Controlled Environment Agriculture for year-round vegetables: Production systems, costs, and potential crop yield

Neil Mattson
School of Integrative Plant Science
nsm47@cornell.edu 607-255-0621

Cornell University
College of Agriculture and Life Sciences

What is Controlled Environment Agriculture?

An innovative method of growing plants that involves creating optimized aerial and root zone environments, focusing on production benefits such as:

- *high plant quality*
- *predictable crop timing*
- *consistently available quantity, and limited environmental impact*

High Tunnels
Modified Environment Agriculture

Controlled Environment Agriculture

Why CEA?

- Fresh, high-quality produce, free of pesticides
- Locally grown
- Year-round
- Water – *can* be 20 times more efficient than field production
- Space efficient
  - Ex: Lettuce 20-50x field production

U.S. Food Crops Grown Under Protection

Crop	Production (tons)	Hydroponic production (tons)	Value ($million)
Total	260,966	165,557	796
Cucumbers	36,310	33,101	78
Herbs (cut fresh)	17,761	3,811	71
Lettuce	10,965	7,719	56
Peppers	3,851		6
Strawberries	353		1
Tomatoes	96,265	82,797	401
Other	95,461	36,791	184

USDA 2014 Census of Horticultural Specialties

New York State Greenhouse Vegetables

	2012	2007
Production Operations	435	201
Wholesale Value (millions)	27.4	17.7
Acres of greenhouses	114	69

Growth in greenhouse vegetables, 54% increase in value in 5 years

Ranks 2nd in U.S. for greenhouse vegetables

USDA NASS, Census of Agriculture

CEA Crops and Systems

- Leafy greens/herbs
  - Lettuce, kale, pak choi, baby leaf greens, basil
  - Systems
    - Deep water culture (raft/pond)
    - Nutrient film technique (channels)
- Vine crops
  - Tomatoes, cucumbers, pepper, egg plant
  - Systems:
    - Rockwool or coconut coir slabs
    - Bato buckets / Dutch buckets (with perlite/expanded clay)
    - Bag culture (with potting mix)

