Research Paper

Integrating Vertical Farming at Scale in Urban Food Planning

Practical Considerations for Planners

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Abstract

At all stages of food production and consumption, resources are utilized in an inefficient manner and at an unprecedented rate, clearly affecting urban food systems. This raises future concerns in terms of climate change, and in terms of long-term food security and availability for growing urban populations. A supply-side solution to these issues - with particular potential in megacities - is Vertical Farming (VF), a high-yield form of controlled environment agriculture with promised potential to produce fruits and vegetables within cities, ultimately reducing their resource intensity. This research builds on an Urban & Regional Planning MSc thesis conducted at the University of Amsterdam. The research aims to provide a practical guide for planners, who aim to integrate Vertical Farming into urban food planning. Through this, an indication of whether and how VF can contribute to reducing the impact of food systems in terms of anthropogenic climate change is provided, and ultimately, it helps to understand if and how VF can be up-scaled for further impact. The research utilized an abductive approach with a qualitative design, where 17 experts working in the field were interviewed. These experts represent academia, consultancy, municipal officers, entrepreneurs, and investors. The findings are particularly applicable to planning with VF in cities in and integrative manner. The findings relate to 26 separate factors, along the lines of categories developed by van Doren et al. (2018). These categories include: Measures for Low-Carbon Urban Development, Operational Arrangements, Policy Context, Market Context, Social-Cultural Context, and Natural and Built Context.

Keywords

Vertical Farming, Urban Food Systems, Up-Scaling, Sustainability, Low-Carbon Urban Development

1. Introduction

The growing complexity of global food systems has produced a number of undesired social and environmental externalities in the past. This is particularly true for how food is consumed in urban areas, ultimately building a global network of extensive and resource intense supply chains (Steel, 2013; Ilieva, 2016). The amount of resources consumed in the process, raises future concerns in terms of the climate impact of food systems as well as in terms of availability of staple foods for growing (urban) populations.

Ultimately these problems require the assessment of potential interventions in light of multiple considerations and integrated systems perspectives, whilst keeping the goal of sustainable urban development in mind. To illustrate the wicked nature of this problem, an urban food systems lens can be utilized for assessing a potential technological intervention, which promises to contribute to greening the way food is produced and consumed in cities. This specific intervention is that of Vertical Farming (VF) – a form of closed environment agriculture (CEA), capable of producing fruits, vegetables, and medicinal plants (Despommier, 2010) on multiple physical layers. This technology is particularly suitable for urban environments, as it allows for the efficient use of space, as the surface area of the given farm is not a limiting factor anymore when it comes to food production. Next to this, VF promises to reduce the resource use of global supply chains due to its localized nature, can provide year-round supply of produce, and does not require the use of pesticides (Ibid.). Nevertheless, questions have been raised as to how the high energy demand resulting from the use of aquaponics systems and LED lighting among other unaccounted for externalities should be considered for if one plans for truly sustainable urban food systems (Al-Kodmany, 2018).

This paper outlines, based on the framework developed by van Doren et al. (2018), what practical factors need to be taken into consideration when it comes to successfully planning for the up-scaling of VF, and through this embedding this technology in the city as a Low Carbon Urban Initiative (LCUI). Van Doren et al. (2018) outline two pathways to up-scaling – horizontal and vertical. Horizontal up-scaling entails the spatial reproduction of a given technological intervention, both in terms of quantity, as well as in terms of size. Vertical up-scaling describes the institutional embedding of a technology, be that in terms of policy, culture, or economy among others. In total van Doren et al. (2018) outline 19 factors, which should be considered – these factors have been amended with 7 additional factors, which emerged throughout the data analysis period. This is due to the structuring of the research design through an abductive approach. The principle data collection method was that of semi-structured key informant interviews, with a total of 17 having been conducted with the informants' perspectives representing different geographies as well as constituencies.

This article focuses primarily on practical considerations, which urban planners should consider when planning to apply the technology of VF to transitioning to sustainable urban food systems. The research is based on the data collected as part of an MSc thesis, forming a part of the Urban and Regional Planning MSc degree at the University of Amsterdam. The theoretical findings of the research are presented in a separate publication (Petrovics & Giezen, forthcoming), and for this reason this article should be utilized as a practical guide primarily.

In the following, the article discusses the theoretical framework in more detail, summarizes the methodological approach taken, outlines the practical considerations for planners in detail, and briefly concludes.

2. Theoretical Perspective

In an attempt to accelerate urban development trajectories towards low-carbon pathways, it is essential to understand what pioneers, innovators, and ultimately urban planners need to take into consideration whilst planning for socio-technical interventions. Van Doren et al. (2018) outline that such Low Carbon Urban Developments (LCUDs) are informed by scalable Low Carbon Urban Initiatives (LCUIs). As mentioned in the process of scaling these initiatives, two types of pathways exist: horizontal and vertical. Horizontal pathways entail the spatial reproduction of LCUIs (e.g. through introducing physically larger interventions, or through introducing a higher number of initiatives in a given city). Vertical pathways entail the institutional embedding of these initiatives (e.g. through transitioning the policy landscape, establishing favourable market conditions, or affecting the levels of awareness when it comes to a new innovation).

The linkage and relationship of vertical and horizontal pathways to up-scaling LCUIs does not follow in a linear relationship; rather the two pathways interact in a dialectic manner reinforcing each other in a virtuous cycle. This framework can also be linked to Geels' (2002, 2011) Multi-Level Perspective (MLP) on sociotechnical transitions, in that it describes the specific interactions between *niche* and *regime* level dynamics, and in particular helps one understand the process of scaling *niche* initiatives into a *regime*.

