2 Beyond Eco-Design Towards Designing Sustainable Circular Production-Consumption Systems

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1 Resource Efficiency, Circularity, and Consumption

What are the challenges humanity is facing today regarding raw material consumption and ecosystem services? Several different research groups and approaches come to similar conclusions.

1.1 Resource Efficiency Research

In the early 1990s, Friedrich Schmidt-Bleek and his research group at the Wuppertal Institute for Climate, Environment and Energy proposed that Western industrialized countries have to dematerialize their production-consumption systems by a factor of 10 (Schmidt-Bleek and Klüting 1994). This group also came up with a definition of eco-intelligent consumption as consumption that is not based on material possessions but the resource-efficient use of goods (i.e. products, infrastructure, services). Eco-efficient consumption would then mean, selecting in each consumption decision the offer that provides the functions needed to fulfill the consumer's needs with the lowest possible use of materials and energy (Schmidt-Bleek et al. 1997).

Another member of the materials flow group at the Wuppertal Institute, Joachim Spangenberg, developed the Environmental Space concept, first presented in a report for Friends of the Earth Europe in 1995 (Spangenberg 1995). The

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environmental space concept is based on Opschoor's initial definition of environmental space and identifies thresholds for resource consumption to secure non-deteriorating ecosystem services for future generations. Resource consumption should be reduced to a level at which the annual reduction of resources and their service potential can be compensated by newly discovered resources and efficiency gains in using them. In addition, Opschoor assumed equitable per capita consumption entitlements and concluded that a reduction of per capita consumption in industrialized countries by a factor of 8–10 was necessary (Opschoor 1987). Consequently, according to Spangenberg, the environmental space that every citizen of planet Earth can occupy is a space below the line of overconsumption (the 'ceiling' of the environmental space) but above a so-called poverty line or the line of dignity (the 'floor' of the environmental space). Thus, the lower line represents the minimum condition for **social sustainability**, while the upper line indicates **environmental unsustainability**. The environmental space between the two lines is a zone for free choice of consumption patterns. Comparable to monetary income, consumers have a budget for ecosystem services that they can spend on those goods and activities that are most important to them (Spangenberg 2014) (see Fig. 1).

Many years later, a similar model was developed by Raworth (2017) in her Doughnut Economics concept based on the planetary boundaries method developed by Johan Rockström and his team at Stockholm Resilience Centre (see below). Raworth (2017) in her concept also describes—like Spangenberg—that there is an upper limit for consumption (ecological ceiling) which is defined by the limits of our planet and that there is a minimum level of consumption (social foundation), i.e., everybody on this planet should be able to fulfill their basic needs like access to water, food or housing. In between these two circles is the safe and just space for humanity to live, according to Raworth (2017).

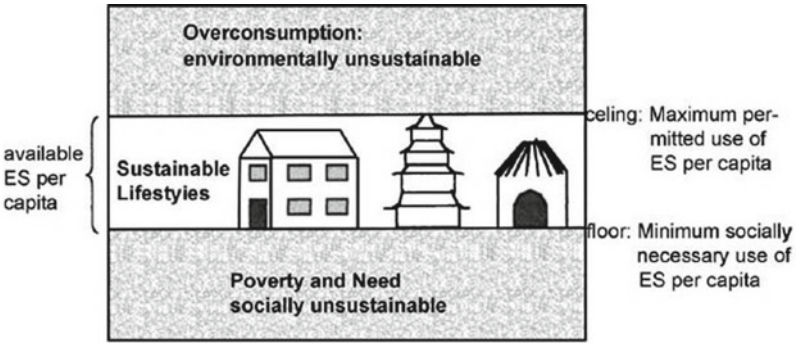

Fig. 1 The environmental space model developed at the Wuppertal Institute for Climate Environment and Energy, acc. to Spangenberg (1995)

1.2 The Circular Economy Concept

The idea of a Circular Economy is not new. In 1976, the US Congress passed the Resource Conservation and Recovery Act (US Congress 1976) to promote waste prevention, recycling, and resource conservation. Thus, the 3 Rs (Reduce, Reuse, and Recycle) were created as a slogan to communicate the idea to the population. Germany passed a circular economy and waste law in 1996, which was revised and updated in 2012 (KrW-/AbfG 2012). Both laws were developed within the framework of waste prevention approaches, i.e., they approach the issue from the waste perspective.

Re-think approaches that integrate circular economy strategies into the creation of products and business models were developed by Walter Stahel of the Institute for Product Life Cycle Research in Switzerland as early as the 1980s (Stahel 1991). He coined the term "performance economy" (Stahel 2010). At the end of the 1990s, the cradle-to-cradle design principle was formulated by the German chemist Michael Braungart and the American architect William McDonough. They suggested designing products in such a way that materials can be reused and recycled in natural or technical cycles, thus turning residual materials into nutrients (McDonough and Braungart 2002). Later on, the Circular Economy approach was widely publicized and promoted by Stahel and MacArthur (2019), the Ellen MacArthur Foundation.

