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What Does the Circular Household of the Future Look Like? An Expert-Based Exploration

Saskia Keesstra [1,2,*], Tamara Metze [3], Linda Ofori [4], Marleen Buizer [5] and Saskia Visser [6]

[1] Team Soil Water and Land Use, Wageningen Environmental Research, Wageningen University and Research, Droevendaalsesteeg 2, 6700 AA Wageningen, The Netherlands
[2] Civil, Surveying and Environmental Engineering, The University of Newcastle, Callaghan, Newcastle, NSW 2308, Australia
[3] Public Administration and Policy Group, Wageningen University and Research, Hollandseweg 1, 6706 KN Wageningen, The Netherlands; tamara.metze-burghouts@wur.nl
[4] Environmental Economics and Natural Resources Group, Wageningen University and Research, Hollandseweg 1, 6706 KN Wageningen, The Netherlands; linda.ofori@wur.nl
[5] Strategic Communication Group, Wageningen University and Research, Hollandseweg 1, 6706 KN Wageningen, The Netherlands; marleen.buizer@wur.nl
[6] Wageningen Corporate Strategy and Accounts, Wageningen University and Research, Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands; saskia.visser@wur.nl
* Correspondence: saskia.keesstra@wur.nl

Abstract: Circularity is a necessity for the future of our society but individual households often find it difficult to contribute to this transition. This paper presents possible future visions of circular (and climate-neutral) households, inside and outside the house, regarding their contributions to the circular society, and taking into account food, energy, waste, household devices, and recreation. We combined expert interviews and a literature review to (1) explore imaginable futures for circular households, and (2) make a qualitative evaluation of the inside- and outside-house influences of households on a climate-neutral and circular society. Interviewees were selected to represent different scientific backgrounds. The four household types were organized according to more local or global, and collective or individual, levels: (1) the Household (centering around neighborhoods); (2) the HouseNet (connecting households); (3) the Sharing Household (sharing goods between households); and (4) the Designing Household (input from circular-by-design products). The analysis shows that households can become more circular by connecting developments in social, ecological, and technological systems, such as those in price dynamics, policies, or land-use design. However, barriers and limitations need attention, including: (1) public awareness and willingness to change; (2) economic models; (3) waste; and (4) social justice.

Keywords: circular bio-economy; future vision; circular agriculture; renewable energy; commodity sharing; recycling

Citation: Keesstra, S.; Metze, T.; Ofori, L.; Buizer, M.; Visser, S. What Does the Circular Household of the Future Look Like? An Expert-Based Exploration. *Land* **2022**, *11*, 1062. https://doi.org/10.3390/land11071062

Academic Editor: Christine Fürst

Received: 3 June 2022
Accepted: 7 July 2022
Published: 12 July 2022

1. Introduction

Earth Overshoot Day marks the date when humanity's demand for ecological resources and services exceeds the resources and services that can be regenerated by the Earth in that year (Global footprint network, 2022). In 2021, it fell on July 29. However, in the Netherlands (and many other developed countries), this day occurred earlier in the year. The footprint of developed countries is much too high, and huge sustainability transitions to new ways of living are needed to remain within the planetary boundaries [1,2] and to ensure a social foundation [3]. These sustainability transitions are related to many domains, such as energy, mobility, viable cities, a nature-inclusive society, and circular food systems (e.g., European Green Deal).

The concept of a circular society has been proposed to contribute to these different sustainability transitions from a more systemic and integrated perspective that (1) better

includes societal dimensions in the transition from a linear production and consumption system to a more circular one [4–6] and (2) better includes the perspective of consumers or citizens, for whom moving to a more sustainable lifestyle also means adapting in many areas: energy, food, waste, textiles, and water. Ng and To (2020) show that a systems thinking approach improves resource efficiency in households. This means that evaluating the household in terms of all its elements—both resource use and socio-economic conditions—is essential to efficiently transition to a circular household. In addition, it is widely recognized that, to make sustainability transitions happen, all stakeholders should be involved. This means all consumers, including those who feel as if there is ample immediate space for change toward more sustainability, and those who do not have the financial means to contribute to a more sustainable consumption pattern [7]. As a result of the development of four imaginable visions for circular households of the future, we aim to contribute to visionary, yet practical and concrete, ways of societal sustainability transformation [8,9].

Visions of how households influence and are influenced by the needed sustainability transitions are of vital importance to making the necessary changes in the practices of our everyday lives [10–13]. The household is one of the smallest social units through which humans affect the use of natural resources for heating, eating, and clothing, and through which we produce a large amount of waste. Focusing on households centers the attention on the private sphere—the actions of households, and their consumption behaviors and decisions. Yet, such an approach goes beyond individual behavior [14], thus drawing attention to collective choices regarding everyday practices. At the same time, it may arguably deflect attention away from broader systemic requirements of a circular economy or other spheres. Hence, the household is the ideal scale for visualization of an imaginable future, to show how behavioral and systemic changes may impact a personal future.

In the same manner that all households were not the same in the past, they are not all the same in the present nor will they be in the future [15]. Furthermore, they will not be able to contribute to greater circularity or sustainability in similar ways [7]. Households are different in terms of composition, age, location, financial possibilities, opinions, and behaviors; as a result, they have different mentalities toward sustainability [16]. For example, in the recycling behavior of households, differences are evident between rural areas and cities, where recycling is more difficult due to, for example, having less space in the home environment [17]. In this paper, the household is defined as a "single person or group of persons who share resources, activities and expenditures on a regular basis for a specified period of time" [15].

The objective of this paper is to explore the influence of these households on the natural system from two perspectives: (i) the things that are done *inside* the house (food, packaging, heating, household devices, clothing, waste, electricity use); and (ii) the things that are done *outside* the house (recreation, cities vs. rural environments, transport, food production, waste treatment). Based on expert interviews and a literature review, and with the use of scenario thinking [18–20], this paper aims to provide four imaginable visions of what future circular and carbon-neutral households may look like, inside and outside the house. In the following discussion, we debate the possible barriers and opportunities for the transformation of these four imaginable future households. We conclude by presenting the next steps that are needed to achieve sustainable circular households, including a set of innovations and enabling conditions, and explore the trade-offs associated with these steps.

