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THE RISE OF ASIA'S INDOOR AGRICULTURE INDUSTRY

NEWBEANCAPITAL

SINGAPORE Farming

ABOUT THE AUTHORS

Newbean Capital is a registered investment adviser that manages early stage venture capital mandates for institutional investors. Its founder – Nicola Kerslake – has a longstanding interest in agriculture investment, having previously covered agriculture stocks as an equity analyst and managed institutional investment portfolios that covered the sector. She founded the Indoor Ag-Con event three years' ago to provide a meeting place for those who are as passionate as she is about the promise of the indoor agriculture industry.

hello@newbeancapital.com www.newbeancapital.com

SG Farming is an online lifestyle and tech journal about the agriculture scene in Singapore. We explore and track the latest developments, trends and challenges of the local food system. We aim to promote local food and food sustainability, as well as to educate people regarding the origins of food and the processes in which they are produced.

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singaporefarming@gmail.com www.sgfarming.wordpress.com

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DISCLAIMER

EXECUTIVE SUMMARY

Asia consumes 75% of all vegetables globally[1], and in extraordinary variety, from the Chinese cabbage and radish that form the basis of Korean staple kimchi to medicinal Japanese specialty leafy green ice plant. Its consumers are changing their food preferences and supply chains are adjusting to meet their needs. As a consequence, its agricultural landscape is shifting, enabling the rise of technology-based farming approaches, such as, indoor agriculture.

Indoor agriculture is growing vegetables in controlled environments, such as warehouses, containers and purpose-built growing chambers, using hydroponic systems. It is not a new practice, its roots go back to Roman times, but it has undergone a revival in the past five years as enabling technologies become more available, more sophisticated and cheaper.

Asia has longstanding greenhouse and field agriculture industries, so it is perhaps unsurprising that it also has the most developed indoor agriculture industry of any globally. Japan alone had more plant factories by 2010 than the United States has today. The world's first plant factory was established in Japan in 1983[2], and there are now approximately 450 across the region.

The majority – just over 40% - of Asia's plant factories are in Japan; China, South Korea and Taiwan also have substantial plant factory industries. Despite 70%+ pa growth in the number of Taiwanese and Japanese plant factories since 2009, there is still plenty of scope for industry development as it is small in comparison to the overall vegetable market. Even in Japan, the industry provides less than 0.6% of total vegetable production[3], and only 18% of consumers are aware of plant factories and have purchased vegetables from them[4].

The changing expectations of Asia's consumers are the primary driver of Asia's indoor agriculture industry. Rising pollution, media coverage of food scandals and an increasing distaste for excessive pesticide use have led Asia's consumers to demand "clean food", typically defined as being pesticide free and from reputable sources. These trends favour indoor growers whose vegetables are typically grown without pesticides and in semi-clean room conditions.

In some countries, the industry has also benefited from supportive government policies and subsidies. In Japan, more than half of plant factories received either a loan (20%) or a subsidy and a loan (35%) to establish operations[5]. Supporting indoor agriculture is a way of incorporating low-environmental impact farming into Asia's rapidly expanding cities.

We anticipate that we will see better economics and more international expansion from Asia's plant factories over the next few years, driven by rapid technology development especially in lighting and data usage. Indoor agriculture is at an exciting point in its development, with technology advances changing the economics of the industry, and enabling new business models, at a rapid clip.

1 Euromonitor figure, based on volume for 2014
2 "Plant Factory; An Indoor Vertical Farming System for Efficient Quality Food Production", Kozai, Niu & Takagaki, October 2015
3 Calculated based on ¥13bn in plant factory revenue for 2015 per Yano Research Institute Ltd, and total vegetable market size of ¥2tn for 2011 per Ministry of Agriculture, Forestry and Fisheries
4 Mitsubishi UFJ Research & Consulting 2013 Consumer Survey
5 Ministry of Agriculture, Forestry and Fisheries (MAFF) figures, March 2014

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A INTRODUCTION

Asia consumes 75% of all vegetables globally[6], and in extraordinary variety, from the Chinese cabbage and radish that form the basis of Korean staple kimchi to medicinal Japanese specialty leafy green ice plant. Its consumers are changing their food preferences and supply chains are adjusting to meet their needs. As a consequence, its agricultural landscape is shifting, enabling the rise of technology-based farming approaches, such as, indoor agriculture.

Indoor agriculture is not a new practice, its roots go back to Roman times, but it has undergone a revival in the past five years as enabling technologies become more available, more sophisticated and cheaper. We refer you to our earlier white paper – "Indoor Crop Production; Feeding the Future" of March 2015[7] – for a brief history of the industry.

This paper is intended as an introduction to the indoor agriculture sector in Asia; it provides an overview of the current status, technologies and future prospects for indoor agriculture. Its authors are active in the industry, but do not consider themselves experts by any means. We are bound not by contractual arrangements, but by a mutual interest in seeing a thriving indoor agriculture industry as a component of a stronger, healthier global food supply chain. By the very nature of the exercise, our survey will omit many noteworthy projects and players.

For the purposes of this paper, we define indoor agriculture as growing vegetables in controlled environments, such as warehouses, containers and purpose-built growing chambers, using hydroponic systems. This definition covers a broad range of indoor farms, from basic table top systems in one's apartment through large scale automated commercial operations, as is shown in table one over page.

Within Asia, the more sophisticated of these indoor farms use substantial robotics and automation to control operations, and are generally referred to as plant factories, but are sometimes called plant factories with artificial light (PFAL), vertical farms, and controlled environment agriculture (CEA). Our report focuses on commercial plant factories, whose major characteristics are:

- *Controlled Environment*. Grow rooms are typically controlled environments, such as a floor of an office block, with some being operated in semi or completely clean room conditions. This shields the plants from the outside world, so allowing better control over plant growth and excluding most pests.

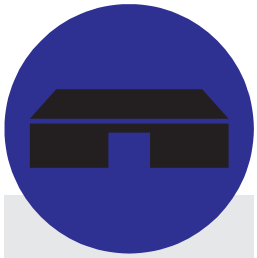
- *Artificial Light.* Plant factories mostly rely on artificial light for plant growth, and this typically takes the form of either sodium or – increasingly – LED lights.

- *Resource Usage.* Plant factories use a fraction of the water required in the open field, in some cases as little as 1% of that used outdoors. Many eschew pesticides, and some are certified as organic.

- *Use of Automation & Robotics.* With sophisticated data and associated analytics becoming increasingly available, plant factories rely on an expanding range of technologies to minimize resource (energy, water) usage and optimize crop yields.

6 Euromonitor figure, based on volume for 2014
7 This paper can be downloaded at https://indoor.ag/whitepaper

CHART ONE: ASIA'S INDOOR AGRICULTURE INDUSTRY BY STRUCTURE

	HYDROPONIC GREENHOUSES	PLANT FACTORIES	CONTAINER FARMS	IN HOME SYSTEMS
DESCRIPTION	Like soil-based greenhouses, these greenhouses grow crops in a single layer. Transparent roofs are employed to utilize natural sunlight, augmented with supplemental lighting during dark days and off-peak growing seasons.	Industrial, commercial or retail space is constructed or retrofitted with hydroponic, aquaponic or aeroponic equipment and crops are grown vertically to achieve economies of scale. Artificial lighting systems are used at all times.	Standardized, self-contained growing units that employ vertical farming and artificial lighting. In contrast to custom-designed warehouses, container farms strive for standardization.	Systems targeted at consumers for small scale in home growth, whether as fridges in kitchens or as standalone units elsewhere in the home.
ESTIMATED NO. OF COS IN ASIAN MARKET	Our estimate is at least 500, covering at least 54k ha / 134k acres based on Cuesta Roble Consulting data	450 plant factories, with an estimated 518 by the end of 2016	3 commercial, likely 4-5 others in process of commercializing	At least 7-8 offering some form of in-home solution
COMPANY EXAMPLES	Iwaki Onahama Veg. Farm, Kagome Co. Ltd, Le Gaga	Jingpeng Plant Factory, KiMiDoRi Corporation, Mirai, Refresh Hamyang, SCATIL, Spread, Vegetechs	Alesca Life Technologies, Daiwa's agri-cube, FreightFarms	Hulying Ecological, iGrowths, Pacific Construction Co

Source: Miscellaneous public sources, greenhouse data from Cuesta Roble Consulting, Newbean Capital analysis

When we refer to Asia, we include the following countries: China, Hong Kong, Japan, Mongolia, Singapore, South Korea, Taiwan, Vietnam. We have selected these countries as they have commercial plant factories, and we discuss China, Japan and Taiwan most as they have the largest indoor agriculture industries.

