

# In the new FARM

**Vertical farms** save land and water, do not use pesticides and are protected from bad weather. But they take a lot of **energy**.

by Vito Tartamella



**T**oday is harvest day. It is 8 in the morning, when Davide turns a knob on the control panel. A door opens at the top of a wall, and from there comes out a platform filled with bright green lettuce plants that are just ripe enough. Davide presses a button, and the tray with the plants descends to the ground floor with a goods lift. David wears a white coat with shoe covers, gloves, mask and a hairnet. He observes the quality of the crop by typing in the shape and colour of lettuce heads on a tablet. Then, the tray will be loaded on trolleys and transferred to a refrigerated room, where the plants will be cut, checked and packaged. In the afternoon, the salad bags will be in the wholesalers' cold stores, ready to be sold the next morning. Davide is not working in a field. He is in an industrial warehouse on the outskirts of Melzo, east of Milan. This is the headquarters of Agricola Moderna, Italy's largest commercial vertical farm, where Davide Sosso, a 38-year-old agronomist with a post-doc at Stanford University, is Head of R&D. In the farm's growing chamber, an 8-metre high metal box—almost like a three-storey building—there are 800 m<sup>2</sup> of stacked trays filled with lettuces and brassicaceae lit by purple LED lights.

## THE LARGEST FARMS IN THE WORLD

This is not a laboratory experiment: the two tonnes of salads produced each month with zero pesticides are sold by a network of hypermarkets in the area and by a farmhouse products website. Nor is this an isolated case: in April, Planet Farms, a 10,000-m<sup>2</sup> automated vertical farm, will open in Cavenago, also in Lombardy. It will be one of the largest in the world: Nordic Harvest, a 7,000-m<sup>2</sup> facility, is being built in Copenhagen. To date, the largest vertical farm is AeroFarms in Newark, USA: it extends over several floors for a surface of 6,500 m<sup>2</sup>. Ikea, the Swedish furniture multinational, has also invested in this company. While Jeff Bezos (Amazon) and Eric Schmidt (Google) have invested in Plenty, a robotic vertical farm in San Francisco. Why this boom occurred? 'Covid has made people more aware of healthy food and its environmental impact', said Sosso. But the reasons go deeper.

## ZERO MILE

According to its proponents, vertical farming could solve many of today's problems. Indoor fields are not subject to natural disasters, global warming or insects, therefore there is no need to treat plants with toxic fertilizers and pesticides. They allow many more harvests throughout the year, as they do not depend on the weather and the cycle of the seasons: for the same surface area, an indoor square metre is 10 times more productive than a traditional one (and some species are up to 500 times more productive). Moreover, they save a lot of soil and water thanks to hydroponic and aeroponic techniques—the roots of the plants are immersed in a water solution or sprayed with a nutrient spray mist. This means no land consumption and very low water consumption. Not to mention that, being located in cities, these farms cut down on transport emissions: they are truly zero-mile.

Urban farms make it possible to produce fruit and vegetables in small spaces: they can be "indoor farms" (set, for example, in disused warehouses), "vertical farms" (in vertically stacked layers), "plantscrapers" (cultivated skyscrapers, indoors or on the roof) and "deep farms" (set in former mines).

London-based Growing Underground produces vegetables in abandoned WWII tunnels. Local Roots, a Los Angeles-based start-up, patented Terra-Farms—12-metre containers equipped as indoor greenhouses that can be controlled remotely with a smartphone. ▶

## GREEN WALLS

An agronomist checks the rocket, black cabbage and beetroot plants arranged on a 6 meter high wall: we are at Plenty in San Francisco, an avant-garde vertical farm.

