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**City integrated water-energy-food futures – CitySelfy project and stakeholders
co-creation process**

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Abstract

Urban areas are major consumers of water, energy, and food (WEF). In 2015, Cascais municipality's water, energy, and food imports dependence was 68%, 86.6%, and 85.9%, respectively. This high dependence on external resources induces indirect WEF system pressure and poses risk to the municipality's long-term resilience.

The CitySelfy project aims to analyse if WEF self-sufficiency at local scale can be a promoter of sustainability. The project includes participatory methodology, engaging local stakeholders in the conceptualization and exploration of prospective scenarios for the municipality's WEF systems. The first project stakeholder workshop highlighted a strong potential in achieving local WEF self-sufficiency. Throughout the process participants suggested a variety of solutions, such as rainwater harvesting, minimizing household food waste, and the establishing cohesive communities on integrated local WEF resources.

This co-creation process facilitated the definition of detailed scenario narratives, which in turn will subsequently frame the modelling scenario development. This assessment will be crucial to identify the most viable and sustainable strategies for achieving self-sufficiency in WEF in Cascais.

Keywords: Scenario development; Co-production; water-energy-food nexus; local scale

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Introduction

Cities are the main drivers of resource consumption and related environmental impact, namely carbon emissions (Ang et al., 2023). They are home to more than half of the global population and produce over three-quarters of the global economic activity (United Nations Department of Economic and Social Affairs, 2018). However, the challenge of rapid urbanization can acute the associated resource consumption pressures (Steffen et al., 2015; Turner et al., 2021). To tackle this challenge, a range of solutions are required to be implemented to support more sustainable and climate-neutral cities.

One way to achieve this goal is to experiment and innovate with technologies, instruments and policies that can reduce the carbon footprint of cities (Crocì et al., 2017; Fuso Nerini et al., 2019). One example is the EU mission for 100 climate-neutral by 2030, where 100 cities have financial and technical support to reach their commitment to reach climate neutrality by 2030 (*Commission Announces 100 Cities Participating in EU Mission*, 2022).

Nevertheless, a more comprehensive and integrated system approach is becoming a necessity (Albrecht et al., 2018). Such an approach considers the interconnections and interdependencies between various systems within a city, including energy, water, waste ma The concept of the Water–Energy–Food (WEF) nexus emerged as a response to the need for the integrated sustainable management of these resources (FAO, 2014) and defines a web of mutual interlinkages to ease the co-operation of those institutions in charge of their supply (Bazilian et al., 2011). This integrated system approach provides cities the capacity to analyse how to optimize resource utilization and reduce trade-offs across other and multiple systems (Bazzana et al., 2023; Gondhalekar & Erlbeck, 2021).

The design of scenarios storyline also plays a pivotal role in envisioning and planning for sustainable futures (Fishman et al., 2020). Incorporating stakeholder co-creation processes into scenario development enhances the credibility, relevance, and robustness of the outcomes (Kok et al., 2015; McBride et al., 2017). Also the scenario creation phase should combine broad stakeholder participation to contribute to model quantitative tools development and results (Göke et al., 2023).

Stakeholders can be included in the development of scenarios in various modes and phases (Mahmoud et al., 2009) such as development of scenario narratives and storylines (Huang et al., 2024).

There is a strong necessity to produce and show the inclusion of typically underutilized contributions of social sciences into technologic based energy modelling (Süsser et al., 2022) and policy-making (Foulds et al., 2022). One core approach for integrating social aspects within energy modelling is the establishment of storyline, scenario conditions (Krumm et al., 2022).

In this context, CitySelfy project includes local stakeholders engaging processes that will support both WEF reference conditions validation and early-stage scenario co-creation (Figure 1). CitySelfy project aims to expand a technology-based energy system optimization tool, applied to Cascais municipality, to include interlinkages with water and food resources, technologies, and practices, while taking inhabitants social preferences and economic profiles. Key outcomes include future optimal configurations for the WEF systems up to 2070 (e.g. decentralized power, urban farming systems, water harvesting solutions), corresponding to different levels of sufficiency and sustainability. To each the inclusion of local stakeholders’ perspectives are a key component to support modelling and scenario development robust results.

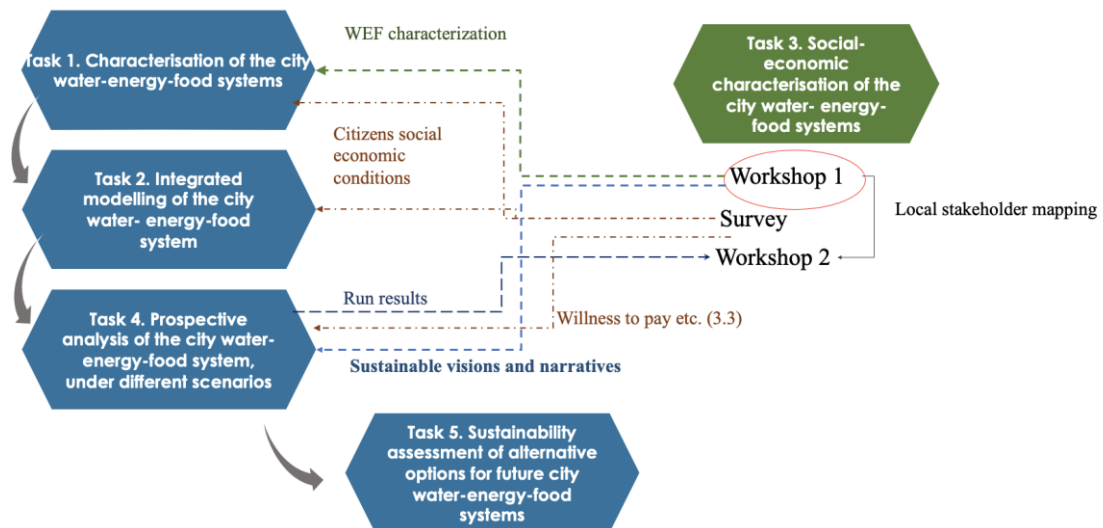


Figure 1. CitySelfy Project tasks overview and flow and high the relationships of stakeholders’ workshop outputs

Literature review

Effective stakeholder involvement, along with innovative frameworks and approaches, is crucial for addressing urban sustainability challenges (Lopes & Videira, 2016; Soma et al., 2018; Tourais & Videira, 2024).

