1) Research project (H2020 REFRESH)

Resource Efficient Food and dRink for the Entire Supply cHain

WP4 Behavioural economic approaches and simulation scenarios for food waste prevention, reduction and valorization.

Governments and private actors are increasingly facing food waste management challenges often failing to reach the expected food waste prevention outcomes. Development of a simulation model by integrating methodological - econometric and computational (Agent based Model) - approaches to ex-ante analyse the consumers’ and businesses’ behaviours of relevance for food waste, the technological and social innovation effects, the socio-economic conditions, and the environmental impacts on a multi-scale level.

Furthermore, in a rapidly changing and growing society, the amount of waste enormously impact on the environment and have implication with regards to resources consumption, for example of water used to grow the food. The drivers behind these phenomena are complex and not all of them are known and correctly taken into consideration for policy and business development.

To this extent behavioural economics try to explain why people behave in ways that deviate from traditional economics holds, that human as rational being, make choices to maximize their welfare. As Stewart (2005) observes people make biased decision that sometimes run counter to their best interests. For this reason behavioural economics includes psychological, social, cognitive and emotional factors to study the economic decisions of individuals and institutions and is largely applied to unpick consumers’ behaviours (Baxter, J.L., 1993). For the scope of the project, behavioural economics will provide an in-depth understanding of economic agents’ decisions to develop a DSS tool that enables regulators and managers to intervene more effectively, and in new ways, to secure a better control on food waste phenomena because behavioural factors matter and have to be taken into consideration to tailor largely accepted policies, interventions and business strategies that can drive the change to 30% food waste reduction by 2025.

A bottom-up approach to design nudge effects improving decisions to reduce, prevent, valorise food waste will be used. The variety of conditions, actors and relations underlying food waste, and the nature of changes that a transition toward a sustainable food production, supply and consumption implies, depict a highly complex system. Modelling approaches often tend to be focused on specific phases of the food system. To describe and understand highly complex systems REFRESH is integrating two modelling approaches: Agent-Based Modelling (ABM) and Bayesian networks. The integration into one process allows capitalizing on the strengths of the two modelling approaches and overcoming their specific limitations. ABM is a class of computational models capable to simulate the action and the simultaneous interactions of autonomous agents (both individual than groups) with the scope to assess and predict the emergence of complex phenomena. This type of model has been largely applied in biology (Politopoulos, 2007), ecosystem and natural resources (Bousquet, 2004), land use change (Parker et al, 2003), technological diffusion (Schwartz et al, 2009) and economic and social science (Macy et al, 2002) but its application is new to the waste filed. Gilbert (2007) is convinced that this particular simulation technique is one that can best explain social - economical phenomena, especially due to their capacity to synthesize the reality. An ABM is composed of a computer programme in which actors are represented and characterized by the behaviours the researcher intend to study, and they interact with a given environment. This model allows: to create reasoning agents of different type; endow them with heterogeneity at both decision making rule and agents’ attributing value; introducing agents actions and interactions among them and with the systems described as the environment (it can be a geospatial representation as well as a network of ties). This descriptive capacity and its unique ability to approach complex issues with a bottom- up approach thanks to the agents, is what gives these types of models an additional “gear” in comparison to traditional simulation methods.

Critical point arises when dealing with uncertainty or lack of complete information or only partially describing an agent. In this regards the research has explored the use of Bayesian networks to improve the representation of cooperation between agents (Lei et al., 2005; Kocabas and Dragicevic, 2007) also simulating an interactive spatial planning process. A BN is expected to add capabilities to agents to learn, since BN capacity lies in the ability to depict the extent to which one variable is likely to affect another and
thus one agents to learn from the others (Vergesten et al, 2010). Additional BNs strength includes the graphical depiction of probability structure that makes easy to interpret cause and effect, the provision of direct output concerning likelihood to meet specified targets with uncertainty, the integration of different data sources, capturing and transferring expert knowledge. In REFRESH ABM - BN model will be used to depict both business and consumers behaviours, to investigate how endogenous elements linked to preferences and practices of each actor and the tangible factors linked to the political and socio-economical context, impact on generating/controlling food waste. This model capacity doesn’t end with depicting impacts and effects, as it can go further in testing and explaining the results of applied actions and the emergence of unexpected phenomena. Abstract scenarios have proven effective for eliciting, describing and validating different options being economic, political etc. In this regard the model developed will allow the running of dynamic simulations, identifying different food waste scenarios according to changes in key variables (economic, environmental, political, social, technological) and provide a flexible decision support tool to inform policy makers and private actors on expected outcomes of their choice. The model will provide a comprehensive look at REFRESH Framework for Action and the results will be enclosed in a road map of suggested routes for consumers, business and public authority alike.

