Circular Codes

PRACTICE-OBJECT-ORIENTED COMPUTATIONAL DESIGN

Methodology for Collaborative Domestic Circular Environments

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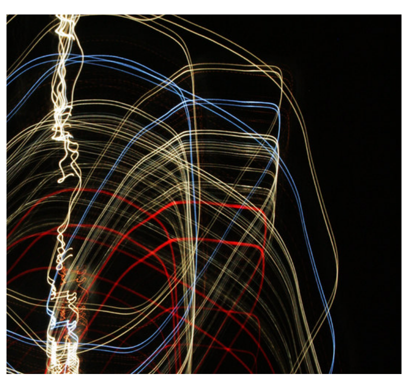

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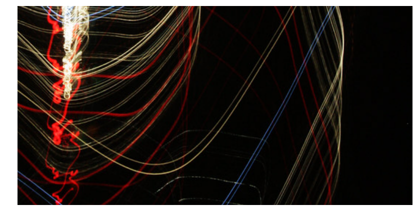

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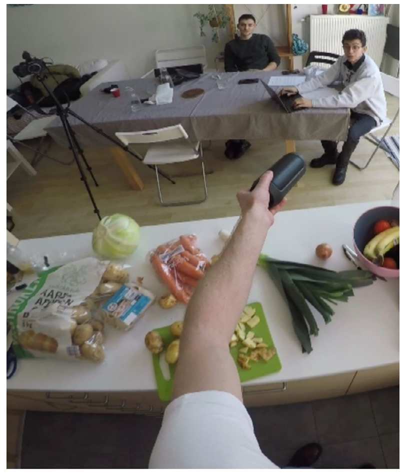

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RESEARCH INTRODUCTION

Prelude

Nature can be considered a dispersed field of dynamic energy and network of nuclear interconnected events (Spyropoulos, 2013). Within, a network of cells forms a human body integral of an interconnected society (Doucet et al., 2009). The ability to acquire food combined with social, material-tool and fire discoveries led humans to disruptive events, as the Neolithic or the Industrial revolution. Overall, these led humans to shape the natural environment with urban civilizations (Britton et al., 2018). The conditions favored our growing population to reach 7,6 billion in 2017 (UN-DESA, 2017). The events progressively blur the role and position of humanity, nature and technology (Gilbert et al., 2012). The term Anthropocene, as the geological epoch of permanent human impact on the planet reflects our behavioral influence or agency.

The disproportionate relation of population and urban growth, results in excessive land and resource consumption, which is a violation of the planets sustainability (UN Habitat, 2016). In this context, western societies lead the revolution conquests of the previous centuries, implemented the current economical system and established consumption and development standards. Followed by rising societies in development, western practices have long surpassed inherent physiological needs and consume faster than the planet can replenish (Allyn et al., 1999). The root of current behavior is the accelerated mentality from the 50's of "take-make-consume-dispose", as the essence of linear economy (Peck, 2018). Therefore, the way social entities currently operate requires change towards more sustainable practices, meaning behavioral and cultural shift.

The alternative circular economy, as way of consuming and living proposes more alignment with sustainable development (Blomsma et al., 2017). The socio-cultural importance is recognized in the transition to a circular built environment. However, approaches and solutions are mostly technocratic (Geldermans, 2016). In parallel, technological development demands an increase of resource extractions and other environmental impactful activities. Therefore, should at least contribute to the development of sustainability itself. Technocratic solutions have proven to be highly ineffective in restraining collective consumption rates. Instead of consumers, green citizens are required to be formed through conservation agency and self-sufficiency (Harbo et al., 2017). However, the complex and interrelated human activity makes shift difficult to manage and execute without technological integration.

The latest information or digital revolution enhanced our mechanisms to control regulate and coordinate by means of computational machines and Internet (Ashby, 1999). In the digital information age, omnipresent algorithms increasingly steer everyday life practices, form perception and intellect of individuals. The continuous use of formal systems, as global dynamic network of code and mediator of communication, embedded algorithms into social culture (Kittler, 2003). Therefore, the potential of code appears as vital mechanism of social and cultural integration (Trogemann, 2010). The expanding notion of art in relation to media and architecture as form of communication connects to these predominant mechanisms and technologies. In common ground, code and architecture are similarly a medium of communication with social entities, where design transmits information (Branscome, 2017). In this context, the computer as design tool is regarded as extension and releaser of the creative power, where code establishes new possibilities for the architect to interact (Jaffe, 1964).

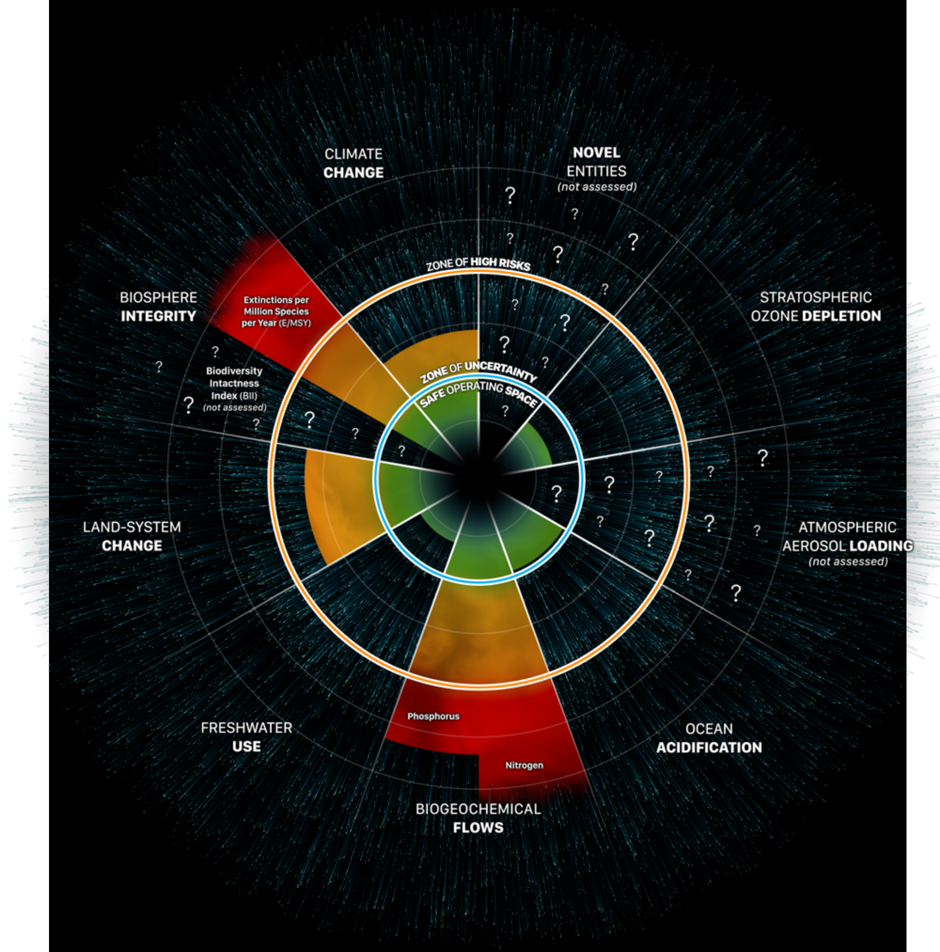
Fig.0 - Hunter gatherers from the Ju/'hoansi tribe in the Namibian Bush.
Fig.1 - Wired representation of India's rapid, chaotic urbanization
Fig.2 - Light - City - Planet - Network - Science Fiction

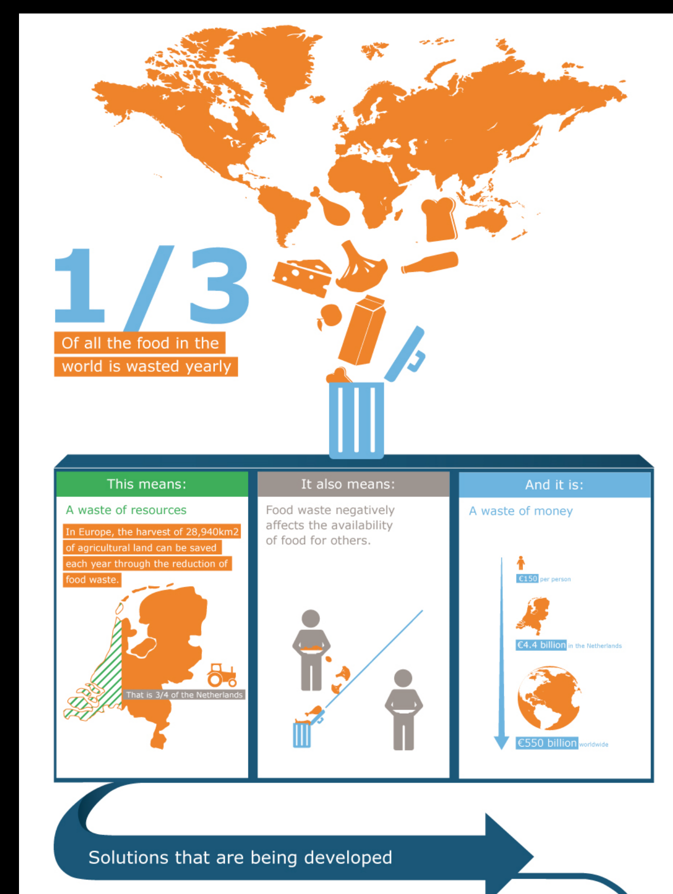
The field seeks reformulation and connection with the social sciences and fields of humanities, in order to respond to environmental, social and political challenges (Doucet et al., 2009). In this sense, code can be part of the answer, as theoretically the meaning and communication character of architecture can be codified. As in genetics form evolves over time in interaction (LeCuyer, 1995). The built environment can be distinguished, on one side by technical function, responsible for physical integrity, constructability and performance, and on the other side by social function, that is to create a communication frame.

Consequently, the designer should ask "What does the user need to know about an urban or architectural environment and what can an urban or architectural space communicate about itself?" (Schumacher, 2016). In relation to current 21st century challenges, this means to transmit the appropriate facilities to form the required sustainable practices of citizenship. In other words, the built environment should therefore technically incorporate and communicate the principles of circularity. In order to increase sustainable successes, technological innovation should be embedded in a wider system of innovation able to integrate consumer behavior, product use and waste management. This thesis explores a computational programming method to contribute for that integration.

Problem Statement

On a global scale, an estimated one third of the produced edible food is wasted (UN-FAO, 2013). In the context of circular economy, the food sector is critically regarded, due to the related production and reduction of waste (Ellen McArthur Foundation, 2019). The production and surplus reuse of the food sector appear as a promising focus for the implementation of circularity in cities, as engines of a regenerative food system. Next to mobility and domestic energy





use, food provision is one of the most resource intensive final consumption activities (Gram-Hanssen, 2010). In this, the process of food consumption itself is mostly disregarded from the scope. However, in developing countries including the phases of production, storage, processing and distribution, the consumer is responsible for most of the wasted food (World Resources Institute, 2018). In fact, the Dutch consumer has a 33% share of the total wasted food, according to the Netherlands Nutrition Center. In the country's domestic realm, an estimated 41 kg of edible food per person are wasted every year, representing the linear behavior in the preparation and consumption of biomass nutrients in western European countries (The Netherlands Nutrition Center Foundation, 2017).

Food practices appear as connector of practices and nexus point to understand the dynamic of daily domestic life (Paddock, 2015). In addition to the fundamental biological role, the sector has also direct implications on the general consumption and production dynamic of domestic environments. The reduction of domestic consumption is often presented as a top-down consequence of different products, productions and marketing. However, apart from rational decision making in behavioral frameworks, behavioral habits are fundamental in the formation of consumption practices. In this sense, far from the influence of producers, the spatial force which allow consumers actually prepare and perform these consumption habits is simply disregarded (Sunstein et al., 2008). Consequently, to shape these phenomena, socio-technical perspectives are required to understand the relation of material flows, technological infrastructures and everyday life (Geels, 2005).

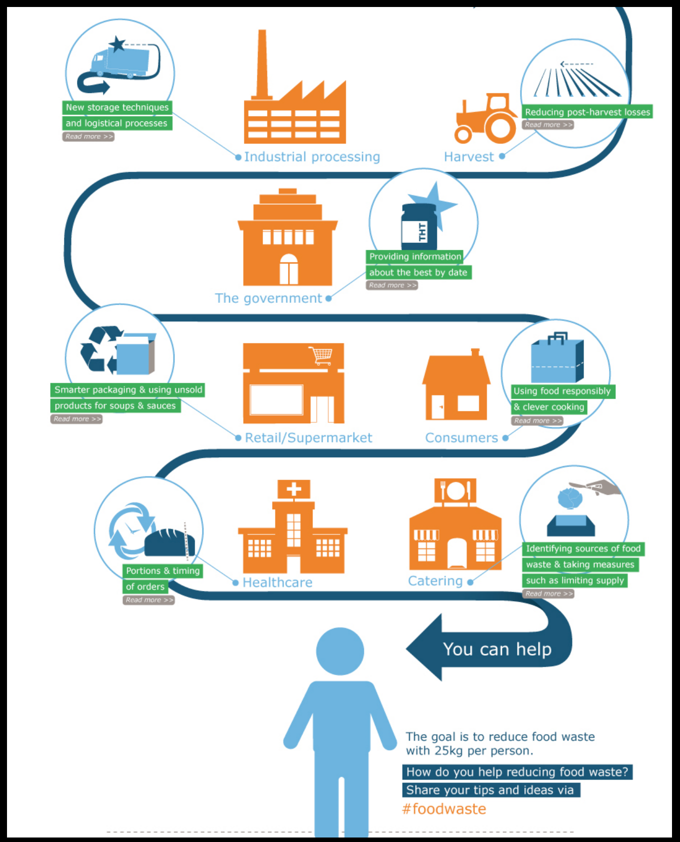
However, from a social perspective the hidden technical infrastructural systems warp our sense of vulnerability and decrease our awareness of the consequences of our actions and habits. In this sense, users actually have reduced interaction with the flow of our material, food, water and waste streams. In this way, users are isolated in an illusory

Fig.3 - Planetary Boundaries concept identifies nine global priorities relating to human-induced changes to the environment.
Fig.4 - Food waste: towards half as much.

built environment over generations. Finally, the natural environment is invisibly affected by our comfortable decisions in relation to our needs and desires of consumption. This effectively contributes to an indifferent view of the surrounding environment and planet. The apparent discrepancy between building innovation and the daily habits of the people this innovation is designed for is highly related to global markets and developers. Nonetheless, this phenomenon is also related to the forgotten ability of architecture to engage, be critical, and intentionally create agency and alternative worlds (Doucet et al., 2009).

Conclusively, in the transition to a circular built environment, the problem is not only the economical and technical solutions, but also the disconnection between the fields of architecture and humanities. In this sense, architecture has agency over users, as facilitator and situational factor of social practices. These are effectively rooted in different factors of the overall individual situation and not only in the physical space. However, in question in this thesis is the influence current domestic architectural elements promote towards practices, specifically related to biomass subsistence in kitchen configurations. The linear wasteful practices related to nutritional biomass are finally acted in the domestic kitchen design. The space provides the methods for preparation and consumption of resources, that is ingredients, tools and kitchen components itself.

Concluding, the problem statement of this thesis is that current designs are established for linear practice, that is to buy, store, use and waste, without the inclusion of principles and systems for circular practices. The kitchen design system should support circular biomass practices, so that consumers evolve to green citizens, who extend resource use and regenerate the environmental biosphere.



Research scope

In order to address these sustainability challenges, this thesis speculates on the communicative and integrative potential of computational code to support architectural design on the micro as well as on the macro scale. In the broader scientific context, this research aims to contribute for the further study and implementation of social and digital studies in the design and construction process of the built environment. In vision is to provoke thought and question over current domestic configurations in relation to the required change towards sustainable practices. Therefore, the scope of this thesis lies in the domestic sphere of action, where the daily acts of most humans start. Within that sphere, the focus lies on biomass subsistence practices in the kitchen.

Research objective

In concrete, the main objective of the following research thesis is to explore, outline and develop an object-oriented programming tool to configure elements of architecture systems, which integrate the principles of practice-oriented design and circularity in domestic design. In particular in focus is the kitchen as a shared collaborative domestic-working space. Therefore, this thesis aims to emphasize the potential between building circularity and computational design in relation to social food practices.

The result of the research aims for the development of a proof of concept application of object-oriented programming, as an application method for circular and practice design. Therefore, conceptual configurations for a circular domestic maker-space, in particular a biomass regenerative kitchen are the practical objective of this thesis.

Fig.5 - Food waste: towards half as much.

Research question

How can object-oriented programming enable practice-oriented design for circular collaborative domestic environments?

> *1. What are object oriented programming applications in architectural design?*
>
> *2. How can the principles of circularity be applied to object--oriented programming in practice-oriented domestic design?*
>
> *3. How expandable is this application for the built environment?*

The first sub question aims to understand the current state of the art of computation in the field of architectural design. In order to, provide insights on how and why object-oriented programming is applied in the design and construction process.

The second question targets to understand how to translate circular and practice design into the object-oriented programming methodology for domestic design. Therefore, this sub-question represents great part of the theoretical development towards the main objective.

The third question aims to understand then how scalable this methodology is from the (domestic) micro to the (urban) macro context. So, the developed methodology is positioned in a broader context. In addition, this should also provide further understanding of possibilities and limitations as well as insights for further research recommendations.

Research methodology

The research is divided into three parts. The literature review and case studies are complemented by the practical experiments and as result, connected to the development and delivery of the tool methodology. All parts are integrated into the thesis report.

> *1.Literature: reviews and case studies*
>
> *2. Experiments: subsistence practice and programming*
>
> *3. Development: tool and design application*

1. Literature: General research strategy

The context, main objective and research questions are the result of exploratory research and continuous redefinitions. The research on programming in architectural design is complemented with the circular and collaborative context.

In general, the understanding of programming object-oriented and the relation of code and form establishes a new perspective to look at circular economy with collaborative production. The parallel perspective of circular and bio-economy provides understanding of current principles. Moreover, insights in the evolution of the kitchen through the 20th century provide a broader perspective over present domestic environments.

In this context, the actor-network and practice theory establishes a framework to understand spatial interconnectedness and agency of practices, as metaphysical and socio-technical fundament of the research. Finally the connection to cybernetics, as the art and science of steering human and machine actions, as well as the theory of (computational) design is established and relates again to the main objective.

1. Literature: In-depth research strategy

The application of object-oriented programming within the context of form and code is further explored on the level architecture. In particular, the parameterization and generative design approach of buildings is reviewed and understood as integral part of the OOP methodology. In addition, as well explored is the integrative potential of OOP for collaborative BIM approaches, legislative regulation and physical analysis, simulations and evaluations of design options. In this sense, the domestic focus is further understood in a mathematical sense.

The synergetic potential between circular economy and collaborative production is correlated to the built environment as shared living and co working typologies in parallel with the perspectives of two circular design frameworks. The socio-technical importance and design requirements involved are explored and related to the integrative potential of OOP.

The domestic focus on the kitchen design is further studied in case studies, as the past Frankfurter kitchen, the recent IDEO test kitchen, the IKEA 2025 kitchen and the METAvilla kitchen. The insights are correlated with circular design framework. In addition, biomass cyclic principles and systems including domestic food residues are understood. In order to exemplify a circular component for domestic food waste, the compost method of vermiculture is further explored.

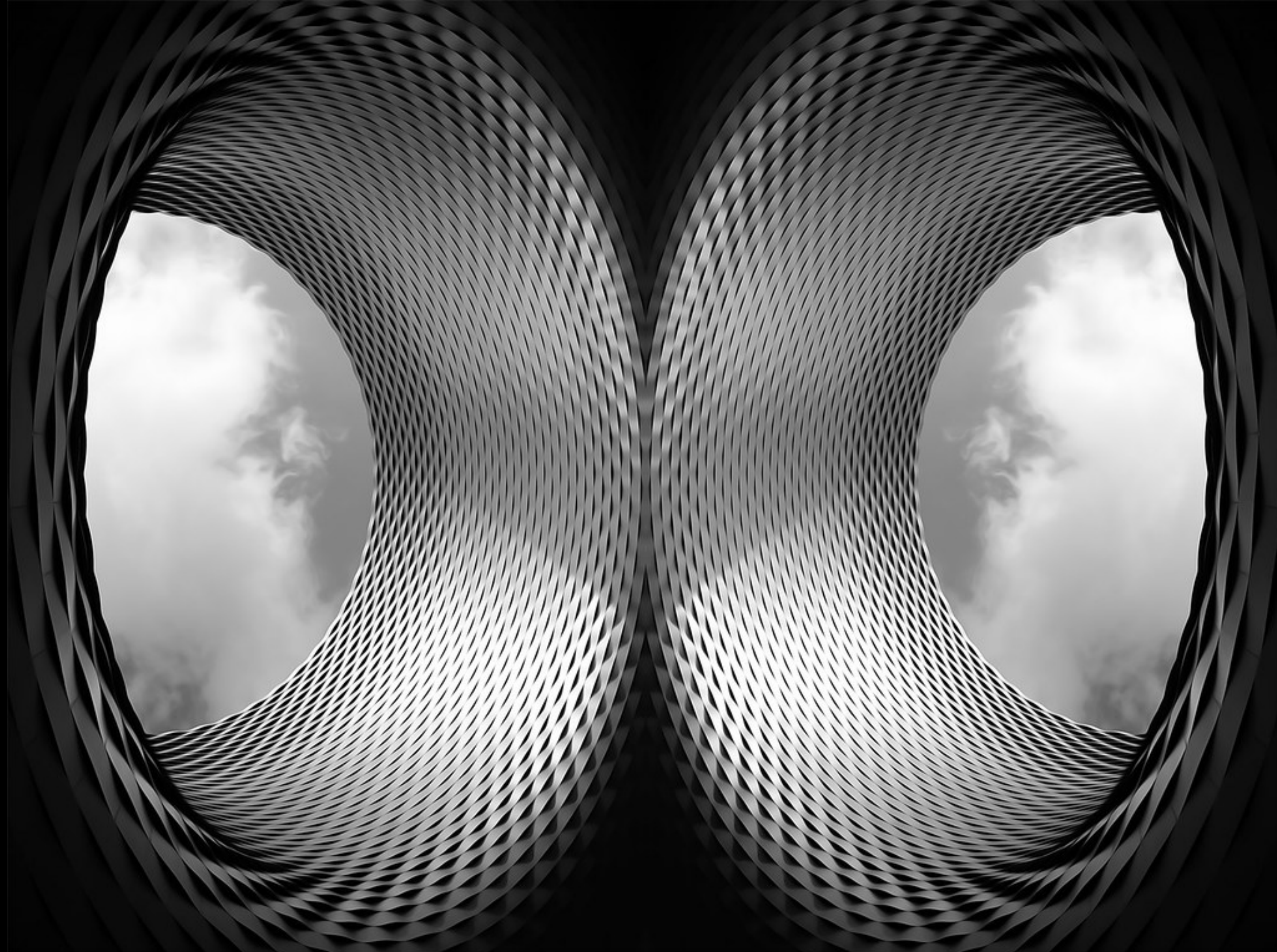
In this context, the paradigm of technological and biological sustainable development is explored from the point of view of practice theory. The formation of practices is described as clusters of actions configured by networks of material objects. Specifically, research was further conducted in practice oriented design frameworks, as methods to assess food subsistence practices and influence the design development of circular kitchen components. In addition, the connection to cybernetics, as design theory, art and science of steering human and machine actions is established.

2.Experiments

In parallel, literature research is balanced out with programming and scripting experiments for skill and tool development. In this sense, various scripts to create inventories, parametric customize user-ergonomics, include user inputs and categorize actions, as network of physical elements were attempted. All experimental tests contributed to the results. In order to obtain insights and practical data on subsistence practices in domestic kitchens, experiments were conducted and video recorded. According to frameworks of practice-oriented design, the analysis allowed the extraction and decomposition of practices as networks of objects and sequence of performances. Additionally, the deconstruction of practices into networks enabled further the application of circular design frameworks and overall application to object-oriented programming systems.

3. Design Application

As result, the application is simplified into a designer's computational tool, which outputs various configurations of circular kitchens and floor plans for collaborative domestic maker-spaces. The definition allows parametrically adjustments of kitchen components, as elements to incentivize circular change of thought and practice. The main inputs are recipes in combination with a given contextual spatial boundary, as water and access points. The code contains recipes, as clusters of actions and particular objects, whose properties influence design parameters of components. In this sense, the output of this thesis application represents variations of recipes and context. In specific, the circular coded kitchen demonstrates possibilities to extend the biomass cycle in the raw division of nutritional resources and act as situational factor to promote resource extensive user activity. In order to expand the vision, a product-service system is proposed to develop, prototype and collect practice information of circular living environments.



PROGRAMMING IN ARCHITECTURAL DESIGN

In design and architecture, after the Second World, the German Bauhaus craft and technological traditions spread to various countries institutions and influenced next generations. In the US Le Corbusier developed the "Machine for living" and Buckminster Fuller aimed for a "design science" to optimize material and energy use for human advantage. The historical reviews of design methods of pioneers, as Nigel Cross in combination with technological production and fabrication developments influenced the next generation of designers (Bayazit, 2004). In addition, systems theory and analysis established the ground for systematic design methods (Archer, 1981). In architecture, Christopher Alexander synthesized form into information patterns (Alexander, 1963).

Design required a measurement unit to be scientific, so that the designer could also analyze human behavior. At the time, the attempts to fix life situations into logical framework were over simplistic, therefore not capable of matching the problems and complexity of the world. However, the introduction of computational and programming systems into design methods changed this perspective. Computer-aided design programmers started to code environmental building performance evaluations and artificial intelligence introduced into design (Gero, 1994).

In this computational context, Charles Eastman set the focus on the designer's behavior while designing. (Eastman 1970). In this sense, Omer Akin carried the design research work further with his recognized PhD in Psychology of Architects (Akin, 1986). Consequently, philosophies and theories of design, as well as its relation to practice are currently still in discussion and reevaluation in academic and professional spheres (Bayazit, 2004).

Fig. 6 Computational skylight opening mirror

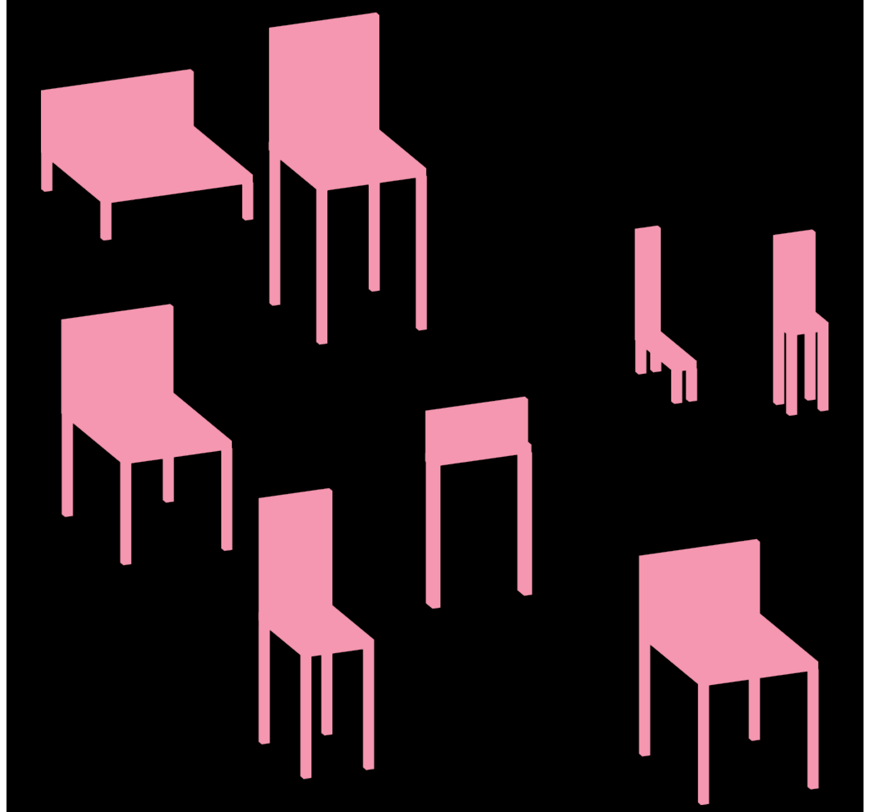
Code and Form

In this context, Design, Art and Architecture are under one umbrella, as visual spatial structures. The development of computer-aided design (CAD) systems allowed efficient drawing of mathematical lines as alternative to board and pencil drawing. However, these were considered restrictive and insufficient for conceptual stages, therefore not changing the fundaments of the design practice itself.

