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Developing and Implementing the Design-led Nexus Approach for Sustainable Urbanisation

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1 ABSTRACT

The design-led nexus approach aims to integrate design thinking and nexus thinking for urban food-energy-water (FEW) management. The approach was originally proposed in the M-NEX project with a grant by the Sustainable Urbanisation Global Initiative (SUGI) and has been developed through a series of participatory design workshops since 2018 in six consortium cities, including Amsterdam, Belfast, Detroit, Doha, Sydney and Tokyo. This article describes theprocess to develop the methodologies and applications about this unique approach, for SUGI peers to share and learn from each other. The M-NEX design-led approach is developed reflectively in a series ofdesign workshops in six target cities. Through the iterative practices in different contexts, we found that (1)the food-as-entry approach serves as a trigger to attract stakeholders' attention, and the FEW nexus provides a common ground for stakeholders to rethink the sustainability of cities by breaking down the barriers of siloed thinking, (2) the design-led method works by combining design thinking and systematic nexus thinking iteratively in visual and scientific languages, (3) the iterative application of a scientific evaluation tool, FEWprint, makes the performance of design solutions visible and comparable through communication, and (4) living labs play a key role in networking actors, practicing ideas, and scaling up to the policy landscape. We also learned that (1) FEW issues and solutions are sensitive to contexts, (2) redundant resources and the potential for improving self-sufficiency can be discovered even in developed cities by creatively integrating knowledge, technology and policy, and (3) the nexus approach is beneficialfor all actors, including governments, companies, and community leaders who are looking for collective ways of working towards policy goals such as zero carbon emissions and the Sustainable Development Goals (SDGs).

Keywords: urban living lab, FEWprint, design workshop, moveable nexus, supporting platform

2 INTRODUCTION

Human civilization faces many threats and is on the brink of several planetary boundaries (PBs) (Steffen et al., 2015). Accelerating rates of urbanization are increasing the global demand for food, energy and water (FEW); climate change is amplifying the rate and extent over which resource degradation is occurring (Hoff 2011). As consumption levels increase, the couplings between FEW resources tighten, making theirmanagement complex and difficult. Increased productivity or efficiency in one sector often impacts the economic, political and environmental security of the whole FEW system (Bazilian et al. 2011). On the other hand, the Paris Agreement not only urges all to reduce global warming, but also points to the need to design a comprehensive transformation of urban systems and the way societies will be organized. The United Nations initiated the SDGs in whichFEW-related goals sit at the center of the vision (Liu et al, 2018). Implicitly, this calls for (a further) integration of FEW sectors to overcome siloedthinking and encourages innovative actions.

Typically, the relationships between food, water, and energy are not yet mutually beneficial. Our cities, and the systems that support them, have not been designed to address the FEW nexuses. Consumers in cities are not very much aware of the complex interrelations of food, water, and energy, and therefore will not change their behavior easily. Meanwhile, farmers in rural areas of the world produce food under increasing stresses of water and energy. Gaps exist in awareness of the roles and impacts of climate change. To date, most FEW research has resulted in assessment tools and policy proposals. The integration of food, energy and water in practical urban environments is problematic, and can be detailed in terms of three main aspects: spatial design is often lacking in FEW projects and programs; assessment tools are mostly used at the end or long after a plan or project is realized; and the involvement of stakeholders and citizens is limited to approving or declining a proposition.

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Due to the connectedness of FEW in social and ecological systems, the nexus approach has been attracting attention since the first Nexus Conferencein Bonn, Germany (Hoff, 2011). The European Union implemented the Urban Nexus Project in 7FP(http://www.eurocities.eu/) from 2011 to 2014 and released a series of reports on the urban nexus, including climate change resilience, health and quality of life, and competition for urban land (Urban Nexus, 2013). The National Science Foundation (NSF) of the United States allocated a large research budget for the food-water-energy nexus and launched priority research activities in 2017. Correspondingly, Belmont Forum openeda call for the Sustainable Urban Global Initiative: Food-Water-Energy Nexus (SUGI-NEXUS, https://jpi-urbaneurope.eu/calls/sugi) with the Joint Programming Initiative Urban Europe,and consequentlyprovided grants for 15 projects at the end of 2017,among diverseapplicationsfrom around the world.