Moreover, exploring integrated water-energy-food futures in cities requires the inclusion of local experts and stakeholders to envision different scenarios and challenges addressing the complex interconnections of these systems (Williams et al., 2023). Furthermore, stakeholder engagement can help the proper representation of reference systems and system support the implementation, in particular if the research tackled a topic (Jäger et al., 2023).

In specific, the examination of the convergence of WEF futures configurations and sustainability objectives within urban settings can be supported by multiple disciplinary domains (Qiu et al., 2024).

Kliskey et al., (2021) provide a review and meta-synthesis of models, frameworks, and toolkits for community and stakeholder engagement for nexus WEF systems to address complex issues. Kliskey et al., (2021) stated that the methodological approach can support adaptation planning by engaging stakeholders directly in the scenario building process, to elaborate on plausible future urban developments while considering an array of different stakes and challenges. Suchá et al. (2022) evidenced the benefits of engaging stakeholders directly in the scenario building process, to elaborate on plausible future urban developments while considering an array of different stakes and challenges. It enhanced the potential of scenarios to developed adaptation measures and spatial expression of their implementation within the cities (Suchá et al., 2022).

Tye et al. (2022) highlights that a successful WEF governance require stakeholder inputs as a component of an iterative process of reflection and responses. The studied literature by Tye et al. (2022) revealed scarce cases of interactive and participatory research of WEF nexus integration. Also Bazzana et al. (2023) analysis demonstrated the lack of real coordination between political actors and stakeholders for practical implementation of WEF nexus approach.

Hainoun & Loibl (2022) followed a participatory process involving key local stakeholders to project future FWE demand and supply for Berlin, Bristol, Doha and Vienna cities regions. This approach provided consistent long-term scenarios of socio-economic and technological development of the considered city regions (Hainoun &

Loibl, 2022). Similarly, Garcia Ferrari et al. (2021) created a framework to represent intersections between WEF nexus and adaptive co-management (ACM) approaches to resource management in Galapagos. The stakeholder engagement was only done through interviews and the results evidence the relevance of the implementation of the framework could *promote resilience by opening a space for deliberation and conflict resolution between legitimate stakeholders, thus supporting more effective and balanced participative governance* (Garcia Ferrari et al., 2021).

Melloni et al. (2020) carry out a stakeholder enrolment process to support the decision-making process of the WEF nexus assessment in Atlantic Forest Reserve of Ribeirão das Lajes, Brazil. Although it contributes to highlight the relevance of stakeholder inclusion on resource management, the process unexploited group interactions as it used only silo interviews. Similarly, García-Martínez et al. (2024) has applied a multi-stakeholder approach to access scenarios to measure WEF availability, accessibility and sufficiency in Sonora, Mexico. The 30 scenarios provided a high range of possibilities for reducing competition of resources in the case study region. Although, the approach and results only consider stakeholders individual contributions with no direct interaction in the formulation of systems configuration scenarios.

Di Felice et al. (2023) applied the quantitative storytelling approach to the question of dominant narratives of four innovations with a strong nexus component in EU policy: biofuels, shale gas, electric vehicles, and alternative water resources. Author's conclusion suggested that narratives should not directly induce policy change but means to *open discussions on innovations outside of dominant nexus imaginaries* (Di Felice et al., 2023).

Similar work on co-design has been done in the ENGAGE project (<https://www.engage-climate.org/>), which is advancing knowledge co-production through an iterative process of stakeholder engagement with two main streams: (i) stakeholder co-design and assessment of global decarbonization pathways and (ii) stakeholder dialogues on national policies and pathways. The online stakeholder engagement activities provided significant input design of new decarbonization pathways using integrated assessment models feasibility of different mitigation pathways (Jäger et al., 2023).

McGookin et al. (2024) study provide multiple entry points for modellers to incorporate participatory elements either throughout the process or in individual stages.

The existing literature establishes the necessity of case studies representing transdisciplinary co-creation processes into the definition of local and integrated system sustainable configurations. This article aims to contribute this emergent area by presenting the approach used and key results of stakeholder involvement into a city integrated decarbonized and resource self-sufficiency pathways storylines creation. It also aims to show the process and effect of inclusion of integrated WEF nexus perspective into a stakeholder dialogue.

The article is organized in four main chapters, starting with an introduction, and a description of the methods applied, following the results presentation and the final section with short conclusions.

Methodology

This chapter aims to present the methodologic approach to develop the narrative that underlie the scenarios future *Sustainability and the Water-Energy-Food nexus visions* for Cascais (case study municipality).

Case study

The CitySelfy project case study is Cascais municipality located in Portugal. Cascais municipality is located in the Lisbon region (Portugal) and is composed of four parishes covering an area of 97.40 km² and around 210 361 inhabitants in 2015 (INE 2021), corresponding to a population density of 2 160 hab./km². The municipality is located in a region with one of the highest solar radiation levels (Huld et al., 2012) providing exceptional conditions for solar PV and solar thermal technology deployment. The municipality imports most of the consumed water (around 80% in 2015) and food resources. The territory is also located in the region with highest risk to climate change impacts (Feyen et al., 2020) which can further pose challenges to WEF security of supply and access.

