Silicon Quantum Dots in Solar Greenhouses: Sustainable Food-Energy Generation Systems

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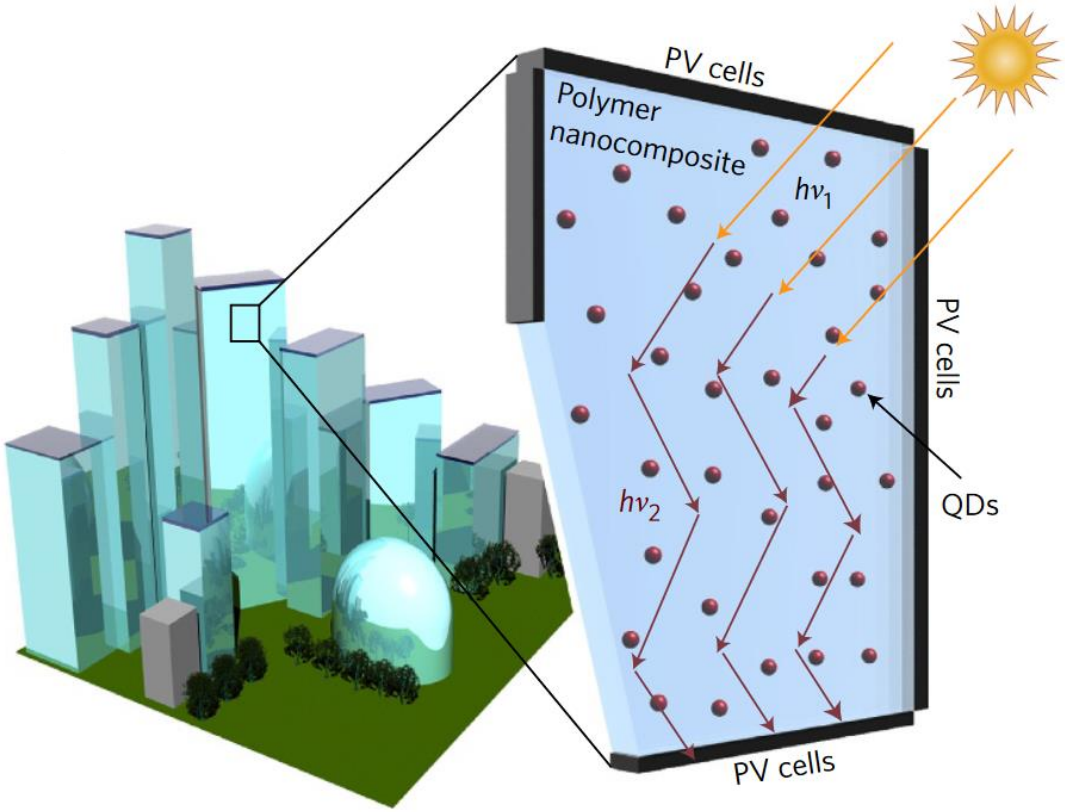
About Me

- Kristine Loh (she/her)
- 3rd year PhD Candidate in Chemical Engineering
- Research focus: plasma-synthesized nanomaterials for renewable energy tech.
- Co-advised by Profs. Uwe Kortshagen and Vivian Ferry
- BS/MS from Drexel University
- Hometown of Miami, FL

Advantages of Luminescent Solar Concentrators (LSCs)