Objectives
The main objectives of WP4 are to contribute to an in-depth understanding of business and consumer behaviour with reference to the behavioural economics concepts, to analyse food waste simulation scenarios, to support consumers’, businesses’ and policy makers’ decisions to prevent and tackle food waste phenomena at European and national levels.

WP4_Obj1: Providing new information on consumer and business behaviour by measuring the effects of major tangible factors on food waste, by identifying hidden and emerging profiles of consumer’ and business’ behaviours affecting food waste, and by allowing the detection of intangible food waste drivers. WP4_Obj2: Developing a simulation model by integrating methodological - econometric (Bayesian Networks, BNs) and computational (Agent based Model, ABM) - approaches to ex-ante analyse the consumers’ and businesses’ behaviours of relevance for food waste, the technological and social innovation effects, the socio-economic conditions, and the environmental impacts on a multi-scale level. WP4_Obj3: Enhancing the performance of the food systems, analysing consumer behaviour and dynamics, and facilitating the design of policies and close-to-the market interventions at Pan-European level by testing/simulating the implications of identified major behavioural variables to prevent/reduce food waste.

Description of work
The variety of conditions, actors and relations underlying food waste, and the nature of changes that a transition toward a sustainable food production, supply and consumption implies, depict a highly complex system. To define adequate and effective policies and initiatives is a challenging task, since the multiple actors involved can generate multiple failures. Therefore, since the actors involved are influenced by a multiplicity of drivers and their responses to proposed system changes could not be the one expected, a good understanding of the system is necessary. For this reason behavioural factors matter and have to be taken into consideration to tailor largely accepted policies, interventions and business strategies that can drive the change to 30% food waste reduction by 2025.

In order to deal with this complexity, a bottom-up approach is used to depict with insight of behavioural economics both business and consumers behaviours, to investigate how endogenous elements linked to preferences and practices of each actor and the tangible factors linked to the political and socio-economical context, impact on generating/controlling food waste.

This WP will refer to the Behavioural economics principles and concepts to making better analysis and projections on the food waste phenomena in relation to REFRESH identified actions, and to highlight how these impact positively or negatively on food waste actors’ decisions.

Key to this task is to develop a realistic and reliable tool to support the decision making strategies of policy and industrial makers, therefore to represent the current food supply chains, the interactions among relevant
actors and the drivers of production/ control of food waste in an integrated and holistic way. Agent Based Model (ABM) and Bayesian Networks (BNs) will be used in a synergic fashion. BNs are used to develop a decision support tool facing the waste volume and to identify future research priorities across the whole system using a value of information approach. ABMs are used to model physical aspects of the systems with economic dynamical analyses based on simulation. WP4 will thus pursue a linked data and iterative approach that will exploit and integrate all data captured in WP1, WP2, WP3, WP5, WP6, providing feedbacks on the one hand for additional high-quality, focused, reliable experimental data and information to increase consumer and businesses behaviour understanding. On the other to simulate and thus provide understanding of resistance or positive impacts of targeted solutions.

Main outcomes of this work package are:

- **Integrated scenarios analysis** considering emerging trends and behaviours along the supply chain and the consumption life cycle to predict outcomes and implications of REFERSH interventions.
- **Impact analysis** of REFRESH interventions concerning governance and technological innovation targeting prevention/ controls and reduction of food waste in each case study.

The impact analysis and the scenarios results will flow into a **Roadmap**, designed as a path of integrated solutions that will guide Europe to reach 2025 food waste reduction objectives.

**Table 1. WP4 Structure**


Identification and measurement of the major socio-economic conditions and driving factors that influence businesses’ and consumers’ choices in the creation / reduction of food waste (Source: REFRESH DOW).

A large set of explicit and latent / hidden variables influences consumers’ and businesses’ behaviour determining how efficiently food is produced, processed, delivered and consumed. However there is still a missing knowledge on the causal dynamics that link the major socio-economic conditions and the creation / reduction of food waste. Those missing linkages can be explained through a behavioural economics approach that is based on the influence of different factors - i.e. economic, psychological, social, cognitive, emotional – on the decisions of individuals, institutions and businesses.