In order to analyse these potential pathways the up-scaling framework of van Doren et al. (2018) has been amended with a set of factors, which emerged throughout the data collection process – marked with an asterisk. In total 6 categories, exploring 26 factors allow for understanding how urban planners should assess LCUIs and in particular work with VF for the sake of sustainable urban food systems. The categories and factors are as follows:

Measures for LCUD

- Financial Advantage
- Reliability
- Low Complexity
- Integrative Functions*

Operational Arrangements

- Leadership
- Stakeholder Involvement
- Resource Mobilization
- Communication
- Logistics*

Policy Context

- Regulatory Policy Instruments
- Financial Policy Instruments
- Informative Policy Instruments
- Political Leadership
- Trust in the Policy Framework

Market Context

- Low Capital and Instalment Costs
- Expertise and Skills of Supply Actors
- Information Availability
- Access to Credit
- Energy Price
- Market Dynamics and Conditions of Peripheral Industries*
- Insurance*

Social-cultural context

- Environmental Awareness and Values
- Consumption Culture*
- Product Qualities*
- Social- and Power Relations*

Natural and Built Context

- Technical Compatibility

3. Methodology

As mentioned, the research is based on the data collected for the completion of the thesis as part of the MSc degree in Urban and Regional Planning, completed at the University of Amsterdam. The research design took an abductive approach, and by this not only produced findings related to VF but also amended the set of factors outlined above. The primary method for data collection was semi-structured key informant interviews. These interviews were conducted with 17 experts working with VF in different geographical regions and capacities. The perspectives of these accounts span academia, consultancy, municipal officers, entrepreneurs, and investors. The anonymized accounts of these interviewees are marked with 3-digit codes. The practical considerations outlined below build on their accounts in combination with the slim literature existing on the applicability of VF as an innovation.

4. Practical Considerations for Urban Planners

The following section outlines the findings based on the amended theoretical framework of van Doren et al. (2018). As mentioned, the findings are based on the 17 interviews conducted in the spring of 2018, which follow three-digit codes for reference. The section outlines, factors falling under measures for LCUD, operational arrangements, the policy context, the market context, the social-cultural context, and the natural and built context.

4.1. Measures for LCUD

Financial Advantage. The financial advantage and profitability of vertical farms is generally dependent on external factors and the business model of the farm. The external factors can be categorized on the lines of real estate and land availability, economic conditions affecting this availability, food scarcity, and the scale at which the operation takes place. As is generally the case with Urban Agriculture (UA), VF is also directly dependent on land availability and is hence receptive in periods of economic downturns, as vacant buildings and lots are more available, and accessible at lower prices in these times (004). This directly affects the viability and profitability of VF as well, especially if the business models consider the availability of vacant space necessary (017). Flipping this logic on its head, economic peeks produce competition in the real estate sector, which makes land less available to UA and VF (e.g. Amsterdam in the recent years) (012, 017). Next to this the scale of the operation also counts, as small-scale installations are not likely to be profitable. This is a typical example of capital expenditure intense industries becoming profitable at scale (011).

The business model related factors can be categorized on the lines of pricing and the ability to charge a premium, the potential for integrating multiple sites within one business, and the potential for integrating functions. Food scarcity and the distance fresh produce has to travel directly impacts the profitability of VF, as this is where premiums can be charged for local and fresh produce (011). If a city is dependent on imports it is sensible to introduce VF and there is potential to charge premiums on the fresh produce. Moreover, dependent on the economic conditions (as is outlined above), business models, which integrate different types of land availability can produce a financial advantage. For example, combining a small-scale, downtown demonstration project, which showcases the technology and produce to consumers, with a large-scale peri-urban production facility can off-set the incurred financial weight of high land prices in the centres of cities (013). A further type of integration, which can enhance the financial advantage of VF is to integrate functions by for example including some form of hospitality directly linked to the farm (017). This type of integration is explored in detail further below.

Reliability. In terms of horizontal pathways VF is reliable to a certain extent if the installations generally work in self-contained, replicable units or blocks, which allow for easy scalability. This is necessary, as VF is a form of CEA, as is discussed above, which requires tight control over all growth parameters. The production logic of CEA in terms of produce quality directly contributes to the reliability of VF, as the physical aspects of crops are fully controllable, meaning that the visual and aesthetic, the taste, the health and nutritional value, and the shelf life of produce can be directly controlled (010). Due to these factors, the logic of self-contained units has proved successful in the industry on various scales – e.g. InFarm introduced these types of units directly in super markets (InFarm, 2018), CoolFarm utilizes plug-and-play farms (CoolFarm, 2018), while Agrilution has created household level units the size of a small fridge (Agrilution, 2018) (008, 014, 016). The following account from an Innovation Manager from a large tech company working with VF components fittingly describes how this dynamic creates tensions, when one aspires to repurpose vacant space in cities:

> *"I love the whole idea that you take space and transform it into a vertical farm. I love it but I don't believe in it, because with that it's not scalable. I always think you can take an existing old warehouse and build into it another house for vertical farm. But to make it really scalable you need to have always the same set up. […] You need to standardize modules which you can put somewhere, but it always needs to be and in itself an existing ecosystem and not relying on the real infrastructure which the warehouse has given." (016)*

This means that the reuse of vacant spaces is only possible if a self-contained unit is built within the given structure. This way the installation can fulfill the requirements of CEA and can contribute directly to the scalability of the initiative. All these points are however dependent on the knowledge of optimal growth recipes (light, temperature, humidity, nutrition, etc.), which is not yet present in the industry (004). Once these recipes are developed to a sufficient extent, automation and robotization can also enhance the effectiveness of VF (004, 013).

In terms of vertical pathways, the availability of horticultural technolgy and knowledge (e.g. extensive multi-generational knowledge in the Netherlands) can serve as a catalyzer as VF follows many of its principles (008). This being said, a structural restraint persists in terms of staple foods:

crops, such as rice, potatoes, and corn are still difficult to grow in VF (008). Finally an urban planner responsible for green projects in Amsterdam suggested that viable, existing, and functioning examples make municipalities receptive to the technology, as this directly proves it's reliability in the eyes of public authorities. The mentioned example is GROWx in Amsterdam, and the way it is perceived by the municipality as a functioning farm (017).

Low Complexity. As mentioned before the availability of horticultural technology makes the technology utilized in VF available and reliable as well (009). This means that highly developed greenhouse and horticulture industries, such as the Dutch one, can catalyze technological developments as well and can play a great role in ensuring the reduced complexity of VF (015). Nevertheless a key caveat in the industry is that many startups and companies try to develop all of the technology themselves and by this try to reinvent the wheel, ultimately increasing complexity (013). This is unnecessary and risky, as it is better to focus on the core business model of a farm, instead of on developing every single component when such an industry is in the period of innovation (016).

In terms of horizontal up-scaling firstly inefficient practices are common, which reduce the effectiveness of individual plants (e.g. double scissor lifts moving up and down multiple times during harvest) (006), and secondly CEA makes it difficult to make use of vacant spaces due to hygiene considerations (bacteria and plant diseases), if not utilizing the above-outlined self-contained units or blocks (004, 016). Next to this, a further factor that contributes to excessive complexity is that due to the recency of VF, start-ups typically work in silos and wind up developing all the components, which also means that there is no standardization for these components in the industry (e.g. trays, lights, piping etc.) (009, 006, 015). Nevertheless, initiatives are under way to remedy this – the Association for Vertical Farming (AVF) is pushing for industry level standardization (e.g. in components, and dataformats for control systems) (015, 016).