The Moveable Nexus, in short M-NEX, is one of the SUGI granted projects. It is unique in that it formalizes management tools, policy proposals, and assessment methods, both qualitative and quantitative, into physical design solutions through explicit design principles and procedures for understanding the complexity of FEW cross disciplines, fields and sectors.Since the commencement of the project, the M-NEX methodology has evolved incrementally through a series of design workshop held bi-annually at six consortium cities, including Amsterdam, Belfast, Detroit, Doha, Sydney and Tokyo (see http://m-nex.net). As a result, M-NEX has become not only the project acronym for the key concept of the movable nexus, but also the name of the output of the project, the design support platform that integrates nexus thinking into design, evaluation and engagement.This article describes the development process and the results of the project. It provides rich experience on how to incorporate the FEWnexus perspectives into urban design at the building, neighborhood, city, and regional level, to conduct collaborative urban FEW design with stakeholders and inhabitants.

3 NEXUS CHALLENGES AND RESPONSES

3.1 Complexity of FEW Nexus in Cities

FEW is a wicked problem in consideration of the complexity of cities and related to many urban problems. Food, energy, and water are highly intertwined, and even parametrically related. There are trade-offs and synergistic effects (Haase, Haase& Rink, 2014; Vogt et al., 2010). Due to the inter-connectedness of FEW in social and ecological systems, it is assumed that a nexus approach could improve sustainability in general terms, and as a result has attracted attention as a way to challenge the complex urban issues related to the status quo.However, “the application and implementation of a nexus approach is still in its infancy” (Liu et al., 2018). This is particularly true in urban contexts. Most research is focused on the supply side of the equation, namely on how to secure FEW resources in response to growing global demand. In academic research there was a tendency to view food, energy, and water separately, whether it was for resource management, production and supply, or product distribution. Thus, awareness of the nexus concept was often weak. Governmental sectors or utility agencies typically treat the problems as independent issues (Bettencourt & West, 2010). Each sector generally has its own system, making it difficult to act in a broad and integrated way. When it comes to the environment, someone would argue that considerable efforts have already been made and that efficient resource use has been achieved, so there is little room for further improvement. Citizens take thecity as a given service, as long as they pay their bills, regardless of the fact that, in reality, maintaining food, energy, and water services involves enormous costs, and this leads to severe constraints for urban sustainability.

Substantial research has been conducted on food, energy, and water (F, E and W) separately, as well as the nexus-pairs FE, EW and FW (Varbanov, 2014), and for the nexus of all three (Endo et al., 2014; Endo & Oh, 2018). Most of the research highlights scientific mechanisms of nexuses and the increase of F, E, W-related risks associated with population growth and development. Examples of typical approaches are surveys of ecological resource availability (Daher & Mohtar, 2015), urban metabolism modeling of production, consumption and disposal (Bazilian et al., 2011), shifting to a low-carbon circular economy (Bhaduri et al., 2015), and reducing external inputs from outside the region while and encouraging local production for local consumption (Siddiqi and Anandon, 2011). Limited studies have been conducted that delve deeply into the urban space and design solutions (Romero-lankao, McPhearson& Davidson, 2017).

3.2 Response from the Moveable Nexus

The goal of the M-NEX project is to develop an integrated design methodology that links complex and location-specific FEW problems at the architectural, urban, and regional scales. Instead of defining the nexus as risks, we consider that the FEWnexuses should integrate their components and by doing so, turn problems into opportunities to create a supportive environment and sustainable services. Actually, every city is unique in terms of its land, people, and relationship to the bioregion. Similarly, resource flows are different in every city around the world, too. Solutions for sustainability will be also unique in different contexts, scales, and timing. FEW provides a common playing field in the forms of buildings, transportation, green space, etc. (urban design, spatial design, architecture) for stakeholders to overcome the complexity. The moveable nexus combines the physical world in situ and cybernetic knowledge in human brains or computers into design solutions that are adapted to local contexts. To respond to the challenges and achieve the purpose, this project uses the term moveable nexus philosophically (Yan and Roggema, 2019). The multiple facets of the moveablenexus have been highlighted by the project publication (Roggemam, 2021). The following three are vitalin particular for understanding and implementation.

