

REDUCING CONSUMER FOOD WASTE USING GREEN AND DIGITAL TECHNOLOGIES

ACKNOWLEDGEMENTS

This publication may be reproduced in whole or in part and in any form for educational or non-profit purposes without special permission from the copyright holder, provided acknowledgement of the source is made. The United Nations Environment Programme and UNEP DTU Partnership would appreciate receiving a copy of any publication that uses this publication as a source. No use of this publication may be made for publicity, advertising or resale or for any other commercial purpose whatsoever.

DISCLAIMERS

The views expressed in this publication are those of the authors and do not necessarily reflect the views of UNEP DTU Partnership or the United Nations Environment Programme. Trademark names and symbols are used in an editorial fashion with no intention on infringement of trademark or copyright laws. Mention of a commercial company or product in this document does not imply endorsement by UNEP DTU Partnership or the United Nations Environment Programme or the authors. We regret any errors or omissions that may have been unwittingly made.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, nor concerning the delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does the citing of trade names or commercial processes constitute endorsement.

CITATION

UNEP DTU Partnership and United Nations Environment Programme (2021). Reducing Consumer Food Waste Using Green and Digital Technologies. Copenhagen and Nairobi.

Copyright © 2021 UNEP DTU Partnership

ISBN No: 978-87-93458-06-2

2021

This report is a key output of the project 'Build Back Better: Using Green and Digital Technologies to Reduce Food Waste at Consumer Level' led by UNEP. The project was managed by Ying Zhang, Programme Management Officer of the Economic and Trade Policy Unit (UNEP), under the overall guidance of Fulai Sheng, Head of the Economic and Trade Policy Unit (UNEP), and Steven Stone, Chief of the Resources and Markets Branch (UNEP). Coordination and operational support was provided by Dominic MacCormack (UNEP) and Suzan Lazaro Nshoka (UNEP).

The report was produced in close collaboration between UNEP DTU Partnership and UNEP Economy Division. The research team was led by Simon Bolwig from UNEP DTU Partnership, to which Anne Nygaard Tanner and Paul Riemann, UNEP DTU Partnership, and Barbara Redlingshöfer, National Research Institute for Agriculture, Food and Environment (INRAE), France, also contributed. Ying Zhang (UNEP) led the writing of the Executive Summary and the Conclusion chapter, and contributed to the overall structure and messaging.

The report received further valuable contributions from UNEP staff: Clementine O'Connor, Laetitia Montero, Nils Heuer, Dominic MacCormack, Dina Abdelhakim, Pornphrom Vikitsreth, Paolo Marengo, Norah Mugita, Beatriz Martins Carneiro, Mateo Ledesma, Damjan Rehm Bogunović and Ana Gabriela F. Vergara (intern).

The project team would also like to thank the following experts for their reviews and comments: Karin Dobernig (University of Applied Sciences Wiener Neustadt), Erica van Herpen (Wageningen University), Niels Heine Kristensen (Roskilde University) and Christian Reynolds (City, University of London).

Publication guidance: Solange Montillaud-Joyel (UNEP) and Mette Annelie Rasmussen (UNEP DTU Partnership).

Graphic design and layout: Fabrice Belaire and Monna Hammershøj Blegvad

Cover photo: Stefan Redel, Shutterstock

The report and the project were funded through contributions made to UNEP from the Government of Norway.