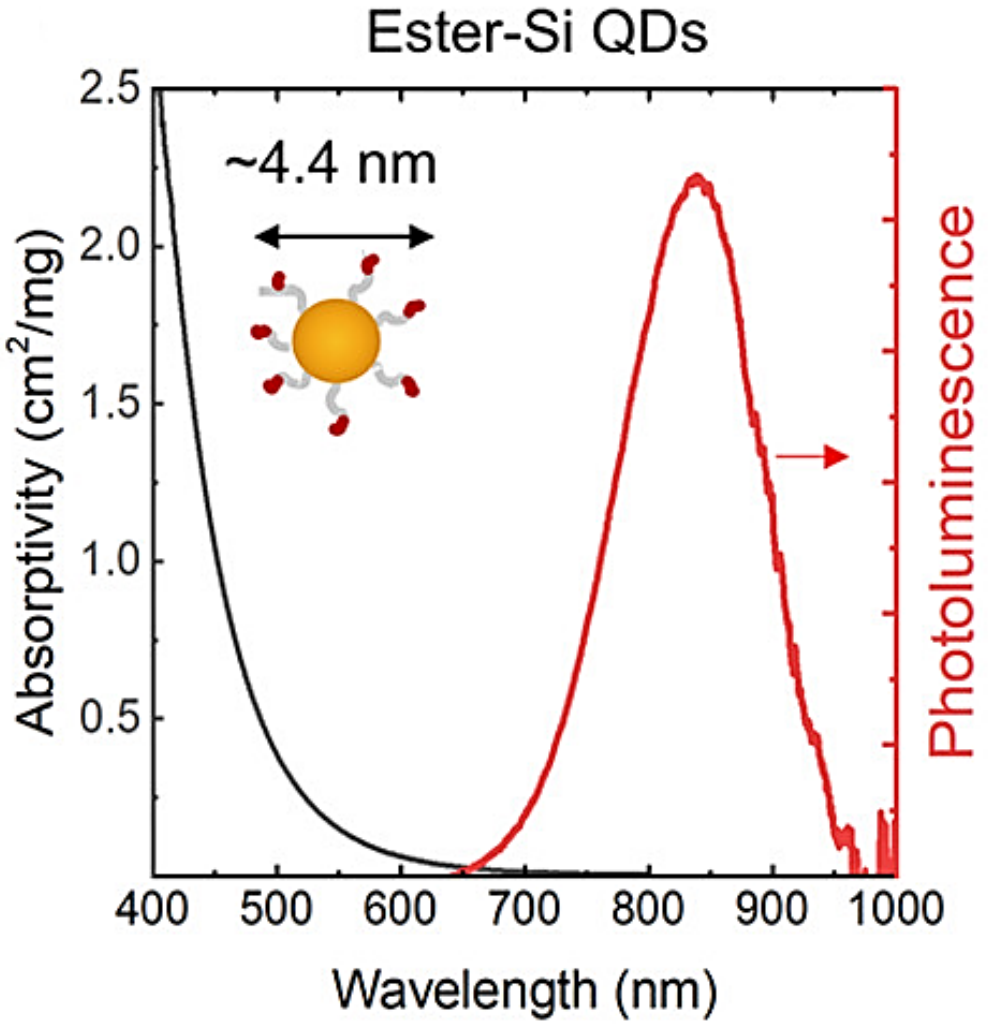
- Harness solar energy with LSCs
- Downshifts higher energy light (blue) to lower energy light (red)
- Directs light *via* total internal reflection to PV cells
- Captures direct and diffuse sunlight
- Great design freedom for BIPV – solar windows!