The municipality has set a 2050 carbon neutrality goal and has a strong political commitment for climate mitigation actions (Cascais Ambiente, 2019). The municipality is also aligned with CitySelfy project objectives and showing a progressive scope of sustainability by combining climate action goals and WEF resources sustainable systems.

Stakeholder engagement process

The process of developing a link between CitySelfy project scientific challenges to stakeholders' concerns was done through a one-day structured workshop (Figure 2). The workshop aimed to (1) raise awareness about interlinkages among water-energy-food, focusing on the opportunities and challenges of the interdependence of resources' use, in terms of sustainability, and (2) to co-create future scenarios for the city's sustainability transition.

The first step in this process was a comprehensive stakeholder identification and assessment on which stakeholders would be included. The process assumed a representation of different stakeholder sectors. It also aimed to assure relevance and inclusivity of stakeholders which would provide diverse perspectives, expertise, and interests during the co-creation activity (Andersen et al., 2021).

The mapped stakeholders covered environmental NGO (2 participants), academia (1 participant), local administration (5 participants) representing water, energy and water departments, central government (1 participant) and public sector (2 participants), private companies (8 participants) and civil society (3 participants) (ex. Food cooperatives). The total 22 stakeholders (table 1) WEF system classification represented 38% for energy, 31% to food and 8 for water systems.

Table 1 - Cascais 2050: Sustainability and the Water-Energy-Food nexus workshop participants

WEF system	Institution	Type
Water	Linhó Circular	Cascais Municipality Social department
Water	Cascais Ambiente - Aceleração da Transição Urbana	Cascais Municipality Environment department
Water	ZERO	ONG
Water	S317	Private sector
Water	Adene/AQUA+	Public sector
Water	Águas do Tejo Atlântico	Private sector
Food	Cercica	Public social Cooperative
Food	Cascais Ambiente - Terras de Cascais	Cascais Municipality Environment department - Food sector
Food	Quinta da Samarra	Private sector
Food	Re-food Cascais	Public social Cooperative
Food	Aquaponics Iberia	Private sector
Food	Turismo de Portugal	Private sector
Food	Unidade de Saude Pública de Cascais	Central Governance - Public health
Energy	Coopérnico, LNEC	Public social Cooperative
Energy	Get2C	Private sector
Energy	MobiCascais	Cascais Municipality Transport and mobility department

WEF system	Institution	Type
Energy	Adene/MOVE+	Public sector
Energy	S317	Private sector
Energy	LNEG	Academia
Energy	Cascais Ambiente - Aceleração da Transição Urbana	Cascais Municipality Environment department
Energy	ZERO	ONG
Energy	Tratolixo	Private sector

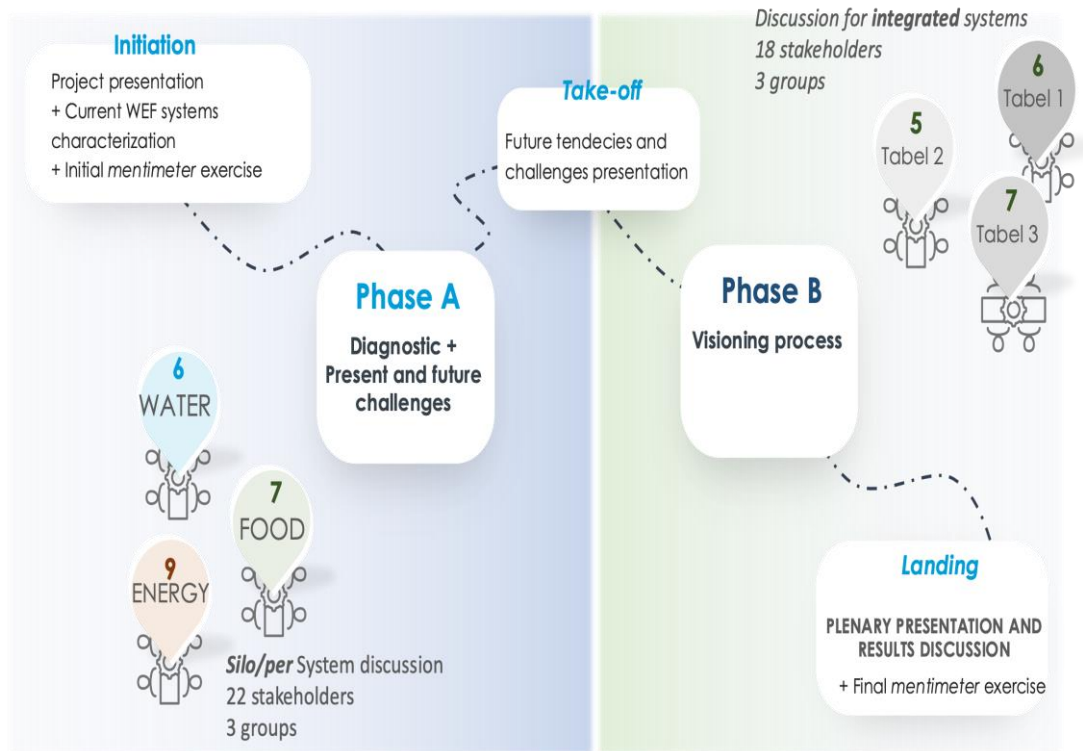
The workshop framework (Figure 2) was conceptualized based on the base research questions and the scenario and storylines objectives. The stakeholder participatory method considered a merge between visioning approach (Madsen & Ulhøi, 2021), with world café (Brown et al., 2006). This aimed to assume a high degree of stakeholder interaction in line with Schreuder & Horlings (2022) good communication practices levels. This guaranteed the foundation for engaging stakeholders effectively and ensuring that the co-creation process aligns with the intended purpose of the scenario’s development.

