وزارة التغير المناخي والبيئة

MINISTRY OF CLIMATE CHANGE & ENVIRONMENT

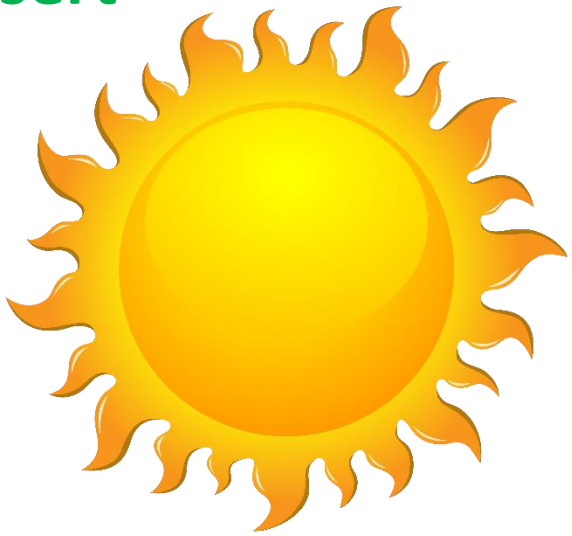
ICARDA

Science for resilient livelihoods in dry areas

Introduction to Greenhouse Type and Cooling system

Arash Nejatian

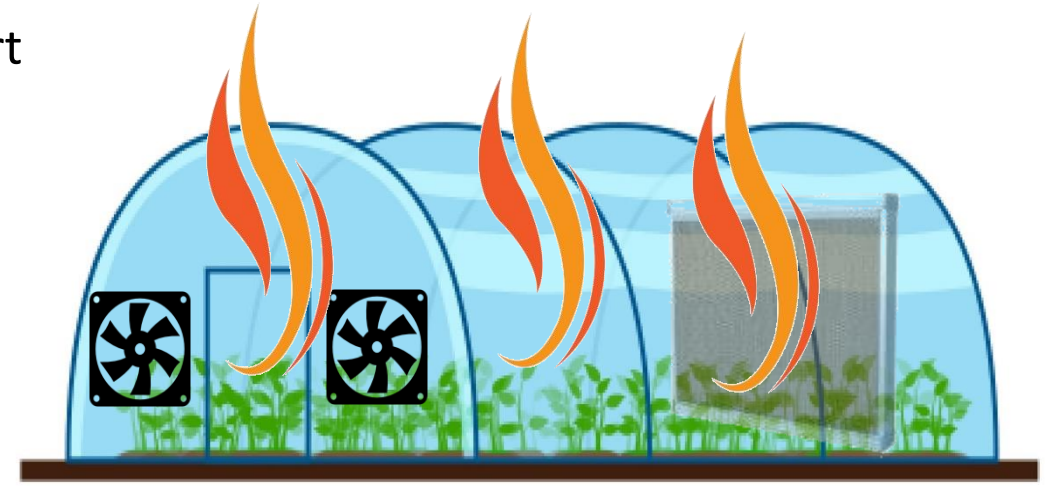
Control environment agriculture is the main pillar of desert farming



Protecting crops from the harsh environment and enhancing and managing crop production throughout the year.

The main technical problem of using conventional greenhouses:

- maintaining the inside air temperatures and relative humidity favorable for plant growth under a desert farming system (Abdel-Ghany & Al-Helal, 2020)
- High water and energy consumption for plant production and cooling system



Greenhouse Type

BASIC SHAPE

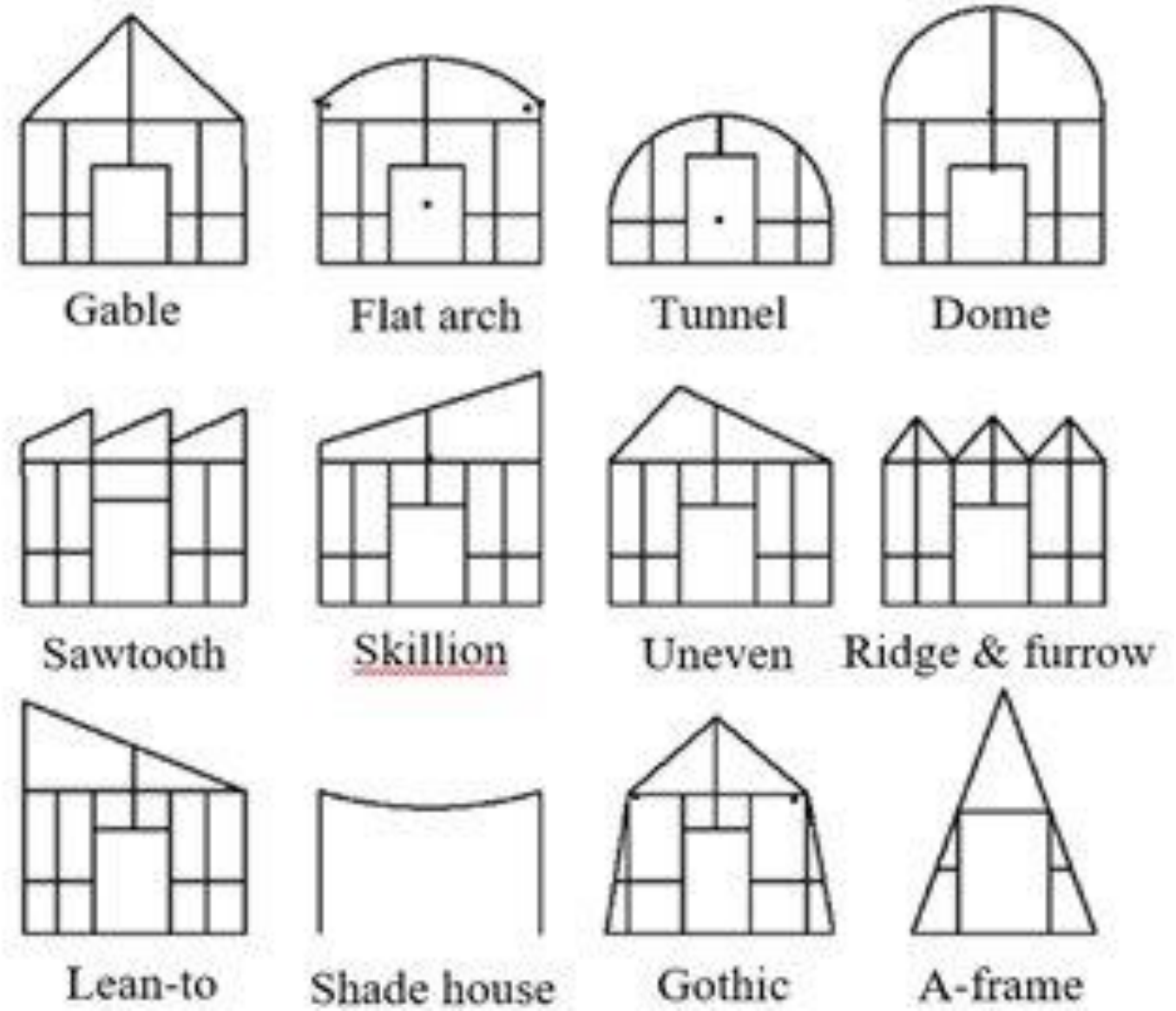
GREENHOUSE STRUCTURE COVER

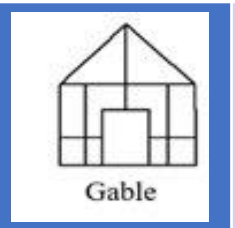
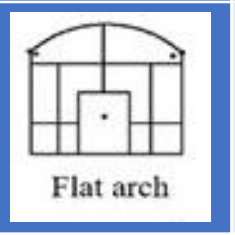
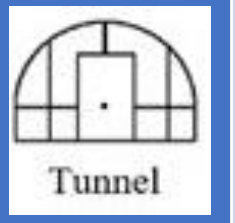
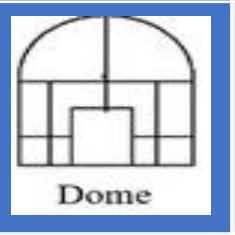
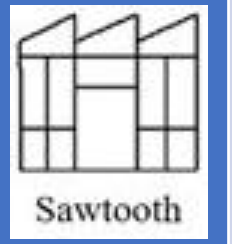
GREENHOUSE COOLING SYSTEM

