NordDesign 2016
August 10 – 12, 2016
Trondheim, Norway

From linear to systemic: an integrated design solution for sustainable household consumption in Iceland

Min Hua[1], Shan Huang[2], Peter Childs[1]

[1]Dyson School of Design Engineering, Imperial College of London
m.hua15@imperial.ac.u, p.childs@imperial.ac.uk
[2]College of Design and Innovation, Tongji University
shan_huhu@aliyun.com

Abstract

Sustainable consumption patterns are one of the key driving forces to achieve sustainable development. However, studies in design research tend to draw on the existing system of production and consumption with its inherent linear processes, which are often wasteful and polluting. Here we report on a project for a Nordic family in Iceland which had the dual aims of introducing a new holistic research method into the consumption research sector and investigating ways to optimize the family's use of resources from a Systemic Design (SD) perspective. Using SD theory, we redesigned the material and energy flows run in the house and optimized the relationships between its system elements. These programmed changes improved the efficiency of the current system and provided opportunities for subsequent design innovation.

Keywords: Household Consumption, Systemic Design, Sustainability, Resources and Energy

1 Introduction

Prior SD researches mainly focus on the industrial and agricultural production process. Limited research has been carried out in the sustainable consumption sector. Gallio (2012) carried out a study on systemic consumption model, in which he tried to define new scenarios for creating positive relationships between the protagonists within a system, and in which flows of energy and matter can constitute new resources and opportunities for the territory. They identified key variables and areas for consumption study, but little is known about each specific area, e.g. the indoor context. Subsequent work revealed the network of relationships and flows of resources that exist in the home system, and also pointed out that the area surrounding our home system is another system which interacts with it (Allasio, L., & Balbo, A, 2012). However, the specific interactions between the system elements both inside and outside of the home system are not well understood. Besides, SD is a design method which is always based on territory context, without which SD methods cannot be applied and tested in design practice. Therefore, we conducted a SD research project for a Nordic family in Iceland, in which we studied the local family's home consumption pattern, and transformed it from a linear system into a systemic one with higher efficiency and lower environmental impact. The main steps of the project are outlined in this paper, including the territory study for Iceland. Data on incoming and outgoing flows of materials and energy in the system are also presented and analyzed. The paper then presents the results of this project, including a redesign home consumption system for the family, one of the selected product design solutions and a set of summarized design guidelines for subsequent designers.

2 Methodology: From Theory to Practice

This paper is mainly based on the application of the SD method. SD has its roots in cybernetics and system complexity. It regards production and consumption processes as its study fields and aims to eliminate waste by transforming a linear system into a systemic one. It is the ability to outline and plan the flow of material and energy running from one system to another in a continuous metabolism which can decrease the ecological footprint and activate the local economy. Thus, SD seeks to create not just industrial products, but also complex industrial systems (Barbero, 2010). The following are the guidelines of SD method:

- The output (waste) of one system becomes input (resource) for another, creating an increase in cash flow and new job opportunities;
- Act locally: the local context is fundamental;
- Relationships generate the system itself: each relationship contributes to the system and it can be within the system or outside of it;
- Self-producing systems support and reproduce themselves, thus allowing them to define their own paths of action and jointly coevolves;
- People at the center of the project to be connected to their environmental, social and cultural context (Barbero, 2012).

The methodology applied in this research, has several steps, each of which uses one or several established methods, concerning design and environmental sustainability. This project started with a holistic survey of the local territory. Then we investigated the household environment, both qualitative and quantitative data were collected to help us to get a comprehensive understanding of the design context. Based on these data, a system model was established, which enabled us to simulate the operation of the current home system. By evaluating the input and output of the process, studying the local energy and resource needs, and analyzing the relationship between all of the system elements, we then successfully identified the problems occurred in the system. Finally, a redesigned household consumption system was established and four product design solutions were generated, one of which is discussed here.

