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10. Key indicators and variables in citizen science for the water-food-energy Nexus analysis in Tulcea case study

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Abstract: This study presents the first results from the activities carried out within the BELMONT project - Creating Interfaces (Building capacity for integrated governance at the Food-Water-Energy-nexus in cities on the water), more precisely from the implementation of data collection activities, by collecting a large number of questionnaires and applying the participatory working method, from the Urban Laboratory (Urban Living Lab). The project aims to identify and promote innovative solutions for multifunctional practices of urban resilience to hydroclimatic stress, by developing conceptual models, at the level of participatory decision support, at local level, by innovative approaches in creating knowledge, and by coordinating the knowledge governance. A very important component of the project is the involvement of local decision makers. The case study area, presented in this study, is the region of Tulcea municipality, and includes an artificial lake, called Lake Zaghen, within the project area. For the implementation of the present study, two perspectives were approached: the environment and the interdependencies of the "Food-Water-Energy" (Nexus) system. The first perspective refers to the study of water use, in the natural environment, gardening and agriculture, in the area of Lake Zaghen. The second perspective includes the study on irrigation, the cost of energy supply for irrigation systems and wastewater. Within the project, the concept of Citizen Science was applied, based on correlations between variables (e.g., stakeholder involvement; collected data; citizen involvement; pressures; management plan) and key performance indicators (e.g., the ratio between the interviewed stakeholders and the stakeholders participating in the ULL/Urban Living Lab; quality of provided data; size and complexity of data; conversion of raw data into meaningful scientific knowledge; learning opportunities; interpretation of the "Food-Water-Energy" Nexus; visions; strategies). Regarding the involvement of stakeholders, after interviews, which were held by DDNI, between March and June 2019, most citizens responded that the proximity of Lake Zaghen would be a benefit for the agriculture in the area, and the farmers stated that they are facing problems regarding the energy and presented solutions they implemented. The collected data, within the Urban Laboratory, as well as through interviews and questionnaires, were the basis of the detailed situation analysis, based on Tulcea case study. It can be observed the fact that the "Food-Water-Energy" system represents a dynamic system, with significant variations over time.
Keywords: Urban Living Lab, BELMONT, Food-Water-Energy Nexus, Citizen Science

INTRODUCTION

Citizen Science is the scientific research carried out, partially or totally, with the involvement of citizens. In addition to the results obtained by scientific research, this method brings, as an additional result, a better understanding, by the citizens involved, of the existing situation and of the scientific method that is to be implemented.

The term "nexus" represents the existing or possible interconnections of the Food-Water-Energy/FWE chain. The better the connections will be highlighted, the complexity of the Food-Water-Energy Nexus at Tulcea municipality level will increase, leading to a better situation understanding and reducing existing pressures on the environment (DDNI, 2019).

With more than half of the world's population presently living in urban areas (United Nations, 2015), much of the demand for food, water, and energy (FWE) occurs in cities (Ramaswami, et al., 2017). The urban FWE metabolism and infrastructures present a complex socio-technical process of co-evolution "interrelated with urban development and urban space" (Graham, 2000, p. 114). Growing in importance in recent years, the FWE nexus was first discussed at the World Economic Forum in 2008 (World

Economic Forum, 2011) as a mechanism to promote sustainable use of resources, and has evolved to incorporate various facets, additional components and disciplinary perspectives.

A review of the current state of research on the FWE nexus by Endo et al. (Endo, et al., 2017) indicates that the concept and supporting activities vary depending on the social, economic and environmental goals of the region and sector. In many cases, one FWE component takes a central focus and the other components are considered as inputs (e.g., water and energy for food).

The project adopts an Urban Living Lab (ULL) approach, referring to the definition of the JPI Urban Europe Strategic Research and innovation agenda of ULL as a forum for innovation towards new urban products, systems, and services, involving users as co-creators to test and evaluate creative solutions and ideas (JPI Urban Europe, 2015, p. 59). In the proposed project, urban living labs will be realized in three partner cities: Tulcea/Romania, Wilmington/USA and Slupsk/Poland. Common analytical and methodological frameworks will ensure coherence and comparability as well as scientific rigour. The concrete approach in the ULL will be based on a citizen science perspective. Citizen science refers to any project or effort to involve citizens (i.e. anyone other than professional scientists) into the scientific process (Fradera, et al., 2015), which usually translates to the processing or collection of data by citizens (Silvertown, 2009); (Dickinson, et al., 2012). According to Fradera et al. (Fradera, et al., 2015) citizen science might enhance relationships across nexus life-cycles, even between policymakers responsible for different nexus issues, and that exploration of the nexus through citizen science has the potential to contribute to a range of nexus needs. However, existing projects and case studies related to the FWE nexus are rare. These projects tend to focus on one aspect and don't fully satisfy the nexus approaches' call for cross-boundary research.