The workshop session named “Cascais 2050: Sustainability and the Water-Energy-Food nexus” had two key components/phases: phase A – *Diagnostic and challenges* and Phase B – *visioning*.

The first phase “Diagnostic” aimed to frame the problem and collect perceptions of stakeholders on Cascais WEF systems current conditions and possible challenges on self-sufficiency and sustainability dimensions. In this phase stakeholders were organized by WEF resources and distributed to each thematic table. This aimed to secure a discussion without an explicit system integrated perspective.

The phase B that aimed to make a vision process, where stakeholders were inspired to imagine the configuration and main characteristics of *2050 Cascais water-energy-food system*. This required a dip dive process which included a preparatory stage, named “take-off” where it was done a presentation of the various global and innovative tendencies for each WEF system component. Phase B also included outcomes in an integrated perspective which was done by rearranging the stakeholders’ places with a mix of WEF representation in each table. Nevertheless, it didn’t include a final feedback loop, where each table’s insights could be further debated across and open to participants from other tables. Both phase A and B had a moderator to guarantee a homogenous and diverse contribution by all participants and the compliance of session duration. The moderator had no intervention on the participants’ contributions.

Figure 2. General Framework of the CitySelfy Project workshop on “Cascais 2050: Sustainability and the Water-Energy-Food nexus

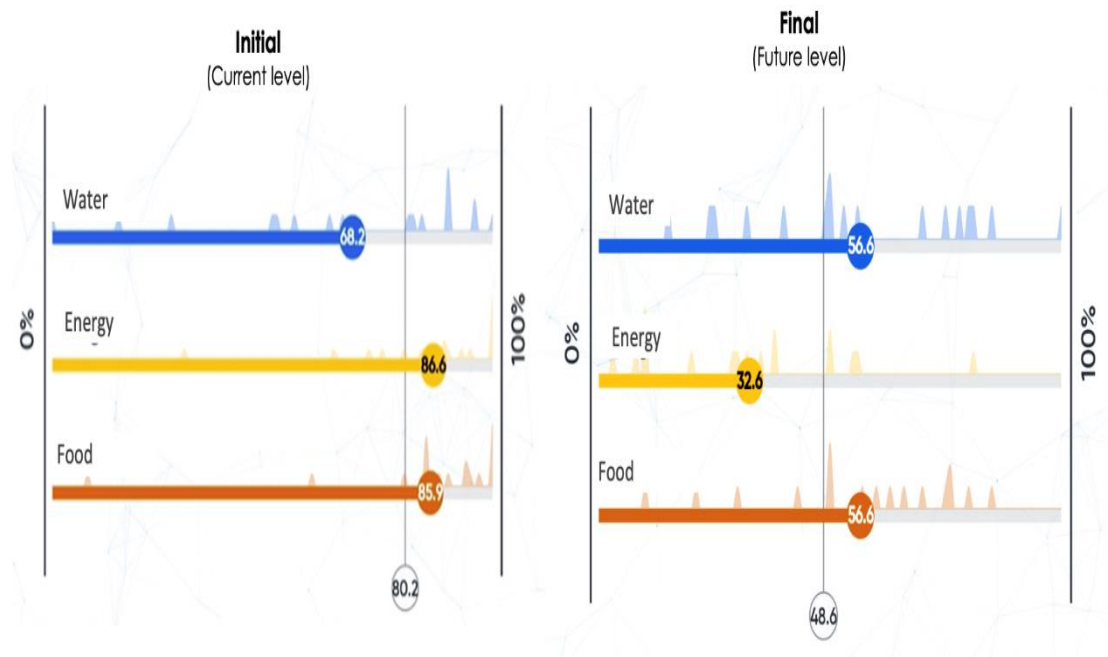


Results

The scenario-building process aimed to be an interactive process and included an initial phase for problem framing to bring all stakeholders to focus on the research questions and session goals. To do so an initial exercise was done where stakeholders were asked a range of questions related with their perceptions of the case study region WEF resource self-sufficiency level. It included inquiring their perception of the project core research project question and local WEF system transformation capacity. This exercise was made with use of Mentimeter¹ software due to its capacity to support effective and active participation and discussion-driven dialogic approaches (Mayhew et al., 2020).

¹ Mentimeter: Interactive presentation software, at <https://www.mentimeter.com>

Figure 3. Mentimeter exercise results from the question: *What is Cascais water, energy and food external level of dependency?* (Dependency level (%): water-energy and food consumption with external origin to the municipality)



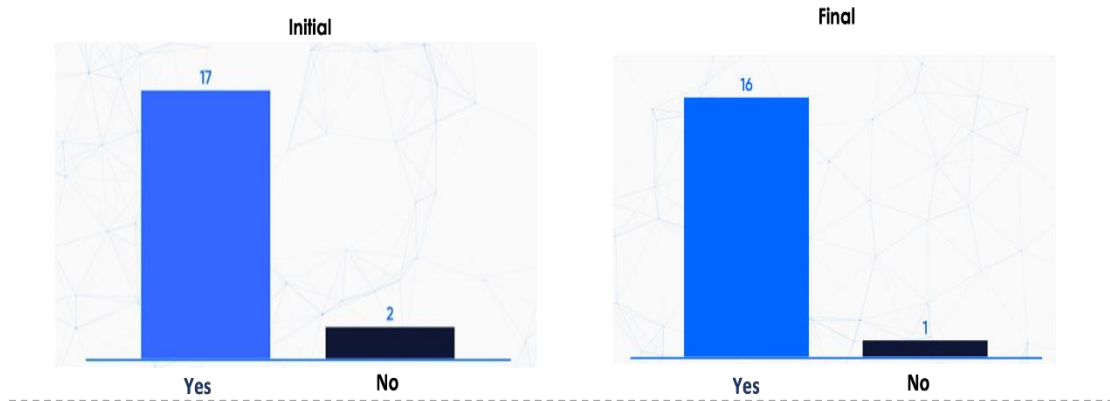
The stakeholders showed an alignment the reference year level of resource external dependency register in 2021 (