Deep water culture


Nutrient Film
Technique

High Wire Production

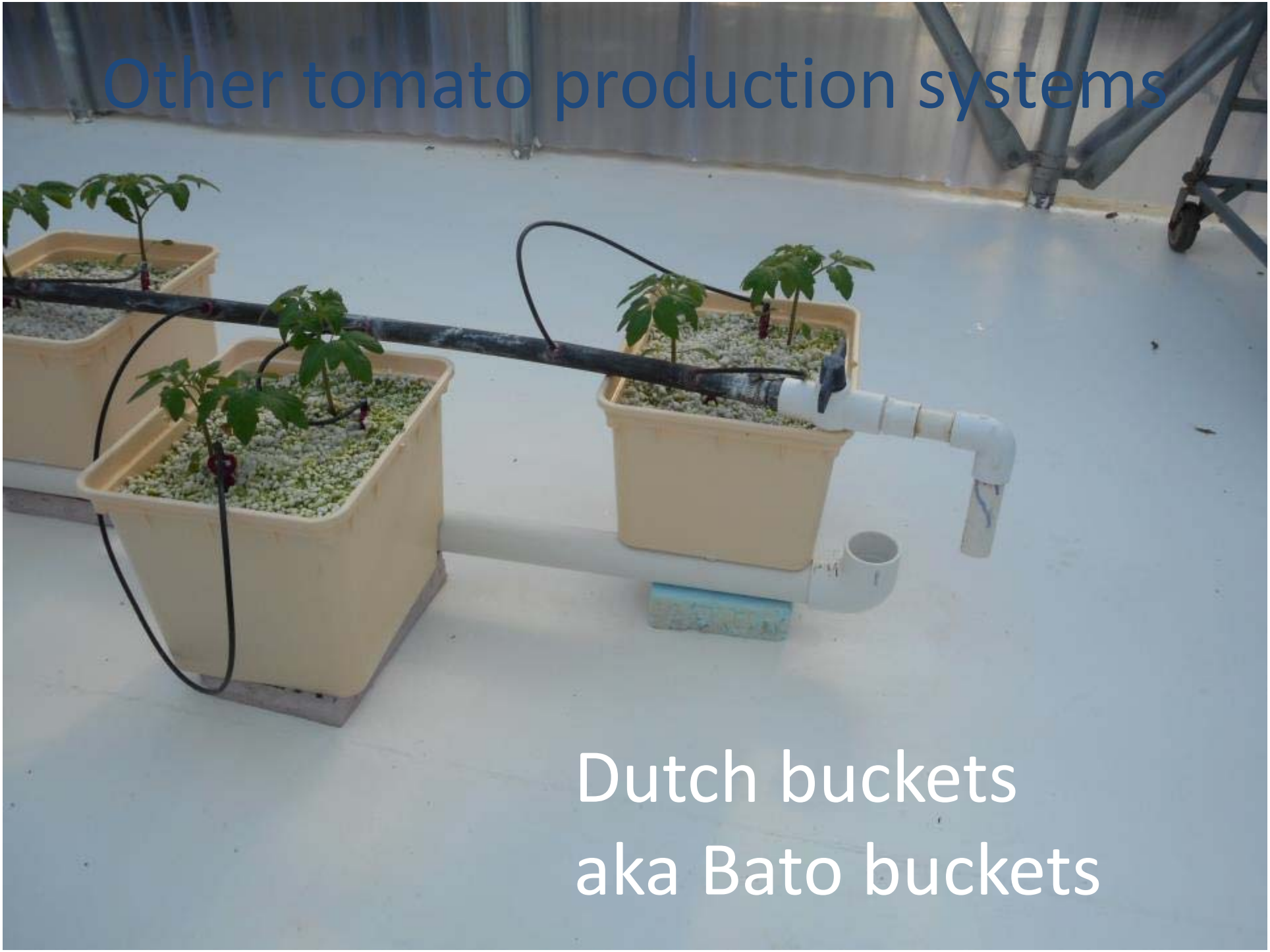
- Wire supports the vine
- Gutter height of greenhouse 18-21 ft (6-7 m)
- Drip irrigation
- Rockwool/Coir slabs
  - Small roots for large plant, frequent irrigation
- Plants growing in tall canopy sometimes >10 feet
- Double row system


Delta
grodan
Delta
grodan
Delta
grodan
Delta
grodan


15 8 2003

Coconut Coir
(alternative to rockwool)