The SUGI (Sustainable Urbanisation Global Initiative Food-Water-Energy Nexus) Nexus proposal "Creating Interfaces" will provide, after its' implementation, significant advancements in this research stream. The project will respond to the need for methodological developments, fundamental research on reliability, and on questions surrounding justice and integration. It integrates fundamental research as well as applied research and innovation to realize a feedback loop between science and application, integrating natural and social sciences, humanities, engineering, data management and modeling as well as stakeholders from civil society, administration and policy, and economy.

The study was conducted within the BELMONT - Creating Interfaces project (Building capacity for integrated governance at the Food-Water-Energy-nexus in cities on the water). The overall objective of the project is to develop a system on different levels of Food-Water-Energy relational management, while guaranteeing environmental sustainability and social equity. The project is part of the Europe 2020 Strategy and Europe's sustainable development strategies.

The project aims to identify and promote innovative solutions for multifunctional practices of urban resilience to hydroclimatic stress, by developing conceptual models, at the level of participatory decision support at the local level, by innovative approaches in creating knowledge and by coordinating the knowledge governance. A very important component of the project is the involvement of local decision makers. The case study area, presented in this study, is the region of Tulcea municipality, and includes an artificial lake, called Lake Zaghen, within the project area; the total area covers 2.2 km^2.

The Zaghen Polder is located in the Tulcea-Nufăru precinct, which was embanked, in the 1960s, to give the land agricultural use. Due to the high level of the groundwater and the intense evaporation (also favoured by the mechanized agricultural works), the lands tend to be salted and the agriculture can only be practiced under intensive irrigation conditions. Between 2007-2013, the Zaghen Polder was ecologically reconstructed, benefiting from an investment project financed by the European Regional Development Fund, through the Operational Programme "Environment" (OPE), and implemented by DDBRA (Danube Delta Biosphere Reserve Authority) (DDNI, 2019).

MATERIALS AND METHODS

The Performance Indicators, abbreviated KPI (Key Performance Indicators) are quantitative and qualitative measurement tools for the performance of the project that indicate the achievement of quantifiable objectives related to the established variables.

The following variables have been defined which, by their action, influence the success rate of the project and, at the same time, indicate the use of the Citizen Science concept, within it:

- Stakeholder involvement;
- Collected data;
- Citizen involvement;
- Pressures;
- Management plan.

In order to analyse these KPIs, the Urban Laboratory method was chosen as the optimal approach. On July 5, 2019, DDNI organized, in Tulcea, the first Urban Laboratory within the BELMONT-Creating Interfaces Project. The workshop was divided into 5 modules which, by using several group methods, made it possible for participants to understand the existing situation, to identify needs and concerns, to present ideas and to find future visions and solutions.

The Urban Laboratory was divided into 5 phases and the participants were positioned at 4 working tables, each one with one moderator from DDNI. The first phase was introductory, and in the other 4 phases, the participants worked together using methods such as the Participatory Modeling, group work and brainstorming.
The Urban Laboratory phases are as follows:

Module A0: Welcome and Introduction to the project and its concepts;
Module A1: Warm-Up, brainstorming, gathering needs and concerns;
Module B1: Future visions;
Module B2: Viewing and connecting visions to Nexus: Participatory Modeling exercise;
Module C: Presentation of results, discussion and next steps.

Converting raw data, into meaningful scientific knowledge, is a key performance indicator, impacting stakeholders on the entire process of this stage of the project, starting with the presentation of the project and the concept of Food-Water-Energy Nexus, during the interviews, continuing with the awareness of the problems, related to the case study in Tulcea and of the possible interconnections between stakeholders, in the first phases of the Urban Laboratory, and ending, in the last phase of the workshop, with finding possible solutions for the presented situations .

Within the project, a series of variables have been defined which, by their action, influence the success rate of the project and, at the same time, indicate the use of Citizen Science concept: stakeholder involvement, collected data, citizen involvement, pressures, management plan. These variables were analysed, in detail, with the help of stakeholders, during a session of Urban Living Lab (Urban Laboratory), the data collected being the basis of the "Food-Water-Energy" system analysis.
The data collected in the Urban Laboratory, as well as through interviews and questionnaires, were the basis of the detailed analysis of the situation, based on Tulcea case study. It can be observed the fact that the "Food-Water-Energy" system represents a dynamic system, with significant variations over time. This aspect is the basis of future analyses, which require the introduction of several methods of analysis, in order to supplement the system with more descriptors and data. This activity will be ensured through the BELMONT project, through the implementation, in the following phases, of an automated data collection tool.