Integrative Functions. This emergent factors is essential, as multiple interviewees outlined that the reliability, viability, and most importantly profitability of VF in this phase of innovation is dependent on integrating food production functions of a farm with other functions (003, 009, 002). These integrative solutions include firstly, functions for marketability (e.g. proximity of the produce and a story) (003), secondly, functions for environmental sustainability (ecosystem services, biodiversity, enclosing nutrient cycles, etc.) (003), thirdly, thermodynamic functions (e.g. cooling water to be used for district heating, or utilizing excess energy and heat from logistical hotspots, server systems, or airports) (001, 003, 009), and finally, functions for educating the public (e.g. nursery visiting center, VF at public institutions [schools or hospitals] and public space) (010, 002, 007, 014). As a professor working with horticulture explained,

> *"there is an advantage when your are very nearby where the consumers are; I think you should also take the opportunity to make the connection with the citizens, so make some part of your firm or the nursery open for public or that you have sometimes that they can visit so that they can see it. This is because they can't consider it as a factory, and in particular if nobody is allowed to have a look inside how it looks, they might have all types of ideas which are not correct." (010)*

Finally, functions for citizen engagement and community meeting points can also be introduced, in order to re-establish the social aspect of food in cities (009, 010). Such places are considered substantial, as this is "where people meet, discuss about food – this is extremely important for the evolution of community" (009).

In terms of vertical up-scaling this function mixing takes a different dimension. As a respondent outlined, dependent on desired goals, municipalities should directly push for and require function mixing (003). This respondent went on to describe the benefits as

> *"all of a sudden your urban farming is a means to many different ends […] maybe you don't want to optimize for efficiency but for social impact." (003)*

4.2. Operational Arrangements

Leadership. With regards to the role of leadership, the only opportunity outlined by interviewees was by a start-up working in Amsterdam, whose founder mentioned that next to their core three person team it is necessary to partner with visionary and powerful individuals who are vested in the project. He said this is absolutely necessary for the success of such an initiative (008). As he mentioned in explanation for why a tender for a farm was turned down,

> *"You need individuals that are both visionary and powerful. And we had powerful people in that process. I'm not sure if we had some visionary ambassador in that project." (008)*

This account highlights the necessity of fitting leadership qualities not only to the extent of power but also in envisioning what is required for the success of a VF initative. Nevertheless it becomes questionable where such individuals can be found, as an account from a member of the

Amsterdam Economic Board suggests, based on this logic cities would have to rely on "kind of superheroes, super engineers saving the planet" (001).

Stakeholder Involvement. Without conducting an extensive stakeholder mapping exercise, based on the accounts of the interviewees the following can be said. Generally the respondents indicated that the industry is disproportionately focused on engineering and technology, mostly dismissing social elements, which also results in a disproportionate focus on stakeholders in this realm (001). Nonetheless initatives exist, which can be understood as *niche* developments, such as OneFarm in Amsterdam, putting an inclusive approach as a centerpiece to its business model (008). Through engaging local community members in education activities and a volunteering program, they not only aim to open up the black box of the vertical farm to the public, but they also aim at utilizing locally available knowledge and social institutions (OneFarm, 2018). This logic was further extended to a systemic level by a member of the Amsterdam Economic Board. He suggested that outlining a vision for inclusive and participatory approaches to planning by involving all stakeholders from citizens through tech companies to farmers is the way to plan for the success of a food system (001).

In terms of engaging stakeholders necessary for conducting and maintaining operations to a sufficient and successful degree, it has been stated that due to the young nature of the industry, these necessary stakeholders (e.g. light engineers, data scientists, horticulture specialists, entrepreneurs) are not used to collaborating in this manner (015). Next to this there is no framework present yet for establishing this cooperation (015). This being said opportunities do lie in collaboration between *niche* experiments and *regime*-level actors, as was outlined by an Amsterdam based VF entrepreneur, who has set up a business relationship with one of the major lettuce producers in The Netherlands (009). In this sense it is not only resistance that originates from *regime*-level actors, but windows of opportunities also open for collaboration, which ultimately support the up-scaling of VF.

Resource Mobilization. VF carries an advantage in the sense that technical platforms (such as the control systems necessary for handling the production system) can be set up and run by relatively few people (008). This fact is furthered by the tendency of component prices to fall, enabling the per unit output of the VF industry to grow in financial terms. The recurring example for this dynamic is how the prices of LED lighting have decreased due to growing efficiency and broader availability (010, 011). Such developments can reinforce *niche* formation. Next to this due to the small profit margin there is a general awareness in the industry of the necessity to utilize resources (human, electrical, and spatial) in the most effective and efficient manner (006). Nevertheless, as a sustainability consultant outlined, traditionally in the agricultural sector, there is a race to efficiency rather than quality. This means that there is a serious risk of recreating this dynamic in the VF industry, which could ultimately lead to a race to the bottom, hindering horizontal as well as vertical pathways to up-scaling (003).

Communication. The accounts regarding communication are not clearly categorizable as directly contributing to horizontal and vertical pathways, as they are applicable to individual plants as well as the resulting broader societal dynamics equally, if replicated sufficiently. In general, multiple intervewees suggested that there is a general lack of trust and fear towards new and innovative technologies from the public. The examples mentioned were primarily hydroponic growing systems and soiless cultivation methods (008, 014). Nevertheless with growing interest in local produce, great opportunities lie in communicating the proximity of VF produce (010).

Logistics. Once again, planning for interventions in the supply-side of food systems carries potential, if one thinks in systemic terms, which necessitates a focus on logistic systems as well (003, 006, 017). By looking towards integrated systemic solutions in terms of distribution logistics, and by creating an alternative scaled logistics system for distributing food in cities, the ultimate connection can be made between farmers and consumers. The principle *niche* experiment mentioned as an example for such a system is the FoodLogica experiment, which is a bike-based food delivery system aiming to “clean the last mile’s of Amsterdam’s local food system” (FoodLogica, 2018). If one aims at introducing VF from a sustainable urban food systems perspective, it is essential to conceive of this type of alternative logistic system. Next to this by connecting individual, local producers and end consumers, using such systems can result in "creating an economy of scale without actually needing to scale up yourself" (003). This is especially true as the larger a city, the larger the required logistics operation for scaling, and hence the more difficult it will be for individual plants to scale themselves (006). Next to this, as Steel (2008) outlines in detail, with the lengthy food supply-chains, countries such as the U.K. tend to create bottlenecks in the forms of food distribution centers. Hence, localizing food production and combining it with alternative logistic systems based on more decentralized solutions carries great potential in terms of establishing resilient urban and regional food systems as well.