3.2.1 Moveable nexus thinking

The FEW nexus should be seen as a moveable nexus, which is capable of transforming its parts, its shape, and its capabilities. “The urban environment is changing all the time and, under influence of climate change, pandemics, migrationtowards the city and many more mechanisms, seems to be transforming at an ever faster pace” (Roggema, 2021). The traditional way these processes are approached is often by reducing them to simple problems for which a straightforward solution is sought. This is a misconception. For static problems a simple solution suffices, and is even needed to let society function properly. But at the same time when problems are unstructured, or wicked, a simple solution often proves to make problems worse. Thinking about the future city in terms of the ways food-energy-water generation, distribution and supply are organized may well make a difference for urban dwellers’ quality of life. The urban context is unprecedented and cannot be predicted very well. When uncertainties increase, the demand for simple responses seems to be the preferred way of treatment. This is, however, an implicit flaw, because when the complexity of the problems rises, the responses can no longer be simple. Responding as if the city is stable while in reality it is increasingly dynamic would only bring fake solutions that last for a short time. The opposite approach must be the way forward: when problems are wicked, self-organizing processes and responses that do not bring definite solutions are preferable, as they can adjust themselves as the problems change along the way. For FEWnexuses this implies that a moveable approach, in which the solutions are flexible, and benefit from all other components in the system, will decrease uncertainty, in the longer term in particular(Roggema, 2021). The moveable nexus will be presented as a way of thinking that brings this alternative within reach, with examples from around the world, in different contexts and at different spatial and temporal scales. As befitsa moveable philosophy, all perspectives can be used elsewhere, and the knowledge is meant to move around. This inspires alternative way to collect the knowledge and create solutions that adapt to changing conditions.

3.2.2 Design-led nexus approach

The integration of food, energy and water is not yet mainstream, and there is no established methodology to practice the nexus approach (Yan and Roggema, 2019). It was not common in urban planning and design because of the complexity of the problems per se, the uncertainty of outcomes, and the difficulty of communication between scientific research and design practice. On the other hand, design is by nature a trans-disciplinary approach to problem-solving, which draws upon logic, imagination, intuition, and systemic reasoning in order to explore potential innovative solutions to problems (Kimbell, 2011). Designers explore concrete integrations of knowledge that will combine theory with practice for new productive purposes (Buchanan, 2010), integrating the opinions and needs of multiple stakeholders. In spite of the romantic image that design is a highly personal process, in most cases design proposals are in fact the culmination of shared knowledge and consensus on a specific issue (Kimbell, 2012).

These advantages make a design-led approach particularly appropriate to address wicked problemson the philosophy of moveable nexus thinking. It is extremely useful, as it is able to create something out of nothing that existed before, presenting opportunities to be continuously and collaboratively adaptive, as a city, as a landscape, and as a society(Roggema, 2021). This is particularly true in participatory design where design proposals are the result of professional design activities and communications with a variety of stakeholders.

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With this concept, the M-NEX project developed a design-led nexus approach for urban FEW designs. This approach organizes the sophisticated design process into a series of charrette workshops, an intensive form of design activity often adopted in design practice (Yan and Roggema, 2019). It offers a demanding process with expectations about delivering innovative solutions within a tight time schedule. The need to present the outcomes visually creates pressure to deliver content that is aspirational. The step-by-step design process gives a clear guide for performance and turning inspiration and creativity into regional-to-local design propositions that belong together. Participation and communication provide opportunities for stakeholders to envision and create a new perspective on the future of a geographical area from diverse perspectives.

3.2.3 Moveable nexus platform

Making the workshops workable requires the support of data, informationand communication tools. The M-NEX project planned the moveable nexus platform with three modules: design method, evaluation tools, and participatory mechanisms. Each module consists of the following functions (Yan and Roggema, 2019).

Design method

The design method provides guiding procedures to explore solutions with stakeholders. The procedures are composed of the following steps.

(1) Inventorying FEW-related existing or potential resources and availability of space for urban agriculture, including rooftops, vacant houses, and abandoned, inadequately used or vacant lands

(2) Designing solutions to improve the efficiency of land and space use for food production and ecosystem services with less energy and water consumption by integration of FEW technologies and knowledge

(3) Composing the nexus matrices that mobilize the material and flows of resources cross sectors and disciplines in the social-ecological context

(4) Evaluating the environmental costs and added benefits of solutions through the enhancement of spatial, temporal and service connections among specific social-ecological systems

(5) Delivering the alternatives of solutions and reiterating the design process with stakeholders

This is an iterative and learning process with stakeholders working together. The inventory includes social, financial, and industrial aspects. The mobilization of resources implies the activation and connection of existing and potential capital across industrial, administrative and academic boundaries, with more flows and services.