In addition, the internet and network technologies evolved the computer into a collaborative tool, forming new ways of working and the open-source software movement (Reas et al., 2010). Meanwhile, the evolution of CAD systems is changing the fundaments of design from drawing to calculation of information.

Information, as positions in coordinates and shapes in graphic points or pixels. The translation of mathematical representations into human spatial perception methods, allows form to be produced from abstract code. This means digitally through color pigment with material structure and physically through fabrication processes. These system processes are based on modular repetition of patterns or recursions and transformations methods, as acts of manipulation of the viewer's perception. In this sense, the code constructs meaning through visual language (Reas et al. 2010).

Overall coding deals with data processing issues, including the description of calculations, as well as the definition and treating of functions and objects. The preparation of sequential coded data to a precise instructive program or algorithm, as computer feed, is the activity of programming. This activity requires assumptions, decisions and modular composition with various ways of execution (Blackwell et al., 2001b).



Object-Oriented

In this frame, Object-Oriented Programming (OOP) is a dominant coding methodology of software engineering to view situations and context. Specifically, OOP represents a technique to structure the communication between interconnected functions, as abstracted tasks and variables, as elements.

This pragmatic method of programming found attraction in the creative minds divided between technology and the arts. The principles of interaction, motion and visual form are related to software concepts including OOP. In this sense, understanding the art of programming allows to use the computer to its potential, as an expression medium of relationships and behaviors. The machine enables the creation of tools, systems and environments (Reas et al., 2010).

Objects are single items or instances of a class. A class defines functions and variables in a cluster, as the blueprint or recipe for objects. This conceptual model enables a relatively intuitive approach, in which the usefulness increases with the elements quantity.

The program is normally composed of code modules with particular functions and variables, which can be reused. The methodology enables an analogy between real-world artifacts and digital objects. In this context, three applications and a fourth extension potential are identified for the field of design and construction of the built environment.

Fig.7 - Parameterize: Chair.

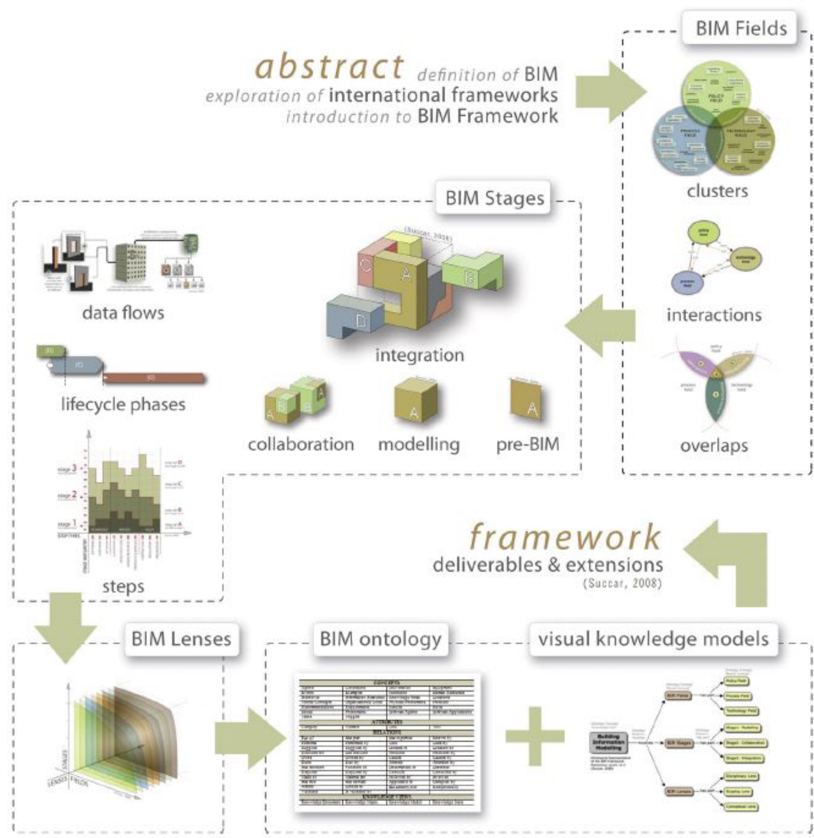
Parametric and Algorithmic Architectural Design

In the initial stage of projects, OOP is applied for design development. Instead of making choices for single final object, the designer creates and explores restriction matrixes for a field of possibilities according to the desired intentions. Therefore, the designer creates an algorithm with variable elements of design, which encode and constrain the system outcomes. These increase with the increasing number of parameters. The parametric definition and variability lead to the composition of the overall system. The variability of the parameters transforms the form and its repetition offers form exploration. Therefore, the process is a passage between repetition and transformation. In this sense, control over parameters in relation to outcome possibilities is important. All parameters of a composed system can finally form an interface to control the design generation of the building.

In this sense, the building can be parameterized into elements, as boundaries and openings and further into the components of each opening, as glass and frame. Therefore, parameterized design is a decomposition process of form into parts, as variables (Reas C et al. 2010). As one of the three elements of OOP, parameterization processes are included in this methodology.

Management, Regulation and Simulation integrated BIM

In a broader sense, OOP is as well applied for general collaborative digital approaches to design, planning, construction and management. Currently, increasingly demanded this is known as BIM or building information modeling. In BIM, the parameterization of regulations enables the understanding and manipulation of the implications in



urban design. The urban model performances are then analyzed in relation to the legislative sustainable development. (Kim et al. 2011, 2013). Similarly, efficient integration of time and schedule information of construction is suggested in BIM development of projects. This is accomplished through hierarchical aggregated and structured parameterization of construction operation objects. In combination with functions, automatic conditional responses to changes in the construction process are generated. Therefore, costs are controlled according to activity. In this sense, successful tests of OOP applications to industrial scale and simulation of construction projects are suggested in JAVA software (Ahn et al., 2010).

In addition, the potential for data exchanges, act as enabler of the integration of multi-domain performance simulations. In BIM the method expanded, as Object-Oriented Physical Modeling allows efficient and effective communication with Building Energy Modeling (Jeong et al., 2016). Conclusively, OOP coding extends from parametric generative form design, to integrative legislative regulation and physical performance simulation. The ability to communicate descriptive information through mathematics in OOP enables integrative design for sustainability, as well as participative and collaborative design.

Urban Planning, Monitor and Analysis

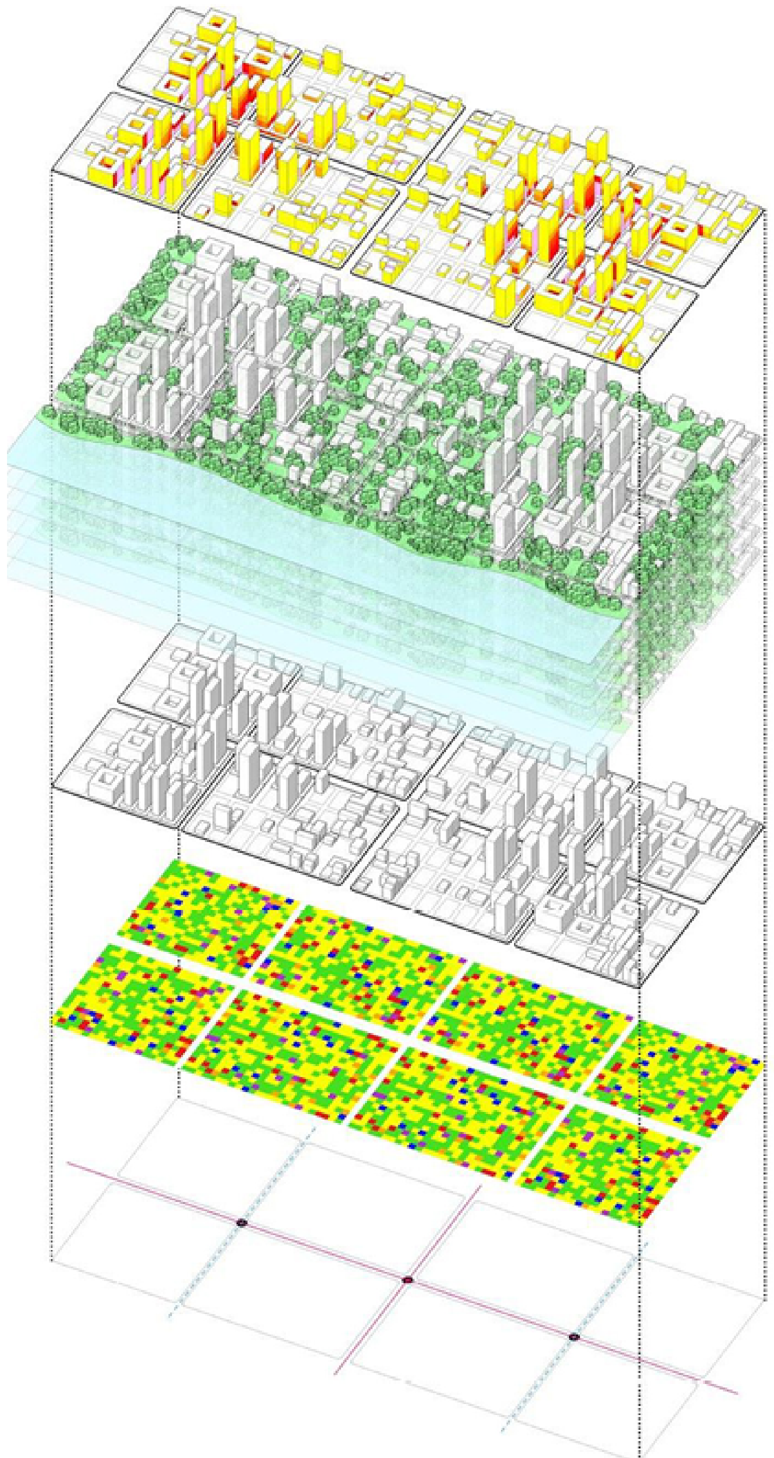
On the macro scale, this methodology is as well applied in urbanism. Since the "Models of Segregation" by Thomas Schelling in 1971, the relation between urban life and software is increasingly connected. OOP is applied for the classification of urban images by levels. For example, in order to distinct between urban and non urban areas or vegetated and built areas. In comparison to conventional pixel based classification methods, increased result accuracy is produced. Conditioned by high quality images, in this application further

Fig.8 - Landesgartenschau Exhibition Hall. Robotically Fabricated Lightweight Timber Shell
Fig.9 - Building information modelling framework: object-based

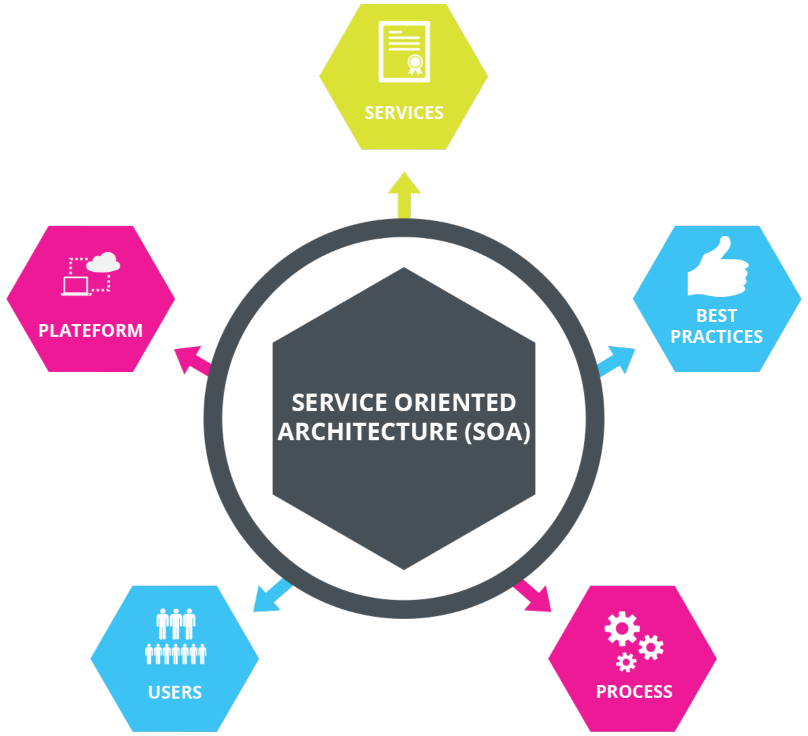
information parameters, as image size, color or shape are included. In a broader sense, this is proposed to support monitoring and planning of urban expansions (Mashee et al. 2014). Moreover, OOP is tested for integration of spatio-temporal data modeling, in particular to manage parcel and urban land use changes. However, major challenges lie in the management of the continuous urban data inputs (Raza, 2001). In complement to urban OOP methods, the development of agent-based modeling and computational social modeling are approaches presented to manage and deal with abstract urban complexities (Fuller et al. 2016). Conclusively, the OOP ability to engage with large scale and complex system processes enables its further application to urbanism. Parallel to design and BIM applications, OOP can support the inclusion of sustainable principles in the overall built environment.*

Application Extension: Service Oriented Programming Architecture

*These urban related applications are increasingly required to implement various services and business models. In this sense, service oriented software architecture (SOA) is regarded as an evolution and further complement of OOP, where business processes are deconstructed into modular work units or services. Similarly, encapsulation, reusability and abstraction are concepts shared by both methods. The inclusion of business strategies in service oriented software architectures are often combined with web service technologies (Stubbings, 2009). In this context, an application to the building industry is proposed to allow for dynamic, coordinated and distributed building services management. The application aligns with established building automation practices and considers interoperability as well as the integration of open standards and principles for the performance evaluation of system levels (Malatras et al., 2008). In broader long-term vision, OOP can technically be extended into a wider service



system in order to support the required dynamics of sustainable built environments.*



Mathematics of Domestic Space

In computation, space is a dynamic object or entity, as container and interface of social actions. Computable order is studied by mathematics, which regards domestic sphere as "the spatial nature of a subset of social actions". This is continuously shaped by social actions and natural events. Space is the property of interacting entities, as Leibniz suggested in the 17th century. In this sense, social space can be regarded as a set of physical objects and agents which are modified by the function of time. Therefore, design should deal with events instead of objects (Barceló et al., 2014).

Fig.10 - Smart-City: Computational Urban Design and Analysis
Fig.11 - Service Oriented Architecture in a nutshell

An event expresses the occurring of social activity in a certain spatial location at a certain time, with certain material consequences. In this context, spatial processes are represented in a "landscape" of probabilities. Due to the performance interdependence of prior intentional actions, certain actions are also more probable at certain locations. In this sense, things near to each other are more related than distant things. All together the domestic environment can be described as a network of material attraction, radiation, repulsion and cooperation reproducing the required energy for a particular social system (Barceló et al., 2014).

This particular sphere of actions relate to subsistence, maintenance and reproduction. Combined with natural processes and mechanisms of physical space, these form a dynamic relational framework. On one hand, this relational structure is defined in metric space by Euclidean spatial dimensions and the fourth dimension of time. On the other hand, space can be defined topologically, in terms of neighborhood instead of distance. That is, points in relation to other collections of points. These definitions enable the description of geometric and non-geometric objects, as points, lines, spheres or functions in relation to each other by distance or neighborhood (Barceló et al., 2014).

The construction of relational space can aid to understand spatial dynamic complexities. In their surrounding environment, human intentions produce spatial structure and characteristics of form, which change and emerge according to their particular sequence of actions (Barceló et al., 2014). In domestic subsistence, the intention to prepare a certain recipe in a kitchen requires a certain component infrastructure and the allocation of certain material tools and resources. All are in relation to each other to different extends. Conclusively, the overall character, form and structure of kitchens embody the recipes of actions performed by particular human actors and their respective culture.

Synthesis: OOP for circular re-production of built environments

Conclusively, the spatial interaction of social actors and performed transformations in the built environment is understood in terms of events and relational attractions. The mathematical framework considers the reproduction of domestic space from action subsets over time. In this context, the capacity of OOP to communicate data structures increases the potential of computers as expression medium of relationships and behaviors.

This methodology allows analysis tools, systems, services and physical environments to be created. In relation to architectural design, the method shifts the designer approach to create and explore restriction matrixes for a field of possibilities according to the desired intentions. Consequently, the designer decomposes the design into parametric elements and parts. In addition to design development, OOP facilitates collaborative BIM environments between project stakeholders. Moreover, the method allows also for the further physical analysis, simulation and evaluation of design options. In this sense, the translation of sustainable principles and systems of design and construction into OOP can probably establish methods to explore and compare design options for circular domestic and other built environments. In extension, OOP presents potentials to establish urban and economical services for management, regulation and control of emerging circular living systems.

In this sense, the translation of sustainable principles and systems of design and construction into OOP can probably establish methods to explore and compare design options for circular domestic and built environments. In extension OOP presents also potential to establish connections for urban and economical service management, regulation and control. In combination and synergy this might as well be an essential method to implement circular living systems.

LINEAR TO CIRCULAR EMERGENCE: A PRODUCTION PRACTICE

After WW II, planned obsolescence was introduced to fuel industrial profit in the linear "take-make-waste" economy (Packard, 1960). These consumption practices contribute to waste mentality and environmental damages associated. In opposition to the current linear system, the alternative circular economy proposes more alignment with the environmental, social, economical dimensions of sustainability, connecting to the People - Planet - Profit framework. In this sense, the idea can be reduced to a 'transformational agenda that aims to redesign production and consumption systems' (Preston, 2012).

The emerged regenerative circular concept includes a general range of policies, services and products in closed material loops. The complexity of biological and technical cycles requires design to integrate also business models in the generation of circular services and products (McDonough, 2002). More concretely, the alternative system is incentivized with three principles: Design out waste and pollution; keep products and materials in use; and regenerate natural systems (Ellen MacArthur Foundation, 2017). The term is therefore broad and subjectively understood.

Underneath the circular economy umbrella concept are many individual waste and resource management strategies and frameworks, as cradle to cradle or blue economy. In this context, the developed circularity compass by F. Blomsma, can aid the analysis of the various approaches and scopes resultant of the relation between practitioner's interpretations and actual enactment. Despite the vague and broad terminology, the concept can be summarized under the extension of the productive life of resources by keeping them in 'loops'. Therefore, understanding the way material flows are shaped in interaction with various social forms, can contribute for socio-institutional change in waste and resource management (Blomsma, 2017).

Fig. 12 Blue light red white lines in abstract black. Jeremy Whiting. Digital painting.

Circular bio-economy

All model variations have an impact on society's structures. The generated actions develop the waste and resource grid and in parallel, contextual suitability is tested. (Blomsma, 2016). In this sense, bio-economy is defined as the production of renewable biological resources and their conversion into food, feed, bio-based products and bio-energy (European Commission, 2012).

Although the synergetic potential between circular economy and bio-economy is not clearly established and understood, there are clear recognized connections. Although, chain value collaboration as well as product and infrastructure design is less represented in bio-economy, the principles can be translated into a circular bio-economy. Both the action and policy plans of circular economy and bio-economy strategies target food waste, as well as biomass and bio-based products. Common in both concepts is the global perspective, the chain approach, resource efficiency, the cascading use of biomass and addressing production and consumption.

In fact, current and future generations need for food, medicines, construction materials and chemicals have to be addressed by biomaterial cycles. The focus lies on optimization through cascade and extraction of bio-chemicals, while returning all nutrients to the biosphere. In relation to technical material cycles, the different time dimension of bio-material cycles requires more systematical methods to assess ecosystems impact of models. The biomaterial cycle is integrated in the planets ecosystems, so in the major cycles of nutrients, as carbon, phosphorus, oxygen, nitrogen and sulfur. Therefore, their assessment, control and regulation appear as vital for the circular bio-economy. For that, technological cycles should provide supportive methods (European Environment Agency, 2018).

In this sense, design has a major role due to the technical and social nature of designers' abilities (Roy, 2006). In order, to create appropriate

circular environments, as situational factors of consumption and production trans-disciplinarity is required. Consequently, all design and construction perspectives from product design to the urban built environment are essential.

Collaborative Production: A complement to circular production

Complementary, playful sharing and learning by doing practices can help to explore design and construction towards activity and sustainability by means of prototyping. Revived from the undervalued and often forgotten ability to make, these practices are part of a broader context of urban mining, DIY, collaborative living and production movements. In this sense, architects and cooks, as humans are all biological makers! The exchange, creation and learning of new ideas and skills enrich our lives. Objects, more than a consumption source, are artefacts to engage with passion. These cultures are interconnected by events or fairs and practiced in workshops, where new affordable digital tools and fabrication processes are combined. The Chinese, USA government, MIT, Deloitte characterize the maker movement as a "new industrial revolution" which will disrupt future work and education.

As extension of circular production and consumption, the movement can lead to a stronger community, where social connectivity is a source of talent, innovation and creativity for the economy. On a macro level, between market regulation and democratized manufacturing tension, in lack are viable business models, safety and control insurance. On the micro level, subjective local perceptions about maker-spaces, sharing and entrepreneurial misconceptions can be the limiting factor. In this scenario, the current collaborative maker ecosystem emphasizes the need to network in search for best practices and expand the holistic communal role of urban maker-spaces.

Fig.13 - Cities and Circular economy for food representation.

Shared living and working: A lifestyle parallel to circular production

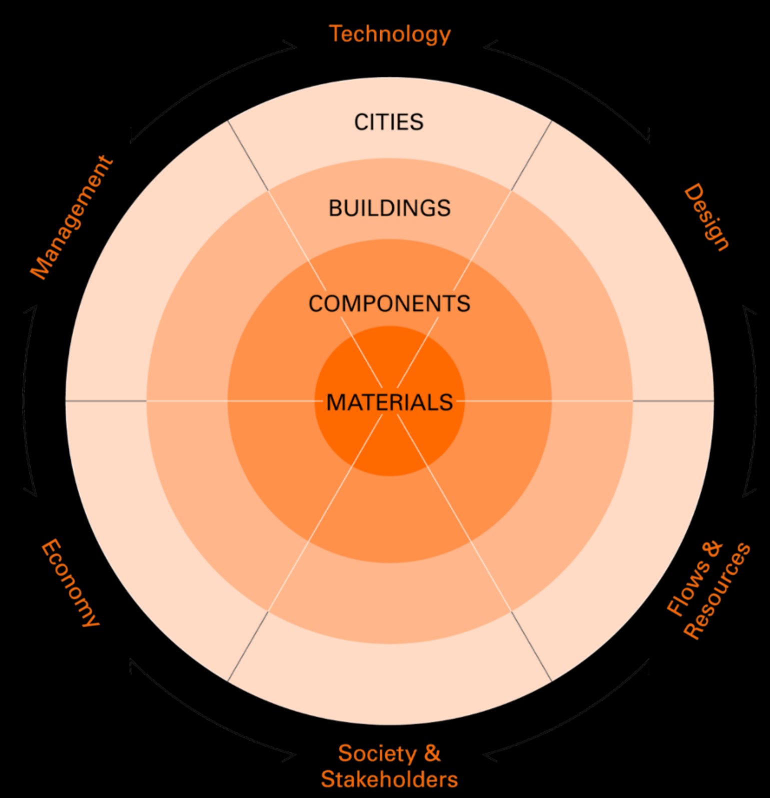
In addition to this context, there is visible trend towards more comfort in sharing parts of the traditionally private domestic sphere. This is visible in the online shared personal computer "space" and in the physical world, where invisible networks of technological infrastructures and services allow food, tool, cloths and housing to be shared.

In exchange for facilities and opportunities of urban life, the populations are willing to rescale their privacy. This blurring of shared and private space is most visible in co-living and -working configurations. These are becoming a marketing commodity, as representative lifestyles that emphasize productive collaboration and social interactions.

Moreover, major driver of future job transformation is the flexibility of working models, including co-working spaces, free-lancing, and telecommuting (World Economic Forum, 2016). In contrast to traditional culture, co-working translates itself into open, flexible, transparent and accessible designed spaces with the required socio-technical infrastructure for a multitude of shared activities.

In these sense, two normally segregated activity domains of working and living are merging into one (Forbes, 2016). In addition, increasing shared urban gardens and community kitchens create relationships and practices of exchange. Overall, these reflect the rising value of community. In which, collaborative sharing culture is expected to decrease domestic size and item quantity, while increasing neighborhood-sharing facilities (Ting, 2016).

Conclusively, design needs to be readjusted to focus on social interaction, participation and communal activities. In addition, social and urban ecosystem analysis to (re)design and (re)construct appropriate spaces, can support collaborative lifestyle movements. At the same time in symbiosis with circularity, these environments could provide innovation to design and construction fields, while create stronger connections with society, technology and the contextual place. On the long-term circularity is promoted in the built environment.



Design for Circularity

Circular economy as wide umbrella concept demands trans-disciplinary socio-technical design and construction approaches for a translation into built environment. The presented circular design framework includes strategies for the biological and technical cycle as well as for the business model behind. All stakeholders involved in the planning, development and (re)production of the urban environment should stimulate and catalyze situations for innovation and shift. In this sense, a redefinition of the design role is required. That is in relation to recycling, decrease of environmental impact, efficient use of resources, the transition from products to services and the broader understanding of behavior, lifestyle and society's structures. So that, design as well contributes to establish perceptions over sustainable lifestyles and the development of green cultural practices (Ilstedt et al., 2014).

In order to influence consumer perceptions and consumption patterns, designers require mindful with system thinking and the capability to decide on circular strategies in economical, as well as socio-cultural dynamics (Joore, P, 2016). In this sense, design for sustainability (DfX) represents holistic strategies for the creation of physical objects in compliance with the environmental, social and economical dimensions. Related with circularity, the DfX taxonomy provides an intersectional overview about holistic circular design and multiple life-cycle design. A wide Circular Design Framework is formed by five circular design strategies of the taxonomy over five circular business model archetypes. (De los Rios et al., 2016). The strategies

Fig.14 - Transdisciplinarity of circularity in the built environment.

emphasize design for circular supplies, for resource conservation, for multiple cycles, for long life use of products and for systems change. The framework aligns with the ideas of the Ellen McArthur Foundation to shift the industrial system and enables product and business model perspectives to be integrated in the design practice.

