

TE_K **New paradigms on how to achieve zero food waste in future cities – Optimizing food use by waste prevention and valorization**

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1. Context

Cities currently manage uneaten food and other food system based biowaste quite inefficiently. The organic compound, despite its high nutrient value, is only to a small extent recycled and returned to farm soil and therefore, does not contribute to closing ecological nutrient cycles and to supporting sustainable food production [1]. In the US, over 97% of food waste is estimated to be buried in landfills [2]. Forkes has shown for Toronto that only 4.7% at most of food waste nitrogen (including sewage waste) was recovered and/or recycled [3]. For Paris and its suburbs, a similar estimate has been obtained, and this share of nitrogen food waste recycling has been in steep decline in the course of two centuries, from 40% to close to 5% estimated for today [4]. One study has analyzed the nutrient balance (N, P) for Bangkok Province [5]. These studies mainly focus on food waste and sewage waste management from a nutrient recycling point of view.

Furthermore, food waste related resource use and environmental pollution are highlighted as no longer acceptable in the context of global warming and increasing pressure on the planet's limited boundaries [6], [7]. According to an analysis from the Waste & Resources Action Program (WRAP), prevention of 1 ton of food waste can yield in carbon equivalent savings of 3090 kg when food from manufacture or retail is redistributed to people. But savings are much lower when food from manufacture is redistributed as animal feed (220 kg eq CO₂/ ton food) or used for anaerobic digestion (162 kg eq CO₂/ ton food). This analysis illustrates from a climate point of view priority for food waste prevention over food waste valorization.

The problem of food waste is crucial: the FAO estimates that one third of world food production is lost or wasted. In industrialized countries, food waste amounts to close to 300 kg/cap/year in North America or Europe – and more than two third of it occurring at distribution, catering and in-home consumption [8]. A “preparatory study on food waste across the EU 27 Member States” estimates annual food waste generation in the EU27 at approximately 89 million tons, or 179 kg per capita (without agriculture) [9]. Households (42%) and manufacturing (39%) have been identified as the most important food waste producers, followed behind by food services/caterers (14%) and retail/wholesale (5%). The high share of food waste occurrence close to consumption, cities' dense population and the accumulation of waste in periurban areas, together with the numerous socio-technical initiatives coming from both urban citizens and stakeholders are all factors that place cities as important players. Although food waste in cities in Asia, Africa and South America is relatively lower at the downstream stages of supply chains, the fast growing population and changing habits towards urban diets nevertheless raise the question also for these sets on how to optimize food use in cities. The world population is going to become more and more urban, being expected to make up 66% of the world population by 2050 compared to 30% in 1950. Ongoing population growth together with urbanization is expected to increase the urban population predominantly in Asia and in Africa. Today, the most urbanized regions include Northern America (82%), Latin America and the Caribbean (80%) and Europe (73%), but all regions in the world are projected to urbanize further [10].

Our study analyses the specific link between food waste and cities in a zero waste perspective in the future. By using a foresight approach we suggest to identify and discuss key prevention and valorization measures, to pinpoint knowledge gaps on the specific character of food waste in cities and to bring up relevant questions for research.

2. Objectives

Objectives of our work are twofold: i) identify high potential socio-technological innovations in food waste prevention and valorization and ii) extract research questions contributing to fostering and accompanying cities' breakthrough strategies towards zero waste sustainable food systems, spe-

cific to different urban settings worldwide (covering both industrialized and unindustrialized areas). Data collection on urban food waste flows was expected to support the analysis, but could not be accomplished in the course of this study as this kind of data has not been available at urban scale so far, a point that literature on urban metabolism applied to case studies confirms [11], [1]. Our analysis is based on examples most covered by media of food waste prevention and valorization initiatives from European, American or industrialized Asian cities. The lack of literature and of media attention makes us not consider the situation of cities in less advanced countries, although we have been reminded by experts that there exist similar initiatives as well.

3. Methodology

We define food waste as “any food with its edible and inedible parts which leaves the supply chain meant for human consumption”. Included are uneaten food (edible and inedible parts), by-products, organic solid waste and effluents from food processing, preparation and distribution (food industry, caterers, restaurants, shops and artisanal food producers). Sewage waste however has not been considered in this study.

We used a definition of urban scale close to the concept of functional urban regions. Not political or administrative indicators determine “urban scale”, but the influence on activities and prescription of these (for example on farming practices or on waste management) coming from the city. Urban scale according to our definition can therefore include non-urban areas on which the city bears influence.

Twenty experts related to disciplines and fields of interest like industrial ecology, urban metabolism, urban farming, aquaculture systems, waste recovery and processing techniques, law, ethics, system innovation and foresight studies were organized as a working group following a foresight study approach. A literature review, stakeholder interviews (food sector companies, waste management companies, NGOs, local governments) and 5 workshops with the group of experts were being conducted from September 2014 to June 2015.