PRODUCTION SYSTEM

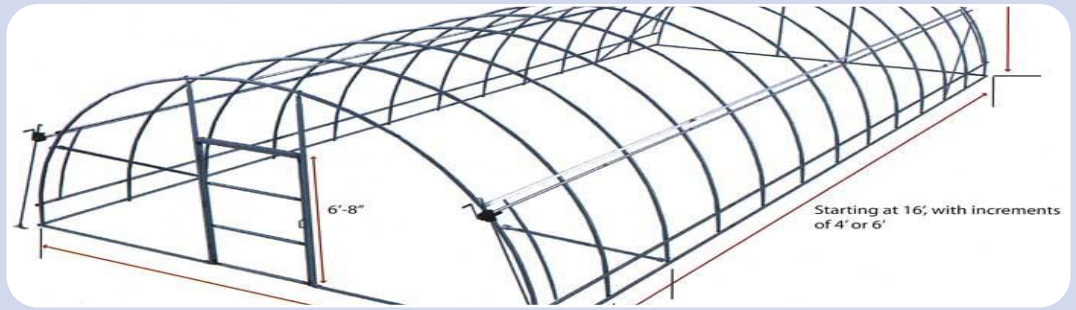
Classification of a greenhouse according to its basic shape

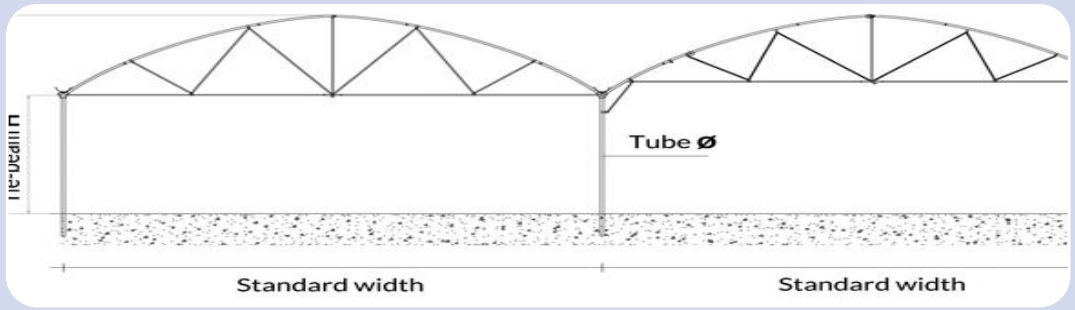
- Gable
- Flat arch
- Tunnel, Dome
- Raised dome
- Sawtooth
- Skillion



	Advantage	Disadvantage
Gable 	• Steep roof pitch can shed snow and water more efficiently, minimizing structural stress. • High peak offers more vertical space, beneficial for plant growth and natural ventilation.	• The design can be more complex and costly to construct. • May require more materials than simpler designs, increasing costs.
Flat Arch 	• Simplicity of design makes it easier and more cost-effective to build. • Efficient use of space with uniform height throughout the greenhouse and Easy to join multiple units' side by side for expansion.	• Snow and water may accumulate on the roof, requiring a strong structure. • Less aesthetic appeal due to its simplicity. • Limited light distribution
Dome, Tunnel 	• Excellent light distribution due to the circular design. • Energy efficient for heating due to less surface area exposed to cold compared to rectangular designs. • Wind resistant due to its aerodynamic shape.	• Inefficient use of ground space compared to rectangular designs. • More challenging to construct due to its geometric complexity. • May not be suitable for commercial-scale operations due to space constraints. • More energy consumption for cooling
Raised Dome 	• Enhanced benefits of a dome shape with elevated base for better accessibility. • More vertical space for the growth of taller plants. • Can offer more controlled environment compared to standard domes.	• Increased complexity in construction and may need more material. • Potential for inefficient use of space due to circular design. • May still not be suitable for commercial-scale operations due to space constraints.
Sawtooth 	• Excellent natural ventilation due to the sawtooth design. • Allows plenty of sunlight in, benefiting plant growth. • Easily expandable, making it suitable for large-scale operations.	• Construction can be more complex and expensive due to the unique design. • May not perform well in heavy snowfall or rain due to the roof design. • Requires a larger plot of land compared to more compact designs. • Reduce air mass, Less wide span

Single Span vs. Multi Span Greenhouse





Single Span

Usually simpler in design and cheaper to build.

Can be easily moved or expanded, making them suitable for small-scale or hobby farming.

May require more land for the same amount of growing space.

Temperature and humidity can fluctuate more due to having fewer internal buffers.

Multi Span

More complex and costly to build but offer a high amount of growing space.

Better at maintaining consistent temperature and humidity due to more internal buffers.

Less affected by wind, due to shared walls.

Can be more difficult to ventilate properly, needing careful design and potentially additional cooling systems.

Both types have their advantages and disadvantages, and the choice depends on the needs of the farmer, the crop being grown, and the local climate and environment

Let's discuss

- What is the most popular greenhouse structure shape in your area?
- What you recommend between these greenhouse shape for desert farming in your area? Why?

Greenhouse cover and cooling system

Glass

Polycarbonate

Polyethylene

Shade net

Insect proof net

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Glass, a traditional choice, provides high clarity and aesthetic appeal

Advantages:

- Maximum light transmission for optimal plant growth.
- Long-lasting when well maintained.
- Aesthetically pleasing.

Disadvantages:

- High cost of installation and maintenance.
- Need very strong structure as glass is heavy
- Poor insulator, significant energy required for cooling in desert farming.
- Vulnerability to breakage.

