"New products and innovations in greenhouse engineering”

Presented by

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Controlled Environment Plant Production Systems
Greenhouse Crop Production

The issues are:
energy,
water,
labor,
product quality
[marketing],
food safety
and
to make a profit
Controlled Environment Plant Production Systems
Greenhouse Crop Production

The issues are:
- energy,
- water,
- labor,
- product quality [marketing],
- food safety
- and to make a profit

Requirements/Limiting Factors

Education / Understanding
Intelligence - IT, sensors, telepresence
Resource [re-]utilization (energy, water, elements)
Design / Planning for current & future needs
Market Development
Social/Economic acceptance
Controlled Environment Plant Production Systems
Greenhouse Crop Production

Controlled Environment is defined as an integrated science- and engineering-based approach to provide specific, controlled and repeatable environments for plant productivity, while optimizing resources, including water, energy, space, labor and capital.

CE systems will produce any plant, any where, at any time
Controlled Environment Plant Production Systems

Greenhouse Crop Production

Require:

**engineering and horticulture knowledge** for technical success, and;

**experienced and educated labor** for production success, and;

**marketing and sales** for economic success
Controlled Environment Plant Production Systems
Greenhouse Crop Production

Where has the industry evolved from?
Where is it going?

Innovations from 20th Century
focused on resource conservation

Innovations of 21st Century
will focus on resource re-utilization, and resource generation
Controlled Environment Plant Production Systems
Greenhouse Crop Production

Innovations from 20th Century focused on resource conservation

Multi-layer glazing – rigid plastics; double-poly film
Filter glazing – thermal long-wave radiation
Energy screens – movable
Microenvironment control – root zone heating
Drip irrigation & Hydroponics – precision fertigation
Automated control – non-interactive
Information – potential with computerization

Strategy was to invest in hardware/control systems to improve efficiency
Controlled Environment Plant Production Systems
Greenhouse Crop Production

Innovations from 20th Century focused on resource conservation

Summary of North American research and application experiences in NRAES publication at Cornell University:

“Greenhouse Engineering”
Innovations of 21st Century will focus on resource re-utilization, and resource generation

Recirculating hydroponics – nutrient solution
Integrated resource systems – cogeneration; biofuels; local resource recovery & use
Recirculating atmosphere – “closed” greenhouse systems for CO2 & water vapor condensate
Non-greenhouse controlled environment systems – growth rooms; vertical farms [buildings]
Resolving Global Issues with Controlled Environment Plant Production Systems

CE plant-based systems will help:

- Agricultural Food Production
- Bio-Regenerative Life Support
- Bio-Remediation of Atmosphere and Waters
- Transportation Fuel Production
- Electrical Power Generation
- Telepresence
- Human Quality Of Life Improvements
- Phytochemicals for Health/Life
- Urban Agriculture
- Why Controlled Environment Agriculture?
- About CEAC
Commercial CEA Hydroponic Food Production

Houweling Nurseries

Canadian greenhouse vegetable grower in Camarillo, California

“Closed” Greenhouse Energy from PV Water re-capture Heat storage
Houweling Nurseries

Canadian greenhouse vegetable grower in Camarillo, California

“Closed” Greenhouse Energy from PV
Water re-capture Heat storage

2 structures of 8 ha each
8 m to gutter
Positive pressure
Glass with energy screen
Hot water storage
2M gallon storage tanks
22 – 45oC water storage
2100 + 700 Ton chillers
Cool irrigation water
4% vent area of Venlo Ultrafiltration + ozone water purification
Private company
500 employees
Certified GH Tomatoes
California leading growth in nation's green jobs economy, study finds

http://www.latimes.com/business/la-fi-green-jobs11-2009jun11,0,3978144.story
LA Times June 11, 2009

7000 solar collectors (1.6 m² ea = 1.2 ha in 1.6 ha field]. (3.5 x 5 ft², 122,500 ft²)
Provides 50% demand; Provides 1.5 million kW-h per year.
Beneath the collector field is a 2 m deep water storage pond
Modern Greenhouse Systems
Glass covered structures use natural ventilation and fan & pad evaporative cooling, and heating and CO2 enrichment with natural gas for computerized environmental control. (40 acre, shown below)

Computer control
Intensive plant monitoring
Real-Time Data for decision support
Energy conservation
Alternative energy
Labor management
Market development
Resource recycling
Optimizing plant environment

Eurofresh Farms, Willcox, AZ
High Tunnel Technology

Basic greenhouse farming
Success from experience
Very adaptable
Very popular now

Photo source http://plasticulture.cas.psu.edu/
Urban Agricultural Food Factory

Tucson, Arizona “Vertical Farm”
“Vertical Farm”

Technically possible

Far from economic except under extreme conditions

South Pole Food Growth Chamber

Modular hydroponic plant production
25 kg/week of fresh vegetables

~ 1 kg/ m² / week
~ 52 kg/ m² / year (polyculture)

Lettuce
Herbs
Tomato

Operations Cost:
100 US$ per kg of fresh vegetables

Cantaloupe
UA-CEAC South Pole Food Growth Chamber
Provides fresh salad crops for the isolated south pole
Hydroponic controlled environment food production
and attitude adjustment room

Harvest: 65 - 100 pound per week
Area: 240 square feet

South Pole Station

Extreme Locations
The New South Pole Green House Lounge

Open 16 hours a day.
So bring your beverage invite your friends call your family and
Feel the Green!

