BETTER
Metaprogramme

INRAE

Bioeconomy for urban areas

Supported actions

2020 / 2023

BETTER Metaprogramme
Bioeconomy for urban areas

According to the UN, close to seven out of ten people in the world will live in an urban zone by 2050, notably in very large cities, compared with barely one out of two today. The trend toward urbanisation in modern societies comes with considerable challenges in terms of waste and wastewater management and the supply of food, but also the supply of energy, materials and water. In addition, city living also comes with mounting problems of congestion and pollution which affect the health and well-being of city dwellers. Lastly, cities are public enemy number one when it comes to greenhouse gases, and as such, are expected to contribute to reaching the climate goals set out In the Paris Agreement.

Challenges for society: how to manage the impact of tomorrow's cities?

The goal of the BETTER programme is enabling the bioeconomic transition of cities, that is, bringing about the socio-economic, organisational, structural and technological changes that will help cities better recover and recycle waste, minerals and organic wastes, and reduce their direct and indirect consumption of fossil carbon with a triple goal in mind: achieve zero net CO2 emissions by 2050, contribute to sustainable development goals, and better withstand shocks caused by climate change and other crises. Currently, we are witnessing a growing awareness that cities are not only places of pollution, but may also harbour solutions.

Scientific challenges: how to implement bioeconomic solutions in tomorrow's urban areas?

The scientific questions we need to answer are:

- How can rolling out the bioeconomy and accelerating circularity within and between cities and the countryside help make cities more sustainable?
- What are the preconditions for these transitions and how can they be achieved?

Tackling them implies:

- Improving the circularity of flows in urban zones but also crossing city-countryside flows with the aim of recycling products, waste, nutrients and water resources, to curb waste and keep pollution in check;
- Studying the potential of expanding the production, transformation and recycling of bio-based products adapted to urban and peri-urban areas, the goal being to make cities less dependent on products made from petroleum and other fossil resources and to mitigate their net greenhouse gas emissions while simultaneously improving cities' resilience and capacity to adapt to global changes;
- Obtaining the necessary tools to evaluate, model and support bio-economic transitions in urban zones and their areas of influence.

Interdisciplinary challenges for a systemic approach

Making the transition to a bioeconomy in urban zones requires a systemic approach that combines bio-tech disciplines and human and social sciences. Technological innovations that lead to new processes are inextricably tied to the way biomass and organic waste products are produced, transported and stored, and to how the socio-economic system, the configuration of urban and rural regions and consumer and citizen preferences evolve.

BETTER represents a research community at INRAE that calls on multi-disciplinary skills and knowledge and is able to work across disciplines to develop a circular and sustainable bioeconomy by concentrating on solutions to the urban challenges of tomorrow.

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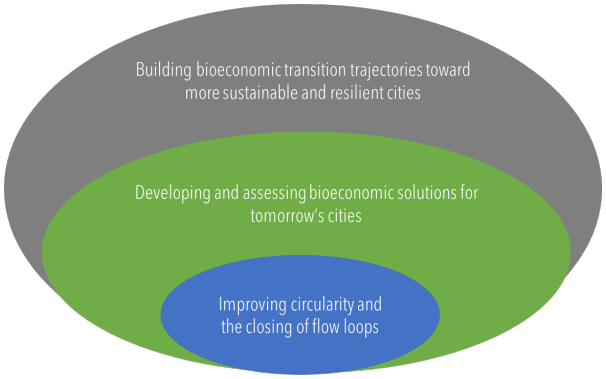
About BETTER

What is an INRAE metaprogramme?

INRAE's metaprogrammes are part of the Institute's coordination and scientific strategy to take on a limited number of problems that require systemic and interdisciplinary approaches to the scientific and societal challenges as laid out in INRAE2030 strategic plan. Metaprogrammes foster interdisciplinary research, forge new scientific communities and provide a network of support for them.

The bioeconomy at INRAE



In 2020, INRAE finalised an interdisciplinary foresight study on the bioeconomy (Axelos et al., 2020). Bioeconomy is defined as the development of a circular and sustainable economy based on the production, transformation and recycling of renewable organic resources. In particular, bioeconomy calls for replacing fossil carbon by renewable carbon, thereby helping reduce greenhouse gas emissions while preserving natural resources and biodiversity and enhancing ecosystem services.

Direction

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BETTER, a new but legitimate domain for INRAE

The challenge of developing a bioeconomy in urban areas is rarely taken up by research entities from a comprehensive perspective. While it falls outside INRAE's typical areas of expertise, the Institute is well acquainted with urban environment. All the skills, tools and disciplines used for studies of the interconnections between the bioeconomic and food dimensions of urban zones and of the silvo-agricultural and environmental stakes are in zones with a direct influence on cities are already applied by INRAE and its research divisions.

INRAE addresses urban-related research through three primary thematic areas: 1/ Urban and peri-urban agriculture, which encompasses initiatives aimed at increasing green spaces within cities, promoting short food supply chains, and, more recently, understanding urban food systems ; 2/ Urban wastewater and biowaste management, focusing on sustainable solutions within urban areas; 3/ Investigating the intricate interplay between urban and rural dynamics, which includes considerations of city size, configuration, and optimal locations in response to land limitations, transportation infrastructure, and resource accessibility.

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The goal of the metaprogramme Bioeconomy for urban territories (BETTER) - and what makes it unique - is combining:

- knowledge of nutrient flows, land improvement and fertilisation practices, associated health risks, and the quality of urban soil;
- skills related to the metabolism and ecology of a region and regionalised agri-food systems;
- skills in modelling and assessing the environmental sustainability of regions and how this relates to data acquisition technologies (including remote data collection), and processing big data;
- skills related to bioprocesses, agri-food processing, eco-design, methanisation, and the reuse of treated wastewater;
- strengths in social sciences to deal simultaneously with economic, social and institutional issues (respectively, the location of activities and modelling markets; perceptions associated with developing the bioeconomy and conflicting uses; and regional governance, collective action, and the role of social values, thanks to interdisciplinary research defined by the scientific strategy of INRAE metaprogrammes.

BETTER brings together around 80 INRAE researchers in an inner circle and some 200 in a broader circle, mainly recruited from the TRANSFORM, ECOSOCIO, ACT, AGROECOSYSTEM, MATHNUM and AQUA divisions of INRAE. Other divisions involved include PHASE, on the place of animals in closing cycles, notably in urban and peri-urban zones; SA on animal health and the risks associated with proximity to humans; MICA on microbial transformation processes and keeping biotic contaminants in check; and BAP on plant species adapted to urban constraints.

A three-fold programme to:

1. Improve the circularity of flows and close the bio-geochemical loop

Today's cities are giant nutrient sinks and treasure troves of waste: they harbour and "absorb" large quantities of commodities, notably foodstuffs. Most frequently, they have a centralised system for managing biowaste and wastewater that comes at a cost for the community (financial, pollution, noise, etc.) and barely contributes to closing the loop when it comes to nutrients and water.

Diagnosing urban and peri-urban metabolisms

The goal is to characterise, quantify, track and model the flow of materials and nutrients that cities require, and to propose metrics to measure cities' impacts on the environment. When it comes to nutrients, INRAE and its partners are already conducting methodological and quantification studies using metabolic approaches to food systems and regions based on regional ecology. Our goal is to **include not only incoming and outgoing flows but also to consider the forms in which nutrients such as carbon, nitrogen, phosphorus (residual sludge, food waste, green waste) are stored, their variability in space and over time, their divergencies and characteristics**. Traditional metabolic analyses also need to be supplemented by analysis of incoming and outgoing contaminants. These diagnoses require improvement of existing databases and the creation of new databases and evolving information systems, including ensuring traceability not only using digital and spatial technologies but also citizen participation.

Re-thinking recycling and recovering residual waste from urban zones

How can reverse engineering best be structured to collect and sort residual waste according to the need for secondary raw materials? Different forms of waste collection and recovery, for example by comparing centralised systems with innovative local solutions such as micro-methanisation, neighbourhood composting, co-generation or biorefineries adapted to urban waste and on a small scale, will be evaluated. These options raise **technological questions linked to infrastructures that need to be re-designed and changes in the scale of transformations**, for example, how to manage the different sources of bio-waste, storage, treatment and pollution over time and at local scale. **Addition, organisational and economic questions concern the uses and distribution of the value of "waste/resources", and societal stakes such as the acceptability of the proposed solutions and management by new bodies**. Further, an understanding is required of how the rules and regulations as well as public policy incentives can make or break transitions, and who are the winners and losers of such changes and potential resistance to change.