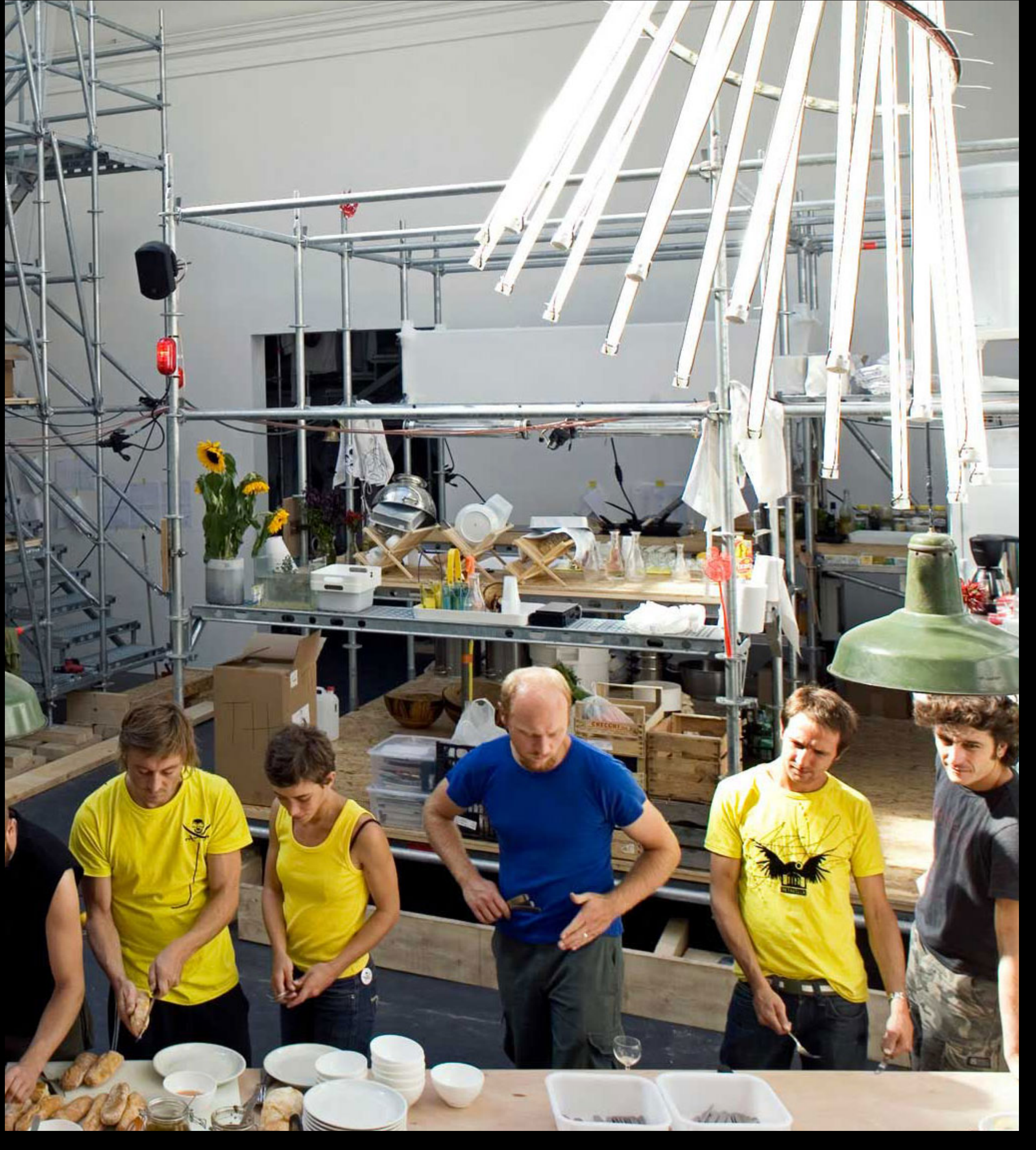
As a major consumer of resources and producer of waste, design and construction of the built environment, is challenged by the concept of circularity and circular economy. In this context, recommended is for the designer to extend its mindset from creator of "objects" to provider of "services" (Meroni, A 2008). In addition, a stepwise framework to circular building and product development (CBPD) is proposed on three levels: reduce, reuse and recycle (Geldermans, 2016). Overall essential is an attitude of sharing, dematerialization, optimization, selection and reduction of material and product (Peck, 2016). For this shift, strategies as design for disassembly, adaptability, reuse, recycling, repair, application of material passports together with smart leasing contracts and circular business models should be promoted and applied (Guldager et al., 2016).

The values of circularity can be found at the intersection of intrinsic and relational properties. Only the combination of material, product and building design with use characteristics has impact regarding circularity in built environments. In fact, any specific technical or design property is decisively significant. Therefore, without regard to socio-cultural and institutional parameters, circularity in its essence will not work (Geldermans, 2016). Conclusively, as human behavior shapes the built environment, the approach has to be socio-technical.

Synthesis: OOP socio-technical circular design integration

In order to achieve circularity in the built environment, it is therefore essential to influence and (re)shape the mentioned deteriorating social practice by means of design and construction. The required socio-technical integration could be enabled by the overall integrative potential of code combined with the mathematical domestic action framework. In addition, the two circular design frameworks provide guidelines and principles, which can be translated into design parameters and functions of OOP. Moreover, OOP can aid to explore and establish circular service systems for collaborative built environments.

KITCHEN: THE HEART



Evolution

The discovery of fire lies in the origins of this typology. Often considered the heart of the house, the kitchen is an energetic field of constant interaction and transformation. The force and power of this heart derives from the associated activity, as it expresses the satisfaction of social, psychological, physical and nutritional needs in form of practices. In this sense, as domestic core of the biomass, water and energy nexus, the kitchen connects humans with their resources. The designs articulate and actively challenge our relationship to food as well as popular attitudes and domestic practices related to family life, consumerism or even political ideology. This core domestic environment is therefore an ideal starting point to understand how the design and construction of situational configurations can affect practices towards circularity and sustainability.

In 1841, in order to ease and improve the efficiency of domestic servants, Catherine E. Beecher addressed the subject of kitchen design as a work profession. Therefore, rationally organized and structured workplaces required standardization and prefabrication as streamline. Moreover, Christine Frederick and Lillian M. Gilbreth identified preparation, cooking and cleaning as the three fundamental steps of housekeeping processes. In Germany, architects, as Margarete Lihotzky, Bruno Taut and Erna Meyer, led the household rationalization movement. Including as well user social needs, interaction and future lifestyle, the person is functionalized focusing on time, energy and material savings (Surmann, 2017). The increased diversity of production techniques and materials brought designs with more freedom of form, consideration for psychological issues and personalization. In parallel to that, the increased introduction of electric appliances and storage shelves increased kitchens sizes too. Specially, with the trolley and island concepts, including also breakfast bars and eating areas. The kitchen became larger, a representation of prestige and social communion.

Fig.15 - METAville Kitchen French pavilion - 10th Venice Architecture Biennale 2006

So, the starting fire, where people sat around in ancient times is replaced by the kitchen (Surmann, 2017). This typology facilitates our nutritional subsistence and reproduction of related events. Although not directly in the natural environment, this domestic typology still has a close relationship with the biomass cycle.

The Frankfurter kitchen

In 1926, the Austrian architect Margarete Schuette Lihotzky designed the prototype, which influenced western kitchen design, as the living space complementary to the private working space. The "housewife's laboratory, factory or workshop" concept aimed to be a compact instrument and mechanism to decrease labor time and effort, through comfort and equipment strategies for the women in working class apartments. The design was based on scientific research on management, ergonomic design and references of railroad dining car kitchens. In the analysis process, she retraced the path of the person performing, in order to transform the life of ordinary people. Instead of being in the basement as secondary annex the kitchen was primarily exposed in the domestic sphere. The result was a 1.90 m wide and 3.40 m long narrow space with ideally reduced number of steps. The design was a mono-functional room for individual work. Moreover, the design included the experimental application of new materials, technological electrical and mechanical. Nearly, 10,000 units were mass produced and installed. All this developments placed the kitchen design into public debate and cities even integrated local kitchen planners into building departments (Antonia Surmann, 2017).

Time, Effort & Performance

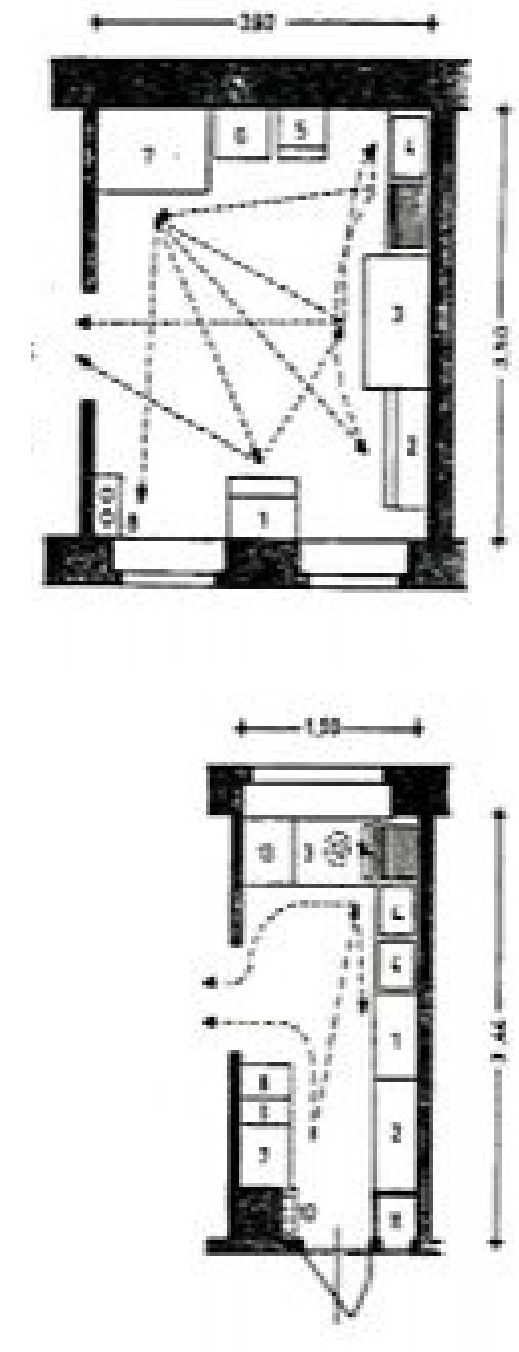


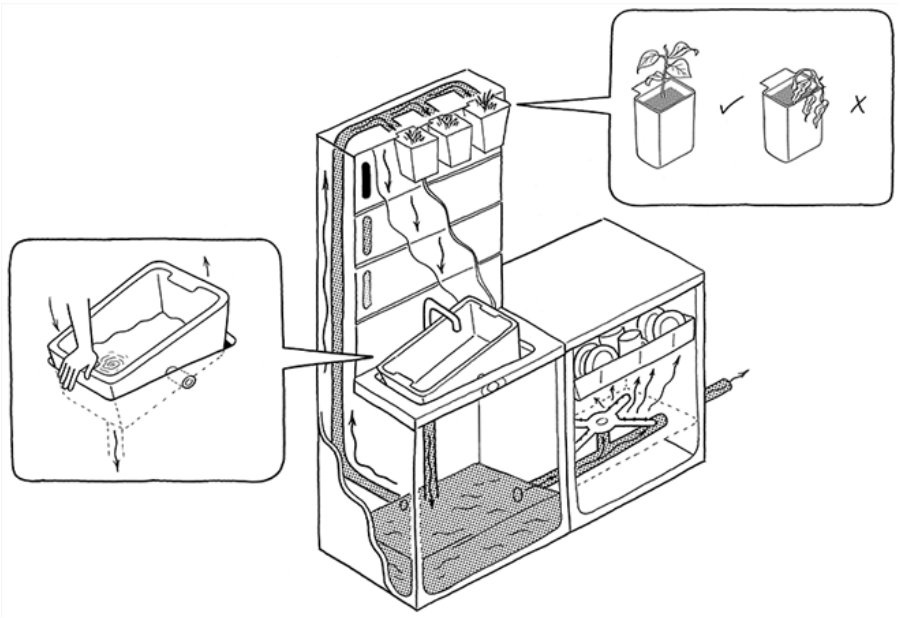
Fig. 16 - View into the Frankfurter Kitchen by Margarete Schütte-Lihotzky
Fig. 17 - Movement analysis comparison: 1927 Traditional vs Frankfurter Kitchen

The IKEA 2025 kitchen

The partnership IKEA and Design Company IDEO regards the kitchen as the heart of the house, in which space carries energy, activity, comfort and creativity, which is supported by the human centric design research of TU Eindhoven. In a scenario of adaptation to food access, while resources scarce, costs and waste increase and technological developments flourish. Students and companies explored the interaction of embedded technological systems with different contexts and groups.

The resulted Concept Kitchen 2025 focus on mindfulness in user and food relationship, aiming to increase clarity of action and decision through the tactile and visual experience combined with technological integrations. In order to create more storage visibility than the fridge, the use of transparent cool-induced shelves and containers regulates temperature, in accordance to RFID stickers of food packaging.

The idea incorporates as well the "Table for Living", which interacts in preparation with suggestions and guidance by means of a camera sensor and projector. The concept aims as well to optimize food consumption. In addition the "Modern Sink", where mechanically the user directs the flush of different water streams from the pivoting-basin to be reused for dish washing and plants. Supportively, the kitchen accounts also for a manual adaptable disposal system to induce separation. The manager Gerry Dufresne views the kitchen in tangible communication of future behaviors (TUE IO, 2019)



Mindful & Technological

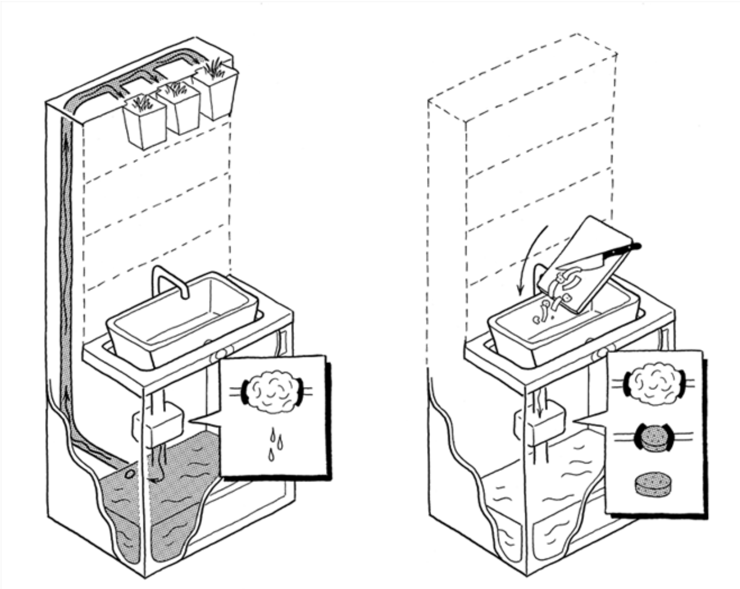


Fig. 18 - IKEA Concept Kitchen 2025.
Fig. 19 & 20 - IKEA Kitchen 2025 exposed: Grey-, Black-water & Compost concept

The IDEO test kitchen

The Design Company IDEO prototyped an office kitchen, that was built to play while cooking. In order to inspire and change the experience, the design follows openness, versatility and interactive reconfiguration. In addition to idea, the kitchen island creates connecting situations of conversation and collaboration. The design team, emphasizes the dynamic use of the space, therefore encourages adaptability, simplicity and minimalism as recipe for a reactive design, where the focus lies on the food itself (IDEO Rachel Maloney, 2017).

Inspire & Play

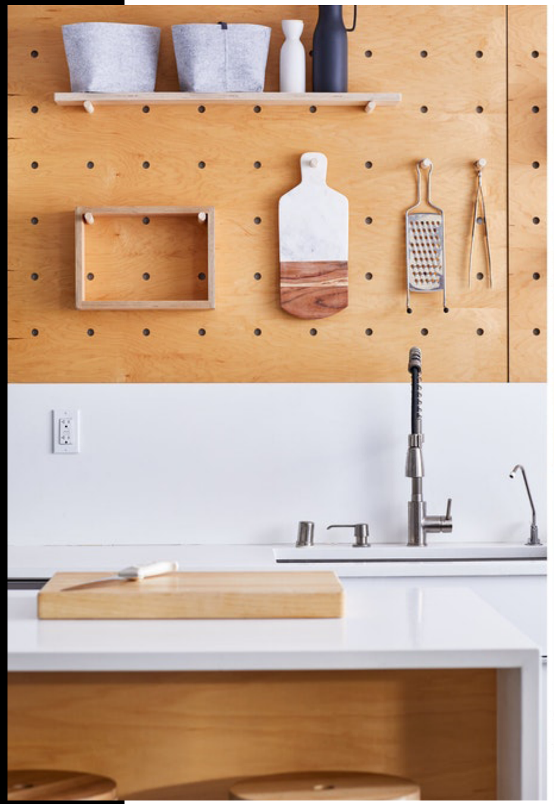
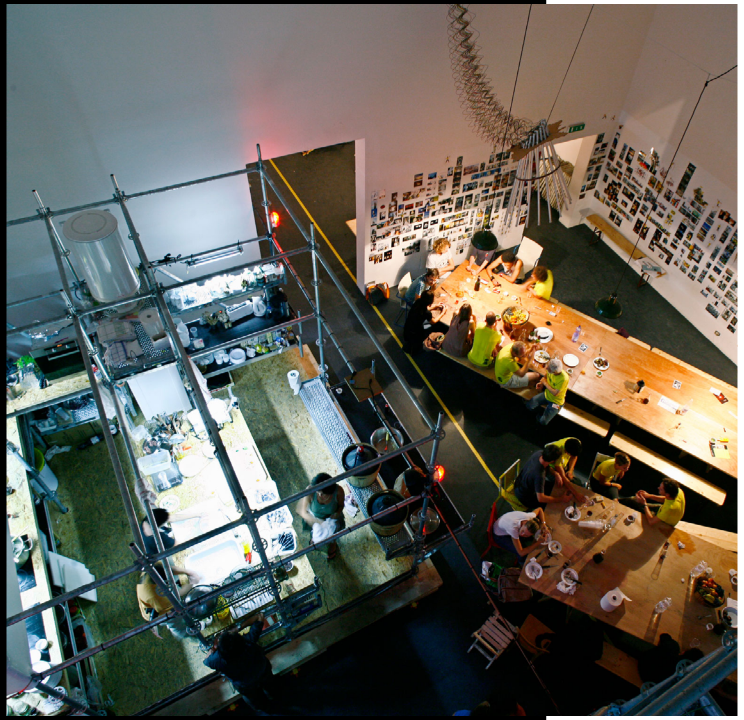


Fig. 21 & 22 - Ideo Office test kitchen: Counters, Stool-island, Pegboard

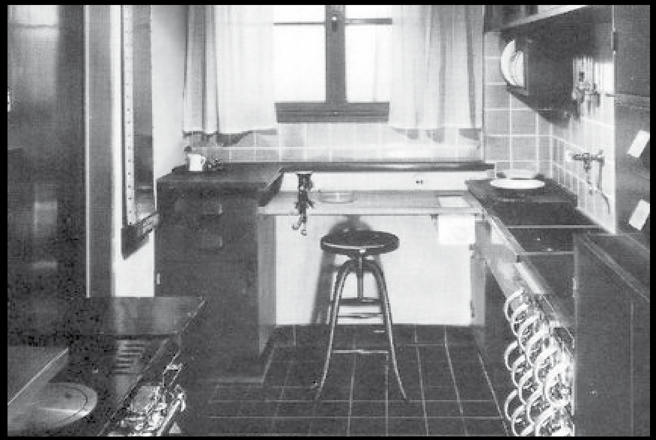
The METAville kitchen

In 2006 within the topic of META-cité, Patrick Bouchain, as French pavilion curator of the 10th edition of the Venice Architecture Biennale invited the atelier 1024, construction collaboration group EXYZT in partnership with Daniel Buren, Liliana Motta, Jean Laufrey, Igor Dromesko to present an inhabitated space. The creative studio 1024 combines digital code with the production of multi scalar art and architectural expressions. The idea in the project is established as temporary collaborative construction process for a lively space of events. The villa allowed a variety of activities, including a hotel, bar, kitchen, work and read spaces, as well as spa, sauna, swimming pool and showers. The METAvilla allowed the exposition space to be lived and experienced, challenging the users engagement, therefore the space created agency and was more than only an exposition itself. In this the kitchen had highest activity. The construction is based on temporary metallic scaffolding structures. In the center of the rectangular transparent structure is an island where collaborative work is concentrated. The surrounding edges support this with additional horizontal storage and work platforms as well as electrical and manual appliances, as fridges and boxes. The spatial characteristics and appearance suggest flexibility, dynamic and informality. Next to that structure, a wide long table creates the environment for wide diversity of social activities. Therefore, in combination the temporary METAvilla kitchen invites and allows a wide range and quantity of users to work and live within (Exyzt, 2006).



Collaborative , Dynamic Experience

Fig. 23 & 24 - METAville Kitchen of the French pavilion - 10th Venice Architecture Biennale 2006

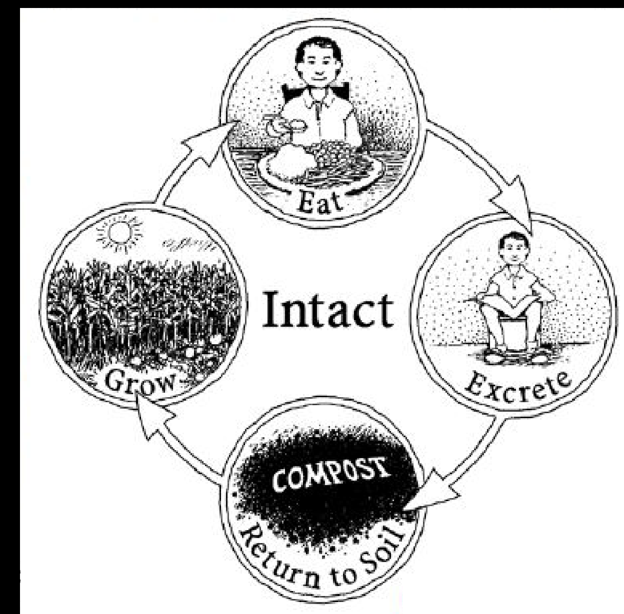


Conceptual Goal	*Architectural Expression*	*Circular Design Correlation?*
performance *less time & effort*	*compact space* ergonomic *design* *wall centered*	*experimental application* *of materials & technology*
mindful *actions* *technological integration*	*humanistic, engaging* *wall centered*	*mechanical separation of* *water-streams* *compost press "puck" device* *integrated mini-garden*
inspire & play	*adaptability, simplicity,* minimalism *wall + island centered*	*components for system change*
lively experience *collaborative* dynamic	*temporary scaffold-structure* *open & flexible configuration* boundary + island *centered*	*components for system change*

Fig. 25 - Comparison diagram

Kitchen: Biomass subsistence

Organic residues, as result from crop production in soil nutrients have to be returned to the soil, so that the natural human-nutrient cycle remains intact. The continuous addition of recycled organic materials, food scraps and agricultural residues enriches the soil and ensures fertility to grow human food (Jenkins, J. C. 1999). The Dutch government proposes a broad framework outline for the transition to a sustainable circular residual biomass use. The outline combines environmental and socio-economical indicators as well as assessment methods weighted by limitations and goals, as boundary conditions. Moreover, risk assessment is also included, for example due to pathogens and contaminants in residual flows. Generally, the government proposes the use of cascade principle to increase efficiency. The assessment remarks clearly the possibility to recycle and almost close the natural cycle, through local compost of organic matter and reuse as local soil fertilization. The framework seems however more appropriate for the macro level (RIVM Report, 2016). Although, principles are considered, a micro approach seems to be more appropriate in the scope of this thesis. The sustainable need to reconnect with the biomass cycle can be supported by consumers through diet and habits, as eating less animal-based protein, preventing food waste and separating bio-waste from other waste streams. Where possible, systems of composting or digestion can convert these into soil fertilizer and recover biogas.



Vermi-compost vs. Hot-compost

In order to address food sustainability issues, vermi- and hot-composting is explored and compared in Michigan State University. The project aimed to increase the collection and composting of the campus kitchen preparation residue as well as food waste, in order to return nutrient values to student organic farms and gardens. The study focus investigates medium scale vermin-composting methods. Small scale "worm bins" appear as common family household composting method (Biernbaum. J. A., 2013)

The application requires limited equipment and is more manageable and practical than hot compost. However, low or excess temperature, moisture or feeding conditions can lead to a rapid or total loss of worm population. Therefore, the appropriate treatment and regulation of the animal (pet) is required and presents itself as risk of failure. Moreover, another risk is the limited research available on the pathogens, which might survive the composting process, which requires further attention. The worm system produces higher concentrated mineral castings than thermophilic composting, therefore is nutrient richer. Indoors, the thermophilic process can have negative health impacts with ammonia gas and mold breathing. This is excluded in vermin-composting, therefore is more indoor appropriate.

Any of the systems, if applied correctly do not produce odors as usually misconceived. Depending on the quantity and type of worm population, the vermin-process is continuous and relatively fast in six to eight weeks. Recommended are red-worm populations, which can double every two months under the right conditions. Additionally, as process byproduct liquid fertilizer can be used as alternative to chemical fertilizers (Biernbaum. J. A., 2013). In comparison the worm system can even have didactic value, due to more exciting and interactive perception of the biological decomposition processes.

Fig. 26 - Human nutrient cycle
Fig. 27 - Vermicompost soil product

Synthesis: Bio-circular collaborative kitchen

The evolution of the kitchen proves its vital importance in socio-technical and biological processes. The mutual related reproduction and transformation of practices has shaped the kitchen over time. Past designs, as the frankfurter kitchen targeted time and effort performances and provide rational methods to understand subsistence processes. In addition, these were complemented by the necessity to integrate as well the social and communicative role of the kitchen in subsistence related practices. In this sense, contemporary experimental projects continue to demonstrate this focus in different designs.

The kitchen, as an island prevails as connective concept to focus on collaboration and communication. Additionally, surrounding boundaries are often used to support this central action. In this sense, metal, wood and composite materials are commonly used. Moreover, technical translations show different intensities in the application of modular disassembly and adaptable systems. The METAvilla kitchen is temporary, while the IKEA 2025 concept and IDEO office kitchen provide a static result with integrated dynamic storage systems. Therefore, these kitchen design case studies provide technical and social design concepts with synergetic potential for collaborative domestic circular design, as minimalism, design for disassembly, separation and adaptation systems. In addition, the overall process is not regarded from an OOP perspective.

In order to support the extension and regeneration of the biomass loop in these designs, compost and digestions systems can be included. The composting system could be integrated into the nourishment process in the kitchen. The convenient integration and didactic perception of the system in the kitchen can support biomass separation practices. The systems implementation involves limitations and risks which have to be further researched for a successful long-term application. Nonetheless, in the speculative sense of this thesis the synergetic potential between humans and worms to recycle nutritional values is promising to explore as possible system to implement circular and regenerative awareness in subsistence practices. This is especially attractive in urban farming and circular collaborative domestic environments, due to higher biomass and user quantity. In collective community sustainable approaches are more effective and impactful.

NETWORK OF PRACTICE: ACTIONS, PEOPLE & OBJECTS

Cybernetic action

In general changes of practices are dependent on the processes of interaction and decision-making among the actors involved in a collective problem, as a category of social facts this is the definition of governance (Hufty M. 2011). The definition can be related to the "art of steering" or Cybernetics, as an existing science which studies the regulation of any circular causal system, coined by Ashby's work in 1956. Later, further extended by "Control and communication in the animal and the machine" by Norbert Wiener. In this context, control exists within the circulation between the systems and not in any particular side. In this sense, code as medium is the circulation. The concept is therefore based on feedback loops, which let an actor in a situation, know if the result of his action is as desired and otherwise modify his behavior. Embodied with Ashby's idea of the Black box, that is a viewed system of inputs and outputs, the human actor in the world environment has the ability to continue to perform, although not knowing what is actually "there". In this circulation system, the human actor wakes up through input of all his senses of space and time. Directly the human system outputs action.

In a standard philosophical conception, action is a term of intentionality, while theory of action explains this in causation of events and mental states of agents. The performance of intentional actions can be defined as agency and is everywhere, as causal relationship or interaction (Schosser, M., 2015). However, the specific application and execution of an idea, belief, or method is defined by the Oxford dictionary as a practice. The term practice can be regarded as a recursive sequence of intentional actions or agency. Mutually affecting the individual and the environment, all daily practices, habits and customs are expressions of agency, all combined form a lifestyle and rhythms of everyday life.

Fig.28 - Exhibition ON AIR

Actor-Network Theory

In this abstract context, the actor network theory (ANT) proposes an understanding of conditions, constraints and modifications of agency within networks. The idea of a relational web between human and non-human, which interlinks culture, language, mind, society, as well as all natural and technological artefacts is supported. In this sense, subjects and objects are decentralized and network dependent. Bruno Latour developed the theory as an application of the study of activity and processes or semiotics. In this sense, form and attributes of an entity are a result of its relation with other entities, having no inherent qualities. In this way, divisions as human and non-human, agency and structure or materiality and sociality are overcome and understood as outcomes. Entities are therefore performed in, by and through those relations, which have a degree of stable durability.