TABLE OF CONTENTS

Acknowledgements	2				
Lists of tables / figures / boxes.....	4				
List of acronyms and abbreviations.....	5				
Executive summary.....	6				
1 State of food waste and its consequences	11				
1.1 State of food waste at the consumer level.....	12	3.2 Smart packaging, labelling and storage technologies	32	4.3.5 Recovery through engineered landfill with gas utilisation	60
1.2 Implications for the SDGs	13	3.2.1 Smart packaging	32	4.4 Cost-effectiveness of food-waste reduction interventions	63
1.3 The food-waste hierarchy.....	13	3.2.2 Smart labelling.....	32	4.5 Towards versatile and multidimensional food-waste interventions.....	63
1.4 Cities as major hotspots of consumer food waste	15	3.2.3 Smart logistics	34		
1.5 The role of green and digital technologies	15	3.2.4 Smart storage and disposal (Internet of Things)	34	5 Comparative analysis of five cities ...	65
1.6 About this study.....	16	3.3 Smartphone apps enabling food-waste prevention in households	36	5.1 State and causes of consumer food waste.....	66
2 Understanding the causes of consumer food waste.....	17	3.3.1 Reminder and food-storage apps.....	36	5.1.1 Diversity in patterns and factors of food waste.....	66
2.1 Individual factors.....	17	3.3.2 Integrated consumer apps (food planning, shopping, storage, recipes).....	38	5.1.2 Diversity in socio-economic conditions and food security	66
2.2 System-level factors.....	18	3.4 Smartphone apps enabling food-sharing and redistribution (re-use)	39	5.1.3 Dominance of the informal sector in food provision and waste handling	67
2.2.1 Economic factors.....	18	3.5 Technology as an accelerator of food-waste reduction initiatives	41	5.1.4 Lack of waste infrastructure	67
2.2.2 Social factors, including gender and household composition	20			5.1.5 Data constraints	68
2.2.3 Cultural factors	22	4 Actors, policies and instruments in food-waste reduction initiatives.....	42	5.2 Policy and regulatory instruments.....	68
2.3 Food consumption as a social practice.....	23	4.1 Actors and partnerships in food-waste reduction initiatives	44	5.2.1 Policy incentives and perverse effects.....	70
2.4 Understanding consumer food waste at multiple levels.....	25	4.1.1 Government-led initiatives.....	44	5.3 Partnerships and initiatives seeking to reduce food waste.....	70
3 Green and digital technologies.....	26	4.1.2 Public-private partnerships.....	45	5.3.1 Initiatives targeting local food markets.....	70
3.1 Food-preservation technologies along the supply chain.....	28	4.1.3 Industry-led initiatives	46	5.3.2 Initiatives targeting collaborative consumption.....	70
3.1.1 Thermal preservation (refrigeration, cold chains).....	28	4.1.4 Grassroots initiatives	49	5.3.3 Food banks.....	71
3.1.2 Biological and bio-chemical preservation.....	30	4.1.5 Global and regional partnerships	50	5.3.4 Initiatives targeting food services	71
		4.2 Instruments of consumer food-waste prevention and re-use	51	5.3.5 Partnerships to develop better food-waste policies.....	72
		4.2.1 Public policy and regulation	51	5.4 Opportunities created by green and digital technologies.....	73
		4.2.2 Voluntary agreements	54	5.4.1 Green technologies	73
		4.2.3 Information-based approaches (awareness-raising and information-sharing).....	54	5.4.2 Digital technologies	73
		4.2.4 Consumer information tools, including ecolabeling	56	5.5 From food-waste hotspots to innovation hubs	75
		4.2.5 Behaviourally informed approaches (nudging).....	56	6 Conclusion.....	76
		4.3 Recycling and recovery infrastructure to manage unavoidable food waste....	57	Annex 1. Examples of food-waste interventions in five cities.....	78
		4.3.1 Recycling into animal feed.....	58	Bibliography	81
		4.3.2 Recycling via composting.....	58		
		4.3.3 Potential conflicts between recycling and prevention	59		
		4.3.4 Recovery through waste-to-energy and multi-purpose infrastructure.....	60		

LIST OF TABLES / FIGURES / BOXES

LIST OF TABLES

Table 1.1. Average food waste by World Bank income classification	12
---	----

LIST OF FIGURES

Figure 1.1. The food waste hierarchy	14
Figure 2.1. Environmental Kuznets curve for food waste showing a leapfrogging pathway through prevention and re-use strategies	19
Figure 2.2. Household food practices and the links to food surpluses and food waste.....	24
Figure 3.1. Technologies addressing the prevention and re-use of food surpluses	27
Figure 4.1. The key building blocks of food-waste reduction initiatives: actors and partnerships, instruments, technologies and outcomes in relation to the food-waste hierarchy	43

LIST OF BOXES

Box 1.1. Definitions of green technologies and digital technologies	16
Box 2.1. A gender perspective on food waste	21
Box 3.1. Sustainable cold chains and the Kigali Amendment.....	29
Box 3.2. High-end innovative household storage.....	29
Box 3.3. Air-tight grain packaging in Uganda.....	30
Box 3.4. Bioprotection: increasing shelf-life and freshness the natural way.....	31

Box 3.5. Extending the shelf-life of fresh produce through coating	31
Box 3.6. Gas sensors indicate freshness on meat packaging labels.....	33
Box 3.7. Alerting consumers of expiry/Best Before dates	37
Box 3.8. The OLIO C2C and B2C food-sharing platform.....	40
Box 4.1. Measurement as a basis for reducing food waste in hotels and conference venues	47
Box 4.2. Reducing food waste in food service and catering through IoT scales and a smart menu-planning and tracking platform.....	48
Box 4.3. 'Freedge': sharing surplus food through public refrigerators.....	50
Box 4.4. Date labels explained.....	52
Box 4.5. Mobilizing young people to adopt sustainable lifestyles and avoid waste	55
Box 4.6. A pay-as-you-throw food-waste recycling system in South Korea	58
Box 4.7. Speeding up the composting of food waste in Malaysia	59
Box 4.8. Upgrading the Vinča landfill in Belgrade through a public-private partnership	62
Box 5.1. Policy coordination mechanisms for food-waste reductions in Bogotá	69
Box 5.2. Reducing food waste in canteens: the Chula Zero Waste Initiative in Bangkok	72
Box 5.3. Food-sharing schemes enabled by digital technologies in Bangkok, Belgrade and Bogotá	74

LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating current	NGO	Non-governmental organisation
AI	Artificial intelligence	OECD	Organisation for Economic Co-operation and Development
AP	Active Packaging	PCC	Pacific Coast Collaborative
AOA	Anatomy of Action	PCFWC	Pacific Coast Food Waste Commitment
BBE	Best before end	P2P	Peer to peer
B2C	Business to consumer	PPP	Public-private partnership
C2C	Consumer to consumer	QR code	Quick response code
CO₂	Carbon dioxide	RFID	Radio frequency identification
CO₂eq	Carbon dioxide equivalent	RRR	Reduce-Reuse-Recycling
CSR	Corporate social responsibility	SDG	Sustainable Development Goal
DC	Direct current	SME	Small and medium-sized enterprise
DEB	Data embedded barcode	UK	United Kingdom
EU	European Union	UN	United Nations
FAO	Food and Agriculture Organization of the United Nations	UNDP	United Nations Development Programme
FLW	Food loss and waste	UNEP	United Nations Environment Programme
GDP	Gross domestic product	UNFCCC	United Nations Framework Convention on Climate Change
GHG	Greenhouse gas	US	United States of America
H₂S	Hydrogen sulphide	WBCSD	World Business Council for Sustainable Development
ICT	Information and communications technology	WHO	World Health Organization
IDB	Inter-American Development Bank	WtE	Waste to energy
IFC	International Finance Corporation	WRAP	Waste & Resources Action Programme
IoT	Internet of Things	WRI	World Resources Institute
IP	Intelligent packaging		
IPCC	International Panel on Climate Change		
ISO	International Organization for Standardization		
ITC	International Trade Centre		
MSW	Municipal solid waste		
N₂	Nitrogen		
NFC	Near Field Communication		

EXECUTIVE SUMMARY

The world is facing a food-waste crisis. It is estimated that 931 million tonnes of food were wasted by households, retailers, restaurants and other food services in 2019 [1]. Around 61% of this waste occurs within households.

Reducing food waste offers multiple benefits for people and the planet, contributing to improving food security, cutting pollution, saving money, reducing the pressures on nature and climate, and creating opportunities for economy and society. It is for this reason that the UN's Sustainable Development Goal (SDG) 12.3 sets a clear target of halving per capita global food waste by retailers and consumers by 2030.

The UN Food Systems Summit in 2021 highlighted innovation as the key to transforming the way food is produced and disposed of. Green and digital technologies are playing an increasing role in reducing consumer food waste and driving food consumption towards more sustainable patterns. Cities in both developed and developing countries are well positioned to harness new opportunities arising from green and digital technologies.

