Sustainable Food Design: A Four-Dimensional Transformation of Theory and Methodology Towards Post Carbon Era

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Abstract. Food design is an emerging field of research in the past decade, with interdisciplinary attributes that integrate culture, ecology, health, and society. Especially in the post-epidemic and post-carbon context, the importance of food design as a pathway to sustainable development has been gradually highlighted. By summarizing the food design research from the perspectives of eating, cooking, experience design of food, as well as ecology, agriculture, and system design of food, the article defines the research scope of sustainable food design. Based on this, the author proposes a four-dimensional transformation theory of food design in the post-carbon context and analyzes how to translate strategy into action with case studies. The four-dimensional transformation are *from Human-Centered to Life-Centered*, *from Object-Centered to Hyper-object Centered*, *from Experience-Economy to Post-Carbon Economy*, *from design for consumption to design for Crisis*. In this way, the article builds a new framework and guideline for sustainable food design and propose strategies to deal with the crisis of the times.

Keywords: Sustainable Food Design · method transformation · Crisis · Post-epidemic Era · post-carbon era

1 Introduction

Threatened by multiple risks such as climate change, epidemic, natural resource degradation, trade frictions and regional conflicts, the current global agriculture system is developing in an unsustainable way. Thus the situation of global food security and nutrition is facing unprecedented challenges. Food is an important link among people, nature and society. Sustainable food design is an *open complex giant system* [1] involving agriculture, ecology, industry, consumption, poverty alleviation, community and other issues. Although contemporary food design just rose 20 years ago, multiple research directions have been developed so far, such as small-scale design with perspectives centered on *eating* from diet, cooking, to experience design, as well as large-scale design with perspectives centered on *production*, from ecology, agriculture, and systems design.

However, it is important to realize that food design is not new as the object of the study, but rather the link the food design made, leading to a re-examination of resources, industries, and consumption. The article focuses on food design as a response to crisis,

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with proposing four kinds of transformation of food design thinking: (1) shifting *from Human-Centered to Life-Centered*, (2) *from Object-Centered to Hyper-object Centered*, (3) *from Experience-Economy to Post-Carbon Economy*, (4) *from design for consumption to design for Crisis*. The following questions are addressed: How to use food to design inter-species relationships? How to reduce the carbon footprint of food consumption? How to use food waste? How to produce food in extreme climate conditions? How can food security and nutrition be addressed? What are the possibilities for future food design? As the exhibition *Edible Futures* suggested that "Changing the world through food," the article aims to provoke rethinking the value of food design with the suggestion of design solution to cope with crises in this era.

2 Research Scope of Sustainable Food Design

2.1 Food Experience Design and Food System Design

Analyzed from existing research, scholars are in the initial stage of research on food ecology and system design. Contemporary food design began around 2010 [2] and is mainly divided into small-scale design of diet, cooking and experience, and large-scale design of ecology, agriculture and systems. In China, food design research mostly revolves around food and culture. According to Linghao Zhang, food design carries aesthetics, memory, cultural meaning and values, including the perception of the naturalness of ingredients, the interaction and activities between people and food, dining and packaging design, etc. He emphasized that designers should provide new solutions for the future food system, considering experience, technology, convenience, democratic participation, social responsibility, and social education [3]. Songfei He from Beijing Institute of Fashion Technology focused on food design for rural revitalization [4]. The research of Fang Hu from China Academy of Arts focuses on the perceptual system of taste and the reconstruction of food culture, culinary experience and story-telling space [5]. Crisis and Ecology Design at Central Academy of Fine Arts focuses on food and body, culture and identity, food systems and ecology, as well as productive space in the city. Ting Liang from Hong Kong Polytechnic University, reflects on food production and consumption services in a sustainable design context [6] (Figs. 1 and 2).

In western countries, food design focuses more on eating experience and ecosystem innovation. Francesca Zampollo proposes the connotation of food design thinking: eating design, food product design, Design with food, food space design, food service design, critical food design, food system design and sustainable food design [7]. While the design approaches of Marije Vogelzang and Martí Guixé combines the methodogy within practices. Vogelzang develops sensory, natural, cultural, social, technological, psychological, scientific, and action dimensions of food design. Guixé works on topics such as the ecology, policy, science, eating rituals and habits, as well as food waste of food [8]. The research of Harvard University School of Design focuses on the intersection of food and ecology, public health, agricultural systems, and landscape design. The University of Copenhagen Sustainability Science Center focuses on how food systems can become more sustainable, including four strategies: subtle improvements, massive changes, waste reduction, and smart diet.