Intensify and reorganise nutrient flows within cities and between the city and the countryside

One of BETTER's goals is to close bio-geochemical loops by returning nutrients to the soil in order to maintain the production capacity of agricultural and forest systems in zones that provide food and other resources to urban centres. What kinds of markets and contractual exchanges can be set up in the cities themselves, for example to supply water and fertilisers for green spaces, farms, and urban forests, and

to enable flows between cities and agricultural and forested zones? **How should the city supply areas and assimilation areas be set up to ensure circularity**? What are the expected consequences in terms of the spatial organisation of fertility in cities, in the immediate vicinity of cities, and in rural areas?

Finding solutions to control the fate of contaminants

What will become of biotic and abiotic contaminants in recycling systems or when by-products, organic waste and wastewater are treated as a priority health issue. The phenomena of bio-accumulation and bio-amplification through trophic networks and bio-geochemical cycles, the identification of contaminants, their management and elimination are major challenges cities will have to face if they commit to the recycling and recovery of waste: **how are these contaminants transformed, how do physico-chemical and biological mechanisms contribute to this transformation, how can they be traced and kept in check, how can their volumes and their toxicity be reduced, and how should they be handled to maximise efficiency and close loops?**

2. Achieving sustainability and resilience in the cities of tomorrow via the bioeconomy

One way to reduce the environmental impact of cities, notably their carbon footprint, is to reduce their direct or indirect dependence on fossil fuels to fulfil their food and energy needs, and their supply of materials and molecules of interest. It is a question of re-thinking their organisation and using resources more sparingly, reducing waste at the source, relying to a greater extent on bio-resources, optimising their functionality and uses, and of course, recycling. In an urban setting, this raises specific questions concerning:

1. the analysis of future demand;
2. technological, organisational and institutional solutions for rolling out a bio-sourced urban economy;
3. the articulation of local and global flows and a multi-criteria and multi-scale evaluation of these approaches.

Changing demand for and expectations of bio-sourced products

The new living conditions of city dwellers, their income, practices and preferences (getting around, homes, ways of consuming, packaging, perception of waste, etc.) **will have an effect on both demand for and expectations** of, notably, bio-sourced products and food, but also building materials, the bio-energy mix in cities, and nature-based solutions to replace oil-based technologies. Changes in patterns of consumption and uses will, in turn, affect the volume, nature and location of things to be recycled and of the final waste. These changes must be foreseen in order to identify the most appropriate technology to be developed, and to predict the scale of investments required.

We need to include the production, processing, use, recycling and end of life in the design of bio-sourced products right from the start

When it comes to the location and optimal scale of these activities, there are choices to be made. In cities or far from them? Always bearing in mind what kinds of technology and infrastructure are required to respond to urban needs and constraints: changes in the scale of processes to cope with limited space, safety and security standards, pollution and drawbacks, infrastructure constraints, etc. Assessments will also need to cover the inevitable compromises between local drawbacks and global benefits, and vice versa.

Striking a balance and assessing the coexistence and complementarity of local and global flows

Some cities place their bets on **greater autonomy in terms of food supply**, but also, more recently, on non-food-related autonomy, to reduce their carbon footprint but also to better withstand certain shocks or crises. This is testified by the explosion of local short circuits, the development of urban farms, and ever-stronger public policies in favour of local food projects and the management of the agricultural and forested zones under their aegis. BETTER evaluates these strategies through the lens of sustainable development goals and resilience and aims to **strike a balance** between local supplies and flows from major production hubs in Europe or further afield. These **changes will have an impact on the organisation of zones around cities that needs to be foreseen** to better manage the increased demand from cities (demand for biomass but also for soil), while preserving ecosystems and stepping up the services they provide, including for recreational purposes.

3. Build bioeconomic transition trajectories towards more sustainable and resilient cities

Build both practical and modelling tools for bioeconomic transition pathways of cities and their zones of influence

BETTER fosters thinking about how to close loops and recourse to bio-sourced products and services, with a view to implementing a **simplified model of a virtual urban area** where the impact of different proposed scenarios can be measured concretely. This innovative modelling exercise will serve first and foremost to facilitate exchange between researchers from different disciplines to identify research priorities and data and information gaps.

Establish evaluation methods for transition trajectories

Beyond the scope of cities themselves, it is crucial to assess the trade-offs between impacts on the global environment, local impacts borne by city dwellers, or indirectly by peripheral zones and zones influenced by cities, particularly **when these effects are unequally distributed in space and over time**. This implies improving existing evaluation techniques (territorial life cycle analyses, models for dynamic optimisation, multi-criteria analyses, metabolic assessments) while paying particular attention to whether they enable comparisons between **different transition dynamics.**

Analyse the governance of bioeconomic transitions in cities and regions

The way cities change in the future will also depend on the will of local elected officials, the legislative and incentive tools at their disposal, the involvement of economic actors, and finally, the citizens' commitment to transitions. Can a typology of urban zones be built and linked to transition pathways? How will **such pathways be influenced by confrontations between actors with different interests and ways of thinking?** The skills acquired by INRAE to help farmers and rural areas proceed through the agro-ecological transition will be used to build tools that foster exchange and innovation and bring citizen groups together at different scales, notably in a triangular urban-peri-urban-rural dynamic. The transformative potential of participatory approaches (for example coming together to find practical solutions that are accepted and shared) will be evaluated.

M. A.V. Axelos, L. Bamière, F Colin, J.-Y. Dourmad, M Duru, S. Gillot, B. Kurek, J.-D. Mathias, J. Méry, M. O'Donohue, S. Recous, V. Requillart, J.-P. Steyer, A. Thomas, S. Thoyer, H. de Vries J. Wohlfahrt. 2020. Réflexion prospective interdisciplinaire bioéconomie - Rapport de synthèse INRAE, p 70.

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BETTER, the tools

Annual call for expressions of interest for funding

- **Interdisciplinary consortia**

Consortia (duration 18 months – 10,000 €) are designed to facilitate exchange and interactions between researchers from different disciplines, in the framework of the metaprogramme BETTER. Activities may involve:

- incubation of projects involving new interdisciplinary communities
- writing reference articles
- organising and carrying out scientific events
- organising a research school, summer school, or training programme

- **Exploratory projects**

Exploratory projects (2 years – 50,000 €) propose concrete actions to respond to clearly identified research topics, in line with the priorities and scientific parameters of the metaprogramme. They target original and innovative interdisciplinary projects that cannot easily obtain funding from traditional sources.

- **Flagship project**

A flagship project, which typically spans over two years and ranges in budget from 100,000€ to 300,000€, emerges from interdisciplinary co-construction efforts involving different teams and holds significant scientific and societal relevance. A portion of its funding can come from sources other than research institutions.

Funding from INRAE units. External contributions are possible but do not guarantee the right to MP funding

Science animation

Conferences, meetings, a website, a mailing list, etc…

More information on our website: https://www6.inrae.fr/better_eng

Contact us at: better@inrae.fr

Supported actions

The INRAE BETTER metaprogramme supports interdisciplinary research defined by the scientific strategy of the INRAE metaprogrammes through the funding of various projects, such as consortium-networks or exploratory projects. Since 2020, 7 consortia and 5 exploratory projects have been winners of the 3 calls for expression of interest issued by BETTER. Summary sheets on these projects can be found at the end of this document.

Consortia

CIRCUTEBIO

The ambition of this consortium is to study the extent to which the deployment of Circular Economy (CE) centered on waste collection leads to the coexistence of different waste treatment/recycling models at the scale of urban systems and/or urban areas.

INSECT4CITY

In urban and peri-urban environments, where waste management is an ever-increasing challenge, entomo-conversion offers an attractive solution but naturally also raises questions. Upstream of the development of this high potential research field, this multidisciplinary consortium focuses on global benefit-risk assessment, to identify all the questions the general public, the legislator as well as the insect producers themselves may have concerning this way of valorizing bio-waste.

MOSAIC

MOSAIC aims to bring together communities, both within INRAE, and outside, to better understand the complex metabolism of agricultural and food systems, from production to consumption spaces, with all its systemic and geographical dimensions...

PERIURBANWASTEENG

This consortium is investigating the engineering of agricultural and food waste in a circular flow logic at the scale of a large urban area, which includes the Saclay plateau and the plain of Versailles.