3 Territory Study

An ecosystem is deeply influenced and shaped by its habitat, which is the same with any other "living" systems; therefore, the design research context must stay local. Basic information about the territory must be investigated, including its climate, energy supply, natural resources, population, culture and customs. These data can give us the basic knowledge of local resources, people involved in the context, their know-how and the available technologies which is presented in Figure 1.

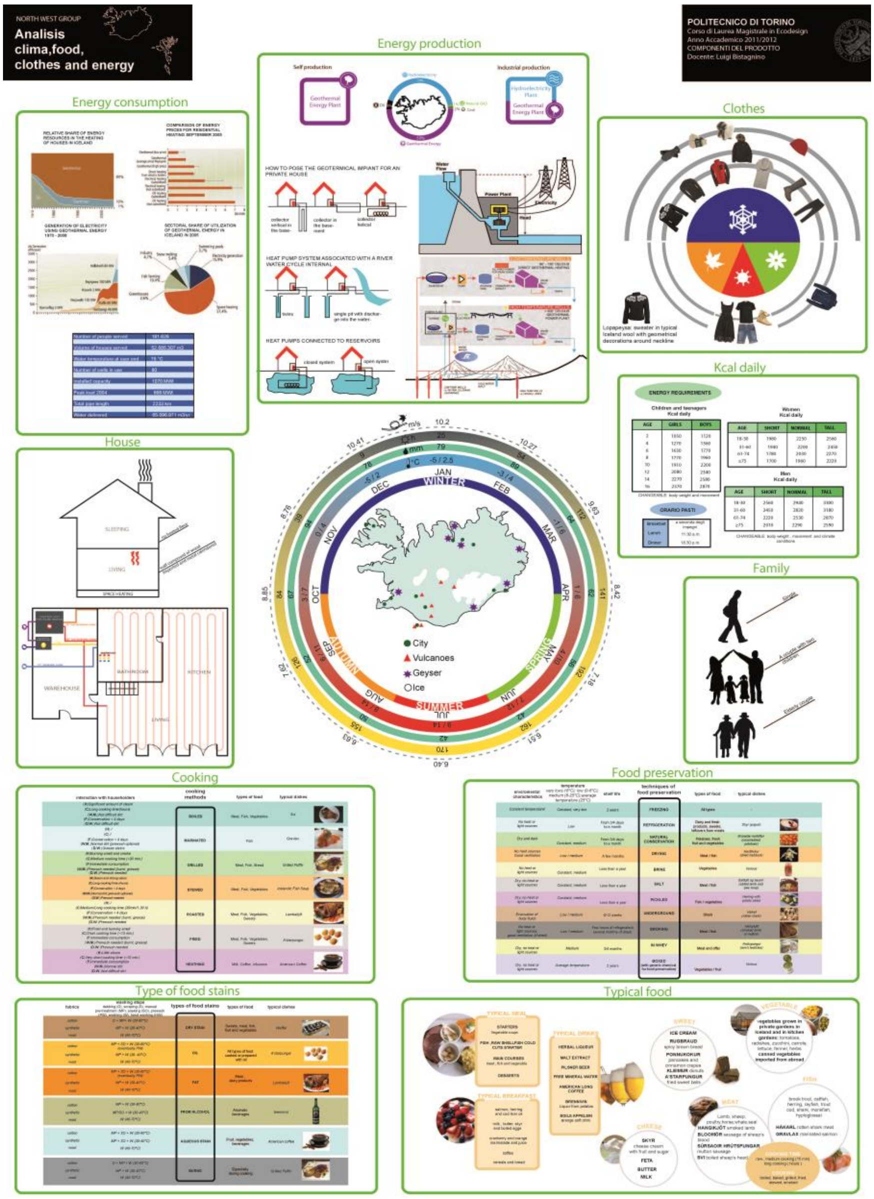

Figure 1. Data of the territory study

4 Current System Study

Home environment strongly affects our consumption behaviors and also reflects the way of life we really lead. If we analyze it with the critical approach borrowed from the SD methodology, we observe various problems that can be improved, which also give us opportunities for sustainable design innovation.