Other tomato production systems

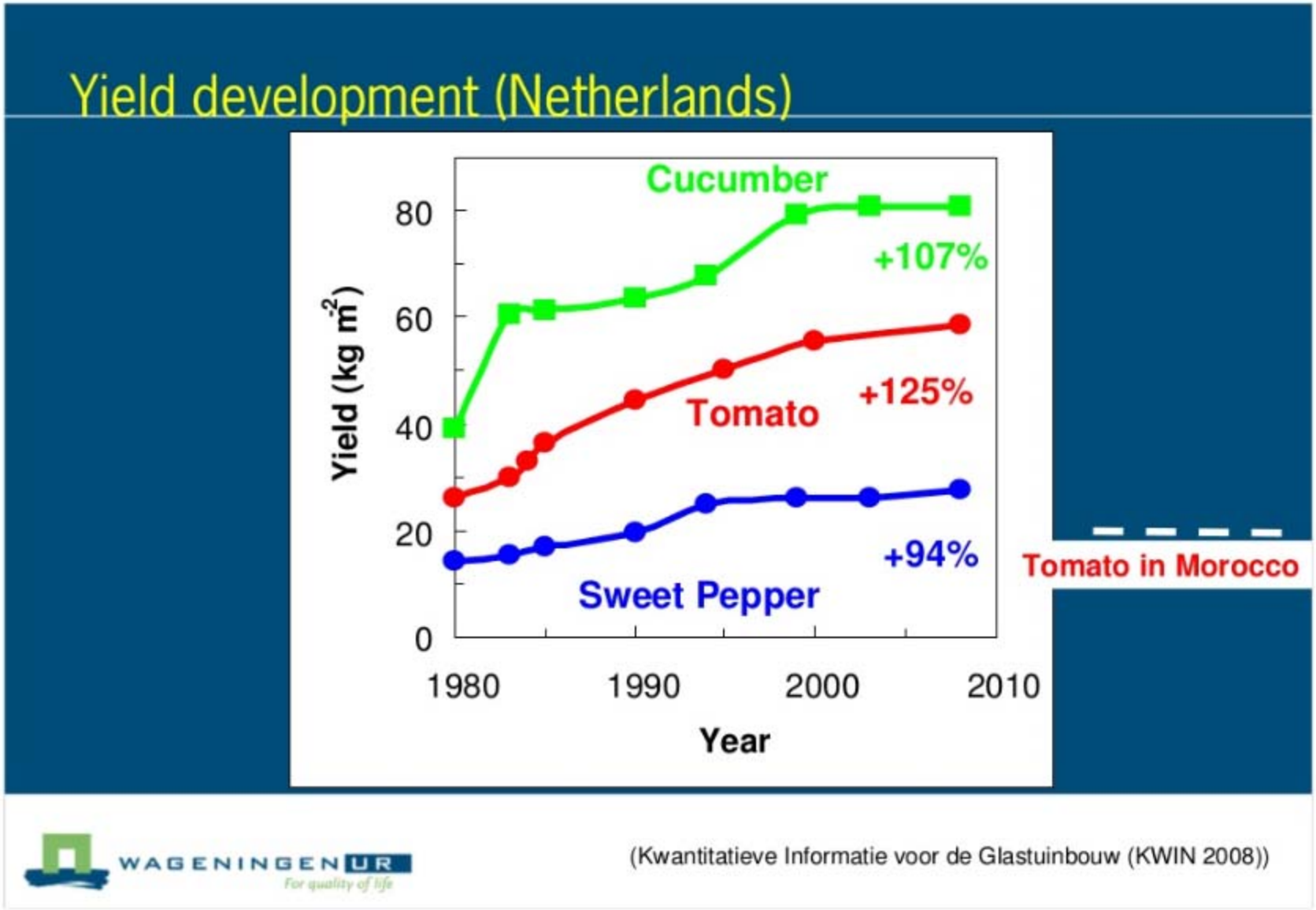


Dutch buckets
aka Bato buckets

Tomatoes in Bag Culture

CEA site selection – ideal site:

- <5% slope (flatter land is easier to clear and develop)
- and with good soil drainage - bedrock not too close to the surface
- areas with 40+ contiguous acres of clear land
  - Zoning, limited shading, (actual acres vary according to plan)
- access to an aquifer or municipal water of sufficient capacity
- road suitable for large trucks
- access to three-phase power of sufficient quantity
- access to natural gas
- limited winter wind exposure (not on a hill top)



- Dutch greenhouse yields
- Source: Ep Heuvelink, 2009

Optimum yields in CEA

Crop	lbs / square ft / yr	lbs / acre / yr
Lettuce	23	1,000,000
Cucumber	16	697,000
Tomato	12	523,000
Sweet pepper	6	261,000

Example 1 acre CEA Lettuce*

Construction cost	$1 Million
Annual Energy cost	$125,000
Employment	7
Yield	up to 1 million pounds
Gross revenue	$1-3 million

*CEA Technology is scalable to any size farm

Barriers to CEA in NYS

1. Securing **financing** for capital intensive business with low margins
   - Realistic business models (cost/revenue)
2. Availability of skilled and unskilled **labor**
3. Need processing and marketing infrastructure (**food hubs**)
4. Relatively expensive **electricity** (high energy costs)

Business tools to stimulate growth of NYS's year-round greenhouse vegetable industry

- NYS Dept. of Ag and Markets Specialty Crop Block Grant
- 2-year project Dec. 2016-2017
- Consumer willingness to pay for in-state produce
- Cost accounting tools
- 2-day entrepreneur workshop Fall 2017

Developing Interactive Cost Spreadsheet

Irin Nishi, Miguel Gomez

- Direct costs (or variable costs or operating expenses)
  1) Labor
  2) Energy
  3) Inputs (seeds, fertilizer, packaging)
- Fixed costs (or overhead costs)