B STATE OF THE INDUSTRY

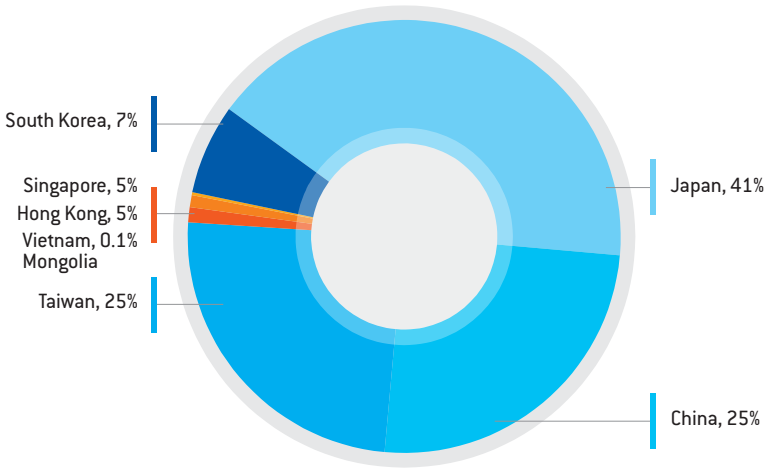
Asia has longstanding and well established greenhouse and field agriculture industries, so it is perhaps unsurprising that it also has the most developed indoor agriculture industry of any globally. Japan alone had more plant factories by 2010 than the United States has today. The world's first plant factory was established in Japan in 1983[8], and there are now approximately 450 in operation across the region, as is shown in the maps over page. The industry's major characteristics are:

Geographic Spread
The majority – just over 40% - of Asia's plant factories are in Japan; we have included a list of the artificial light and combined artificial and sunlight plant factories in an appendix for reference. China and Taiwan also have substantial plant factory industries.

Industry Growth
Despite 70%+ pa growth in the number of Taiwanese and Japanese plant factories since 2009, there is still plenty of scope for industry development as the industry is small in comparison to the overall vegetable market. Even in Japan, the industry provides less than 0.6% of total vegetable production[9], and only 18% of consumers are aware of plant factories and have purchased vegetables from them[10].

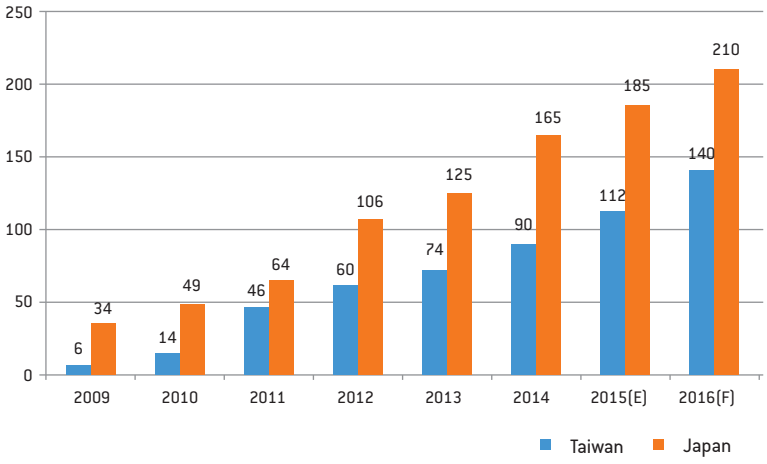
Crop Diversity
As is the case for plant factories globally, lettuce is the largest crop representing just under half of the crops produced by number[11]. Other leafy greens and herbs are also popular, at 14% and 17% of crops produced by number respectively[11]. Otherwise, Asia has a greater range of crops than is seen elsewhere in the world, for example, it has commercial production of specialty crops such as berries.

CHART TWO: GEOGRAPHIC SPREAD OF ASIA'S PLANT FACTORIES



Sources: Japan Plant Factory Association, Dr. Wei Fang, Dr. Changhoo Chun, Dr. Qing Yang, Singapore Farming / Newbean Capital analysis

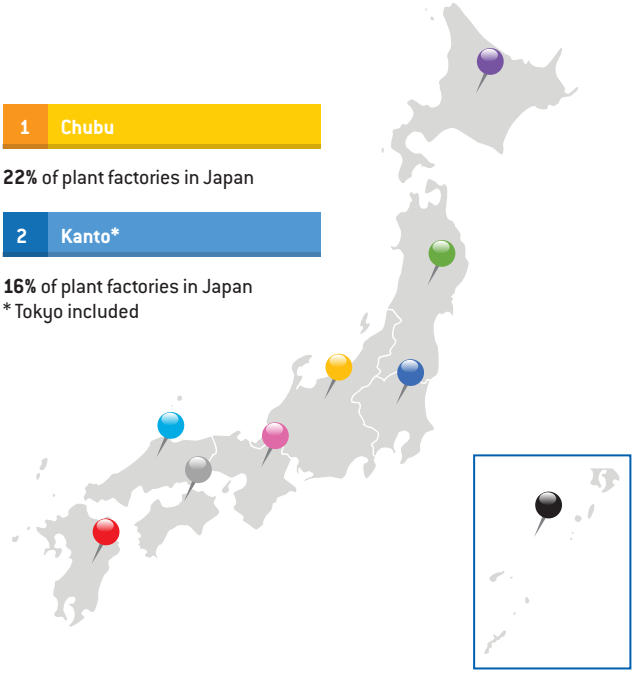
CHART THREE: NUMBER OF JAPANESE AND TAIWANESE PLANT FACTORIES



Source: Japan Plant Factory Association + PIDA, 2015/12

8 "Plant Factory; An Indoor Vertical Farming System for Efficient Quality Food Production", Kozai, Niu & Takagaki, October 2015
9 Calculated based on ¥13bn in plant factory revenue for 2015 per Yano Research Institute Ltd, and total vegetable market size of ¥2tn for 2011 per Ministry of Agriculture, Forestry and Fisheries
10 Mitsubishi UFJ Research & Consulting 2013 Consumer Survey
11 Calculated by taking crops produced by each of the plant factories with artificial light and plant factories with combined artificial light and sunlight in Japan, with data from Japan Greenhouse Horticulture Association