Figure 3), providing a relative level of confidence on the knowledge and understanding of municipality WEF characteristics. The same question asked after all the visioning process (Phase B) showed an overall optimism on what the future WEF self-sufficiency level can be. Stakeholders identified energy as the resource with higher potential to self-sufficiency with achievable 32.6% and water and food resources with the same level of self-sufficiency 56.6%. This result shows an impact of the session/table discussion exercise where the consideration of integrated and combined perspective induced a modification on the self-sufficiency perspective in a positive manner. Nevertheless, stakeholders' perspective on the relationship between local WEF resource self-sufficiency and sustainability goals were uniform in both initial and final exercise (Figure 4).

Figure 4. Mentimeter exercise results from the questions “Can resource self-sufficiency be a determinant factor for local sustainability?” and “What is the role cities can play in the water-energy-food system transformation?”

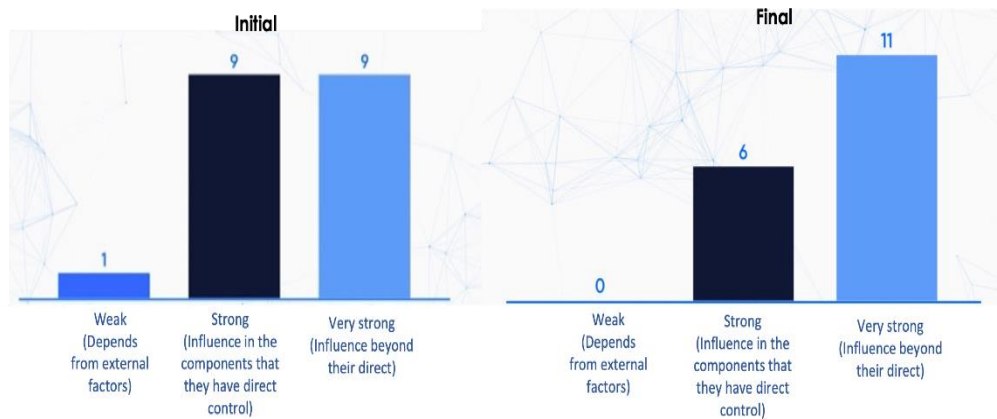
Question: Can resource self-sufficiency be a determinant factor for local sustainability?

Portuguese: *Pode a autossuficiência de recursos ser um fator determinante para alcançar sustentabilidade local?*



Question: What is the role cities can play in the water-energy-food system transformation?

Qual o papel que as cidades podem ter na transformação dos sistemas alimentares-energéticos e de abastecimento de água?



Stakeholders initially revealed an equilibrium between strong and very strong municipality WEF transformation power (Figure 4). The integrated/nexus setting stimulated during the discussion process contributed to positive rise in the perception of the role of cities WEF systems transformations. Stakeholders suggested there’s no dependence from external factors and a higher recognition that cities can even influence beyond their direct control WEF system transformation components. These results reveal the effect of integrated system perspective in the higher direct recognition of cities potential on WEF systems transformation (de Andrade Guerra et al., 2022).

Vision and narratives for Cascais 2050

The second phase of the session aimed to explore alternative futures and co-create vision and narratives for “*Optimization/maximization of endogenous resources in a progressively complex context with multiple influencing factors*”. It started by asking the participants to “imagine that there are no funding limits, no restrictions on imagination, and effectively look to 2050 and see how we would like to see the water-energy-food system in the municipality of Cascais”. This process aimed to provide a way to address complex nature of nexus sustainability challenges with a pluralistic approach of including multiple actors’ knowledge (Norström et al., 2020) into sustainable pathways (van Vuuren et al., 2022). The inclusion of “non-limitation thinking” aimed to collect combined elements of individual contributions with no influence of normative classification of true or false contributions of all actors, in line with Di Felice et al. (2023) work. Therefore, it was a pluralistic process of co-creation of alternative narratives and imaginaries to the WEF system in the municipality of Cascais.

The findings from the visioning process during the workshop Phase B have been thoroughly analysed and synthesized into two distinct storylines. This was a result of the elaboration of generated dialogues and variety of shared thoughts. It’s essential to note that the obtained results reflect the overall combined vision and perceptions captured during the discussions and may not correspond to the specific individual contributions of the participants.

Storyline 1: Technology-Driven Self-Sufficiency

Cascais municipality achieves its vision of combined sustainability and self-sufficiency through a strong emphasis on technology-driven solutions. The municipality invests heavily in cutting-edge technologies to optimize resource utilization and minimize waste, as “Circularity is the future. Closed-loop systems.” and that “By 2050, we won’t be in a transitional phase anymore; we’ll be fully immersed in another cycle. The model we are envisioning now will have been consolidated and in full force by 2050.”. The core characteristics of this created storyline are:

1. **Smart Water Management System:** Cascais implements a smart water management system that efficiently monitors and controls water usage throughout the municipality. IoT sensors are deployed to detect leaks and measure water consumption

in real-time. Residents receive personalized water usage data and conservation instructions through smart devices, promoting responsible water consumption. The system also optimizes treated wastewater reuse and rainwater harvesting, ensuring water availability during periods of scarcity. As identified by the stakeholders "This complementarity of water services is inevitable, we do not know where the resources will be available, unfortunately. By 2050, we will be forced to have to think in different ways to have potable water and water that can meet the needs of the community in its various aspects.". This solution is aligned with water system solutions identified by Magic Valley, Idaho (USA) stakeholders for the region WEF future (Williams et al., 2023).