Actors are network effects. The spatial attributes secure the continuous displacement of objects in various forms and create topology, as the preserved spatial properties after deformation. For example, the spatial attributes of the domestic network of objects, around which food preparation occurs, enables and shapes the subjects preparation practice. The combined object and subject movement forms the kitchen, as topology. The ANT system offers an alternative topological understanding. The position in a set of relations maintains elements in their spatial integrity, meaning in stable linked patterns. On one side, the theory can be seen as a description, enabling the analysis of various connection patterns, representing different typologies. On the other side ANT can be seen as a form of spatiality itself, conditioning and restricting relations, entities and topological possibilities.

The social visible micro level and the indirectly visible macro level are interlinked, equally complex and abstract. Instead of agent and structure based, Latour proposes also the possibility of the social to be an endlessly circulating entity. Movement, as the parallel framing and summing up of interactions through different devices and forms to a small locus is a principal focus of the idea. In this sense, the action is supplied to actors by the circulating entity (Law, J., 1999). Conclusively, the social ANT enables multidisciplinary relations with physical sciences, as it provides an abstract metaphysical perspective over the interconnection of space and the agency of practices.

Social practice

The development, persistence and disappearance of everyday life practices demand and actively imply objects, as artefacts that enable and shape actions through usefulness. As a result, movement, skills, behavior, social relations, goal configurations and aspirations are inscribed and hardwired into the design of material artefacts (Shove et al., 2007). For example, by identifying a knife an individual is aware he can realize a wide range of different tasks, from cutting, murdering or sharpening. However, in a kitchen the knife incentivizes the cutting of ingredients. The knife incentivizes the user's hand to grab it a particular way. In assistance of the other hand and certain skill, the cutting can also be executed in the air. These are often cultural and individual related habits. However, in combination with a cutting board the knife configures the user for a more desired, stable and precise execution.

The reproduction and transformation of practices involves and depends upon the active integration of materials and objects, images and meanings. In this sense, the interaction between human and non-human results in the emergence and distribution of agency. The interaction is mutually vital, actively configuring the user and his practices. Therefore, these relationships are essential for socio-technical change and innovation, emphasizing the question over design and practice (Shove et al., 2007).

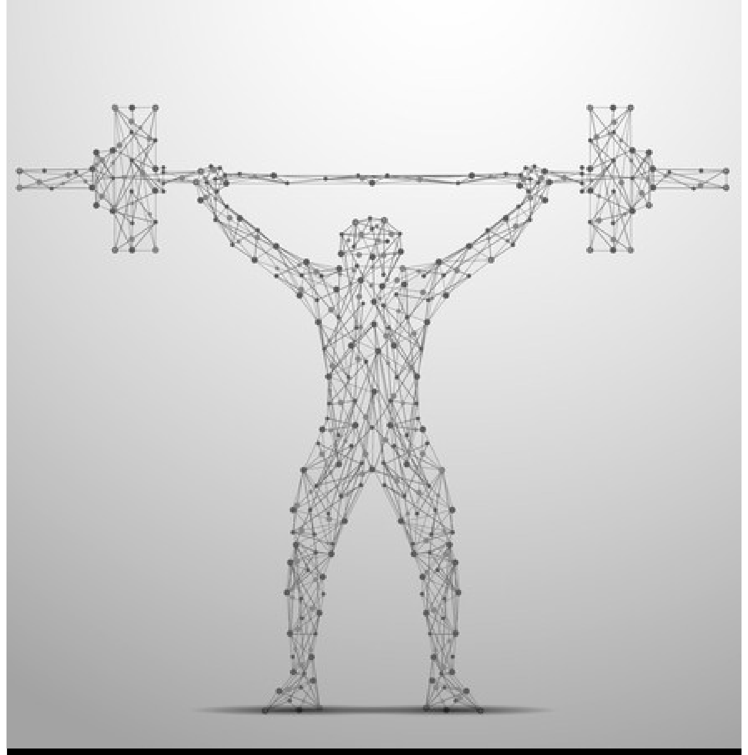
Fig.29 - Exhibition ON AIR

Practice Theory

In practice theory, a conglomerate of practices performed by individuals builds up stability and change in society (Reckwitz 2002b). In this sense, human behavior is the performance of practices, in which involved "material phenomena are part of society" (Schatzki, 2010). Performance is the act of performing or executing an action, therefore not necessarily related to efficiency improvement, as commonly associated. The conceptual abstract framework appears essential to understand complex relations of social behavior, as consumption (Warde, 2005) or Human-Computer-Interaction (Pierce et al, 2013) and potentially can contribute for the development of "designed" behavioral change in relation to sustainability and culture. In this context, practices become unit of analysis.

The description of practices as configurations of material, competence and meaning elements provides a system to analyze the human-non human relationship (Shove et al, 2005). In the kitchen, the human identifies the meaning element of a practice through a desirable output, as for example a specific meal. Then, he steers the physical material elements, as tools and ingredients with the required competence skills, as theoretical knowledge and practical know-how of himself. The behavioral role of design in these relational configurations is clearer, if practice-as-entity and practice-as-performance is added in interrelation.

The performance is driven by the organization of practice elements, however even if not performed at the given moment, a practice still exists as a moving entity in time and space. This means an organizational configuration of a cooking practice in India has a different entity and so performance than in the Netherlands. Both are variations of the general identity of cooking, since fire was mastered. Conclusively, a configuration of elements creates a performance and a dynamic entity



in the form of a practice. In this sense, the reconfiguration and introduction of new elements changes the behavioral practice through a change in performance, which results in a mutation of the practice-as-entity (Kuijer, 2017). In the language of ANT, these configurations are understood as networks, in which all elements are actors.

Practice-oriented design: a cybernetic computational perspective

In this context, cybernetics as the art of steering practices performed by humans and machines is therefore a complex multifaceted field. Moreover, the official science is proposed as theory matching the practice of design in a sensitive, integral and natural way (Glanville, 1997). In this, the design and construction of the built environment is also included. In fact, this inclusion could aid the fields to establish the required social and technological connections. The ANT's social circulating entity, which provides the actor with action, can be aligned with the cybernetic system, in which control exists as circulation in feedback loops. Moreover, the cybernetic world environment can be regarded as the network itself, in which the human actor performs his practices. The multidisciplinary approach of Cybernetics is relevant for many fields, including computer science, sociology as well as architecture. The application resulted in new experiential forms of practice, leading to growing interest on interactivity among architects (Usman, 2007). In this sense, the computer is presented as a partner, medium or tool extension and enhancer of creativity in the design process of interaction with the unknown and unpredictable (Glanville, 1997).

In order to influence practices, the human and material artifact is decentralized to understand the broader situational interdependence of social practices. Therefore, the computer and other interactive technologies are not the central focus, but instead become just one

Fig.30 - Abstract weightlifter in motion with cybernetic particles.

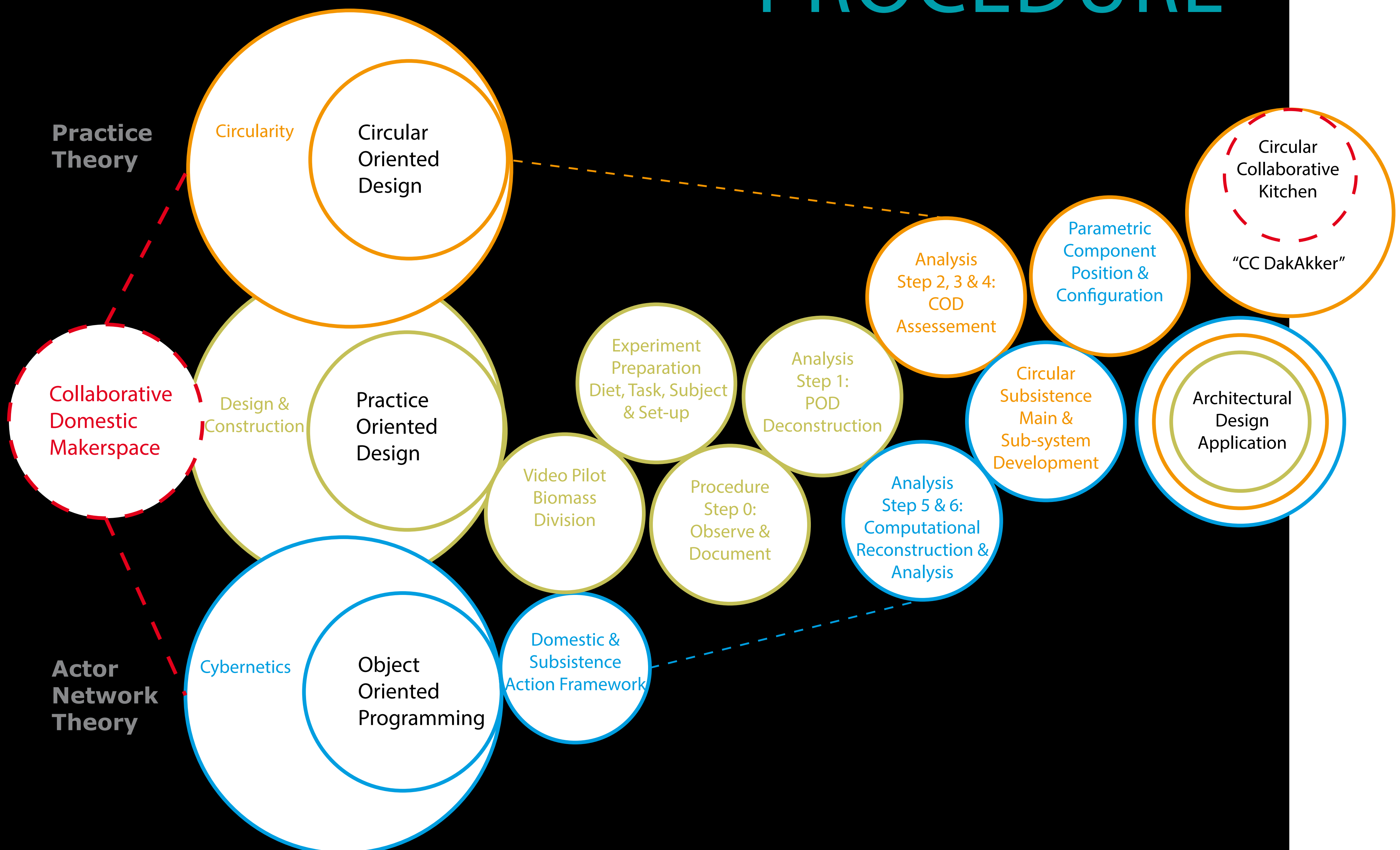
important element in practice configurations. Due to the time and place relationship of practices, study results can have limited value as sample extraction excludes most of the dynamic involved. Therefore, practices are viewed as part of a place ecology, in which movements are generated, perceived and experienced over time. The actual translation of these theories to practice and design is however still the major challenge (Pierce et al., 2013). In collaboration with social sciences, practice-oriented design emerged in 2005-2006 in the context of product-design. As key in the emergence and organization of daily human performance, four methods to approach practice theory are presented.

One method is the analysis and study of situated practices by means of surveys, workbooks, observations or interviews with the focus on the user-product interactive performance as unit of analysis. Another method is to compare and trace practices over space and time, in which the contextual focus lies here on the practice-as-entity. Disruption is a less analytical method, in which the problem-solving designer iteratively reframes and understands the situational practice. The practice itself becomes the unit of design and through experimental trial and error of different configuration's new designed practice arises in interaction with the users. Another approach takes design, as a part of an organizational and professional ecology of practices, in which it proposes the reflection over the practice of design itself and in relation between practices. The approaches can be complementary and combined, resulting in stronger outputs (Kuijer, 2017). In relation to the focus of this thesis, the first method of analysis in the study of situation practices is chosen by means of physical observation of the practice, short interviews and the video recording of the practice from different perspectives.

Synthesis: OOP for circular practice oriented design

Cybernetics provides a different perspective over practices and their shift. Moreover, cybernetic theory establishes multidisciplinary connection to computational systems and design theory. Complementary to this context, ANT provides the abstract metaphysical framework to understand spatial activity and interconnection. In combination with perspectives of practice theory and practice-oriented design frameworks, current subsistence practices can be deconstructed for analysis and reconstructed integrating the principles of circularity. The research on computational design, specifically object-oriented programming applications as parametric architectural generation and complementary regulation and simulation of BIM systems, represents the field's state of the art and the potential of OOP to integrate design and construction processes, principles and systems. Therefore, this should also enable circular and practice oriented design frameworks to be included into one methodology, which facilitates the general socio-technical integration required for circular built environments. In addition, the Actor-Network Theory and Practice Theory support OOP methods. Conclusively, in order to support more sustainable and circular practices object-oriented programming methods can technically reconstruct current practices as clusters of objects with circular systems introduced as supportive situational factors. The interconnection of the different discussed methods, theories and frameworks form the methodology developed in this thesis.

PRACTICAL APPLICATION: MEDIUM & PROCEDURE



According to the focus of this thesis, on domestic biomass subsistence practices, the computational development of a bio-circular collaborative kitchen is defined as objective to proof the concept in a practical context. For this purpose, programming experiments are conducted. In the procedures, both manual and computational mediums are explored. The mathematical domestic framework is used to establish the concept to categorize the domestic sphere of action.

In order to test application of practice-oriented design performance methods of biomass related subsistence practices are observed, documented and analyzed according to the situated practice-oriented design (POD) framework, focusing on the interactive performance of one student in their domestic environment.

In order to test the application of object-oriented programming, in relation to actor-network theory, as well as the circularity and practice oriented design frameworks, a software workflow composed of Rhino 6 extended by Grasshopper and GH Python was explored. Consequently, different computational logics, programming tests and experiments were conducted.

Fig.31 - Thesis procedure overview

Domestic Action Framework

The domestic sphere is regarded mathematically as subset or object of social actions. Mostly related to subsistence, maintenance and reproduction, these form a relational framework with the mechanism of physical space.

In the scope of circularity, the acts rely on resources related to water, biomass and energy to different degrees. In order to design for circular systems and practices, domestic actions are understood in relation to each other and their physical constrains.

From the point of view of practice and actor-network theory, these actions are enabled through the components of domestic spaces, as well as tools and ingredients. From a design and construction perspective, domestic components are therefore the first parameter, which can promote circular practices.

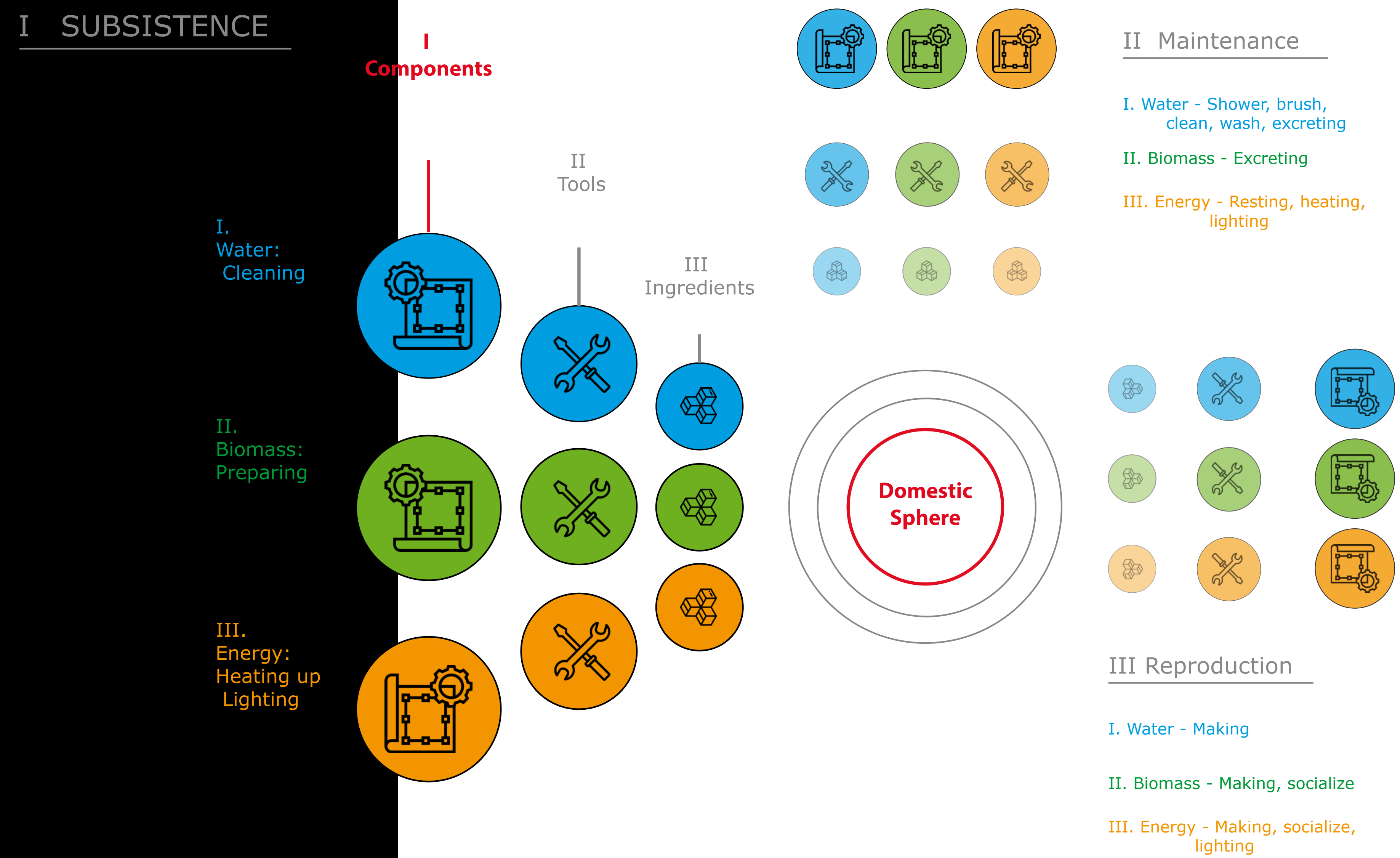


Fig.32 - Domestic Action Framework Diagram

Subsistence Action Framework

The kitchen correlates to subsistence actions. Water is essential, mostly used for cleaning. For example, as ingredient soap with a sponge as tool and a sink as components are required. In addition, water is also used for heating up and preparing biomass.

Biomass provides the actual subsistence and requires various preparations methods, depending on the cultural context. In western culture, many recipes include the division and mixture of biomass. In the process, food and package waste is usually disposed.

Moreover, to cook the prepared biomass, as core of most nutritional cultures, energy is required. Furthermore, also allows electrical automated appliances, which complement both clean and preparation methods. In addition to that, enables also the kitchen to function independent of the natural light cycle, as it provides artificial light.

In this context, the computational subsistence action framework, can be further extended and adapted according to cultural practices. In this thesis, the procedural application example regards only the following subset of actions.

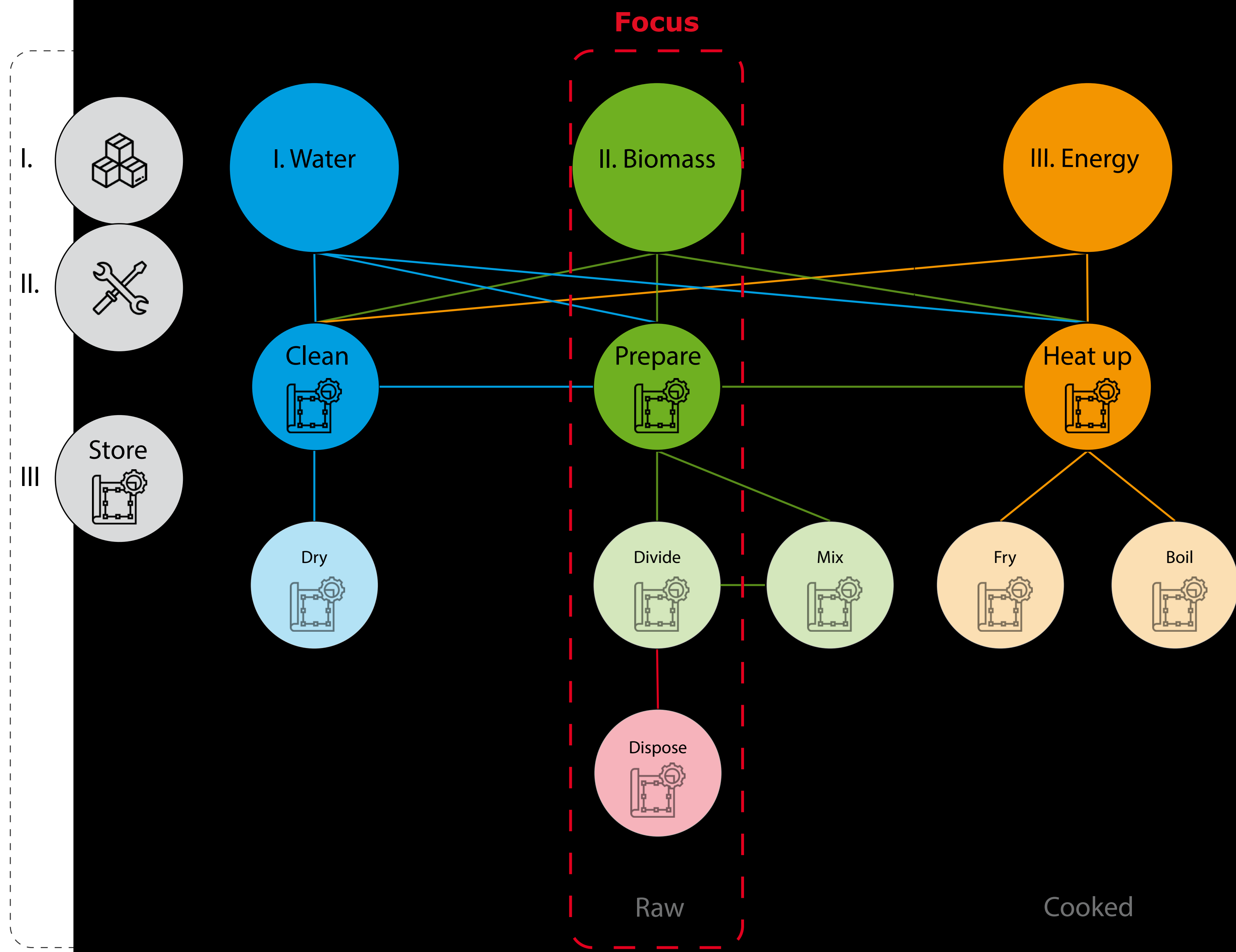


Fig.33 - Subsistence Action Framework

Biomass Experiment preparation: Pilot self-video

In order to better understand and test how to video-record actions, a self-pilot experiment was conducted by means of a GoPro 6 with an elastic head-set-gear. The additional equipment enables to set up the small camera above the head with perspective over the arm and hand range.

However, from the human head perspective, the camera captures less from the surrounding environment. Therefore, for the student experiments a second and if necessary a third camera perspective is set up, so that the kitchen itself as situation is recorded. This enables a clear perspective on the human movements between kitchen components and therefore its relation with the overall process.

Consequently, the workflow can be documented from a human perspective. All objects and surfaces operated can be extracted manually from the video documentation and further analyzed manually or as digital analysis input. In this sense, the biomass division practice can be deconstructed and that is the main objective.

In the sense of the first pillar of circularity, that is to reduce, the biomass supply should originate from short distances, therefore the biomass ingredients of the experiment should be from local national suppliers. The Dutch Wheel of Five (DWF) is the nutritional recommended diet in the country (Netherlands Nutrition Centre, 2017).

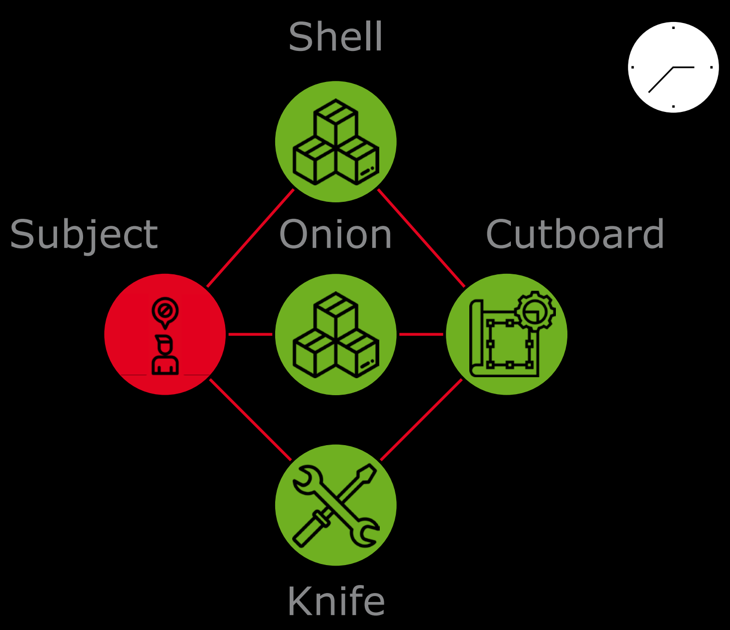


Fig.34 - Pilot self-video: biomass division frame
Fig.35 - Example of practice deconstruction process

Preparations: Circular dutch diet

Food group	Subgroup	Foods in subgroup	Supermarket Classificati 07.02.2019 Jumbo	Albert Heijn	Lidl
Vegetables	Onion family	Onions, garlic and leek	0, 2, 0	0, 1, 0	0, 1, 0
	Stalk v	Celery and fennel	1, 1	1, 1	3, 1
	Root and tuberous v	Radish, carrot, beets, celeriac, salsify, patatoes	0, 0, 0, 1, 2, 0	0, 0, 0, 0, 2, 0	0, 0, 0, 0, 2, 0
	Leafy vegetables	Spinach, chard, endive, Belgian endive, lettuces, turnip greens, purslane, gai choi, Tahitiar	1, 4, 0, 4, 4, 4, 4	, 0, 4, 0, 4, 4, 4, 4	0, 4, 0, 4, 0, 4, 4
	Cabbages	Kale, red cabbage, white cabbage, green cabbage, sauerkraut, savoy cabbage, Turnip	3, 0, 0, 4, 4, 4, 4	1, 0, 1, 0, 1, 0, 0	3, 0, 0, 4, 4, 0, 4
	Fresh legumes	Garden peas, broad beans	3, 2	2, 2	0, 2
	Fruiting vegetables	Tomato, cucumber	0, 0	0, 0	0, 0
Fruit	Fruit	Pear, Apple Apricot Plum Grapes Grapefruit Banana	0, 0, 4, 4, 1, 4, 2	0, 0, 4, 2, 2, 2, 2	0, 0, 4, 2, 4, 1, 2
Bread	Whole wheat bread		0	0	0
Grain products	Oatmeal		1	1	1
	Whole wheat pasta		1	1	1
Egg	Chicken eggs		0	0	0
Pulses	Lentils		3	3	1
	Chick peas		3	3	1
	Other beans and peas	White beans, brown beans, marrowfat peas, green peas	3, 3, 3, 3	3, 3, 3, 3	3, 3, 4, 3
Nuts & seeds	Seeds	Pumpkin, sesame, linseed, sunflower	3, 3, 3, 3	3, 3, 3, 3	4, 4, 4, 4
	Walnuts		3	3	1
	Peanuts		3	3	1
Milk & products	Skimmed milk		0	0	0
	Semi-skimmed milk		0	0	0
	Fermented milk products	Buttermilk, Low-fat yoghurt	0, 0	0, 1	0, 1
Cheese	Fresh cow's milk cheeses	Cottage cheese, Low-fat fresh cheese, Mozzarella	0, 0, 1	0, 1, 1	1, 0, 1
	Rambol		1	4	4
	Fresh goat's cheese		1	0	0
Fats and oils	Low-fat margarine		0	3	1
	Liquid margarine		3	3	4
	Soybean oil		4	4	4
Drinks	Tap water		0	0	0
	Tea		3	3	3
	Coffee		2	2	2
Fish & Meat	EXCLUDED				

Circular Diet

Celery	Garden Peas
Kale	Lentils
Onions	Chick peas
Leek	White beans
Radish	Brown beans
Carrot	Marrowfat peas
Beets	Green peas
Celeriac	Pumpkin seeds
Endive	Sesame seeds
Lettuces	Linseed seeds
Purslane	Sunflower seeds
Red Cabbage	Walnuts
White Cabbage	Peanuts
Green Cabbage	Chicken eggs
Savoy Cabbage	(Semi)skimmed Milk
Turnip	Low fat Yogurt
Tomato	Low-fat fresh cheese
Cucumber	Buttermilk
Pear	Cottage cheese
Apple	Fresh goat's cheese
Whole wheat bread	Low-fat margarine
Patatoes	Liquid margarine
Tap Water	Tea

Origin	Location
0	Netherlands
1	Europe
2	Inter-continental
3	Unclear
4	Unavailable

Moreover a study of DWF adherent diets concluded that with meat exclusion and the selection of low GHG emission products, the environmental impact in GHG emissions can be reduced by one third. Moreover, a selection of low emission foods from the DWF is presented. In this sense, one local store of LIDL, Albert Heijn and JUMBO supermarket chains in Delft were visited and tested according to these ingredients and the vegetarian condition.