Fig. 1. The Framework of knowledges in the course of the vision of Food, School of Design, Central Academy of Fine Arts, China

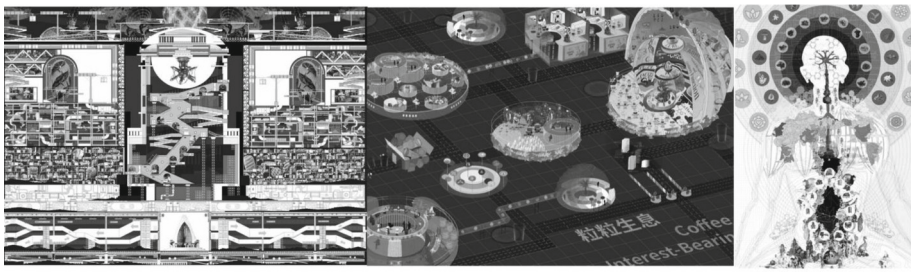

Fig. 2. Part of the Student works in the course of Food Geology, School of Design, Central Academy of Fine Arts, China

In summary, the study of the entire food system, including growing, harvesting, processing, packaging, transportation, marketing, consumption, distribution, and disposal as an interacting system has not yet been proposed.

2.2 The Research Scope of Sustainable Food Design

Sustainable food design must be beneficial for food systems. The *2022 China and Global Food Policy report* points out that "agri-food systems" are an important foundation for achieving the goals of national nutrition, food security, ecological civilization, common prosperity, and "carbon peaking and carbon neutrality goals". Agri-food systems contains agricultural products and food from agriculture, forestry, pastoralism, fisheries, industry, and services, involving factors and their interactions across the entire chain of inputs, production, storage, transportation, processing, marketing, consumption, disposal, as well as the broader economic, social, and natural environments in which they

are embedded" [9]. The complexity of the food topic determines that its study is trans-disciplinary, trans-historical, trans-cultural, and trans-industrial. For a long time, food design related topics have not been adequately viewed and studied in a systematic way. The concept and approach of food systems, with its importance for sustainable development, have only gradually received attention in recent years. Its complexity often involves phenomena which seemingly irreverent with food but in fact play an important role in the food system.

The transformation of technology and societal demands have led to sustainable food design that goes beyond the traditional discipline-based design of objects, brands, products, services, and spaces to a more intertwined mesh of ecological and health-based ecosystem design. The article defines sustainable food design as a system and future-oriented design that uses food design as a tool for human health and ecological sustainability, with proposing the four-dimensional transformation of sustainable food design toward carbon neutrality (Table 1).

Table 1. The research perspectives of food design in China and the World.

Category	Representative Scholar	Institute	Key Words
Eating, Cooking and Experience Design of Food	Marije Vogelzang;	Food Non Food Program, Design Academy Eindhoven, Netherland;	Eating designer, Sensory, natural, cultural, social, technological, psychological, scientific
	Martí Guixé;	Scuola Politecnica di Design, Italy;	Making food more humane and interactive; Food ecology, food policy, food science, eating rituals, eating habits, and food waste
	Francesca Zampollo		Food Design Thinking, Food Product Design, Design with Food, Food Space Design, Design for Food, Eating Design, Food Service Design, Critical Food Design, Food System Design, Sustainable Food Design

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Table 1. (*continued*)