The 5 workshops allowed:

- The definition of precise objectives and methods of the study (definition of food waste, boundaries of urban food systems, foresight study approach),
- The validation of the method and discussion of a state-of-the-art working paper on initiatives in food waste prevention and valorization,
- The organization of initiatives into broader categories of prevention and valorization measures; combination of measures into coherent food waste reduction scenarios within one business-as-usual and two alternative (green economy, “alter”) food system contexts;
- Set-up of these scenarios according to a typology of different urbanization dynamics (retrieved from the Agrimonde Terra foresight study) [12];
- Identification of key measures expected to have high potential in food waste reduction; multi-criteria analysis of these key measures and identification of issues for research.

4. Results and discussion

4.1 Characterization of food waste prevention and valorization measures

Stakeholder interviews and literature review have shown that innovative approaches in food waste management are abundantly experimented worldwide (for example in Canada, the USA, UK, France and other European countries). Table 1 provides an inventory of the different food waste prevention and valorization initiatives collected in the course of this study.

Food system actors involved are as different as business and catering companies, civil society, NGOs and municipalities.

However, the specific link between these initiatives and urban systems is difficult to identify. Indeed, some of them have been mentioned in relation to cities (for example in Seattle, in New York) which have been known for elaborating an urban food system approach. However it has not become clear from the analysis whether the initiatives’ occurrence is specific to a city’s context or whether they could be occurring as well in rural areas. Furthermore, literature on the topic of food waste prevention has not been found specifically applied to urban settings.

Table 1: Inventory of food waste prevention and valorization initiatives, classified by supply chain stage

	aim	FOOD WASTE PREVENTION	FOOD WASTE VALORIZATION
Supply chain stage			
Farming	-	<ul style="list-style-type: none"> - Better matching of supply and demand due to proximity of consumers with farming (including business and community-based urban farming) - Genetic selection of raw material - Information availability and access - Field gleaning - Urban garden gleaning - Connection between food donors and receivers - Marketing of surplus or of food not according to standards 	<ul style="list-style-type: none"> - Industrial synergies - On-farm composting and anaerobic digestion
Processing	-	<ul style="list-style-type: none"> - Optimization tools for stocks - More resistant packaging - Donation to charities - New products from discarded food 	<ul style="list-style-type: none"> - Animal feed
Logistics	-	<ul style="list-style-type: none"> - Better transport packaging 	<ul style="list-style-type: none"> - Inverse logistics to return food waste to farmers for composting or soil amendment
Distribution	-	<ul style="list-style-type: none"> - Better planning and shelf management - Collaborative management of stock and orders to match both better - Adjustment of sales promotions and sales campaigns - Adjustment/deletion of expiry dates - Stock clearance operators - Tools for matching demand and supply - Processing and delivery at order - Reduced transport duration - Donation to charities - New products from discarded food 	<ul style="list-style-type: none"> - Animal feed - Conversion to energy
Catering, restaurants	-	<ul style="list-style-type: none"> - Incentives to leftover reduction - Price reductions close to shop closing hour - Management tools - Adjustment of plate sizes to clients' appetite - Removal of lunch tray at self-service (canteen and restaurant) - Meals based on "inedible" parts of food - Doggy bags 	<ul style="list-style-type: none"> - Frying oil recycling - Collection for composting and anaerobic digestion
Households	-	<ul style="list-style-type: none"> - Changes in food related habits (e.g. use of a shopping list) - Changes in use of preservation techniques (cupboard organization, freezing, use of canned food, etc...) - Donation - Distribution of food amongst other households 	<ul style="list-style-type: none"> - Use of hens for recycling kitchen waste - Individual or community composting or drying
Technologies	-	<ul style="list-style-type: none"> - Higher yielding technologies at processing - Longer shelf-life - Remaining shelf-life indicator - Analysis and monitoring of consumption data (big data) - For food use (new products, extraction of valuable compounds for food) 	<ul style="list-style-type: none"> - For feed use - Biorefinery - Drying of organic waste - Composting - Anaerobic digestion of food waste
Overarching tools			
Politics & regulation	-	<ul style="list-style-type: none"> - Landfill ban for organic waste - Waste taxation - Obligation in handling of organic waste (separate collection, valorization, ...) - Changes in regulation of product standards - Obligations for food donation to charities - Reduced tax payment schemes due to food donation to charities, recovery of VAT - Certification, labelling - Support to the use of hens as food waste recyclers 	
Awareness raising, education, training to professionals	-	<ul style="list-style-type: none"> - Awareness raising campaigns - Recommendations for food waste reduction (households, catering, ...) - Education and training - Networking tool and exchange of experience 	

4.2 Key measures for food waste prevention and valorization in urban settings

Food waste prevention strategies mainly use communication and awareness raising tools, whereas valorization of food waste mainly aims at energy recovery so far. However, coherent concepts and strategies linking different initiatives are currently missing in most case studies, while single initiatives on food waste prevention and valorization are abundant and using manifold tools (regulation, technology, social innovation).