Evaluation tools

The evaluation of design solutions is a tricky issue. There exists a long list of indicators to assess the impact of human activities on the environment, such as the most typical ones, which include food mileage, CO2 emissions, virtual water use,and the ecological footprint (EF) (Wackernagel & Rees, 1998),etc. Inspired by EF, we developed an indicator we call FEWprint which expressesin terms of land area asthe sum of (1) the land area needed to meet with the demand for food, energy, and water, and (2) the forest area to absorb the corresponding CO2emissions related to FEW resources and services. FEWprintwill be applied iterativelythrough the design process. The output can expressthe existing environmental loadof the FEW demand as a baseline, or the effects ofFEW production and creative design for FEW supply at local level within a household, a street block, a neighborhood, or a city.Such a simplified indicator is extremely useful to assess the performance of design work under different scenarios and alternatives. Stakeholders can understand the environmental costs, the trade-offs and the synergies of different solutions, and eventually rethink the inter-relationships of their behaviors.

Participatory mechanisms

The engagement of multiple stakeholders is conducted through a series of design workshops in the moveable nexus approach. There could be four types of partners: intermediate support organizations, the local community, experts in spatial planning, and public or private sectors.Each partner potentially brings specific resources and advantages, such as physical space, skills, knowledge, financial or regulatory options. During the workshops, design experts visualize resources and produce solutions. The local community can gain an awareness of the issues and co-create the shared values. Private or public sectors might be inspired and then turn the plan and design into policy and business actions. Our experience has told us that intermediate

support organizations such as an urban living lab driven by local actorscan play a key role to connect stakeholders together (Yan and Roggema, 2017).

In summary, the moveable nexus platform is a technical support for moveable nexus thinking. The design-led moveable nexus approach is a process to develop the platform through informed design workshops. Urban living labs are the physical places to accommodate the activities for engagement. Consequently, the moveable nexus thinking, the design-led nexus approach, and the moveable nexus platform in cooperation with an urban living lab commonly form the framework and methodology of the M-NEX project.

4 IMPLEMENTING THE MOVEABLE NEXUS

4.1 Establishing Living Labs

The M-NEX project has unfolded at six living labs, including Amsterdam,Belfast, Doha, Detroit, Sydney, and Tokyo-Yokohama. The six cities differ in terms of geographical features, bioregions and societal conditions, but all of the cities are mature and share several concerns in terms of sustainability in their urban areas. Yan and Roggema (2019) reported on the geographical features, bioregional differences, and social themes of every study area. Each city has developed the urban living labin flexible ways. It can be initiated by the research team originally or be a joint facility with stakeholders such as the WISE Living Lab in Tokyo-Yokohama (http://sankaku-base.style).