Pic credit: https://ggs-greenhouse.com/what-is-greenhouse

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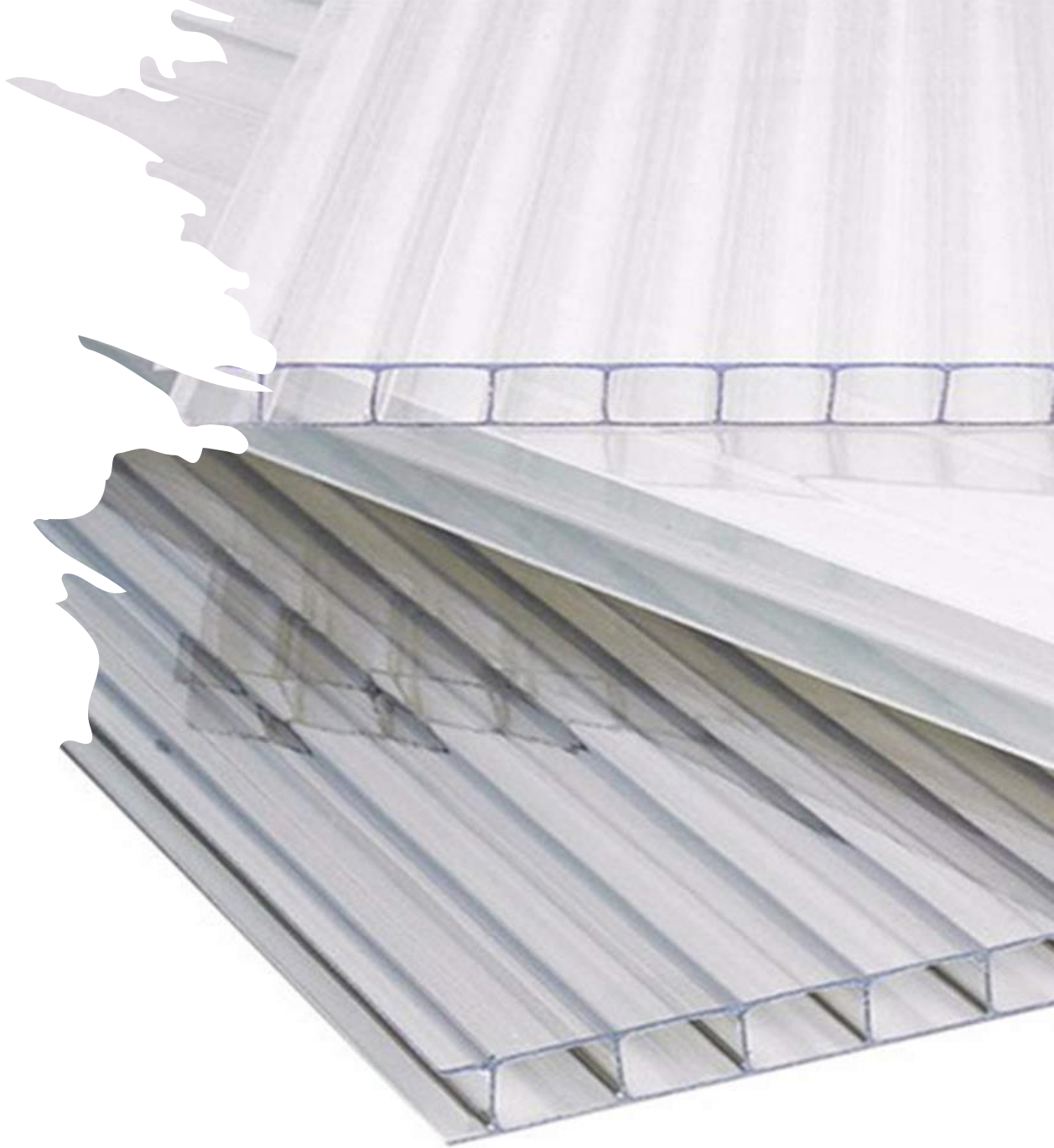
Polycarbonate, a modern alternative, offers excellent durability and insulation

- **Advantages:**
  - High impact resistance.
  - Good insulator, less energy required for cooling compared to glass."
- **Disadvantages:**
  - Lower light transmission compared to glass.
  - Can degrade and yellow over time with sun exposure specially in desert farming.
  - Relatively high energy still required for cooling in hot climates.



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Polyethylene, a cost-effective choice, is popular for hoop houses and poly-tunnels

- **Advantages:**
  - Economical and easy to replace.
  - Lightweight and versatile.
- **Disadvantages**:
  - Less durable, needs replacement every few years.
  - Lower light transmission than glass or polycarbonate.
  - Insulation properties are weaker than polycarbonate, considerable energy required for cooling in desert farming.

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Picture credit: https://www.greenproventures.com/choosing-the-right-shade-net-knitted-or-woven/

Shade nets are used to protect plants from extreme sunlight and reduce temperature

Advantages:

- Reduces light intensity and heat, preventing plant damage.
- Economical and easy to install.
- Low-cost structure.
- No-energy for cooling in wintertime

Disadvantages:

- Balancing shade level is crucial, as too much can limit plant growth.
- No insulation provided, Production in Summer stop in desert farming
- No protection against pest

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Insect-proof netting is a great option for pest protection and air circulation

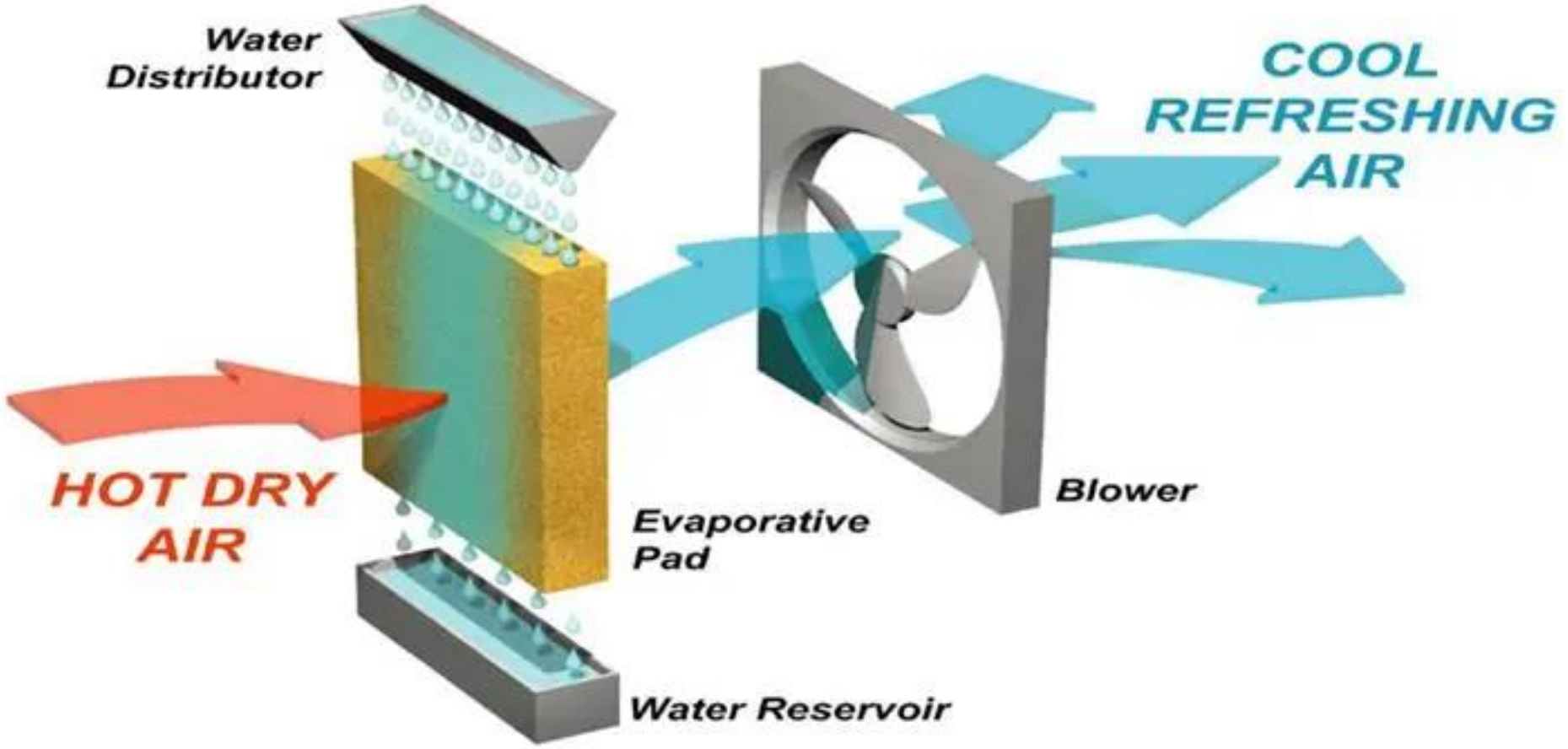
Advantages:

- Effective pest control without use of pesticides.
- Permits air flow, reducing risks of plant diseases.
- Low-cost structure.
- No-energy for cooling in wintertime

Disadvantages

- Lower light transmission, may affect plant growth.
- Provides no insulation, No active cooling system. Production in Summer stop in desert farming .
- Requires additional structural support

How **EVAPORATIVE COOLING** works



Pad and fan challenges and constrains

Expensive and required maintenance and replacement

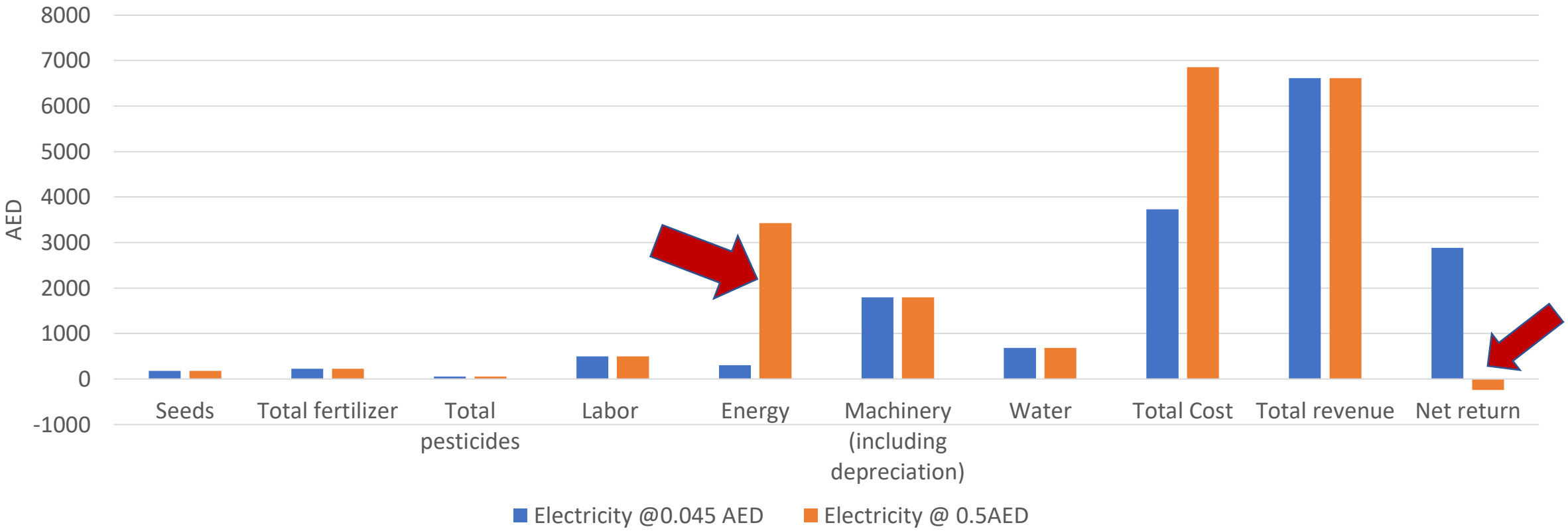
High water consumption

Average in GCC countries 8 liter/day/m2 of greenhouse (collected from different ICARDA studies)

High cost of electricity

In Dhaid, more than 30,000 kWh for a single 8x40m GH per year

Net Return for Cucumber crop in cooled GH in UAE (25 March – 15 June) with two Scenario for Energy cost



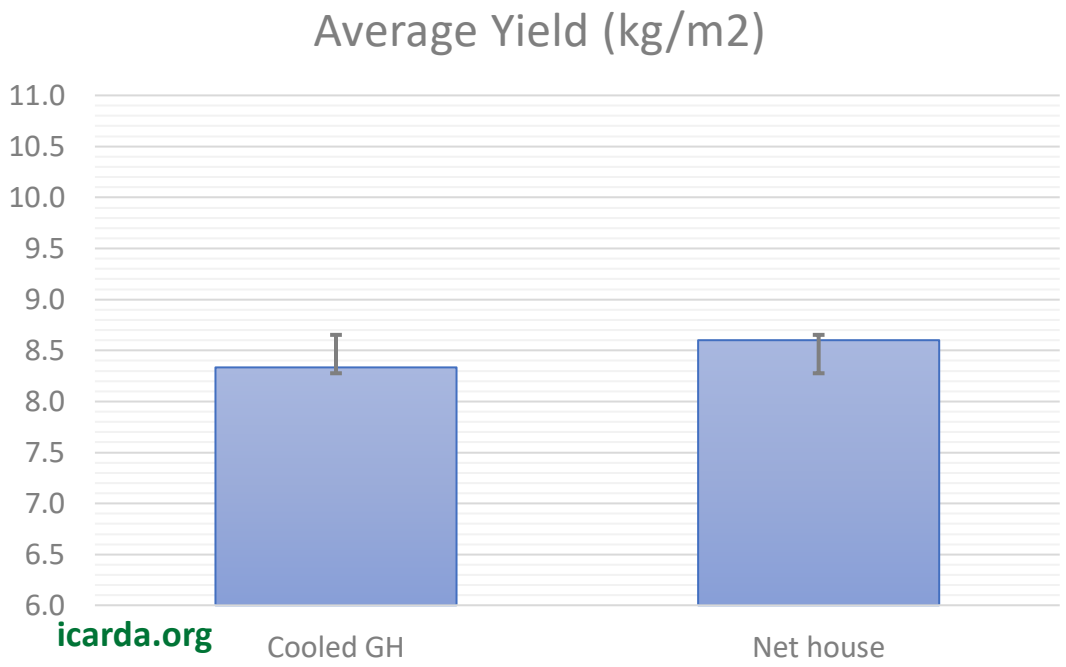
- Scenario 1: The cost of electricity is 4.5 fills/kWh based on agricultural electricity tariff (Abu Dhabi Distribution Company, 2017)
- Scenario 2: average business electricity price worldwide in March 2021 was reported at 0.135US$ or 0.5AED per kWh (Electricity prices, 2021)Average

- Active
  - Fan-and-pad cooling
  - Fog
- Passive
  - Ventilators
  - Net house

Net-house using insect-proof net

Considering the average monthly temperature, the production of cash crops could be successfully adopted in net-house for 7-8 months/year.

Comparing cucumber production in Net-house VS. Cooled GH in UAE (September to December 2012)