4.3. Policy Context

Regulatory Policy Instruments. In terms of VF this factor can be understood broadly as the role zoning regulation plays and the way municipal institutions interact with VF in terms of up-scaling. Zoning is generally perceived as a barrier, however progressive municipalities have found ways to accommodate existing zoning codes. Moreover, establishing municipal level authorities responsible for food planning has pushed for more innovative approaches to city-level food planning and has created the *milieu* necessary for up-scaling VF. Nevertheless institutional barriers on the *landscape* level also persist mostly on the lines of bureaucracy, exemplified by difficulties arising from administrative boundaries, stringent health and labor regulation, and lacking harmonization of agricultural regulation across countries. In the following these points are outlined in detail.

First of all, most interviewees regardless of constituency suggested that zoning codes generally do not recognize VF, and do not fit directly in any category. It is not clearly industry, nor food processing, nor agriculture (008, 009, 010, 006, 011, 017). Next to this if vacant space is available, the zoning categorization (e.g. for a space originally intended for commercial use) becomes problematic in a similar fashion (009). Furthermore, the integrated use of electricity and water is a red flag for code enforcement officials, as was suggested by a supplier of horticulture technology components:

> *"you watch the eyes of the officials when you say 'hey I want to run electricity-water-electricity-water'- that's what you're saying right? You want to put irrigation systems and electricity together in a sandwich style" (006)*

Seeing that regulations are not yet ready to accommodate the socio-technical reality of VF it is also essential to take a step back from focusing solely on the codes and regulations, and to look at those resposible for applying them in practice. This same supplier cited above, suggested that the problem is not only with ill-suited and outdated regulation, but with administrators' and clerks' lacking awareness of how to apply them in the context of VF (006).

Despite this, flexible regulators who decide on zoning permits also exist as was outlined by a VF entrepreneur in Amsterdam (008). By utilizing categories of exception, VF can find its space within predefined zoning codes. This claim is further supported by what a municipal officer outlined: certain zoning plans allow for making case-by-case exceptions, as was the case in Amsterdam with GROWx (017). The same officer went on to describe the tendency of UA to gain prominence in zoning plans (017). He furthermore suggested that VF does not directly produce noise or smells that could be problematic for neighbourhoods (017).

In terms of vertical pathways, it has been suggested that the establishment of municipal level food councils can serve as an enabler, as these authorities can create fitting food strategies, where VF can become a key element (002). The primary example for this type of *niche* development mentioned was that of Amsterdam, which established its own council in December 2017 (FoodCouncil MRA, 2018). Next to this municipal level policy initiatives can also catalyze the development of VF. Pushes for sustainability and green agendas, as in the case of Amsterdam (Municipality of Amsterdam, 2015) and Singapore (Building and Construction Authority, 2014) were mentioned (015, 017), alongside the establishment of public food strategies, such as the *Good Food Strategy* in Brussels (Brussels Environment, 2016), or the *Voedselvisie* in The Netherlands (Natuur & Milieu, 2017) (015, 017). However, the key takeaway here is that it is necessary to make urban and vertical farming an explicit goal within public and municipal policies and strategies in order to see a systemic transfer of land to VF, as was outlined by an urban planner working with the Municipality of Amsterdam (017). A key consultant working at building networks within the VF industry fittingly suggested that,

> *"It's not so much about just creating a vertical farm, it's really building a totally different environment with institutions, organizations. […] in the end I hope that you can say there is a better contribution to delivering fresh foods from highly productive, highly sustainable, and circular ways with a very low footprint." (004)*

This being said the reality of the regulatory landscape is one of extensive red tape, which slows and blocks innovation (002). This boils down to the following. Firstly, municipal and administrative boundaries do not always overlap with those necessitated by urban and regional food systems, which ultimately results in lacking communication, influence, and coordination (002). Secondly, stringent health (006) and labor safety (014) regulations also hinder the cause of VF in terms of vertical pathways, and finally, difficulties also arise from the heterogeneity of agriculture related legislation and categorization between different countries, ultimately hindering the up-scaling of an industry already riddled by an inadequate legislative environment (015).

Financial Policy Instruments. Multiple sources of public and private funding exist and are available to VF. This section assesses the public instruments primarily, as the private ones are described in detail further down. Among the public instruments are municipal level subsidies and loans directly targetting urban agriculture (and VF), alongside peripheral subsidies targetting CO_2 reduction, EU level funding through the *Horizon 2020* program, the *SME Funding Instrument*, and potentially the *Common Agriculture Policy* (CAP). Nevertheless the scope of these funds is relatively limited, and in general confusion persists on the accessibility of these instruments.

In terms of municipal finance, the case of Amsterdam is illustrative, as small start-up subsidies targetting urban agriculture purposes, as well as larger loans for green innovation purposes targetting entrepreneurs in this field exist simultaneously (017). On the EU level, the *Horizon 2020* program has been mentioned multiple times as an available instrument (014, 015). Nevertheless it has also been criticized for the slow and inefficient processes, which can generally set back innovation (016). A living example for the success of this funding scheme is InFarm, a Berlin based VF company, which raised €2 million through this program (European Commission, 2017a). Moreover, an interviewee working closely with agriculture policy at the EU level suggested that the CAP is turning towards urban instruments and innovation in the field of agriculture more and more (015). This is exemplified by a Communication Paper published by the European Commission, titled *The Future of Food and Farming*, which mentions VF – for the first time – as an industry with potential for urban applications (European Commission, 2017b). Finally it was also mentioned by an entrepreneur that peripheral subsidies (targetting CO_2 reduction for example) also carry potential for this field and are an active consideration in their business model (009). Nevertheless, most of these subsidies generally target needs-based industry actors – for example the staple crop agriculture sector in the U.S. (006), or the large-scale farmers in the EU through the CAP (015), which can be understood as *landscape* level pressures creating resistance for up-scaling. Finally, the general accessibility of these funding schemes was accounted for as problematic by the same EU agriculture policy specialist (015).