Like the Resource Efficiency approach, the Circular Economy aims to decrease the consumption of virgin raw materials and to increase the intensive use of resources once they have been introduced to the technosphere, which also results in a reduction of waste. The means suggested by the Circular Economy are closing loops in the technosphere or the biosphere, especially by extending the useful lifespan of products through longevity and repairability, and by re-using as much as possible products, components, and materials on the highest value level in the technical systems. Alternatively, non-toxic bio-based materials can be cycled back to nature as food to natural systems. All of this should be based on using energy from renewable sources and supported by new circular business models. Digitalization can act as an enabler for these circular systems (Circular Economy Initiative Deutschland 2020).

1.3 The Ecological Footprint Concept

Another framework that pays regard to the need to cut global resource use is the Ecological Footprint concept by Mathis Wackernagel and the Global Footprint Network team (Rockström et al. 2009). They seek to capture the ecosystem services planet Earth provides and compare them with what people on this planet consume per country and overall. Some of the results of this type of calculation are that

- If everyone wanted to live like the average North American, this would require six planets,
- If everyone wanted to live like an average German, we would need four planets,
- Earth Overshoot Day, when humanity has consumed all the ecosystem services that the planet can renew within one year, takes place earlier each year. In 2022, it was already the 28th of July. To use an economic analogy: from that day on, humanity does not live from the interest but consumes the assets (the substance) of planet Earth (https://www.overshootday.org).

1.4 The Planetary Boundaries Research

Johan Rockström and his team at Stockholm Resilience Centre defined a framework of boundaries of ecosystem services that our planet offers. They described nine so-called Planetary Boundaries (Rockström et al. 2009). According to their research, humankind has already pushed climate change, biodiversity loss, shifts in nutrient cycles (nitrogen and phosphorus, very important for agriculture, i.e., food production), and land use beyond the boundaries into unprecedented territory. In addition, human societies have exceeded a planetary boundary related to environmental pollutants and other 'novel entities' including plastics (http://www.stockholmresilience.org) (see Fig. 2).

1.5 Overall Raw Material Reduction Targets

These different concepts all aim for the absolute reduction of global resource consumption. Industrialized countries (ICs) like Germany will have to decrease their resource consumption disproportionately in relation to the resource consumption of developing and emerging countries. Currently, reduction targets of a factor of 4 to a factor of 20 by 2030 or by 2050 are being discussed for ICs (e.g., Ressourcenkommission am Umweltbundesamt (KRU) 2014). The challenge is to secure prosperity, quality of life, and happiness for those who have access to them today, and to increase quality of life, prosperity, and happiness for those who lack it respectively, while at the same time reducing resource consumption overall. This level of reduction requires changes both in production and consumption and in the political framework conditions. It requires resource-efficient circular lifestyles as well as new economic models and radical technological and social innovations for more resource efficiency and circularity.

1.6 Role of Designers

This is a challenge for consumers and producers, politicians and academic researchers alike. But also designers have to ask themselves how they can design

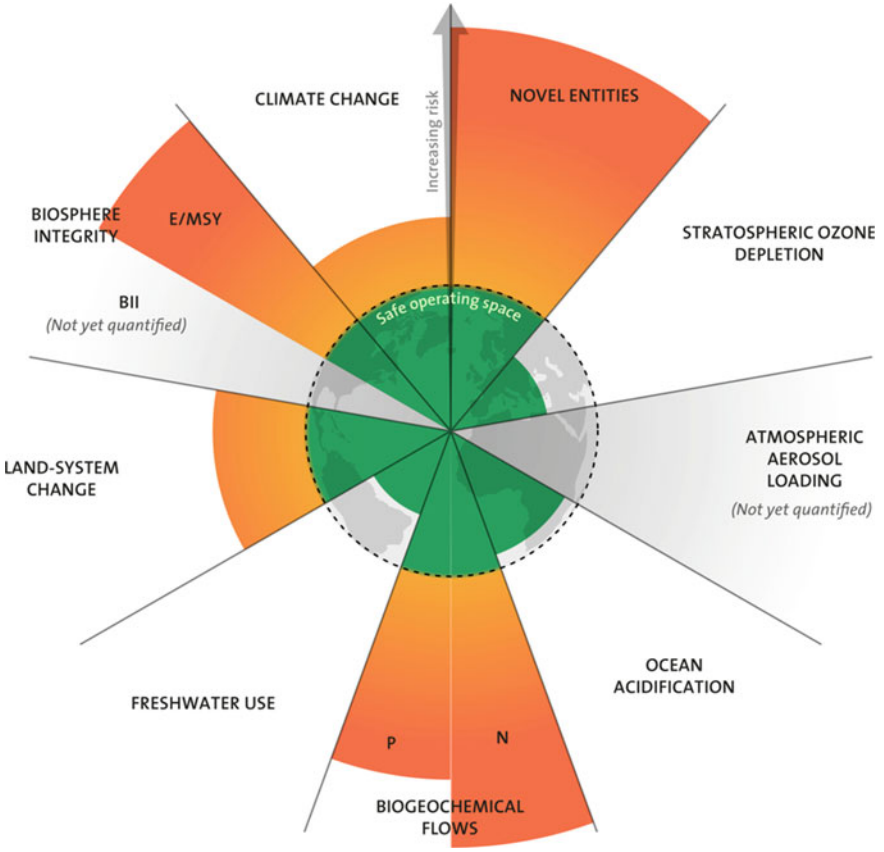

Fig. 2 Planetary Boundaries acc. to Stockholm Resilience Centre. *Source* Azote for Stockholm Resilience Centre