CHART FOUR: JAPAN'S PLANT FACTORIES



22 %

1 Chubu

22% of plant factories in Japan

16 %

2 Kanto*

16% of plant factories in Japan
* Tokyo included

11 %

3 Tohoku

11% of plant factories in Japan

11 %

4 Kansai

11% of plant factories in Japan

10 %

5 Chugoku

10% of plant factories in Japan

10 %

6 Kyusu

10% of plant factories in Japan

9 %

7 Hokkaido

9% of plant factories in Japan

7 %

8 Shikoku

7% of plant factories in Japan

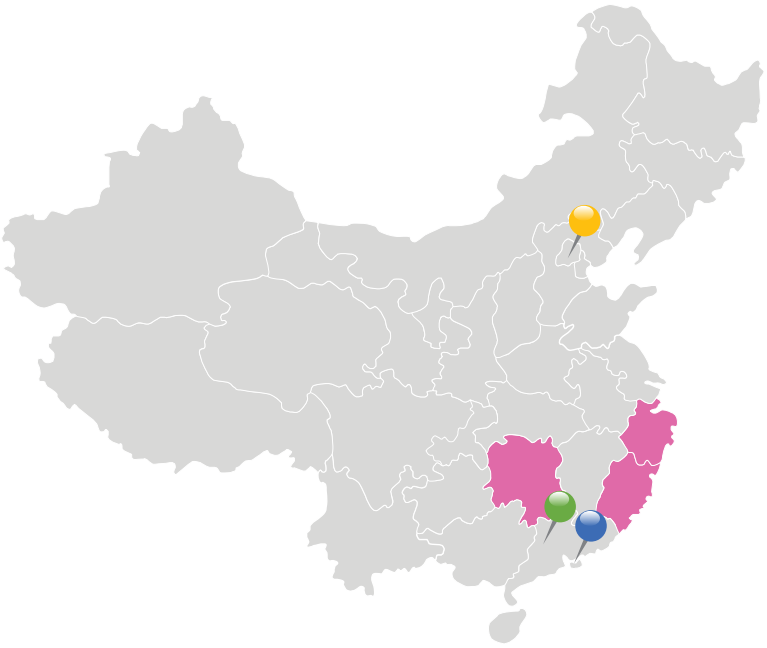
4 %

9 Okinawa

4% of plant factories in Japan

Source: Japan Greenhouse Horticulture Association , 2013

CHART FIVE: CHINA'S PLANT FACTORIES



32 %

1 Beijing

32% of plant factories in China

26 %

2 Hong Kong

26% of plant factories in China

21 %

3 Guangdong

21% of plant factories in China

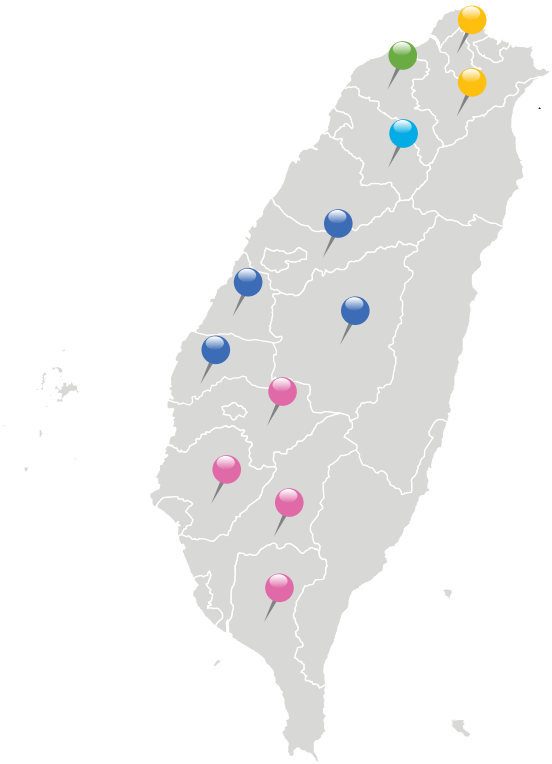
21 %

4 Rest of China

21% of plant factories in China

Source: Prof. & Dr. Qichang Yang, shows only plant factories with artificial light

CHART SIX: TAIWAN'S PLANT FACTORIES



Source: PIDA,2015

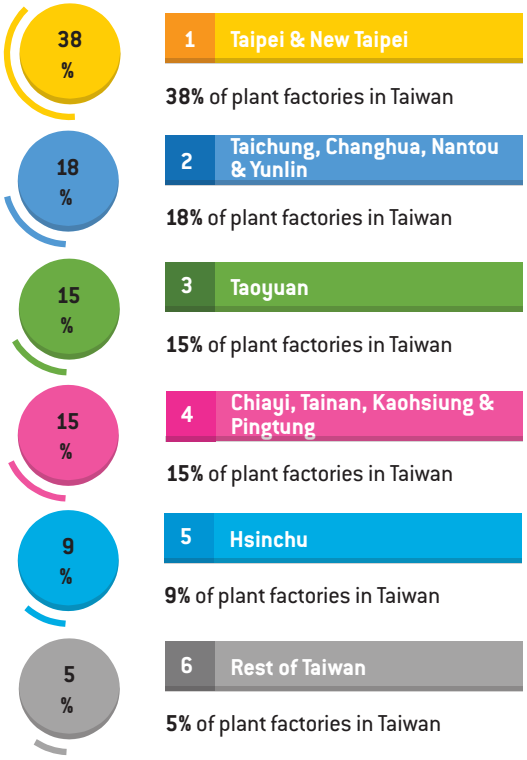
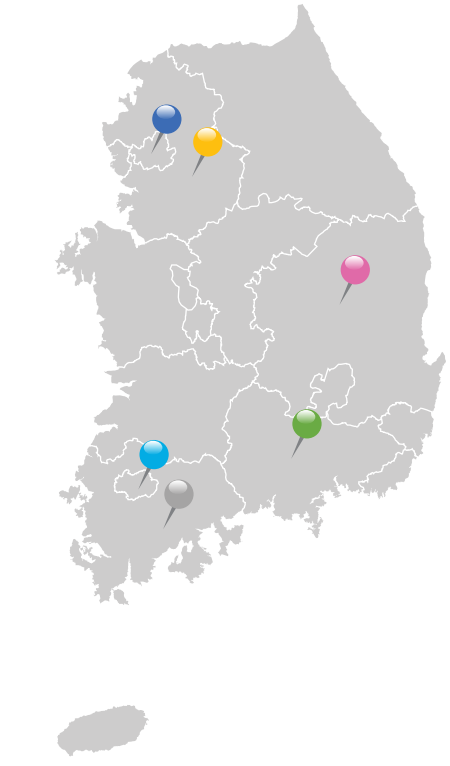


CHART SEVEN: SOUTH KOREA'S PLANT FACTORIES



Source: Dr. Changhoo Chun

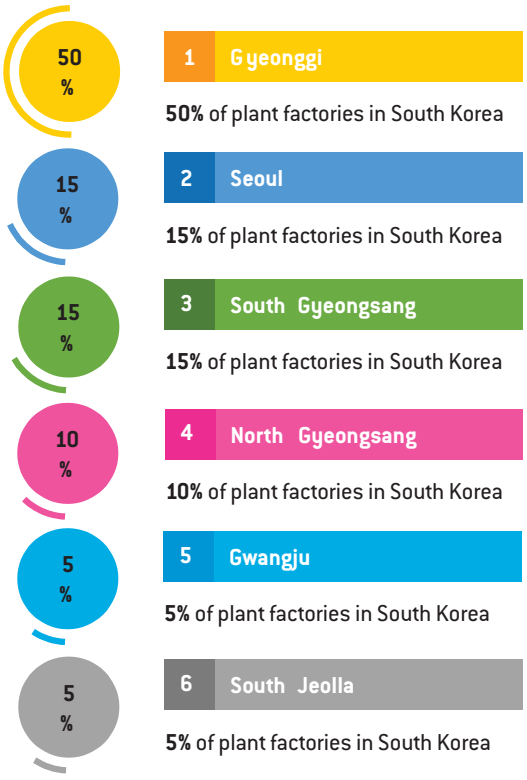


CHART EIGHT: PLANT FACTORIES IN OTHER PARTS OF ASIA

5

1 Singapore

There are **5** PFALs in Singapore

2

2 Mongolia

There are **2** PFALs in Mongolia

1

3 Vietnam

There is **1** PFAL in Vietnam

Source: News Reports, Newbean Capital / Singapore Farming Analysis

C WHAT'S DRIVING ASIA'S INDOOR AGRICULTURE GROWTH

The changing expectations and behaviour patterns of Asia's consumers with regard to food consumption are the primary driver of Asia's indoor agriculture industry. In some countries, the industry has also benefited from supportive government policies and subsidies.