In terms of vertical pathways, general willingness for municipalities to establish green agendas (017), the creation of platforms for knowledge sharing (e.g. Amsterdam Economic Board or the AVF) (003), and simple changes in EU legislation describing minimum acreage for qualifying as a farmer (015) can be mentioned as creating supportive environments for the dissemination of financial instruments.

Informative Policy Instruments. Based on the accounts of the interviewees informative policy instruments are clearly lax in the VF industry. This can be exemplified by the perception that vertical farms are generally seen as black boxes (009), which not only hinders societal acceptance, but also reduces the access to information on how to set-up and operate such an installation successfully. Next to this, simple information on for example the CO_2 reduction capability of VF is also not yet available, as was mentioned by a municipal officer working with the City of Amsterdam as well as multiple entrepreneurs (017, 008, 009).

A further problem arises from the general categorization of produce. There is industry-level confusion on how to categorize the produce, as it does not clearly fall into the pre-established categories of organic, non-organic, processed foods, and the like. (008). Besides, simple elements such as a label for VF are also not yet existent. As the head of a large tech company working with lighting solutions outlined,

"it might be worthwhile seeing if there is a label that could on the one hand side guarantee quality and basically standardize quality a little bit. And on the other side trigger a discussion and explain to the consumers what it is you're doing." (013)

This lacking label hinders both consumer acceptance as well as the necessary discussions that can push for the development and adjustment of food safety categorization and regulation (013, 014).

Finally, for vertical up-scaling it is essential to have supporting frameworks for initiating business processes. In established industries this would mean that farmers can turn to the ministries responsible for agriculture, and SMEs can go to the business bureau. Yet still, as a policy specialist outlined, VF has no such public contact point, which can setback the initial phase of starting-up vertical farms (015). As the policy specialist outlined,

"One of the administrations should take this field and say, 'Okay, you are interested in vertical farming. You want to set up an activity, so come to us and we will advise you on the different stages you have to go through and the different partnerships you can enter into.'" (015)

Political Leadership. Once again in terms of political leadership, progressive and forward looking municipal officers and institutions are of great importance. City Councils carry the opportunity to enhance VF (004), hence in an ideal scenario such authorities should also focus their work on UA and VF. This also means that food strategies should be outlined by understanding the food related practices of the consumer and citizen (001), as is also outlined by Cohen and Ilieva (2015). This being said it was also mentioned that Urban Agriculture is generally not on the agenda of politicians (003). Closely related, a significant problem of the AVF is that governmental authorities and public figures are not present to a sufficient degree in the industry association (011). Next to this, extensive involvement of public authorities can also hamper developments, as was outlined by an interviewee:

"the government tends to want to be involved too much, so it really sometimes also slows processes down because they are so active in promoting it and trying to subsidize it that everything needs to be reported and that you can hardly do any work because you're continuously playing tour guide for the government." (013)

Hence, political leadership is a necessary and a generally missing element in the VF industry, nevertheless if present it should be conducive to the goal of the farms, and not to the agendas of politicians and public authorities. Finally, the shifting nature from country level food diplomacy to city level food diplomacy was also outlined as a supporting factor (004).

Trust in the Policy Framework. In general, trust in the functioning of existing regulatory instruments is regarded as lax, considering that a fitting policy framework specifically targeting VF does not exist, as was outlined above. This is primarily due to the regulatory barriers that persist, the general policy landscape, and the fact that institutions tend to follow academic and entrepreneurial endeavors with a lag (008, 004). As the Chief Innovation Officer of an Amsterdam based start-up accelerator also working with VF mentioned, “the policy space usually follows the experimental phase” (008). In more systemic terms, this also means that considerations for food security, food planning, and the concept of a food chain generally are not integrated into the political and administrative systems of countries as of yet (002). Nevertheless, exceptions for these dynamics do exist as was explained by a researcher from the University of Wageningen: “There has been the example in the Netherlands for even a ministry on food. You know, not on agriculture but on food” (002). Such an institutional switch may seem of small nature, nevertheless concentrating on food rather than solely agriculture suggests systemic shifts, which could also prove conducive to the cause of VF. Next to shifting institutions it was also discussed that on a case-to-case basis soft-power mechanisms can come in handy exemplified by knowing government officials (013).

4.4. Market Context

Low Capital and Instalment Costs. Virtually all interviewees agreed that VF as the most technology intense form of UA carries high up front costs (001, 005, 008, 010, 002, 016). Seeing that components such as LED lights, trays, pumps, and control systems, among others are essential, costs per m^2 can add up to €2,500 (009). This ties in with the reluctance of traditional lending institutions to support the up-start of VF projects, as well as the emergent Venture Capitalist (VC) funding schemes present on the North American context, as is outlined in more detail below.

Expertise and Skills of Supply Actors. With regards to expertise and the skills of supply actors, it can be said that the VF industry is in the beginning of the innovation cycle. This carries certain defining characteristics, which are also applicable to the field of VF; such as lacking industry-level integrated and shared knowledge, the development of certain types of partnerships with research institutes, tension with *regime* level industries – especially the greenhouse horticulture industry, multiple individual failures, and the emergence of alternative business models, which challenge the incumbent *regime* from within. These are outlined here-on.

Firstly, multiple interviewees mentioned that there is lacking integrated knowledge, which would be essential to VF. As a Sustainability Consultant working with aquaponics systems outlined, “I'm basically looking for a plumber, farmer, chef” (003) or in other words "in terms of skill sets you need a slightly different set of yet unavailable skills. It needs a rare combination of plant scientist, farmer, data scientists, etc." (008). These accounts highlight two points. On the one hand, integrating this type of diverse knowledge within a multi-disciplinary team can be challenging due to the different backgrounds of the individuals, while on the other hand this set of knowledge is more available and affordable at scale (014, 003). This tension however is being slowly resolved seeing that more and more partnerships are established for knowledge generation at the *niche* level for example, by universities such as the HAS University of Applied Sciences collaborating with companies such as Philips through Public-Private Partnerships (PPPs) (010, 013, 016).