In this sense, the products were evaluated by origin as, unclear, national, European or international. Some products were evaluated as unavailable. Consequently, from that list, with less environmental impact a smaller local selection was established, sufficient to provoke thought and challenge in the student. In addition, it establishes a circular Dutch diet, as basis for the task experiment and biomass set for computational developments.

Table. 0 - Circular Diet: Local Product Analysis

Preparation: Subject

In order to meet the local, time and budget constraints, the focus was set on Dutch students of the same master track (building technology). In this sense, essential is the ability to perform biomass related subsistence practices, therefore there is no necessity for clear target specifications. In this case, the subject recorded is male, 25 years old from Tilburg. He likes Mediterranean, as well as Thai food. Therefore the ingredients chosen for his Thai recipe:

1 Onion, 1 Leek, 1 Carrot, 1 White Cabbage, 4 Eggs, 10 Potatoes, 1 Sesame pack.

The task was a meal for four persons with a minimum use of six ingredients from the list complemented with own spices and seasonings. The subject's ingredient choices were collected before, so that these were previously bought and brought to the experiment. Consequently, the overall duration of the experiment was bounded to approximately 1 hour and half. Prior, the experiments task was explained and the ingredients selected by the volunteer, which was also asked to sign a consent form.

Fig. 36 - Experiment: subject in own kitchen

Preparation: Set-Up

For the student experiment i decided to contact a friend cameraman to support and aid to set up the student experiment with two additional cameras. Therefore, the documentation task was separated from the observation. In this sense, prior meeting with the cameraman was required to provide contextual understanding and clarify the experiments documentation targets. The cameras were also tested for batteries and memory space. The set up possibilities were as well discussed before based on photos of the kitchen and the available supplementary equipment.

Before the subject starts the practice, information and clarification time is required. Also, so that the subject can acclimatize to the unfamiliar camera set-up, in order to document the situation as natural as possible. In this sense, the uncalculated externalities as music, conversations and events during the performance were included in the documentation as part of the natural practice environment.

During execution casual communications occur, while the designer observes and documents. Sketches and written notes can capture the sequence of actions, the ingredients, the components and tools involved, as well as general insights and conclusions. In this way, the practice process information can be retrieved for later analysis by means of human and machine perspective.

Fig. 37 to 39 - Experiment: All video equipment and perspectives

Procedure: Observation & Documentation Step 0

In order to document the practice performance, the camera set up was decided on time in the day of the experiment. Accordingly, camera one was fixed above the sink on the window. The wide angle allowed to record from a bird eye view. So that, the electrical heater is on the left, the movement area is in front and the additional preparation counters on the right with the fridge and direct view to the long dining table. The second camera was set up with a tripod at the height of the counters, so that a side view over the process and environment was captured. However, this perspective focused more on the relation between the division and cleaning area, hence capturing the sink in use from behind. The end of heat area was still captured so that all resource points can be correlated. In addition, as main record and extraction method the head-set-camera was used, which enables a clear image of the practice execution, in relation to tools and ingredients, as well as which component parts are used.

Finally, this camera set-up allowed deconstructing and categorizing the subsistence practice. Various actions are related to the displacement and introduction of tools and ingredients, which was categorized under "get". This occurs in various component areas of the kitchen. Others are more specific applied and bounded to one particular location, as divide and clean. In this sense, this is related to the resource or social constrain of the situational practice.

The cleaning processes are determined by water access, in dependence of the sink component. On the other hand, biomass divisions are established in the middle counter directed towards the dining table, in dependence of social attractions. The video documentation allows to list and visualize relations of actions, the resource nexus, objects and the movements of the performance.

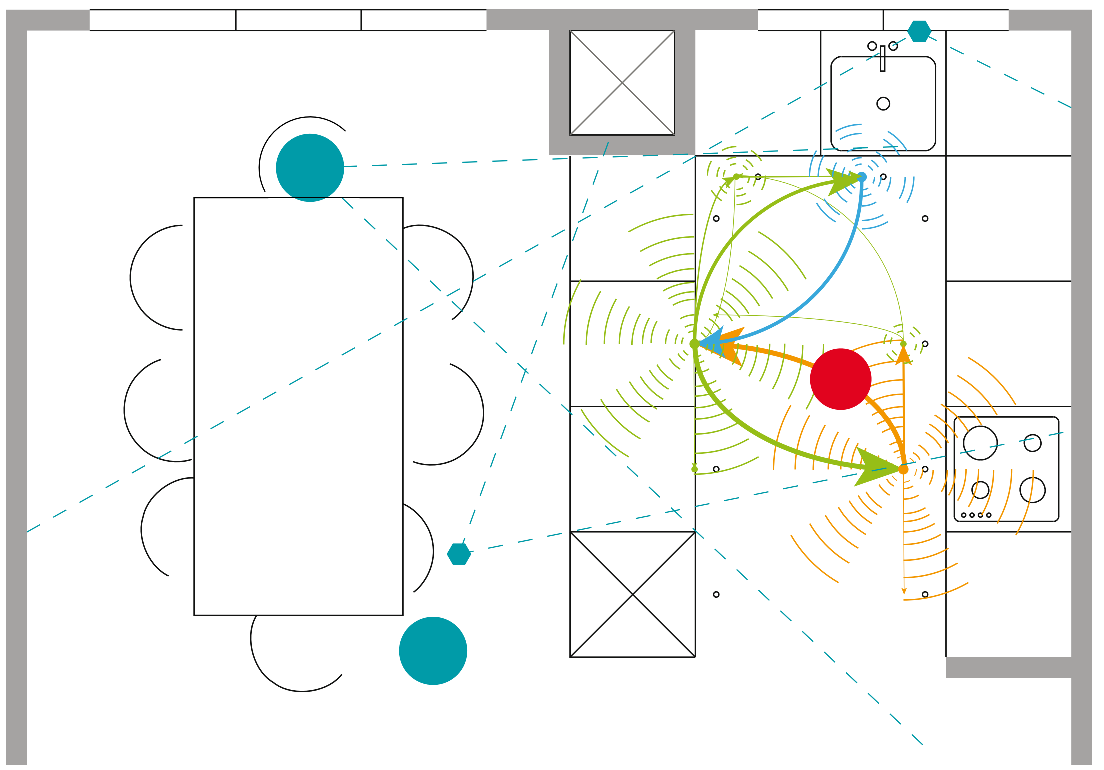
Circular Agents

Designer
Cameraman

Water

Biomass

Energy



A0 Get	**A10 Get**	A20 Clean	A30 Mix
A1 Sharpen	**A11 Divide**	A21 Divide	A31 Divide
A2 Get	**A13 Dispose**	A22 Clean	A32 Mix
A3 Clean	**A13 Clean**	A23 Divide	A33 Get
A4 Divide	A14 Divide	A24 Take out	A34 Mix
A5 Heat up	A15 Clean	A25 Get	A35 Get
A6 Break	A16 Divide	A26 Get	A36 Mix
A7 Get	A17 Get	A27 Mix	A37 Take out
A8 Mix	A18 Divide	A28 Dispose	A38 Serve
A9 Mix	A19 Dispose	A29 Get	

Fig. 30 - Experiment: Set-up, movement & action analysis

Analysis: Practice deconstruction
Step 1

The documentation and observation list and visualizations of the subsistence practice can then be deconstructed further into a network in the sense of POD and ANT. Therefore, for each listed action the quantity and name of the objects are extracted through digital review of the video-record. In this sense, for each action a network between the subject and the objects can be established. This can be documented manually or digitally with excel or python. In this case the documentation was manual, so that the video could constantly be kept on the screen. Afterwards, the necessary data was visualized with Adobe Illustrator. Conclusively, the deconstruction and visualization helps to communicate the abstract idea of practice networks.

Analysis: Circular 3 Levels
Step 2

The POD deconstruction and visualization is followed by the analysis according to the three levels of circular building and product development in correlation with the circular design framework strategies. This assessment aims first to establish a further perspective over the documented practice and provide insights on how design components can possibly contribute for a more circular practice. Therefore, this step doesn't aim for absolute results.

Similarly, each action was evaluated in search of possibilities to reduce resource waste and user inconvenience. Moreover, the relation to reuse and recycle actions is evaluated. For example, the fact that the knife is sharpened reflects maintenance behaviour or the disposal of biomass into a separate bin reflects the separation practice. However, it is difficult to know to what extend the subject is biased by the experiment context itself. Finally, this assessment provides a general perspective over the level of circularity in the practice observation and this is summarized into conclusions, as goals for the circular design.

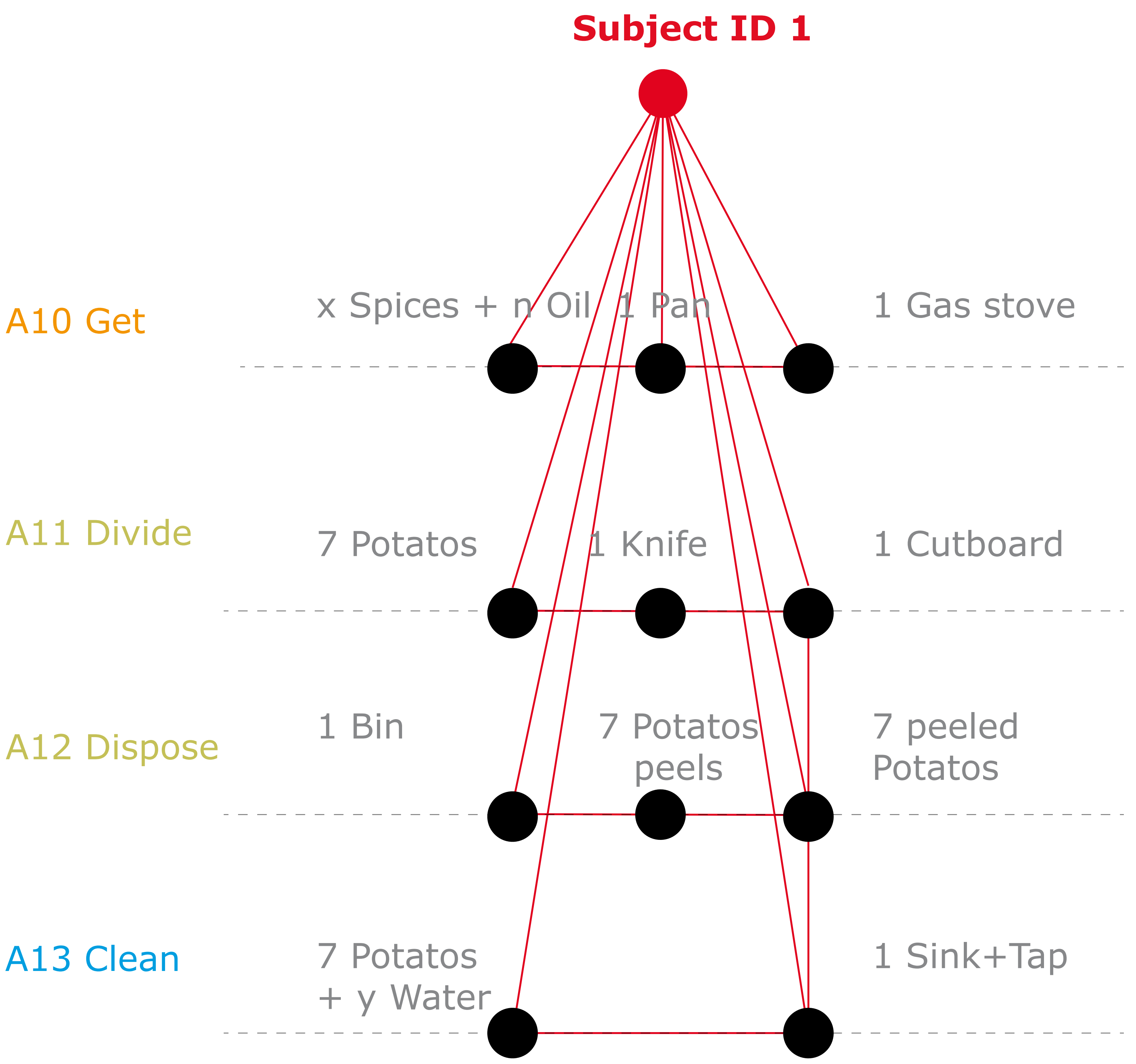


Fig. 41 - Step 1 : Practice Deconstruction of A10 to A13

Water

Biomass

Energy

I Reduce —

II Reuse +

III Recycle

3 Pillars of Circular Design

5 Circular Design Strategies Framework

	I Reduce	II Reuse	III Recycle
A10 Get	2. Long distance		
A11 Divide	2. 2 cutboards on counter Measure inconvenience	5. Resharp knife	
A12 Dispose	2. Long distance Manual effort	1. Separation of bio-waste	1. No bio-waste recycling system
A13 Clean	2. Long distance Cutboard - Sink	3. No separation or direct reuse	3. No recycling system

1. Circular Supplies

The biocycle principle "waste = food"

2. Resource Conservation

Systems awareness, Preventive loss of nutrients/materials, Full potential use

3. Multiple Cycles

Enable longer circulation of components

4. Systems Change

Sharing and Service Systems

5. Longer life use

Design for complex living systems

2. Convenience & short distances

1. 3. Integrate circular systems

Conclusions

Fig. 42 - Step 2 & 3 : Circular Analysis & Design Assessment: of A10 to A13

Analysis: Circular Design Strategies
Step 3

Afterwards, with circular design goals from the analyzed and deconstructed practice, the appropriate circular design strategy is searched for. In this sense, the five strategies framework introduces further guidelines to complement the design goals. The reduction of distances and user inconveniences is correlated to resource conservation strategies and the integration of reuse and recycle systems is correlated to resource conservation, circular supplies and multiple cycles. The other strategies are integrated into the design process on building and urban scale.

Circular Design Target
Step 4

This step takes the analysed circular goals with correlated and reinforced circular design strategies into an overall target. This is set to aim for durability and create an emotional communication and relationship with the users. Moreover, four main milestones are set as priority to be accomplished in the design.

In first priority was set the implementation of reuse and recycle systems for the water, biomass and energy flow of the kitchen. In second priority the communicative character of the design is set to target minimalism and the display of synergies, so that reduction and transparency is transmitted to the user by design. The first two goals are the main with regard to the socio-technical context. Complementary, for third priority the modularity and disassembly of the technical systems is set as goal. Therefore, this target includes largely the system connections, hence the detail scale. In addition to that, the fourth design priority is set to aim for the expansion of the design product into a wider product-service-system, considering therefore supporting durability and use of the product during lifecycle.All together the four

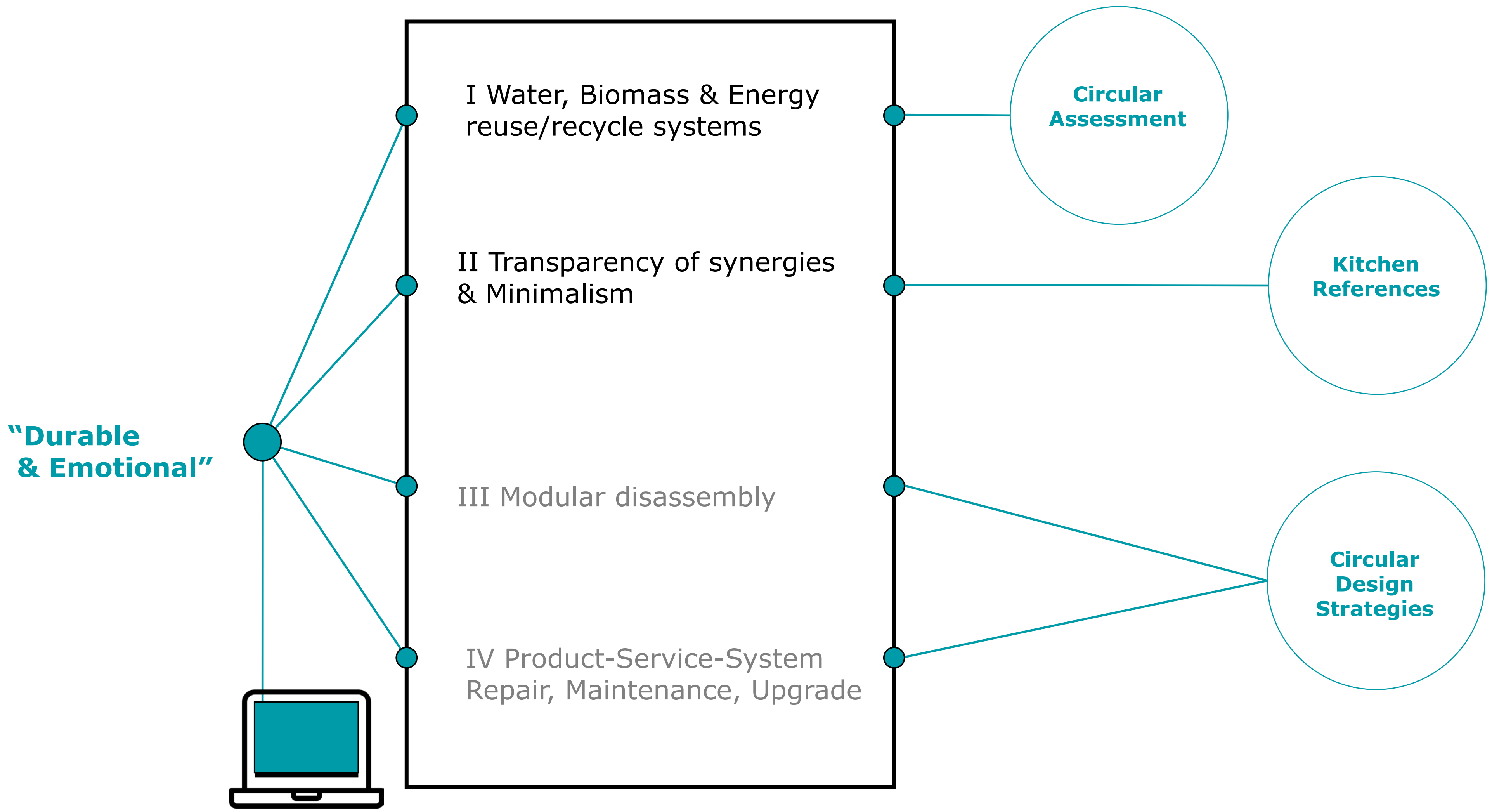


Fig.43 - Step 4 : Circular design target development diagram

Computational OOP Reconstruction
Step 5

Afterwards, the deconstructed resource objects of each action of the practice experiment are reconstructed computationally into a network, considering the hierarchy of the classes, from human, component, tool to ingredient over time. Each class is correlated with an axis and is weighted according to the rank. In this case, the reconstruction was exemplified with Adobe Illustrator; however the process can technically be automated with OOP.

In the context of the kitchen, with the variety and complexity of recipes and cultural subsistence practices, this is a method to represent and compare the complex relation between objects and practice. This also applies to the domestic space, allowing a domestic resource inventory and visualizing it as network ecology.

For the design this aids to understand the time and relational position of possible circular component introductions in the network. This can be further analysed computationally with the definition of ergonomic parameters.

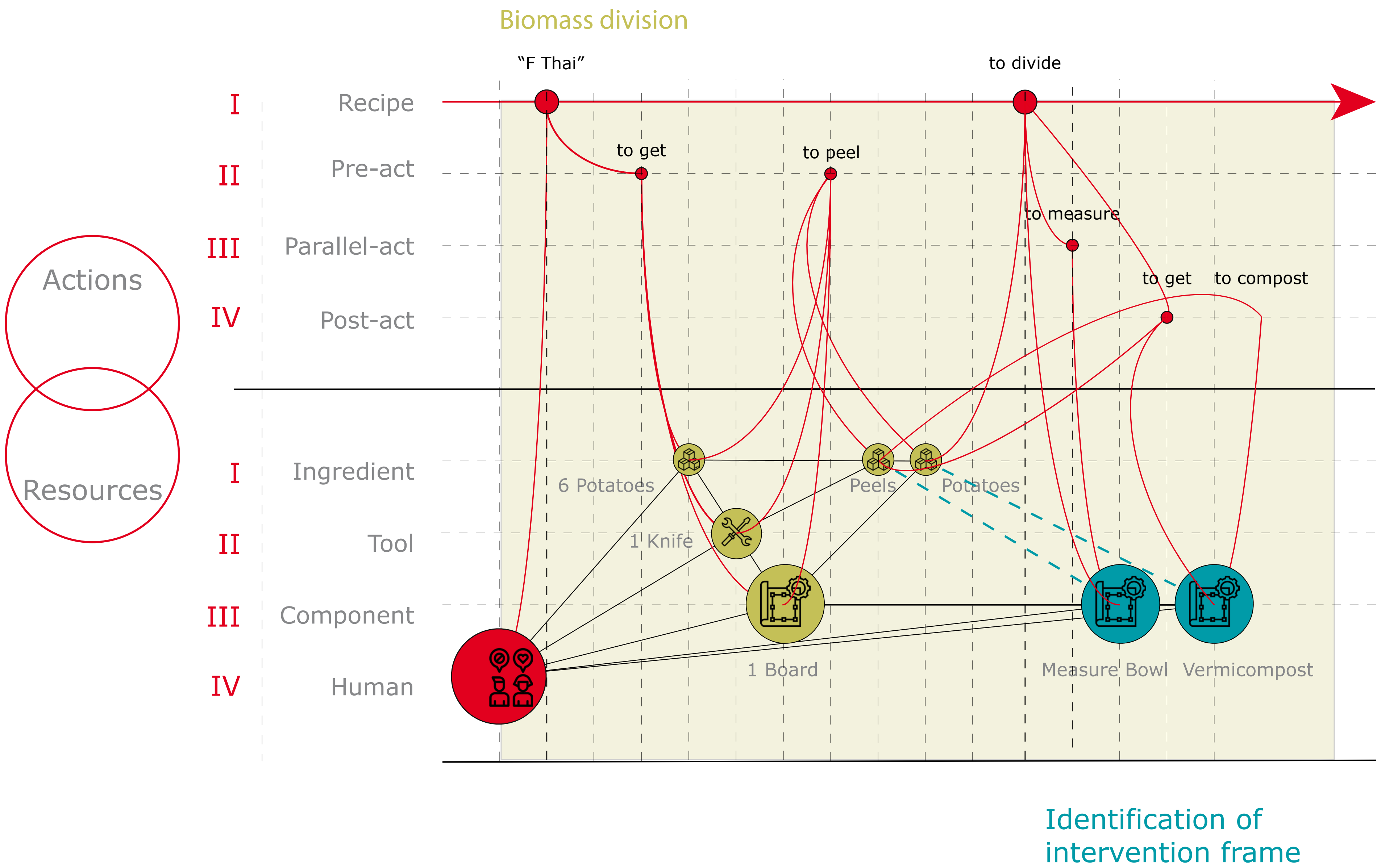


Fig. 44 - Step 5 : Action-Resource network: computational reconstruction of biomass division in experiment

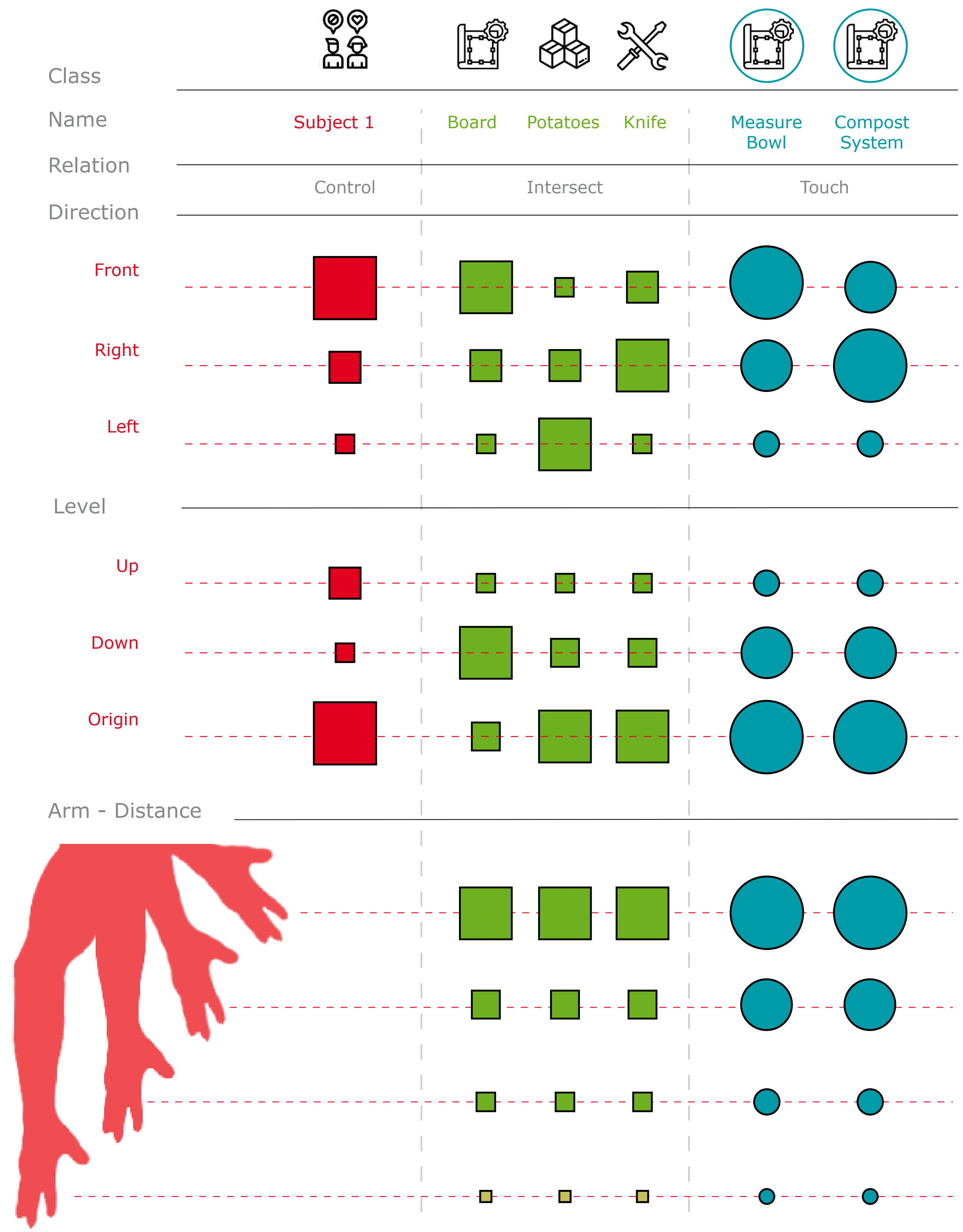
Computational OOP ergonomic analysis Step 6

In addition, to the practice oriented design and circular design analysis, is further complemented with ergonomic computational analysis parameters to determine the position of circular components.

The development of computational code started manually with overall trial and error of pseudo-coding, as well as parallel acquirement of skills by means of video tutorials. Consequently, the development of the logics to position and design circular coded components is regarded as an open process.