POPCORN

Food plays a determining role in the material and energy flows of an urban zone. In collaboration with researchers focussed on urban metabolism, the POPCORN consortium aims to characterize the population of a region and the food it consumes to identify links with the material flows that take place upstream of agricultural production and of the downstream flows to enable the restitution of waste and prevent and reduce emissions.

REBUS

The RÉBUS consortium focusses on the stakes and the sustainability of the concept of urban environmental biorefineries, i.e. biorefineries fueled by residual urban organic matter (biowaste and by-products from urban agriculture, for example) and whose products can be valorized in the same region.

REUSEINCITIES

Reuse of treated wastewater is at the heart of the water-energy-material-environment nexus, and is a major lever in the mutation of urban zones, in particular because of the large number of available management options, for its treatment or as an object of urban development. A specific reflection on this topic will be undertaken by the REUSEINCITIES consortium.

Exploratory projects

CARIBOU

CARIBOU is interested in bread scraps and unsold bread (RIP) at the production and distribution stages, which represent about 500,000 and 270,000 tons in industrial processing and distribution respectively and are mainly produced in urban and peri-urban areas. The first objective is to better characterize these flows particularly their local specificity.

EDIFICE

The current system of managing the market garden waste produced on the outskirts of Nantes is costly, is a source of tension (bad smell, storage problems) and pollution, and contributes almost nothing to the bioeconomy of the area. The aim of EDIFICE is to develop a wat to judge scenarios based on combining models that will account for the characteristics of the area, the technical and economic performance of the processes plus provide a multi-criteria evaluation of sustainability.

FLY4WASTE

Following the INSECT4CITY consortium, the FLY4WASTE project builds on reflection by the members of the consortium and by the resulting network to start a two-year interdisciplinary research project that will include a thesis. The objective of the project will be to simultaneously evaluate the benefits and risks of recycling of different types of substrates and in particular of biowaste using entomoconversion.

NEWLINK

To fight against food waste in collective catering, the EGalim law (2018) large establishments are the subject of a regulation that obliges them to enter a donation partnership with food aid associations. NEWLINK aims to analyse and optimise the redistribution of unsold meals from collective catering to appropriate associations. First an inventory will be made in order to describe the functioning of the different stages, to identify critical points, and to evaluate the participation of the establishments and associations in the region who are participating in the programme and their relationships with one another. Second, a cost-benefit analysis will be performed to identify effective optimisation strategies. A decision support tool for the collection and redistribution of unsold meals may also be proposed.

TEVALU

The valorization of urine, which is rich in nutrients that are useful for agriculture, is part of a circular economy approach to resources, since phosphorus has to be mined and the production of nitrogen fertilizer requires large quantities of fossil energy. TEVALU intends to optimise a nitrogen and phosphorus extraction process that meets the same criteria as products already on the market while at the same time, evaluating the impact of the process using life cycle analysis. A quantitative analysis of urine deposits and potential outlets for urine-based fertilizers will be conducted in the Toulouse metropolitan area, along with an analysis of expectations in terms of quality and willingness to pay.

Thesis

- Applying multiple barrier approach in participatory and integrated risk management of wastewater reuse projects (Alice-Rose THOMAS)

- Evaluation of the advantages and risks of entomoconversion of urban and peri-urban biowaste by the insect Hermetia illucens – focus on the bioaccumulation of micronutrients and micropollutants (Marie PAPIN)

Distribution of the actions along the programming axes

The 12 projects are spread across the 3 programming axes of our guiding document, and some are positioned in more than one of BETTER's thematic proposals.

Distribution of consortia on BETTER's programming axes. The increasing intensity of the colour from pale grey to black reflects their contribution to the axis (the bigger the contribution, the more intense the colour)

THEMES		2021	2021 - 2022					
		INSECT4CITY	PeriUrban WasteEng	MOSAIC	CIRCUTEBIO	REBUS	REUSEinCITIES	POPCORN
Ensuring circularity of flows and closing the loop of biogeochemical cycle	Diagnosing urban and peri-urban metabolism							
	Rethinking the recycling and recovery of waste products from urban areas							
	Intensifying and reorganising urban-urban and urban-rural nutrient floe							
	Identifying solutions to control the fate of contaminants							
Achieving sustainability and resilience in the city of tomorrow through the bioeconomy	Foresee changes in and expectations of biobased products?							
	Include the production, transformation, use, recycling and end of life of biobased products right from their conception							
	Think about and evaluate the coexistence and complementarity of local and global flows							
Building bioeconomic transition pathways towards more sustainable and resilient citie	Build tools to enable the creation of scenarios and the modelling of bioeconomic transition pathways for cities and their zones of influence							
	Design methodologies to assess transition pathways							
	Analyse the governance of bioeconomic transitions in cities and regions							
Feeding ourselves with and through the city								
Making the most of water and urban waste								
Decarbonising the city								
The metabolism of cities								
Transforming the city for tomorrow								

Distribution of exploratory projects on BETTER's programming axes. The increasing intensity of the colour from pale grey to black reflects their contribution to the axis (the bigger the contribution, the more intense the colour)

THEMES		2021	2022			
		TEVALU	FLY4WASTE	NEWLINK	CARIBOU	EDIFICE
Ensuring circularity of flows and closing the loop of biogeochemical cycle	Diagnosing urban and peri-urban metabolism					
	Rethinking the recycling and recovery of waste products from urban areas					
	Intensifying and reorganising urban-urban and urban-rural nutrient floe					
	Identifying solutions to control the fate of contaminants					
Achieving sustainability and resilience in the city of tomorrow through the bioeconomy	Foresee changes in and expectations of biobased products?					
	Include the production, transformation, use, recycling and end of life of biobased products right from their conception					
	Think about and evaluate the coexistence and complementarity of local and global flows					
Building bioeconomic transition pathways towards more sustainable and resilient citie	Build tools to enable the creation of scenarios and the modelling of bioeconomic transition pathways for cities and their zones of influence					
	Design methodologies to assess transition pathways					
	Analyse the governance of bioeconomic transitions in cities and regions					
Feeding ourselves with and through the city						
Making the most of water and urban waste						
Decarbonising the city						
The metabolism of cities						
Transforming the city for tomorrow						

Metaprogramme BETTER - 2020-2023
Supported actions

Consortium	
CIRCUTEBIO	Circular economy models for urban areas: what transitions towards a bioeconomy?
INSECT4CITY	Benefits and risks of using entomoconversion to recycle bio-waste from urban and peri-urban areas
MOSAIC	Metabolism of agricultural and food systems along the city-hinterland continuum
PERIURBANWASTEENG	Toward agricultural and food waste engineering in increasingly urban peri-urban areas: how can waste be transformed (or not) and for what uses?
POPCORN	Research network on populations and their food consumption in urban areas
REBUS	Research network for a sustainable urban biorefinery
REUSEINCITIES	Network for reuse of treated wastewater in cities
Exploratory Projects	
TEVALU	Urine recovery in urban areas
CARIBOU	Circularlty of bakery production
EDIFICE	Assessment of biorefineries to recover market gardening waste near the city of Nantes (France)
FLY4WASTE	Assessing the risks and benefits of the entomoconversion of urban and peri-urban biowaste by the insect *hermetia illucens*
NEWLINK	New link in the cold chain between collective catering and food aid associations: inventory, cost-benefit analysis and optimisation strategy
Thesis	
Applying multiple barrier approach in participatory and integrated risk management of wastewater reuse projects	
Evaluation of the advantages and risks of entomoconversion of urban and peri-urban biowaste by the insect *Hermetia illucens* – focus on the bioaccumulation of micronutrients and micropollutants	

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Bioeconomy for urban areas

CircuTeBio

Consortium 2020

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Circular economy models in urban areas: what transitions towards a bioeconomy?

> Articulate and compare field observations and model simulations of the bioeconomic transition

Context and challenges

In 2018, the European Union revised its bioeconomy strategy by shifting the focus onto the development of the circular economy, seen as an alternative to a linear economy, reducing both dependence on resources and the cost of waste management. Given the forecasted growth of urban systems and growing demand for food, energy and water, along with the production of waste associated with their growth, the development of these sectors based on the principles of the circular economy is a major challenge but also a way to support the ecological transition in cities and their zones of influence.

The challenge of developing the circular economy stems from the fact that managing waste requires changes to production models, notably in favour of the use of secondary resources.