Secondly, it can be said that a great source of resistance comes from the traditional greenhouse and horticulture industries, which carry much of the necessary knowledge, as well as technological components required and suitable for VF (010). As is outlined below, this resistance can be understood as the *regime* maintaining its position, something that is particularly visible in the Netherlands. As a lighting specialist working with both industries outlined,

> *“greenhouse growers are sceptical of vertical farming and they fear that as a kind of destructive instrument. These interest groups are not geared toward helping vertical farming.” (011)*

A potential way forward from this systemic resistance is through the creation of alternative business models, which are on the rise in the VF industry. These models are based on flat hierarchies (016) and partnerships (009), which essentially produce efficient, transparent and innovative workflows, as well as higher levels of aggregate knowledge, which can catalyze changes and progress in the field of VF.

Finally, the role of public authorities should also be outlined, considering conflicting accounts persist. On the one hand, the inherent inexperience of municipalities towards VF combined with an experimental and progressive setting can result in municipal officers being open to experimentation and innovation, and ultimately allowing for the licensing of innovative forms of UA (002). On the other hand, this total lack of public experience with the industry can create tension seeing that municipalities generally struggle with various types of regulation, as evident from the afore-discussed issue on zoning. (002)

Information Availability. As previously mentioned, the principal problem with regards to information availability lies with the absence of knowledge sharing across the industry. This stems from 1.) entrepreneurs' lacking knowledge - closely linked to the required combination of specific but diverse types of knowledge, 2.) the structural conditions of the political economy, which push for working in silos, and 3.) the technological focus of the industry - rather than the required plant physiology focus. Nonetheless, certain pushes exist for uniting the necessary expertise and personnel, as well as to create a much-needed industry association. The first point – entrepreneurs lax knowledge – has been exhausted above; hence this section discusses the others.

With regards to the structural conditions of the political economy, it can be said that on the one hand, the trend towards neoliberalism has created a political economy geared towards competition, which inherently reduces opportunities for collaboration (001, 004). As a consultant working with business networks outlined, within this *landscape* pressure,

> *"Competition is a great good but if you do it in a collaborative way, you can learn from each other." (004)*

Hence, competitive elements are crucial in such an early stage of an industry; nevertheless certain forms of collaboration are necessary for optimal results. On the other hand, in certain contexts the VC mode of financing also creates silos for R&D on the *niche* level, seeing that this form of financing is geared towards producing and patenting intellectual property (006). As a supplier of horticulture technology described the North American context:

> *"In my experience 99 percent of the decisions made in the industry are about short term profit." (006)*

This account highlights that a pure profit-oriented focus is likely to produce an outcome of short-term returns, and not long-terms transitions, which could benefit the industry as a whole. Next to this, the AVF is still not perceived as a full-fledged functioning industry association, which would be crucial for overcoming these types of barriers for the advancement of the field (011).

Furthermore, the focus of the industry is disbalanced and too concentrated on technological solutions. More focus should be paid to plant physiology (006), as this should guide the development of growth systems and not *vice versa*. As the afore-mentioned supplier of components outlined, "the industry won't ever grow until we focus on the plants" (006). The head of a lighting supplier company also outlined a misconception from the side of many entrepreneurs, namely that

> *“people think you can just put racks into a warehouse, start growing microgreens and you’re in indoor vertical farming, and you’re going to solve the world food hunger.” (013)*

By failing to develop plant physiology centered knowledge and growth technology simultaneously (013), the process of businesses focusing on building farms solely has been exacerbated. The key point here is that without the fitting operational knowledge, no farm can function optimally and hence the transfer of this knowledge is also necessary (016). An example for how this knowledge transfer can function in a beneficial manner, is the business model adopted by Signify City Farming – Philips City Farming at the time of data collection – which focuses on lighting technology as their core business model, and offers knowledge services after setting up plants in order to maintain the functionality of their business partners’ installations.

This being said, pushes for sharing knowledge and integrating and consolidating the necessary information are under way. On the one hand private companies have pushed for business ecosystem approaches to industry-level collaboration. For example, MeetingMoreMinds based in Amsterdam focuses on building business networks, and has initiated such a process in the VF industry as well. Next to this, companies directly working with VF components, as for example Osram, also put building a business network at the core of their business model (004, 015). On the other hand, as previously mentioned, the AVF is gaining more and more traction (009). Sharing knowledge, shaping policy and legislation, pushing for standardization, and providing networking opportunities all fall under their core activities (Association for Vertical Farming, 2018). Nevertheless, certain entrepreneurs are generally sceptical of the AVF due to its young nature and overlapping personnel with private VF initiatives (009, 011). Two explanations can be provided nonetheless. From a structuralist perspective, the inherent competition of industry actors embedded in the landscape of the neoliberal political economy creates a general perception of distrust, which can mean that such an initiative is treated with scepticism. From the perspective of the innovation cycle however, it can be argued that the critical mass of VF initiatives has not been reached yet, which in effect hinders pushes for standardization, knowledge-sharing, and the maturation of the AVF into a full-fledged industry association (006).

Access to Credit. With regards to access to credit and funding schemes external to the above outlined public financial instruments, it can generally be said that traditional lending institutions, such as banks are reluctant to invest in agriculture (006). This is especially true for

Europe, where banks will generally not fund VF due to the high sales price per product (013). In the U.S. the iconic exception to this dynamic is the $200 million investment by Softbank in Plenty, a *niche* VF initiative (Bloomberg, 2017). Despite the reluctance for traditional lending institutions to fund VF, other funding structures, which can be categorized as developments on the *regime* level also exist. Examples for this are large technology companies funding experiments, as is the case with BrightBox in Venlo supported by Philips (013), or start-ups receiving Foreign Direct Investment (FDI) as was the case of GrowX in Amsterdam (002). Next to this it was suggested that there is a growing trend for impact driven investment, which can qualify as a *niche* development (008). This being said in general it is still funding schemes originating in the public sphere that carry the potential to support the industry primarily, as is discussed above.

Energy Price. Energy is the most expensive factor when it comes to the operational costs of VF (009, 006, 002, 014). This means that any kind of dynamic present in the energy sector will affect the operations of a vertical farm to a great extent, and is worth exploring through the accounts of the interviewees. Without conducting an exhaustive review of energy sector market dynamics, those explicitly mentioned can be categorized in two clusters: price volatility and dependence on the energy price, and structural availability of (renewable) energy sources and their relation to the grid. In terms of price volatility, a general *landscape*-level trend of decreasing energy prices is perceived as conducive to the growth of the industry (008). Moreover, the high degree of dependence on local energy prices makes it questionable to what extent VF can be a solution deployable universally regardless of market conditions (010). This fact is further intensified by the conceived opportunity to make case-by-case energy deals in order to enhance the reliability of affordable energy access, however interviewees expressed that it is difficult to strike these case-by-case deals with energy companies (009).