Category	Representative Scholar	Institute	Key Words
	Linghao Zhang	Jiangnan University, China;	Aesthetics, memory, cultural meaning, values, perception of the naturalness of ingredients, interaction and activity between people and food, dining and packaging design elements
	Songfei He	Beijing Institute of Fashion Technology, China;	Food and Food Nourishment in the Chinese Cultural Context
	Fang Hu	China Academy of Art, China;	Experimental Art and Design of Food
	Wen Liang	Academe Arts and Design, Tsinghua University, China;	Food, Space and Narrative
Ecology, Agriculture and Systems Design of Food	Montserrat Bonvehi Rosich	Harvard Graduate School of Design, Course: The Landscape We Eat	The relationship between food systems and their landscape, climate, infrastructure, time and culture
		Harvard Graduate School of Design, Course: The Desert We Eat	the relationship among agricultural water, dryland diet, ecological activities, and cultural practices
	Gary Adamkiewicz	Harvard Graduate School of Public Health, Course: From Farm to Fork: Why What You Eat Matters	The study of nutrition, agricultural and environmental sciences, occupational and human health, economics and ethics to select the healthiest food for people and the planet and create it with the right tools and technology

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Table 1. (*continued*)

Category	Representative Scholar	Institute	Key Words
		Copenhagen University, Sustainability Science Centre, Cousre: Transformation of the Global Food System	How food systems can become more sustainable, small improvements, big changes, waste reduction, smart eating
	Ting Liang	Asian Style Design Research Laboratory, School of Design, The Hong Kong Polytechnic University	The innovative design of food is transformed from the five senses and the Eastern philosophy of life to a complex social system composed of a new economy (development, service systems, business innovation, poverty alleviation, etc.), a new society (sustainability, socialization, empowerment, health, etc.), and a new technology (manufacturing, distribution, handling, customization, etc.)
	Siyang Jing	Central Academy of Fine Arts, Direction of Design for Crisis and Ecology, China; Course: Climate Currency-The vision of Food	Food and the Body, Culture and Identity, Food Systems and Ecology, Food and the City, Design and Empowerment
		Course: Food Geology-from Cell to Metaverse	The spatial and geographic development, production, consumption and distribution of food, from molecular synthesis technology at the XS scale to planetary food strategies at the XL scale

3 From Human-Centered to Life-Centered Sustainable Food Design

3.1 Community of Life

The Community of Life refers to the empowerment of animals, plants and even microorganisms in food, as to advocate the bio-diversity and to fight against extinction, namely the "interspecies" responsibility of design, as mentioned by the curator Paola Antonelli [10].

For animal rights, Siegfried Gideon's book *Mechanization Takes Command* traces the mechanization of slaughterhouses, including devices for catching and hanging pigs, "thousand-knife" cutting machines, and design for other horrific assembly line [11]. Design works of Lala Tam "How to consume Romie18" exposed the opacity of the food production system. Through the perspective of Romie18, a cow adopted by the designer, the work follows the whole process of food related to this cow. By understanding this, the project hopes to improve people's attitude towards food. Thus, consumer choose their food types and improving the alienated relationship between humans, nature and animals.

In terms of bio-diversity, the diversity of dietary species not only ensures human health but also guarantees the stability of the entire ecosystem. However, there were once more than 6,000 species of plants eaten by humans, but today only nine commonly used. In response to this question, Chaoqun Li's work "Endless Nature: Designing for Diversity" designed new species possibilities for future wheat through style GAN techniques based on the evolutionary decomposition of large numbers of wheat and rice samples from around the world throughout history (Fig. 3).

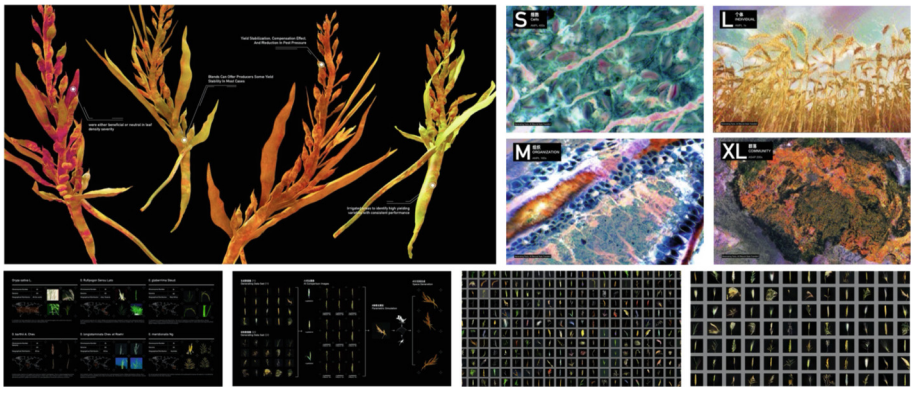

Fig. 3. Student work: Endless Nature, Chaoqun Li, in the course of the Vision of Food, School of De-sign, Central Academy of Fine Arts, China. Instructor: Siyang Jing