It is essential to identify the technical, economic, social and policy-related components of the diversity of models and then to analyse the significance of the diversity for the models. For instance, will diversity lead to confrontation, competition, porosity or hybridization between models?

Goals

In this political context, the goal of CircuTeBio is to study the extent to which the Implementation of a circular economy based on waste collection would enable the co-existence of different waste treatment/recycling models at the scale of urban zones and systems. How would the different models help transform waste into resources, incorporate secondary resources into production processes, and re-define the relationships between urban systems and rural spaces? After having served as markets to be conquered, can cities become major suppliers of secondary resources?

The project targets waste produced in cities - be it from households or economic activities such as – and pays particular attention to waste of bioresources.

A gap has already been detected between, on the one hand, models that prioritise environmental safety through large-scale infrastructures and, on the other hand, society's demand for reversible,

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Bioeconomy
Urban/peri-urban areas

INRAE divisions
AQUA
ECOSOCIO
MATHNUM
TRANSFORM

participatory locally anchored projects. The project will seek a meso-economic understanding (i.e. socio-technical systems), the pathways of possible changes and the effects of such divergences.

To reach this goal, the researchers from the consortium combining their respective skills in a multi-disciplinary approach. The challenge facing this new consortium is uniting different perspectives and skills to identify different models for waste "sectors" in urban systems and to question their co-existence and porosity.

Project members

INRAE division	Units	Expertise and contributions
AQUA	UR ETTIS	Sociology, urban waste policy
ECOSOCIO	UR ETTIS	Institutional economics of bioeconomy sectors Sociologist, environmental justice Political science, political forest economy Geographer, analysis of socio-technical systems Economy, network analysis
MATHNUM	UR LISC	Simulation of social systems
TRANSFORM	UR OPAALE	Technical, environmental and spatial optimisation of residual biomass recovery sectors

Partners	Team	Expertise and contributions
NEOMA BS	Chaire de Bioéconomie Industrielle	Economy, Bioeconomy Sociology
Université Paris 8	Ladyss	Economy, Transition studies
URCA	Regard	Economy bioeconomy

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Bioeconomy for urban areas

INSECT4CITY

Benefits and risks of using entomoconversion for recycling biowaste from urban and peri-urban areas

Consortium 2020

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Insects
Urban/peri-urban zones

INRAE Divisions

ALIMH
AGROECOSYSTEM
ECOSOCIO
MATHNUM
MICA
PHASE
TRANSFORM

Incorporating entomoconversion in a circular bioeconomic approach

Context and challenges

Insect farming (entomoculture) is seen as an ecological way to recycle waste or organic residue and recover agro-industrial joint products (entomoconversion). Several countries such as the Netherlands have taken an interest in entomoculture for several years and consider insects to be a credible way of producing food for animals and even for humans. In France, several companies (Ynsect, Agronutris, Nextalim, Mutatec, Innovafeed, Invers, etc.) have embarked on the mass production of insects at different scales depending on the company, the insect and the growing media. In an increasingly urban world, one of the major challenges today is recycling biowaste and organic residue by entomoconversion in urban and peri-urban areas (BioMiMetiC start-up) with the specific questions that raises in terms of growing media heterogeneity, controlling health risks, and environmental, economic and societal consequences (acceptability, drawbacks, etc.).

Goals

In urban and peri-urban areas, where today waste management is a bigger challenge than ever before, entomoconversion is an attractive solution but also raises specific questions concerning the variability of biowaste, controlling health risks, and regulatory and societal constraints. This cross-disciplinary consortium focuses on overall benefits-risk assessment, and has brought together no less than eight INRAE divisions to date. Upstream of the development of this very high-potential sector, the consortium will address all the questions facing the public at large, lawmakers and insect farmers when it comes to using this method of recovering biowaste. The consortium focuses on the potential ability of entomoconversion to recover biowaste/organic residue in urban and peri-urban areas with all that implies.

A major goal is to overcome stumbling blocks to the implementation of entomoconversion in a circular bioeconomy approach.

Project members

INRAE division	Units	Expertise and contributions
AGROECOSYSTEM	UMR ITAP	Economic and social impacts of insect culture
ALIMH	UMR C2VN	Nutrition, bioaccumulation of micronutrients and phytochemicals in edible insects
	UMR CSGA	Sensory acceptability, organoleptic drawbacks
ECOSOCIO	UMR SMART-LERECO	Societal acceptability, economic evaluation
MATHNUM	UR LISC	Societal acceptability, social impact of innovations
MICA	UMR MICALIS	Insect health and microbiological safety in insect culture
	UR LBE	Microbial ecology
	UMR SECALIM	Microbiological safety, benefits-risks evaluation of health/food
PHASE	UMR BOA	Zootechny, animal nutrition, insect protein in animal nutrition
	UMR SAS	Environmental impacts of entomoculture, role of insect farming in circular bioeconomy
TRANSFORM	UR QuaPA	Chemical safety
	UMR IATE	Multi-actor/criteria evaluations, benefits-risk analysis
	UMR SAYFOOD	Procedures for processing insects
Partners	**Units**	**Expertise and contributions**
Université de Tours-CNRS	UMR IRBI	Insect biology
CNRS	UMR GEPEA	Procedures for processing insects for feed or food
SYSAAF	Antenne de Nouzilly	Genetic selection of insects

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Bioeconomy for urban areas

MOSAIC

Consortium 2020

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Metabolism of agricultural and food systems in the city-hinterland continuum

> Material and energy flows between the city and the countryside, questioning agri-food systems: relocation, valorisation of biomass for purposes other than food, combatting soil artificialisation...

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Keywords

Urban metabolism
Nexus WEFE
(Water energy food Environment)
Flows
Bio-economy
Urban/peri-urban areas

INRAE divisions

ACT
AGROECOSYSTEM
AQUA
TRANSFORM

Context and challenges

Bioeconomic strategies consist of ramping up and diversifying the use of biomass, in particular biomass of agricultural origin (products and by-products), via technological innovations (in a broad sense).

For researchers, the ambitions of the bioeconomy raise the question of the capacity of ecological systems and natural resources to support economic activity and renew themselves, The challenge is to understand the interactions between activities that produce, process, recover and consume biomass at a systemic rather than sectorial level, and to account for how the water, energy and land resources that underlie these activities come into play.

The relationships between where and how produced, processed and consumed and waste/by-products are collected are an essential part of this challenge. Yet, analyses of the flows of agricultural biomass and, more broadly, of natural resources, waste, sources of energy, sources of value and of human capital that link cities with their hinterland are conducted by individual communities, each of which has its own issues.

Goals

The MOSAIC consortium focuses on the complexity of flow systems that geographically and systemically link cities to their hinterland. Research that requires this perspective include the interlocking dynamics of agricultural and food systems, the vulnerabilities of specific areas caused by ripple effects, the organisation of relaationships between a city its hinterland and how they co-evolve.

MOSAIC is based on sharing and increasing mutual knowledge between researchers by using (among others) socio-metabolic approaches and integrated modelling and assessment

approaches to study agricultural and/or food systems in different types of regions. The goal is to achieve a balanced view of the hinterland-city relationship, in a co-evolving and systemic perspective. MOSAIC makes it possible to pool knowledge and networks related to "water", "food", "energy", and "waste/by-products" when allocating resources (food vs. energy; feed vs. food, etc.) between spaces, uses, and users.

Project members

INRAE divisions	Units	Expertise and contributions
ACT	UR LESSEM	Ecological economics, systems agronomy
	UR LAE	Integrated modelling
	UMR INNOVATION	Systems agronomy, food
AGROECOSYSTEM	UR LAE	Integrated modelling
AQUA	UMR G-EAU	Water science
TRANSFORM	UR OPAALE	Bioengineering, environmental engineering, environmental evaluation, systemic approach (waste and by-products)

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Bioeconomy for urban areas

PeriUrbanWasteEng

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Key words

Flows
Territory
Biowaste
Bioeconomy
Circular economy
Urban/peri-urban areas

INRAE divisions

ACT
AGROECOSYSTEM
ECOSOCIO
TRANSFORM

Toward agricultural and food waste engineering in increasingly urban peri-urban areas: how can waste be transformed (or not) and for what uses?