In Section 2, we explain the notions of planetary boundaries and social foundation, and further conceptualize how different sustainability transitions are interrelated from the perspective of households.

2. Concepts: Future Circular Household within Planetary Boundaries

In many sustainability transitions, the major challenges form a starting point. These challenges arise from, for example, climate change, biodiversity loss, depletion of natural resources, and pollution. In 2009, these challenges were described and empirically studied

as "planetary boundaries" by Rockström et al. [1]. Building on the "carrying capacity" notions of the Limits to Growth report [21], the planetary boundaries depict the safe use of our planet's natural resources (Figure 1). The associated diagram divides the natural resources into nine elements. From the assessment of the EEA (2019) of the status of the planetary boundaries, it is clear that some planetary boundaries are under severe threat or are already far beyond their carrying capacity. The most urgent elements are: (1) biosphere integrity, which can be roughly seen as the decline in biodiversity; (2) biogeochemical flows—specifically, nitrogen and phosphorus cycles are over-exploited and not sustainably managed; and (3) climate change.

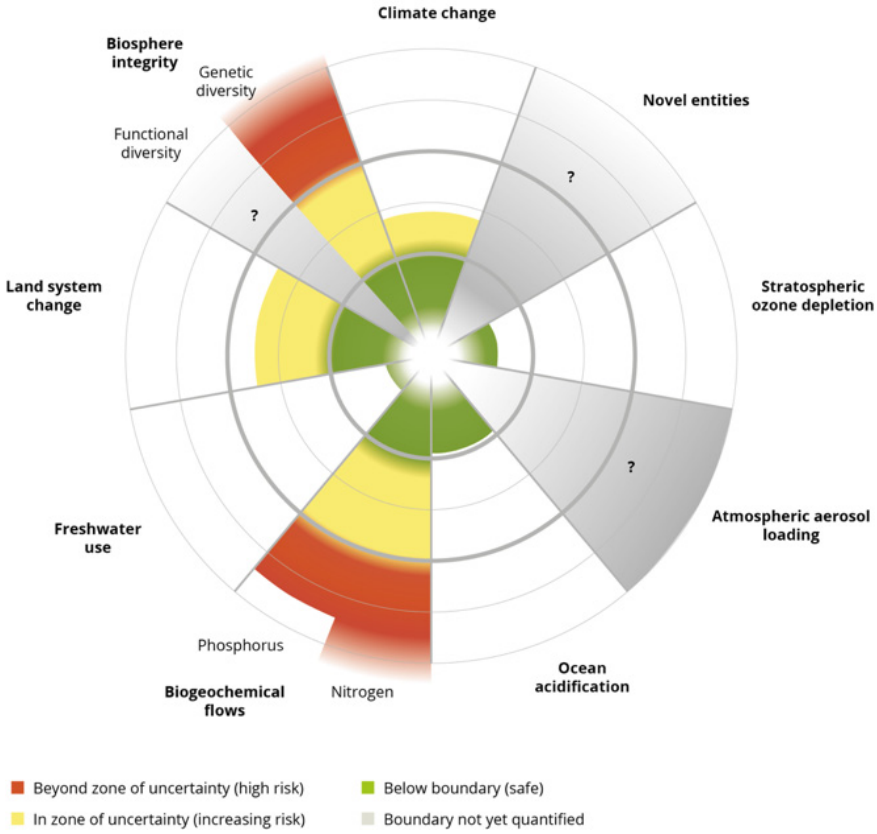

Figure 1. Status of the nine planetary boundaries, 2020 (https://www.eea.europa.eu/soer/2020/soer-2020-visuals/status-of-the-nine-planetary-boundaries/view, accessed on 15 October 2021).

Other factors, such as stratospheric ozone depletion, ocean acidification, and freshwater use, are all under pressure but still within the boundaries, according to the assessment of the Stockholm Resilience Centre in 2015 [2]. Finally, there is uncertainty regarding the status of two elements, novel entities and atmospheric aerosol loading, relative to the planetary boundaries, because it is either not clear where the planetary boundary lies (aerosol loading); it is not clear how much of the elements is present (novel entities); or it is not clear how the elements are impacting the natural environment (both).

It is important to realize that these planetary boundaries should not be seen as individual issues. All are interconnected and should be treated as such. For instance, deforestation impacts climate change; climate change impacts nitrogen cycling; and nitrogen cycling impacts biodiversity (biosphere integrity). These interrelations are very similar to the way the Sustainable Development Goals are connected [22–24].

Hence, it seemed logical that Kate Raworth [3]), together with Steffen et al. [2], developed the notion of a doughnut economy, in which she argued that, next to these planetary boundaries, we also need to take into account a "social foundation" that covers the basic needs of humanity (Figure 2). For this social foundation, Raworth developed 12 indica-

tors that can be clustered as follows. In a world having a social foundation, people are (1) *well*: energy, water, food, housing, and health; (2) *productive*: education, income, and work; and (3) *empowered*: peace and justice, networks, political voice, social equity, and gender equality [3]. Between the social foundation and the planetary boundaries sits the "safe operating space". Others have noted interactions between the planetary boundaries and social foundation: if we exceed planetary boundaries, people will become unwell, unproductive, and powerless [25] (Capmourteres et al. 2019).