In order to reduce distances and inconveniences, as well as introduce parameters to position circular components and the object hierarchies of the practice in space, basic ergonomic parameters were introduced to analyse further the actions. In this sense, given the time constrains, each object class has an index, an identification name, a resource relation, a direction, level and arm-distance variable to define its position. Accordingly, a parameter can require the input of hierarchical preferences of the available options. For example the general direction of the subject is prioritized to the front first, to the right secondly and thirdly to the left. More variables can be introduced, although that increases complexity as well as time investment.

In this way an ergonomic preference set up is defined for the design of the kitchen. Moreover, this allows further defining the possible positions of circular components in relation to the objects and user of the action. In this sense, the performance area is regarded as a field of points occupied by the object geometries.



Ergonomics of practice objects

+

2 Component Circular Code

=

Convenient position of CC components

Fig. 45 - Step 6 : Considered ergonomic parameters for the position of practice objects

Application: Design case study

In order to contextualize the approach in an application, a rooftop farm in Rotterdam was visited, the plans were obtained and digitally reconstructed. The rooftop building is situated near the central station. Since 2012, as a test site the rooftop was converted into rooftop farm the "DakAkker".

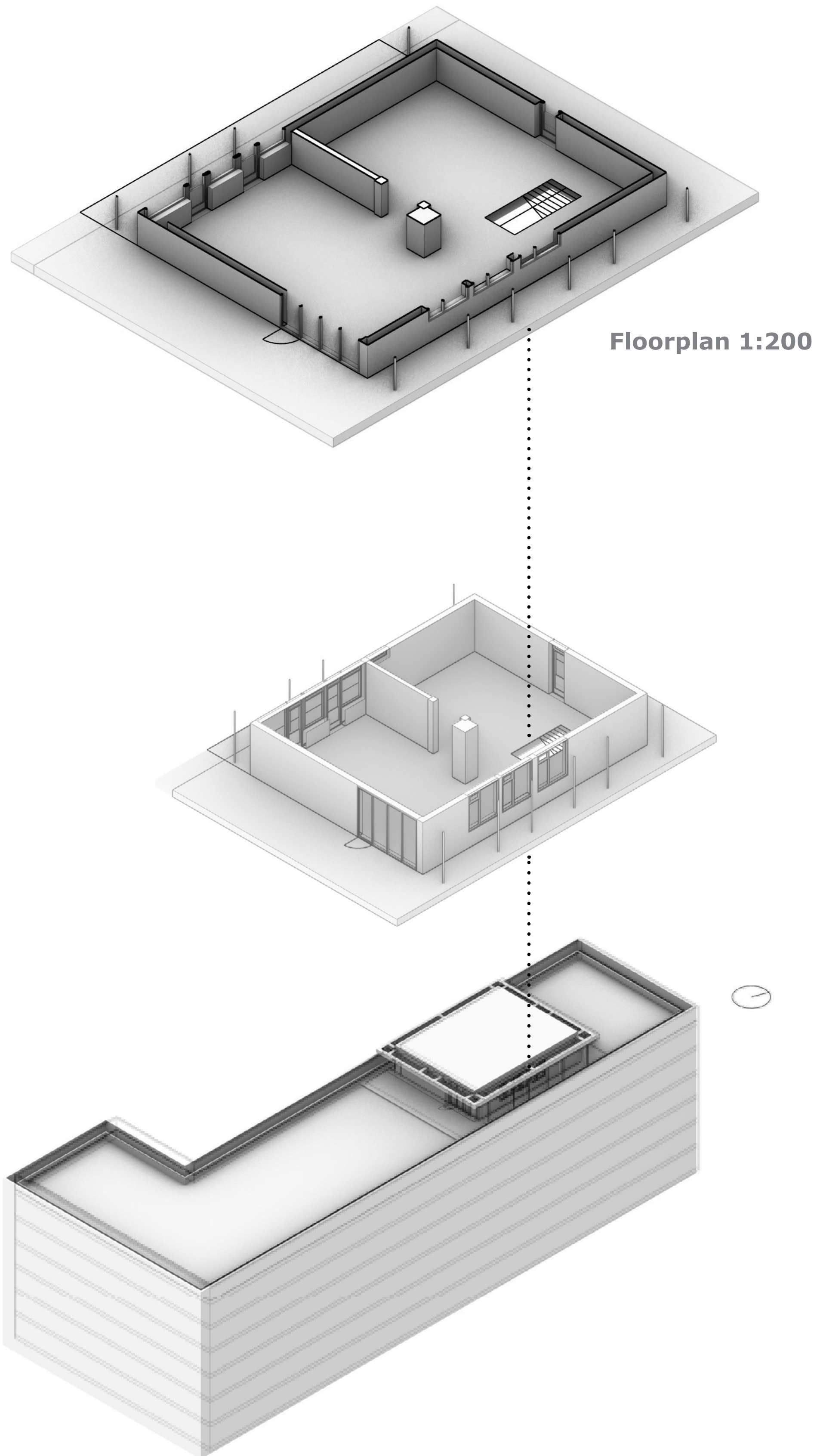
Here, bee-hives are kept edible flowers, herbs, fruits and vegetables are grown and sold to different restaurants. The Binder Groenprojecten created the project developed by ZUS in collaboration with Rotterdams Milieucentrum. The farm is run on the basis of volunteers. Every Friday circa 10 people come up to the rooftop to help in the farm. For the volunteers it's a way to escape the urban rhythms. The location is close by and familiar to me, as a par-time volunteer. Therefore, this location was chosen as it suits the time and budget constraints as well as the urban circularity context.

Currently the rooftop-building is separately run from the rooftop-farm. The space inside the building is rented out to the café "Op Het Dak". Their model is profit driven. Currently the café does not collaborate very well with the farm and sometimes during crowded events damages to the farm occur. Possibly the café would wish to extend its use hence profit into the area currently used by the farm.

In this sense, it is interesting to speculate on the possibility of the owner deciding to support the farm and no longer rent out the space to the café. In this speculative scenario, the owner seeks to support sustainable urban development, therefore rent the space in collaboration with the farm.

In this context, as test site I propose to establish a circular collaborative domestic maker space, which would aid the farm to develop further in synergy. The space will provide private rooms for three persons, as well as shared hygiene facilities. The kitchen and the maker areas will be semi public, where farm volunteers and visitors can walk through during open hours. This will as well enable the experience of an alternative circular way of living and working to the outside.

Fig. 46 & 47 - Dakakker, urban rooftop farm near Rotterdam Central: northwest and southwest perspectives

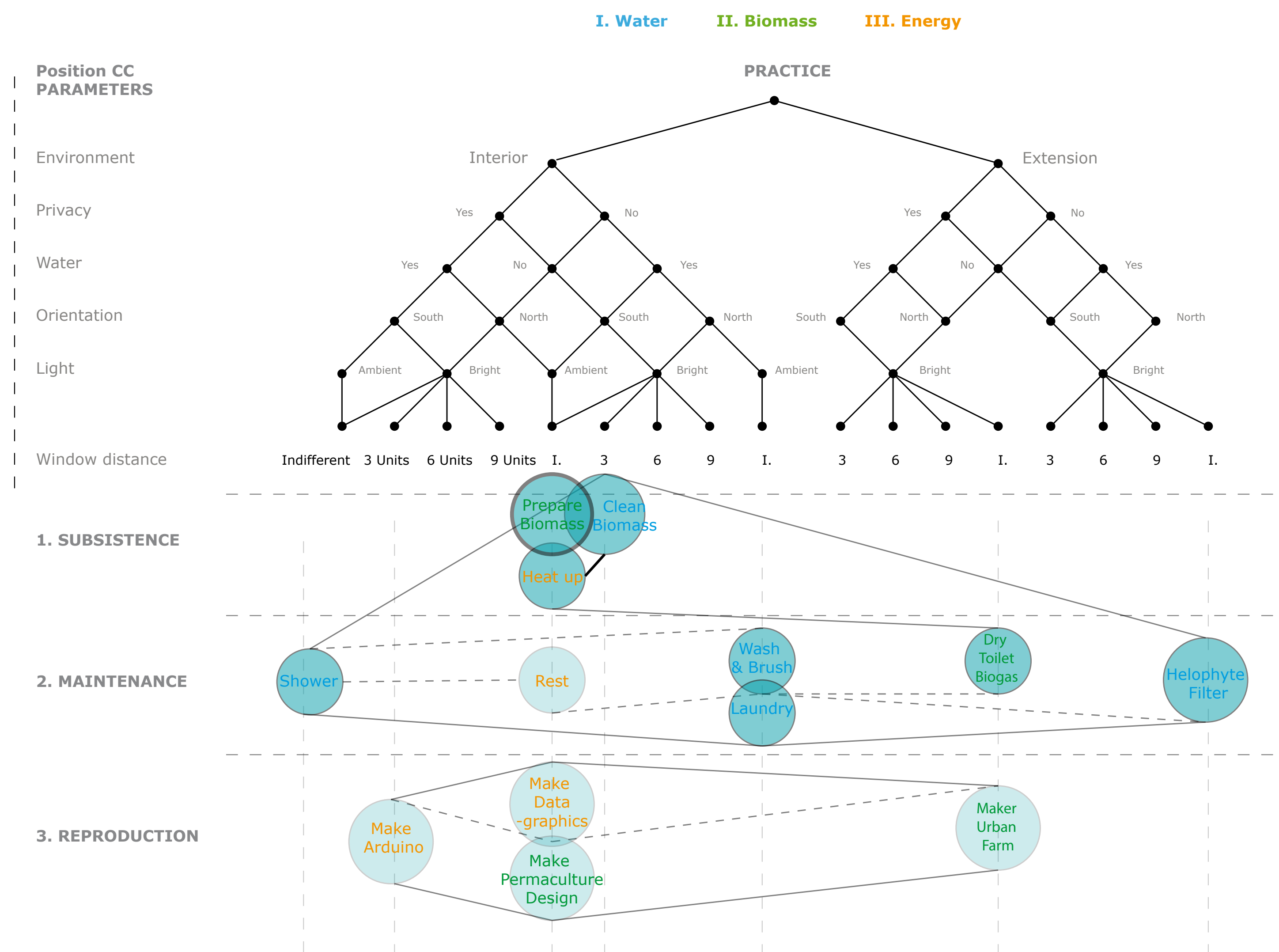


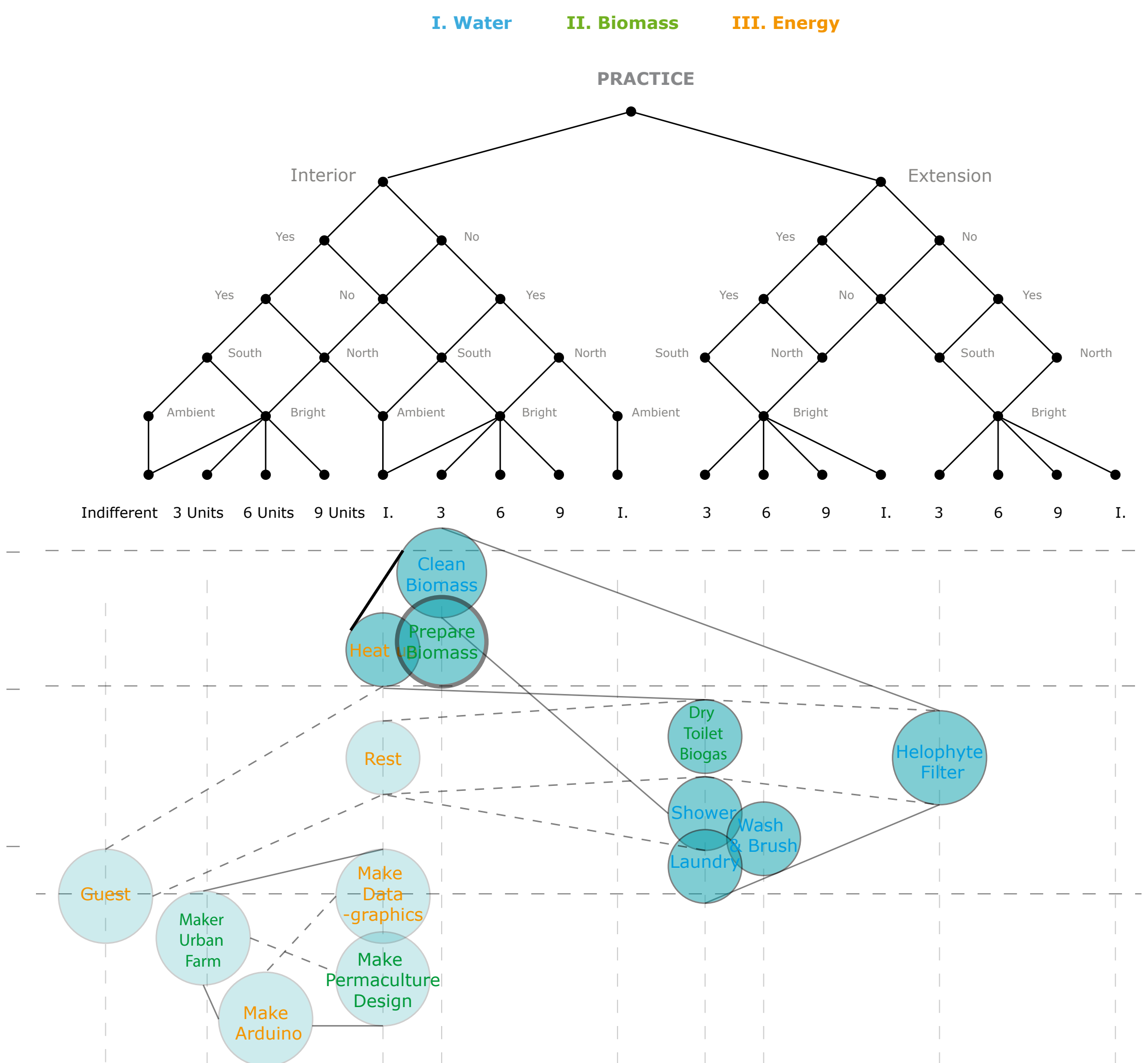
For that purpose, the rooftop building was reconstructed based on field measurements and acquired floor plan.

Firstly, the circulation area is divided into an over-all grid of points, on a 30 cm unit. Accordingly, subsets of points are defined for different physical parameters. In this case, the type of environment, water range, type of natural light and window distances. These represent physical boundary conditions, resource access, temperature and airflow. Therefore, the point subsets describe positions of component clusters, according to various physical conditions.

This requires designers to master parametric thinking in playful combination with creativ-ity. In a hierarchical tree diagram, the designer establishes for each component possible physi-cal scenarios. Consequently, design variations are rationalized and can be compared. For the given time and contextual constrain, these parameters were sufficiently accurate to generate floor plan variations as proof of concept.

Fig. 48 - Dakakker building 3D reconstruction
Fig. 49 - Point-field divisions of floorplan

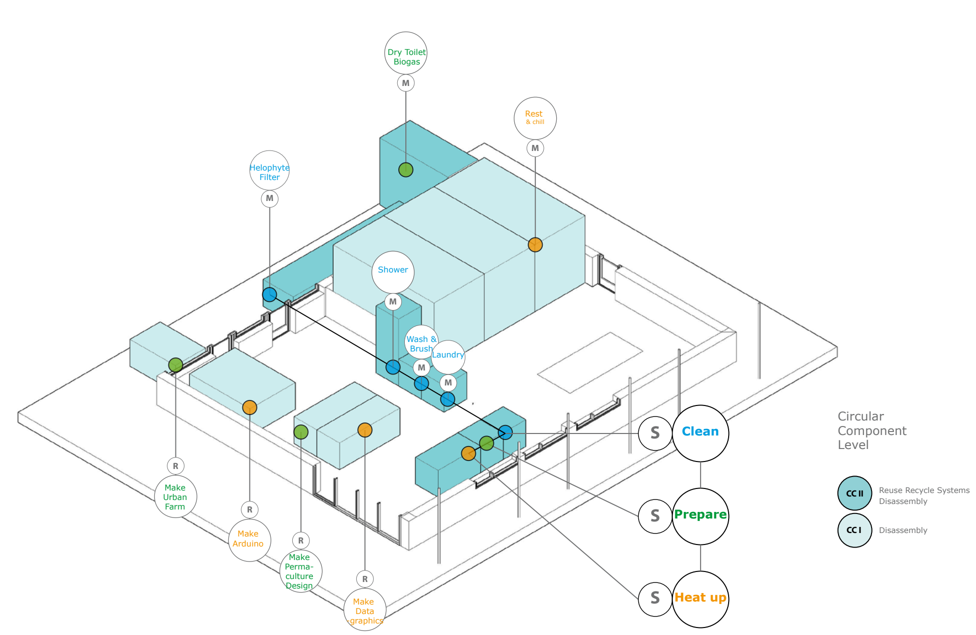




The tree diagram entailing the physical parameters and possible combinations is over-crossed with the computational domestic action framework *(see p. 52).*

Moreover, the designer develops and clusters circular coded components, including principles of circularity. In function of the integrated principles, clusters are categorized and can be compared by levels of circularity.

Therefore, physical attributes of circular clusters are correlated to social action subsets. Each variation outputs a different visual network, representing a different floor plan. In this way, variations generate different domestic action dynamics and influence towards circular lifestyles.



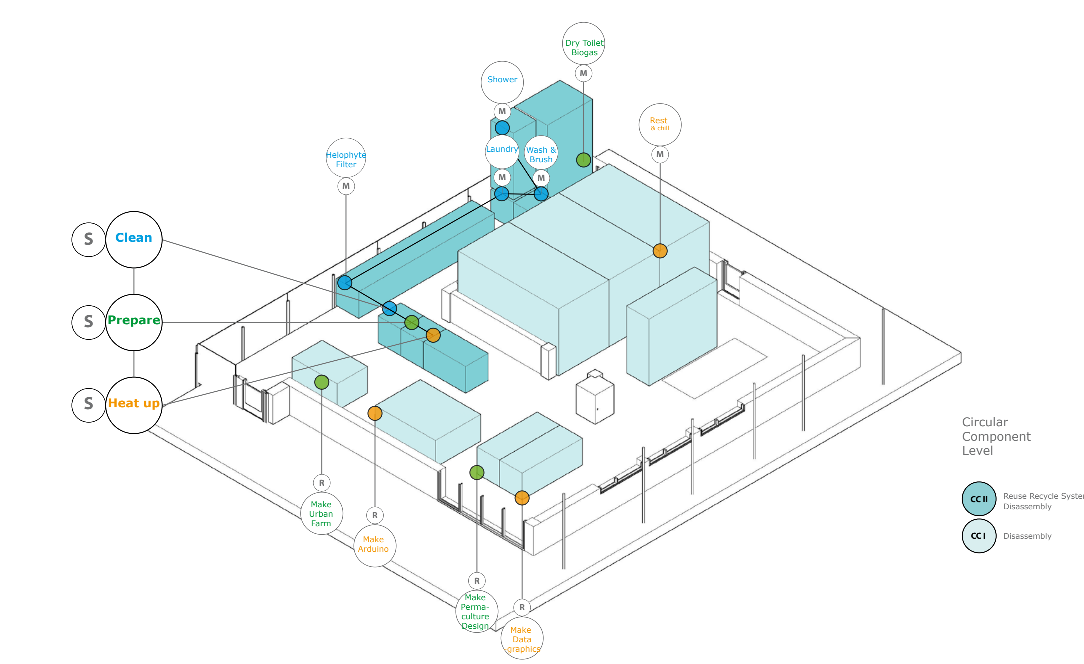


Fig. 50 & 51 - Floorplan generation - Parametric system to position components of practices: variation F0 + F1 (In detial in appendix)

Parametric Development: Subsistence Main-system Step 7

According to the focus on subsistence, the respective computational framework (see p. 54) and the experiment results, the three action subsets relate to cleaning, preparing and heating up. Additionally, these are enabled by store actions. Consequently, the categorization of the required circular component systems is divided into four types.

Store Systems: These assist in the conservation and organization of resources, as the tools and ingredients required. Their position is depended on the location of its practical application in the network.

Clean Systems: These are water depended and enable the maintenance of tool and ingredient hygienic quality. In addition, these systems are vital, as access point for water as a preparation and heating ingredient.

Prepare Systems: These include various forms of preparation components, as the division board, mixing or measure bowls. This subset is the dynamic core and connector of resources.

Heat-up Systems: These are different types of heat preparation, as extension and complement to prior actions. Accordingly, these finalize the preparation and establish the passage to consumption.

All systems can integrate and share circular principles and sub-systems, in order to promote particular actions, as compost, biogas or reuse separating.

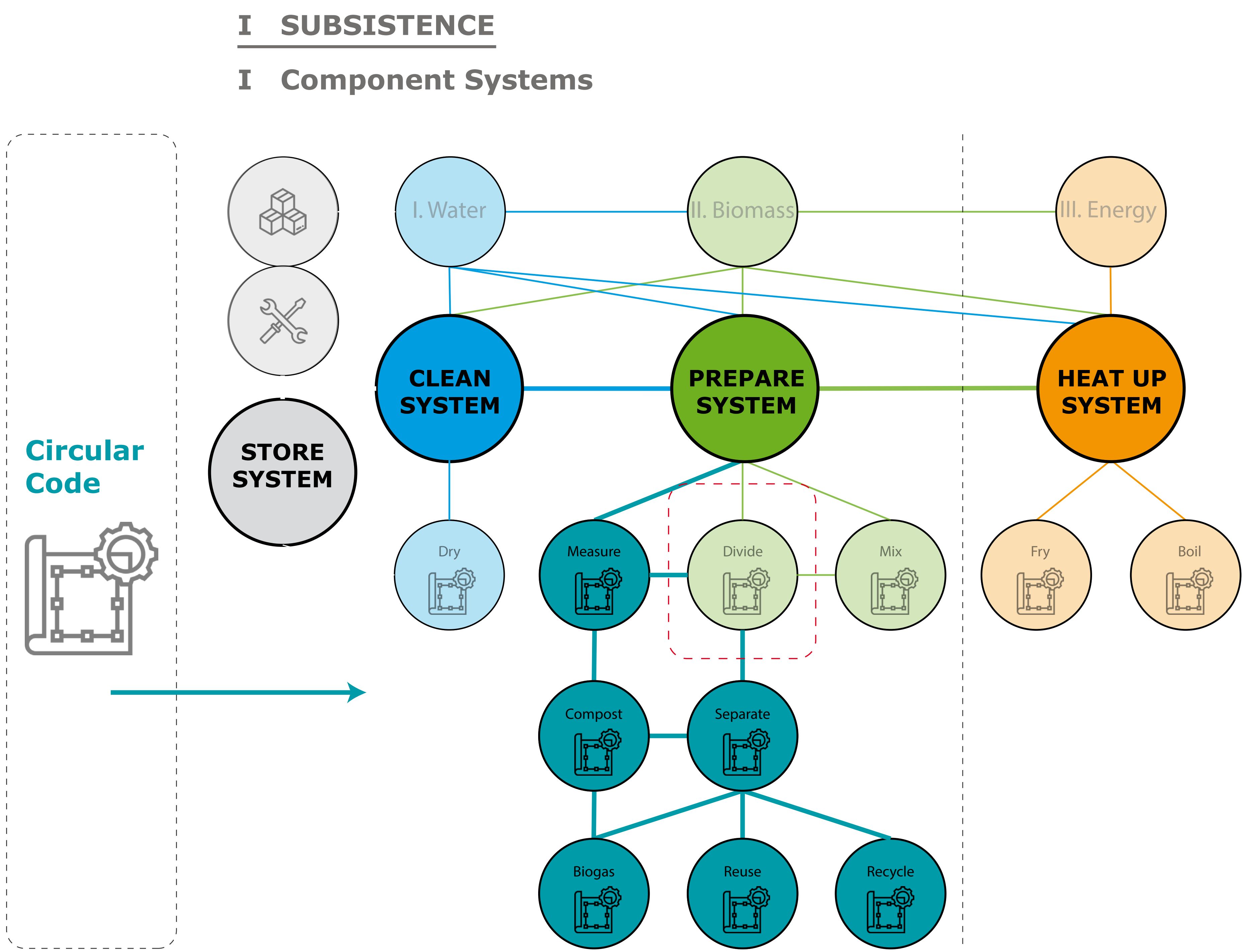


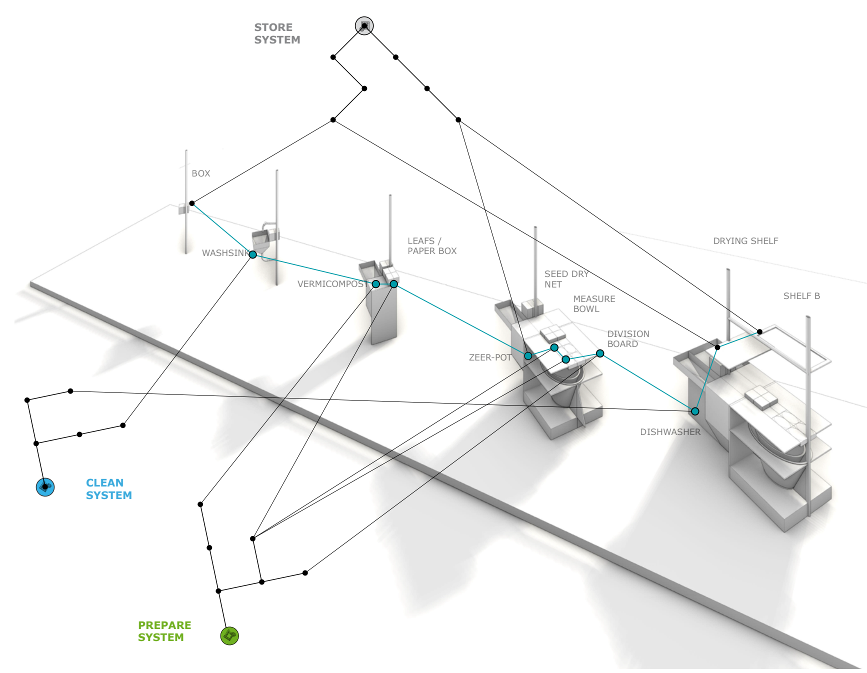
Fig. 52 - Step 7: Level I actions correlated with component systems, including circular coded sub-system interventions.

Parametric Development: Subsistence Sub-system Step 7

Accordingly, component systems are a class type of parametric objects. Consequently, each system is a combination of different objects, as sub-systems. These are defined by fixed variables or instances representing physical requirements. In this case temperature, light, airflow and operation are defined to provide enough possibilities for the given time. However, additional parameters can be defined to increase variety and requirement accuracy. As before, the parametric definition is represented by a tree-diagram.

Each designed object of the component class is correlated to other particular objects of tool and ingredient classes. Therefore, components are connected to particular practice networks, as researched and observed. For that reason, data retrieved from the experiments documentation and analyses is integrated into the design.

The tool class objects are categorized by type, resource relation and unit quantity. Moreover, these objects can be clustered into sets enablers of particular action sets. The ingredient class objects have the same basis parameters as tools. However, as biomass nutrients these demand additional physical conservation conditions. Therefore, ingredients include as components temperature, light and airflow variables.



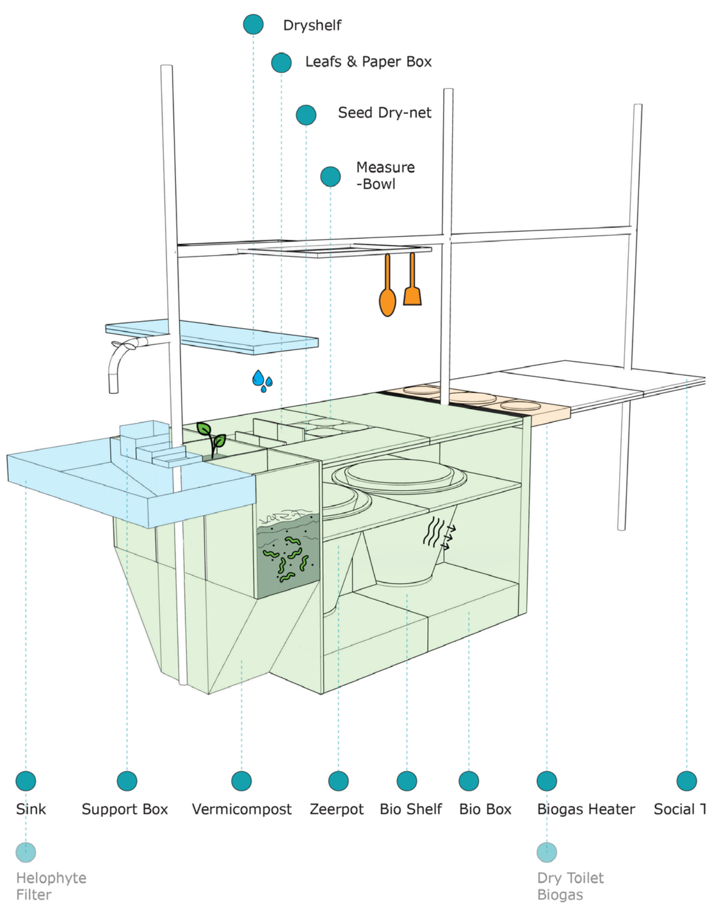
Consequently, used tools and ingredients in the subject experiment are grouped as conditional subsets of the design. Each systems conditional subset is established from certain cultural practice networks. The required physical conditions are than correlated to CC component system geometries with a fixed performance.