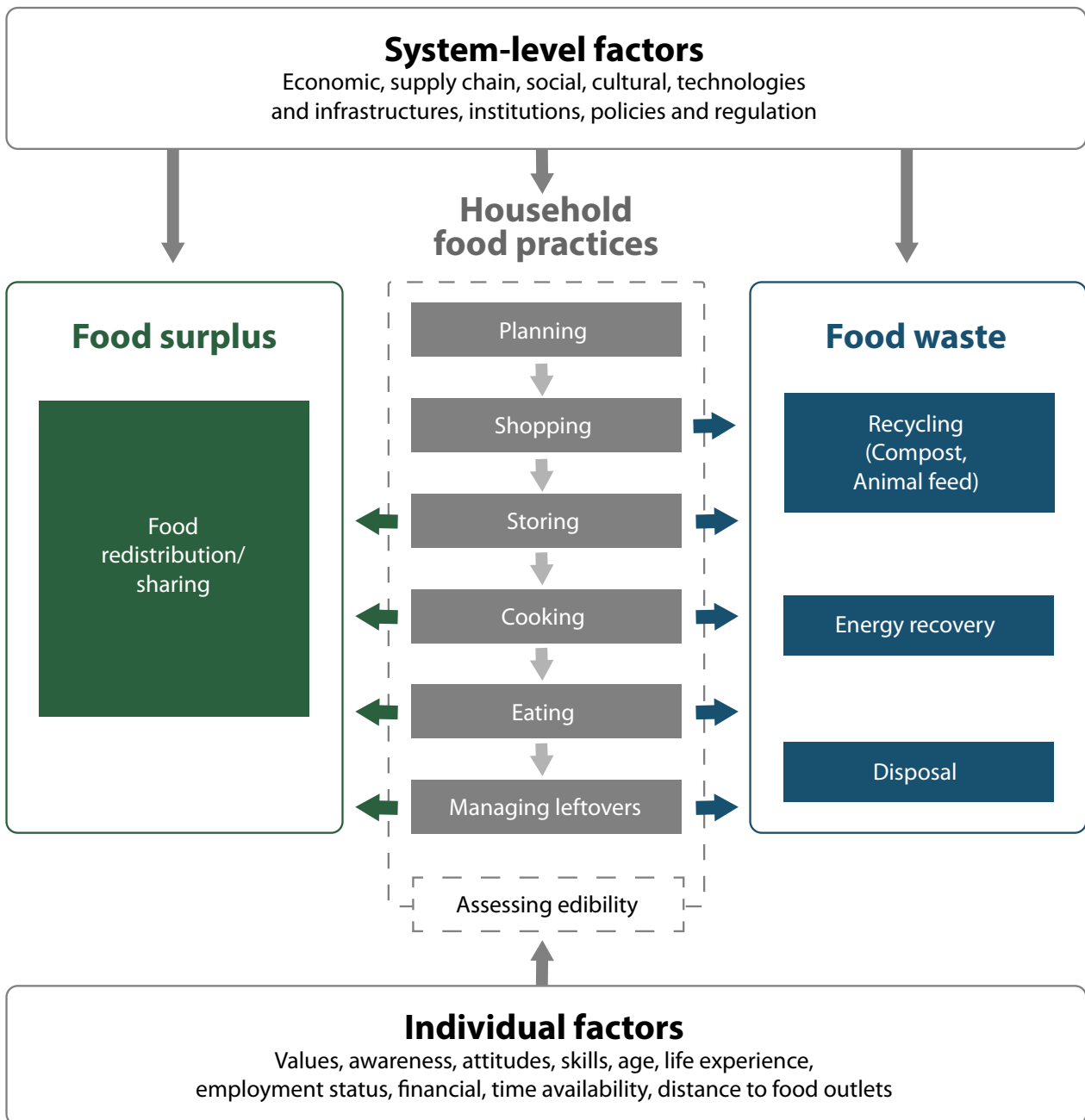
This report provides an overview of the causes of consumer food waste and the opportunities for reducing it through different means: behavioural change, technological solutions, and public and private initiatives to mitigate the problem. This study aims to improve understanding of how green and digital technologies could be used to reduce consumer food waste and what could be done to further unlock this potential. By combining global research cutting across multiple disciplines with city case studies, it aims to provide a comprehensive and integrated approach to support countries and cities in combating food waste and in 'Building Back Better' a more sustainable economy.

Key findings and messages

- **Consumer food waste is driven by intertwined factors at multiple levels** (individual, household, society) **embedded in everyday practices.** These factors include attitudes, knowledge, skills, values, gender, income and living standards, markets, prices, and social and cultural practices, among others. Food-waste interventions thus need to take full consideration of how different factors affect the social practices (e.g., household food practices) that make up peoples' everyday lives.
- **There is a large gap in data and in assessing consumer food waste,** including current status, its economic, social and environmental costs, and future trends. Data for cities is even scarcer, making it difficult to diagnose the problem. None of the five cities covered in this report (Bangkok, Belgrade, Bogotá, Doha and Kampala) has official data systems to measure and analyse consumer food waste. Better data is urgently needed to improve our

understanding of consumer food waste, to support the design and implementation of targeted interventions, and to track progress in achieving related SDG targets.

- **Green and digital technologies are increasingly being used to prevent, reuse and recycle food waste, opening new opportunities for economy and society.** Examples include technologies and innovations in thermal preservation, biological and bio-chemical preservation, solar-powered cold storage, active packaging, waste-to-energy, composting, recycling and upcycling. Emerging digital technologies such as the Internet of Things and mobile applications provide innovative solutions for food-sharing, smart labelling, dynamic pricing, product traceability, intelligent redistribution, planning of shopping and meals, and storage. The list is non-exhaustive, and some measures concerning them have been implemented in the five cities covered in this report.



Food surplus and food waste are generated through households' everyday food practices. Factors at the individual, food-system and social levels influence these practices and the management of the food surplus and waste.

EXECUTIVE SUMMARY

PREVENTION		
Type	Function	Description
Green	Thermal preservation	<i>Refrigeration and cold chains</i>
	Biological and bio-chemical preservation	<i>Use of essential oils and natural extracts in active packaging</i>
Green + Digital	Smartphone apps: Food planning, shopping, storage & cooking	<i>Guide, track and inform consumers in food related choices to reduce food waste</i>
Green + Digital + IoT	Smart packaging	<i>Use of sensors and data carriers to monitor food quality</i>
	Smart labelling	<i>Use of data embedded barcodes (DEB) to improve information about food quality</i>
	Smart storage and disposal	<i>Wifi connected fridges and bins equiped with cameras and sensors to monitor food quality and food quantity</i>
RE-USE		
Type	Function	Description

预览已结束，完整报告链接和二维码如下：

https://www.yunbaogao.cn/report/index/report?reportId=5_31028