In the fight against species extinction, Matilda Boelhauer's fake flower is designed to help insects reproduce again by increasing the number of flowers in cities. In the last 27 years, the insect population has decreased by 75\%. The lack of habitat is one of

the main reasons. To restore the food chain, designer ensured insect pollination habitat, protecting the necessary conditions for fruit growth.

3.2 Cross Integration Between Multiple Species

Focusing on a broader range of living organisms becomes one of the sustainable ways to ensure human welfare. William Myers, author of book *Biodesign* predicts that "synthetic biology and the availability of tools for genetic engineering like crispr/cas9 multiply the possible benefits of harnessing nature, much like html standards helped lay the groundwork for the web" [12]. For example, synthetic biology can help designers synthesize artificial meat to replace beef, extract edible proteins from soil molds, or grow cheese from human bacteria. Oron Catts explored the use of tissue engineering to create test-tube meat. Modern Meadow studio use sugar-fed genetically modified yeast to produce collagen, and biological tissue engineering to generate meat for in vitro applications. The Next Nature Network presents a menu of future diets, including friendly foie gras with no real goose, knitted steaks skewered with extra-long cultured tissue, and in vitro-grown meat ice cream, as well as transparent sashimi, synthetic raw fish without the blood vessels, nerves, or organs of real fish.

4 From Object-Centered to Hyper-Object Centered Sustainable Food Design

4.1 Globality and Locality

Timothy Morton coined the term "hyperobjects" to refer to the large-scale distribution of things in time and space, so that they transcend localization [13]. Morton considers a pen to be as complex as climate change, both being hyperobjects. In the case of McDonald's, for example, the flooding of the Canadian port of Vancouver triggered a "French fry panic" at McDonald's in Japan. The reason is that the potato supplier of McDonald's fries comes from North America. In the design "Culture Sample", Xiaoji Zhou traces the history of the ingredients of scrambled eggs with tomatoes, revealing the 7,000-year history behind this simplest dish, which spans four continents. Bjorn Steinar Blumenstein's artwork "Banana Story" traces the global circulation of bananas to highlight the issues raised by the demand for non-seasonal and everyday commodities, to reflect on the origins of food. The artist creates a "passport" for the banana and follows it from Ecuador to Iceland: 12,534 km in 30 days on a cargo ship, passing through 33 different hands to an Icelandic supermarket, yet a third of it ends up in the trash.

4.2 Colonialism and Class Conflict

Thomas Sankara said: "Look at your plate when you eat. All this imported rice, corn, millet, is imperialism" [14]. Kara Walker's "A Subtlety, or the Marvelous Sugar Baby" is a giant sculpture made of sugar that responds to the painful labor, oppression, race, and other power issues behind the abandoned sugar factories in which it was made. On the other hand, differences in food production, distribution, and consumption are combined with various socio-economic structures, resulting in "haute cuisine" or "common

cooking" [15]. Amanda Huynh's work Diasporic Dumplings was designed to achieve human equality and resource efficiency. Thus, the kitchen is removed from the house and each community has its own dumpling, made from local materials. The shape of the dumplings is symbolic, conveying messages about politics and resistance to oppressive government.

5 From Experience-Economy to Post-Carbon Economy Sustainable Food Design

5.1 Carbon Emissions

According to a study in *Nature*, food systems account for approximately one-third of global anthropogenic greenhouse gas emissions. Of these, the largest contribution comes from agriculture and land use (71%), with the rest coming from supply chain activities: retail, transportation, consumption, fuel production, waste management, industrial processing, and packaging [16]. Therefore, reducing carbon emissions in food design has significant benefits for global carbon emissions.