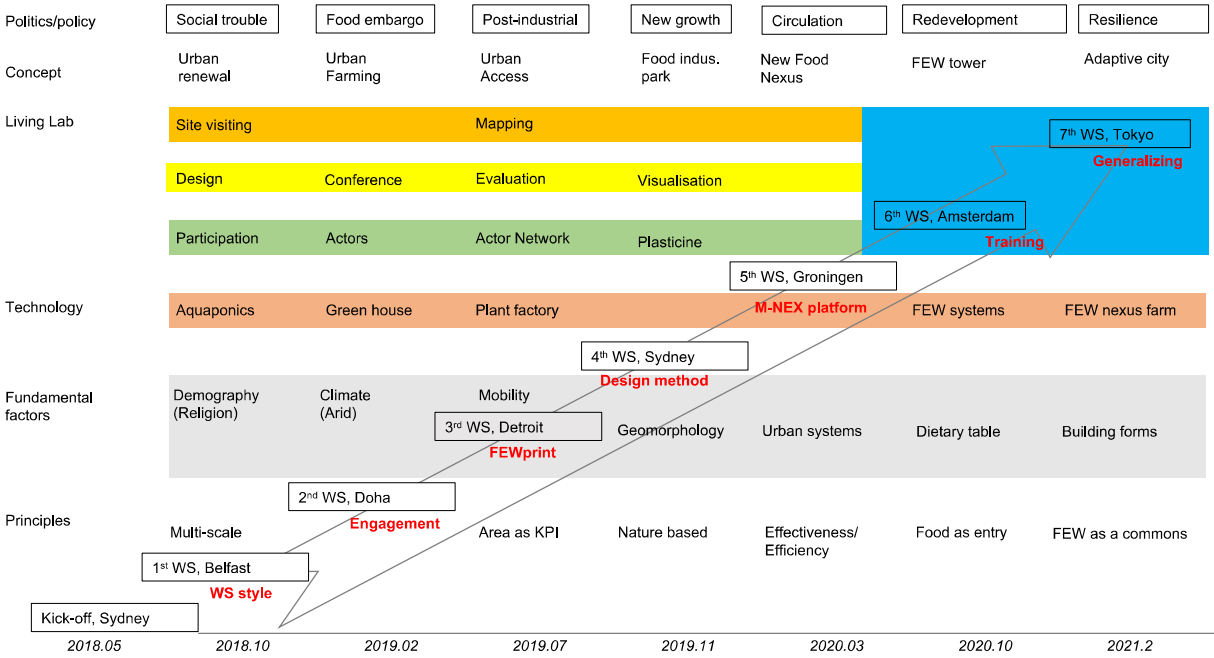

Fig. 1. Incremental project workshop (WS) and results

4.2 Managing the design workshops

The key characteristic of the M-NEX project wasto develop expertise as we harvested knowledge through a series of international design workshops organized at the respective living lab by the individual partner in each of the consortium cities. Every partner country was scheduled to organize aone week-long design workshop with local stakeholders and communities once through the project period. The aim of those workshopswas to co-design a solution for the project site and develop additional knowledge for a specific theme, which then feeds back into the methodology and builds up the evaluation tool (FEWprint). After the first international workshop, the shared knowledge was applied in local workshops in the partner countries for local partners, without international participation. The enriched methodologyat the local level and the advanced evaluation tool was then used as input to the next international workshop in the next partner country. The same process occurredevery six months, following a rotation schedule.Before and after each international workshop, each team held local workshops, practice the learnt method and tools at the local level, and provide feedback to the next international design workshop.By the end of the research project (36 months in total) the design-led meetings and workshops hadsuccessfully been held to harvest the ways of

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approaching and appraising the applicability. The process and results of the workshops are illustrated in Figure 1, which depicts the understanding of how the design-led approach works overtime. The advantage of this management style is the rotation of method development through practice along with partners and participants.

4.3 Results

As shown in Figure 1, following the kick-off event in Sydney, the first workshop was held in Belfast and focused on creating an initial vision for technical food systems in a post-industrial city. The workshop established the participatory style for running the design workshop. The second workshop, in Doha, organized a comprehensive conference with various stakeholders in food and urban farming to look at how to secure the food supply of a city under a food embargo. The workshop highlighted the importance of networking and engagement of stakeholders with a living lab. The third workshop took place on food access and security in Detroit, a post-industrial city with large amounts of vacant land in the urban center. The research conducted by the Detroit team on FEW material flows and actors on urban food issues initiated the development of FEWprint and the visualization of actors. The fourth workshop, in Sydney, worked on the design of a food industrial park near the planned new airport. The design workshop emphasized the development of the emerging area in harmony with natural ecological systems through the iterative design process. The fifth workshop, originally scheduled for Tokyo, was relocated to Groningen because of the nascent outbreak of COVID-19 in the Asian region. The design work and trial of FEWprint tools at three scales (farmland, campus, and region) inspired discussions on urban FEW circular systems. The sixth workshop, hosted by the Amsterdam team online, proposed a redevelopment plan ofthe harbor district based on a pig firm. A technical training session was also organized by younger researchers to apply FEWprint in six cities. The final design workshop was organized virtually by the Tokyo team. The workshop integrated the expertise developed so far and summarized the nexus approachfor designing adaptive cities in response to climate change. This process was repeated bi-annually, with seven international workshops held (after the kickoff workshop) over the course of three years. Each team had the obligation to host one international workshop over the period. Other organizations participated and cooperated. Consequently, the knowledge obtained at each workshop was integrated and provided as expertise and solutions from the M-NEX Project at each level, from building to neighborhood, city, and region.

