any "superficial" modularisation is to be prevented. A modularisation, for instance with increased use of magnetic materials for the module interfaces (as e.g., in the Project ARA modular phone concept), can cause a rebound, as diverse modules would be produced and sold in larger quantities, eventually ending up unused (hibernating in drawers). Consequently, this modularisation would suffer from resource scarcity, as soon as the magnetic element Neodymium, a rare-earth metal, became scarce (which is likely in the future [62,73]). Hence, such modularised, magnetically connecting technology is not featured in the proto-practice's hardware, in order to preclude this possible rebound effect. Similarly, precautions can be taken in light of the diverse display technologies, whereof Active-Matrix-Organic-Light-Emitting-Diodes (AMOLED) are generally regarded most innovative at present time. Despite their further increasing efficiency they do have attached drawbacks to enabling larger sized and flexible displays, higher picture resolution and frame rate (for video, gaming, animation). Their high performance can entail intensified use, and even exceed human perception, therefore constituting a waste of resources that was not necessarily identified upon invention of AMOLED technology. What designers (and design research) could contribute with here, is their foresight in which directions either user behaviour or technical advancements could "go wrong", i.e., what qualities rebound effects would or could have (a matter of creative thinking). This relational approach describes, analyses and reconstructs the formation of rebound processes more than to pinpoint a single cause. By taking into account the relativity of cause and effect for rebounds this practice theory-based approach could preserve design practice and research from "falling prey to causal oversimplification" [33]. Nonetheless, practice theories have a limitation here, since they hardly guide design practice and research in how to apply this empirically, on the case of the mobile phone and those manifold speculative design decisions and possible rebounds [33].

By taking potential rebound effects into early consideration during the design phase, we can recognise how multifaceted the values in design, or valued attributes of designs, are. The value "sustainability" is an addition to existing qualities in design, such as functionality, safety/security, usability and aesthetics, or could even build a new base as "a central design ideal" [8]. The decisions made in design processes usually influence the above four qualities, but also, for example manufacturing costs, as well as environmental and social impacts. Trade-offs between all these qualities are commonly encountered, both for designers/producers and consumers. For sustainable solutions in particular, such trade-off decisions have often entailed higher manufacturing costs, and/or poorer functionality and/or poorer aesthetics. The typical response “Yes, but This Other One Looks Better/Works Better.” from Luchs and Kumar’s work on consumer resonance to trade-offs [89] exemplifies well, how sustainable solutions often are dismissed. Some similar trade-offs we may find among the proto-practice’s hardware features. A preference that has been mentioned is for example the one-screw approach for (dis)assembly. It would have a trade-off towards aesthetics as to how the phone’s casing could be formed then (possibly looking less attractive), and another towards safety and function as to how the casing is produced then (possibly performing worse in the event of fall/demanding a stiffer material). Another example is, again, display technology, with passive e-ink technology being applied in handheld devices, performing highly energy-efficient. Yet, in the light of coloured and animated content commonly consumed on mobile phones, usability is compromised when required to use such a greyscale e-ink display (as proposed for the “Ecom phone”, see related concepts in the Section “**BORROWED FOR USE—A SPECULATIVE PROTO-PRACTICE IN ICT**”). In sustainable design research, design work is considered as being exactly this handling of trade-offs. Instead of “using cost and resource constraints as an excuse for inaction, [producers can] use these constraints to motivate cost-neutral solutions and innovation [… and] help create supply chain practices that clearly differ from industry norms.” [90]. Designers should be capable of, i.e., trained in, making “cost-neutral”, and, more recently, also “social and environmental cost-neutral” design decisions under such constraints.

All these engagements with drawbacks, qualities of actual and anticipated rebound effects, or unpredicted user behaviour, as well as design trade-offs, can be seen as part of what Shove and Pantzar term an “active integration of elements” [54]. Typical for proto-practices, such elements are in part “new, some already well established” [54]. The highly integrative work, where one work procedure with advantage carries out two tasks at the same time (as in the popular saying “Killing two birds with one stone”), is central towards favouring sufficiency. Overcoming the prevailing efficiency thinking and establishing sufficiency thinking [91] is another important aspect in the “Designing for the SCE” challenge described here. “[I]nnovations in practice depend upon” such an active integration of the new into the well-established [54]. What design decision-makers should become capable of is accepting or even making advantage of the innovation-in-waiting position to which they are being urged here. Those provisional solutions, imperfect interventions, the waiting until enacting an immediate and smart response due to new insights, the lifelong learning from past experiences, and similar “unfamiliar” circumstances have to be endured. This is not an easy task, but necessary in terms of the responsibility decision-makers carry for the innovations in practice.