products, services, infrastructure, systems, communication, education, and social innovation that work towards this kind of 'absolute dematerialization' without losing or even gaining quality of life for as many people as possible. Altogether the quest is to encourage more sustainable, circular, resource-efficient lifestyles making them attractive to as many people as possible. Meanwhile, there is almost no product or service on the market that has not been touched by the hand or pen or computer of a designer, and it is the core competence of designers to make 'stuff' attractive. So why not put the skills of designers and other creatives on duty for the transformation towards sustainability instead of creating ever more problems in a throw-away consumer culture?

2 More Sustainable, Circular, Resource-Efficient Lifestyles

What are unsustainable lifestyles? These are lifestyles that cannot be sustained because they go against two fundamental limits: (a) the planet with its boundaries in terms of availability of land, fertile soil, resources, freshwater, i.e., everything that are so-called ecosystem services as described in the previous paragraph and (b) what is socially acceptable. If humankind is serious about equal human rights, then it is not fair that some citizens of this planet consume most resources and others live below the poverty line. Therefore, a sustainability evaluation of lifestyles has to take as a benchmark the more or less fair distribution of ecosystem services among all citizens of planet Earth. This distribution can be calculated on the basis of individuals or whole countries.

It might still be acceptable that some people in a country consume more when others voluntarily consume less. There might even be a trading scheme possible, where people who consume less can 'sell' parts of their share to people who like to consume more, very similar to Carbon Trading Schemes. It also makes sense to take into account the geography and climate of where people live, e.g., very cold or very hot climates need more heating or air conditioning, and food is easier to grow in temperate climates. These calculations of how much environmental space is available for each person in a specific location on planet Earth still are refined and values are negotiated. In an ideal world, however, every person living on this planet would have the equal right to access ecosystem services and each person would not consume more of its share than is available while keeping the planet in a healthy state.

2.1 Healthy Limits to Personal Consumption

The findings of the research groups described above are summarized as follows:

- In the logic of the ecological footprint, a sustainable lifestyle would mean, not consuming more than one planet.
- In the logic of the environmental space concept, this would mean staying above the line of social dignity but below the overconsumption line.
- In terms of resource efficiency, that would mean that people living in industrialized countries would need to reduce their resource consumption (including energy) on average at least by a factor of 4–10.

A closer look at consumption domains shows that the most impactful consumption activities with the highest potential for improvements in Europe have already been identified (European Environment Agency 2007). About 80% of all environmental impacts of European citizens are caused by three consumption domains:

- Housing and especially energy consumption in homes,
- Mobility and transportation,

- Food and agriculture.

Very likely this is similar for most industrialized countries.

2.2 How to Calculate One's Own Footprint

Some simple online tools exist to calculate one's personal environmental impact, such as:

- For resource footprints (or ecological rucksack) the resource calculator of Wuppertal Institute (https://www.ressourcen-rechner.de/?lang=en);
- For ecological footprints the ecological footprint calculator of Global Footprint Network (https://www.footprintcalculator.org/home/en);
- And for carbon footprints the carbon footprint calculator from Carbon Footprint Ltd. (https://www.carbonfootprint.com/calculator.aspx).

The following table shows the individual footprints calculated with the tools above for a person living in Germany. This person eats hardly any meat and buys mainly seasonal, regional, and organic products. She has no car and travels mainly by public transport, bike, and foot but has to fly for quite a few trips. She lives alone in an apartment of 56 m^2 that is heated by district heating and has a green power contract. The person uses limited amounts of products consciously, often buys second-hand, and exchanges products only when they are broken (see Table 1).

While these results are not comparable, they lead to similar conclusions: Individual consumer behavior is only partly responsible for a person's environmental impact. The services provided in the country where a person lives are also decisive, which means consumers alone cannot be made responsible for the resource efficiency of a country. The infrastructure and public services among others have to be taken into account and improved as well.

In the case of the person above, one major environmental impact emerges in the mobility domain from flying per year. In the ecological footprint calculation, 70% of the person's impact is made up of her carbon footprint, and four of the seven global hectares the person consumes come from flying. That is her 'big issue'.