Changing Consumer Needs

Rising pollution, media coverage of food scandals and an increasing distaste for excessive pesticide use have led Asia's consumers to demand "clean food", typically defined as being pesticide free and from reputable sources. Recurrent food scandals – from melamine in baby food to tainted meat served at fast food restaurant KFC – have led Chinese consumers in particular to seek information on the source and safety of their food. For example, popular venture capital-backed food delivery app Ele.me removed 30%[12] of restaurants from its app in Hangzhou alone following media coverage of poor hygiene standards in some kitchens.

Environmental factors also play a part, whether in the form of concerns over radiation exposure in Japan following the Tōhoku earthquake, tsunami and nuclear disaster or smog in China's major urban centres, such as Beijing, where the air pollution index was 20[13] times what the World Health Organization considers to be safe at the end of November 2015. Shigeharu Shimamura, the erstwhile CEO of one of Japan's better known plant factory companies – Mirai – was inspired to start the firm by a wish to help the country recover from 2011's natural disasters.

The same trend is driving renewed enthusiasm for hobby growing, whether in the form of small garden plots or the in-house hydroponic and aquaponics systems. Naturally, a particular concern is young infants' diets, with one Chinese seed seller reporting that fully half of its customers are mothers growing vegetables for their young children[14].

At the same time, Asia's consumers are changing their diets, seeking more dairy, meat and processed foods, the latter often being vegetable-based. Indoor farms are playing a part in satisfying this demand, for example, one Taiwanese company has developed value added products, such as, egg rolls, bread and ice cream based on its plant factory.

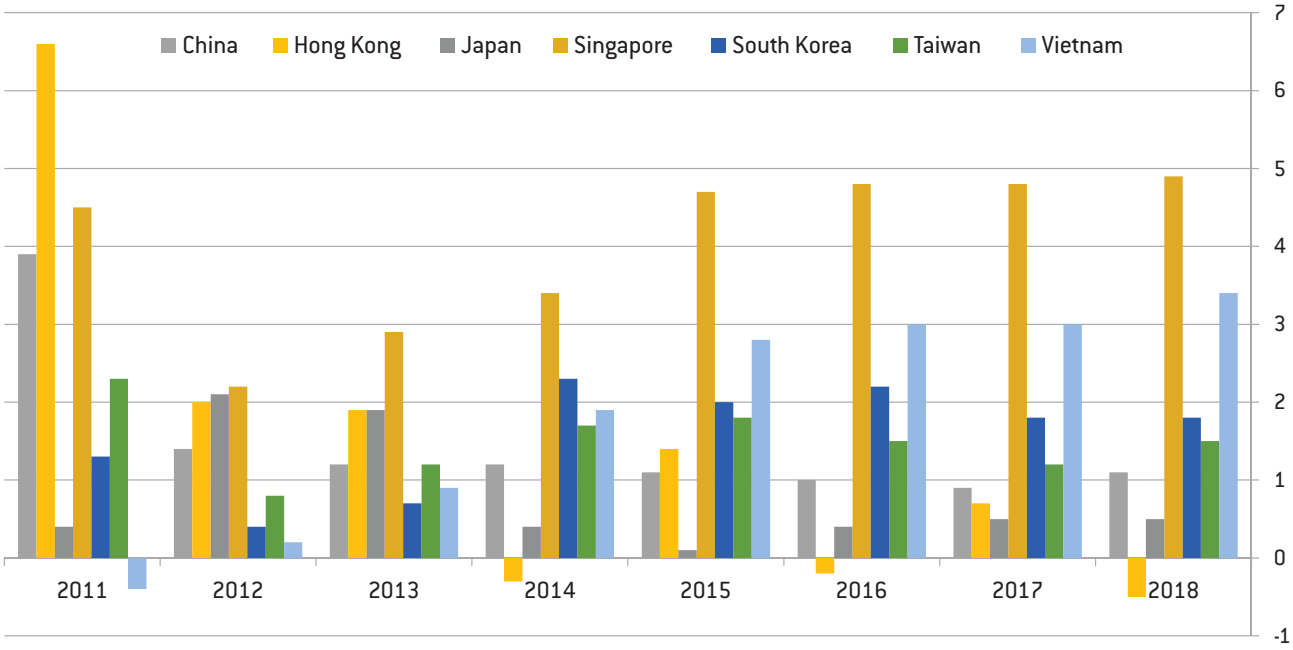
Combined, these trends favour indoor growers whose vegetables are typically grown without pesticides and in at least semi-clean room conditions. Moreover, indoor growers are more easily able to identify the source of their vegetables, rather than there being from a variety of unnamed sources and a long supply chain, portions of which are unrefrigerated.

Supply Chain Restructuring

Based on data from the Economist Intelligence Unit, Asia is the fastest growing region for food & beverage products. Just as traditional wet markets ceded ground to supermarkets over the past few decades, now supermarkets are being challenged by online grocery and food delivery services. Market research firm Nielsen found that more than a third (37%) of Asia-Pacific respondents, and nearly half of Chinese respondents (46%), say they use an online grocery ordering and delivery service, well ahead of global averages[15].

12 "Food Scandals", Shanghai Daily, December 31, 2015
13 "Beijing chokes on off-the-charts air pollution as thick smog settles over northern China", Angela Fritz, Washington Post, November 30, 2015
14 "Urban Farming a Growing Trend in China", South China Morning Post, August 19, 2012
15 "The Future of Grocery: E-Commerce, Digital Technology and Changing Shopper Preferences Around the World", Nielsen, April 29, 2015

CHART NINE: FOOD, BEVERAGES & TOBACCO: MARKET DEMAND GROWTH (% CHANGE PA)



Source: Economist Intelligence Unit, figures are forecasts from 2014 onwards

These changes benefit indoor agriculture, which is able to supplement traditional agriculture by offering a consistent year-round supply of fresh locally grown vegetables, a key factor for increasingly popular organic vegetables and in off seasons when vegetables are hard to source. For instance, Taiwan's farmers grow around 130[16] types of vegetables, but the country still imports 70%[17] of its organic food and beverages.

Supportive Government Policies

Arguably, Asia's governments have been the most supportive of any globally towards the indoor agriculture industry. As is shown in table ten, this support ranges from subsidies to national policy initiatives. In Japan, more than half of plant factories received either a loan (20%) or a subsidy and a loan (35%) to establish operations[18].

Government support is supplemented by the formation of trade associations that combine the talents of private firms and academic institutions. One example is the Taiwan Plant Factory Industry Development Association, formed by twenty businesses and academic research institutions, including the Industrial Technical Research Institute, the nonprofit research institute that famously played a role in kickstarting Taiwan's world-leading semiconductor industry. The region is also home to leading research universities in the space, such as Chiba University.

16 "Postharvest Losses of Fruit and Vegetables in Asia", Food and Fertilizer Technology Centre for the Asian and Pacific Region
17 "Agri-Food Past, Present and Future Report – Taiwan", Government of Canada, June 2011
18 Ministry of Agriculture, Forestry and Fisheries (MAFF) figures, March 2014

TABLE TEN: ASIAN GOVERNMENT SUPPORT FOR THE INDOOR AGRICULTURE INDUSTRY

COUNTRY	COMMENTARY
China	In the 11th Five-Year Plan for National Economics and Social Development, the government stresses the importance of Green and Controlled Environment Agriculture. There are many research projects underway e.g. the National High Science & Technology Project on plant factory production technology, combines 15 universities, institutes and companies and is supported by the Ministry of Science and Technology of China.
Japan	MAFF & MITI began the 5 year "Plant factory with artificial light and/or solar light" project in 2009 with ¥15bn budget. Offers 50% subsidy for commercial plant factory construction. Also offers subsidies for basic research, demonstration, training and PR.
South Korea	In 2009, the national policy of "Low carbon, green growth campaign" was adopted, and MKE began series of research and policy support projects, aimed at technology export. Government announced a "Plan for promotion of agri-food and ICT convergence" in 2013. Applies ICT tech to agricultural products.