2. Renewable Energy Grid Integration: The municipality establishes a sophisticated renewable energy grid integration system, enabling continuous distribution and storage of locally generated solar, wind, and wave energy. Stakeholders also mention that "in 2050, we will have a lot of renewable energy being produced in the municipality, obligatorily. The municipality location and territory characteristics provide a range of possibilities, "We have here the sea, we have energy. We have wind, we have energy. We have sun, we have energy. Cascais is a very privileged area.". AI-powered algorithms dynamically balance electricity supply and demand, ensuring a stable and resilient energy supply. Energy communities flourish, with smart meters allowing individuals to track their energy usage and incentivizing energy-saving behaviours.

3. Advanced Waste Management Solutions: Cascais adopts cutting-edge waste management technologies to achieve a circular economy, as mentioned by stakeholders "Cities must be able to metabolize their waste, make things circular.". Automated sorting systems effectively segregate recyclable materials, reducing contamination and increasing recycling rates. Supported by stakeholders comment on "No more recycling bins, as they won't be needed." Many resources (considered resources, not waste) can be reused at the neighbourhood level to generate energy, compost, or animal feed. No food waste, maximizing reuse for animal feed and composting. Efficient utilization of all organic waste will be essential. Waste-to-energy facilities utilize advanced incineration processes, maximizing energy recovery from non-recyclable waste. Organic waste is efficiently composted or converted into biogas, reducing greenhouse gas emissions.

4. **Autonomous Electric Mobility:** The municipality pioneers the use of autonomous electric vehicles (AEVs) for public transportation and shared mobility as a service (MaaS), as mentioned by the stakeholders, in 2050 there will “be a privilege to collective transport over individual transport, with strong concept application of mobility as a service”.. AEVs are integrated into a comprehensive mobility-as-a-service platform, offering efficient, on-demand transportation to residents. The reduction of individual car ownership and the widespread adoption of AEVs contribute to lower emissions and a cleaner urban environment.

5. **Vertical and Urban Farming:** Cascais embraces vertical farming and innovative urban agricultural techniques to achieve food autonomy. Multi-family/multi-purpose buildings incorporate vertical farming systems, maximizing food production in limited urban spaces. Aquaponics and hydroponics thrive, providing fresh food produce to residents year-round. Stakeholders mention, “In small spaces, one can opt for gardens on shelves/rotating towers (hydroponics). Aquaponics as a solution for the lack of space for cultivation in the urban environment "In urban environment it can be more complicated. The dwellings would require more space and a configuration that would allow it. There I see already the solution of aquaponics, the reuse of buildings/spaces abandoned, warehouses.". This includes insect farms that offer alternative protein sources, further reducing the environmental impact of food production.

Storyline 2: Community-Driven Self-Sufficiency

In this storyline, Cascais achieves its sustainable and self-sufficient future through mainly community-driven efforts and behavioural changes. The municipality prioritizes community engagement and cooperation to build a resilient and interconnected society, via:

1. **Community-Based Water Management:** Cascais fosters a strong sense of water protection among its residents. Community gardens and parks become demonstration sites for efficient water use, featuring rainwater harvesting systems and community-led wastewater reuse projects. Water-saving competitions and educational programs further encourage responsible water consumption. As mentioned by stakeholders, that in 2050 “The sharing economy will be much more important than it is today, sharing resources and even energy (energy communities). As “water as a public good/service, since water should be from the state and not from private entities, it is a public good and must be managed for

everyone and not by a private entity. Changes in social dynamics will happen by necessity, as we need to change everything that people think/do. / "Scarcity will change many behaviours."

2. **Localized Energy Cooperatives:** The municipality promotes the formation of localized energy cooperatives, empowering communities to collectively generate, share, and manage renewable energy. Stakeholders mention "By 2050 there will be many energy communities, associations of people who have a space and join to produce electricity for themselves and to sell to the network or to neighbours (if there is surplus)". Residents, businesses, and institutions collaborate to install solar panels on rooftops and open spaces, creating neighbourhood microgrids. Energy cooperatives organize regular workshops and events to raise awareness about energy efficiency and sustainable practices.

3. **Zero-Waste Communities:** Cascais emphasizes waste reduction and resource repurposing at the community level. Zero-waste communities emerge, adopting waste segregation practices, and actively participating in recycling drives and circular economy initiatives. Neighbourhood repair cafés and swapping events promote the reuse of goods, fostering a culture of resourcefulness and sustainability.

4. **Local Food Hubs and Farmers' Markets:** The municipality has established high-density local food hubs and farmers' markets, where residents can directly purchase products from nearby farms and urban gardens. As mentioned by the stakeholders, "in 2050 the food system has focus on production side that to achieve food self-sufficiency, we need to produce [locally], with a opportunity identified on expanding community and neighbourhood gardens with active participation from the community as "everyone takes what they produce, and what they can't consume goes to someone else.". Also shortening supply chains - people sourcing food directly from local producers. The sense of community around these hubs strengthens social ties and enhances food security. Local chefs and culinary schools collaborate with farmers to promote sustainable and plant-based diets.