> Promote circularity by valorising and reducing waste

Context and challenges

Food systems (agricultural production, transport, storage, processing, distribution, purchasing, consumption) produce waste at every stage and in different ways depending on the situation and region, and involve different actors: farmers, processing professionals, associations, households, restaurant owners and caterers, and ultimately everyone who eats. The corresponding carbon footprint is estimated at more than 3 billion metric tonnes of CO2 per year, i.e., 6.7% of global greenhouse gas emissions.

Goals

Reducing waste is possible "at the source", by limiting losses and waste, but also through a logic of circularity of flows, by promoting the use of some waste as raw material for other uses. That is why our consortium wishes to further explore waste engineering by applying the logic of circularity of flows not only to reduce waste but to recover it. A suitable scale to carry out such studies seems to be local, i.e., at a limited and consequently manageable scale. That is why we suggest this project Is limited to Saclay plateau and Versailles plain. The research objective of our network is to exploit agricultural and food waste engineering in increasingly urban peri-urban areas to answer the following question: How should waste be transformed (or not) and for what uses?

Answering this question requires analysing the current situation and understanding stakeholders' and consumers' expectations. On this basis, we will explore the potential of combining better waste recovery (the idea being a domino effect rather than traditional solutions with little added value) and reducing waste (and consequently the associated impacts). With this aim in view, we will promote more efficient economic and ecological business models while at the same time accounting for how the system is organised (stakeholders; institutions; processes; relationships

between the different components of the system; the scope and limits of the system and interactions with the outside world.

The specific goals of this project are the following:

- **Build a shared understanding of how waste management is currently organised and identify the associated regional stakes:**
  - make an inventory of available data (by consulting ongoing projects, actors in the field, etc.) that offer insights into the typology of agricultural and food waste, where the different types of waste are found and how waste products are currrently used on the Saclay plateau and Versailles plain;
  - Synthesize data to quantify flows and grasp the current organisation of systems and the associated regional stakes;
  - Assess the expectations of stakeholders, including consumers, when it comes to the issue of waste management.
- **Define common interdisciplinary research topics to take up these challenges, by designing collaborative projects.**
  - To this end, we will organise innovative design workshops based on the KCP method, which has already proved useful in pinpointing original interdisciplinary topics

Project members

INRAE division	Units	Expertise and contributions
ACT	UMR SADAPT	Local governance of the circular economy, Environmental socio-economics, Sociology of Law, Urban metabolism, material flow analysis, analysis of food waste
	UMR LISIS	Describing uses
AGROECOSYSTEM	UMR AGRONOMIE	Agronomy, coupled innovations
	UMR ECOSYS	Agronomy, soil sciences, effects of returning Organic Residual Products (at plot and regional scale) to the soil
ECOSOCIO	UMR ALISS	Management sciences (regulatory models, public action, consumers'/stakeholders' expectations, forecasting)
TRANSFORM	UMR SayFood	Processing and bio-processing procedures (food / bio-products), Eco-design, Process engineering – re-territorialisation of food processing, Eco-design
	UR PROSE	Sensory engineering, consumer sciences, food waste, Environmental biotechnologies, waste management and recovery

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Bioeconomy for urban areas

POPCORN

Consortium 2020

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Key words

Food consumption
Territorial metabolism
Databases
Diagnostics
Lifestyles
Bioeconomy
Urban/peri-urban areas

INRAE divisions

ACT
AGROECOSYSTEM
ECOSOCIO
MATHNUM
TRANSFORM

Research network on populations and their food consumption in urban areas

> Characterise the population of a region and their food habits with the aim of identifying links with the flow of materials

Context and challenges

Cities are major players in food flows. Indeed, the majority of the world's population already live in an urban setting, a phenomenon that is expected to increase in the future. Cities are places of transit that attract populations and places where various products are routed. They fundamentally structure the flows of material and energy as well as the resources and energy required and the resulting pollution. Food plays a decisive role in the flows of material and energy In an urban area. Upstream, food systems influence the supply areas, both in terms of the gross volume to be transported and the nature of the products concerned, as urban lifestyles are intricately tied to diets that contain more fat, sugar, meat and processed foods. Downstream, urban populations are a major source of discharge in the form of organic matter via human excreta and food waste.

Multiple challenges face urban food systems and concern both scientific aspects such as identifying the supply areas, modes of production and processing, the food footprint of cities, food relocation, waste management, nutrient recovery and governance of relations between the city and the hinterland. On a more operational level, a growing number of local authorities are interested in relocating part of the city's food supply and reducing its carbon footprint and other sources of pollution within the framework of public policy schemes (for example regional food projects, city food policies, circular economy plans, waste management plans).

The research requires defining exactly who eats in the area, in what form, and In what conditions, as these are the factors that influence and determine both upstream and downstream flows. Characterisation of "the eating population" is therefore an essential prerequisite for many of the issues involved in current research on the food bioeconomy.

Goals

The POPCORN consortium is interested in overcoming two blind spots in the above mentioned research fields. The first one concerns the quantification of the eating population, which is usually based only on the residential population (legal population of municipalities) using census

statistics from INSEE. Yet the additional population (e.g. tourists, commuters) also needs to be accounted for as well as the time they spend in the area. The second blind spot concerns the way in which food consumption is connected to other dimensions of the system, notably agricultural production upstream, and waste production downstream.

The ambition of the POPCORN project is to work on these two complementary dimensions: the eating population and its food consumption, and the transformation of food, thus enabling more reliable quantitative analysis of the materiality of the food system of a given area by connecting agricultural production with consumption and waste – sectors that are often Investigated apart. The aim of the project is thus to create a research network that will gain a broad understanding of the eating population in urban food metabolism studies. To this end, the project will propose resources that can be exploited as a prerequisite for other work on the urban bioeconomy using metabolic approaches to food consumption (e.g., supply areas; agricultural production) and also downstream of consumption (production of waste, losses, management of by-products).

Project members

INRAE division	Units	Expertise and contributions
ACT	UMR SADAPT	Agronomy, Ecology, food autonomy, relocating food production, losses and waste, food waste
AGROECOSYSTEM	UR ITAP	Environmental assessment, life cycle analysis (LCA)
ECOSOCIO	USC1CMH Centre Maurice Halbwachs	Sociology of food
MATHNUM	UR TSCF	Information systems
TRANSFORM	UMR SAYFOOD	Bioengineering, environmental engineering, environmental assessment, systems approach (waste and by-products)

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Bioeconomy for urban areas

RéBUS

Consortium 2020

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Research network for sustainable urban biorefineries

> To understand interactions between the activities that produce, transform, value and consume biomass in a systematic rather than sectoral way, and to account for the dynamics of the water, energy and land resources that underpin these activities

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Keywords
Waste
Organic by-products
Residual organic matter
Biorefinery
Territory
Urban / peri-urban areas
Sustainability
City

INRAE divisions
ACT
AGROECOSYSTEM
ECOSOCIO
TRANSFORM

Context and challenges

Cities and their surrounding areas are a veritable treasure trove of organic waste. For more than a century, the management of residual organic material (waste, joint products and by-products) has been organised around "end-of-pipe" procedures (incineration and storage). Today, there is a shift toward waste recovery and contributing to a circular bioeconomy. Technically speaking, two major strategies for recovering residual biomass already exist: recovering energy and recovering matter. Biorefineries, a concept developed in the 2000s as a viable alternative to oil refineries, allow for this double recovery (matter and energy) by so-called "domino effect" processes. In the 2010s, the biorefinery concept was extended to include the recovery of residual biomass (environmental biorefineries). There is a need to combine the environmental benefits of biorefineries as an alternative to oil refineries, and to recover residual bio-resources.

We also need to constantly think about "tomorrow's waste", i.e. design systems that account for the way the quantity and composition of waste is likely to change, resulting from new trends in consumption. The challenge is to understand the interactions between how biomass is produced, processed, recovered and used in a system as a whole, rather in each individual sector, and to grasp the dynamics of water, energy and land resources that underpin these activities.

The idea of a truly urban and peri-urban environmental biorefinery, that is, designed to be incorporated into cities or their vicinity, is novel and has not yet been the subject of publications.

Goals

The RéBUS consortium was created to explore the stakes and sustainability of urban environmental biorefineries, that is, biorefineries that source organic residual urban matter (biowaste and by-products, for example from urban farms) and produce matter that can be used in the same region. The goal of RéBUS is to "plant the seed" for interdisciplinary thinking about

the concept of urban environmental biorefineries by tapping the diversity of topics and disciplines that comprise INRAE research. This implies identifying the related stumbling blocks, in order to predict potential interdisciplinary research projects that combine the technical, environmental, economic and social aspects of sustainable development.