Silicon Quantum Dots (Si QDs) in LSCs

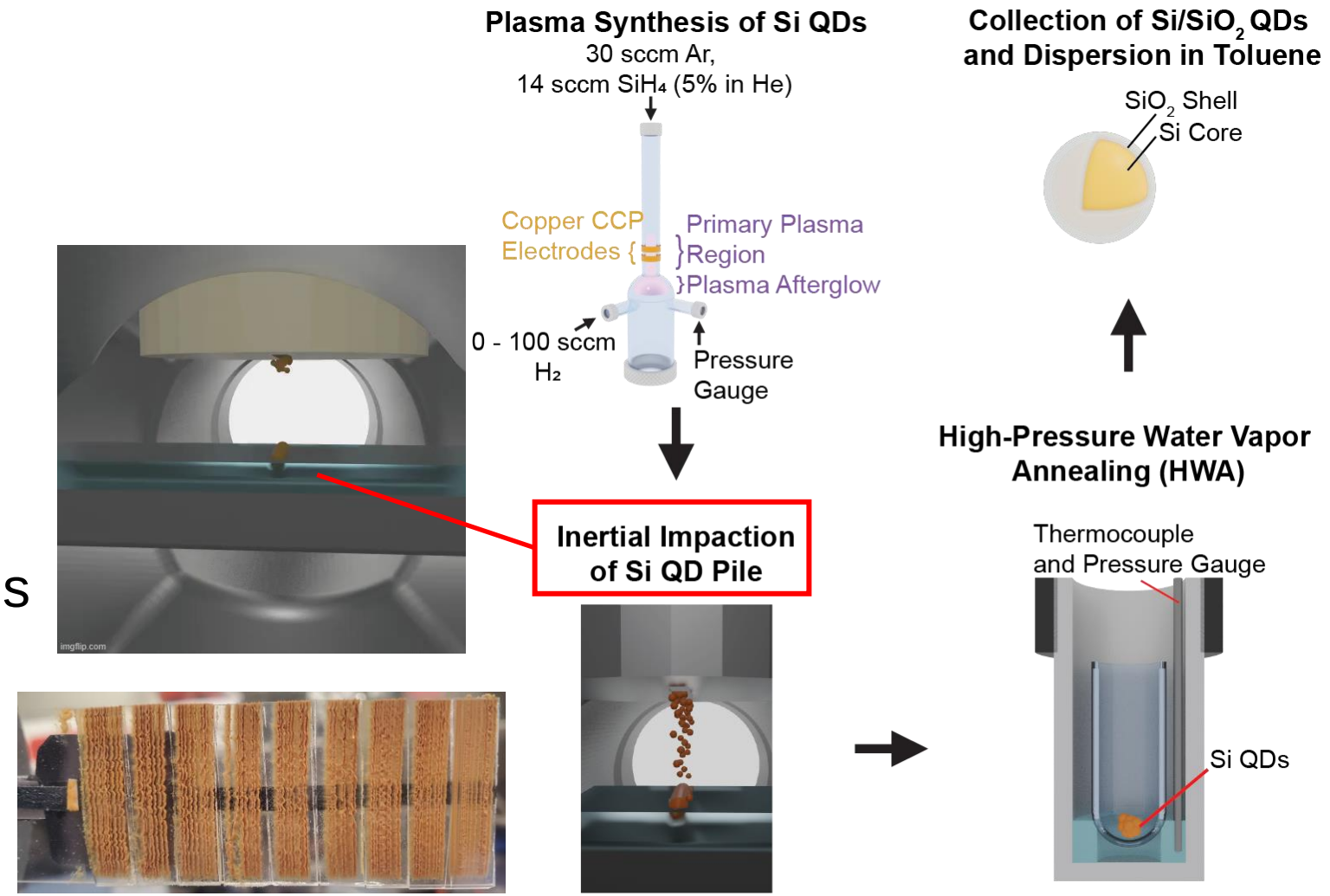
- Nontoxic, abundant element in earth's crust, high solar harvesting performances with relatively low QD concentration

- Larger Stokes shift: lower re-absorption
- Photoluminescence (PL) peak in infrared – matches crystalline Si solar cells