This being said, the structural changes, which the energy sector is undergoing also have to be outlined as respondents highlighted tensions here as well. Firstly, decentralizing tendencies in the energy sector carry decentralizing tendencies for the supply-side of food systems as well (016). With growing availability of power in remote areas – where elements of food crises are also more present – the potential to set-up VF without dependence on centralized supplies of grid-connected power grows. Secondly, it was theoretically outlined that VF could balance energy peeks and dips in grids due to the flexibility of growth cycles by for example reversing the day-night rhythm in a farm to reduce the peek loads on the grid (016). However, this requires careful planning and understanding of the energy infrastructure, as well as the energy up-take requirements of farms, as VF can also put extreme pressure on the grid (002). Thirdly, with regards to renewable energy sources, a number of entrepreneurs pointed out that in their experience it is not possible to cover energy demand by only renewable energy sources (009, 015). This is mostly due to the fact that most VF facilities are not yet at the scale where they can make use of on-site solar energy (006). Furthermore, utilizing on-site renewable energy sources increases the complexity of the farm, which seeing that the industry is still in the early phases of innovation increases the risk of failure (016).

Market Dynamics and Conditions of Peripheral Industries. This factor is essential to consider as seemingly peripheral industries carry great potential for developments in VF. Changes in other industries can affect the market for the produce and the prices or availability of growth components. The primarily example mentioned for this dynamic can be found in the North American context, where the legalization of cannabis is creating a new and controlled market for plant growers. As was outlined by a growth component supplier, the opening of a regulated market has attracted traditional horti- and floriculturists to grow cannabis, leaving their initial markets with an undersupply. The resulting changes in pricing have produced a market environment, which allows for new industry players to enter the market with more capital-intensive production methods, for example VF (006). This point highlights that seemingly external market dynamics can have a direct impact on one specific industry.

Insurance. The final point that did not fit the categorization of van Doren et al. (2018) is related to the role insurance companies and their requirements play in blocking VF. In general it was suggested that insurance companies set the requirements for extra technical additions from a health and safety perspective, by for example requiring sprinklers above the plants incase of fire, which directly effect profitability in terms of upfront costs (010, 013). Furthermore, the general perception is that insurance companies are sceptical of business models aimed at retrofitting old buildings by for example reducing the maximum floor load when installing piping (013). This factor can seriously hinder the potential for reusing vacant space.

4.5. Social-cultural context

Environmental Awareness and Values. In terms of awareness and values two main clusters should be outlined: 1.) general consumer attitudes towards VF and the surrounding dynamics, and 2.) broader societal developments in terms of food related environmental attitudes.

Most interviewees agreed that there is general perception that that VF is not natural (009, 010, 014, 015, 016). In response to this, an Amsterdam based VF entrepreneur suggested that,

> *"for me it's completely not natural that we have cities with more than 10 million inhabitants. […] I would really like humanity to be established in a way that it is spread equally around the globe; we would be okay with growing everything through organic methods and permaculture. That would be perfect, but is it natural to have cities with more than 10 million people? No."*

In the eyes of those working in the VF industry, these perceptions also stem from opinions based on half-information stemming from the early phase in the innovation cycle (008), and generally lacking awareness of how food is produced (009, 010) and how food systems function (001). As a Dutch interviewee outlined, "we are not aware that food is anything else than a given" (008). In a similar conversation a Germany based VF project manager outlined that their company's existence is legitimized by placing VF at the crossroads of fresh food production and reducing environmental impact. She suggested that this is necessary as "we're all very demanding global citizens that want everything all at once" (014).

Nevertheless, there is a general growth in media attention (010) in the topic on the one hand, while on the other hand it was mentioned that VF specifically carries the same educative potential as traditional soil-based UA when it comes to citizen engagement on the local/neighbourhood level, as was explained by a municipal actor (017). It was also suggested that the general gap in the knowledge about food systems can be potentially addressed by appealing to the tech-savy generation(s) through engaging them with agricultural food production in this manner (015). Next to this, on a more *landscape* level, consumer level pushes to buy more local produce (006), the adjoining (global) sustainability agendas, such as the SDGs (004) or growing discourses on circularity, as for example in The Netherlands (006) carries the potential to support VF in terms of shaping mind-sets and behaviour.

This being said, it is essential to point out that efforts to raise awareness about food systems should also conceive of VF in this context. As the same Germany based project manager suggested,

> *"vertical farming particularly in urban city centres shouldn't be seen as a replacement for a local agriculture system that already exists. It's more about really re-shifting our focus onto regional produce and urban food systems [...] the cities themselves can become self-sufficient in their fruit and vegetable needs." (014)*

In this sense, VF is an element of a larger systemic solution targeting regional and urban food systems as is also outlined by Forster and Escudero (2014). Finally, a key point raised by an entrepreneur is that the scepticism towards VF in terms of it being natural or not can be a catalyzer to open conversations about food systems at the consumer level (016). By being exposed to food production that is perceived as unnatural, the above-mentioned scepticism and general questions about the origin of food that winds up on the consumers plate can also be asked. Hence the science-fiction-like look of plants growing under purple lights carries the potential to open up larger discussions about factory farming, food-miles, and year-round availability of fresh produce.

Consumption Culture. When discussing any topic related to the supply of produce, the surrounding consumption culture should also be examined. Hence also in the case of food, it is necessary to also explore the dynamics throughout the consumption chain, which is why food culture is a key point. One respondent outlined that when one looks at any type of transformation within a food system, the focus should be on targeting the predominant food culture (001). He went on to describe the problematic nature of fast-food dominant food culture (001, 003). This aspect highlights the persistence of structural and systemic problems, seeing that the continuous presence of cheap and unhealthy foods make it questionable if green values and marketing or communication strategies on sustainable and organic produce are sufficient to change end consumer behaviour, and if at all the presupposed agency is present. In this sense VF in and of itself will not bring society-wide changes in the context of food consumption, as structural barriers persist, and thus should be targeted from a more systemic perspective.

Product Qualities. Seeing that VF is ultimately focused on produce, the qualities of these products should also be explored, as this is one of the competitive advantages arising from VF. Different qualities that carry competitive advantages outlined are as follows: high-end produce, for example edible flowers, herbs, and micro greens can be produced through VF (003, 007, 012), non-edible produce, for example for cosmetics, pharmaceuticals, and pet foods (014) can be produced in these plants, and finally produce that is difficult to ship long distances also carries a competitive advantage (003).