The analysis of the variables can be done by using the following Key Performance Indicators (Table 1**Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.**):

Table 1

Variables and Key Performance Indicators

Citizen Science Variable	Key Performance Indicators
Stakeholder involvement	Ratio $\frac{Interviewed\ stakeholders}{Stakeholders\ participating\ in\ the\ ULL}$
Collected data	Quality of provided data Size and complexity of data Conversion of raw data into meaningful scientific knowledge
Citizen involvement	Learning opportunities
Pressures	Interpretation of the" Food-Water-Energy" Nexus
Management plan	Visions Strategies

To understand the Food-Water-Energy system, it is proposed to analyze the presented components, using the method of causal loop diagrams (CLD). In this case, the iModeler application (Consideo program) was used.

Qualitative modelling with the use of Consideo is a further development bringing together elements of CLD (system dynamics) and fuzzy cognitive maps. Although the algorithms are the same, the iModeler is web oriented and allows for cloud computing and collaborative modelling (Ullrich & Hördur, 2014).

iMODELER is used to gain insights, explore how things are interconnected and to enhance the brain's capability to tackle complexity. The new iMODELER offers a revolutionary way to both visualize and analyze (via its unique Insight Matrix) complexity, thus allowing for better planning, decision-making and communication. The iMODELER even allows for quantitative modeling of scenarios (e.g., system dynamics) (CONSIDEO GmbH, n.d.).

RESULTS AND DISSCUSSION

The „collected data" variable

The "collected data" variable can be tracked qualitatively and quantitatively, according to the following key performance indicators: the quality of provided data, the size and complexity of data, the conversion of raw data into meaningful scientific knowledge.

For Tulcea case study, the stakeholders considered representative for the Food-Water-Energy Nexus, at the city level and for the Zaghen area, were identified, following DDNI to send official information letters to each authority and actor in the public sector. Subsequently, each institution nominated a representative who would respond competently to the questionnaires and interviews.

The data provided by the interviewees helped to identify new stakeholders, to accurately highlight the problems that some of them face and what solutions they have found or what they consider appropriate for solving some situations.

Interviews and field trips were realized in the area of the Zaghen Polder, during which the citizens and private stakeholders received information about the BELMONT project and the existence of Food-Water-Energy interconnections.

The quality of the provided data is considered a key performance indicator, since the stakeholders, who participated in interviews, are representative persons for the institutions they belong to and, in the case of the private stakeholders, they are entities directly involved in the Food-Water-Energy Nexus or they perform activities closely related to the Zaghen Polder.

During the interviews, there were identified existing or possible Food-Water-Energy connections, the problems encountered on different branches of the Nexus and new stakeholders. Later, within the workshop with the partners of the BELMONT - Creating Interfaces Consortium, which took place between 2-4 July, 2019, the structure of the first Urban Laboratory for Tulcea was created.

Causal loop diagrams in the analysis of the collected data - iMODELER

The collected data, within the Urban Living Lab, were assimilated as the variables of the analyzed system (Food-Water-Energy) and introduced in the causal loop diagram (
Figure **1**). Thus, based on information received from stakeholders, based on completed questionnaires and discussions, within the workshops, the connections between the elements of the system were completed.

The way in which the components of the system work and relate can be traced through the analysis of the internal matrix. In this sense, we extracted the internal matrix of the main components: Water, Energy, Food, both short and long term.

