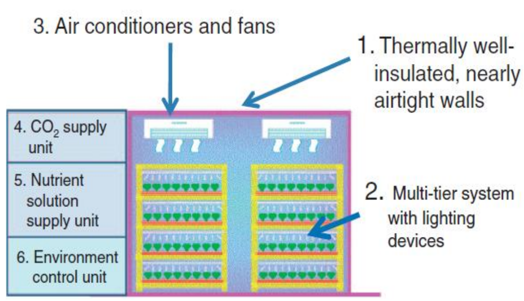
Closed Plant Production Systems (CPPS) with artificial lighting

(Indoor agriculture, Urban agriculture)

Closed Plant Production Systems (CPPS) with artificial lighting

- Thermally insulated, airtight walls → biotic factors
- Multi-tier system
- Artificial lighting (nowadays usually LEDs) → light recipe
- Climate control unit
- Cooling and air circulation system → temperature
- Dehumidifier →relative humidity
- CO_2 supply unit → CO_2 concentration
- Hydroponic system → water, nutrients
- (Air shower → biotic factors)



/Kozai, 2015/

Evaluation of CPPS - Advantages

- Complete independence from outside climatic conditions + environment control → uniform and vigorous growth
- High resource use efficiency (water, nutrients, CO_2)
- Favourable working environment for human
- High productivity per area (optimal conditions, multi-tier design, several harvests per year)
- Possibility for high level of mechanisation and automation
- Possibility for production of functional produce
- Closed environment → disease and pesticide-free produce
- Washing of the produce is not necessary; longer shelf life
- Can be built anywhere → lower transportation costs, fresher products

Evaluation of CPPS - Disadvantages

- High investment and operation costs
- Consumers' aversion (?)
- Restrictions for plants suited to CPPS:
  - short, < 25-30 cm
  - fast growth cycle – harvestable in 10-30 days after transplanting
  - at least 85% in fresh weight of the plant can be sold as produce
  - growing well under low light intensity (< 250 μmol/m^2/s) and high plant density
  - high value
  - considerably improvable quality by environment control

What cultures are grown in CPPS?

- Vegetable and ornamental transplants
- Leaf vegetables (leafy greens)
- Herbs
- Baby leafs (baby greens) and microgreens
- Medicinal plants

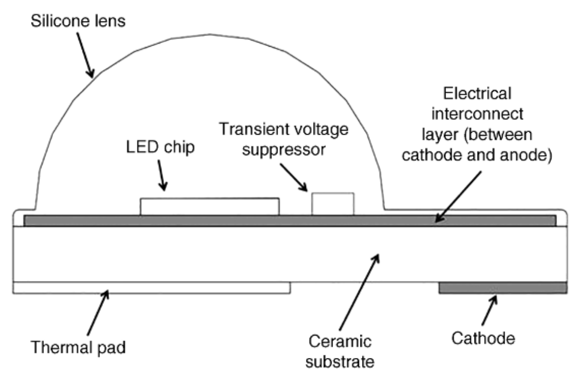
Present worldwide importance of CPPS

- In 2015:
- – USA: 15 operating farms, 35 in development
- – Asia: 453 operating farms, 73 in development; in biggest number in Japan and in Taiwan
- – Europe: it has already started in the UK, the Netherlands, etc.
- Presently a CPPS with 1-2.000 m^2 floor area is considered to be huge
- There is a niche market for premium cathegory leafy vegetables and herbs produced in CPPS

LED lighting in horticulture

Definiton and properties

- LED – Light Emitting Diodes
- illumination is produced solely by movement of electrons in a semiconductor material
- color of a specific LED is determined by the energy gap of the semiconductor used, which is based on the semiconductor chemical composition
- selectable, narrow-spectrum emission (in the range of 250-1.000 nm, with half-peak bandwidths of 25 to 50 nm)
- long life span - (?) 50,000 h of operation
- cool photon-emitting surface (LEDs do not radiate heat directly in the light beam)
- (first tested for plant production in the early 1990's)



/Mitchell et al., 2015/

Evaluation of LEDs - advantages

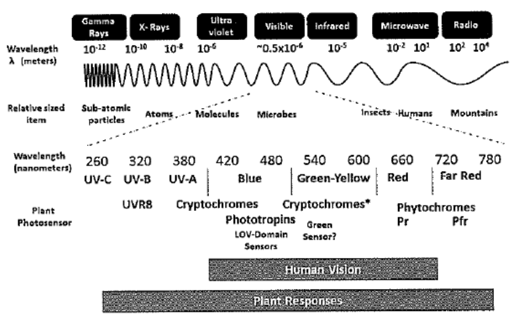
- Improved energy use efficiency – lower operation cost
- Increases in photosynthetic efficiency by matching wavelengths to chlorophyll absorption peaks
- Ability to operate closer to the plant tissues due to their low radiant heat output (thereby reducing power use)
- Control protocols can be used to optimize energy consumption; better light intensity control
- Improving nutritional and health attributes of horticultural products by using specific wavelength combinations
- LED spectral blends can be developed to accomplish specific photomorphogenic goals, and possibly improved yield and produce quality

Evaluation of LEDs - disadvantages

- Currently high hardware costs
- LEDs operate most effectively using direct current (DC)
- Light-emitting diodes also generate heat (just in a different manner)
- LED efficiency is actually less than other light sources; improvements in power efficiency is due to unique configurations and operating protocols allowed by the special characteristics of LED

Main fields for usage of LEDs in horticulture

- Precise control of flowering and product quality for the floriculture industry.
- Providing light for ornamental and vegetable transplants - can be both supplemental and sole-source lightings
- Supplemental lighting of high-wire greenhouse vegetable crops for all-year production – overhead lighting, intracanopy lighting (vertical or horizontal)
- Sole-source lighting for production of rapid-turning vegetables and herbs – overhead distributed source



/Folta & Carvalho, 2015/

Wavebands of interest

- **Red** (625-660 nm) – indispensible, absorption peak for chlorophylls and phytochromes, highest relative quantum efficiency
- **Blue** (450-470) - absorption peak for chlorophylls, increases phytonutrient content, promotes antocyanin synthesis, blue light responses are species specific, requires more energy
- **Green** (520-540) – better foliar penetration, role in synthesis of some phytonutrients,
- **IR** (730-735) – phytochrome absorption peak, increases leaf size, results in elongation, decreases phytonutrient content
- **UV** (365-400) – promotes phytonutrient synthesis