4.1 Current system analysis

According to General System Theory (Bertalanffy, 1972), any system can be basically understood by studying it as a set of entities, relations, attributes, and flows. Within the indoor environment, most of the people's consumption behaviors are related to meet their basic needs. For example, the "food resource" in the home context, also involves several other resources (such as water and energy), use of tools (such as household appliances), implementation of specific actions and even the occupation of spaces. These system elements are the so called "entities" and the qualitative and quantitative data of these entities are called "attributes". Together they create a dense network of relations and flows of resources within the context, which was defined as the "Home System" in our project.
"The connection of house with context is only water, food and energy supply, while the other materials and products have no real and deep connections with the territory (Allasio, L., & Balbo, A, 2012)." Based on this insight, our research mainly focused on the consumption of water and energy. An analysis tool named "system diagram" is adopted from the SD research toolkit, which can be simplified as below:

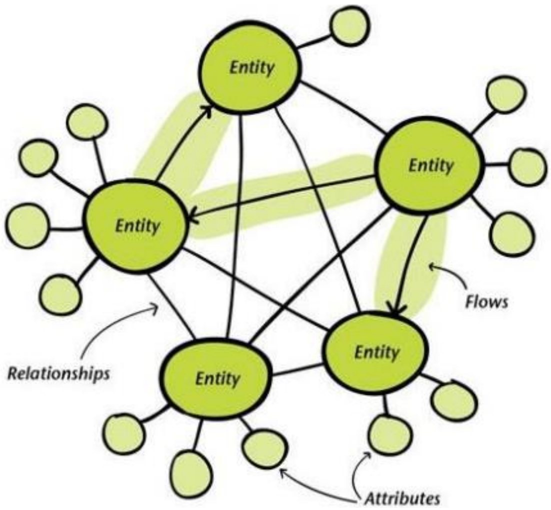

Figure 2. Basic structure of ERAF system diagram

Data of flows of water and energy are provided and their attributes were carefully investigated. This includes information about their physical states, chemical composition, their current origin and their use or destination. The quantities of what enters and comes out of the system were also analyzed, together with what happens inside it. The relations and flows are analyzed and represented as lines and arrows in the system diagram. All of this information is in the system diagram below:

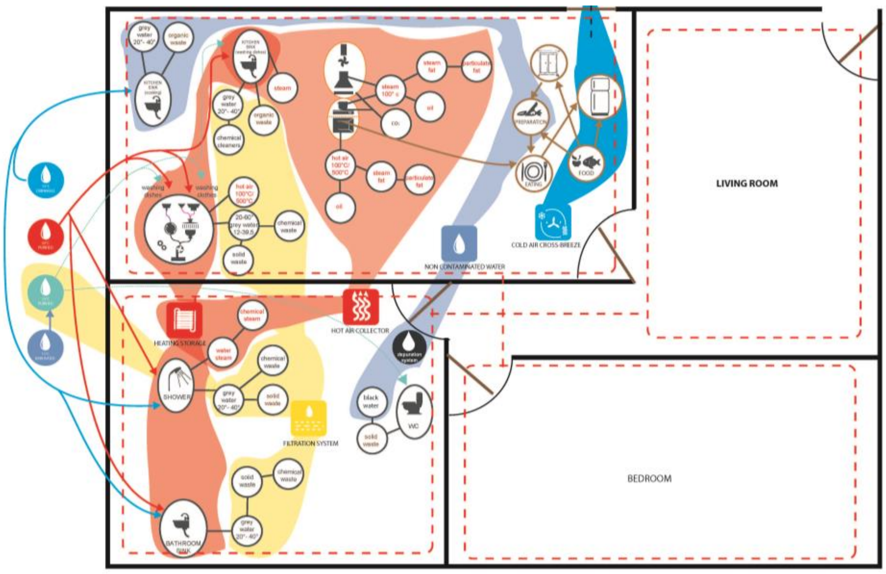

Figure 3. Current system diagram

An improved system diagram is presented in Figure 4, which was used as the general system model in our later analysis and design work. The improvement mainly includes several aspects as below:

- Simplified the system diagram and removed the redundant information;
- Stated the system boundary, which can help us distinguish the home system and the territory system;
- Added new relations to the system diagram, including the relations that had not been found before and the interactions with territory system;

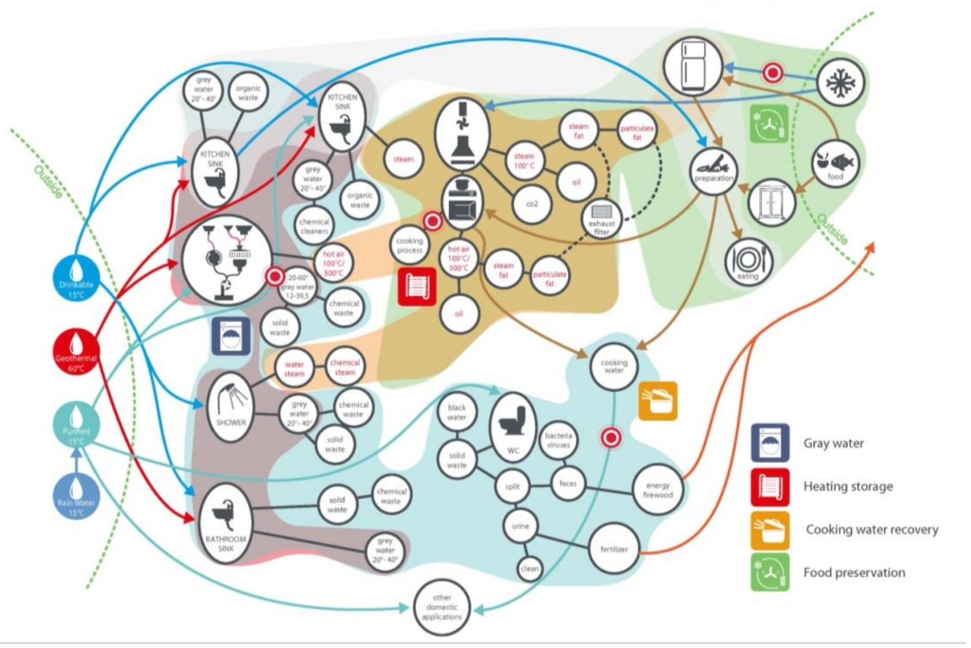

Figure 4. General system diagram

4.2 Problem Identification

Study of the system diagram can help us to diagnose the current state of the context, looking for gaps, disconnects, missing entities, missing/contradictory relations, or other aspects of the system that is a problem or has the potential to become one. The most critical issues that emerged from analysis of the current situation were:

- Grey water: Waste water is discharged and is not seen as a feasibly potential resource. Most of it can be classified as “grey water” by its composition. According to our estimates, a well designed grey water recycle system can save up to18000 liters of fresh water a year for each person. This represents 33 percent of daily household water consumption.
- Heating storage: A large amount of the electricity consumption is used for heating, but the heat was largely been wasted. For example, the temperature of the steam which generates from the ironing process can be up to 200℃, but this amount considerable heat normally disappeared with the steam itself, while which could be used as a kind of heat source.
- Cooking water: Cooking water was considered as a kind of waste which has no value. Discharging it wastes heat and nutrients, also resulting in environmental costs to the community.
- Food preservation: The fridge usually consumes a significant quantity of energy while it’s working. According to the diagram, the current food preservation system is a closed system which has no interaction with the territory. This suggests that it failed to make good use of the local cold climate and long winter.

5 Home System Redesign

5.1 Improved Home System

To address the critical issues highlighted by the SD analysis earlier, we first divided the current system into three sub-systems, namely water recycling system, cooking system and food preservation system. Then, we focused on the relations and flows in each sub-system and between them, and redesigned the entire home consumption system, as shown in Figure 5.