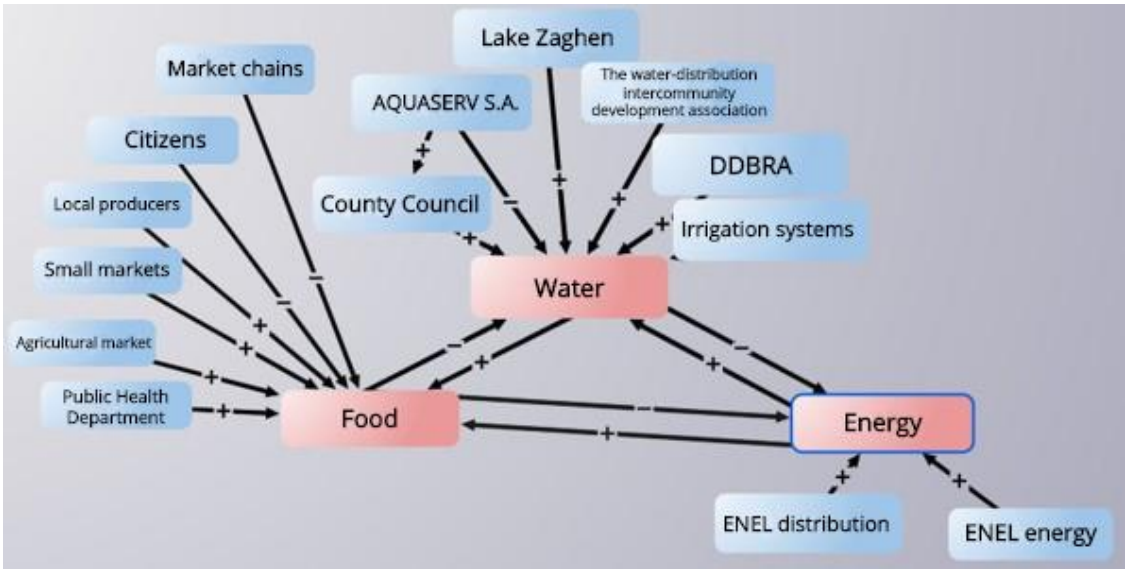

Figure 1 Causal loop diagram of Food-Water-Energy system

The internal matrix of the element "Water" shows that, in short term, the component is strongly influenced by the other main elements ("Food" and "Energy"), these elements being also the elements that have the highest temporal dynamics. A major influence, in the analysis presented, also comes from the element ADI Apă-Canal/The water-distribution intercommunity development association, as the main supplier for large irrigation systems, as opposed to the element "Irrigation", which has a negative influence on the quantity of available water. In the long term, the internal matrix of the element "Water" indicates the major change of the element "Energy" which, in the context of increasing the need for water, becomes a component with negative impact. Similarly, the internal matrices of the elements "Energy" and "Food" can be analysed.

The internal matrices of the element "Energy" highlight the fact that the productions of "Food" and "Water" reduce the available quantity of energy, aspect present both in short and in long term analyse. The internal matrices of the element "Food" highlight the major dynamics of the element. If, in short term, the exploitation, production and distribution of food require a large amount of available water and energy, in long term, the supply of food becomes vulnerable and very expensive, especially in terms of energy consumption.

From the analysis of these components, it can be observed that the “Food-Water-Energy” system represents a dynamic system, with significant variations over time. This aspect is the basis of future analyses, which require the introduction of several methods of analysis, in order to supplement the system with more descriptors and data. This activity will be ensured within BELMONT project, through the implementation of an automated data collection tool.

The „citizen involvement” variable

DDNI has designed short questionnaires for citizens to reduce the interview time. These included information about the ”Food-Water-Energy” Nexus system and questions about the advantages or disadvantages of the location near the Zaghen Polder. During the field campaign, from March to June 2019, interviews were conducted with the citizens from the industrial platform area, from the N-E part of the Zaghen Polder, and from the ”Orizontului” street area. These citizens are considered representative for the category of those who practice gardening only for family use.

The citizens who answered the questionnaires tried to present examples of Food-Water-Energy interconnections, they expressed what problems exist, from their point of view, on each segment, at the city level, and if the fact that they are located in the proximity of Lake Zaghen constitutes a benefit or disadvantage.

The ”citizen involvement” variable is measured by the key performance indicator "learning opportunities". This KPI is represented by all the actions within the project, that had citizens involved and who, as a result of these activities, gained additional knowledge related to the theme of the project and to the concept of ”Food-Water-Energy” Nexus.

The „pressures" variable
The elements that form the "Food-Water-Energy" Nexus are taken into account, in the case study (e.g., irrigation is a topic, as well as the energy costs for the irrigation system). The water level is different throughout the area. It is used in: environment, gardening and agriculture. The water is used for irrigating the gardens, but it affects the water level of the lake and thus, the environmental balance. If the water level is too low, the water is pumped into the lake from the Danube River (controlled by ANIF/National Agency for Land Improvements), and the lake's governance is under the authority of DDBRA. The project-team from Tulcea, has already identified the quality of the water as a concern, due to a high level of nitrates in the water. Near the lake, there is an area of agricultural and food production (milk, cold meats (now closed) etc.). In the lake area, a small restaurant and an ethnographic museum have been founded, the last one being often used by nearby residents, and which can attract potential users, such as tourists, families, young people etc., creating a new use of the area, namely free time.