Firstly, reducing carbon emissions in food production. The carbon footprint of the livestock industry is several times larger than that of other industries. Thus "alternative proteins" are a trend for the future. The beef industry research project of the author revealed the staggering land consumption and water footprint of beef production, leading to a proposal to integrate Pennsylvania's beef farm resources and to design farm resources in an overlapping and innovative way to minimize the ecological footprint of the farm (Fig. 4). Zhao and Lin's "Equivalent Exchange - Ecological Footprint of Fish" project uses Larimichthys crocea, the most commonly eaten fish in Chinese family, as the subject of their research, reflecting the overfishing and the use of "garbage fish" (juvenile fish) to feed commercial fish. This shows that consumption-driven fishing has a huge impact on the global ecology.

Fig. 4. The Meat industry Study, Siyang Jing

Secondly, controlling carbon emissions in food transportation. The MIT Media Lab has developed the "Transformative Appetite" project, which is a study of the architecture of pasta that can be flattened inside the package and expanded into various forms when exposed to water, thereby reducing packaging space, improving efficiency and reducing carbon emissions during transportation. Some restaurants have marked the food miles

in their dishes directly on the plates of food, making consumers reflect on the unnoticed carbon emissions of their daily diet and thus be selective in their consumption.

Thirdly, improving the efficiency of food production. MIT Media Lab's Open agriculture project has designed small, high-tech, soil-free growing *computers*. Owners of food computers will be able to share data with each other about the perfect combination of light, water, nutrient, and temperature levels, creating an open-source framework for high-tech indoor agriculture that produces the best tasting food with the least amount of resources.

5.2 Food Waste

The exhibition "Waste age: what can design do" proposes that the Earth's waste is divided into peak-waste and post-waste. Post-waste mainly refers to materials that can be recycled such as mycelium, rice husks, fish farming and agricultural waste. Food waste basically falls into this category. GroCycle's urban mushroom farm project investigates how impossible waste can be turned into edible products through composting, for example, using discarded coffee grounds to make oyster mushrooms. The "Reinventing Food Waste" project by Siyuan Liu counts and sorts the food waste produced by a family of three in a week and provides a guide to making homemade bioplastics. Daily Dump, a company founded by Poonam Bir Kasturi, has designed an odorless home composter to clean up the entire country of India by making the disposal of food waste a part of every family's social responsibility.

6 From Design for Consumption to Design for Crisis

6.1 Extreme Climate and Food Crisis

Since the Covid-19, the world's hungry population has grown again. Poverty, unequal distribution of resources, conflict, climate change, and severe malnutrition are the main causes of this phenomenon. How do you feed a population that is exploding, with limited food, and deeply affected by climate change? Songye Tan's work "ALGAE+: Algae as a Hunger Mitigation Method" attempts to mitigate acute hunger events due to climate, conflict, natural disasters, etc. by using algae as a nutritional supplement and combining it with local food to increase regional resilience to acute hunger events (Fig. 5). Ecologic Studio and Hyunseok An are also experimenting with DIY cultivation of algae at home to provide their own nutrition for everyday use. In extreme drought conditions, designers have also experimented with resilient solutions. Drawing inspiration from the Cape Town drought period when taps were regularly turned off to conserve water, Shakira Jassat attempted to harvest her own water for tea from steamy winter morning showers and frosty dew.

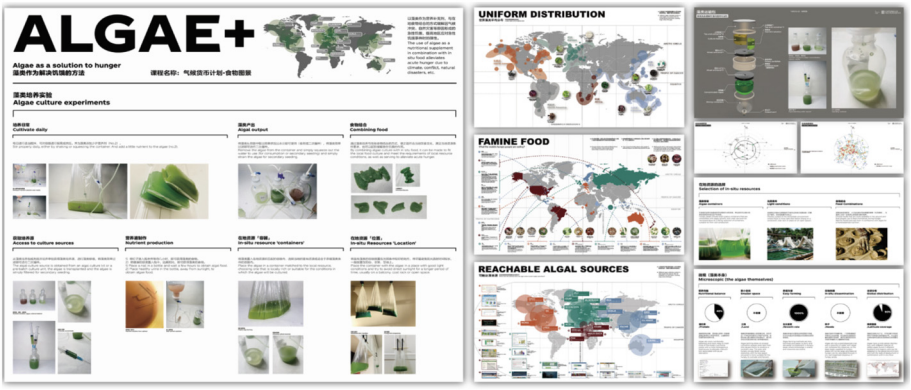

Fig. 5. Student work: Algae+, Songye Tan, in the course of the Vision of Food, School of Design, Central Academy of Fine Arts, China. Instructor: Siyang Jing

