

Technology Roadmap and Innovation Challenges for the Development of Vertical Farming Systems

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Due to the increase of world population and urbanization there is a growing need for food in urban areas. At the same time sustainable and locally produced food is gaining popularity. The production of food in metropolitan areas, also called *urban farming*, may provide an answer for both trends [1]. *Urban farming* comes in different shapes and sizes, one of which is *vertical farming*, where multilayer production of fruit and vegetables and possibly fish or meat production takes place inside buildings within the city [2]. Vertical farming may add to (i) increasing urban sustainability (e.g. by closing waste cycles), (ii) producing food in the city (e.g. by in situ production of fresh, safe, high quality food) and (iii) better use of space in the city (e.g. by creating economical and ecological vitality in the urban environment).

In recent years many vertical farming projects have been started up in cities around the world, especially in the metropolitan area of Amsterdam [3]. Although knowledge of growing technologies is widely available, hardly any high tech vertical farms are currently in operation in the Netherlands or abroad.

To gain insight into the innovation challenges, this paper first shows the desired functionalities of a high tech vertical farm and the systems it should consist of. These systems, which were derived from interviews and a function analysis, are (i) a growth system, (ii) a water and nutrients circulation system, (iii) a lighting system, (iv) a climate control system and (v) a sustainable energy system. Based on desk research, interviews and round table discussions with 10 entrepreneurs and technology suppliers, a technology roadmap for the coming 25 years was established. This roadmap shows both existing technologies and new technological developments needed in order to meet the requirements now and in the future.

Second, the paper describes four major innovation challenges for establishing high quality and sustainable vertical farming systems. These challenges are (i) systems and knowledge integration for high quality, high yield and sustainable production at a competitive price, (ii) sustainable lighting (e.g. by means of highly efficient lighting techniques), (iii) closing cycles (e.g. water and waste), preferably within the system itself, but also by interacting with the city and (iv) adding value by creating new business models.

This paper contributes to formulating a research and development strategy for vertical farming initiatives, companies and academic institutions. Furthermore, it may guide governmental organizations in accommodating innovation challenges.