icarda.org

Net-house Vs. Evaporative Cooling

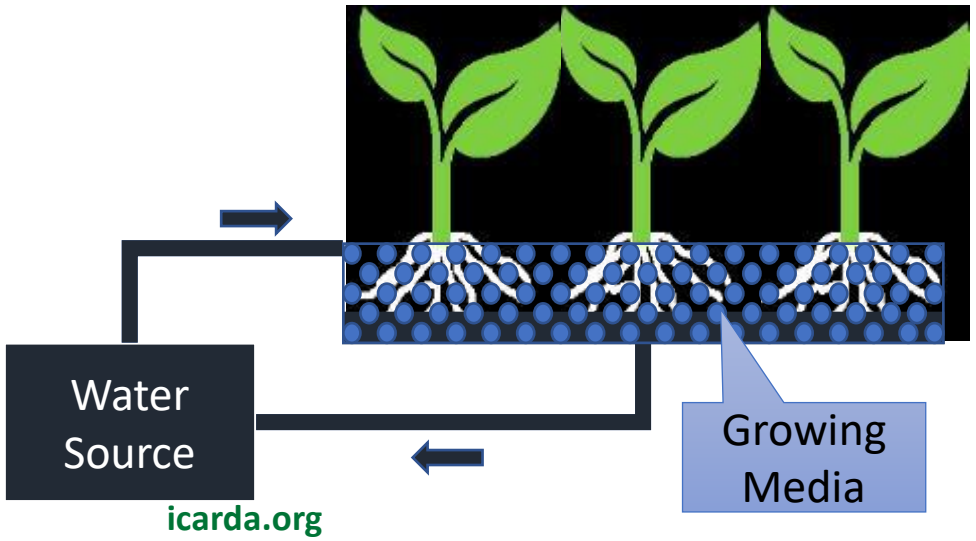
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporative cooling	Work with high Water and electricity consumption						**Very low efficacy**		Work with high electricity consumption			
Passive Cooling (net-house)	Work with no Water and electricity consumption					**Stop Production**			Work with no Water and electricity consumption			
Production	Same Production					**Evp. Cool also low production**			Same Production			
Annual Net Benefit	Annual Net Benefit is the Same Zero cost of electricity and water for net-house Cost of installation and maintenance for Evaporative cooling 7-8 Month similar production											

Let's discuss

Which greenhouse cover and cooling system you recommend for desert farming system? Why?

Simplified Closed Soilless Production System

Reduce irrigation water by more than 50%



The advantages of soilless culture over conventional soil bed systems include:

1. Provide very efficient use of water by reclaiming and reusing;
2. Shorter cropping cycle allows for more crops within the season;
3. Top quality crops grown out of the depleted or contaminated soil;
4. Increased production per unit area;
5. Reduction in labor requirement by more than 50%;
6. Increased job satisfaction among workers;
7. Better control of water and nutrients;
8. Elimination of costly operations such as sterilization, soil cultivation, base fertilizers, and weed control

Root zone cooling (RZC)

The air temperature inside the greenhouse tends to be very high during the daytime.

- **Temperature Regulation**
- **Water Conservation**
- **Enhanced Nutrient Uptake**
- **Reduced Plant Stress**
- **Energy Efficiency**

Root zone cooling presents a sustainable and effective solution to some CEA challenges in desert regions.

Ultra-low-energy drip irrigation and Utilizing Hybrid Solar Energy

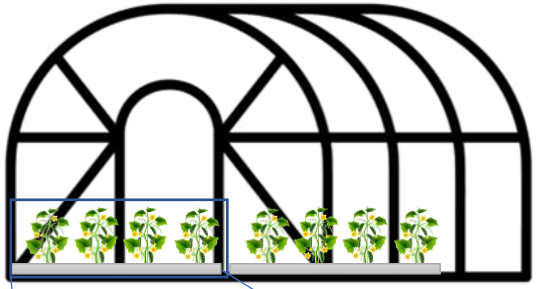
The new emitters studied through ICARDA-MIT research activities

- Cut pumping energy **by 80%,**

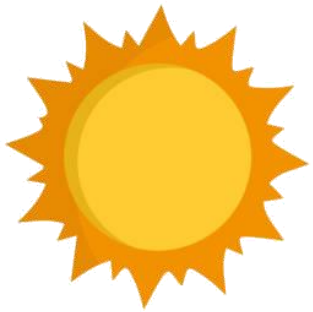
Reduce pumping time with five folds

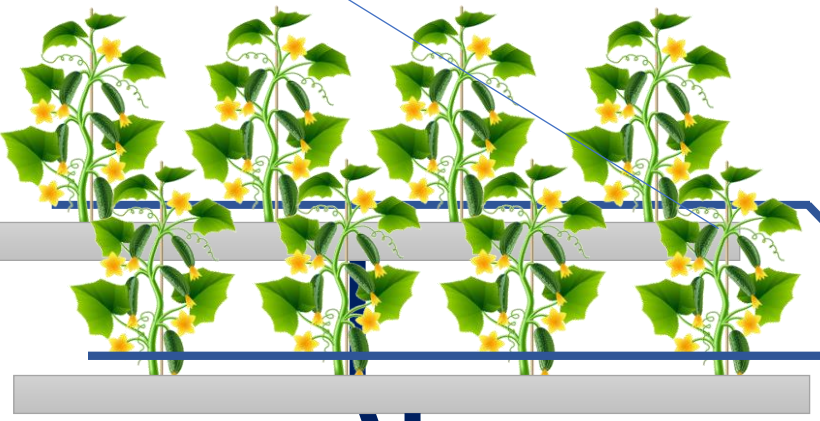
Reduce the Number of panels from three to one panel

Net house 8x30 meter

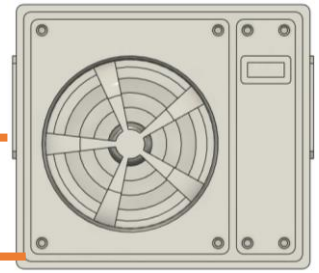


24 Volt AC/DC On-grid Hybrid System

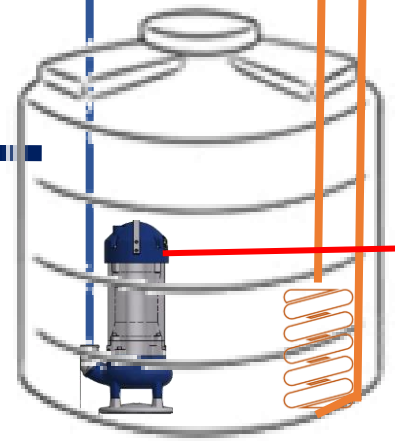


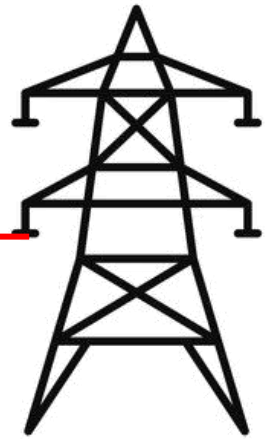


24V Root Zone Cooling



6x300W Solar Panel
80% of total energy



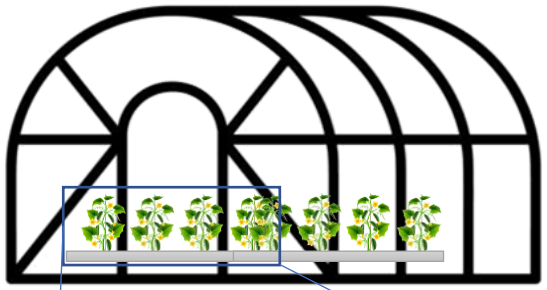


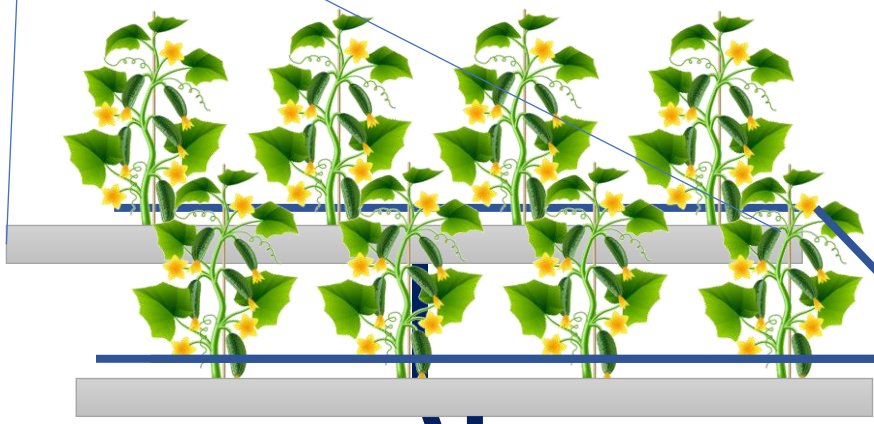
Grid
20% of total energy
Grid needed all the time