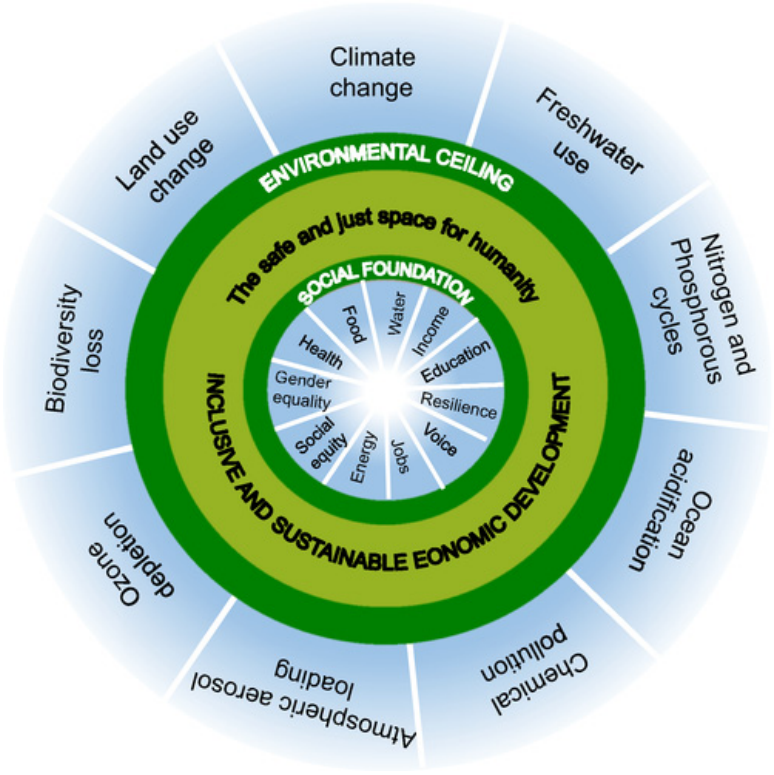

Figure 2. Doughnut economy (Raworth (2012)), which shows the safe operating space between the social foundation and the planetary boundaries.

Sustainability Transitions within the "Safe and Just Operating Space"

In sustainable development, current and future generations can live within the safe operating space [3]. Various actors, such as governments, industries, NGOs and citizens' initiatives, collaborate to define and achieve a sustainable way of living. They do so in many different policy domains and different economic sectors. In Europe, e.g., through the Green Deal [26,27], ambitious visions are being formulated to make transitions to more sustainable food production and consumption (for example, through a circular food system and circular agriculture); to achieve a fossil fuel-free generation (for example, through circular plastics, biobased textiles, and the energy, heat, and mobility transition); and to restore biodiversity and reduce waste. These global ambitions have been translated into transnational, national, regional, and local "monodisciplinary" policies in different domains, e.g., energy, food, and agriculture. They have also been translated into "multidisciplinary ambitions", such as realizing a circular economy [28].

Although not complete, and without prioritization, in various academic documents we identified six transitions that are needed to achieve the objectives of both remaining within the planetary boundaries and ensuring a socially just foundation [29–32]. These transitions can be organized roughly into two branches: the first relates to climate change and the elimination of the use of fossil fuels for electricity generation, production (of furniture, clothes, household devices, and plastics for packaging and other uses), and

mobility; the second relates to reconnecting to nature, a nature-inclusive biodiverse society in cities and rural areas, and the production of food in a nature-inclusive and circular manner. The identified transitions are: (1) energy, (2) mobility, (3) fossil fuel-free production, (4) viable cities, (5) a nature-inclusive society, and (6) a circular food system (Figure 3). When successful, these transitions will have a significant impact on the daily lives of citizens.

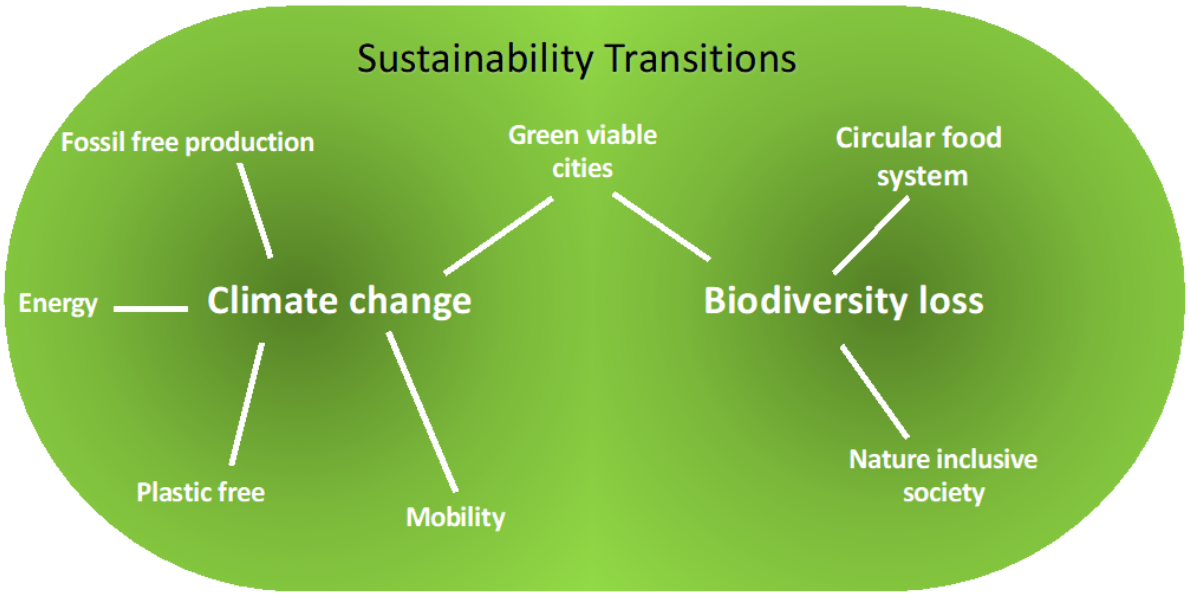

Figure 3. Sustainability transitions (energy, mobility, circular food system, viable cities, nature-inclusive society, fossil fuel-free production) necessary to ensure that society can live within "a safe operating space", as defined by Raworth (2012), and having an impact on the circular household from the perspective of two major global challenges: climate change and biodiversity loss.