Many different scientific issues arise from such a concept ranging from the technical adaptation of existing procedures to technological innovation to societal relevance and identifying inputs and outputs. Other questions also arise concerning the behaviour of the different actors involved, governance, economic and business models, compromises with other strategies and public policy, regulations, the size and setting up installations in the region concerned, their impacts, drawbacks, and interactions with urban farming (in terms of both refinery inputs and outputs). What is more, the need for compromise with other strategies and public policy raises the question of assessment and the assessment tools that need to be developed. In particular, the need to take the economic and social stakes into consideration that simultaneously contribute to resource flows underlines the benefit of using an ecological economic approach. In other words, an interdisciplinary approach is indispensable.

Project members

INRAE division	Units	Expertise and contributions
ACT	UMR SADAPT	Territorial agronomy, relationships between a city and its hinterland, agricultural transition, agri-food metabolism, urban food systems, the eco-socio-economic aspects of residual biomass recovery facilities.
	UMR LAE	Bioeconomy, energy and ecological transition of regions
AGROECOSYSTEM	UR LBE	Technological, sanitary, regional and environmental characterisation and optimisation of residual biomass recovery processes and sectors
	UMR ITAP	LCA and environmental evaluation of regions
ECOSOCIO	UMR MoISA	Economy, management and marketing. Business models, behaviour of consumers/users of products from biorefineries, organisation of new markets
	UMR BETA	Economy, coupling economic models (partial equilibrium, multi-agent) and models from other disciplines (LCA, Material Flow Analysis, etc.)
TRANSFORM	UR PROSE	Technological optimisation and innovation of residual biomass recovery processes; microbial ecology, modelling, systemic approaches
	UR OPAALE	Technological, territorial and environmental optimisation of residual biomass recovery sectors, LCA
	UR QuaPA	Recovery of livestock slaughter residue (by-products and household waste), regulatory watch
	UR LBE	Technological, sanitary, regiojnal and environmental characterisation and optimisation of residual biomass recovery processes and sectors
	UMR FARE	Transformation and recovery of lignocellulosic biomass using bio-technological methods
	UR BIA	Plant biomass fractionation, biobased materials, modelling and knowledge engineering

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Bioeconomy for urban areas

ReuseInCities

Network for reuse of treated wastewater in cities

> Improve the quality of water and water reuse, increase ecological connectivity, render urban landscapes attractive and provide ecosystem services that contribute to the creation of a circular water economy

Context and challenges

The management and reuse of urban wastewater must go beyond the treatment of water and its recycling in an industrial context or for irrigation on farms. If wastewater is to be incorporated into urban ecosystems, the entire small water cycle needs to be redesigned, from identifying all available resources in a given region to characterising all possible uses and their constraints In all socio-technical systems that allow water to be treated, transported, stored and (re)distributed. The cities of tomorrow will be home to 70% of the world's population, and cities will be where the majority of wastewater will be produced. Current urban metabolism mobilises production zones most often located in rural areas, far from urban centres. While support for the development of urban farms to make cities more resilient in the face of global shifts (relocation of production and making cities greener) is promising, it has its limits. Re-using wastewater is one Important way to face up to the challenges linked to changes that are already underway. Its central location in the water-energy-matter-environment nexus makes water an essential component of the bioeconomy in urban zones.

Goals

The ReuseInCities consortium strives to use this systemic approach under the regulatory, socio-economic, health and environmental constraints the network is designed to overcome. Reuse is inseparable both from the territory involved whose potential for implementing a new form of management of water flows and/or the associated nutrients must be described, and local players who have to be mobilised to co-construct feasibility conditions for a circular water economy in their zone.

Strategies for local, or "short" circuits, must be designed to foster synergies between production facilities (treatment plants, factories), and urban uses, be they conventional or emerging, and for which non-conventional water can be used instead of drinking water (street cleaning, watering green spaces, etc.).

Consortium
2020

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Key words
Bioeconomy
Circular economy
Public policy support
Small water cycles
Urban water

INRAE divisions
ACT
AGROECOSYSTEM
AQUA
MATHNUM
MICA
TRANSFORM

These issues can only be addressed using an integrated approach which involves many of the disciplines studied in INRAE's different divisions: agriculture, agronomy, soil science, human and social sciences, ecology, environment science, process engineering, water savings, digital science, and more…

Project members

INRAE division	Units	Expertise and contributions
ACT	UMR TETIS	Geography, environment, urban, sustainability, land use modelling & hydrological cycles
AGROECOSYSTEM	UR LBE	Modelling and control of bioprocesses and microbial ecosystems, micropollutants, pathogens, physico-chemical health risks – process engineering
	UMR CEREGE	Water treatment – transfer of contaminants in the water use cycle - impact on soil quality and permeability
	UMR EMMAH	Quantification of bio-aerosols, sprinklers, irrigation, transport modelling and risk assessment
AQUA	UMR G-EAU	Irrigation technologies, technical sustainability of irrigation systems, nutrients, risk of soil salinisation, health risks, participatory approaches, governance of REUSE projects
	UR RIVERLY	Urban ecohydrology – water and substance flows
MATHNUM	UMR LISC	Complex systems, dynamic systems, modelling
	UMR MISTEA	Modelling and control of bioprocesses, optimisation and viability for decision-making support, crop modelling
MICA	UR LBE	Modelling and control of bioprocesses and microbial ecosystems
TRANSFORM	UR REVERSAAL	Process engineering and consulting engineering, nature-based solutions for urban water treatment, decentralised management of urban water for resilient cities and the circular water economy
	UMR TBI	Biological and membrane processes, source separation, eco-design and modelling, water quality/use
	UR OPAALE	Sanitary microbiology, nutrient recovery processes and reuse, interactions with energy recovery

Partners	Expertise and contributions
ENPC (France)	Urban challenges of reuse
ENGEES (École Nationale du Génie de l'Eau et de l'Environnement de Strasbourg) / CNRS	Ecological engineering, process engineering, urban ecological infrastructures for water management, membrane technologies for reusing water
INSA Lyon (France)	Management at the source of urban rainwater
OFB (Office français de la biodiversité) (France)	Public strategies
International Union for Conservation of Nature (Switzerland)	Making cities greener

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Bioeconomy for urban areas

Exploratory project
2021

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Key words
Recovery
Urine
Urban area
Valorisation
Bioeconomy
Fertilisers

INRAE divisions
AGROECOSYSTEM
ECOSOCIO
TRANSFORM

TEVALU

Urine recovery in urban areas

Production of nitrogen fertilizer, urine reprocessing, circular flows

Context and challenges

Separating and recovering urine at the source is of particular interest for increasing the circularity of nutrients, notably nitrogen and phosphorus since urine consists of 86% nitrogen and 60% phosphorus per person. On the scale of a region like Ile-de France, human excreta represent 22% of nitrogen and 13% of phosphorus inputs by synthetic fertilisers since producing nitrogen fertilisers requires large quantities of fossil resources since the Haber-Bosch process uses large quantities of fossil gas.

The environmental benefits of implementing regional urine recovery schemes in can be significant:

1. Reducing the use of fossil resources, by reducing the use of the Haber-Bosch process;
2. Mitigating climate change thanks to a decrease in traditional fertiliser production and direct reduction of greenhouse gas emissions originating from the treatment of nitrogen in treatment plants.

Goals

This project is designed to study urine recovery at regional scale via an innovative extraction process for use on farms, and assess the impact on sanitation services. It aims to respond to the challenges that arise from separating urine at the source by evaluating:

- The technical feasibility of producing one or several fertilisers from urine and their environmental impact. A physico-chemical profile of the product will be drawn up to determine the potential of the fertilisers produced and guide their uses. The operating data obtained from the pilot unit will also be used to qualify the treatment process in terms of its environmental footprint;
- The regional feasibility of urine separation in terms of its deposits and uses. An inventory of product use niches will be taken for the area in question and urine deposits will be mapped;
- The economic sustainability of territorial urine recovery for use in agriculture. The project will conduct an economic analysis that combines economic value related to environmental amenities and positive externalities of urine recovery.

The project is expected to advance our knowledge of products made from innovative urine treatment - in terms of both health and economics – and of the potential of implementing a system by analysing regional deposits and needs, in addition to its economic analysis.