  1) Greenhouse structure & environmental controls ($30-50 / sf)

  2) Hydroponic systems, lights

  3) Equipment (seeding, harvesting, refrigeration)

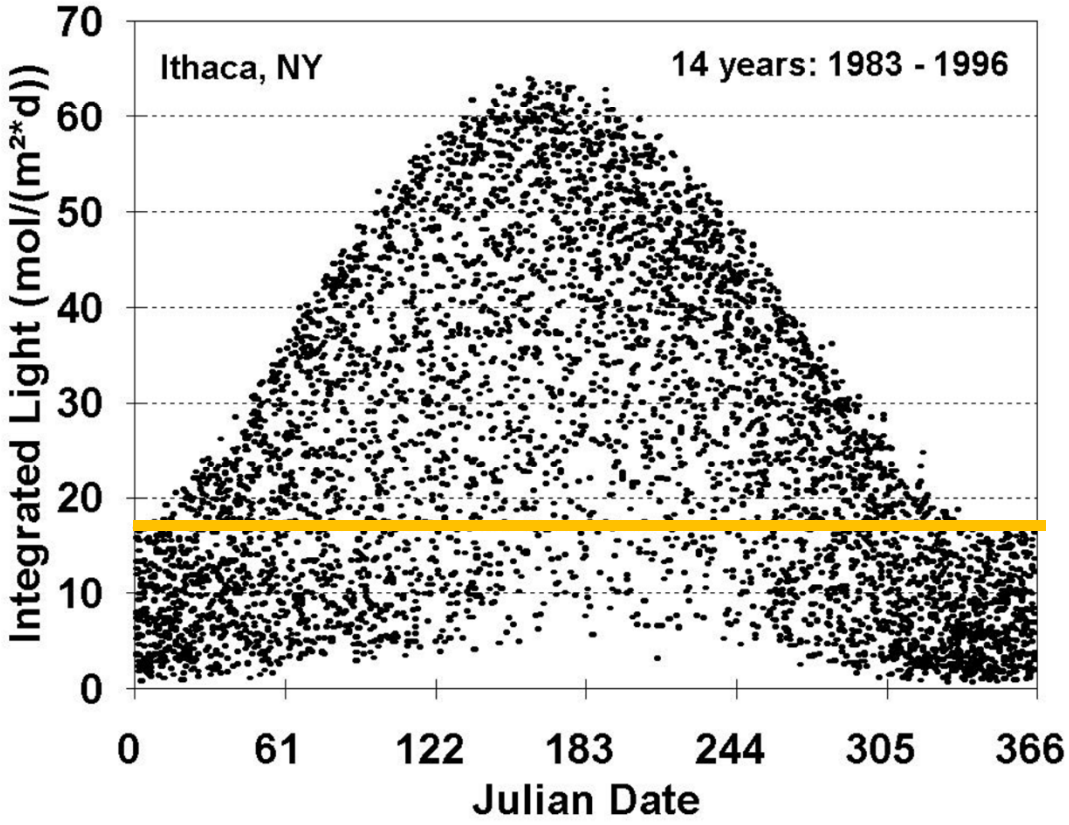
Light is key for year-round production

Without added light

- 105 days to harvest (winter)
- $0 / sf to light

With added light

- 35 days to harvest (year-round)
- $6 / sf to light



Focus on Energy

2nd largest production input (after labor)