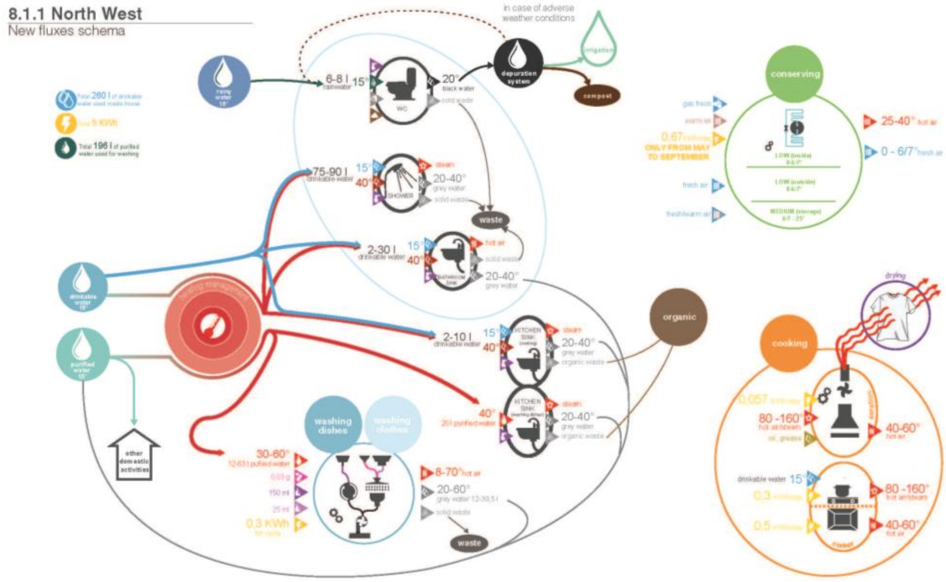

Figure 5. Redesigned system diagram

5.2 System Flow Design

5.2.1 Water flow

The water flows in this system can be divided into several different types according to their composition: drinkable water, grey water, black water, rain water and purified water, and they will be re-defined as follows:

- Drinking Water: qualified for drinking, here mainly refers to the tap water.
- Grey Water: in the home context, a large percentage of waste water are considered grey, they contaminated by the use of chemicals not highly harmful, but which make the water unusable without a purification process.
- Black Water: black water is the kind of water which contains those wastes, that are recognized as harmful to public health or nuisance to the public (such as those from the toilet).
- Rain Water: rain water mentioned here actually represents the natural precipitation, including the snow melt water.
- Purified Water: purified water is water that has been mechanically filtered or processed to be cleaned for consumption.

The water flows run in the system have been re- planned is shown in the new system diagram. In brief, grey water will be collected and purified. This purified water can be used for a variety of domestic activities, such as car washing; black water will be filtered and separated into water and solid waste. This water is ideal for irrigation and the solid waste can be used as organic fertilizer; at last, the rain water can be directly used to flush the toilet.

5.2.2 Energy flow

Electricity: In home system, the electricity consumption is mainly generated by lighting, heating/cooling system and other electrical appliances. To reduce the electricity consumption, we could use heat exchange between the output and the input to improve the efficiency of our heating/cooling system; and use geothermal energy and other clean energy supply.
Hot water: water used for bathing and clothes washing need to be heated to a certain degree which is always carrying a lot heat after has been used. So we can still use it to preheat the input washing water through heat exchange.

6 Utilizing the Cold Climates in Iceland for Food Preservation

6.1 Applying Systemic Design Principles

The local context is fundamental, because it values local resources, including people and their culture. According to the theory of Material Culture History (Miller, 1998), each specific geographical area can be defined by different resources, which during centuries have been used by local people to meet their needs. Subsequently, the specific “knowhow” was developed, which is strictly connected with the corresponding territories and is very useful and valuable for SD designers at their product design stage. This kind of knowhow can provide SD designers with extra and reliable techniques to support their problem solving process.