5. **Neighbourhood Sustainability Competitions:** Cascais organizes neighbourhood sustainability competitions, encouraging friendly challenges between communities to achieve WEF self-sufficiency goals. Competitions range from energy-saving challenges to waste reduction contests. The results can provide

models of sustainability practices. As mentioned by stakeholders, “A model of self-sufficient homes, which extends from individual houses to condominiums, neighbourhoods, and ultimately the entire city. Individually, those living in detached houses have more potential for self-sufficiency compared to those living in apartments. However, at the building scale, it is easier to implement resource reuse solutions. Therefore, strategies should be planned at the neighbourhood level – housing is a small unit, but condominiums or neighbourhoods are more functional units, allowing for effective planning and strategic solutions for water-energy-food nexus at the neighbourhood level. Although, (Barrier) regulation at the neighbourhood level may be more challenging, for example new neighbourhoods must comply with new regulations, incorporating new technologies and integrated solutions, while older neighbourhoods need rehabilitation. Nevertheless, this can turn to an opportunity since new architectural options and domestic network management solutions (energy, water, wastewater) can be applied to new constructions, and older buildings can be gradually retrofitted.

The first storyline has technology as the pivot that drives Cascais' pathway towards sustainability and WEF self-sufficiency. With the use of advanced systems and AI-powered solutions it enables efficient resource management and reduces environmental impact. On the other hand, the second storyline emphasizes community involvement, where behavioural changes and grassroots efforts lead to self-sufficiency. Also, the second storyline evidenced the stakeholder's perspective on the power of collective action and cooperation among residents and local communities. to bring about a sustainable future. The two storylines also have a division from a top-down approach to a bottom-up strategy, with the second empowering individuals to be active participants in the transformation.

This 2nd phase showed a collection of knowledge, ideas and practices across all participants and concluded in partly-consensus and it retained a plurality of thoughts on the integrated vision. It was a process of knowledge co-creation (Pohl et al., 2021) as the results outline the incremental ideas of all participants and evidence and a contribution of transdisciplinary research (Schreuder & Horlings, 2022). Moreover, it contributed to knowledge transfer, has stakeholders (Mielke et al., 2016) highlighted by the acquired perception of system interaction when thinking about local WEF

transformation. The evidence of stakeholder's progress to integrated and systemic vision of WEF systems was the indication on influences between possible solutions deployment:

"A significant barrier lies in the approach to the food system itself. We don't see the food system as a whole, from production to distribution, consumption, and waste,"

Which was also associated with the water and energy systems, as well as their integration.

"Connection between water distribution losses reduction and benefits for energy consumption This will also contribute to increasing energy efficiency. The transport and lifting of water have energy costs, part of which is then lost and does not reach consumers."

The results show the importance of stakeholders' involvement approach in WEF nexus perception and impacts at local level (Bazzana et al., 2022) and plurality of thoughts introduced on the integrated vision development. This was evidenced by two complementary comments:

"we should think about nexus connections looking at the territory. For example, consider location on cost-efficiency selection of alternative water resources, namely "desalinized water" vs treated wastewater due to energy consumption and cost of transport of the different options."

Complemented with:

"Maybe the evolution of the concept of energy communities to water communities, with anchoring to the territory, consumption, and consumption typologies."

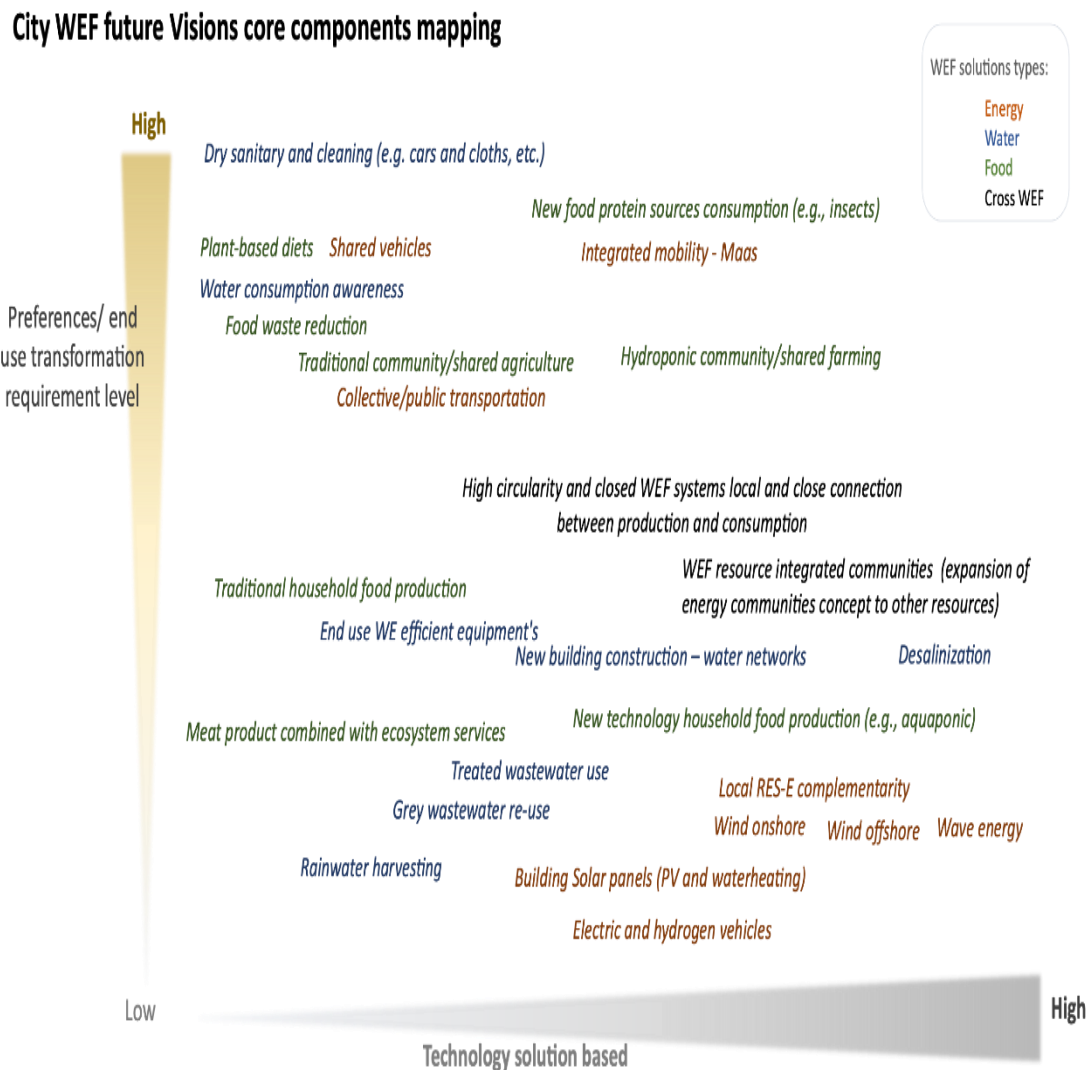
Both created storylines showed connection points, and the following distinct rationales aimed to set two different type and solution levels of implementation.