Table 1 Results of individual environmental impact calculators for the same person, compared (own calculation)

Measuring system	Results
Resource footprint Target state would be 17 tons	19.1 tons are consumed by this person Compared to an average of 27 tons for all users of the calculator
Ecological footprint Target state would be 1 planet	4.2 earths would be needed, if everybody lived like this person Earth overshoot day of this person is 29th of March
Carbon footprint Target state would be 2 tons	CO_2 emissions of this person are 5.03 tons The average of people living in Germany is 8.89 tons

Without taking into account the flights she would only be 'responsible' for three global hectares or around two planets.

For other people that 'big issue' might be eating meat, driving a car every day, or buying and disposing of a lot of products and clothing, etc.

That means, as diverse as the consumption patterns are, as multifold are the options for improvement. There is no such thing as 'the one sustainable lifestyle', but there are many different ways in the various consumption domains to live more sustainably. This relation is especially true across different cultures and consumer groups. *Diversity and freedom of choice are key—also for the acceptance of such more sustainable lifestyles.* That is why the environmental space concept gives an upper and lower limit for the consumption of resources, energy, and land, but does not prescribe how citizens have to live. Every person still has many individual choices on how to'spend' their share of the ecosystem services.

2.3 How to Reduce One's Footprint

Nevertheless, one can formulate a few generic measures as priorities that enable more sustainable living for a relatively homogenous consumer culture, such as the one in industrialized countries, as follows (see Table 2).

If these are some of the most important measures to reduce consumer's individual environmental impact and resource consumption in industrialized countries, then the next question is, how can consumers be attracted to implementing these and similar measures? This will likely be most successful if the behavior changes will contribute to their well-being and happiness.

3 Happiness and Wellbeing

The happiness and well-being quest has become an industry—from the first books about 'simplifying your life' to Marie Kondo (https://konmari.com) helping us declutter our wardrobes and our lives, from uncountable magazines, websites, and coaching services to educational programs on how to live happily. Indeed, our lives in the modern digital world have become stuffed and filled with digital gadgets and information overload all around. Work and consumption pile up in our waking hours and haunt us in our nocturnal dreams. Today, time has become a scarce resource, and it is almost a social obligation to search for one's own happiness.

3.1 Unhappy Consumers

The multi-optional consumerist society is deeply unhappy and unhealthy. Stress and burnout rates are at a high level and still increasing. According to the AOK, a German public health insurance fund insuring around 1/3 of the German population, an average of one burnout case per 1,000 AOK members was

Table 2 Consumption domains and most important sustainability measures. Own compilation based on findings from the European SusProNet (cf. Tukker and Tischner 2006) and SCORE (cf. Tischner et al. 2010) research projects

Consumption domain	Measure
Housing/energy consumption in homes	Reduce the space you occupy for housing or increase the number of people sharing the space
	Take care of good insulation and construction of your home so that heating/cooling needs are reduced
	Select a green energy provider or produce your own green energy
	Reduce the number of products that consume power in your home, use them efficiently, and prefer energy-efficient devices
Mobility/transport	Reduce the need for mobility/transport, e.g., by living close to where you work, buying local, going on holidays close to where you live
	Prefer efficient mobility means: Walking/biking before bus, train, and car
	Prefer efficient transportation means: Bicycle courier before ship, train, and truck
	Avoid flying and transportation by air
Food/agriculture	Eat no or less meat
	Consume no or less dairy products
	Prefer regional, seasonal, organic, unpacked, unprocessed produce
	Eliminate/reduce food waste

diagnosed in Germany in 2005; in 2017, there were already 5.5 cases of incapacity for work per 1,000 members. According to the AOK, the number of diseases due to burnout diagnoses has more than quadrupled in the last ten years (https://de.statista.com/statistik/daten/studie/239672/umfrage/berufsgruppen-mit-den-meisten-fehltagen-durch-burn-out-erkrankungen/). Burn-out is associated with a high burden in work and private life. Similar increases can be detected in other countries (Abramson 2022).

3.2 Aspects of a 'Good' Life

When asking what makes us happy, again, it is easier to understand what makes us unhappy. Interesting anecdotal findings in this context, come from the Australian palliative nurse Bronnie Ware talking to her patients, who knew that their lives would soon end, about what they wished they had done differently. Common themes surfaced again and again. The most common five were (Ware 2012):

1. I wish I had the courage to live a life true to myself,
2. not the life others expected of me.
3. I wish I hadn't worked so hard (especially male patients).
4. I wish I had the courage to express my feelings.
5. I wish I had stayed in touch with my friends.
6. I wish that I had let myself be happier.

It seems that none of the dying persons Ware nursed wanted more money, a better job, a faster car, or more beautiful clothing, etc. All of the regrets of the dying are about immaterial issues such as self-actualization, developing one's own talents, social connection to others, and living a life true to oneself. In Maslow's hierarchy of needs, these are the needs of self-actualization and transcendence, self-esteem, and the social needs of love and belonging, not the physiological or safety needs (Maslow 1943).