Nevertheless, demand for food is more varied than VF can currently meet (005), which is a major barrier. As two interviewees outlined, “we cannot feed the future cities in this way at least not with the current technology” (006), which means that “vertical farming will definitely not feed the world” (016).

Social- and Power Relations. A key factor, which was preconceived of as missing from the theoretical framework is that of social- and power relations. For this reason, explicit attention was paid to assessing this element of VF as well. This is the key factor when considering the politicizing focus of the critiques of transition theories (Wachsmuth, 2012), and the metabolic conception of cities (Swyngedouw, 2016). In terms of societal problems, the following can be said. Firstly, socio-cultural divides between different groups within a city are apparent in food cultures as well (003). This means that health problems related to food are often grounded in economic standing (003). Secondly, food policy is often too focused on middle-class consumption patterns (004). For VF to be successful these points need to be actively considered by those working in the field, be those entrepreneurs, public officials, or the AVF, as societal acceptance of this type of innovation depends on its accessibility by the wider public.

In terms of problems explicitly mentioned in relation to VF the following can be said. Firstly, the industry has an extractive tendency. A respondent mentioned that certain companies even utilize the up-coming food crisis to market their products with only profit in mind (009). Secondly, VF does not directly and inherently carry an inclusive social dimension, which is common in soil based Urban Agriculture (004). Finally, closely linked to the societal points above, VF produces high-value products that tend to serve the wealthiest strata of society – the top 5% of the consuming public (006). These points are essential to consider when planning for the up-scaling of such a technology, as wide applicability and acceptance depend on considerations for wider societal needs.

4.6. Natural and Built Context

Technical Compatibility. The final point within the predefined theoretical framework developed by van Doren et al. (2018) is that of technical compatibility. The most general result under this factor is that VF solutions always have to take the specific urban context into consideration (003). This means that plug-and-play solutions are theoretically viable, and in terms of yield quantity and quality even more reliable; however, it does not directly guarantee market competitiveness or acceptance in societal terms directly. In this sense, contextual factors to consider are 1.) levels of development, 2.) sunlight hours and growing seasons, 3.) density and fresh produce availability from local/regional sources, 4.) the tension between universal applications and adaptability to already existing built environments, and 5.) the logic demanded by different urban settings when it comes to food systems. These points are discussed hereon.

Firstly, from a technical perspective, due to the unitary logic of CEA, VF is possible anywhere in the world (010). However technical compatibility and advancement is always dependent on the levels of development where VF is to take place. This means that possibilities to automate for example are dependent on the relationship between capital and labor costs (009). Next to this, compatibility with locally available parts produced by local manufacturers should also be considered from a sustainability perspective, as was outlined by an Amsterdam based VF entrepreneur (009). Nevertheless, viability of a farm is also dependent on natural conditions, namely the general growing seasons and sunlight hours. Environments with ample sunlight do not directly necessitate VF as in these areas greenhouses can suffice (006). It is environments with low sunlight hours and short growing seasons, for example in Scandinavia, which necessitate VF (006, 014). Besides general soil quality should be considered (015), which is an essential point in the context of the global imbalance in the nitrogen and phosphorus cycles (Rockström et al. 2009).

Furthermore, factors specific to the given urban environment, which were mentioned and should be considered, are density (014), the extent to which mega-cities are dependent on long supply-chains, extensive food miles, and imports of fresh food (009, 014), and the land price in city centres (010, 015). This being said there is no perfect recipe for choosing fitting cities. These factors illustrate that multiple points need to be considered when choosing the viable sights for VF, and highlight that the theoretical universal applicability of the technology does not compare to universal viability. A LED lighting provider based in Finland illustrated this, who suggested that,

> *"you have different logic in different cities depending on the geography, the political system, and development." (011)*

He went on to categorize cities on the basis of the different kinds of enabling logics that allow for VF. Firstly, he mentioned Hong Kong and Singapore as cities with limited land availability. Secondly, he suggested that mega-cities such as the urban areas around Shanghai and Beijing have concerns for food safety, which can support VF. Finally, he mentioned North American cities, such as New York and Chicago as having a growing environmentally conscious consumer base, which can similarly be conducive to VF, but from a completely different perspective (011). This theoretical exercise once again highlights that different contextual factors can be conducive to up-scaling from different perspectives, and therefore prove the point that there is not a perfect recipe for the best-case urban environment, when it comes to VF.

5. Conclusion

What emerges from the above accounts is a reaffirmation that there is a need to transition urban food systems to a more sustainable state, and that VF under certain conditions can be an active component of such a transition. Nevertheless, understanding what practical steps need to be taken is a crucial first step in this process, and for this reason the accounts of the 17 interviewees scope 26 factors, which should be considered in this process. The case of VF illustrates that even technologically, and in terms of resource use potentially intense interventions also carry opportunities to transition cities on to more sustainable and green pathways. However, it is essential to reconsider these interventions from a more holistic perspective, which allows for assessing environmental impacts from multiple perspectives, and also allows for understanding the socio-economic structures underlying these interventions, and what this means for planning with this type of transition.

As can be seen from the emerging tensions from the above accounts, one-dimensional promises for any type of sustainability intervention should be treated with a grain of salt. This is due to the fact that without appropriate reflection, and the resulting multi-factor mapping of what has to be considered, introducing complex elements into already complex systems – such as VF into urban food systems - can accelerate the given systems level of complexity to unimaginable and unmanageable levels. Ultimately such interventions can result in unwanted side-affects, such as even higher GHG emissions per kilo of produce, hence, a careful assessment of multiple factors should be the bare minimum when conducting planning exercises. As can be seen, the amended framework of van Doren et al. (2018) can suffice in catering to these needs through the 26 factors outlined above, when considering LCUD in cities. As can be seen from the emergent factors, a predominant focus has been put on social and political factors, and their implications for assessing socio-technical interventions. The reason for this is that the initial framework did not sufficiently cater to these elements, and the accounts of the interviewees highlighted the necessity to amend the initial framework.

All-in-all, having applied an urban food systems lens to a potentially scalable socio-technical intervention – Vertical Farming – has proven that multiple and integrated perspectives need to be considered when assessing the true climate mitigation as well as up-scaling potential of such experiments. Next to this conducting such an exercise, encompassing the amended framework of van Doren et al. (2018), has proven that a handful of factors, previously not considered can also emerge in the process, adding analytical depth to the analysis.

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