The task recognizes the theoretical implications related to behavioural economics integrating the data on consumers and the interventions identified within WP1, the framework of action developed by WP2, the policy approach suggested by WP3, the environmental implications detected in WP5 and the valorization streams identified in WP6. The theoretical background further serves as basis for the development of the integrated
models (ABM, BNs) in Tasks 4.2, 4.3, 4.4, and for the definition of the simulation scenarios and the policy impacts analysis in Task 4.5.

T4.1.1 Narrative of the integration with the other WPs, in particular those on consumer behaviour WP1, businesses engagement WP2, policy approaches WP3, environmental implication WP5 and waste valorisation streams WP6, on the basis of behavioural economic implications.

T4.1.2 Identification of different consumers behavioural economic interrelationships and typologies, across pilot studies, and on the basis of the data provided by WP1, and of the agents’ (i.e. actors and decision makers in the model) basic attitudes and characteristics to be utilized in T4.3.

T4.1.3 Identification of different business behavioural economic interrelationships and typologies, across pilot cases and on the basis of data provided by WP2 and of the agents’ basic attitudes and characteristics to be utilized in T4.4.

T4.1.4 Food value chain management: identification of the economic implications of food waste generation and reduction in terms of price transmission.

T4.1.5 Economics of innovation: identification of the potential economic implications of food waste generation and reduction in relation to innovation deployment and diffusion.

The development of the Agent Based Model (ABM) and the Bayesian Networks (BN), as well as the iterative synergies between the two methodological approaches, leads to a unique integrated model and to analyse food waste dynamics targeting consumers and businesses (Source: REFRESH DOW).

The development of the ABM and the BNs, as well as the iterative synergies between the two methodological approaches, allows to realize a unique integrated model and to analyse food waste dynamics with emphasis on socio-economic conditions and consumer behaviour concerns (Task 4.3). A second model based on the integration between BNs and ABM methodologies is designed and developed to analyse and simulate businesses’ behaviour facing food waste saving innovations (Task 4.4). The last subtask foreseen the integration of the models in a simplified version aimed at putting them into communication.

T4.2.1 Model design and data standardization protocol: definition of the methodological structure of the model and its inner functioning and iterative synergies between its two modules (ABM, BNs); quality of data assurance: a protocol is defined in order to ensure completeness and coherence of the data set.

T4.2.2 Model development (reference run, calibration, sensitive analysis and validation): design and implementation of the integrated system; simulation of reference baseline in order to calibrate the model to the observed food waste dynamics; definition and execution of the necessary sensitive analysis procedures and elaborations; implementation of feedback control procedures for simulation runs.

Analysis of consumers behaviours and dynamics: measure of the influence that main tangible drivers exert on consumers’ choices, identification of the hidden relations among the latter (emerging dynamic clusters), and detection of emerging signals of major attitudes and preferences (WP1) that affect consumer’s decisions in generating / preventing / reducing food and packaging waste in the selected EU pilot Countries (Source: REFRESH DOW)
Socio-economic conditions and consumer choices and habits play a pivotal role in determining food waste generation/prevention/reduction. Thus, it is of paramount importance to understand the determinants of final consumer’s decisions, quantify their impacts on food waste and how they change over time. This task aims at a comprehensive investigation of behavioural economic implications measuring the influence that main tangible drivers exert on consumers’ behaviours, at identifying the hidden relations among the latter (emerging dynamic clusters), and at favouring the detection of major intangible / personal attitudes and preferences (WP1) that affect consumer’s decisions in generating / preventing / reducing food waste in the selected EU Countries. Qualitative and quantitative data are derived from the work carried out in WP1, additional background insights and evidences are produced by Task 4.1. In case of limitation of the data set, Bayesian Networks will be able to provide more probabilistic variables needed by the ABM, through the elicitation of expert opinions.

**T4.3.1** Preliminary simulation: the model receives data inputs from WP1 and runs a first simulation.

**T4.3.2** Detection of socio-economic food waste drivers and of hidden interrelations among behaviours.

**T4.3.3** Simulations: projections and scenarios analysis.


Analysis of businesses behaviours and their modifications over time. Results of WP2, WP5 and WP6 are tested at multi-scale level (pilots) to identify conditions and impacts of food waste related innovations (Source: REFRESH DOW).