Local stakeholders WEF 2050 vision solutions

The stakeholders visioning discussion results were also mapped into a matrix of future conditions/solutions mentioned in each storyline (Figure 5). To achieve this, all proposed solutions have been systematically arranged and categorized to offer a comprehensive overview of the type of solutions considered. This included an association (by colour) to each WEF resource it focusses on. A relative classification in

terms of level of behaviour change requirement and/or technology innovation level was applied to locate each solution in this matrix.

Figure 5. Cascais 2050 Sustainability and the Water-Energy-Food nexus visions solutions mapping.



Two generic WEF systems characteristics raised from stakeholders' contributions. One focus of the circular economy “circularity” at local scale, which included a “close” links between resource production and consumption. This showed the perception of circular economy to resource self-sufficiency (Valverde & Avilés-Palacios, 2021) and climate mitigation (Fortes et al., 2019; Murakami et al., 2022). The participants also conceptualized the potential for integrated local communities that synergize water, food, and energy resources. This concept envisions the creation of water communities, adapting and enhancing the principles of energy (Hanke & Guyet, 2023) and food

(Birtalan et al., 2021) communities to foster interconnectedness within the local WEF systems.

The scenario design planning exercise promoted systems thinking by encouraging participants to think of the future in complex and dynamic terms as sustainability research requires knowledge integration between various actors (Smetschka & Gaube, 2020) the obtained results are core insights to scenario development and further including in modelling process (Fortes et al., 2015) contributing increased societal impact.

This exercise results provided a first stage pillar for integration between stakeholders, research and policy actors to ensure a necessary more inclusive and effective future policy implementation process (Bazzana et al., 2023).

Also the inclusion of integrated/nexus perspective as the basis for the discussion on cities transition towards sustainability capacity, can act as a prompt to innovation generation mechanism in line with Soares Dal Poz et al. (2022) conclusions.

Conclusions

In the exploration of an optimal combination of city climate neutrality and resource use sustainability, it has become evident that the selection of disconnected solutions is insufficient to address the complexity of challenges faced by integrated resource systems. As cities continue to expand, they contribute and face increasing pressures on resources availability. Therefore, a more comprehensive and integrated resource systems approach is necessary to guide decision making. Moreover, local stakeholders possess valuable insights and knowledge about the specific challenges, needs, and opportunities to design transformation scenarios.

CitySelfy project contributes to filling this research and practice gap by including local stakeholders early in the scenarios developing process and by applying a framework that can maximize the effective contribution.

The analysis of the workshop results reveals a convergence among the participants on the core elements of the socio-economic portrait and characteristics of a sustainable and self-sufficient Cascais municipality WEF system in 2050.

The application of an integrated perspective of nexus discussion was a challenging aspect for stakeholders, as it required them to think about the connections between

different systems while formulating solutions. Nevertheless, certain core difficulties emerged related to stakeholders' integrated system thinking, partially due to limited time dedicated to envisioning integrated systems. Two distinct visions were identified concerning a top-down approach or a bottom-up strategy, with the second empowering individuals to be active participants in the transformation.

While some solutions, like local energy communities, are already being deployed, others require in-depth potential analysis, such as vertical farming, insects processing and other food production methods. Some of the identified solutions also need specific cost-effectiveness analysis, for instance, decentralized wastewater treatment systems. Other solutions also show the capacity to show some trade-offs such as desalination: this technology provides potable water but requires high energy necessities.

These narratives will guide the quantitative and modelling exercises to support the development of scenarios and key inputs for the WEF modelling exercise.

This work contributes to highlighting the necessity to improve the base WEF resource self-sufficiency modelling exercises by enhancing the representation of social factors and stakeholders' perspectives in energy modelling and leveraging energy models to inform local policymaking.

The research's co-creative narrative design process allowed for early-stage stakeholder involvement and inclusive exploration of future sustainable configurations. The stakeholder dialogue will continue in the second workshop, where quantitative indicators associated with the visions generated in the first workshop will be presented.

Overall, the workshop's output contribute to validate the reference year local WEF interdependencies and also will inform the assessment of effect of local sustainability new technologies, social practices, and localized economic, business, and consumption models. These efforts are essential in realizing the sustainable and self-sufficient Municipality WEF systems envisioned for 2050.

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