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# Critical Elements of CEA Economics

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## Overview of VF/CEA Profitability Analysis: Profit Scenarios Based on Japanese Plant Factory

- **FOCUS ON PROFITABILITY**
  - Publicly available sources focus on VF/CEA cost analyses and not profitability analyses
    - Little sharing of economic information due to strategic confidentiality
    - Highly diverse and unique growing systems
  - Simple profit analysis: Return on Investment (ROI) based on Earnings before Interest and Taxes (EBIT)
  - Applied to a publicly available economic data set for a Japanese Smart Plant Factory
  - Track ROI changes across scenarios that vary system elements
  - Brief comparison to a Model European VF
- **Scenarios based on "what if"**
  - Built using logically consistent but simplifying assumptions (spreadsheet model).
  - Results show potential changes in profitability if assumed circumstances can be realized.
- **Overview of Scenarios**
  - Base Case: ROI of model Japanese Plant Factory
  - Scenarios 1 & 2 vary the scale (1/2 x and 2 x)
  - Scenarios 3-7 vary elements of growth cycle, equipment cost, salable biomass, and lighting consumption
  - Scenario 8: Alternative crop
  - Scenario 9: Decrease an otherwise high premium selling price

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## Description of Japanese Plant Factory

- **Citation of source**
  - T. Kozai (ed), Smart Plant Factory, Springer, Singapore, 2018
  - Chapter 6, Kaz Uraisami author
  - Approved model by the Japanese Plant Factory Association
- **Production parameters**
  - Ideal product: 90-gram head (stock) of specialty lettuce packaged for retail sale
  - Growth cycle of 38 days progressing through 4 stages of growth
  - Rented building; Owned equipment depreciated over approximately 7-year life.
  - Continuous daily planting and harvesting (360 days/year)
  - Basic structure of growing system: 241 racks with 6 vertical levels
  - LED lighting system designed to deliver 100 µmol/s/m2
  - Hydroponic delivery of water and nutrients

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## Returns to Scale

**Base Scenario**
- EBIT = Earnings Before Interest & Tax
- ROI = Return on Investment
  - EBIT/equipment cost (simplistic)
- Modest profitability: **ROI = 1.78%**
  - **US target for ROI: 20% or more**

**Scenario 1**
- ½ scale
- EBIT and ROI go negative
- Fixed costs don't fall in proportion

**Scenario 2**
- 2 x scale
- EBIT and ROI rise due to fixed cost leverage
- **ROI (5.82%)** improved but still modest

| Scenarios based on the Japanese Smart Plant Factory Model | Base Scenario | Scenario 1 1/2 scale | Scenario 2 2 x scale |
|---|---|---|---|
| stocks planted/day | 5,000 | 2,500 | 10,000 |
| packs sold (90g)/day | 3,600 | 1,800 | 7,200 |
| price/kg | $12.00 | $12.00 | $12.00 |
| Annual revenue* | $1,400 | $700 | $2,799 |
| Annual variable cost* | $611 | $316 | $1,199 |
| Annual fixed cost* | $750 | $453 | $1,343 |
| EBIT* | $39 | -$70 | $257 |
| equipment cost* | $2,208 | $1,104 | $4,416 |
| crop space m2 | 2,168 | 1,084 | 4,336 |
| facility size m2 | 997 | 587 | 1,817 |
| ROI (based on EBIT) | 1.78% | -6.31% | 5.82% |
| Change in ROI | | -8.09% | 4.04% |
| Number of employees | 9 | 5 | 17 |
| Growth cycle (days) | 38 | 38 | 38 |
| salable bio kg/m2/yr | 53.8 | 53.8 | 53.8 |

*Thousand $

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Note: Scenarios are built using logically consistent but simplifying assumptions. Scenario results show potential changes in profitability if assumed circumstances can be realized.