Beyond the anecdotal, research about happiness and well-being was carried out early on by economist Richard Layard. He detected that the happiness of people in industrialized countries, e.g., the US, is not automatically correlated to higher income. Between 1956 and 1996, the percentage of very happy people in the US declined despite a constant increase in GDP per capita (Layard 2005).

Layard is also co-editor of the World Happiness Reports of the UN. These reports collect and discuss findings about the state of happiness in the world. In the 2019 issue, for instance, the connection between the use of digital media and well-being has been analyzed and the authors concluded that longer screen time is correlated to lower well-being of adolescents. Vice versa reducing the use of digital devices and media increases happiness. These might be rather indirect effects: screen time takes away time for other activities that contribute to well-being. The report refers to many scientific studies (Hartgerink et al. 2015; Lieberman 2014; Zhai et al. 2015) concluding that deprivation of social interaction and lack of sleep are clear risk factors for unhappiness and low well-being in adults (Helliwell et al. 2019).

Similar conclusions come from the Greater Good Science Center, based at the University of California Berkeley, which started in 2001 to collect academic studies from psychology, sociology, and neuroscience around the well-being of people with the aim to offer the gathered knowledge and education on how to build a thriving, resilient, and compassionate society to the public. The center promotes the concept that individual happiness is connected to strong social bonds, altruistic and cooperative behavior, mindfulness and compassion, and overall a meaningful life (https://ggsc.berkeley.edu/what_we_do/event/the_science_of_happiness).

To conclude, earning more money, above an income that allows us to fulfill our basic physical and safety needs, and spending it on more adorable products, entertaining us in front of computers and mobile phones, having a lot of friends on social media, and other seemingly satisfying activities might not deliver to us the happiness and well-being that marketing and advertising agencies and the companies work for to make us believe. It might rather be true what Annie Leonard

says in the 'Story of Stuff' video clips: "*We are trashing the planet, we are trashing the people and we are not even having fun.*" (https://storyofstuff.org/movies/). Important first steps towards more sustainable lifestyles would be to educate consumers about these findings early on, e.g., in schools, and to promote more ethical advertisements.

As the core competence of designers is to make goods attractive for consumers/users with the promise that buying and using the goods will make them happy or will be good for them, the next paragraph discusses the role of design and designers in this context.

4 System Design for Sustainability and Circularity

The traditional position of designers and design is in the middle between production and consumption. Designers work for companies that like to sell 'stuff' and design that 'stuff' (product-, industrial, user experience design, also software design) and the communication (communication-, graphics-, media design) and other services (service design) around it so that the targeted consumer or user groups like and buy the offer. Thus, designers normally have two types of clients: the producers and users/consumers. But because they are paid by the producers, their interest is a little more important to the designers. Environment had no agency in the design process until the 1970s when it became clear that the throw-away society creates considerable damage to the natural environment.

4.1 From Eco-Design to System Design for Sustainability

Industrial designers like Victor Papanek described early on that the design as taught and practiced was creating more problems than solutions (Papanek 1985). Then Green or **Eco-Design** (Tischner et al. 2000) was defined as a different design discipline taking into account environmental issues alongside other common aspects like function, aesthetics (Papanek 1985, 1995), and price, and covering the whole life cycle and product system of a product. The circularity of products, components, and materials was already part of the Eco-Design method and strategies (Tischner and Moser 2015).

Because of constantly increasing global consumption and the rebound effects that counteracted the improved eco-efficiency of the products (more products are used, or the efficient products are used in very in-efficient ways), it became clear that the whole system of production and use of products would have to be redesigned; not just the products alone. Thus, the approach of **Product-Service System design (PSS)** for Sustainability was developed (Tukker and Tischner 2006). Here the focus is on fulfilling the needs with the most efficient combination of products and services moving as much as possible towards immaterial services rather than selling a lot of material products, e.g., as is the aim of the sharing or servicizing economy. The PSS concept was the transition to an even more systemic

approach to designing or influencing overall production and consumption systems such as mobility, food and agriculture or energy production and consumption, that was also supported by the United Nations under the term **Sustainable Consumption Production (SCP)** system design or **System Innovation for Sustainability** (Tischner 2008a, b).

4.2 More Radical System Design Approaches

Although these more complex systemic design approaches are still far away from being regular design practice, there are more and more designers suggesting similar radically different approaches to design, because these are needed to tackle the big and complex challenges for humanity as described in the previous paragraphs. Upcoming terms are eco-centric or humanity-centered design instead of human-centered design. Other examples are:

- **Transformation Design**, first suggested by the Design Council in London around 2003 and applied in the RED projects, is a human-centered interdisciplinary process that aims at creating desirable and sustainable changes in behavior and form of individuals, systems, and organizations. The process is multi-staged, iterative, and applied to big, complex issues—often social issues. The challenges are holistically examined, and then new small-scale systems including objects, services, interactions, and experiences are prototyped that support people and organizations in achieving the desired change. Successful prototypes can then be scaled. The RED projects have resulted in the creation of new roles, new organizations, new systems, and new policies (Burns et al. 2006).
- **Speculative Design**, a term suggested by Anthony Dunne and Fiona Raby is a discursive, research-oriented, experimental design approach based on critical thinking and dialog that aims at including the public in the rethinking and envisioning of and dialog on new technological realities and new social relations. Dunne and Raby had explored the potential of new technologies for the future issues of our time under the label ‘Critical Design’ and then moved to Speculative Design as a method to initiate discussions—not to offer concrete solutions that can be implemented directly. However, a successful Speculative Design project is necessarily connected to the research of a social context and is fundamentally directed towards individual needs and desires (Dunne and Raby 2013). Its results are often imaginations of desired futures and visions of possible scenarios. Speculative Design is transdisciplinary or even post-disciplinary in nature which means it relies on interactions between various disciplines.
- **Transition Design**, as promoted by Terry Irwin and her colleagues at the Carnegie Mellon University acknowledges that societal transitions are happening and needed to reach more sustainable futures, and argues that design has a key role to play in these transitions. The interconnected fields of social, economic, political, and natural systems are taken into account to suggest a

rethinking of entire lifestyles with the aim of harmonizing them with the natural environment and making them more place-based, convivial, and participatory, yet global in their awareness and exchange of information and technology. Basic human needs shall be satisfied locally, within economies that exist to meet those needs, as an opposite to the mainstream dominating economic growth and profit-maximizing paradigm. Transition designers draw on knowledge and wisdom from the past to conceive solutions in the present with future generations in mind. The tools to do so come from complex systems theory, transition, and change management, as well as philosophy, psychology, social science, and anthropology among others (Irwin et al. 2015).

4.3 Common Elements of System Design for Sustainability

All these new and radically different approaches to design have common elements that are also intrinsic to **System Design for Sustainability**. These are mainly the following characteristics:

- System perspective, beyond a product, or a service, or communication, or a user experience design. System design analyses complex systems, and identifies problems—even wicked problems (Rittel and Webber 1973) and opportunity spaces for many different actors (users, producers, service providers, etc.) to act more sustainably.
- Multidisciplinary, Cross-disciplinary or Transdisciplinary, across the design disciplines, of designers with many other disciplines, and between other disciplines.
- Multi-stakeholder approaches and Co-Creation: Diverse groups of stakeholders are involved. The approach is often participatory from the research phase over the design to the implementation of the results. This approach requires empathy and collaboration/co-creation skills on the side of designers, as well as high-level facilitation and organizational skills.
- They aim at radical new solutions and disruptive changes in existing systems to create a more sustainable society focusing on all three pillars of sustainability as defined by the UN—environment, social, and economic (World Commission on Environment and Development 1987).
- They acknowledge that this change is not only about technological innovation, but also social and organizational innovation might be equally or even more important, ultimately aiming at encouraging more sustainable ways of living.
- Often new start-ups, services, business ideas, and business models emerge in the context of system design projects. Here, the business model canvas (Osterwalder et al. 2010) and work done by Oliver Gassmann and the team at the University of St. Gallen on business model innovation patterns is helpful (Gassmann et al. no date). Even circular business model innovation guides are available (e.g. https://bmilab.com/topics/circular-economy).

5 From Circular Design to Design of Sustainable Circular Systems

So far, Circular Design is often understood as focusing on the circular design of products by using circular design strategies like 'the Rs' of circular design: Reduce, Repair, Reuse, Remanufacture, and Recycle. This is a good first step. In addition, 'the Ds' of Circular Design should be considered as well; we should design so that it is possible to De-polymerize polymers, De-alloy metals, De-laminate composites, De-vulcanize rubber, De-coat materials, and De-construct high-rise buildings and major infrastructure (Stahel and MacArthur 2019).

However, this is still not enough to guarantee sustainability. Every circular process still needs energy, transportation, collection, sorting, remanufacturing, recycling technologies, etc. Many of these technologies are still lacking. In addition, according to the 2nd law of thermodynamics, simply put, these transformation processes increase the entropy in the system. As long as the share of renewable energies is too low—according to Eurostat, it was around 22% on average in the European Union in the year 2020 (https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-4c.html), the energy needed for recovery and recycling processes still increases climate change. Thus, all energy sources used in a circular economy should be renewable.

Furthermore, some processes can simply not be reversed, e.g., dissipative losses of materials such as tire abrasion, aerosols or microplastics. Thus, all of these dissipative materials should be non-toxic and digestible for nature. Generally, with more and more circulation of materials, toxic and hazardous substances contained in the materials will accumulate in the system. Thus, the use of toxic and hazardous substances should be eliminated or reduced to a minimum.

In addition, social aspects of the circular economy, such as what kind of jobs are lost and created by circular systems and who will do the work, are often neglected.