Conclusively, in this way possible design clusters are constrained. In addition, this allows organizing circular kitchen clusters through defined relations, between social and technical resource parameters.

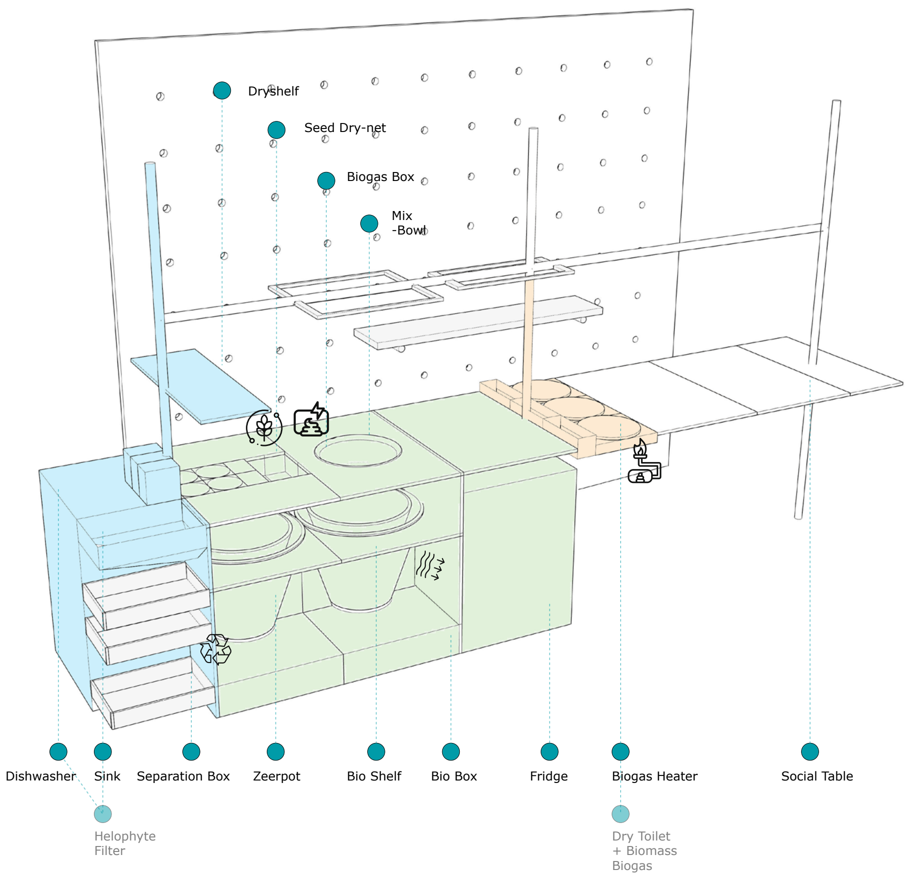
Fig. 53 - Step 7: Parametric logic from main to sub-system components, including tool and ingredient property correlation.
Fig. 54 - Development of design variation: application example of step 7

RESULTS

In this domestic maker-space the kitchen is located in the centre, between reproduction and maintenance components. The encounter point enables fluent flow of actors, closely connected to water access and related maintenance components, as laundry, shower, washing and helophyte. These establish one line in the winter garden, as west extension connected to the kitchen. Here, visible helophytes filters clean the grey water and human excretes are reused through a dry-toilet connected to the bio-digester system. In the south, the urban farm access with workbench and storage to support the weekly workflow of the Dakakker volunteers. In the northwest, rest and chill clusters provide all circular makers with required private sphere. The semi-public space forms a landscape composed of the circular kitchen and personalized maker components. In addition to the urban farming set up, three additional maker fields were defined in the speculative scenario. So that, work is balanced in terms of the two resource cycles, an arduino programmer and a data graphic visualize share the environment with a permaculture designer and the weekly volunteers (see p.90). In this environment, synergies emerge naturally between actors, as visual, olfactory and acoustic communication occurs without boundaries. Therefore, collaboration between bio and technical cycles is supported. The actors, who rent the place, are as the landlord interested in sustainable practices. Therefore, social domestic actions are complemented by CC systems. In cooperation with the right CC systems, the circularity level of the living system can be further improved.



K0



K1

Cost	*less expensive*	*more expensive*
Material cost	*smaller = less material objects*	*larger = more material objects*
Energy demand	*no electrical appliances*	*2 electrical appliances*
Reuse/Recycle	*vermicompost*	*biogas box*
Lifestyle rigor	*advanced circular lifestyle*	*intermediate circular lifestyle*
Collaboration	*less execution area*	*more execution area*

Fig. 55 - Simplified socio-technical comparison of design variations: K0 and K1

Circular Collaborative Kitchen

This is the result of particular practices, understood as a cluster of actions configured by required physical resources, as objects of space. Afterwards, analyzed in relation to the pillars of circularity: reduce, reuse, recycle and the three levels of circular building and product development (CBPD). Afterwards, correlated to the five strategies of the circular design framework (CD). In parallel, sketches and programm exercises aided to achieve clarity and design ideas. These were then parameterized manually, translated into a digital Rhino-Grasshopper-Python software workflow. This clustered product is the result of the tool, representing circular codes (CC).

The circular kitchen is an ecosystem between the technical, biological and social cycles of action. Increment of the dynamic network, the CC component cluster is adaptable to the extension of practices. The open island concept increases the communication between actors and supports collaborative subsistence practices. In addition to that, the cluster integrates reuse and recycles systems, described via computational logics and parameters. The biogas bowl enables the reuse of food waste into valuable cooking gas and nutrients for the farm. Complementary, a technical modular system for disassembly enables experiment, exchange, repair and reuse of components and parts.Conclusively, the design in its nature invites try-out, in order to induce new and reshape old daily habits, so that domestic behavior shifts are supported with and for the surrounding environment, by CC.

Fig. 56 - Rendered perspective of the circular kitchen (K1) in the circular collaborative Dakakker (F1)

Circular Collaborative DakAkker

In this domestic maker-space the kitchen is located in the center, between reproduction and maintenance components. The encounter point enables fluent flow of actors. In addition, closely connected to water access and related maintenance components, as laundry, shower, washing and helophyte. These establish one line in the winter garden, as west extension connected to the kitchen. Here, visible helophytes filters clean the greywater and human excretes are reused through a dry-toilet connected to the bio-digester system. In the south, the urban farm access with workbench and storage to support the weekly workflow of the Dakakker volunteers. In the northwest, rest and chill clusters provide all circular makers with required private sphere. The semi-public space forms a landscape composed of the circular kitchen and personalized maker components. In addition to the urban farming set up, three additional maker fields were defined in the speculative scenario. So that, work is balanced in terms of the two resource cycles, an arduino programmer and a data graphic visualize share the environment with a permaculture designer and the weekly volunteers (see p.90). In this environment, synergies emerge naturally between actors, as visual, olfactory and acoustic communication occur boundaryless. Therefore, collaboration between bio and technical cycles is supported. The actors, who rent the place, are as the landlord interested in sustainable practices. Therefore, social domestic actions are complemented by CC systems. In cooperation with the right CC systems, the circularity level of the living system can be further improved.

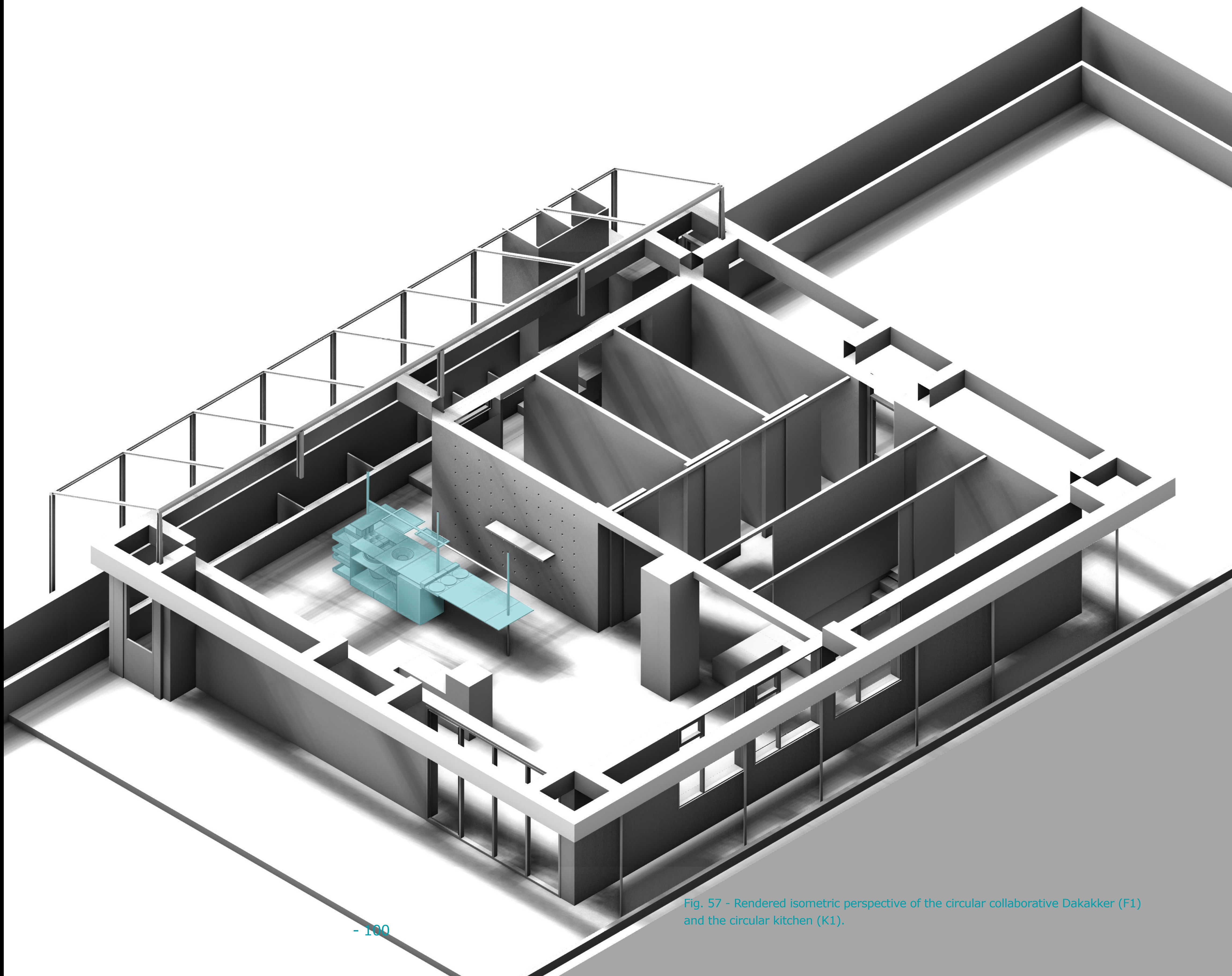


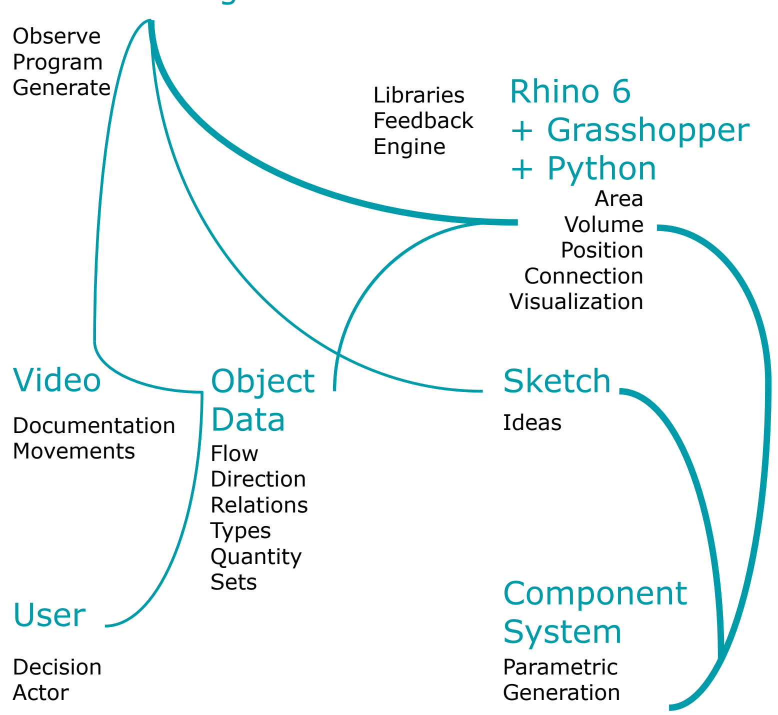
Fig. 57 - Rendered isometric perspective of the circular collaborative Dakakker (F1) and the circular kitchen (K1).

Circular Codes Methodology

Finally, the CC methodology is the main result of the open progress of this thesis. All the developed workflow, process and executed steps are summarized in this diagram. The idea of circular coded solutions, as blueprints to form a supportive eco-system for circularity by digital medium has potential. To actual implementation, there is still a long way to go.

Computational Workflow

Practice Designer



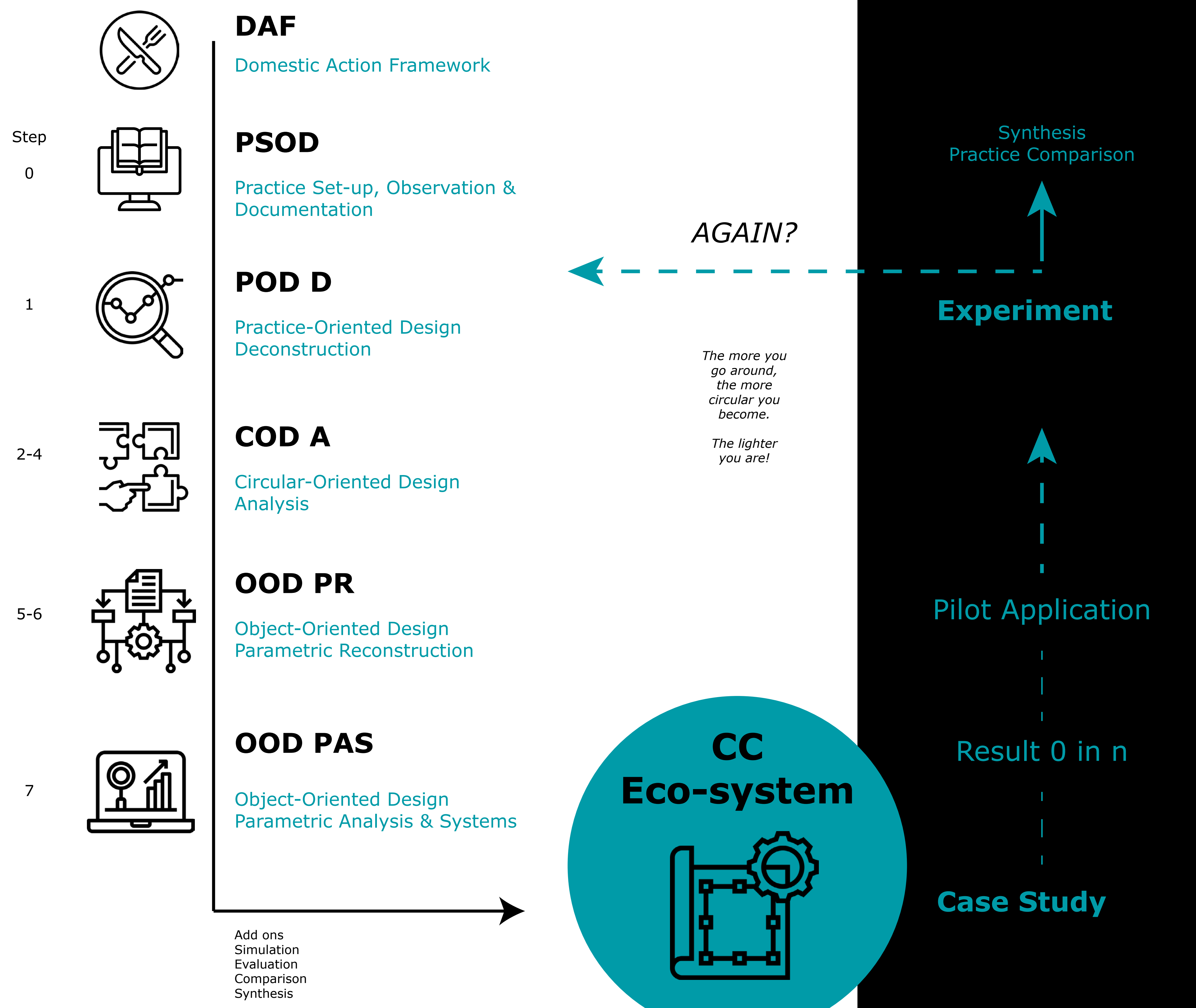


Fig. 58 - Circular Codes Methodology: procedure and workflow overview

DISCUSSION

This methodology, as the result of this thesis, presents a possibility to integrate and stimulate socio-cultural practices in the development of the built environment. The application lead to the development of circular component clusters, as architectural systems and enablers of domestic and subsistence practices according to the mathematical action framework. For that, an OOP parametric tool was developed and two variations presented as proof of concept. The main objective to explore, outline and develop an object-oriented programming tool to configure components of architecture systems was therefore successful.

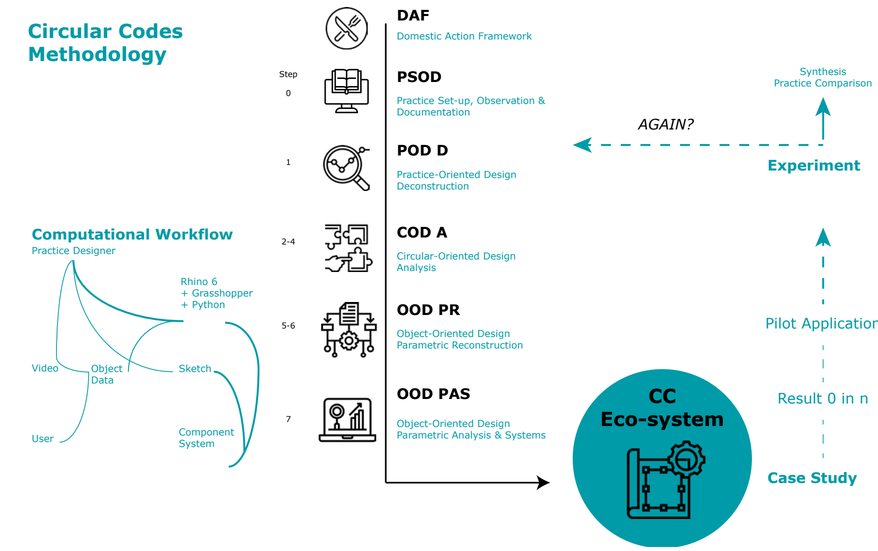
The first and third sub-question, regarding the OOP application state of the art is answered by the research review chapter "Programming in architectural design", in particular in the synthesis. The OOP systems have a wide range of potentials for the overall building industry. That is, from BIM for financial and project management, to urban analysis, design development, physical simulation, evaluation and optimization. In extension, for benefit of circularity, the complementary SOA method can allow implementation, use and maintenance support-services. The second sub-question is answered through the research of the remaining respective chapters and synthesis. The studied domestic design, frameworks of circular and practice design allowed to answer each element of the question and systematically interlock the solutions into an inclusive OOP method. The practice oriented analysis of video recorded experiments enables the translation to object-oriented programming including circular design principles. For that, the actor-network and practice theory was an essential abstraction framework to fundament this method.

How can object-oriented programming enable practice-oriented design for circular collaborative domestic environments?

1. What are object oriented programming applications in architectural design?

2. How can the principles of circularity be applied to object oriented programming in practice-oriented domestic design?

3. How expandable is this application for the built environment?



The domestic design application in the Dakakker case study enabled to contextualize, represent and further validate this methodology. The resulted collaborative kitchen varitation K0 and K1 supports circular biomass subsistence practices. These parametric alternatives enable and promote more circular lifestyles in the Dakkakker, therefore demonstrate a possible application. Although, acquirement of intitial clarity, skill and mind-set was still very slow, the main research question is answered with the developed and prescribed CC methodology. Conclusively, all research questions of this thesis are answered to a satisfactory degree for the given time, budged, social, psychological and situational factors. The initial motivation to provoke thought and change towards green citizenship remains. Change is complex and invisible. What we perceive here is maybe already an outdated starting-point. This work contributes to set in question our daily (micro)-actions, as well as the design and architecture practice.

Fig. 58 - Circular Codes Methodology: procedure and workflow overview

CONCLUSIONS

The process of living and designing a sustainable life can surely be accomplished without computational methods. However, given current world complexity and consumption aspirations, human and machine collaboration is a credible way to deal with global challenges, as social, economical and environmental sustainability.

In the built environment, OOP methodologies present powerful applications to support global creative development and industrial production. In this sense, this process and results present a small fraction of the wide potential of OOP methodologies for the implementation of circularity in the built environment. The integrative potential of code can include socio-technical factors, towards the regeneration of the current biological environment and circular economy transition.

For that, designers, architects, engineers are required to broaden their skills and perspectives over technology and their professional fields. However, as digital technology increases in application, users can over-saturate, therefore a balance between physical and digital practices is required.

Conclusively, for the development and implementation of sustainable and technological practices, work, living and educational practices have to be reframed in parallel constant collaboration.

RECOMMENDATIONS

In our field, this thesis provides an initial starting point to explore the OOP potential for circular profit. The actual implementation and OOP tool requires further skill for proper development and application. In general, further mutldisciplinary collaborative approaches to extend the methodology into an overall ecosystem process are recommended.

In particular, in order to carry this work further on the short-term, I recommend repeating this process several times. Additionally, the next step is to build a prototype of a selected design variation, document and analyze its use over a period. In parallel, BIM and service-systems can be developed too. In addition, the development of a library of parameterized circular systems into adaptable blueprints seems a useful long-term task. Afterwards, these designed ecosystems can systematically be introduced into the market. Accordingly, interaction and development can be steered attuned with the economical and social ecosystem.

Most importantly, i think we need to shift our perspective towards what the standard medium of design and living practice is. In my opinion that, is the most important conclusion and recommendation of this process.

ACKNOWLEDGEMENTS

Firstly, I would like to thank both my building technology thesis advisors at TU Delft for this journey. As first mentor Dr. Serdar Aşut of the chair Design Informatics, was always patient, open for crossing boundaries and supportive of my exploration. As second mentor Dr. David Peck MBA of the chair Climate Design and Sustainability, for his support with all critical discussions, valuable comments and reflective questions. Whenever, I become stuck or had a question about my research or writing, one of the mentors was there. Finally, both consistently allowed this report to be my own work, but steered me in the right the direction whenever they thought I needed it.

Moreover, i would like to thank, Felix, Marieke and Remi, the three students involved in the subsistence experiments of this research project. Their enthusiastic participation added social practice to the research and enriched the perspective over this work. Without their input, the methodology could have not been successfully tested. Special thanks, as well to Lucas, as he was the camera-man who supported me with the set-up and equipment during the experiments. Without him the experiments could have not been documented with the diverse perspectives and high video quality.

Overall, i want to thank all the formal and informal discussions with the different humans during my time in TU Delft. All the interactions over the last two years, combined with my previous experiences lead to the development of this work. Discussion and conflict is very important.

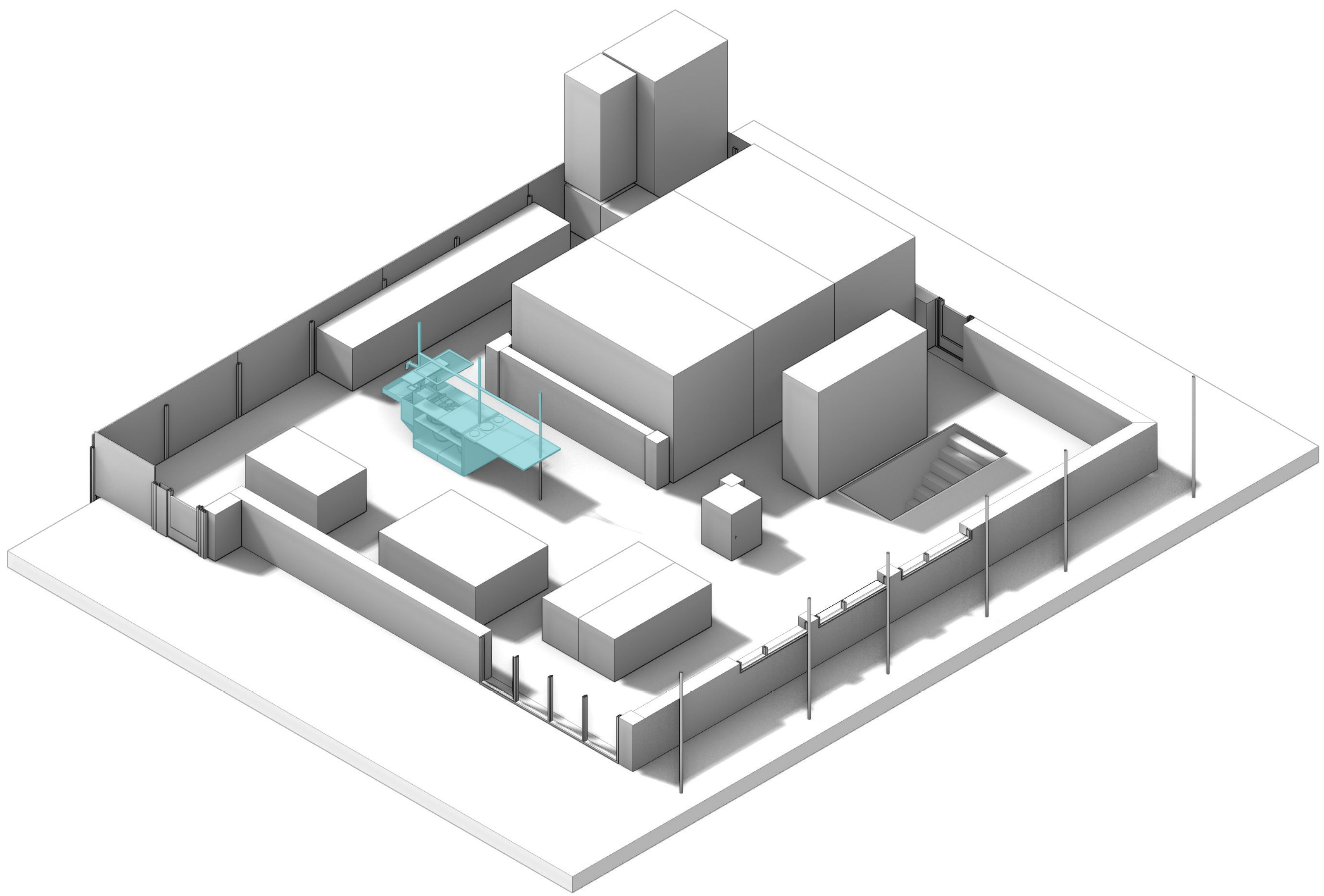
Finally, I must express my very profound gratitude to my parents for their support over the years. I want to express my gratitude to Ameya, my flatmate and good friend for all the creative conversations and journey's we did together and influenced this work. Lastly, providing me with unfailing motivation, support and continuous encouragement throughout the process of researching and writing this thesis, my lovely friend Soujanya, who was there in all my up's and down's. As alone no one can manage, We hitchhike together in this spaceship of life, we create and imagine in the dark. This small accomplishment would not have been possible without you all around.