For an individual, living within the planetary boundaries feels very abstract, and as if it is far beyond a personal responsibility or reach, whereas, ensuring a "Social foundation", "feels close, secure and personal" [33] (Hulme, 2020). Raworth [3] successfully combined these two aspects in her "doughnut economy". Furthermore, the six sustainability transitions show pathways to make use of the "safe Operating Space". However, for a transition to take place, behavioral change in people who are part of the transition is a key requirement [34]. Therefore, it makes sense to connect the doughnut economy and the sustainability transitions to the smallest and most personal unit within which people interact, apply their norms and values, and are affected by the transitions, i.e., the household. From there, we explored how the household is affected by the transitions and how the household has an impact on the transitions. We identified elements that are affected by the sustainability transitions, namely, six elements related to the household within the house: (i) electricity, (ii) heating, (iii) household devices, (iv) waste, (v) food, and (vi) textiles; and five elements related to the household outside of the house: (i) transport, (ii) recreation, (iii) the living environment, (iv) green cities, and (v) the landscape. Each of these elements is involved in different interactions and has different barriers and opportunities for the transitions needed.

Figure 4 presents a graphical summary of the concepts we use and their relationships. The planetary boundaries are shown in the outer ring as a safe living environment from a biophysical point of view, and the inner red box represents the social foundation as the minimum socially just level. The two inner rings show the elements of the circular household (inside and outside of the house), and the ambitions of the sustainability transitions and the "safe operating space" of the households.

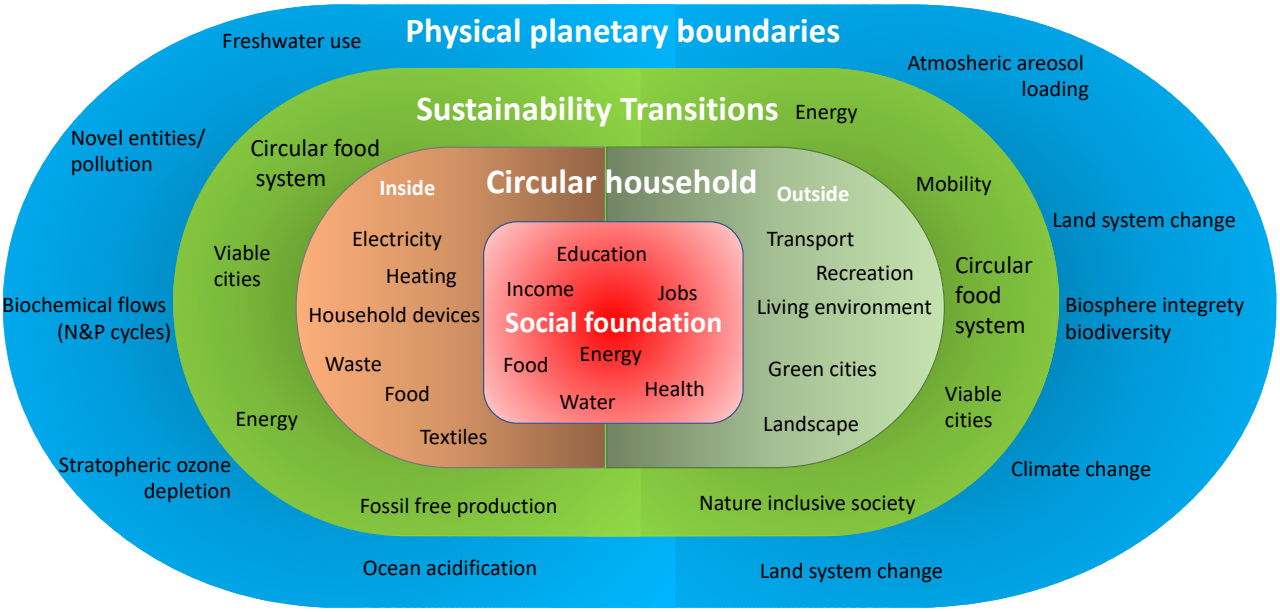

Figure 4. Graphical representation of the connection between the planetary boundaries (blue outer ring) and the social foundation (inner red square). The contribution of the circular household and the sustainability transitions related to climate change and biodiversity loss (see Figure 3) that are needed to create the safe operating space are depicted by the two inner rings.

3. Methods

The visions for the circular household of the future were based on a qualitative study and "futuring" techniques in which imaginable, possible, feasible, and desirable futures can be constructed based on existing data, the identification of uncertainties and ambiguities, and imaginations [11] (Hajer & Pelzer, 2018). For the construction of the imaginable visions, and their relation to the current barriers, drivers, and design of possible pathways to achieve these visions and overcome barriers, as explained below, a two-step approach was used for data-gathering, comprising a literature review and interviews.

First, we conducted a literature review using the CBE on the elements relevant from a household perspective. The selected household domains were identified in interviews with experts as those affected by the sustainability transitions both inside and outside the house: electricity, heating, household devices, waste, food, and textiles; and transport, recreation, the living environment, green cities, and the landscape. In this review, we gathered information from academic papers suggested to us by the experts on these issues. We then reviewed these papers in terms of how the authors described the manner in which planetary boundaries and the social foundation may affect the household inside and outside of the physical house.

Second, we conducted interviews with Wageningen University and Research academic experts on these domains (see Table 1). The identified elements formed the basis of the selection of the interviewees to obtain their input on each element. We conducted semi-structured interviews using a questionnaire that consisted of a set of questions in which the following issues were addressed: (i) the experts' visions of the future in terms of the transition in their topic of expertise; (ii) what they perceived as the major obstructions to this transition; (iii) what they saw as the big unknown element for the future that may impact the transition in the topic of their expertise; (iv) what they saw as the main leverages for the transition to circularity; (v) the way the household of the future will look on a daily basis; (vi) what they saw as the next steps in the transition in the coming 10 years and over the longer term; and (vii) what they saw as necessary to ensure a transition in which we respect both the planetary boundaries and the social foundation of our society. Transcripts of the

interviews were used to analyze and assess the outcomes. The interviews were also used for 2 documentaries on the future circular households (https://youtu.be/TeA7RWkka_k and https://youtu.be/mAMsKa3iRaI, accessed on 30 May 2022).

Table 1. Elements of the circular household and interviewed experts.