Sources: News reports, discussions with industry participants Newbean Capital / Singapore Farming analysis

In our view, the driving forces for this support are economic development and food security.

Food security is especially important in countries that are experiencing declining food self-sufficiency rates. Japan, for example, has seen its food self-sufficiency ratio – the proportion of consumption that is grown in the country – fall from around 80% in 1960 to around 40% today[19]. The issue is becoming more pressing as the average age of farmers rises, farmland is abandoned whether owing to pollution, soil erosion or for conversion to other uses, and water becomes scarcer. Supporting indoor agriculture is a way of incorporating low-environmental impact farming into Asia's rapidly expanding cities.

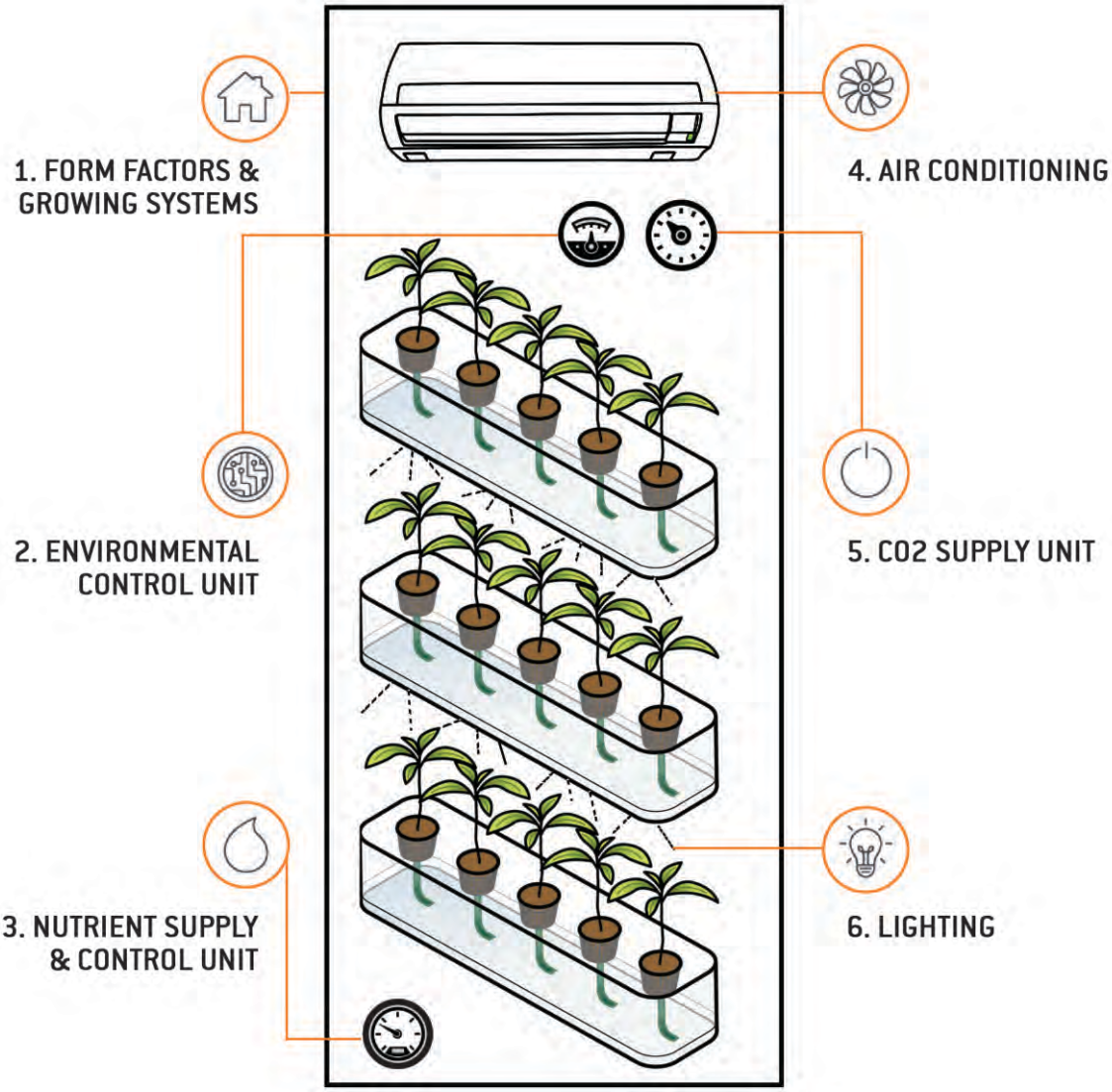
A secondary driver is economic development, especially where the redeployment of existing technologies into the indoor agriculture industry can lead to higher equipment and technology exports. For instance, Japanese major Fujitsu's Aizuwakamatsu Akisai Plant Factory uses a repurposed semiconductor factory infrastructure combined with the company's expertise in energy conservation, environmental technology and semiconductor manufacturing[20]. Technology export has been the engine of several waves of economic growth in Asia, with earlier examples being petrochemicals and semiconductors, so it's logical that technology-based agriculture should now be a focus.

19 "Food Self-Sufficiency and International Trade: A False Dichotomy?", Food and Agriculture Organization of the United Nations, March 2015
20 "Introduction to Fujitsu's Food and Agriculture Cloud Akisai", Fujitsu Ltd, July 24, 2014

D PLANT FACTORY TECHNOLOGIES

The following is an overview of the components of plant factories, the basis of which is the classification delineated by leading plant factory researcher Dr. Toyoki Kozai. We look briefly at the purpose and status of each component, and at the opportunities for development in each.

CHART ELEVEN: PLANT FACTORY COMPONENTS



1. FORM FACTORS AND GROWING SYSTEMS

Plant factories are housed in controlled environments, and these are generally insulated and isolated from the outside world via air locks or by operating in entirely clean-room conditions. They are in a variety of settings, from purpose built warehouses to repurposed semiconductor factories. For instance, over 90% of Taiwan's plant factories are housed in office buildings[21].

21 Per Dr. Wei Fang

Growing systems comprise a series of up to 20 vertical layers of grow racks with troughs that contain the nutrient-rich water in which plant roots grow, and each layer of which incorporates lighting. Historically, growers have mostly chosen to build their own growing systems – using everything from basic PVC pipes to professionally engineered racking systems – but a plethora of firms now offer turnkey solutions.

Opportunities: With numerous systems now commercialized – from players as varied as majors such as Panasonic and Fujitsu through to one-person startups – natural opportunities are in improving the efficiencies of the systems, or in creating add-on solutions and integrated products, such as white-labeled organic nutrient solutions. Adding automation and robotics to systems is also a promising research avenue, as this offers the potential to reduce the labour costs that generally make up around a quarter of plant factory operating costs.

2. ENVIRONMENTAL CONTROL UNIT

Environmental control units monitor, and sometimes adjust, a range of indoor farm factors, for instance, pH, nutrient and humidity levels. Companies such as Argus Controls, Autogrow and Priva offer plentiful products, from the simplest pH monitors to sophisticated systems that track worker productivity. Several have cloud based options that allow users to remotely access and control their farms. Thanks to the advent of big data – vast data sets that can be analyzed to identify patterns, trends, and associations – control systems are one of the most attractive areas of indoor farms for further development as market commentators anticipate better crop yields from the application of results from big data analytics.

Opportunities: The explosion of cheap sensors and analytic platforms over the past few years has opened the possibility of creating a better understanding of plant behavior, one which is likely to be captured by both existing players and startups alike. We discussed this opportunity in more detail in an earlier white paper; "Robotics and Automation in Indoor Agriculture" of October 2015[7].

3. NUTRIENT SUPPLY & CONTROL

In hydroponic systems, plants' nutrient needs are supplied through the solution in which roots rest, and differ according to plant type and life stage. Some growers use commercially available nutrient mixes, while others choose to create their own custom mixes, and view these as part of their unique approach to growing. Most also use dosing control systems that monitor and administer nutrients to the farm's recirculating water system. Such systems are offered by a combination of longstanding greenhouse suppliers, such as Dosatron International, and newer market entrants.