CARBON FOOTPRINT

Imported to NY

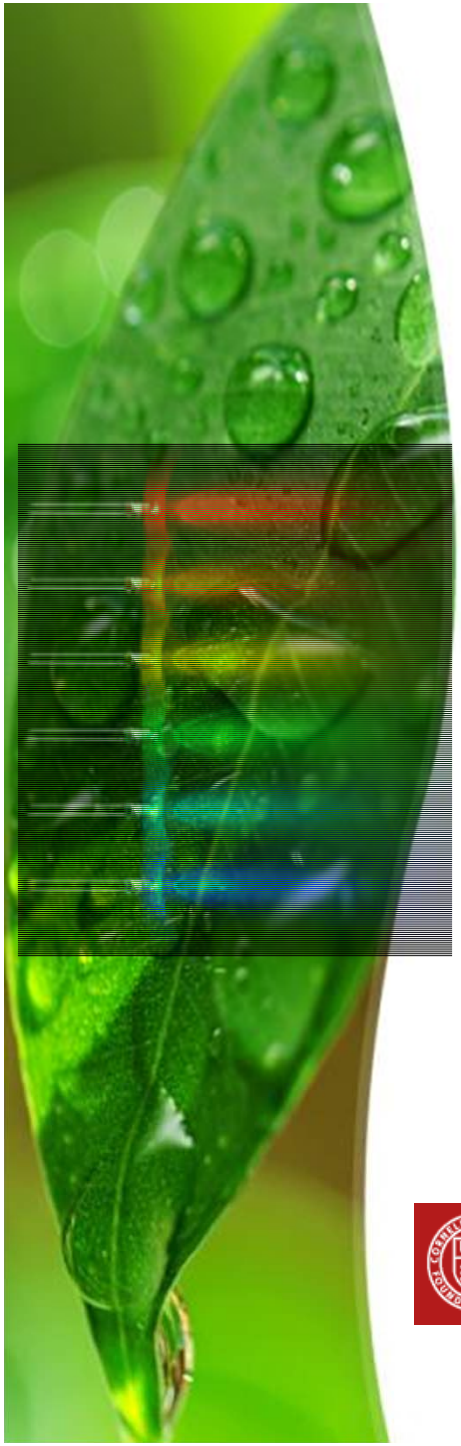
Transport 2,963 miles

0.7 lbs CO_2/lb lettuce

Locally Grown

Central NY light/heat

2.0 lbs CO_2/lb lettuce



Greenhouse Lighting and Systems Engineering (GLASE)

Advances possible:

- Dynamic greenhouse control of light and CO_2
  - CO_2 reduces need for electric light by 50%
- Efficacy of light delivery
  - Improvements in diode efficiency (50%)
  - Better thermal management and optics - direct light where needed (15%)

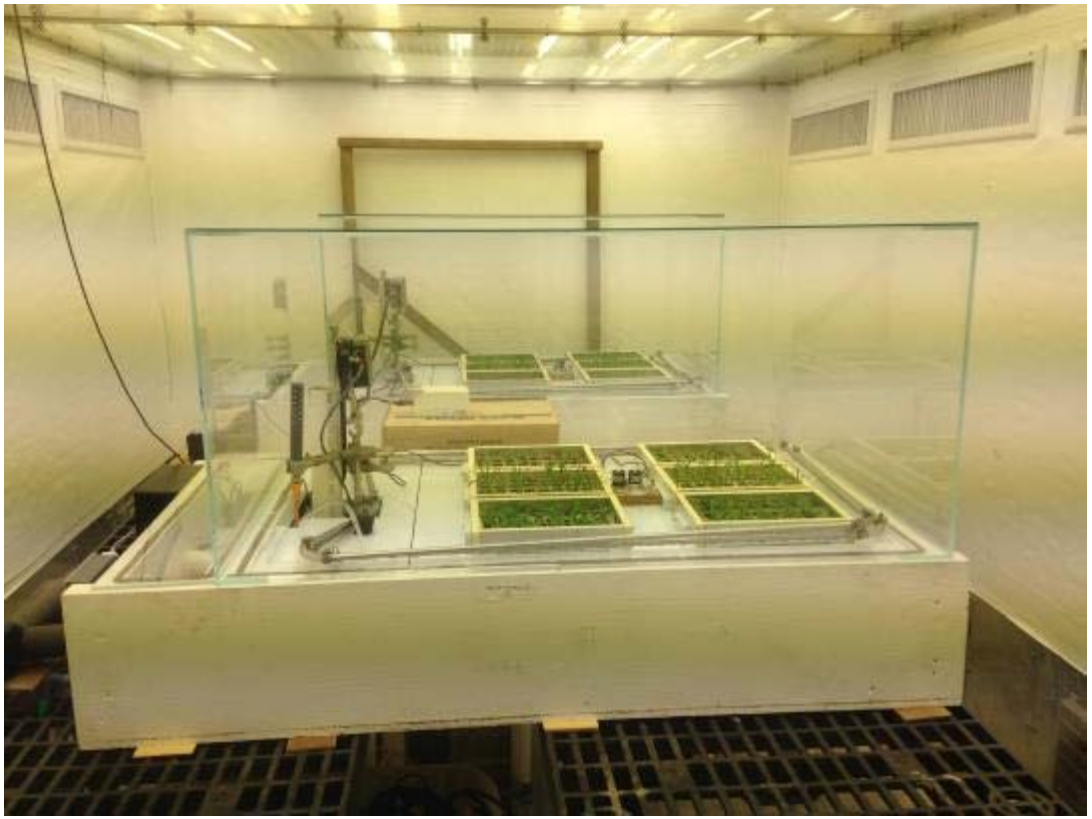
Cornell University
College of Agriculture and Life Sciences