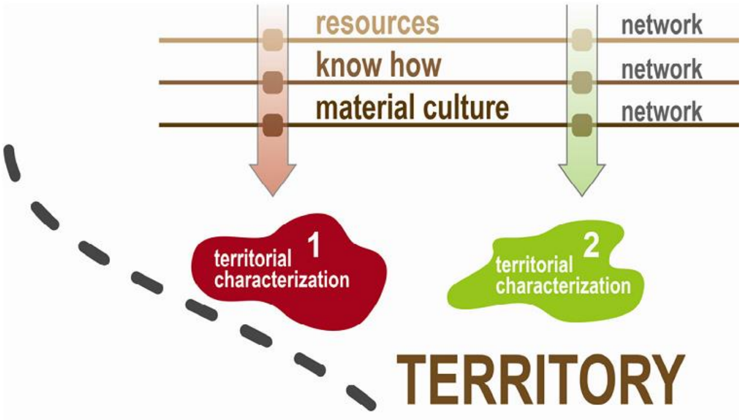

Figure 6. Territory and material culture research framework

6.2 Design Solution for Food Preservation

People most commonly use a fridge to preserve their food, but to keep it working day and night consumes a huge amount of power. To solve this problem, we need to temporarily shift our attention from the problem itself to the local resources. The climate of Iceland is characterized by cool summers and relatively mild but long winters. It snows a lot during these winter months, but this snow is generally considered as waste which needs to be cleaned out of the garden. However, according to the SD principle of “output>input”, what is not used by one system can become a raw material for the development and survival of someone/something else. From this design perspective, cold weather and the heavy snow can be used as a kind of “natural refrigerant” for us to preserve food during the long winter time in Iceland. Then, the knowhow of the local craftsman had been considered at the product manufacture stage. The materials used in this project are local and renewable. In summary, we took the advantages of the winter weather and found a smart solution for Icelanders to preserve their food in winter with totally no energy consumption. The detailed design information is illustrated in Figure 7.

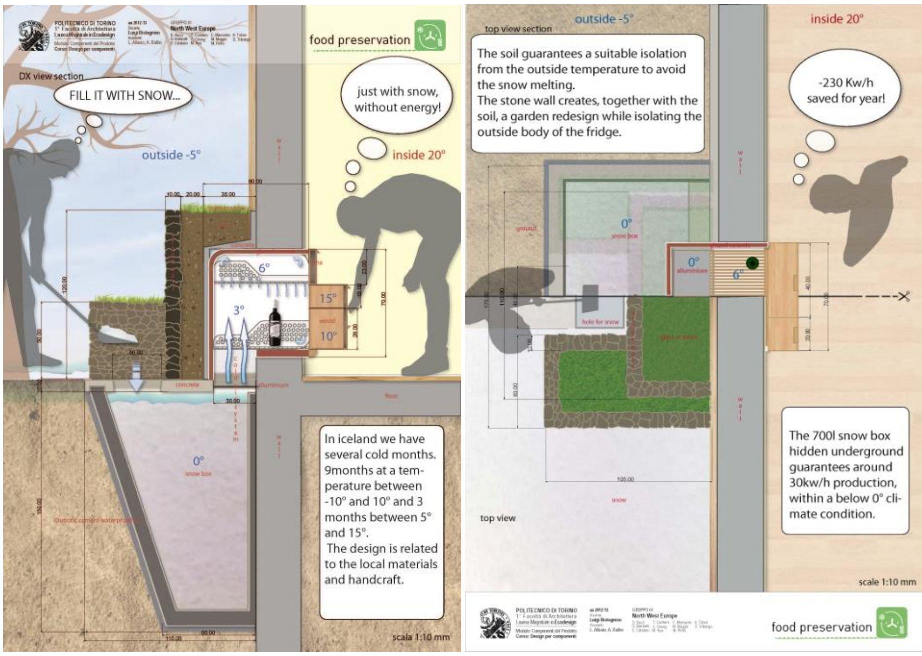

Figure 7. The concept sketch of fridge design

7 Results and Discussion

Prior work has documented the importance of consumption pattern in achieving the sustainable development. Gallio (2012), for example, studied a home consumption system and identified the key variables for this study area. However, these studies have not revealed the network of relationships between the system elements in a home consumption context.

