Vertical farming is the common term for farms that grow crops in stacks and layers, in an indoor environment. The crops are illuminated with LEDs in lighting ‘recipes’ to enhance growth and quality. Vertical farming can be distinguished from traditional farming in the sense that all the conditions are extremely controllable. Light, temperature, humidity, carbon dioxide levels, soil-substrate and irrigation can all be fine-tuned. The aim is to grow high quantities of quality crops that have an appealing taste and aromas, high nutritional levels, and a long shelf life. Unlike traditional farming, this can be achieved without the use of pesticides, with low water usage, and very close to the end-market. However, the big challenge is: what is the perfect growth recipe for each type of plant? And: can it be produced in an energy-efficient way? Dr Céline Nicole, Project Manager for horticulture research and innovation at Signify: “The Netherlands is very active in horticulture in general and while vertical farming has been explored throughout the world, there has been hardly any scientific research done on this topic, except for some studies in Japan and the USA. The SKY HIGH program (a NWO TTW Perspectief programma) is the first university research program entirely dedicated to indoor farming. In this program all aspects of the industry will be researched: design and control of the farm, and targets regarding sustainability, yield, quality, and energy-efficiency. This research will contribute to further optimizing existing concepts and dive deeper into the technology to improve all the aspects.” Next to researchers from TU/e and several other universities, Signify is involved in the program along with several breeding companies, growers, horticulture technology companies, architects, and food suppliers.

THE QUEST FOR RECIPES

Horticulture took-off with the emergence of LED lighting, a relative energy-efficient way of producing light and digitally controllable. Céline: “The game is complex since there are a lot of parameters and interactions involved. For starters, we hardly have any reliable scientific knowledge about how plants ‘perceive and use’ (the narrow band spectrum of) LED-light. There is research - also within ILI - about how people perceive light and what conditions add to wellbeing and productivity - but for plants we are only at the beginning. We need to identify the optimum lighting recipe within the factors of intensity, photoperiod, spectrum, schedule… We have recently observed in our own research center in Eindhoven (GrowWise) that it is possible to grow arugula with a significantly higher vitamin C and K content (vitamin C
ENHANCEMENT THROUGH AI

One of the work packages in the program is the use of artificial intelligence (AI). Assistant Professor of Machine Learning at the TU/e, Joaquin Vanschoren: “We want to learn about the relationships between factors such as light, water, temperature and soil substrate in order to effectively tune the conditions for the best growth and quality of different crops. To enhance and accelerate our insights, we have introduced camera monitoring in combination with machine learning into the program. The yet to be designed camera system will monitor the growth of the plants and signal problems like plant diseases or burns; a unique approach, since former measurements of the crops were usually done by hand and human inspection (harvesting and weighing the crops). Machine learning comes into play by being able to automate the camera monitoring and relate to data about the conditions. We therefore have to design the proper algorithms and train the machine. We have some models of plant growth, but the amount of data is insufficient. That’s why we use advanced techniques, based on Generative Adversarial Networks (GANs), to generate realistic artificial data from a smaller data set. This will help to refine our models which we will sequentially check with biologists and growers. A conclusive part in our work package is meta learning. We would like to be able to transfer captured knowledge from plant to plant, so that we can create recipes for different species of plants more accurately and by using far less data. The overall idea is to build a fully automated control system for vertical farms.”

CREATING THE PERFECT VERTICAL FARMING BUILDING

The technology sounds promising, yet the most heard critical question for the team and vertical farmers is: is it economically viable? Cilivre: “This very much depends on the situation and geographical location of the farm. What is the climate? What do you want to grow? How far do your crops need to travel? What is your water and pesticide usage? Twan van Hooff, Associate Professor in Building Ventilation, TU/e: “We are used to looking at conditions for people in buildings. This is quite different. And there is hardly any reference material since most available studies concern greenhouses. Within the program, we are exploring the ideal design of facilities for vertical farming. Vertical farming has the potential to allow the crop grower to control the conditions completely. However, it is not that simple to realize the same conditions in air temperature, air velocity, carbon dioxide levels, humidity, everywhere in the farm. Vertical farms consist of different stacks and layers, and there is an exchange of moisture and carbon dioxide between the crops and the environment. Furthermore, in addition to the general requirements, you want to operate in an energy-efficient manner. We use numerical simulations, i.e. Computational Fluid Dynamics (CFD) to get detailed information about air temp, air velocity, humidity and carbon dioxide levels, and aim to develop a tailor-made vertical farming approach for that. After that we will validate our numerical simulations to ensure their accuracy using experiments in different farms and labs. The final goal is the establishment of a series of guidelines on the design of climate systems and building properties for vertical farms.”

Vertical farming is a promising new technology for world food production, especially where it concerns growing fresh and perishable crops close to the customer, climate-independent farming, and high-quality nutrient in fruits and vegetables. The SKY HIGH program contributes from a multidisciplinary perspective to the improvement of the technology as a whole - valuable and interesting research!