Opportunities: Many growers would like to better verify the plant growth and flavour claims made by commercial nutrient suppliers, and to better understand the impact of microbiomes in soil. Naturally, smaller growers are always on the lookout for cheaper, simpler systems to use in their farms in addition.

4. AIR CONDITIONING

Creating optimal temperature and humidity conditions is vital to plant health, so growers devote a good deal of attention to selecting air conditioning equipment. A large range of options are commercially available, and the grower's selection is generally determined by a combination of initial capital cost, unit capacity and operating costs, as air conditioning typically comprises 20-30% of electricity costs. There are substantial economies of scale in air conditioning, such that larger farms have lower capital and operating costs per square metre of planted space.

Opportunities: Growers consistently seek air conditioning systems that integrate well with farm control systems, and are cheaper and more efficient than those currently available. This is especially the case for smaller farms, which do not currently have access to larger, more efficient options.

5. CO2 SUPPLY UNIT

Carbon dioxide or CO2 supplies essential elements to plants. It's common to enrich the CO2 available in plant factories above ambient levels as studies as far back as the mid-1980s have established a correlation with better yields - especially when used at certain plant life stages - and with more efficient plant water use. CO2 is generally piped directly into the facility to reach the required level, though ventilation systems and local regulations may preclude some farms reaching the level that's theoretically optimal for the plants.

Opportunities: Though not the area of greatest promise among those listed here, cheaper methods of supplying and controlling carbon dioxide in plant factories are always welcome, as is better understanding of the interrelationship between crop yield and CO2 levels.

6. LIGHTING

Lighting design is a vital component for plant factories, as it provides the only source of illumination for plant growth in a closed system. It is also an important financial decision for the grower, typically comprising around half of the build cost of a farm when LEDs are used. Some growers run LEDs as much as 18 hours per day, representing a large portion of electricity spend, often in the region of 70-80%. Though sodium lighting has been a mainstay of the horticulture industry, it is rapidly ceding ground to LED lighting, which has the benefits of lower heat and better grower control over its behavior. Large falls in LED prices have been accompanied by efficiency improvements, and there are myriad options for growers, from turnkey solutions from leaders such as Heliospectra, Illumitex, Lumigrow and Philips Lighting, through to custom manufactured solutions from companies such as Hungry Planet Technologies of the US or Nuetech of Singapore. The sector has seen rapid innovation over the past decade, as both academic and commercial understanding of the way that plant biology and light interact become more sophisticated. For instance, one European company has developed 'light recipes' that are intended to deliver the optimal light spectrum required by a plant through its lifecycle without grower intervention or adjustment. The investment community has played a substantive role in spurring this innovation, plowing US$800mn of venture capital into the lighting sector between 2008 and 2010 alone[22].

Opportunities: We are only at the beginning of our understanding of how light and plant biology interact, and consequently there are numerous opportunities for commercialization of new approaches and discoveries. For example, Dr. Toyoki Kozai has proposed research into the use of green LEDs and of upward lighting (as opposed to the intercrop lighting that's common now) for densely spaced crops[8].

22 "Research Report: LED Lighting", Martin Jackson, Woodside Capital Partners International, 2012

CHART TWELVE: LED LIGHTING PRICE FALLS

Source: LEDinside, for 40w Equivalent LED Street Price

E WHAT COMES NEXT

We anticipate that we will see better economics and more international expansion from Asia's plant factories over the next few years, driven by rapid technology development.

Technology Development

Indoor agriculture is at an exciting point in its development, with technology advances changing the economics of the industry, and enabling new business models, at a rapid clip. At present, developments in LED lighting and in 'big data' usage are being commercialized, bringing better yields and lower resource usage to plant factories. Examples include 'light recipes' and the exploration of adjusted light spectrum for LED lighting. Further out is an expansion of the crops that can be grown in indoor systems; research ranges from staple crops such as rice, to highly specialized medicinal crops. For example, a 2014 research study published by Dr. Toru Maruo et al concluded that rice could be grown in plant factories[23].

International Expansion

As is shown in the case study over page, Asia's plant factory companies are leaders in exporting their technologies to establish new farms in other countries. This is hardly a surprise given that the export-led economic growth model – whereby companies focus on developing and exporting technologies – has been the dominant one in Asia since at least the 1960s when the 'Four Tigers' (Singapore, Hong Kong, Taiwan and South Korea) mimicked Japan's earlier success in focusing on exports. To date, this expansion has been contained to a limited number of Asian markets, but we anticipate that these companies will eventually look to Europe, Africa and the United States as export destinations.