Mattson & Albright

Rensselaer

Tessa Pocock

CO_2 enrichment of baby leaf arugula, spinach, lettuce



Cornell University
College of Agriculture and Life Sciences

Focus on Energy

2nd largest production input (after labor)

CARBON FOOTPRINT

Imported to NY

Transport 2,963 miles

0.7 lbs CO_2/lb lettuce

Locally Grown

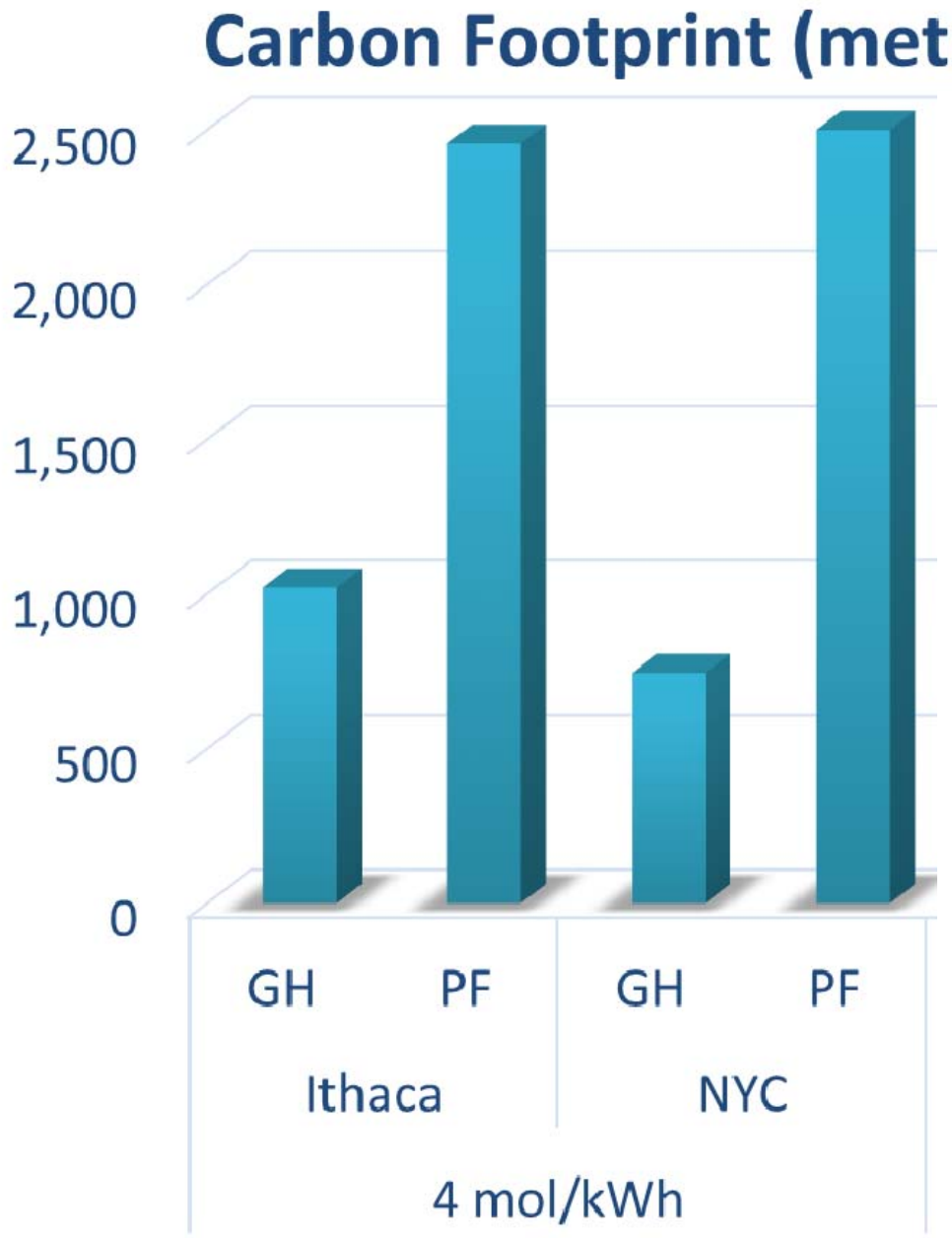
Central NY light/heat

2.0 lbs CO_2/lb lettuce

Advances in

- Lighting
- Reducing heat loss
- Greenhouse control

0.6 lbs CO_2/lb lettuce



Are warehouse / vertical farms a viable alternative to CEA greenhouses?

Natural Gas: 45 kg CO_2 / GJ Electricity NYS Average: 97 kg CO_2 / GJ Harbick and Albright

Printed in the February, 2015 edition of InsideGrower

Top Misconceptions About CEA

Thinking about getting into hydroponic growing or expanding your current business? You need to read this first.

by **NEIL S. MATTSON, LOUIS D. ALBRIGHT, DAVID DE VILLIERS, MELISSA BRECHNER & ROBERT LANGHANS**

Controlled environment agriculture (CEA) uses advanced horticultural and engineering techniques to optimize crop production, quality and production efficiency. A controlled environment allows crop production year-round in regions where they would otherwise be impossible. With today's consumers increasingly demanding a diet that includes fresh, high-quality vegetables, CEA production systems have seen increased attention by both traditional growers and entrepreneurs alike. While CEA greenhouses can supply a tremendous quantity of produce,

"Anything that can go wrong, will go wrong."
MURPHY'S LAW

"Murphy was an optimist."
BASIC LAW OF CEA

considering beginning or expanding your own CEA operation.

Production misconceptions

We will have full production

spite your best intentions to exclude insects and disease, there will always be insect and disease problems. Some will be persistent and some new issues will show up every year.