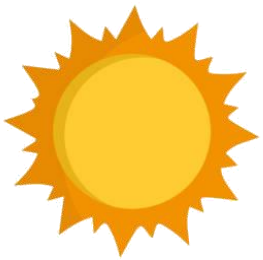
24v Solar hydroponics production system with Automatic Fertigation controller

48 Volt 100% off grid

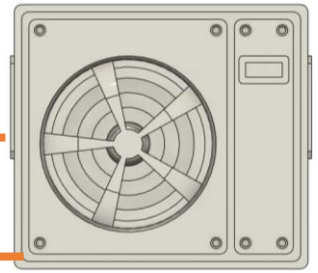
Net house 8x30 meter



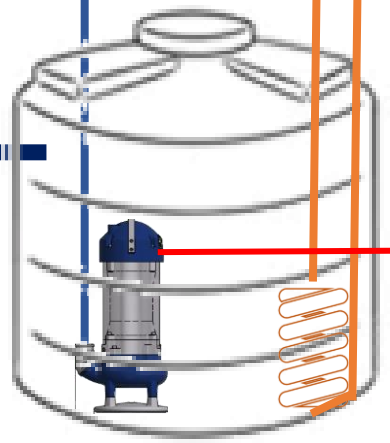


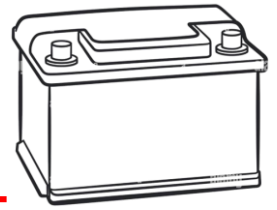


48V Root
Zone Cooling



10x300W Solar Panel
100% of total energy

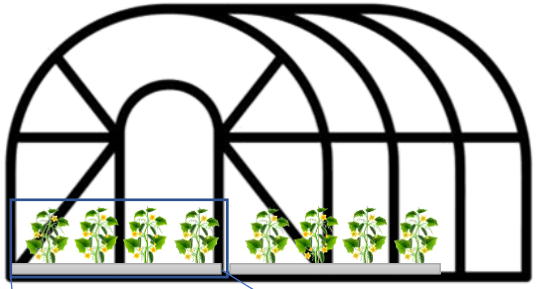




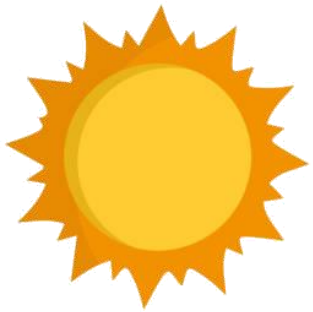
6x120Ah batteries

24v Solar hydroponics production system with
Automatic Fertigation controller

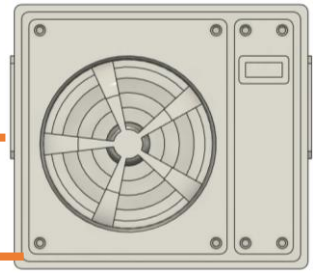
Net house 8x30 meter



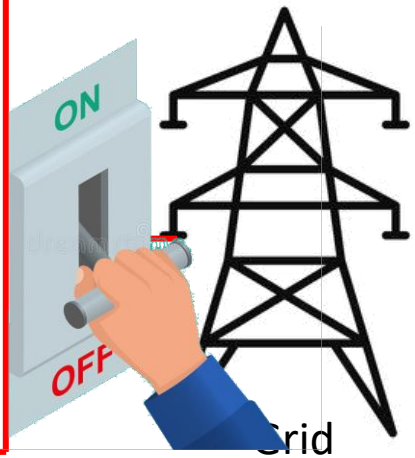
New technology
24 Volt AC/DC
off-grid
Hybrid System



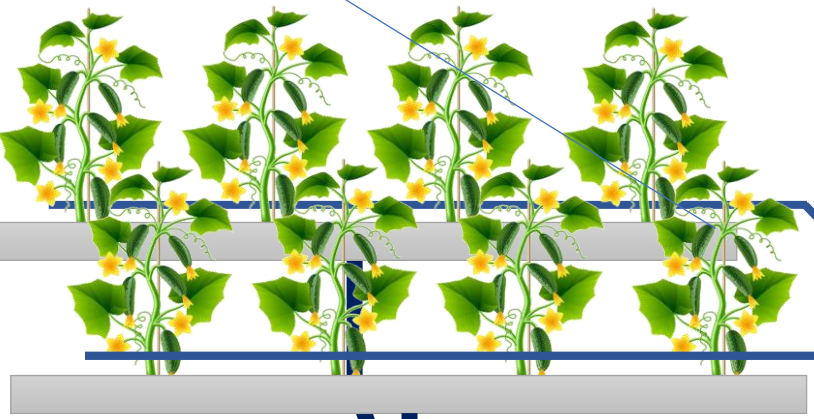
24V Root
Zone Cooling

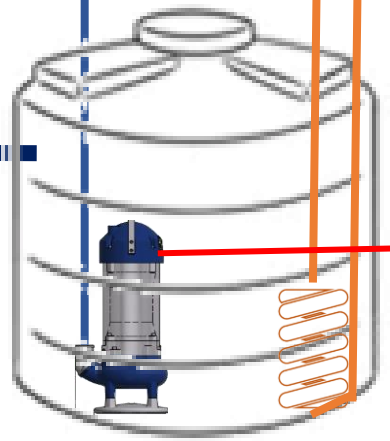


6x300W Solar Panel
85% of total energy



Grid
25% of total energy
The grid can be disconnected





24v Solar hydroponics production system with
Automatic Fertigation controller

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Solar irrigation setup and wiring chart for Closed Hydroponics System

Recommended irrigation time: 5min/h

Greenhouse size: 8x30 meter

Irrigation lines: 4 lines

Solar Charge Controller

30Amp

Recommended:

FOXSUR

12V/24V

30A

Irrigation controller (output 24VAC)

SOLAR PANEL 310-330 WATTS MONOCRYSTALLINE

Miniature circuit breaker

16 A –DC

Recommended:

Schneider C60H-DC

24 VAC Modular Contactor

25Amp-2 Normally Open

Recommended:

Finder 22.32.0.024.4340

2NO-25Amp-24V AD/DC

UPS/SOLAR Battery 12V 20AH

UPS/SOLAR Battery 12V 20AH

Pump

DC (solar), 450Watt 1½ inch outlet

3rd Step

Combination of Five technology packages

Combine the five technologies to improve productivity and extend the production period of the net house,

- closed soilless production system,
- net house,
- ultra-low energy irrigation system,
- root zone area cooling,
- and low-cost solar energy (AC/DC hybrid tie-grid)

Investigate the potential of solar-powered root zone cooling to extend the production period of cucumber crops grown in net houses.

The study aimed to

Assess the cost-effectiveness and efficiency of solar-powered irrigation with ULED and nutrient solution cooling in net houses using hybrid solar energy during summer.

The research activity was carried out simultaneously in both the UAE and Oman.