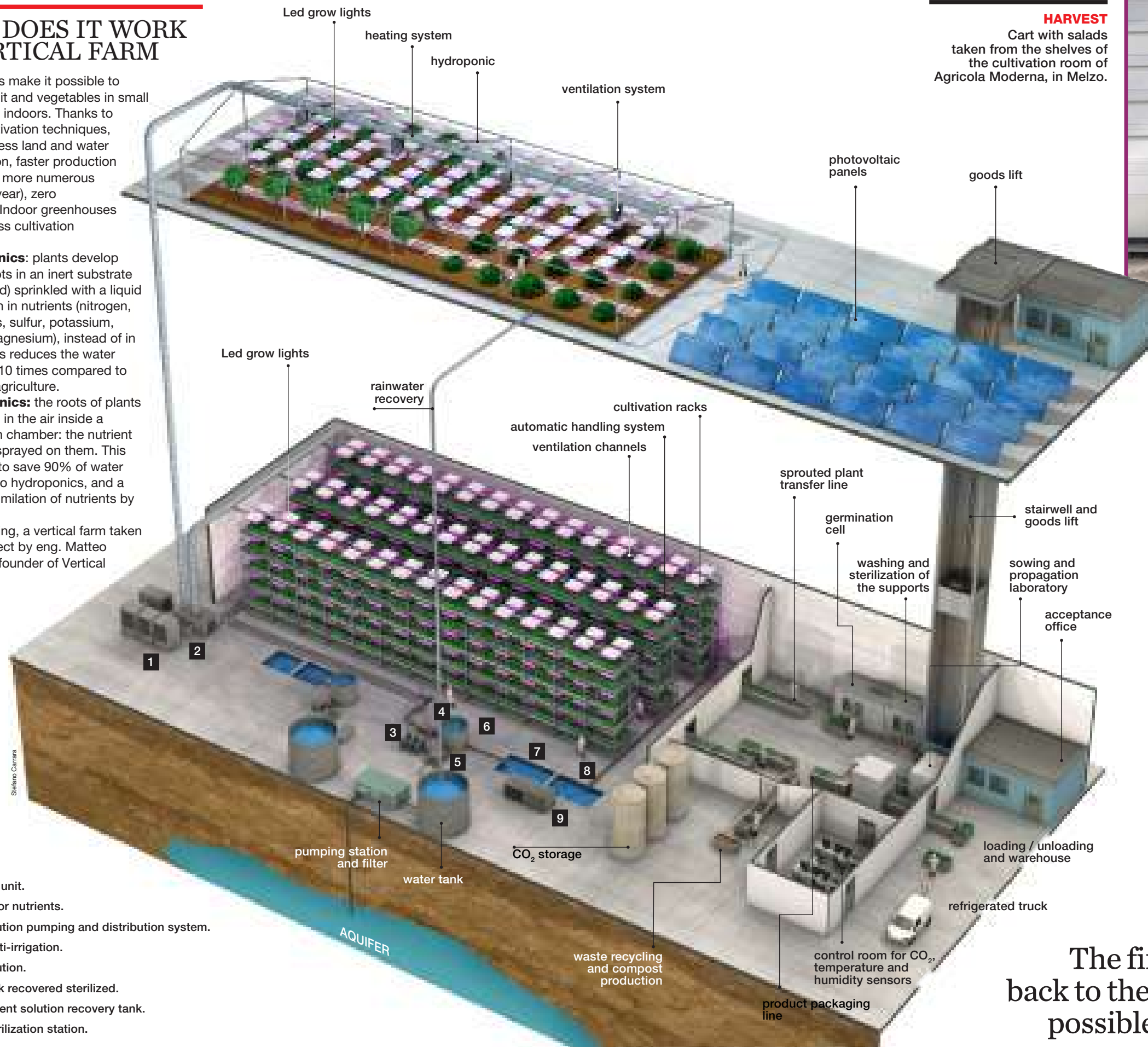
# HOW DOES IT WORK A VERTICAL FARM

Urban farms make it possible to produce fruit and vegetables in small spaces and indoors. Thanks to soilless cultivation techniques, they allow less land and water consumption, faster production cycles (and more numerous during the year), zero pesticides. Indoor greenhouses use 2 soilless cultivation techniques:

**hydroponics:** plants develop their roots in an inert substrate (gravel, sand) sprinkled with a liquid solution rich in nutrients (nitrogen, phosphorus, sulfur, potassium, calcium, magnesium), instead of in the soil. This reduces the water needed by 10 times compared to traditional agriculture.

**aeroponics:** the roots of plants develop in the air inside a nebulization chamber: the nutrient solution is sprayed on them. This allows you to save 90% of water compared to hydroponics, and a greater assimilation of nutrients by plants.

In the drawing, a vertical farm taken from a project by eng. Matteo Benvenuti, founder of Vertical Farm Italia.