Inside	
1	Electricity and heating: Jeroen Sluismans
2	Household devices: Prof. Gert Spaargaren
3	Waste and Plastic *: dr. Maarten van der Zee, dr. Christiaan Bolck and dr. Ulphart Thoden van Velzen
4	Food: Prof Imke de Boer
5	Textiles: dr. Michiel Scheffer
6	Economy: Prof. Hans van Meijl
Outside	
6	Recreation/Landscape: Dr. Lawrence Jones
7	Living environment, green cities, and transport #: Dr. Marleen Buizer
8	Living environment and interaction urban/rural areas: Prof. Eveline van Leeuwen

* For the waste category, the experts were required to further specialize, and deal with waste avoidance, recycling, and, specifically, plastic waste. # For the transport category, we specifically looked at the future mobility of the household, and not the logistics within a circular society.

Based on scenario thinking for strategic planning (e.g., [18,20], we analyzed the interviews and coded them in terms of future uncertainties that were mentioned by interviewees. We selected the two most mentioned uncertainties: (i) individual vs. more collective (communal) behavior; and (ii) more local vs. global production. These served as two axes. For each quadrant we were then able to develop an imaginable but possible vision. In the next step, we determined the opportunities and barriers for each of the visions, and designed pathways for the future.

4. Results

In the interviews and literature, many uncertainties were mentioned. Regarding the transitions currently being faced as a society, it is important to realize that the outcome of the transition, and its speed, will depend on many unknown developments. One important uncertainty is behavior. There is a vast body of literature that reports on the behavior of people in many different settings [35–37]. In addition, many questions exist regarding the availability of resources. Limited availability of oil, for example, may cause the transition to fossil fuel-free products to rapidly accelerate (interview M. Scheffer [38]). The third important uncertainty relates to differences in biophysical, economic, social, and cultural backgrounds in regions, thereby impacting the way circularity can be achieved. The ideas developed in this paper, of course, may be useful in other parts of the world; however, it is important to realize that the generated visions are painted on the backdrop of the landscape, climate, and society in the Netherlands.

In the interviews, two main uncertainties stood out: one related to *production scale* and the other related *to our behavior*. In addressing the question of what they would ask an oracle about the future, the experts' responses were: Will we be able to produce and consume more of our food, energy, water, clothing, etc., locally, or at larger industrial and global scales? Would we indeed be able to change this type of production and consumption? Questions relating to the uncertainties of behaviors concerned whether we would live in more communal and collective ways, or whether we would further individualize.

Projecting these two axes formed a coordinate system having four quadrants. Each of these quadrants was used to represent a single vision (Figure 5). The first quadrant is the Household, which is a neighborhood seen as a circular household; in this quadrant, a local scale of production and consumption is combined with a future in which our behavior is more collective. Consequently, a whole neighborhood starts living together as a household, shares many communal places and activities, and, for example, jointly grows food and recycles products within the neighborhood.

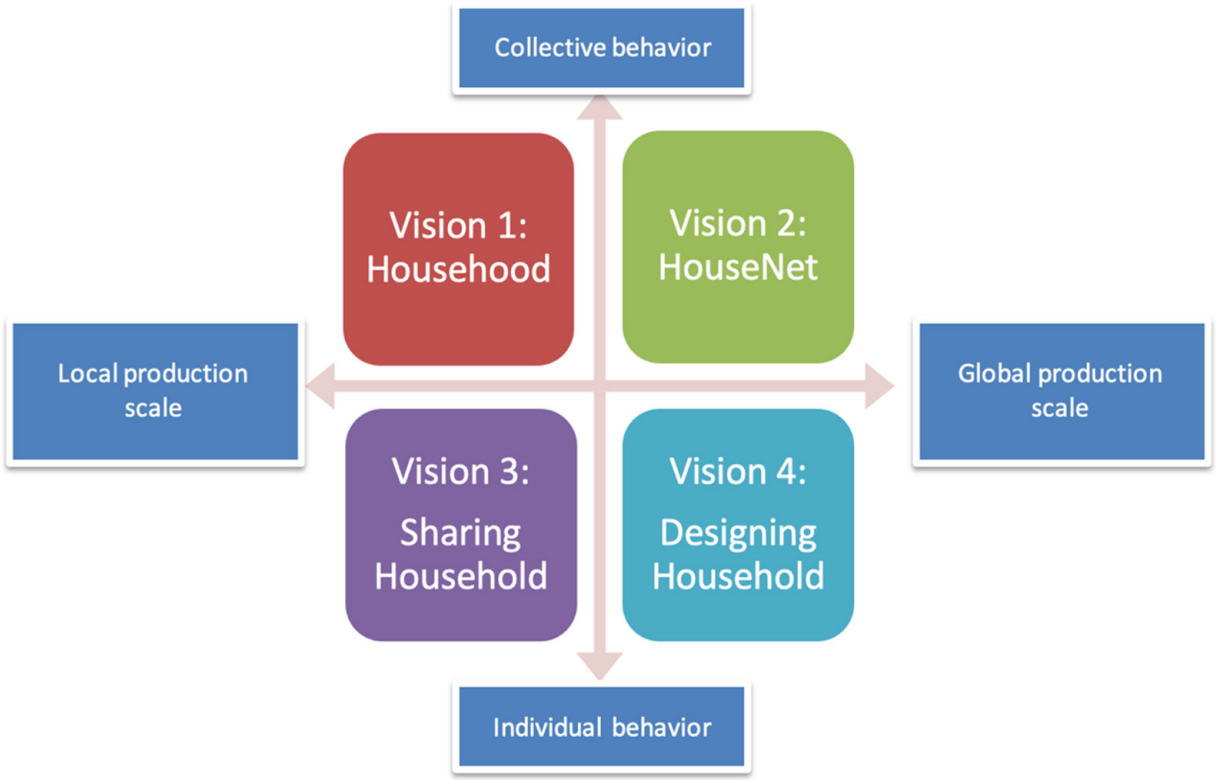

Figure 5. Four visions of future circular households mapped along two axes: production scale (from local to global) and behavior (from individual to collective).