Materials and Methodology

Setup

- Two sites, each with a 240 m^2 net house
- Four cucumber varieties: IZZ F1, Qaisar F1, Nassem F1, Sultan F1
- Seeds planted on May 15th, 2022; transplanted to the net house on June 1st

Planting

- Completely Randomized Design (CRD) used
- Perlite-filled polystyrene pots (23x23x20cm)
- Each plot: 25 pots with two plants each; 50 plants per plot (plot size: 8.4m^2)

Technology

- Solar-powered irrigation system with ULED technology
- Root zone cooling system powered by an AC/DC hybrid solar system keep the Irr water temp at 25^{o}C
- Net house
- Additional insect-proof netting added for shading

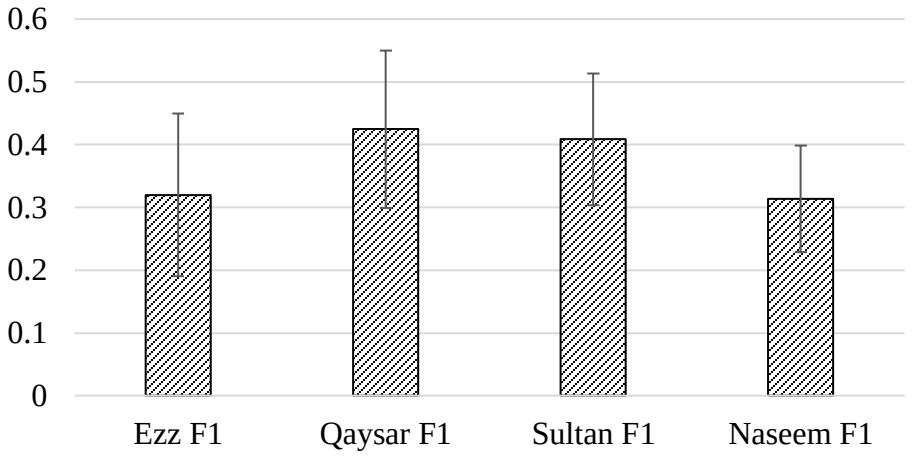
Data Collection

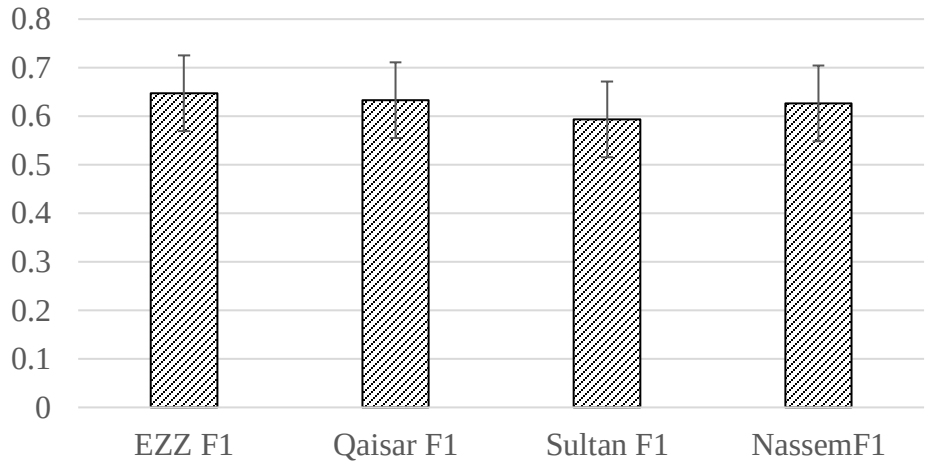
- Factors measured: yield, water and fertilizer usage, temperature variation, and electricity consumption
- Data related to cost of production

Results and Discussion:

Productivity of Solar-Powered Irrigation System

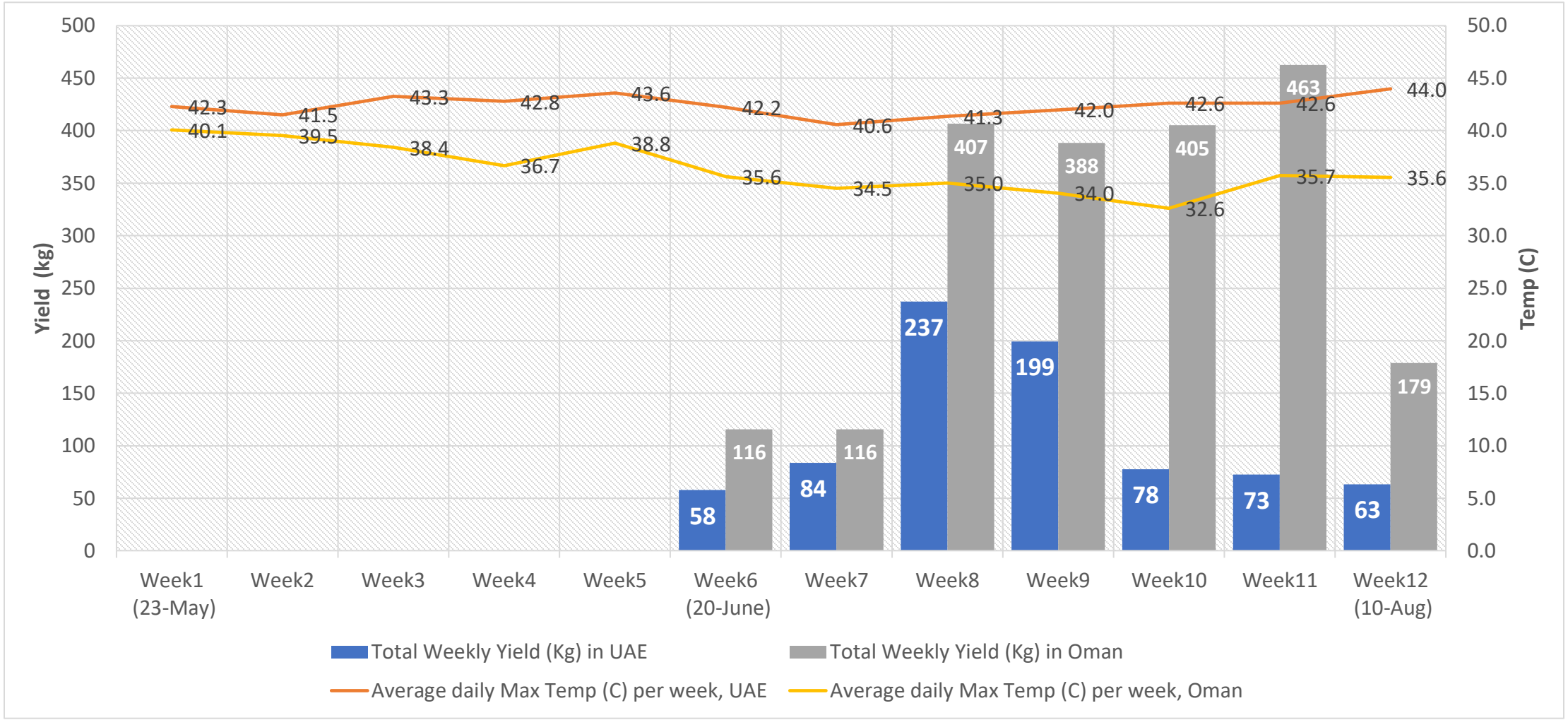
- **Overall Findings**: Crops remained in production throughout the summer in both locations.
- **Results in UAE**: First harvest on May 26, 2022, with production until August 10, 2022. A total of nine harvests with a yield of 3.3 kg/m^2.
- **Results in Oman**: Local researchers reported 15 harvests with an 8.3 kg/m^2 yield.
- **Comparative Analysis**: No significant differences in fruit number and yield among cucumber varieties.