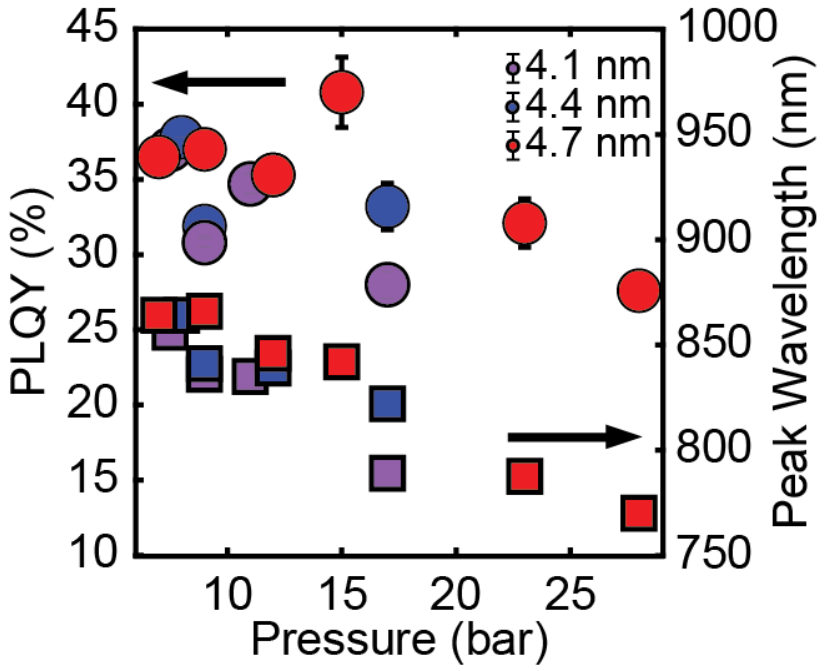
Synthesis and Protection of Si QDs

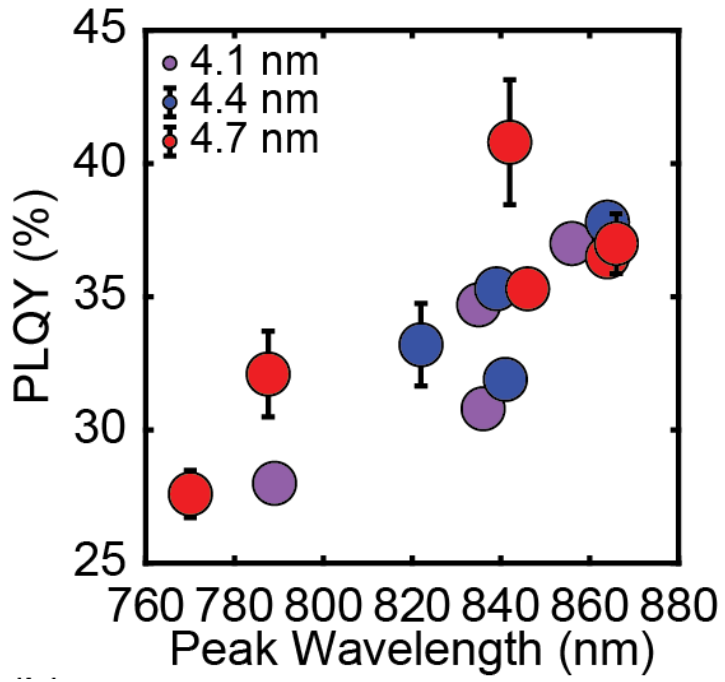
- Nonthermal plasma synthesis:
  - Gas-phase
  - High electron temperatures
  - Fast!
- As-synthesized Si QDs have high defect densities
- How can we protect Si QDs to improve their PL?
- **High Pressure Water Vapor Annealing**

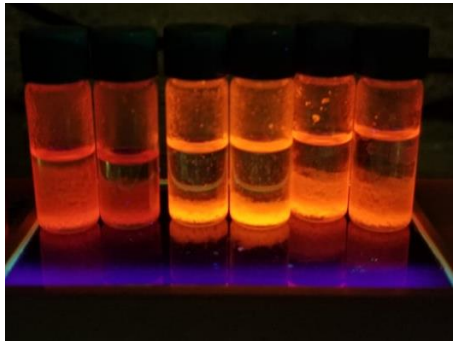


Tunable, High Intensity PL *via* HWA

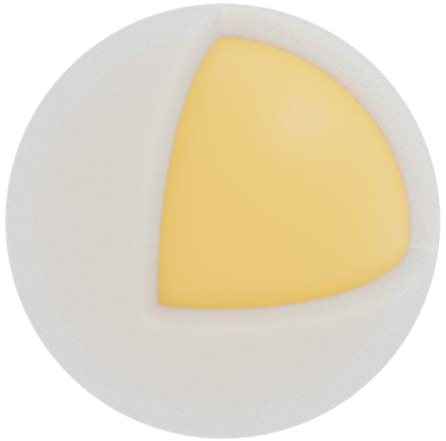
- Tuning pressure tunes PL efficiency (PLQY) and PL color
- Aiming for the same core size: oxidizing larger as-synthesized Si QDs leads to higher PLQY values
- **Stable Si QDs using just steam!**