The second quadrant is the HouseNet, which consists of networks of circular households. This also relies on communal efforts but depends on larger-scale production of the necessary goods and services. Actions in greener cities or circular farming are good examples of this.

The other two quadrants relate to more individual lifestyles but differ in their scale of production. The third vision, the Sharing Household, often makes use of digital platform-mediated connections between circular households, which have a more locally organized production system and rather individualistic lifestyles. This includes putting solar panels on a house's roof and sharing the resulting energy through digital applications with neighboring households, and sharing commodities such as cars.

The fourth vision is the Designing Household, which relates to large-scale production for individual lifestyles. In this scenario, individual consumers/households may contribute to giving feedback to large-scale production systems (value chains) to enhance circularity in the production and consumption system. As a result, a variety of goods and services will become more circular by design; for example, the use of more biobased or virgin plastics to make re-use and recycling easier. This vision resembles the circular economy model, and is mostly based on changes in individual behavior regarding buying, using, recycling, etc.

Based on the interviews held with experts, these four visions were further elaborated on, and pathways were provided for households that aim to be more circular or carbon-neutral. We first sketch the visions as described by the experts, and then discuss possible trade-offs, barriers, and opportunities.

4.1. Vision 1 Circular "Households"; Neighborhood as a Circular Household

The first vision focuses on the circular neighborhood, which not only provides the context for households to be able to contribute to the circular economy, but includes households as part of the circular economy. The "Circular Household" is dependent on

a basis of social cohesion and collectivity; for example, in caring for public spaces and services. This basis may also form a social safety net and provide a system of care. Proximity is a starting point for many of these neighborhood-based collaborations, which support both physical and social relationships; for example, the local growing of hops as part of the green structure for the production of local beer that is sold in local bars and restaurants.

The neighborhood provides the basis for all elements of the household. Food is largely grown in communal gardens, and fruits are harvested from a local community-managed food forest. Dairy and meat are sourced from a nearby farm; alternatively, a farmer can grow vegetables using an initiative such as pixel farming (interview De Boer). In all of these cases, the household is highly aware of the origin of their food. This Househood of the future provides space for mixed living, working, education, and leisure. Equipment for manufacturing, repair, and refurbishing is shared and jointly managed and maintained as much as possible (interview Buizer; Bolck). Public gardens and parks in the neighborhood provide a space for meeting, experimentation with novel circular inventions, and other joint activities that connect the households with outdoor public space. Future urban dwellings are also designed differently. In the Househood, household and shared spaces are well tuned to each other (Leeuwen, Buizer). For leisure, inhabitants of the circular Household can use collective spaces for "green" activities relating to climate adaptation, biodiversity, food production, or sports and other cultural activities. Buildings are also designed and constructed in such a way to contribute to urban greening and climate adaptation (Prof van Meijl and Prof van Leeuwen).

4.2. Vision 2: HouseNet: Networks of Circular Households: Organised Resource Use Linked to Larger Economic Systems

In this future vision, circular households are well connected to other households that are living in more circular and carbon-neutral ways. Rather than the neighborhood as a household, nodes of households throughout a country, and even the world, can be connected and supported by research and innovation in industrial and agricultural systems through well-designed information systems. These HouseNets will have an important role in the scaling of circular initiatives. This is because deepening (increasing the circularity) and broadening (connecting to different domains) of circularity in the economy and food system occur concurrently with a greater spread and better connection of households [39]. An example in this vision is energy cooperation, where excess renewable energy of one household is used by another consumer; alternatively, additional energy can be sourced from hydrogen or solar energy parks (interview Sluismans).

This vision was often presented in expert interviews related to future food production and, more specifically, the future of circular and nature-inclusive agriculture. In this scenario, agricultural land is only used to produce food that is consumed by humans; animal feed consists of side streams of human food production (interview de Boer). In addition, recreation will take place in these agricultural areas, which will be significantly more attractive due to the use of biodiverse landscapes using strip cropping, diversification of agricultural land, and allowing space for nature (interview Jones). The natural areas will also be more biodiverse. Our homes will be more integrated with this type of landscape because the landscape will be made part of the architectural design. Furthermore, leisure activities will the same as they are now, with the exception of travel, which will be more limited. However, electric and hydrogen travel may provide new freedom without damaging nature.

4.3. Vision 3: Sharing Households: Mediated Connections between Circular Households: Shared Facilities and Commodities

In this vision, although the household is an individual unit, households share facilities in the neighborhood or beyond (interview Spaargaren, van Leeuwen), thereby reducing the impact of the household on resource use.

For example, energy should be shared in local and regional communities that are part of a network that has invested in, e.g., a windmill or solar park. District heating can

make use of residual heat for households [40]. People may be able to store energy at the household or neighborhood level, and serve the central grid because they can manage the peak loads. Other examples are car sharing and sharing of electrical charging stations. The minimum ambition for any household is to be energy-neutral (interview Spaargaren).

In the future household, "waste" will not exist; all material will be valuable in some form and will be re-used (interview van Meijl). Household devices, furniture, and clothes will be bought to be used for longer periods of time, and some devices may be shared with others (cars, equipment, bikes, etc.). Clothes will be less disposable and the use of second-hand clothes will be more common; clothes will be chosen based on their durability. The Sharing Household is concerned with resource use, and is involved in the production of food and all other necessities. As a result, the Sharing Household is more aware of the "end-of life" of the products they use (interview van der Zee). By sharing commodities and facilities, and working together, the social capital and the social coherence of the community will become more important, thereby making the social capital more valuable (interview van Leeuwen).