5 FINDINGS AND DISCUSSION

5.1 Moveable nexus as a learning process

The project took the complex sustainability challenges of the participating cities, and communicated FEW design solutions in concrete, visual, and physical ways to stakeholders and residents through a series of design workshops. The knowledge developed in each workshop was added to the M-NEX platform and used to gradually enhance the tools. It was then applied to other cities. Each team brought its most urgent topics to the international design workshops, and the teams worked together to refine and build common design methods, evaluation tools, and cooperation platforms. For example, the UK team (Belfast) worked on the design of food factories, while the Dutch team (TUD) focused on energy planning in the FEWnexus.Ultimately, we delivered the research findings, policy recommendations and technical innovations, such as implementation of FEW at the University campus (Doha), revitalization of a post-industrial city (Detroit), and future FEW strategies for consumption-oriented cities (Tokyo-Yokohama, Sydney). The knowledge and solutions developed in these themed workshops were then subsequently integrated finally at three different scales: building, neighborhood and city. The teams also brought what they learned back to their cities, applied them in practice locally and undertook actions toward the next international workshop. This process deepened the understanding of FEW issues and promoted consensus on actions and plans for each city. All of the teams learned from each other and studied the potential to incorporate FEWmanagement into their own cities. The living labs have worked jointly in the six urban areas, and shared design methods to build co-creative platforms, as well as evaluation tools and participation frameworks. Hence, the moveable nexus was a learning process. The series of design workshops provided input on design, evaluation and participation through the generated and distinctive platforms to the case study projects managed in each partner city. The entire project travelled iteratively along the project partner

projects, while developing new knowledge and delivering designs at different scales in each partner city, and then integrated the methodologies, tools and participation at the end.

5.2 Principles forthe Moveable Nexus approach

Common factors and principles were observed by obtaining new knowledge and creating solutions for problem solving through the process as shown in Figure1. Some of the key points are highlighted below.

5.2.1 Food as entry point

The food-energy-water nexus is a wicked problem in cities. To simplify the problem, we used food as an entry point in organizing workshops and eliciting solutions. This was considered from both the demand and supply sides. From the perspective of demand, (1) food is essential to survive, (2) food is coupled with energy and water, (3) the availability of food is an issue of personal mobility as well as a deliverable urban service, (4) the quality of food is a barometer of the quality of life for a family or a community, (5) food is meaningful as a way to enjoy life and look for new opportunities, and an important consideration with regards to health, environment, and mobility, and (6) food culture varies by nation, context, and personal preference (i.e., vegan, vegetarian, meat-eating, etc.) and each results in a different environmental footprint. From the perspective of supply, (1) food is part of a complex supply and demand network within cities, (2) food systems are sensitive and change over time through processes such as urbanization, (3) food services are one of the largest and most complex businesses in cities, (4) food is a hot topic in the environmental realm, taking many forms such as organic food, slow food, food loss, and food waste, etc.The choice to use food as an entry point helped to facilitateour approaches to stakeholders.

5.2.2 FEW as a commons

Generally, the supply of and demand for food, energy and water are managed separately by each sector. While industry and government work hard to secure the life supporting services, FEW is often ignored in urban management. Architectural and urban designers tend to think that FEW is a given output of the market or from public services, and reserve little room for alternative ways to supply the systems in place. Only recently, the movement toward SDGs has been changing the atmosphere in academic and management realms as the food-energy-water synthesis is emerging as a key leverage tool for urban sustainability and social equity. Research indicates that FEW access and consumption emit almost 70 percent of CO2 emissions at the level of individual livelihoods (Dhakal, 2020). Food can be used as a lens to consider social, economic and environmental relationships between the demand and supply in cities. It can be a catalyst to rebuild the relationship between production and consumption of FEW in social-ecological systems. We found that FEW has the potential to be a commons for silo-based stakeholders to sit together at the living lab and think about services and infrastructure collaboratively. This significantly supports the initiative of the SUGI call (https://jpi-urbaneurope.eu/), catalyzing stakeholders to take actions on sustainability issues.

5.2.3 FEWprint as KPI

FEWprint is a tool developed by the M-NEX team for interactive design. It can be considered as a subset of the ecological footprint (EF). As mentioned above, as with EF, FEWprint is calculated as the land area to produce food, energy and water services for a specific social or physical unit and the equivalent forest area required to absorb the correspondent CO2 emissions through the production, transportation and consumption of FEW services. A social unit consists of an individual, a household or any group of people, while a physical unit is defined either as a detached house, a single unit in an apartment, a building, a neighborhood, or a city. This practice enables FEWprintto be scaled upfrom the building or street block level to the urban or regional level forpolicymakers.