Project members

INRAE divisions	Units	Expertise and contributions
AGROECOSYSTEM	UMR ECOSYS	Analysis of agricultural inclusion of urine in crop fertilisers
ECOSOCIO	UMR TSE-R	Environmental and water economics, monetarisation of environmental impacts
TRANSFORM	UMR TBI	Treating urine and nutrient recovery
Partners		**Expertise and contributions**
SOLAGRO		Circular economy and agroecology. Analysis of the uses of products derived from urine

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Bioeconomy for urban areas

CARIBOU

Circularity of the bakery production

Exploratory project
2022

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Key words

Bread waste
Bread
Losses
Valorisation
Flows
Conflict of uses
Bioeconomy

INRAE divisions

ACT
MICA
TRANSFORM

> Supporting the development of circularity in the bread-making industry from the socio-economic, organisational and technological points of view, using bakery waste and unsold bread

Context and challenges

Food losses and waste have been estimated at 20-30% of production in France. These losses occur all along the food chain, from production to consumption, with 35% cumulating at the processing and distribution stages for all types of food products combined. The 2016 Garot Law introduced a two-fold obligation: to gradually reduce the quantity of bread waste and to recover it according to a hierarchy that gives priority to food for humans (preventing waste, donating to charities, reuse for the manufacture of food products, on- or off-site), followed by feed for animals, and lastly composting and energy production. The "food first" priority is stressed, and often justified as another way to minimise the environmental footprint of products.

Goals

CARIBOU combines skills from the social and human sciences, and from environmental assessment and technology to help develop these recovery sectors. The overall goal is to carry out the research needed to create a circular breadmaking sector from a socio-economic, organisational and technological standpoint, and that also sheds light on - and even calls into question - the legislative hierarchy which determines of the uses of bread waste. It aims first to better characterise the flows of bread waste and particularly their regional specificity. This stage is crucial to define the most relevant topics for future research and action. CARIBOU will reflect on the most appropriate economic model to allow for several uses to co-exist, especially those with a strong social function (donations to charities, local synergies that forge ties in at regional scale). Finally, CARIBOU questions the hierarchy of uses laid down in current legislation, and calls for the contextualisation of uses before redefining a hierarchy. As such, the project proposes to explore new recoveries currently considered as medium term priorities in the legislative hierarchy. The goal is to test the first feasibility conditions in preparation for a follow-up project.

Three research goals have been defined by the CARIBOU project:

- Estimate available bread waste deposits and identify their determining factors to improve their management in the future
- Explore the feasibility of innovative recovery routes.
- Prepare future organisational plans for potential recovery of bread waste by other sectors while respecting, and even facilitating, the social function (donations, local synergies) and responding to the needs of the regions where bread waste is produced.

Project members

INRAE division	Units	Expertise and contributions
ACT	UMR SADAPT	Territorial ecology, estimates of flows from surveys and database analysis, interdisciplinary analysis of territorial metabolism
MICA	UMR BBF	Microbial enzymology applied to recovering agro-industrial waste
TRANSFORM	UR OPAALE	Process engineering, environmental assessment, life cycle analysis

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Bioeconomy for urban areas

Exploratory project
2022

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Key words
Scenario
Scenario assessment
What if
Valorisation
Bioeconomy

INRAE divisions
ACT
AGROECOSYSTEM
TRANSFORM

EDIFICE

Assessment of biorefineries to recover market gardening waste near the city of Nantes

> Improve the creation of biorefineries not only from a technical point of view but also through improved inclusion in the region and through better supply

Context and challenges

Biorefineries are often presented as a major component of the bioeconomy to support regional ecological and energy transitions. Scientific journals report that biorefinery design is guided primarily by operational research (optimisation) and industrial chemical or bioprocess engineering approaches. Studies generally focus on biorefinery processes, production units or supply chains, and assess technical and economic performances (cost/benefit, energy and water consumption, etc.) and environmental indicators witg a global impact also found in LCAs (global warming, eutrophication, acidification, etc.). On the other hand, relatively few biorefineries are operational, and their diversity is limited, as shown by a recent study. Likewise, the production of cellulosic biofuels is off to a slow start despite important technological progress notably in biocatalysis. Research in different fields has linked the slow development of biorefineries to inadequate inclusion in regional bio-economies, which may lead to a lack of involvement in the project by market gardeners.

The challenge is therefore to do a better job in accounting a region's specific characteristics and issues when assessing a project for a biorefinery. One scientific challenge is the lack of studies focussed on this highly interdisciplinary problem and consequently the lack of methodologies to carry out this kind of assessment.

Goals

The goal of the EDIFICE project is to develop a method and tools to analyse "what if" scenarios to help answer the following question: « If this type of biomass were treated in this type of biorefinery, how would it affect the region's sustainability? »

The project also aims to develop an application for a concrete case study that demonstrates the relevance of the method.

The approach chosen involves examining the market gardening sector in the peri-urban region of Nantes. Given the complexity of production systems, the EDIFICE project will concentrate on the development of methodology and tools at the expense of the exhaustiveness of the types of market gardening biomass, the types of biorefineries and possible recovery routes. The case study will focus specifically on managing tomato and cucumber waste from greenhouses.

EDIFICE will apply an integrated interdisciplinary approach to scenario analysis, combining experimentation and modelling as well as steps to bring actors in the production sector and decision makers together.

Project members

INRAE division	Units	Expertise and contributions
ACT	UMR LAE	Choice of indicators, modelling and scenario analysis of regional bioeconomy systems
AGROECOSYSTEM	UMR LAE	MAELIA platform
TRANSFORM	UR BIA	Analysis of region around the city of Nantes, conceptual modelling, multi-criteria assessment, use of a participatory approach with stakeholders Biomass transformation processes, extraction and characterisation of the protein fraction Characterisation of lignocellulosic biomass,

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Bioeconomy for urban areas

Exploratory project
2022

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Keywords
Insect
Entomoconversion
Biowaste
Bioeconomy
Circular economy
Urban/peri-urban areas

INRAE divisions
ALIMH
AGROECOSYSTEM
MICA
TRANSFORM

FLY4WASTE

Assessing the risks and benefits of the entomoconversion of urban and peri-urban biowaste by the insect Hermetia illucens

> Evaluate the potential benefits and risks of using entomoconversion to valorise bio-waste from urban and peri-urban areas

Context and challenges

Some insect species like the black soldier fly (*Hermetia illucens*) can grow on a wide variety of organic substrates ranging from "noble" by-products (wheat bran) to waste such as pig slurry. This capacity is now seen as an ecological way to recycle biowaste. Given that total global production of waste will reach 3.4 billion metric tonnes per year, entomoconversion could be an interesting complement to existing methods like composting, micro-methanisation, or incineration to tackle this major challenge. Further, entomoconversion is a possible way to recover biowaste since the larvae could be transformed into very protein-rich meal for use in animal feed, to give one example. *Hermetia illucens* larvae are also very rich in anti-microbial compounds (lauric acid, peptide) and lipids which could serve as energy-dense nutrients or be converted into biofuel. The same larvae may also contain high concentrations of micronutrients (minerals, trace elements and vitamins) that boost their nutritional value for use in food for people or feed for animals. Lastly, when they are developing, larvae produce excrement (frass), that can be used as a natural fertilizer, and chitin, the basis of chitosan used in a variety of industrial applications. Insect rearing (entomoculture) is thus seen as an ecological way to recycle waste and organic residue and recover agro-industrial co-products (entomoconversion). In this context, the project will test the circular bioeconomy concept to simultaneously assess the benefits but also potential risks of using entomoconversion to recover biowaste from urban and peri-urban areas.

Goals

The black solider fly is already being used to turn food-grade by-products and residue into a range of products that are already on the market. The main goal of FLY4WASTE is to assess the extent to which this insect could, if regulations allow, be exploited more widely to recycle urban and peri-urban biowaste with a view to achieving a circular bioeconomy. The primary focus of our research

will be to assess the main benefits and risks associated with using entomoconversion to recover biowaste from urban and peri-urban areas.

As the risks and benefits are potentially very varied, the project will combine several disciplines to:

1. Evaluate the nutritional, health (chemical, microbiological), economic and social dimensions of entomoconversion, and then to
2. use all these criteria to perform a risk-benefit analysis of different scenarios for this type of biowaste recycling.