4.4. Vision 4: Designing Household Circularity by Design

The fourth vision, due to limited collectively and solidarity within and between households, mostly relates to changes in individual behavior. Individuals will aim to live more circularly, use less, and refurbish and recycle more often and more effectively. In this vision, these individuals and their households can play a significant role in providing valuable input and feedback for the redesigning processes of products to make them more circular and easily recyclable. The Designing Household is heavily based on consumer-supported large-scale circular initiatives at the system levels of organizations, industries, and their networks and value chains (interview van Meijl, Spaargarten). Due to large demand, industries will become much more circular and produce only commodities that are circular by design [41,42] (Andrews, 2015; Moreno et al., 2016). In industry and agriculture, natural resources will be protected and recycled where possible. Future products will be made from recycled or biobased resources, and use little or no new resources. Furthermore, new resources will be plant-based, such as new fabrics that can be used for textiles and furniture (interview Scheffer, van Velsen). Fossil fuel-based products will be avoided and products will be designed to be able to be repaired during their lifetime, to make them last longer (interview Spaargaren, Scheffer, van Velsen). Moreover, single-use plastics will be minimized as much as possible in supermarkets and other shops (interview C. Bolck). Designing Households will be enabled and will be better able to recycle their waste; for example, using products having improved designs and having more easily accessible recycling units. For the energy transition, industries will also devise other ways to generate energy, including hydrogen and other forms of energy (which may currently be unknown). Energy may also be sourced from multi-functional solar parks, such as agri-solar systems, where crops are grown underneath solar panels (interview Sluismans). In addition, to become more circular, households will depend on governmental policies for support; for example, government subsidies for insulation and solar panels as part of the energy transition. Governments may also raise taxes on products, or ban certain commodities (such as the Dutch ban on free plastic bags, plastic straws, and plastic packaging for fast food in 2021). Another possibility that may change the way material is used in the Designing Household is to change the tax system in such a way that material use, rather than labor, is taxed (interview van Leeuwen).

4.5. Barriers to the Transition to a Circular Household

During the interviews, many barriers to the transition towards a circular household were mentioned. In this section, we explore how the future circular households may possibly deal with these barriers. These barriers can be roughly gathered into four groups: (1) public awareness and willingness to change; (2) economic models; (3) waste; and (4) social justice.

The first and foremost barrier that was identified in the interviews is the lack of awareness of the urgency to make these transitions.. Due to this lack of awareness, the most important barrier is ensuring that people are engaged. Some people have habits (buying new clothes for every event or buying food in plastic containers to be microwaved) that can be difficult to change (interview Buizer; Spaargaren). These non-sustainable habits are supported by the current economy; for example, Internet purchasing is an increasing market. Due to the influence of appealing commercials, people can purchase their products from all over the world (interview Scheffer). This not only affects personal habits of continuously buying more and more, but also results in the return of many products. Because returns are often costly to handle due to the large labor input required, returns are often treated as waste, which is obviously highly unsustainable (interview Scheffer, Bolck).

The second barrier in the current economy is based on cheap production, which is very linear. In general, the cost of production does not include the true costs (interviews M. van der Zee and H. van Meijl). One major issue is that, if everybody does not change, then the individuals that are trying to act sustainably have an economic disadvantage. Entrepreneurs need money to innovate and, therefore, to transition. The risk of changing is too large for an individual in the current product chain. Another issue that must be addressed is that current models for calculating the "true price" are based on current production systems and the damage to society caused by these production systems. This results in very high prices for food, which are not consistent with the perspective of a just transition (interview van Meijl).

The future view of high costs is not the only barrier to the transition; it is already the case that the sustainable option is often more expensive, which creates an "eco-elitism" (interview Thoden van Velsen).

Dealing with waste and the use of plastics are topics facing many barriers. A barrier to transitioning is that the quantity of materials, and their flows, are currently unclear; this is the case at both the scale of a city and at the global scale. This is especially true for waste streams; nothing is measured and, therefore, there is no evidence-based design for recycling guidelines (interview Thoden van Velsen). The infrastructure currently used for waste streams is hampering the transition (interview van der Zee). Regarding the use and recycling of plastic, it was mentioned that the current plastics are difficult to recycle because there are too many different types, and the collected plastic waste is highly diverse (a package may consist of 9–10 different components). This is sub-optimal for recycling (interview van der Zee, Thoden van Velsen).

Table 2 shows how different households may deal with the mentioned barriers. From this table, we can conclude that households that adopt a more collective way of living (i.e., Household and HouseNet) will have adopted a new set of norms and values. The sustainable way of life is influenced more from the "bottom up" and by social control. By comparison, the more individual households (Sharing and Designing Households) will represent a major change in customer demand for the economy. The sustainable way of living is steered from the "top down" by sustainable policies.

Table 2. The means by which households will deal with the current barriers to transition.

	Public Awareness and Willingness to Change	**Economic Models**	**Waste**	**Social Justice**
Household	Circularity is a way of life. Social cohesion and joint norms ensure shared responsibilities.	Joint local production and provision of services.	All waste is used (biomass) and repaired and recycled locally.	Strong social cohesion and justice ensure that the whole Household is taken care of.

Table 2. *Cont.*

	Public Awareness and Willingness to Change	Economic Models	Waste	Social Justice
HouseNet	High public awareness. Drive for social circularity by sharing experiences.	A "Successful life" is no longer measured against "ownership and income".	Only buying what is needed.	True pricing reduces the difference between rich and poor.
Sharing Household	Sharing could be driven by both economic and sustainability factors.	Sharing is cheaper. Demand for increased lifetime of products.	Limited due to design focus on lifetime of products.	Through sharing, social capital and social cohesion are high.
Designing Household	Individual policy-driven customer demand for circularity at the system level.	Cost reduction through recycling and increased lifetime.	High dependency on recycling for resource use. High dependency on policies to "ban" unsustainable products.	Municipality taxes are relatively high. Taxing material instead of labor ensures local recycling jobs.

5. Discussion

Households of the future will develop in many different directions. We sketched four possible future scenarios that diverge mostly in terms of the ways in which (1) industry will produce commodities (energy, food, packaging, textiles); and (2) people will interact (individually, by sharing facilities, or in collectives). We identified how these future households will deal with the identified barriers for the transitions to a circular society.