How to deal with changes in FEW was the key issue ofthe moveable nexus thinking. FEWprint can be used as a key performance indicators (KPI) to evaluate the effectiveness of design propositions under various scenarios: for instance, business as usual (BAU), incremental change, and transformational change, adapting to climatic and demographic changes in comparison with the currentcondition as a baseline. Typically, the space reserved for producing or managing FEW components locally within densely built-up urban environments is very limited while more opportunities are available in suburban or extra-urban zones. The situation is changing as a result of a revolution in the production of renewable energy such as photovoltaic panels. Self-produced, or locally-produced and harvested food, energy and water could shorten the distance

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between demand and supply, eventually reducing the intensity of FEWprint where that gap is shortened. Therefore, FEWprint is useful to evaluate not only the consumption intensity of FEW but also the effects of efforts to reduce the intensity. By using FEWprint, the M-NEX method can (1) redesign the relationship between demand and supply, (2) reassess the costs and benefits of FEW resources and services, and (3) rediscover the opportunities in cities for innovative FEW management in the future.

5.2.4 Technological innovations

Technology playsa key role in solving problems toward sustainable urbanization by improving productivity, reducing carbon emissions and creating jobs. One of the missions forthe M-NEX project was to integrate the fragmented knowledge and technology into the spatial arrangement of design works. The propositions ofdesign workshops and the activities at the six living labs have intensively reflected this mission. The choice of technology is a selective decision based on local natural and social-economic conditions. For instance, the Belfast team proposed urban vertical farming by aquaponics to revitalize unused industrial buildings; the Doha team invented a semi-underground greenhouse to prevent overconsumption of fossil energy; the Detroit team designed urban agriculture parks with ventures that are developing plant factories underground and on the ground; the Sydney team proposed a food industrial park near a new airport to serve an Asian market; the Amsterdam team designed a food tower that produces diverse food products with a significantly reduced FEWprint; the Tokyo team proposed a renewable energy and hydrogen-based home FEW nexus firm for a large number of detached houses in the suburbs of Tokyo.No one solution fits to all ofthe cities. Adoption ofthe technologies should be based on the understanding of the political visions and the fundamental factors of each study city.

5.2.5 Context dependency

Regarding the urban FEW design, we should always think about how we can input contexts into the design process. As shown on the top of Figure1, each city had distinct concerns and the priority of problems to discuss and the solutions were totally dependent on the socialeconomic and natural conditions of cities.Thosecontexts are absolutely crucial to understand, because they will directly impact the ability to design in any given situation. There is a kind of demographic dimension of contexts to this too. It may beeasier in the Netherlands to propose an all-vegan diet in conversation with stakeholders than in the United States, for example, and practices will differ at the individual and cultural level in Qatar versus in Japan. It is then a challenge to implement the policy goal at a community level. Although the acceptance of this kind of global policy may be distinct from countries and cities, a common indicator like FEWprint or a common language likethe SDGs does help localizethe moveable nexus approach properly into the distinct context.

5.3 M-NEX, the Developed Moveable Nexus Platform

Throughthe processandabovefindings, theprojectteamdevelopedthe designsupportplatform, M-NEX,asshown inFigure2. This diagram illustratestheessenceofthedesign-lednexusapproach. The key concept of the platform, as indicated at the top of the diagram, is land area to be expressed as FEWprint, the key performance indicator to measure the resource-use efficiency and design solution effectiveness. It first accountsfor the land area required to meet the demand for FEW and the forest area to absorb CO2 emissions in FEW resources and FEW services asFEWprint baseline. Then, the area existing and to be created to supply FEW resources and services, as well as to absorb CO2 emissions, are accounted for again. By increasing FEWprint NEW and reducing FEWprint NOW, we can shrink the range needed to meet the FEWdemand and supply.

The design method under the area concept is composed of three phases, with nine steps as a whole, and each phase is supported with sophisticated intelligence and ICT tools. The first phase with three steps is to explore the site at different scales, understand the policy context and define the design concept. FEWprint is calculated as a baseline here. The secondphase iterates design and evaluation with FEWprint under different scenarios and adaptive strategies. Basically, all situations and technologies have the same basic elements that can come into this process, such as new energies, vertical agriculture, or green infrastructure, etc. The third phase is participation and co-creation with players at a living lab. The FEW nexus provides a commons to bring the stakeholders—from the upper stream such as utility companies to the lower stream such as grocery shops and inhabitants—to the living lab.