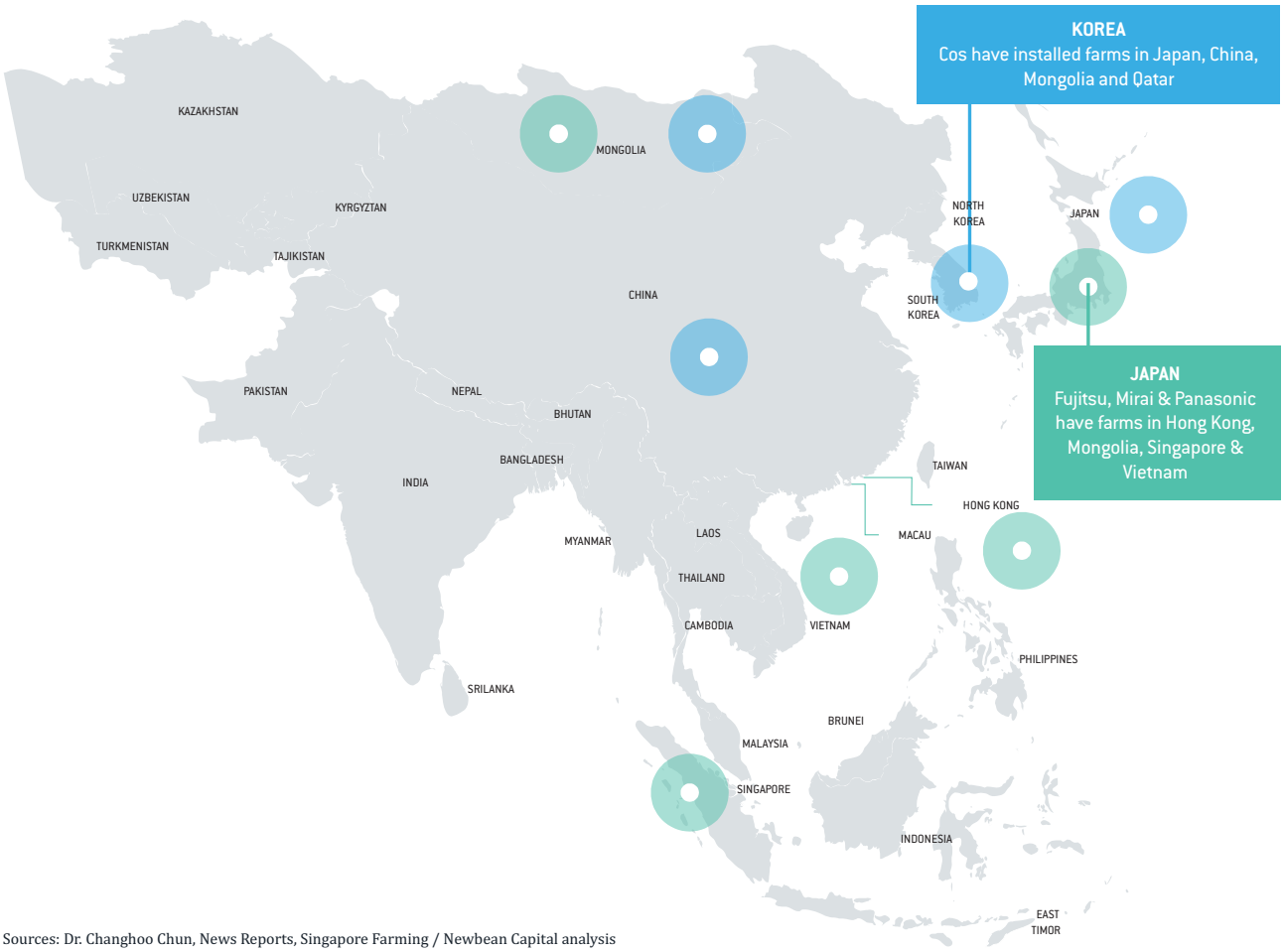
Better Economics

A sometimes reasonable criticism of the indoor agriculture industry is that it is unprofitable; sub-scale operations and a focus on commodity crops, such as head lettuce, being two culprits. Only a quarter of Japan's plant factories are profitable, and half breakeven[24]. Consequently, a major industry focus going forward is likely to be better profitability, the most obvious way of achieving this being by investing in newer technologies, and in expansion of existing operations. Lighting, automation and control systems are likely to be the largest areas of technical upgrades, as growers seek to contain the energy and labour costs that typically take up more than a quarter of operating costs each. Ironically, Asia's "early adopter" status meant that its installed farm base is reliant on less efficient sodium lighting, rather than the LED lights around which increasingly sophisticated research and approaches are based.

Sadly, there are also likely to be a number of business closures as the industry matures. We note that a high level of business failures is a characteristic of a rapidly growing industry, and the same cycle has been seen in analogous industries such as solar; industry blog Greentech Media found that, of 200 solar companies backed by venture capitalists in 2008, nearly 30% had gone bankrupt or closed by April 2013[25].

23 "Feasibility Study of Rice Growth in Plant Factories", Yamori W, Zhang G, Takagaki M, Maruo T, Rice Research: Open Access, February 2014
24 Ministry of Agriculture, Forestry & Fishery of Japan survey of February 2014
25 "Rest in Peace: The List of Deceased Solar Companies", Eric Wesoff, Greentech Media, April 06, 2013

CASE STUDY: EXPORTING PLANT FACTORY TECHNOLOGY



Sources: Dr. Changhoo Chun, News Reports, Singapore Farming / Newbean Capital analysis

F THE FUTURE OF ASIA'S INDOOR AGRICULTURE INDUSTRY

As Asia's governments grapple with the environmental and societal changes that the region's fast-paced growth have brought over the past thirty years, indoor agriculture is a way of stretching scarce resources – water, land, farm labour – further and of ensuring food security.

For its major industrial conglomerates, it holds the prospect that export-led growth can continue and that agriculture can join the list of industries in which it dominates.

Most importantly, for Asia's citizens, it offers the promise that – as we leave the family farms of our ancestors for the cubicle farms of the metropolis – a little of the countryside can join us in our everyday life in the city.

APPENDIX: JAPAN'S ARTIFICIAL LIGHT PLANT FACTORIES

Brand/ Plant Name	Operating Body	Prefectures
Demonstration plant factory	The FIDEA Research Institute Corporation.	Akita
Hiraniwa Factory	Yokote Precisions Industry Co.,Ltd.	Akita
Sanmori Factory	Itagaki Kogyo Co., Ltd.	Akita
Chef-no-Saien	Comfort Hotel Narita	Chiba
Green Flavor Goko	MIRAI Co., Ltd.	Chiba
Urban Farm Inc.	Urban Farm Inc.	Chiba
	Plants Factory Inzai Co., Ltd.	Chiba
	Jardin Co., Ltd.	Chiba
	TDU Inzai Innovation Activation Center	Chiba
	Sankyo Frontier	Chiba
Yume Farm Yanadani	General Foundation Yanadani Sangyo Kaihatsu Kosha	Ehime
	Berg Earth Co., Ltd.	Ehime
	Green Tac Farm Co., Ltd.	Ehime
	Nippon System Group Co., Ltd.	Ehime
Aqua Farm	Aqua Farm Co., Ltd.	Fukui
Fukui Nanzen-mae Factory	Yasai Kobo Co., Ltd.	Fukui
High-tech Farm Takefu Factory	Agricultural Producers Cooperative Corporation High-tech Farm	Fukui
Plant Factory Green land	Kidaya shoten CO., Ltd.	Fukui
Sanbase Ono	Sanbase Ono Co., Ltd.	Fukui
	NAEYA, Inc.	Fukui
	OREC CO., LTD.	Fukuoka
Kawauchi-Kogen agricultural products vegetable factory	KiMiDoRi Corporation	Fukushima
TS Farm Shirakawa	Kewpie Corporation	Fukushima
	Aizufujikako CO., LTD	Fukushima
	JA Tohzai-Shirakawa,	Fukushima
	Fujitsu Group Consortium	Fukushima
Fujita Engineering	Fujita Engineering Co., Ltd.	Gunma
Main Factory	SEIDEN KOGYO Co., Ltd.	Gunma
R.S Farm	TAISEI Yasai Kobo Co., Ltd.	Gunma
Chudenko	Chudenko Corporation	Hiroshima
Restaurant	Furec Co., Ltd.	Hiroshima
	Chugoku Kogyo Co., Ltd.	Hiroshima
Cosmo Farm Iwamizawa	Social Welfare Corporation Cupid-Fair	Hokkaido
Cosmo Sun Farm Pasio	Social Welfare Corporation Cupid-Fair	Hokkaido
Okhotsk Factory	KINJIRUSHI Co., Ltd.	Hokkaido
Plant Factory	Tsuchiya Dairy Equipment Mfg. Co.	Hokkaido
Social Welfare Corporation HABATAKI	Social Welfare Corporation HABATAKI	Hokkaido
	NPO Corporation SARARA SOBETSU	Hokkaido
Hanshin Yasai Plantation	Hanshin Electric Railway Co., Ltd.	Hyogo
Kobe Nunobiki Herb Gardens	Kobe Resort Service Co., Ltd.	Hyogo
Meguminosato	Meguminosato	Hyogo
Mie-ru Ecobata	NTT West Japan Asset Planning CO., Ltd.	Hyogo
Old Minamidani Elementary School	Orix Real Estate Corporation	Hyogo
Shunsai Buffet Megumi	Seven Planning Co., Ltd.	Hyogo
VEGESTORY	KANSAI TEKKO Co., Ltd.	Hyogo
Bakery & Café Maple House	Maple House Co., Ltd.	Ishikawa
In Restaurant	Bistro Heureux	Ishikawa
Main Factory	Tsudagoma General Service Corporation	Ishikawa