Some of the more common problems we've noticed include Pythium root rot, powdery mildew, aphids and thrips. A talented grower will always be on the lookout. Assume there can be a problem at any

seed. Shading is important because lettuce plants develop leaf tip burn when DLI is higher than 17 moles. (Assuming vertical airflow fans [VAF] are operated. Without VAF, the limit is 12 moles. See Figure 2.)

At lower DLI, plants take longer to reach harvestable yield. In Ithaca (one of the cloudiest places in the contiguous 48-states), we provide 30% of the plant's light needs from supplemental light when averaged across the year. Our lighting cost is expensive—about $12 per sq. ft./year. But if we didn't supply it, yields would be markedly lower.

Top misconceptions - production

- Full production from the start
  - Lou's adage: "have sufficient cash flow to account for no crop production in first year and half of optimal in second year"
- No insect or disease problems
- Don't understand the interacting biological systems (plants, pests, bacteria in solution)
- "It is all science, protocols"
- Light amount plants are receiving – human perception vs. PAR received (spindly plant)
- Nutrition
- Seasons!!

Marketing

- Everything that is grown will be sold (marketing)
- Exist with one customer (believe the produce mgr)
- Customers will be loyal
- Customers will understand if crop fails
- Under estimate input costs, over estimate price market will pay
- Label organic if use organic components in hydroponics

Labor

- Labor will be there
- Experienced Head growers/greenhouse managers are waiting to be hired
- No weekends / holidays

Thank you!

Cornell University
College of Agriculture and Life Sciences

nsm47@cornell.edu