Thank you!

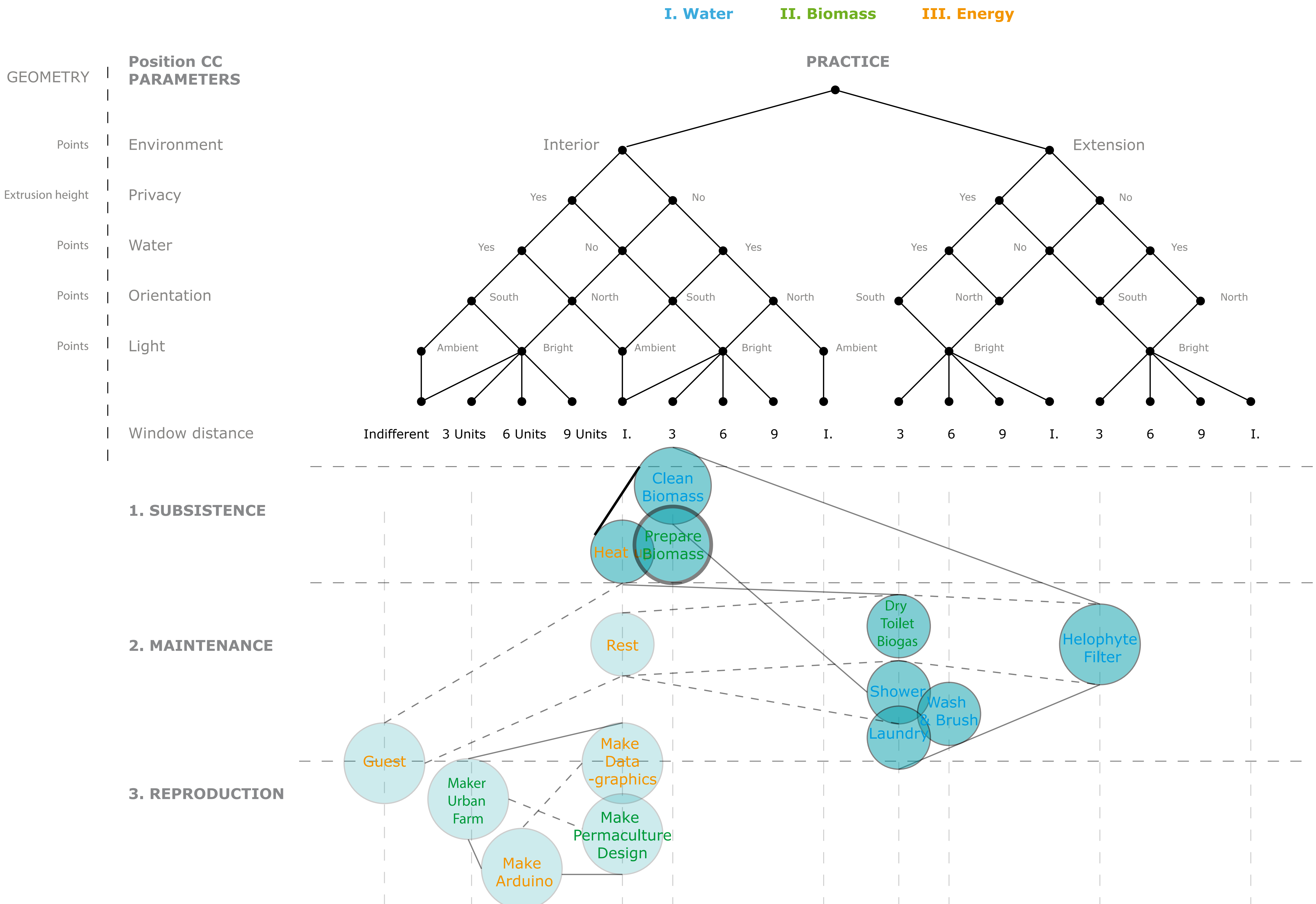
Author

Pierre Pascal Simões Kauter

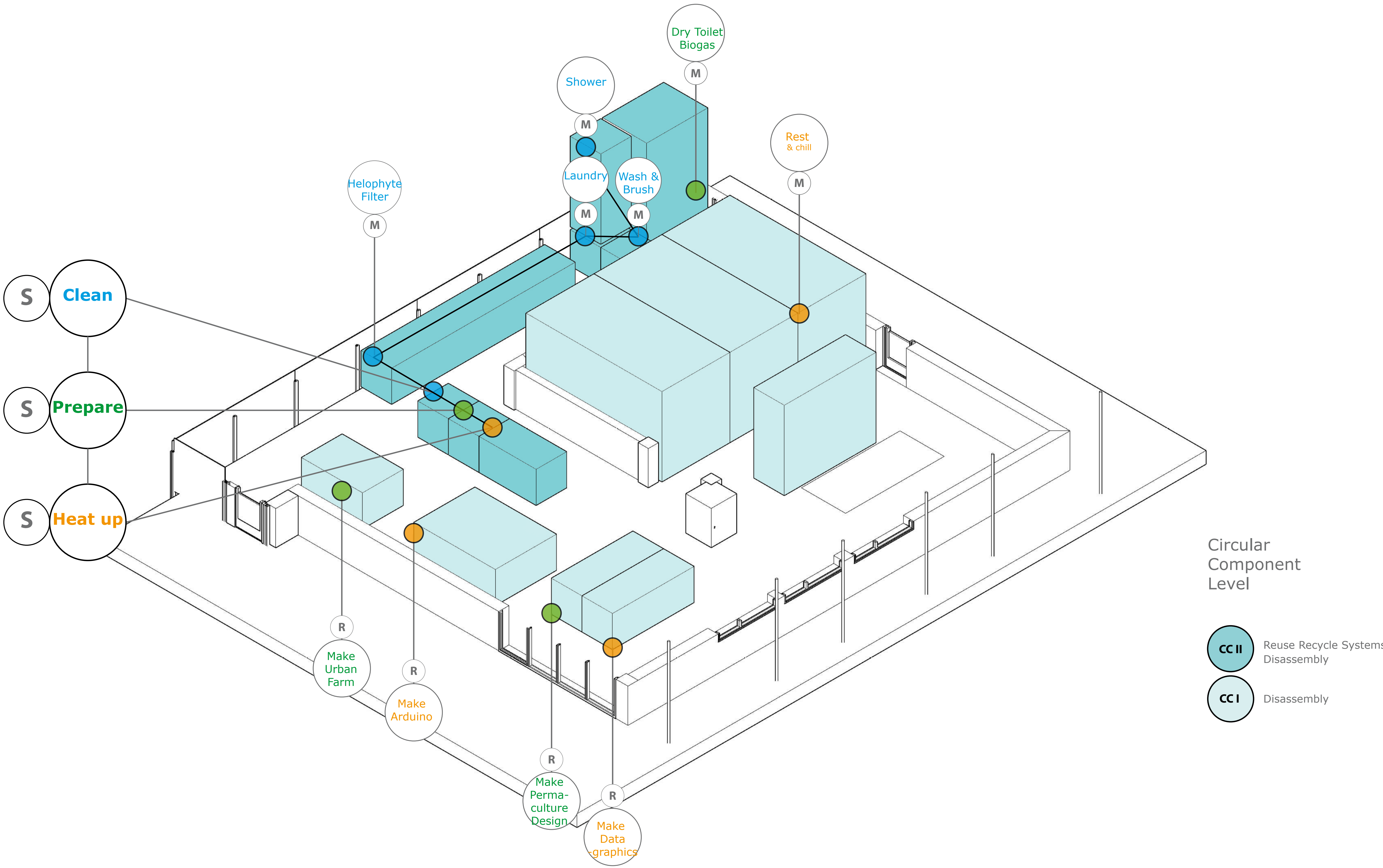
APPENDIX



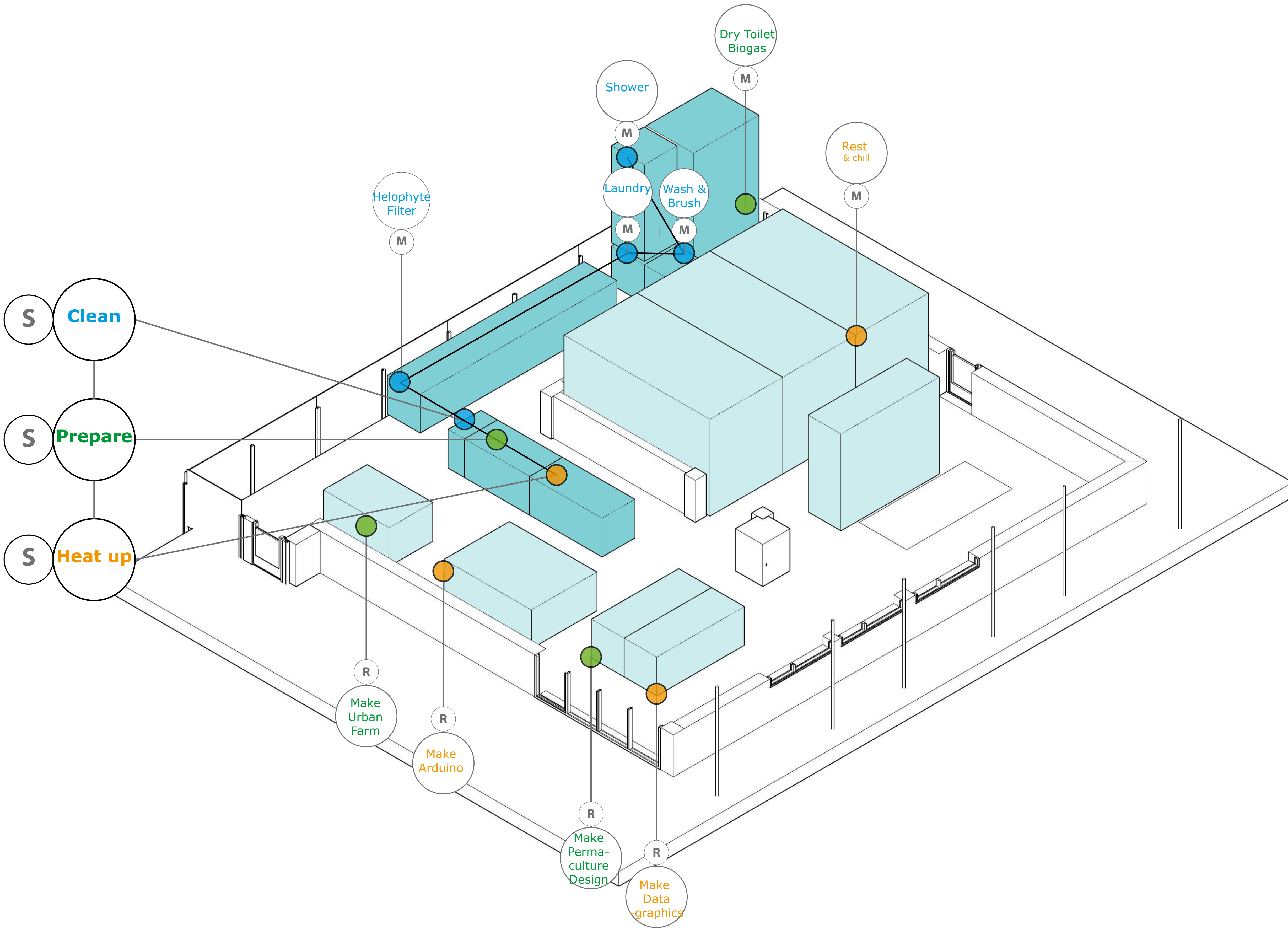
Appendix. A - Circular Collaborative Dakakker F1.K1



Appendix. B - F1 parametric position system of component clusters



Appendix. C - F1 Position translation with cluster circularity level

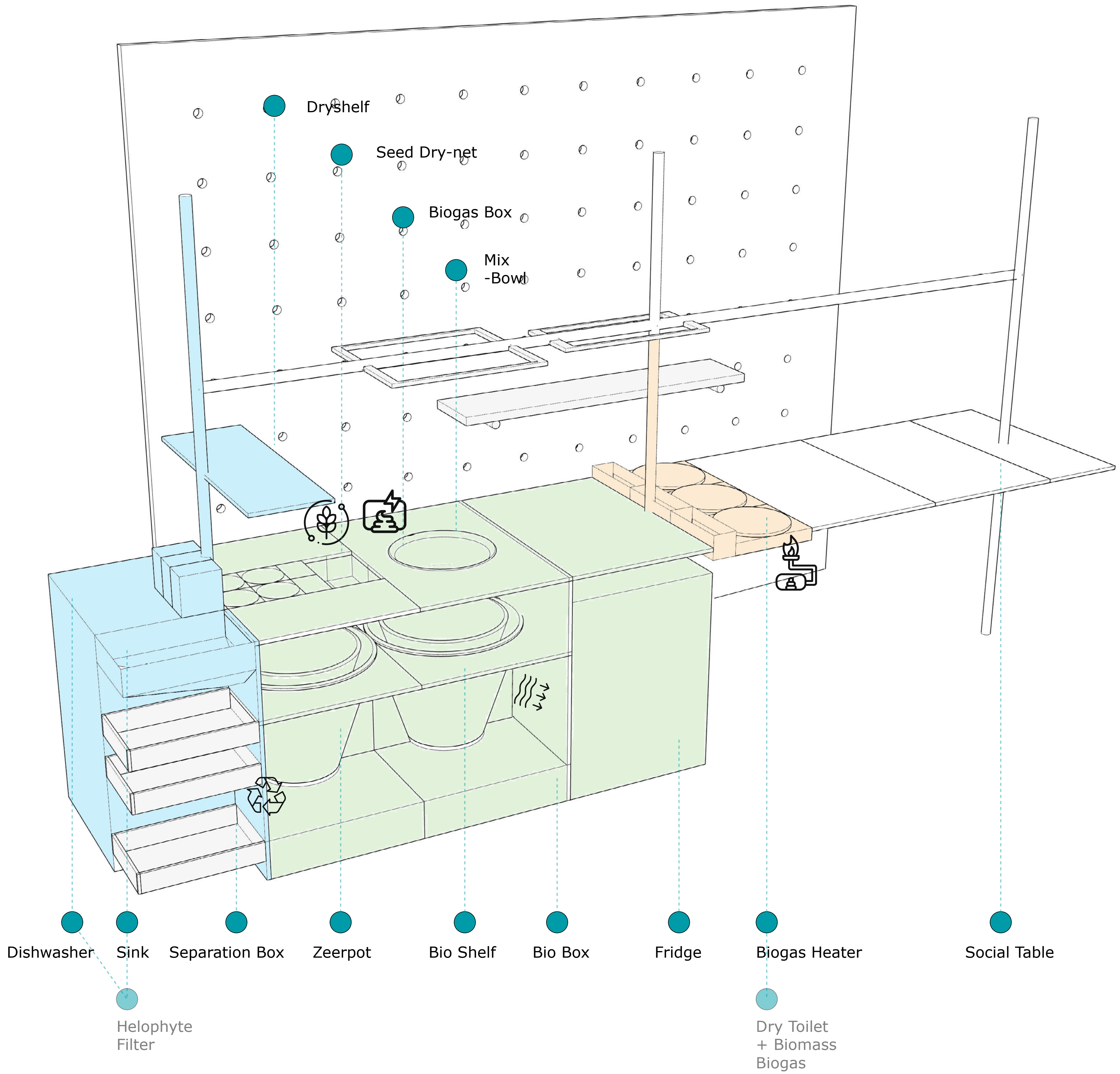


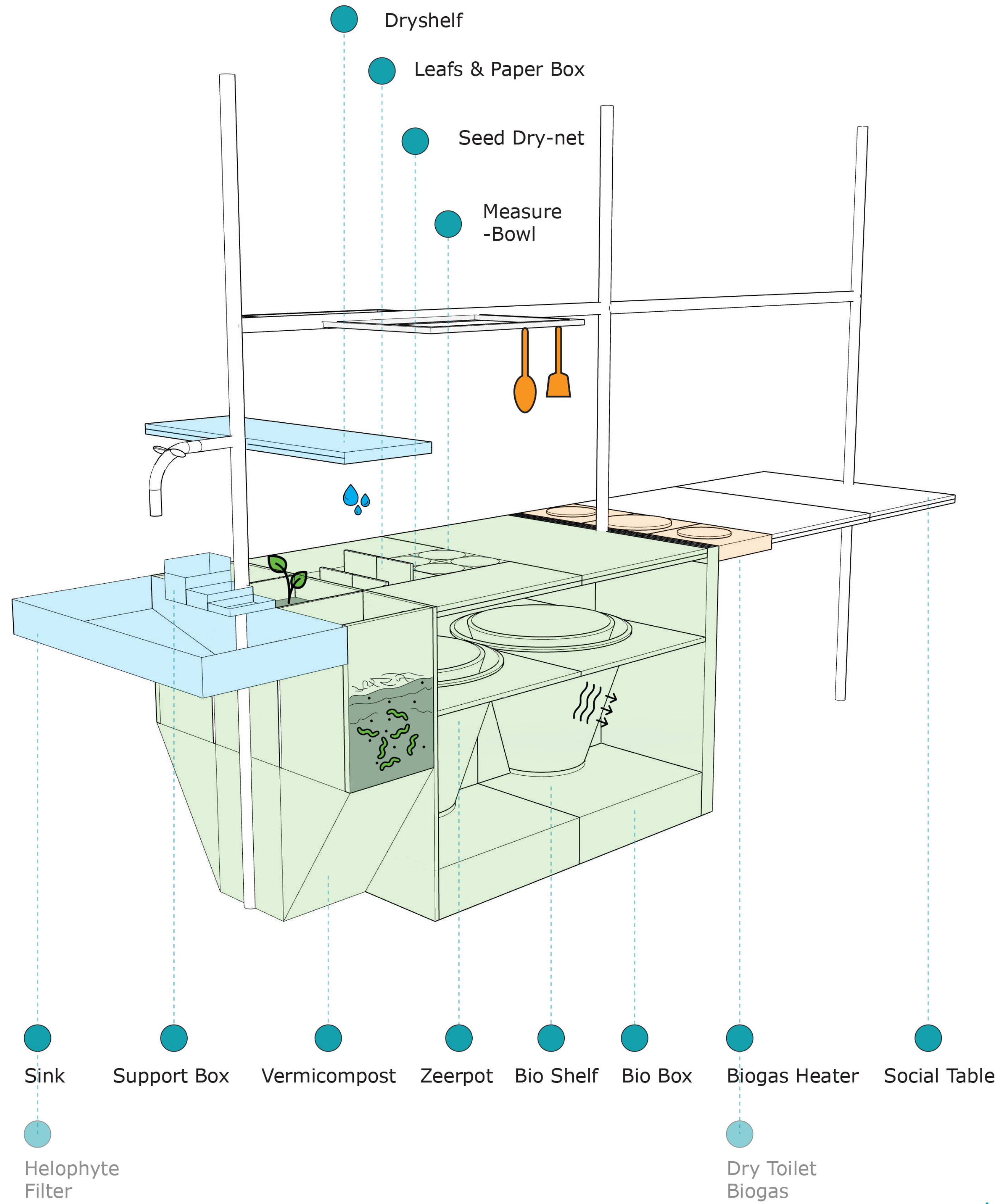
Circular Component Level

CC II — Reuse Recycle Systems Disassembly

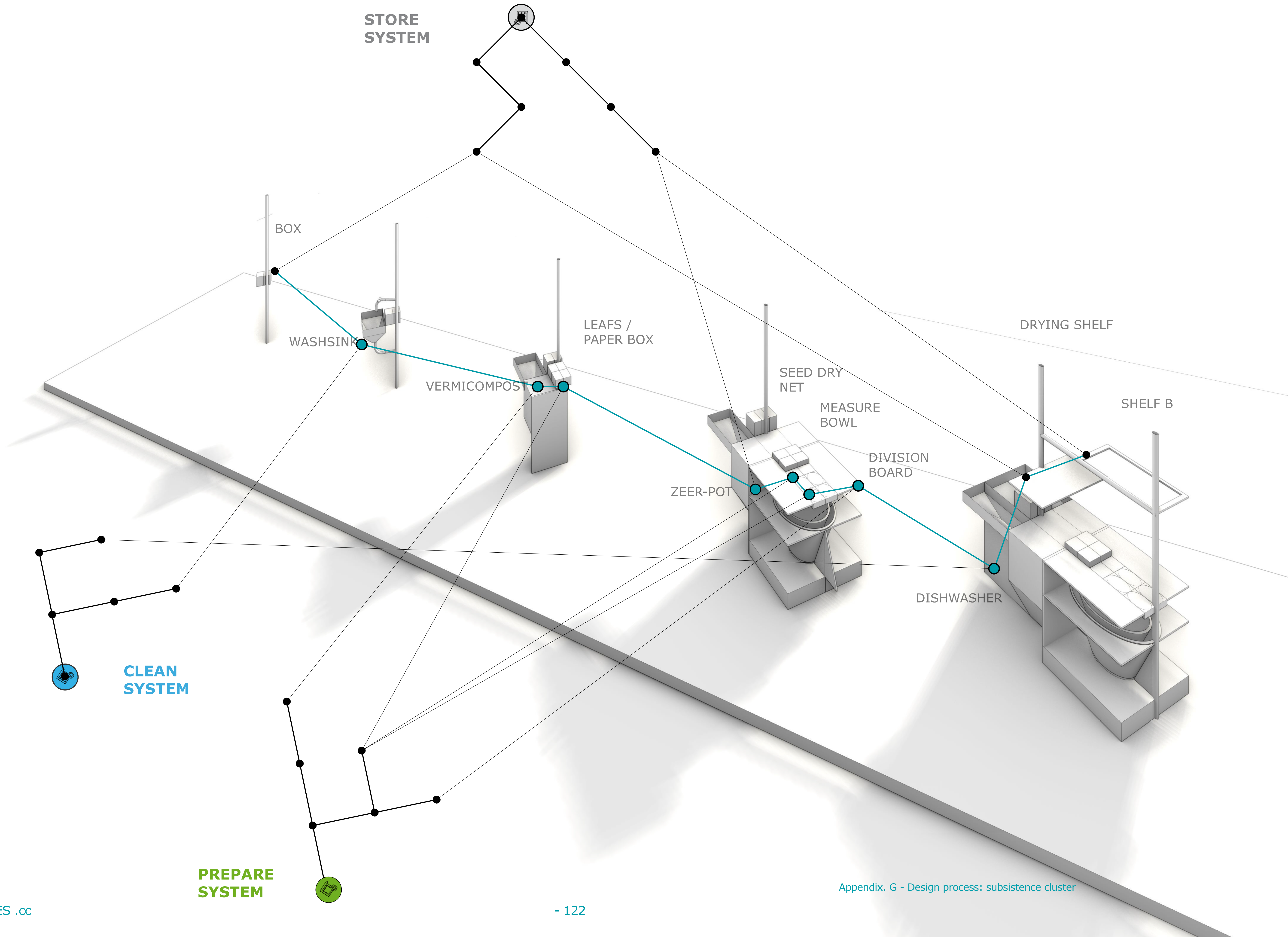
CC I — Disassembly

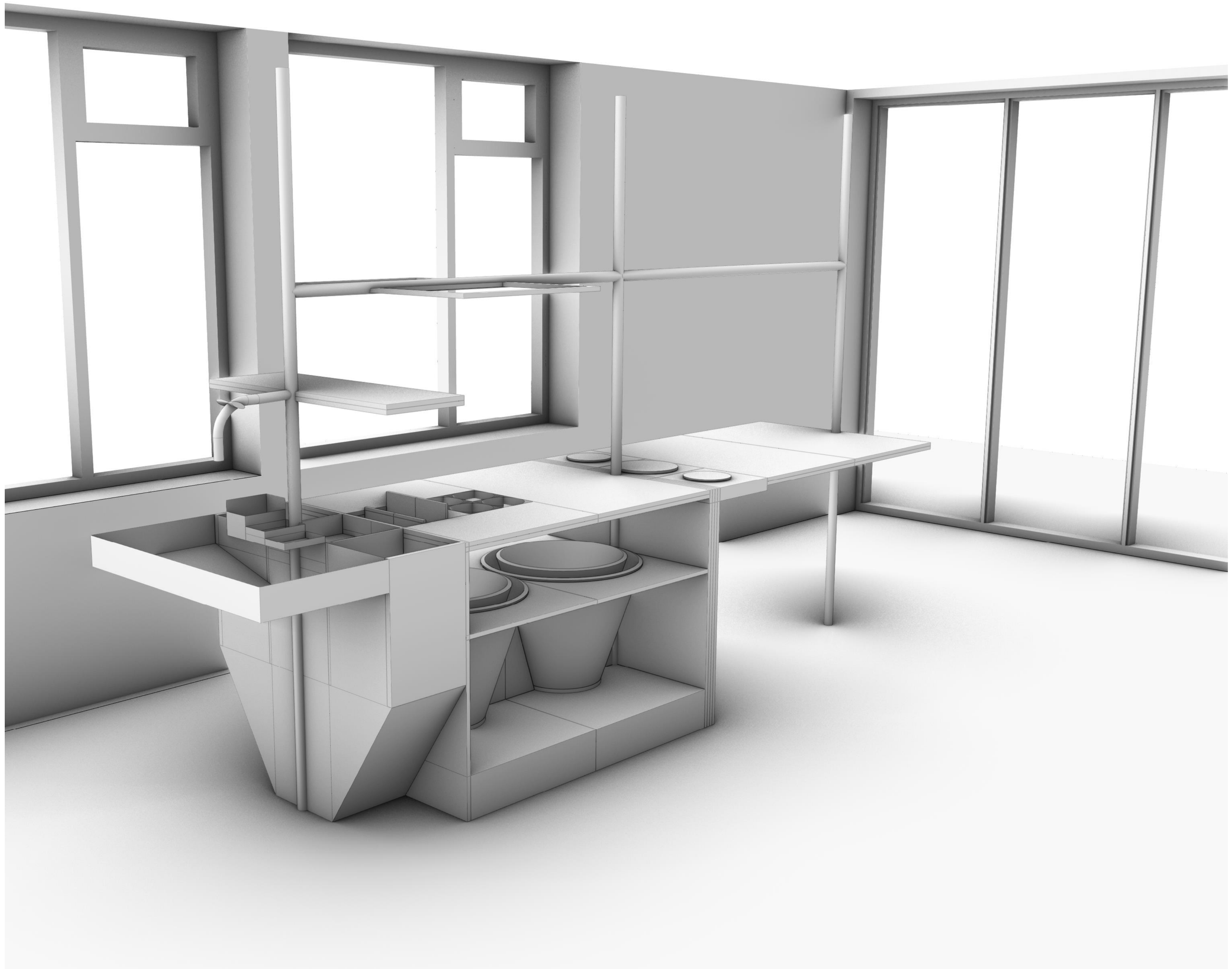
Appendix. D - Subsistence cluster variation from K0 to K1


Dryshelf
Seed Dry-net
Biogas Box
Mix
-Bowl
Dishwasher
Sink
Separation Box
Zeerpot
Bio Shelf
Bio Box
Fridge
Biogas Heater
Social Table
Helophyte
Filter
Dry Toilet
+ Biomass
Biogas



Appendix. F - Subsistence cluster K0


STORE
SYSTEM
BOX
WASHSINK
VERMICOMPOST
LEAFS /
PAPER BOX
SEED DRY
NET
MEASURE
BOWL
DIVISION
BOARD
ZEER-POT
DRYING SHELF
SHELF B
DISHWASHER
CLEAN
SYSTEM
PREPARE
SYSTEM



Appendix. H - Visualization subsistence cluster K0

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Fig.4 & 5 - Food waste: towards half as much.
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