**HARVEST**  
Cart with salads taken from the shelves of the cultivation room of Agricola Moderna, in Melzo.



## A UNIVERSITY CHALLENGE

«With vertical farms», says Dickson Despommier, professor emeritus of Microbiology at Columbia University, «we could ensure a more sustainable future for the planet. All the land saved using this farming system could return to its natural ecological function: absorbing carbon dioxide and oxygenating the planet through forests. By 2050, the world's population is expected to increase by about 3 billion people, and almost 80% of them will live in cities. In order to feed everybody, 10 billion hectares of new land will be needed (an area 20% larger than Brazil), reducing the area of forests and producing greenhouse gases from agricultural activities». Will indoor agriculture be the solution to feed and save the world? As we shall see, the time is not yet ripe.

Despommier is the father of vertical farming, which started as a challenge in his university classroom. Back in 1999, his students, tired of dealing with pests and environmental damage, asked him to cover less depressing topics. Despommier set them a challenge: they had to calculate how many Manhattan residents could be fed a diet of 2,000 calories a day by using the rooftops of the densely populated New York City borough as arable land. The result was discouraging: with a total of 52,000 m<sup>2</sup> of rooftops, it was only possible to feed about a thousand people. So Despommier widened the perspective: why not use not only the roofs but also the interior spaces of the buildings, creating greenhouses lit by large windows and artificial lights? A 30-storey high farm could produce food for 50,000 people, hosting fruit and vegetable fields, chicken and fish farms fed with vegetable waste. Vertical farming was born. «Although», says Matteo Benvenuti, author of "Introduction to vertical farms" (published in Italy by Wolters Kluwer), «a similar idea was launched as early as 1984 by Canadian biologist John Todd, founder of the New Alchemy Institute. In order to make the project feasible, however, a technological breakthrough was needed—artificial lamps to irradiate indoor crops with the same wavelengths as the sun». This result has been made possible in the past decade thanks to advances in LED lamps, capable of stimulating photosynthesis of all different species, and having long life and low energy consumption. A field in which Philips invested millions in research.

## HIGH INVESTMENTS, HIGH ENERGY CONSUMPTION

The first ideas on vertical farms date back to the **1980s**. But they only became possible with the advent of **LED** lights



## FARMERS IN COMPARISON

	OUTDOOR	INDOOR	
CONS	• 1.6 billion hectares cultivated in the world (80% of the earth's arable land)	• 30 hectares cultivated all over the world. Yield of 1 indoor hectare = 10 traditional hectares	PROS
	• 50% of the crops are not harvested	• 90% of the crops planted are harvested	
	• Intensive use of pesticides (and only 0.1% affects insects; the rest ends up in the environment)	• 0% of pesticides	
	• Risk of parasite attacks (insects, birds, rodents)	• Very low risk of parasite attacks	
	• 70%: percentage of land freshwater used for agricultural purposes (and 50-80% of it is dispersed between evaporation and water losses)	• Less than 70-95% of water needed (using hydroponics or aeroponics)	
	• 2,400 km: average distance that a food travels to reach our table (causing pollution)	• km 0: vertical farms already arise in the city	
	• Subject to seasonal cycles and climatic weather	• Not subject to seasonal cycles or climatic weather. And different types of crops can be grown at the same time	
PROS	• CO <sub>2</sub> emissions due to the use of tractors	• No use of tractors, but the high use of electricity has a very high environmental impact (if it doesn't come from renewable sources)	CONS
	• Possibility of cultivating any species	• Limited number of cultivable species: small, fast-growing plants that must not be pollinated by insects	
	• Very low cost per m <sup>2</sup>	• High cost per m <sup>2</sup> (even 800 times more)	
	• Energy requirement: for a greenhouse, 250 kWh of energy per year for each m <sup>2</sup>	• High energy costs: for a vertical farm, 3,500 kWh per year for each m <sup>2</sup>	



**ROOT CONTROL**  
A YesHealth technician checks the roots of a hydroponic garden in Taiwan: they are immersed in a solution of water rich in nutrients.

## Indoor farms are suitable for countries with **little arable land**. And to those with very **hot** or very **cold** climate

### EXTREME VEGETABLE GARDENS

Below, the "Veggie" module, in orbit on the International Space Station; below, tomatoes at the Amundsen-Scott Base at the South Pole.