6.2 Food Safety and Nutrition

Measuring What Matters in Agriculture and Food Systems, published by the United Nations Environment Programme, states that "Our diets are now a major burden of disease, with more than 650 million people suffering from obesity and over 2 billion affected by nutritional disorders." On the one hand, the misuse of agrochemicals and GMOs since the 1950s has led to a loss of soil fertility and nutritional homogeneity of food. The work "counter meal" by Adriana David conveys the problems of food security, soil fertility and extreme poverty of farmers brought about by the agricultural revolution of that period. On the other hand, consumers don't need to take in extra nutrients. Marije Vogelzang's work Volumes is designed to control overeating by enhancing the feeling of satiety during eating.

6.3 Future Food

In the future, as technology advances and the environment deteriorate, will we develop new ways to consume essential nutrients? Paul Gong's "Human Coyote" project uses synthetic biology to create new bacteria and modify their digestive systems with novel tools so that future humans can digest scavenging food like coyotes. This is a response to the serious food waste or food shortage situation. Space 10's book "future food today" integrates the design practices of future food, from "gutless hot dogs" and "seaweed chips" to "bug burgers" and "miniature green popsicles," and how techniques for using alternative ingredients for culinary innovation (Table 2).

Table 2. The Four-dimensional transformation of food design.

Transformation	Keywords before	vs. Keywords after	Sub-Category	Case Study
From Human-Centered to Life-Centered	Humanism, user-friendly,	Animal, Plants, bacterials, micro-organism ect, inter-species,	The living community	Romie 18, Lala Tam; Endless Nature, Chaoqun Li; Insectology: Food for Buzz, Matilda Boelhauer
			Cross-border integration between multiple species	Oran Catts, Victimless leather; biofabrication, Modern Meadow; Future Food, Next Nature Network;
From Object-Centered to Hyper-object Centered	Individual, local, object, independent	Connected, inter-influential, global, interlocking, chain, loop, causal influence	Global and local	Banana story, Bjorn Steinar Blumenstein; The sample of culture, Xiaoji Zhou;
			Colonialism and class conflict	A Subtlety, or the Marvelous Sugar Baby,Kara Walker; Diasporic Dumplings, Amanda Huynh;
From Experience-Ecology to Post-Carbon Economy	Experience, enjoyment, Novelty, fun	Carbon footprint, ecology, sustainable, carbon control, carbon neutral	Carbon Emission	The Meat Industry Study, Siyang Jing; Equivalence - The Ecological Footprint of Fish Chow and Lin; Transformative Appetite, MIT Media lab; Open agriculture, MIT Media lab

(*continued*)

Table 2. (*continued*)

Transformation	Keywords before	vs. Keywords after	Sub-Category	Case Study
			The waste of food	Daily Dump, Poonam Bir Kasturi; GroCycle;
From design for consumption to design for Crisis	Econonmy, promotion, decoration, selling, branding	Problems, crisis, Prevention, future prediciton, resources redline	Extreme weather and food crisis	ALGAE+, Songye Tan; Algae DIY, Ecologic Studio; Hyunseok An; Tea Drop, Shakira Jassat;
			Food security and Food nutrient	counter meal, Adriana David; Volumes, Marije Vogelzang;
			Future Food	Human Coyote, Paul Gong; future food today, space10;

7 Conclusion

In the context of the global economic downturn following the epidemic, it is more important to focus on design responses at the level of the food crisis, both in terms of individual experience and sensory design around food itself, and in terms of collective ecological and systemic design on a larger scale and across domains. Indeed, food design has received multidisciplinary attention and serves as a key to understanding world systems. The article proposes a sustainable food design paradigm that is de-anthropocentric, de-consumption-centric, de-object-centric, and de-consumption-centric, and instead emphasizes system-oriented, crisis-oriented, and life-well-being-oriented design. The article hopes to expand the network of peers through the exploration of food research, influence public food consumption behavior, and finally establish food values in the post-carbon era.

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