And finally, recycling of materials cannot meet the increasing demand, if resource consumption continues to rise globally as it has been the case in the past (International Resource Panel 2019). For instance, in the year 2019, over 14 million tons of plastics have been processed in Germany. The share of recyclates was almost 2 million tons, but only 430,000 tons post-consumer recyclates substituted virgin plastics (Conversio Study 2020). Therefore, carefree overconsumption has to be stopped, especially in industrialized countries, and the upper and middle classes in developing and emerging countries need to change their behavior towards more sufficiency.

All of these arguments point towards the conclusion that the circular economy and circular design alone will not make our production-consumption systems more sustainable, if we continue or even increase current consumption levels. What is needed is a more holistic design of sustainable production-consumption systems that includes circularity but goes beyond that; starting with the question of what is really needed by consumers and society to lead a good life and how we can deliver that in the most sustainable way. It continues with considerations about

new (circular) business models and social as well as technical innovations needed, ultimately also questioning the underlying economic system.

5.1 Activities in a System Design for Sustainability Methodology

A design methodology to design production-consumption systems for increased sustainability should consist of the steps and activities described below. In all of these activities, users/consumers and stakeholders including political actors should be involved as much as possible (participatory/Co-Design). Circularity in the systems is an important element, but even more important are the radical approaches of Re-thinking systems and Reducing consumption:

Step 1: Holistic system analysis	Thoroughly analyze the existing situation to identify major problems/sustainability issues, such as where is the largest resource consumption, what are social issues, and where is the biggest improvement potential, using, for instance, the sustainability SWOT analysis, identify windows of opportunities for improvement
Step 2: Scenarios, backcasting, and roadmap	Scenario building and backcasting: for those areas you have identified, imagine desirable futures and how well-being can increase while resource consumption and environmental impacts can decrease for as many stakeholders involved in the system as possible, start where the system is now and develop potential road maps (steps over a defined period of time) to reach the most desirable and sustainable futures
Step 3: Selection of focus and ideation	Focus on the most promising areas and ideate design interventions (products, services, social innovations, education, communication, bottom-up initiatives, and other activities) that can help to move from one step to the next step in the roadmap towards the desired sustainable future
Step 4: Selection of solutions and detailing business/operational models, networks, etc.	Evaluate ideas according to sustainability improvements, e.g., using simplified sustainability screening tools or even Screening LCAs, and identify the most promising sequence of steps. Formulate business models and financing models for the design interventions (including innovative ones such as crowdfunding), identify the partners needed to implement, and prepare implementation

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Step 5: Implementation	Implement the steps starting with the first. Evaluate progress and learn, and adapt accordingly. If some measures fail, redesign the steps as needed. Start with small-scale application/test in niches, if sensible, and then scale up or multiply

6 How to Make More Sustainable Production-Consumption Desirable

There will only be a social change towards sustainability, if we change personally, if people change in their private lives and at work. One can call for institutions, politicians, and companies, but who is the politician, and who is the entrepreneur? They are all people. In other words, what is needed is a change in the mindsets and behavior of people. If people change their behavior, then organizations change too. However, change is difficult, change creates fear, people may be a bit lazy and uncomfortable in their situation, afraid of the unknown, and hesitant to break new ground. Many studies have shown that people feel secure in their routines. According to behavioral economics, humans like to stick to known routines, because that needs the lowest investment in terms of time and effort for decision-making. Thus, about 80% of everyday behavior is 'routine' (Tischner et al. 2010). People always drive the same way to work, buy the same things in the supermarket, go to well-known restaurants, and so on. To change the learned and routinised behavior is associated with effort and the outcome is uncertain. For example, we don't know exactly whether the food in a new restaurant is as good as in the usual one. The same applies to new products that are unfamiliar, require us to behave differently or might be somewhat unusual. There are adventurous people that always search for new exciting experiences, the trendsetters, but in Germany, they make up only around 10% of the population (acc. to the SINUS Milieus Typology: https://www.sinus-institut.de/sinus-loesungen/sinus-milieus-deutschland/).

One tool to overcome procrastination is the so-called 'nudging', an often subtle, interesting, fun, and humorous way to encourage better consumer behavior, e.g., by design interventions (Thaler and Sunstein 2009). Edutainment, gamification, starting of communities where like-minded people encourage each other are other approaches, as well as the involvement of users/consumers in the design and production of the desired outcomes. The more consumers are also involved emotionally and actively and the more the new behavior feels good and generates positive results, the more likely they stay with it. Ultimately it needs a new narrative away from a consumer culture towards a well-being culture in society, where identity is not mainly connected to the stuff we own and the number of social media contacts we have.

According to behavioral psychotherapy learning new behaviors includes four elements (Kanfer and Schmelzer 2005):

(1) Awareness: one becomes aware that a problem exists,
(2) Motivation: one has (intrinsic or extrinsic) motivation to change one's habitual behavior,
(3) Opportunities: one then has the opportunity to try out a new behavior in a safe space, and finally
(4) Positive Reinforcement or Reward: When trying the new behavior, there should be positive reinforcement or reward, e.g., saving money, a satisfying experience, or admiration by peers, and so on. Thus, the new behavior proves successful and pleasant and can very likely be integrated into daily routines as a positive behavior pattern.