Average cucumber yield by verities (kg/m2/harvest) in UAE (left) and Oman (right) (26 May to 10 Aug 2022)

Weekly Production and Average Max Daily Temp

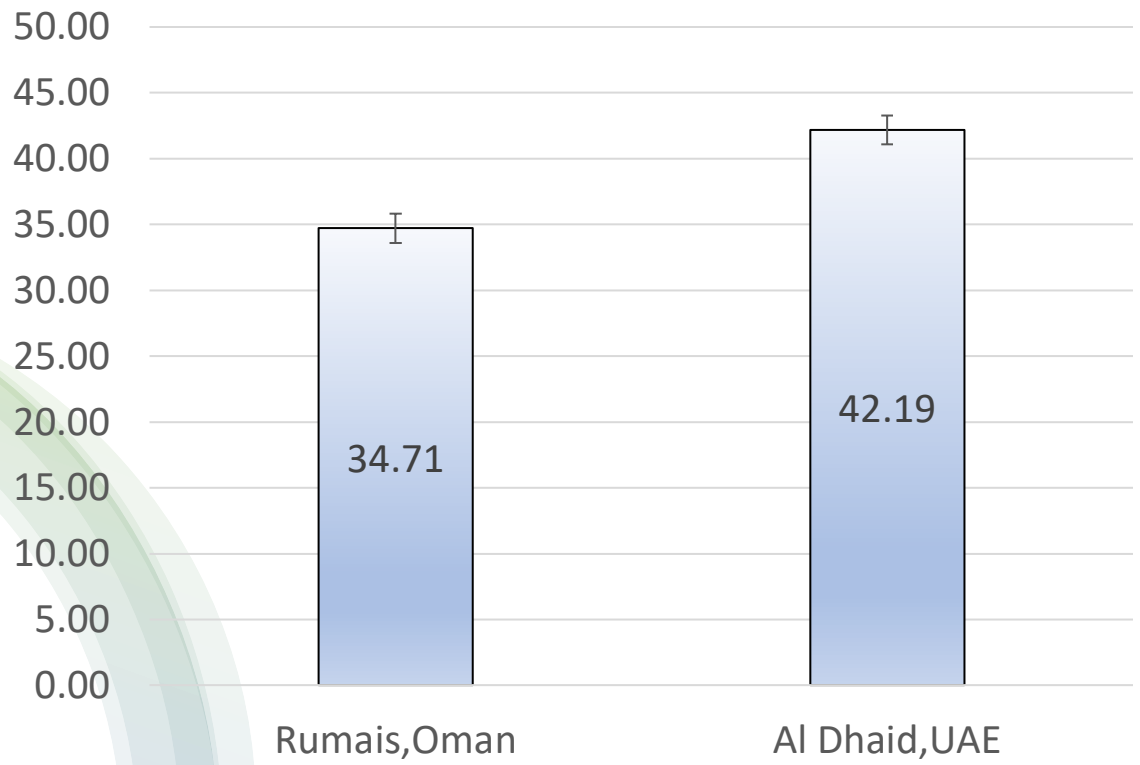


Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Weekly production (kg), Oman	0.813	7	0.055
Weekly production (kg), UAE	0.745	7	0.011
Average Daily Max Temp per week, Oman	0.865	7	0.167
Average Daily Max Temp per week, UAE	0.968	7	0.883

Weekly production levels in the UAE do not follow a normal distribution.

Means Comparison
Average Daily Temp/week



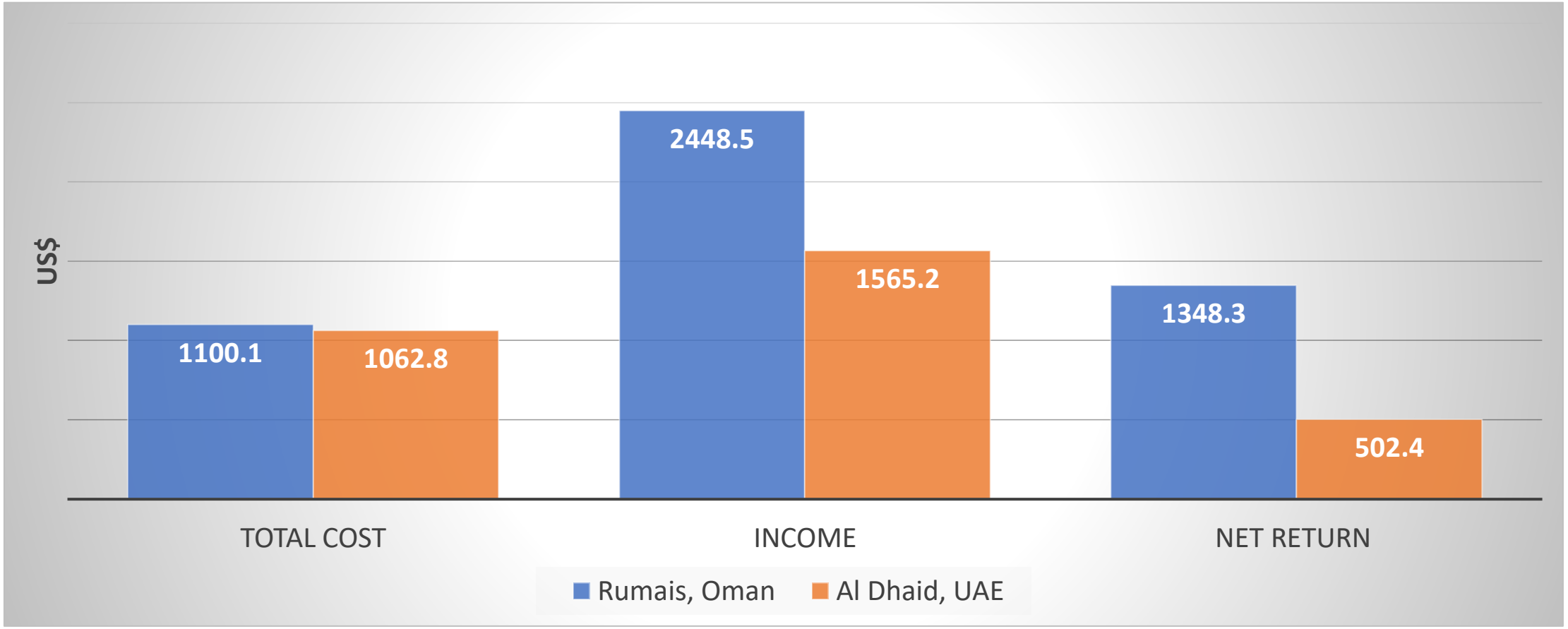
- **Daily Maximum Temperature recorded in both locations**
- **Independent T-Test used**
- **Throughout production, Oman exhibited significantly lower average weekly temperatures than the UAE.**

Means Comparison
Weekly Yield

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Weekly Total Yield is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.017[a]	Reject the null hypothesis.
Asymptotic significances are displayed. The significance level is .050.				
a. Exact significance is displayed for this test.				

Net house in Oman significantly produce a higher yield

Cost Benefit Analysis



Conclusion: Potential of Root Zone Cooling in Extending Production Season

- **Summer Production**: Cucumber plants produced under net houses using the RZC system yielded modest profits, beside cost reductions via solar energy.
- **Extended Growing Season**: Cooling the nutrient solution to mirror the root-zone atmosphere during high temperatures extended the cucumber growing season in net houses by approximately 1.5 months beyond its regular April-May season.
- **Potential Profitability**: This extended growing season could notably increase productivity and profitability for regional farmers.
- **Sustainability Consideration**: Implementing innovative, sustainable technologies like RZC and solar power requires a comprehensive assessment of specific environmental conditions and crop needs to ensure long-term sustainability and profitability.

Key Takeaways

While the study underscores the potential of innovative technologies like RZC and solar power, their implementation should consider specific environmental conditions and crop needs.

Thank you