In our project, SD theory was introduced into this research sector. The adoption of SD methodology offers potential for creating a more sustainable home consumption system. This innovative methodology goes beyond the linear "cradle-to-grave" sustainable design paradigm, showing how consumption can be viewed from a holistic and systemic perspective.

The detailed interactions in the home system were studied, based on which we established a redesigned home consumption system for an Icelandic family. This new systemic consumption system can be activated by the positive interaction between these parameters: the home system, the products, the territory and the people involved.

The first active player is the people, which are always in the center of the project (Germak, 2008) and connect with their other parameters. The flows of resources run in the home system was carefully analyzed and re-planned. Linear consumption generates wastes in each step of its working process, but these wastes were planned to be reused by other processes in a systemic system, so that we can derive extra value from the "waste" and prevent the waste from being released into the environment. A new fridge design was inspired by idea of taking advantages of the local wintry weather. It is estimated that it can save 230kW·h per year for an Icelandic family to preserve food. Finally, design guidelines were summarized for future designers, which are listed as follow:

-Using local materials for manufacturing;
-Taking advantage of local craftsmanship's know-how;
-Small nonrenewable materials employment and avoiding energy-intensive manufacturing;
-Taking advantages of wintry weather in Iceland;
-Designing products according to the interior and exterior architecture;
-Designing products for real local needs;
-Designing one-material products in order to make easily reducing it in components;
-To close the relationship between producers and consumers.

8 Conclusion

This work is one of the initial attempts to apply the SD approach in the household consumption research sector. Our research revealed specific interactions among the components in an Icelandic home system and collected the data of the incoming and outgoing flows of materials and energy. Based on the analysis of these qualitative and quantitative data, we developed a redesigned home consumption system for the Icelandic family on a theoretical level.

Each of the highlighted problems occurs in the current linear system was addressed with a plausible solution. The case study highlighted in this paper has supported the SD approach by adopting a perspective that considers "waste" (output) of one system becoming an opportunity (input) for another one, which is similar to the natural processes and addressed in the TRIZ contradiction matrix (Childs (2013). The tools we use are closely related to the lifestyle we lead, our traditions and culture. The fridge design in the case study is also based on the surrounding environment and the local craftsmanship's know-how, and the principles embodied suggest that it is possible to reevaluate and respect the local (near) territory instead of the global (far) one.

References

Allasio, L. T. P., & Balbo, A. P. (2012). Relations within the home system.

Bistagnino L. (2011), Systemic Design: Designing the productive and environmental sustainability, Bra, CN, Italia: Slow Food Editore.

Bistagnino, L. (2008), The outside shell seen from the inside, Casa Editrice Ambrosiana

Barbero, S., & Toso, D. (2010). Systemic Design of a Productive Chain: reusing coffee waste as an input to agricultural production. Environmental Quality Management, 19(3), 67-77.

Barbero, S., & Tamborrini, P. M. (2012). Systemic Design in AgroFood Sector: EN. FA. SI project.

Childs, P.R.N. (2013). Mechanical engineering design handbook. Elsevier.

Gallio, V. S., & Marchiò, A. (2012). New model of consumption: scenarios for sustainability.

Kumar, V. (2012). 101 design methods: A structured approach for driving innovation in your organization. John Wiley & Sons.

Johansson, G. (2002). Success factors for integration of ecodesign in product development: a review of state of the art. Environmental Management and Health, 13(1), 98-107.

Miller, D. (1998). Material cultures: Why some things matter. University of Chicago Press.

Min, H., & Long, L. (2014). Systemic Design Research for Hospital Laundry.Advances in Human Factors, Software, and Systems Engineering, 6, 192.

Von Bertalanffy, L. (1972). The meaning of general system theory. General system theory: Foundations, development, applications, 30-53.