The „management plan" variable
The "management plan" variable is transformed into a performance indicator, through the visions and strategies formulated by the working groups, during the Urban Laboratory, within the project carried out in Tulcea, on July 5, 2019.

In module B1 of the Urban Laboratory, the stakeholders present the following visions:

Group 1
Regarding irrigation of gardens and agricultural land, in the near future, the group considered that the following should be fulfilled:

- The discovery of technologies to eliminate the use of harmful chemicals to the environment (chemical fertilizers, pesticides, herbicides etc.) and the use of only chemical or natural compounds that do not disturb the ecological regime of the areas in which these substances are used. Even if there are concerns, at the moment, regarding this issue, the cost of manufacturing is high, therefore, producers continue to use toxic substances.
- In the future, a low-cost urban management is desirable. Today, in order to start a business, based on ecological principles, the individual encounters a strong administrative-bureaucratic barrage. Creating a malleable system for small producers would generate an important motivation for local agriculture.
- Creation of aquaponic farms. Described as a farm of the future, which lies between agriculture and fish farming, it is based on a system of water filtration and circulation, from vegetables to fish and back.

Group 2

- Collection of rainwater and its use for irrigation.
- Improvement of the water distribution system.
- Educate the population to reduce water waste.

Group 3

- Creation of associations/companies of agricultural exploitation.
- Rethinking water supply and pumping in Lake Zaghen.
- Use of renewable energy.
- The possibility of small producers to capitalize on their overproduction directly from their location.
- The legislative framework for the development of the area.

Group 4

- Waste sorting.
- Wastewater Treatment Plant.
- Civic education and environmental education.
- Micro-enterprises for reducing the food losses.
- Residential rainwater harvesting system.

In the module B2 of the Urban Laboratory, the stakeholders have formulated the following possible strategies, in accordance with the theme and the study area of the project:

Group 1

In the future, information provided by citizens can make an important contribution to developing and improving the visibility of the ”Food-Water-Energy” Nexus. Among the information the citizens can offer, we mention:

- Information about the implementation of agriculture, in the region, or about the different traditional agricultural practices.
- By keeping in touch with local authorities (e.g., town hall, water management company, local energy distributor, passenger transport companies etc.) citizens can have a broader understanding of many local issues.
- The possibility to improve the energy balance of buildings.
- The infrastructure can be improved, recreational green spaces can be created by applying green filters and efficient removal of pollutants.
- Human resources are required to carry out these activities.

Group 2

Involving citizens and collecting the following information from them:

- Information about accidental/intentional pollution.
- Establishing the level of interest of citizens regarding ECO vegetables.
- Involvement of the local actors, such as: the municipality, the Local Council, DDBRA.

Group 3

- Modernization of water and sewerage systems.
- Creating a platform that will use the ”Tool” to request the opinion of citizens about different issues, at local level.

Group 4

- Environment week (waste collection; loss awareness/efficient use).
- Feedback loop to authorities.
- Energy (solar, thermal, cogeneration).

CONCLUSIONS

This study presents the first results from the activities carried out within the BELMONT - Creating Interfaces project (Building capacity for integrated governance at the Food-Water-Energy-nexus in cities on the water), respectively from the implementation of data collection activities, by collecting a large number of questionnaires and applying the participatory modelling method, from the Urban Laboratory (Urban Living Lab). Within the project, a series of variables have been defined which improve the success rate of the project's objectives and, at the same time, they aim the use of Citizen Science concept. These key variables are: ”stakeholder involvement”, ”collected data”, ”citizen involvement”, ”pressures”, ”management plan”. The variables were analysed, in detail, with the help of stakeholders, during a session of Urban Living Lab (Urban Laboratory), the collected data being the basis of the analysis of the “Food-Water-Energy” system, for the Tulcea case study.

The Urban Laboratory was divided into 5 modules and the participants were positioned at 4 working tables, each group with one moderator from DDNI. The first phase was introductory, and in the other 4 phases, the participants worked together using methods such as the Participatory Modeling, group work and brainstorming, to organize the information related to the key variables. The collected data, within the Urban Laboratory, as well as through interviews and questionnaires, were the basis of the detailed analysis of the situation, based on the Tulcea case study. It can be seen that the ”Food-Water-Energy” system represents a dynamic system, with significant variations over time.

This aspect is the basis of future analyses that require the introduction of several methods of analysis, in order to supplement the system with more descriptors and data. This activity will be ensured by the implementation, in the next stages of the project, of an automated data collection tool.

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