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## Returns to Changing System Components

**Scenario 3**
- 34 vs 38 days
- Increase plantings
- How?
- Modest ROI boost

**Scenario 4**
- Cut capital cost
- Modest ROI boost

**Scenario 5**
- Increase salable biomass
- Only revenue boost shown
- How & at what cost?
- Significant ROI boost

**Scenario 6**
- Lighting efficiency
- Same light, less kWh
- Modest ROI boost

**Scenario 7**
- Do it all (Scenarios 3-6)
- **28.71% > ROI target!**

| Scenarios based on the Japanese Smart Plant Factory Model | Base Scenario | Scenario 3 Reduce growth cycle by 4 days | Scenario 4 Reduce equipment cost 20% | Scenario 5 Increase salable biomass by 20% | Scenario 6 Decrease lighting kWh by 20% | Scenario 7 Combine Scenarios 3, 4, 5, & 6 |
|---|---|---|---|---|---|---|
| stocks planted/day | 5,000 | 5,600 | 5,000 | 5,000 | 5,000 | 5,600 |
| packs sold (90g)/day | 3,600 | 4,032 | 3,600 | 3,600 | 3,600 | 4,032 |
| price/kg | $12.00 | $12.00 | $12.00 | $12.00 | $12.00 | $12.00 |
| Annual revenue* | $1,400 | $1,568 | $1,400 | $1,680 | $1,400 | $1,881 |
| Annual variable cost* | $611 | $682 | $611 | $611 | $582 | $650 |
| Annual fixed cost* | $750 | $779 | $691 | $750 | $750 | $720 |
| EBIT* | $39 | $106 | $98 | $319 | $68 | $511 |
| equipment cost* | $2,208 | $2,225 | $1,766 | $2,208 | $2,208 | $1,780 |
| crop space m2 | 2,168 | 2,184 | 2,168 | 2,168 | 2,168 | 2184 |
| facility size m2 | 997 | 1,003 | 997 | 997 | 997 | 1003 |
| ROI (based on EBIT) | 1.78% | 4.78% | 5.55% | 14.45% | 3.06% | 28.71% |
| Change in ROI | | 3.00% | 3.78% | 12.68% | 1.28% | 26.93% |
| Number of employees | 9 | 10 | 9 | 9 | 9 | 10 |
| Growth cycle (days) | 38 | 34 | 38 | 38 | 38 | 34 |
| salable bio kg/m2/yr | 53.8 | 59.8 | 53.8 | 64.6 | 53.8 | 71.8 |

*Thousand $

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## Two More Scenarios as Food for Thought

**Scenario 8**
- Specializing the crop
  - 4 growth stages vs 1
  - 38 days vs 21
- Hits the ROI target
  - Caution about simplifying assumptions

**Scenario 9**
- Output price drives profitability
  - Scenario price change: $12/kg vs $9.60
    - Scenario 7 reduced to under 8% ROI
  - $12/kg = $5.45/lb.
    - US commodity lettuce $1.00/lb. (ws)
    - Implied 445% price premium
- VF product's bundle of attributes must justify premium price
- Too much focus on cost reduction vs enhanced attribute value is a critical profitability concern.

| Scenarios based on the Japanese Smart Plant Factory Model | Base Scenario | Scenario 7 Combine Scenarios 3, 4, 5, & 6 | Scenario 8 Crop with 1 growth stage of 21 day | Scenario 9 Decrease price by 20% |
|---|---|---|---|---|
| stocks planted/day | 5,000 | 5,600 | 8,500 | 5,000 |
| packs sold (90g)/day | 3,600 | 4,032 | 6,120 | 3,600 |
| price/kg | $12.00 | $12.00 | $12.00 | $9.60 |
| Annual revenue* | $1,400 | $1,881 | $2,379 | $1,120 |
| Annual variable cost* | $611 | $650 | $1,031 | $611 |
| Annual fixed cost* | $750 | $720 | $904 | $750 |
| EBIT* | $39 | $511 | $444 | -$241 |
| equipment cost* | $2,208 | $1,780 | $2,209 | $2,208 |
| crop space m2 | 2,168 | 2184 | 2,169 | 2,168 |
| facility size m2 | 997 | 1003 | 997 | 997 |
| ROI (based on EBIT) | 1.78% | 28.71% | 20.09% | -10.90% |
| Change in ROI | | 26.93% | 18.32% | -12.68% |
| Number of employees | 9 | 10 | 15 | 9 |
| Growth cycle (days) | 38 | 34 | 21 | 38 |
| salable bio kg/m2/yr | 53.8 | 71.8 | 91.4 | 53.8 |

*Thousand $

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## The European Perspective: VF 2.0