Shiawase Shokusai Gottsune	Social Welfare Corporation Nanyoen	Ishikawa
Kanoya leaf kan	Kyokumakoto Kosan Co., Ltd.	Kagoshima
Bashamichi LED Saien	Keystone Technology Inc.	Kanagawa
Gakunan Kenko	Yokohama Construction Association	Kanagawa
Shin-Yokohama LED Saien	Keystone Technology Inc.	Kanagawa
Torihama Green Farm	T&N Aguri Co., Ltd.	Kanagawa
	MARUAKI FOODS Co., Ltd.	Kanagawa
	Colowide MD Co., Ltd.	Kanagawa
	Tohto Rentall Co., Ltd.	Kochi
Aso Kenko Noen House	Agricultural Producers Cooperative Corporation	Kumamoto
Hikarikko Kobo	Create Hikari Inc.	Kumamoto
Nishigoshi Factory	Nakagawa Sangyo Co., Ltd.	Kumamoto
Kameoka plant	Spread Co., Ltd.	Kyoto
Shinsei Industry	Shinsei Industry Co., Ltd.	Kyoto
	General Production Co., Ltd.	Kyoto
Plant factory	Kobashidenki Co., Ltd.	Mie
Onagawa Factory	Sato Kogyo Co, Ltd.	Miyagi
Rokuchome-Nouen	Apple Farm Co., Ltd.	Miyagi
Secom High Plant	Secom Industries Co., Ltd.	Miyagi
Tagajo Factory	Mirai Co., Ltd.	Miyagi
[Bellvia] in front of JR Chino Station	Suwasai Co., Ltd.	Nagano
[Suwaplaza] in front of Kamisuwa station	Yukina Co., Ltd.	Nagano
Azumino Misato High-tech Farm	Oonota Co., Ltd.	Nagano
Greenleaf Shinshu Co., Ltd.	Timely Co., Ltd.	Nagano
Mama Vege Farm	ABN Co., Ltd.	Nagano
Vegetale	NICHIWA KOGYO Co., Ltd.	Nagano
	Agri-wave Co., Ltd.	Nagano
Hasami Care home	Social Welfare Corporation	Nagasaki
Huis Ten Bosch	Huis Ten Bosch Co., Ltd.	Nagasaki
Restaurant [Margherita]	Shoya Foodsystem Co., Ltd.	Nagasaki
Kintetsu Farm Hanayoshino	Kintetsu Corporation	Nara
Mahoroba Mizukoen Narasanjo	Nara Kotsu Bus Lines Co., Ltd.	Nara
	Ryoki Kogyo Co., Ltd.	Niigata
	Anzen Yasai Niigata Kojo Co., Ltd.	Niigata
	Matsudai High-tech Farm Inc.	Niigata
Yumeyasai Ozai Farm	Yumeyasai Ozai Farm Inc.	Oita
[Hinatabokko] Ajisai-Kosha	Showa Co., Ltd.	Okayama
Kyozan Solar Green Park	Ryobi Holdings	Okayama
Vege factory	Tusnetsugu Kogyo Co., Ltd.	Okayama
Yasai-Kura	Y&S Distributor Co., Ltd.	Okayama
Yume Farm Ukan Co., Ltd.	Yume Farm Ukan Co., Ltd.	Okayama
Aguri Industry	Okinawa-keisoku Co., Ltd.	Okinawa
Gushiken vegetable factory	Gushiken Co., Ltd.	Okinawa
Itoman plant factory	Internationally Local & Company	Okinawa
Kitanakagusu Degi Farm	NPO Subtropical Biomass Research Center	Okinawa
Nakagusu Degi Farm	NPO Subtropical Biomass Research Center	Okinawa
Okinawa Murakami Nouen	Okinawa Murakami Nouen Co., Ltd.	Okinawa
Okinawa type vegetable factory	Kamiya Sangyo Co., Ltd.	Okinawa
Plant factory Project	Okinawa Cellular Telephone Company	Okinawa
Ryuseki Kensetsu Plant factory	Ryuseki Kensetsu Co., Ltd.	Okinawa
Social Support Esperer	ESPERER, Inc.	Okinawa

Yasai kobo	NPO Corp Hatsuho	Okinawa
	Oogimi Farm Co., Ltd.	Okinawa
Galleria plant factory	Galleria Co., Ltd.	Osaka
Green Chateau plant Factory	Japan Greenfarm Co., Ltd.	Osaka
Subway Yasai Lavo 2nd shop	Subway Japan Inc.	Osaka
VEGEE WORK FACTORY	Fujiwork CO., Ltd.	Osaka
Yasai Lavo Grand front Osaka branch	Subway Japan Inc.	Osaka
	Hanshin Electric Railway Co., Ltd.	Osaka
	NPO Kamagasaki Shien Kiko	Osaka
	Miracle Green Co., Ltd.	Osaka
Private	Private	Private
Private	Private	Private
Acol-ku no Suisaien	Nishiken Co., Ltd.	Saga
Confirm	Ringer Hut Co., Ltd.	Saga
Smart Agri Kasasagi	Social Welfare Corporation	Saga
Yasai-kobo Ansuri Takeo	NPO Corp [Ryokufukai]	Saga
ChiChibu Midorigaoka Farm	Yasai Kobo Co., Ltd.	Saitama
High-tech Hanyu	Agricultural Producers Cooperative Corporation High-tech Hanyu	Saitama
	SHIBASAKI Co., Ltd.	Saitama
Association of Bio Business	Association of Bio Business	Shiga
Nagahama Factory		Shiga
Plant Factory in Woodypal Yogo	LOHAS Yogo CO., Ltd.	Shiga
Izumono-Shizuku	Eiko Electric Industry Co., Ltd.	Shimane
Yonago factory	Minnano-Yasai Kojo Co., Ltd.	Shimane
Fresh Green	Fresh Green, Inc.	Shizuoka
Fuji Plant Factory	Kobayashi Create Co., Ltd.	Shizuoka
Fujieda Office	Nisshinbo Holdings Inc	Shizuoka
Kakitagawa Vegetable plant factory	MITSUISHI CO., Ltd.	Shizuoka
NLM ECAL	NLM ECAL Co., Ltd.	Shizuoka
Oigawa Farm Oigawa plant	Murakami Garden Co., Pte.	Shizuoka
JA Zennoh Tochigi horticultural Seedling Centre	JA Zennoh Tochigi	Tochigi
Tonkikki	FUTABA FOODS co., ltd.	Tochigi
PF Factory Tokushima	Nisshinbo Holdings Inc.	Tokushima
	Naka Vegetable Co., Ltd.	Tokushima
	Tokushima Seedling Inc.	Tokushima
Chef-no-Noen	Jack Pot Planning Inc.	Tokyo
Green Mate Co., Ltd.	Green Mate Co., Ltd.	Tokyo
Japan Capacitor Industrial	Japan Capacitor Industrial CO. LTD	Tokyo
Keio Cultivation Institute	Keio Corporation	Tokyo
Plantptant Chef-no-Noen	Tamachi Bildg Co	Tokyo
Sci Tech Farm	Tamagawa Academy & University	Tokyo
Shimokitazawa Hospital	Shimokitazawa Hospital	Tokyo
Subway Yasai Lavo The first store	Japan Subway Co., Ltd.	Tokyo
Tokyo dream	Tokyo Dream Inc.	Tokyo
Umeshu-Dining Meisei	Leave a Nest Co., Ltd.	Tokyo
Machinaka plant factory	Tottori job creation conference	Tottori
Main Factory	HRD Co., Ltd.	Tottori
Company Owned warehouse	Fukumitsu Unyu Co., Ltd.	Toyama
Plant Factory	Takatsuki Electric Industry Co., Ltd.	Toyama
Plant Factory at Namekawa Branch	Honda Construction, Inc.	Toyama
Smile Leaf Spica	Smile Leaf Spica Co., Ltd.	Toyama

Takaoka Factory	F&F Co., Ltd.	Toyama
Twin Green Factory	Sankyo Tateyama, Inc.	Toyama
	Kensaido Co., Ltd.	Toyama
	Toagosei Co., Ltd.	Toyama
Anzen Yasai Kojo, Inc.	Anzen Yasai Kojo, Inc.	Yamagata
Fresh Factory	Yamagata-HOUTOKU Co., Ltd.	Yamagata
Saien's Lavo	Endo Shoji Co., Ltd.	Yamagata
	Natural Process Factory Co., Ltd.	Yamagata
Plantation Box	Mizuguchi-denso Co., Ltd.	Yamaguchi
	Fujikasui Kogyo Co., Ltd.	Yamaguchi
Ootoya Green Room	OOTOYA Holdings Co., Ltd.	Yamanashi
Shoun-Service	Shoun-Service co., ltd.	Yamanashi
UNIFARM	UNITECH CO., LTD.	Yamanashi
	FT Yamanashi Co., Ltd	Yamanashi
Ise saien		
(LED Noen)		
[Da Mamma]		
Private	Private	

Source: Japan Greenhouse Horticulture Association data as at 2011 (most recent available), translation by Singapore Farming / Newbean Capital

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