This platform is moveable and flexible for teams to modify for each of their specific contexts and policy issues, ranging diversely from aspects such as carbon neutrality and SDGs to the circular economy. The comparisons can be most meaningful between different adaptive strategies. By applying the platform, we can compare the outputs in the cities, or compare and contrast different approaches in different cities; for example, a business-as-usual strategy versus an alternative proposal within a given city. We can identify the role of an individual household, or an individual stakeholder. We can examine a type of housing, versus a neighborhood organization, or the precinct organization that allows for the institutionalized dimension of the system to be spatialized in the city, or a more general comparison that we would see different patterns across these cities. The comparisons across cities will be more about context differentiation, and the focus could be on how the approach and the tool can be utilized in different contexts around particular technologies and scalar differences.

6 CONCLUSION

M-NEX was designed to have an impact across a variety of scales, stakeholders and locations. The decision-making tool and platform weredeveloped through intense community-based workshops in six locations around the world. The research team visited each location to collaborate with local stakeholders from various sectors in urban living labs to address and formulate a strategy to tackle local FEWproblems. This approach ensured an applicable strategy that provided value for the local academic community, citizens, end users, and commercial parties. The outcomes of each location were analyzed and combined to refine the moveable nexus approach. This process of refinement has helped the output of the moveable nexus platform M-NEX to gradually mature. The iterative design process developed within the project integrated FEW systems, participatory design, FEWprint evaluation and communication formats, and presented a new direction for urban design processes. As the work is disseminated, we expect these methods and processes will help to shape future urban design practices, both academic and professional.

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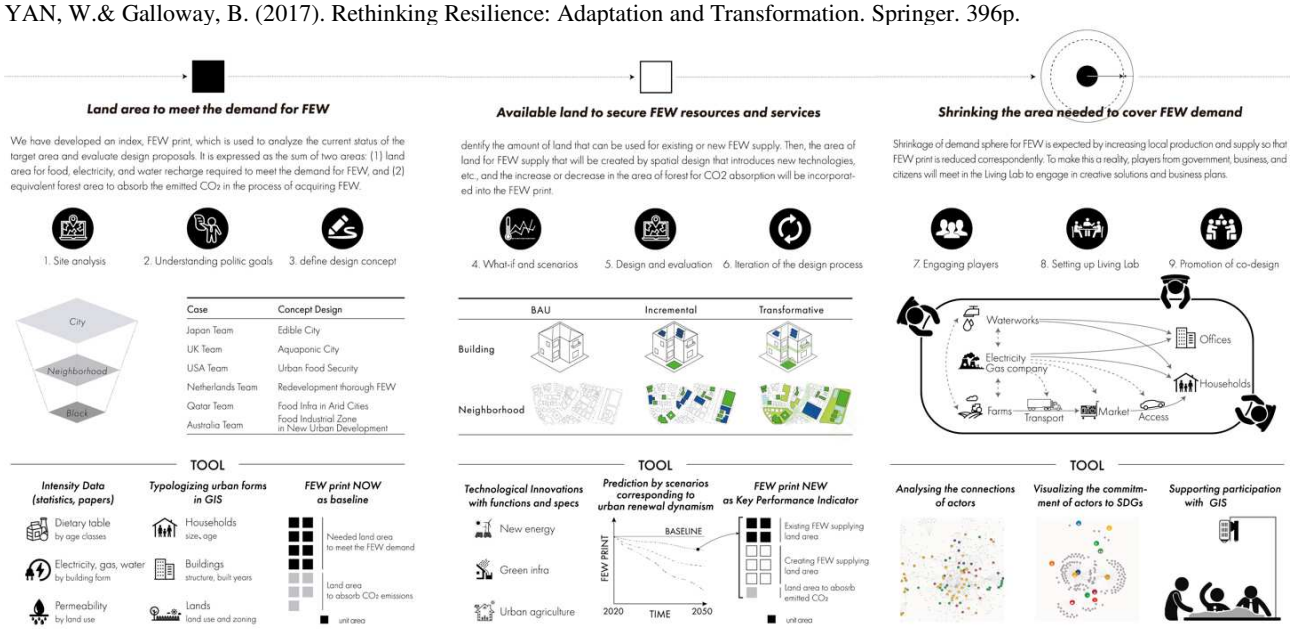

Figure 2. The structure of the design support platform M-NEX