- **Source**
  - Zeidler, C., Schubert, D., Vrakking, V., 2017 "Vertical Farm 2.0: Designing an Economically Feasible Vertical Farm - A combined European Endeavor for Sustainable Urban Agriculture" Technical report, Association for Vertical Farming.
- **Production Parameters**
  - Indoor cultivation using hydroponics and artificial light
  - Overall Building footprint: 2,625 m2, with a Production area of 2,222.5 m2
  - The building has 5 modules (floors), 2 producing lettuce, 2 producing tomatoes and 1 Core ground floor
  - 5 racks (50 x 5 x 5m), each divided in 4 levels = 5,000 m2 growing area
  - Producing Salanova lettuce, with a 48-day seed to harvest life cycle
  - A total of 8,076 heads (200g) harvested per day, the equivalent to 1,615.2 kg/day of salable mass
  - Power consumption in light systems and air management (lettuce) = 97% of energy demand (7 mi kWh)
  - Total investment was €36 mi or approx. US$42 mi, giving an annual amortized investment cost of €1.8 mi/year (30 yrs, approx. 3% disc. rate).

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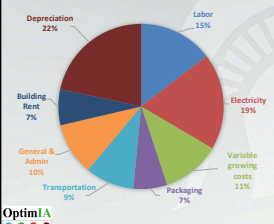
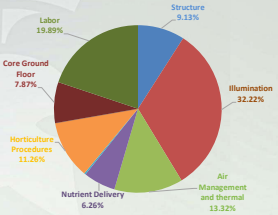
PERCENT OF TOTAL COST (JP)




PERCENTAGE OF TOTAL COST (EU)

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## Economic comparison

- European vs Japanese
  - Roughly 2x scale
  - 5x kgs sold/day
  - 2x revenue
  - Dramatically different product, technology design and cultivation procedures
- Profit and Price
  - *European model only projected breakeven price*
  - 165% price premium vs. normal market price in Europe
  - 250% price premium vs. US commodity price
  - Recall Japanese price having 450% price premium vs US

| Comparing Scenarios | Japanese Base Scenario | European Base Scenario** | American Base Scenario |
|---|---|---|---|
| Harvest stocks/day | 4,500 | 8,076 | ? |
| Total kg sold/day | 324 | 1,615 | ? |
| price/kg | $ 12 | $ 7.67 | ? |
| Annual revenue* | $ 1,400 | $ 3,109 | ? |
| Annual variable cost* | $ 611 | $ 2,393 | ? |
| Annual fixed cost* | $ 750 | $ 716 | ? |
| EBIT* | $ 39 | $ - | ? |
| equipment cost* | $ 2,208 | $ 3,985 | ? |
| crop space m2 | 2,168 | 5,000 | ? |
| facility size m2 | 997 | 2,625 | ? |
| ROI (based on EBIT) | 1.78% | 0% | ? |
| Number of employees | 9 | 4 | ? |
| Growth cycle (days) | 38 | 48 | ? |
| salable bio kg/m2/yr | 53.8 | 117 | ? |

*Thousand $ **EU model based on 1 lettuce module

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## What is learned from the Profit Scenarios?

- **Achieving economic feasibility** for individual companies and for the industry **requires non-marginal innovation in all aspects of VF/CEA systems**.
  - *20% changes* were used to generate various scenarios.
  - Requires multiple changes to significantly move profitability
- **Premium price is essential** to economic feasibility
  - Innovating pieces of the system must not only drive down cost but maintain or enhance product attributes that buyers will pay for.
  - Revenue impacts from innovation are as critical as cost impacts.
- **More VF/CEA models to understand and test are needed.**
  - How sensitive is each model is to changes in its components, both cost and revenue?
    - What are the tradeoffs in different mixes of inputs?
    - What are the tradeoffs in cost and in revenue generation from product attributes?
    - What are the tradeoffs between labor and capital? *(not addressed in the scenarios)*
  - What are the benchmarks for profitability and its components?
  - Some means of sharing info across the industry is critical to answering these questions.

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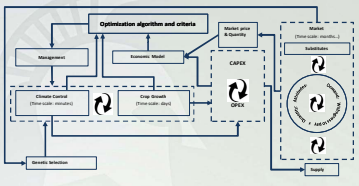
## How does this connect with our Profit Optimizing Model

- The accompanying figure presents the full optimization model representation.
- In the absence of data that informs about costs associated with factors and stages of production, we have been utilizing the Japanese and European models to build the structure behind the optimization model.
- That includes Fixed and Variable Factors of Production.
- The next steps are to adjust these values to a USA scenario and include results from our planned consumer survey work.

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