Based on the initiatives collected for this study, experts have extracted key measures expected to be particularly efficient in food waste reduction and interesting to copy in many different settings.

High potential key measures

- Education of public and training of professionals
- More flexible supply chain specifications,
- Collaborative use of data, flow monitoring and smart sensors,
- Regulation, taxation and financial tools,
- Gradual withdrawal of food from market, selling off, stock clearance, on-site processing and donations,
- Breakthrough manufacturing and packaging technologies,
- Urban practices and urban planning,
- Biomass valorization and biorefinery,
- Fair distribution of responsibility between stakeholders

Key measures identified in the previous stage have been discussed according to a multi-criteria approach both with the experts and during stakeholder interviews. For each measure, analysis key points have been made available as much as possible to show performances, forces and drawbacks. For instance, for the key measure « collaborative use of data, flow monitoring and smart sensors » it has been discussed that a kind of ecosystem of data sharing (production capacity, stock and sales capacities) between stakeholders would be feasible which would enable to produce just-in-time and to diminish food waste. Technologically, a data exchange platform would be possible as well. However, even if the technology is available, its implementation is far from reality. Stakeholders argue that the data is confidential and falls within the scope of data secret; it is therefore difficult to obtain. Furthermore, the economics and profitability of data sharing remains to be proven. Data protection and data ownership are discussed. These obstacles as to the extension of collaborative use of data, flow monitoring and smart sensors are considered highly relevant by stakeholders and experts.

4.3 Perspectives for research on the link between cities and food waste prevention and valorization

Based on the multi-criteria analysis of food waste reduction measures (prevention and valorization), some generic research perspectives specific to urban contexts have been identified:

- **Innovative Logistics** needs to be adapted to urban requirements and limits. The logistics of waste collection and recycling translates into small-scale organized flows. For food waste reduction, close monitoring of supply/demand could entail more frequent delivery of smaller amounts to shops leading to overall higher environmental impacts and congestion. Therefore, innovative logistical networks including supply and food waste collection need to be developed. Furthermore, reversed logistics needs to be considered, for example in urban planning, in order to allow for increased efficiency in the collection. One reason is that recycling infrastructure needs time to become profitable and depends on stable input from waste.
- The **question of scale** is relevant not only for logistics but as well for processing. To what extent should processing and logistics be down-scaled to urban small-scale?
- **Robustness of the supporting system:** Cities services are expected to be increasingly supported by digital information and communication technologies. Smart cities may provide opportunities for improved management of the supply and demand matching, for example by the means of collaborative tools. Yet, the supply of abundant energy may no longer be the unique reference scenario in any case. How can current strongly technology and energy reliant food systems become adjustable to a scenario of instability? What role for alternative preservation options to the cold chain?

- **Urban planning:** How can urban planning back or prompt food waste prevention and valorization measures? What action can be taken by the municipality? Municipal decisions on urban planning can for example include requirements on the nature and share of city infrastructure or surface dedicated to the purpose of food waste reduction.
- **Waste for agriculture:** what is the stakeholders' perception on the "waste character" of organic matter from food waste, an obstacle or an opportunity? Contamination potential for the soil and the water?
- **Social acceptability** of innovation in food waste prevention and valorization in cities. For example social acceptability of livestock in cities, of new packaging and processing technologies for food items, for digital technology based city management?
- What **public health issues** can be relevant (for example infectious diseases from animals and allergies)?

5. Conclusion and outlook

Cities today are acting as laboratories for socio-technological innovations in food waste prevention and valorization, yet coherent concepts and strategies involving the different actors are missing. Technological and cultural challenges remain to be overcome, for example the analysis of "big data" to support alignment of supply and demand, the mutual share of information and joint planning of food supply, and societal acceptance of new technologies. Overall, data on food supply, consumption and food waste flows in cities in order to conduct material flow analysis are challenging to obtain.

In a next step we are going to run fieldwork on food waste flows in four cities (Dakar, Chicago, Antananarivo and Montpellier) to contribute to closing this data gap and to progressing on the urban metabolism approach applied to food systems.

The inventory of food waste prevention and valorization measures doesn't really take into account the diversity of initiatives in cities in the world's less advanced countries. A next step would be to repeat the analysis in developing countries, where population growth rate is projected to be highest in the future. This complementary analysis could be interesting because of the wide diversity of practices observed and claimed by the experts. New tools should be developed in order to access information in those countries despite the lack of literature, such as interviews with local industrials for example.

Key measures for food waste prevention and valorization should be analyzed more deeply and challenged by further stakeholder discussions.

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