CONCLUDING REMARKS

In conclusion, the transfer of the epitomizing case onto the applied case, and, through this, devising a proto-practice, has led us to address temporalities, rebound effects, and design trade-offs. The key takeaways are that a strong overlap between product generations is required, as is thinking in generations (engaging with the past) rather than in versions. With this overlap in place, designers, together with consumers, would be able to integrate insights, regarding rebound effects that occur, into next generation products. The pursuit of longevity should be viewed as being two-directional between longest-possible and shortest-affordable use. This flexible school of thought intends to accommodate the human desire to consume and consumer needs, while aiming for a quasi-infinite circulation of the hard and soft matter in the system, eventually reaching end-of-waste. A level of continuity in such integrative design interventions is called for, as without it, continuously new design trade-offs may appear. The design ethos ought to become one of lifelong change making and learning. These takeaways constitute the sufficient conditions in designing towards a truly sustainable CE.

Methodically, new ways of designing [6] have been proposed, involving to take example from best practices and transfer their existing (maybe forgotten) solutions or known interventions laterally onto the matter of concern. Thus, the creative disciplines are encouraged to raise other types of questions, not to primarily look for solutions, which highlights the ethical dimension of design endeavours. With transfer knowledge originating from an extreme case, it has also been sought to inspire and enliven a more provocative scenario. Thereby challenging designers in terms of their ability to design even under constraints, as opposed to providing guidance, appeals to their intrinsic motivations. The described regulatory power of design(ers) may render—in a positive sense—legislation and regulation unnecessary, i.e., design will represent regulation *through* the built environment, or in any case complement it. Enhancing this regulatory power also appeals to a more integrational motivation, not the prevailing motivation to differentiate. Together, these intrinsic and integrational motivations promise to be more appropriate for to solve the wicked problem that “achieving sustainability through designing for the Circular Economy” poses.

Future Work

Future work will take place in the form of repeated workshops with designers and design researchers in order to invigorate a call for more provocative designs. This way we intend to kick-start a designer dialogue over desirable futures with provided scenario proposals, such as the "borrowed for use" scenario, that are based on continued research *into* design. Participants will set off with prototyping and "proto-practising" during workshops, taking a research *through* design approach. As modelled by an Allen Mc Arthur Foundation's case study, a whole range of imaginable scenarios, even for one and the same technological item, can be created. In this example, an optimist, a pragmatist and a realist toaster have been realized with different sustainability strategies in mind [51]. As it shares attributes like module based repair and adaptation, the "borrowed for use" mobile phone is most comparable with the pragmatist model. Creating proto-practices can provide the participants with a divergent thinking exercise, in contrast to searching for a "Holy Grail", for instance among modular mobile phones [62]. Doing this exercise can help to seek for diversely emphasized and more *provocative* scenarios, as is proposed with the "borrowed for use" scenario, and as others have proposed with the edible or implantable phone (see "Future trends" in [74]). The reason behind "reaching higher", i.e., setting seemingly unattainable, far-fetched goals, is two-fold: Firstly, it enables designers to avoid the mentioned one-sided optimisation. Instead, integration processes may become common, and expand further, forming a *transdisciplinary* approach, which for the mobile phone that roams between (physical) product design and (virtual) interaction design, would be much appreciated. Secondly, we challenge designers' *design ability* [92], instead of prescribing design guidelines and extrinsic strategies. The workshops also give special emphasis to the design process and its "convergence" phase, which oftentimes falls short at the end of such processes. It is, however, a desirable phase, because it asks for participants' critical, pragmatic or idealistic thinking as to how desirable the brainstormed ideas, interventions or solutions are. Strengthening this design ability means devoting considerably more time to the exploration of the highly important *synergies* that designers seek to exploit.

Looking ahead, we anticipate designers being asked, and having the capacity to create such "bold, courageous synthetic visions and facilitate collaboration with other parties", where their methods "foster holistic approaches to design", and are "'post-disciplinary' […] facilitat[ing] synergy between the activities of designing objects and of 'designing' cultures" [35]. As a society, we may eventually resist throwaway culture due to *integrative* innovation based on design-enabled, sufficient consumption and production.

CONFLICTS OF INTEREST

The author declares that there is no conflict of interest.

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