One conclusion is that thinking about the future household cannot be disconnected from the manner in which the socio-ecological and technological systems will organize themselves in the future (see also Bos et al., 2022, for the theoretical framework for the connection between these three systems). We need to better connect experimentation and the existing good examples having these systems' knowledge and goals. The existing literature often places such a focus on households, particularly with regard to changing consumption behavior [43] (Anantharaman, 2018); a previous study, for example, notes that questions of politics and power are neglected, leading to a lack of attention on the way approaches to sustainable consumption may maintain existing patterns of oppression and marginalization [43] (Anantharaman, 2018). If it is assumed that "the household of the future" is chiefly Western, moderately to highly educated, and restricted to individuals who can afford to live in a sustainable or circular neighborhood, then the possibilities of other alternatives will not receive enough attention. If the circular household of the future operates within the existing economic paradigm of economic growth [44] (cf. Lorek & Fuchs, 2013), and does not address justice- and equality-related issues, then it risks "ignoring the conditions of oppression that make it possible" [43] (Anantharaman, 2018: 559).

In our visions, we combine what is often called a "weak approach" with a "strong approach". The household scale is often associated with weak approaches to sustainable consumption that fit easily into models that maintain economic growth. Hobson argues that "A key part of such 'weak' approaches is a focus on the individual and household scale of change" [45] (Hobson, 2020: 102), whereas persuasive communication in behavior-change programs, including nudging, have been shown to deliver only very limited change [45] (Hobson, 2020). In our four scenarios, we aim to work towards an idea that is different from these weak approaches. Strong approaches still involve households, but in a manner that is less individualistic and more social. Strong approaches recognize that an overall reduction in resource consumption is needed, stress non-material values, and pay attention to the non-consumption-related aspects of human and social life, and what these aspects mean for social inequalities [44] (Lorek & Fuchs, 2013). Rather than "greening the economy" or "decoupling" (of growth and environmental impacts), the impact on households is much more radical [46] (cf. Fletcher & Rammelt, 2017).

In addition, the development of these future visions for households within a system leads to insights into practical actions that can be undertaken by households, and for the

systems they are embedded in. Moreover, it draws attention to how citizens, government actors, industries, and others can mobilize and further deepen, spread, and upscale sustainable lifestyles.

In future research, it would be interesting to design, next to the visions we showed here, provocative scenarios to better envision the urgency needed to change our current lifestyles. In conjunction with sketching action repertoires and appreciating the changes and transformations that are already being made for transitions, it may also be useful to sketch negative consequences, trade-offs, etc., at the level of the household (for example, to address the questions: what are the consequences of exceeding the planetary boundaries at a household level; what may be the consequences for the social foundation?).

The study also has several limitations that we would like to mention. First, in thinking about transformative change, historical practices are often overlooked because the focus is so often on the future and large scales, and the commodifiable impacts on profit. Often, however, short chains are part of past activities and, although their profitability in terms of investors and developers may be limited, their social and environmental impacts are significant. In such cases, care needs to be taken to ensure they are not overlooked in the envisioned transformative change. An opportunity faced by one may then appear to be a constraint for another. Security can be provided if the relationships can be sustained in the neighborhood, or other practices or newcomers can be connected, who can benefit from each other and become co-learners.

6. Conclusions

1. Depending on the degree to which households are organized, on a more local or global level, and a collective or individual level, four core scenarios for circular and climate-neutral households were identified: (1) the Househood; (2) the HouseNet; (3) the Sharing Household; and (4) the Designing Household.
    - The Househood represents a future centered around neighborhoods. Production and supply occur at a local scale and households are socially connected in their daily lives. An example that would fit within this scope is a communal vegetable garden, where compost produced by the households is used, children's education occurs naturally, and the health of people is improved using healthy home-grown vegetables and the relaxing environment of the garden.
    - The HouseNet connects households that live in more circular ways at a large scale and with global circular value chains, and is supported by experts. Households are also more integrated with landscapes that are characterized by greater multifunctionality. An example that would fit within this scope is attractive agricultural land that can be used for recreation, rather than solely for agricultural production.
    - The Sharing Household represents a future in which households are individual at the core but make use of and provide local goods and services, such as car sharing. Products are designed for durability and all materials are reintroduced into the value chain, eliminating waste. An example of an action that would fit within this scope is the sharing of cars, or of electricity generated by solar panels installed on a house having a large roof and shared with someone without a roof.
    - The Designing Household represents a future household that remains largely unchanged from current households, but provides input to and benefits from a supply of circular goods and services as provided by industries, and is aided by support from governmental policies. Households deliver expertise to these industries and governments design their products and services in more circular ways. Examples that would fit within this scope are clothes and household devices that are designed to be recycled.
2. There is ample opportunity for households to become more circular in the future. Increased circularity can benefit from connected developments in both social, ecological, and technological systems, such as in price dynamics, policies, or land-use design.

3. However, barriers and limitations must be taken into consideration with regard to public awareness and engagement, existing damage to and limits of natural resources and the environment, existing economic models, technological challenges, and lack of consideration of adoption behavior in production and affordability. Furthermore, uncertainties remain with regard to flows of materials and the preferred ways of living.
4. Essentially, it is important to recognize that households are embedded in socio-ecological and technological systems, which influence and constrain their agency in the transition to circularity. It is important to increase the involvement and sense of responsibility of households.

Author Contributions: Conceptualization, S.K., T.M. and S.V.; Data curation, L.O.; Formal analysis, S.K., T.M. and S.V.; Funding acquisition, S.K. and S.V.; Investigation, S.K., T.M., L.O., M.B. and S.V.; Methodology, S.K., T.M. and S.V.; Project administration, S.K. and S.V.; Resources, S.K. and S.V.; Supervision, S.K. and T.M.; Visualization, S.K.; Writing—original draft, S.K., T.M., L.O., M.B. and S.V.; Writing—review & editing, S.K., T.M., L.O., M.B. and S.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Agriculture, Nature, and Food through the Knowledgebase Program 34: Circular and Climate Neutral; grant number KB-34-016-007.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data is available on website www.wur.eu/circular-at-wur-conference, accessed on 30 May 2022.

Acknowledgments: We would like to thank the interviewees Jeroen Sluismans, Gert Spaargaren, Christriaan Bolck, Maarten van der Zee, Eveline van Leeuwen and Hans van Meijl.

Conflicts of Interest: There are no conflicts of interest.

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