If entomoconversion is to be successfully harnessed to recycle urban and peri-urban waste, in the long term, it will be necessary to extend the risk-benefit analysis to other dimensions by involving different partners in this inter-disciplinary project, especially concerning:

- Societal acceptability
- Use of entomoconversion products in animal feed
- Genetic selection of the insect
- Optimisation of entomoconversion procedures or processing of derived products
- Environmental impact

Project members

INRAE division	Units	Expertise and contributions
AGROECOSYSTEM	UMR ITAP	Economic and social assessment of the entomoconversion of biowaste
ALIMH	UMR C2VN	Nutrition, bio-accumulation of micro-nutrients with health value
MICA	UMR MICALIS	Microbiological safety of biowaste and insects. Entomoconversion and reduction of +/- sporulated pathogens
	UMR SQPOV	Microbiological safety of entomoconversion products. Adaptation of spore-forming Gram+ bacteria
TRANSFORM	UR QuaPA	Chemical safety of biowaste used in entomoconversion products (transfer, bioaccumulation and bioamplification of contaminants)
	UMR IATE	Risk-benefit analysis; multi-criteria and multi-player analysis; arguments & decision
Partners		Expertise and contributions
Société BioMiMetiC (FRANCE)		Entomoconversion; Insect rearing on biowaste
Société PAPREC (FRANCE)		Supplying different categories of biowaste

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Keywords
Food waste
Cold chain
Multi-criteria optimisation
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Urban food system
Loss
Valorisation
Bioeconomy

INRAE divisions
ACT
MICA
TRANSFORM

NEWLINK

New link in the cold chain between collective catering and food aid associations: inventory, cost-benefit analysis and optimisation strategy

> Optimise the redistribution of unsold meals from collective restaurants to food aid associations and other populations in a given urban area, while guaranteeing the sanitary and environmental quality of the food

Context and challenges

A study carried out by ADEME on food waste from collective catering establishments in France showed that a restaurant that serves 500 guests on an average 200 days a year, produces between 15 and 20 tons of waste a year, or, in budgetary terms, between 30,000 and 40,000 euros in food waste annually (ADEME 2016). To combat food waste in collective catering, the EGalim law (Article 88 > Art. L. 541-15-3 from the *code de environment* and ordonnance 2019-1069 from 21 October 2019) requires establishments serving more than 3,000 meals a day to partner up with food aid associations to donate food. This strategy is part of an ethical and social approach (solidarity with the most underprivileged, fight against food insecurity) but also has environmental and economic benefits (reducing carbon footprints and curbing costs). However, this policy implies adding new steps to the management of the cold chain process (packaging, collecting, transporting, storing and distributing donations) in order to guarantee the safety and quality of foods collected by associations until they can be consumed.

Studies have highlighted the need to take the social and technical conditions of cities into account when choosing how to manage flows and reduce waste without compromising the safety and quality of foodstuffs to be redistributed and consumed. While many studies analyse the food supplies of cities and the entire urban system as a whole, very few look to what ultimately happens to purchases downstream: consumption, loss, waste and associated waste, their origins and their future. An urban metabolism approach, here defined as all the material and energy flows that come into play in human societies, enables reconnection of the supply and restitution of materials in the analysis of urban territories. The approach allows a better grasp of the issues in order to foresee, stimulate and promote the prevention and recovery of food waste, and hence optimise

the use of resources and raw materials. In this way, it is possible to explore how food waste reduction and recovery strategies can help transform the metabolism of regions, with a view to boosting sustainability.

Goals

NEWLINK brings together skills from different fields from process engineering and computer science to human and social sciences, and calls on both academic and professional players. The overall goal of the project is to optimise the redistribution of unused food from the collective catering sector to food aid associations and other populations in a given urban zone, while guaranteeing the safety and quality of food when it is finally consumed. Several questions have arisen:

- **How does the link between collective catering and food aid associations work?** Who are the players, what constraints influence the roll-out, what products are collected and where do they come from (traceability), what is their use-by date, which products are most frequently involved, how long does each step in the process take, what equipment (refrigeration and other) and staff is needed, and what are the critical points that could compromise the quality of products being processed and prevent their redistribution and ultimate consumption?
- **What are the benefits (solidarity: economic and social aspects, waste reduction and environmental impact linked to waste) and costs (economic and environmental costs associated with this new link due to the need for additional staff and equipment) in a given area?** Are solutions available to sustain the economic model of this new link and increase the benefits and/or reduce the costs while respecting the quality of products?
- **How will the results of the cost-benefit analysis be affected by optimisation of the redistribution of unsold food in a given region and by accounting for the presence of donor/recipient structures?** What is the potential for expansion? Should an expansion threshold, or, on the contrary, a limit, be set in order to achieve a favourable cost-benefit ratio? How will trends in the redistribution market influence these developments?

Project members

INRAE division	Units	Expertise and contributions
ACT	UMR SADAPT	Ecology, estimate of flows from surveys and database analyses, inter-disciplinary analysis of territorial metabolism
MICA	UMR SECALIM	Safety and quality of foods, microbiological lifespan, Predictive microbiology, Risk – benefit / multi-criteria assessment
TRANSFORM	UR FRISE	Multi-criteria analysis, energy and environmental impact of refrigeration equipment, cold chain, food quality

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Thesis
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Applying multiple barrier approach in participatory and integrated risk management of wastewater reuse projects

> Use a participatory modeling approach to build a simulation tool that allows stakeholders to create and test different pathogen risk management scenarios

Context and challenges

The European Commission published Regulation (EU) 2020/741 of May 25, 2020 on the minimum requirements for agricultural water reuse, which will come into effect in June 2023. To manage sanitary risks, this regulation specifies water quality classes according to the intended uses of the wastrewater. The classes are even stricter than those defined the ministerial decree of August 2, 2010, which was modified on June 25, 2014. Achieving the specified water quality often requires the use of additional treatment technologies, with a negative effect on both the economic and environmental balance of the projects. The European regulation also considers another approach to risk management: Management By Barriers (MBB), i.e. the implementation of protection measures throughout the reuse process rather than management only based on advanced treatment processes.

Objectives

The objectives of the thesis are:

- Draw up an inventory of existing knowledge on possible barriers. The thesis can use the « Multi-barrier » project submitted by the INRAE Reuse network;
- Use a participatory modelling approach to build a simulation tool that will allow stakeholders to create and test various « multi-barrier » scenarios and compare them using different indicators (health, economic and environmental). The stakeholders will discuss the scenarios among themselves and finally define an « ideal » scenario to ensure sufficient health protection as well as comply with the European regulation concerned;
- Evaluate the participatory process (format, number, type and duration of the workshops) using the monitoring and evaluation methods formalised by the ComMod group as well as the resulting scenarios.

The simulation tool will be tested on different water reuse projects: existing agricultural projects (typology 1), new agricultural projects (typology 2) and finally urban projects (typology 3).

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Evaluation of the advantages and risks of entomoconversion of urban and peri-urban biowaste by the insect Hermetia illucens – focus on the bioaccumulation of micronutrients and micropollutants

Given that total production of waste worldwide is predicted to reach 3.4 billion tons by 2050, entomoconversion offers an attractive supplementary solution to overcome this major challenge, particularly in urban and peri-urban contexts.

Context and challenges

Raising insects is an ecological way to recycle and value biowaste by transforming it into, for example, protein for animal feed, fertilizer, and biofuel. In urban and peri-urban zones where waste management is an ever-growing challenge, entomoconversion is an attractive solution but also raises specific questions particularly concerning the different types of waste and management of potential health risks. Faced with this situation, the main objective of this thesis will be to conduct a preliminary evaluation of the advantages and risks involved in using entomoconversion to recycle biowaste in urban and peri-urban zones. As both the advantages and risks are potentially highly contrasted, this thesis will focus on bioaccumulation of nutrients (an advantage) and of micropollutants (a risk) by insect larvae.

The thesis will be supported by a collaborative project named FLY4WASTE, (Evaluation of the advantages and risks of using entomoconversion to recycle biowaste in urban and peri-urban zones by the insect Hermetia illucens - Fundung BETTER - 2022-2024).

Objectives

While focusing on the bio-waste streams that are the most representative of those usually produced in urban and peri-urban zones, the specific objectives of the thesis will be the following:

- To perform separate analyses of the different flows of biowaste and of the products of entomoconversion to screen for micropollutants and micronutrients;
- For each stream of biowaste, to assess the bioaccumulation of micropollutants and micronutrients in insect larvae during entomoconversion;
- To integrate these data into an initial benefit-risk analysis of entomoconversion.

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