Designers can support this learning cycle towards sustainable lifestyles:

(1) They can communicate better and more appropriately to the target group (storytelling, edutainment, etc.) to create more awareness of sustainability issues and the connection to personal behavior—one of the core competencies of communication designers.
(2) They can try to strengthen extrinsic or intrinsic motivation, e.g., by showing role models and positive examples, or by making the abstract sustainability issues more emotional, explaining how things work in other cultures, how sustainability can look and feel nice, and how it can be fun, among others.
(3) Designers can create opportunities and possibilities for more sustainable behavior by designing new products, services, and systems (core competencies of product designers). They are involved in designing more sustainable infrastructure, products, services, and social innovations, and these are precisely the opportunities that can enable people to act more sustainably.
(4) And finally, to ensure that the new behavior becomes a positive experience, designers can help to organize positive feedback, e.g., through communities and peer groups, by saving money, just feeling better, and having a better conscience, among others.

An excellent collection of many different design interventions to encourage better consumer behavior, from very authoritarian ones to fun and gaming, can be found in the Design with Intent Cards by Dan Lockton (http://designwithintent.co.uk). When trying to influence consumer/user behavior there are fine lines between manipulation, seduction, and offering alternative opportunities as choices. Consumer choices are often not purely rational but involve quite a bit of emotion. Transparent, trustworthy, and truthful storytelling, offering honest education and information should be the first choice, but sometimes a bit of seduction is needed to change routinized behavior.

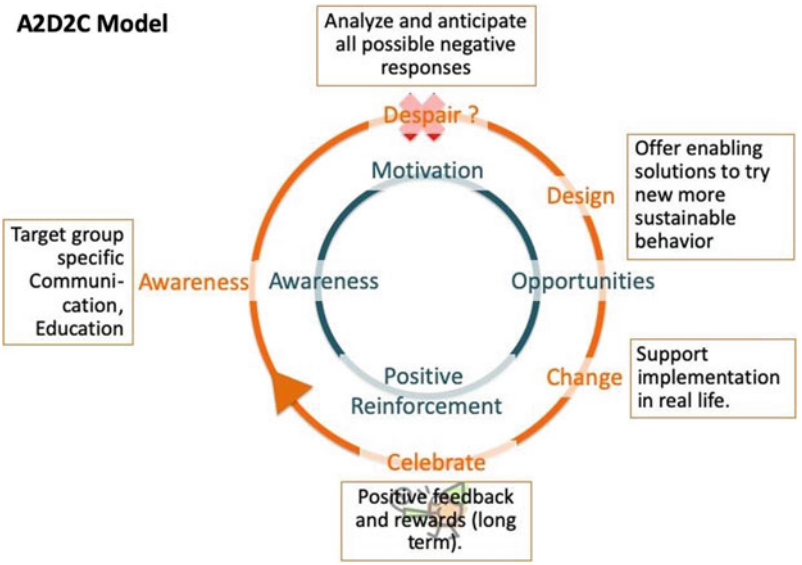

Fig. 3 Awareness, Despair, Design, Change, Celebrate: A2D2C Model. *Source* Stebbing and Tischner (2015)

Figure 3 shows the 'A2D2C Model' (Awareness, Despair, Design, Change, Celebrate), which has been developed by the author as a tool for designers illustrating the interrelations described above.

7 How to Implement System Design for Sustainability

System design for sustainability is an exciting and emerging field for designers and other creatives. For its implementation, an important question remains: Who commissions and pays the designers if they might not be the producer of a product anymore? Fortunately, there are also new financing and funding schemes emerging that can help to fund these kinds of activities. Crowdfunding, crowd donating, and crowd investing for instance (e.g., www.kickstarter.com, https://www.ecocrowd.de, https://www.leetchi.com, https://www.betterplace.org/de), where a larger group of people, especially those that are affected or sympathized with the issues at hand, are invited mainly via online platforms to collectively finance the project—with or without (donation) rewards for them (Tischner and Beste 2016). There might be institutions, other than companies, funding these kinds of projects from public organizations to foundations and NGOs. It is possible to apply for research funding, if the projects have some kind of research question to answer, as most of them have. And finally, there are indeed also companies and start-ups out there that drive and finance these kinds of more radical and more sustainable design and

innovation projects, because they are more interested in long-term positive impact than in short-term profits.

Like everybody else in these systemic design projects for sustainability, designers and other creatives are challenged to move out of their comfort zones. They need to learn and apply new methods and ask and answer more fundamental and more complex questions. Hopefully, these methods and tools will be taught in schools and universities in the future—at the moment there are only very few design programs available where this is offered(according to the research and academic experience of the author and her work in the university accreditation organizations). Once involved in projects like this, designers can also radically increase their positive impact, and this might lead to more happiness—not just for stakeholders, but also for the creatives themselves.

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