Featuring:
Phone and Internet Access
Aquaponics
Aquaculture + Hydroponics

Tilapia Fish + Lettuce
The nanotube sheets combine high transparency with high electronic conductivity, in highly flexible large surface areas for solar cells for light harvesting.

Carbon nanotubes are like minute bits of string. Strength to weight property of nanotube sheets exceeds the strongest steel. A square kilometer of solar sail would weigh 30 kilograms.

Aug. 19, 2005 issue of Science reported assembly of nanotubes into sheets at commercially useable rates.
How to reach our new Controlled Environment plant-based systems society?

What do we need?

Inexpensive climate controllers
  - wireless sensors; wireless Internet access; telepresence
High efficiency energy transfer plant photosynthesis
  - direct wiring?
Low-cost solar photovoltaic power
  “Tunable” glazing transmission
    - for shading; for light quality control
Improved co-generation designs
How to reach our new Controlled Environment plant-based systems society?

What do we need?

Study of thermodynamics for all investors
- reduce break laws of physics;
- understand energy transfer efficiency

Education and Experience

Infinite storage and deep cycle battery “Cloud Eraser” machine (D. Mears)
### Controlled Environment Plant Production Systems

**Greenhouse Crop Production**

<table>
<thead>
<tr>
<th>Maximum in GH</th>
<th>Average in GH</th>
</tr>
</thead>
</table>
| Given 0.278 kW-h per MJ  
3000 MJ per day of solar  
= 833 kW-h per day  
X 14 days  
= 11,662 kW-h  
Or  
X 30 days for 150 g GH lettuce  
= 24,990 kW-h  
= 167 kW-h per g  
= 0.006 g per kW-h | Given 0.278 kW-h per MJ  
2000 MJ per day of solar  
= 556 kW-h per day  
X 14 days  
= 7,784 kW-h  
Or  
X 30 days for 150 g GH lettuce  
= 16,680 kW-h  
= 111 kW-h per g  
= 0.009 g per kW-h |

<table>
<thead>
<tr>
<th>Maximum in Lunar GH</th>
<th>Maximum in SPFGC</th>
</tr>
</thead>
</table>
| 12 g per kW-h total  
@ 50% H.I.  
= 6 g per kW-h | 20 g per kW-h total  
@ 47% H.I.  
= 9.6 g per kW-h |
CE systems will feed the world, improve the world, and create new worlds

Plants are biochemical/biomechanical processors that:

1. create “Products”
   food, feed, fiber & fuel -
   (Plant Vegetables/Flowers, Animal Feed, and Fabrics)

2. provide “Processes”
   life-support, bioremediation, biosynthesis -
   (Water Purification, Oxygen/CO2 revitalization,
   Carbon Sequestration, Plant-made Pharmaceuticals (PMP);
   Nutraceuticals; Algal Biodiesel)
CE systems will produce any plant, anywhere, at any time.

Controlled Environment is defined as an integrated science- and engineering-based approach to provide specific, controlled and repeatable environments for plant productivity, while optimizing resources, including water, energy, space, labor and capital.
Controlled Environment Plant Production Systems

Take – Home Critical Facts

The CE technology exists today!

Controlled Environments & Hydroponics are fundamental

Capabilities are:
Plant controlled for our needs; Independent of climate; Predictable, consistent, quality biological product

Challenges are:
Education of young people; Financial support for economic development; IT sensors for monitoring/control; Creative application/designs from traditional farms, to urban cities, to extreme locations
Controlled Environment Plant Production Systems

Requirements/Limiting Factors

Education/Understanding
IT - sensors, telepresence
Resource re-utilization (energy, water, molecules)
Design/planning for future urban/suburban living

Real-time monitoring of the plant
Social/Economic acceptance
Fundamentals of CEA Provide Food Production and Life Support

Recirculating CO$_2$ - Oxygen System
Supplemental lighting & Solar fiber-optics

Low mass, inflatable film structure
Low mass, cable-supported root zone

Recirculating Hydroponic Plant Production System

CEAC Laboratory, Tucson, AZ

Extra-Terrestrial Environments
Greenhouse Controlled Environment for Moonbase Life Support
[top view]

- Greenhouse
- Post-Harvest
- Central Hub & Living Quarters