This task provides additional clarity with regard to business behaviours and their modification over time. Results of WP2 on changes in detected business’ behaviour and the valorized waste streams identified in WP6 are tested in order to identify the conditions under which entrepreneurs are available to invest and introduce innovation to prevent and reduce food waste in selected EU Countries. Furthermore, conditions influencing the propagation of innovations at Country level are measured and analysed. Qualitative and quantitative data are derived from the work carried out in WP2 (test the set of relation of the selected framework for actions pilots), WP6 (top 5 selected valorisation stream). Additional background insights and evidences are produced by Task 4.1. In case of limitation of the data set, Bayesian Networks will be able to provide more probabilistic variables needed by the ABM, through the elicitation of expert opinions.

**T4.4.1** Preliminary simulation: projection of introduction and propagation of technological innovations.

**T4.4.2** Linking innovations to behaviour economic and investment decisions (panel groups of businesses).

**T4.4.3** Simulations: detection and analysis of emergent behavioural patterns (dynamic clusters), and of the conditions of deployment and propagation of innovation and economic and environmental performances.


Assessment of the impacts of the major food waste prevention policies and interventions, FAs, environmental implications, waste valorisation elaborated by WPs 1, 2,3,5 and 6 using scenario simulations (Source: REFRESH DOW).

This task provides a contribution in assessing the impacts of the major food waste prevention and reduction policies and interventions, framework of actions, environmental implications, waste valorisation streams elaborated by WP1, WP2, WP3, WP5 and WP6 and scenario simulations under the new conditions identified for consumers’ behaviour and businesses investment decisions.
**T4.5.1** Scenarios analysis: simulation runs and comparative analysis of consumer and business behaviours, policy impacts, technological and social innovations on food waste prevention/reduction.

**T4.5.2** Roadmap for 30% food waste reduction by 2025: a plan of interventions to support policy and decision makers that will be developed on the basis of scenario and impact analysis.

**Deliverables**

D 4.1 Socio-economic implications of food waste, *M12*, WUR-DLO.
D 4.2.1 Data protocol Agent Based Model & Bayesian Network model, *M14*, Unew.
D 4.2.2 Integrated model targeting food waste prevention and reduction, *M24*, Unew.
D 4.5.1 Report on Pan-European and integrated food waste scenario, *M42*, UniBo.
D 4.5.3 Roadmap for 30% food waste reduction by 2025, *M46*, UniBo.

**Milestones**

D4.1 Integrated model targeting food waste prevention and reduction analysis, *M24*. 
2) Work plan

The work will focus mainly - but not exclusively - on REFRESH WP4 and in particular on Tasks 4.4 and 4.5 (Please see below). The researcher will support the development of a simulation model by integrating methodological - econometric and computational (Agent based Model) - approaches to ex-ante analyze businesses’ behaviours of relevance for food waste, the technological and social innovation effects, the socio-economic conditions, and the environmental impacts on a multi-scale level.

The researcher will contribute also to the development of scientific publications related to REFRESH Tasks 4.4 and 4.5.


Analysis of businesses behaviours and their modifications over time. Results of WP2, WP5 and WP6 are tested at multi-scale level (pilots) to identify conditions and impacts of food waste related innovations (Source: REFRESH DOW).

*This task provides additional clarity with regard to business behaviours and their modification over time. Results of WP2 on changes in detected business’ behaviour and the valorized waste streams identified in WP6 are tested in order to identify the conditions under which entrepreneurs are available to invest and introduce innovation to prevent and reduce food waste in selected EU Countries. Furthermore, conditions influencing the propagation of innovations at Country level are measured and analysed. Qualitative and quantitative data are derived from the work carried out in WP2 (test the set of relation of the selected framework for actions pilots), WP6 (top 5 selected valorisation stream). Additional background insights and evidences are produced by Task 4.1. In case of limitation of the data set, Bayesian Networks will be able to provide more probabilistic variables needed by the ABM, through the elicitation of expert opinions.*

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**T4.5.2 Roadmap for 30% food waste reduction by 2025:** a plan of interventions to support policy and decision makers that will be developed on the basis of scenario and impact analysis.
Related Deliverables


D 4.5.1 Report on Pan-European and integrated food waste scenario, M42, UniBo.

D 4.5.2 Report on Pan-European impact analysis of food waste scenario, M44, UniBo.

D 4.5.3 Roadmap for 30% food waste reduction by 2025, M46, UniBo.