According to the financial agency Bloomberg, the vertical farming market was worth \$3.42 billion in 2019 and its value could more than double to \$7.3 billion by 2025. Still, it remains a niche: according to estimates by Cindy van Rijswijk of Rabobank Research Food in Utrecht, Netherlands, indoor farms account for 30 hectares of cultivated land worldwide, against the 1.6 billion hectares of traditional farming. There is still a long way to go, and it will not be an easy one, due to technical and, above all, economic restraints. Starting with the investment costs: starting a traditional greenhouse costs about 300 euro/m<sup>2</sup>, while an advanced vertical farm requires between 2,000 and 2,500 euro/m<sup>2</sup>. Not to mention the operating costs: «The highest cost», says Benvenuti, «is electricity, which can account for over 60% of the costs: the lights need to be on 12-18 hours a day, 365 days a year. Air conditioning and irrigation systems also need to be powered. A 500 m<sup>2</sup> farm requires more than 200 kW of instantaneous power, the amount needed to supply 100 flats».

If this energy does not come from renewable sources, the environmental impact is heavy. These costs have an impact on the type of crops that can be grown: it is necessary to choose low plants (given the limited space between growing platforms) and «with a short growth cycle, to have more harvests in a short time», points out Gabriella Funaro, an expert from ENEA (the Italian National Agency for New Technologies, Energy and Sustainable Economic Development). «Tomatoes, for instance, are unprofitable because they take 70 days to grow compared to 20 of lettuce. And rice needs large areas: the price of cereals is too low to justify indoor cultivation».

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### A 27 DOLLARS LOAF

The energy imbalance between a traditional farm and an indoor one

remains huge: according to the Swiss Federal Institute of Technology in Zurich, it takes 4,166 kWh of energy to grow 1 kg of lettuce in a hydroponic farm, compared with only 305 kWh in an outdoor one. According to Louis Albright, professor of Biological and Environmental Engineering at Cornell University, a loaf made with wheat grown on a vertical farm would cost \$27, compared to \$1.3 of one made from outdoor grown wheat.

This is why the first attempts of these growing techniques took place in an area of extreme experimentation: space. The aeroponic technique, in fact, was invented by NASA to supply astronauts on space ships with vegetables. The experiments began in the 1980s, and today the Vegetable Production System ('Veggie'), weighing 8 kg, is aboard the International Space Station: it produces lettuce, cabbage and Japanese mustard in orbit using only 90 W of power. Today, ENEA in Rome has created 'HortExtreme', a vegetable garden for a futuristic human base on Mars: 4 m<sup>2</sup> to grow four species of microgreens with «a high density of vitamins, mineral salts and antioxidants to reinforce the astronauts' diet», says Eugenio Benvenuto of ENEA's Biotechnologies division.

### SALADS IN THE DESERT (AND AT THE POLE)

On Earth, on the other hand, vertical farms appeal to a niche market, that of consumers willing to spend more to have salads or strawberries grown without chemicals. But how much more? «An 80-g lettuce bag costs 1.6 euro, i.e. about 20 euro per kg», replies Sosso. «It is a high-end product, at the same level of organic vegetables». But making money out of it is not easy. So much that there have been epic failures in the sector. In Sweden, Plantagon wanted to build the World Food Building, a

16-storey indoor farm designed to feed 5,000 people. The construction works, which cost \$40 million, started in 2018 and were due to be completed in 2020. But in 2019 Plantagon declared bankruptcy—it would not have been able to sell the products at the prices it had hoped. «A project of this size», admitted Vice-President Owe Pettersson, «was too far ahead of its time». Therefore, in order to make ends meet, vertical farming today aims to save costs or increase profit margins. «ENEA, together with Coldiretti (the main Italian organisation representing agricultural entrepreneurs) of Padua, has launched the Ri-Genera project to use warehouses or abandoned buildings for hydroponic crops», says Funaro. Others are focusing on high-income, medical or cosmetic essences: holy basil, Californian poppy, ginger, and saffron.

But the bulk of the market for vertical farms is in countries with little arable land, such as Japan, that is one of the world leaders in the sector with over 200 companies. China is a leader, too, having lost 123,000 km<sup>2</sup> of agricultural land to massive urbanisation, plus another 200,000 km<sup>2</sup> that cannot be cultivated because of pollution. Vertical farming is gaining traction in countries where the climate makes outdoor cultivation prohibitive: in Dubai, Emirates Airlines is building a 12,000 m<sup>2</sup> vertical farm to supply all its planes with fresh vegetables. The UAE government is investing \$100 million in indoor projects: the desert climate and lack of arable land is now forcing the country to import 80% of its food. And the same goes for cold places. In addition to Nordic Harvest in Denmark, at the South Pole there is the Food Growth Chamber, a room that supplies the 65 employees of the Amundsen-Scott research station with fresh vegetables— a way to grow lettuce when outside it is 70°C below zero. **F**