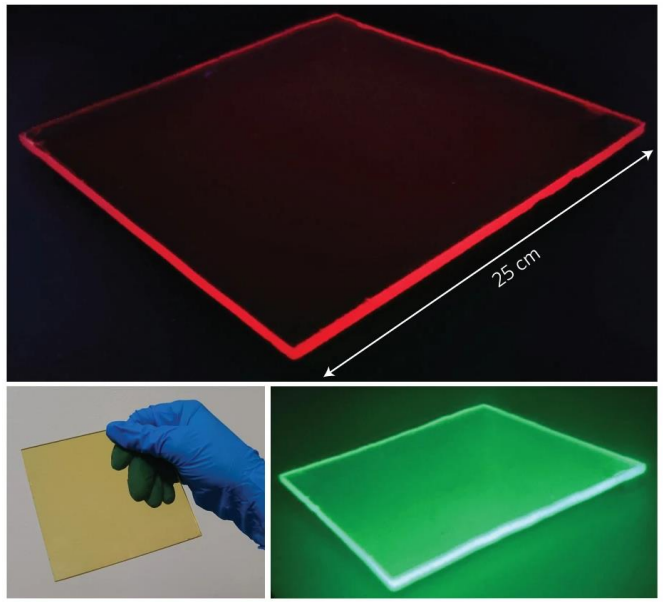


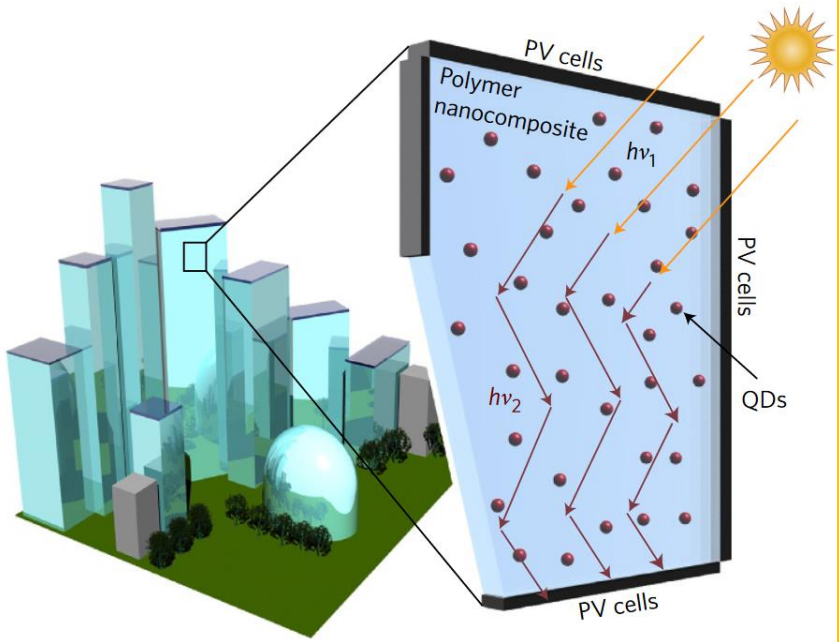




My Research Timeline







Environmentally Stable Si QDs

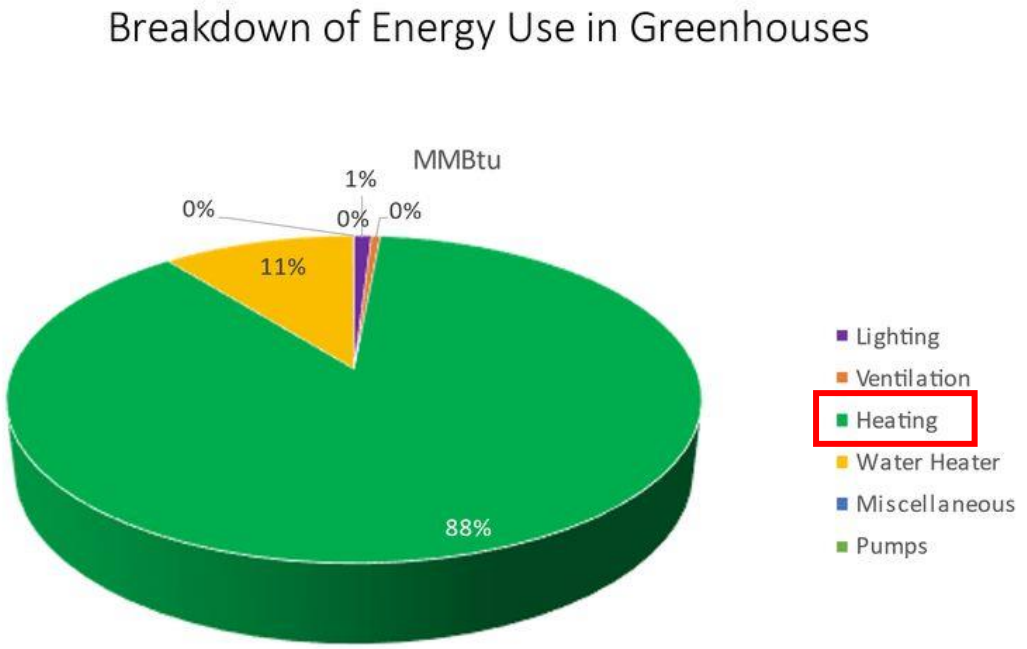
Si QD Films

Films in BIPV

Agrivoltaics: Concomitant Food and Energy Production

Agostini, A., et al., *Applied Energy*, (2021)

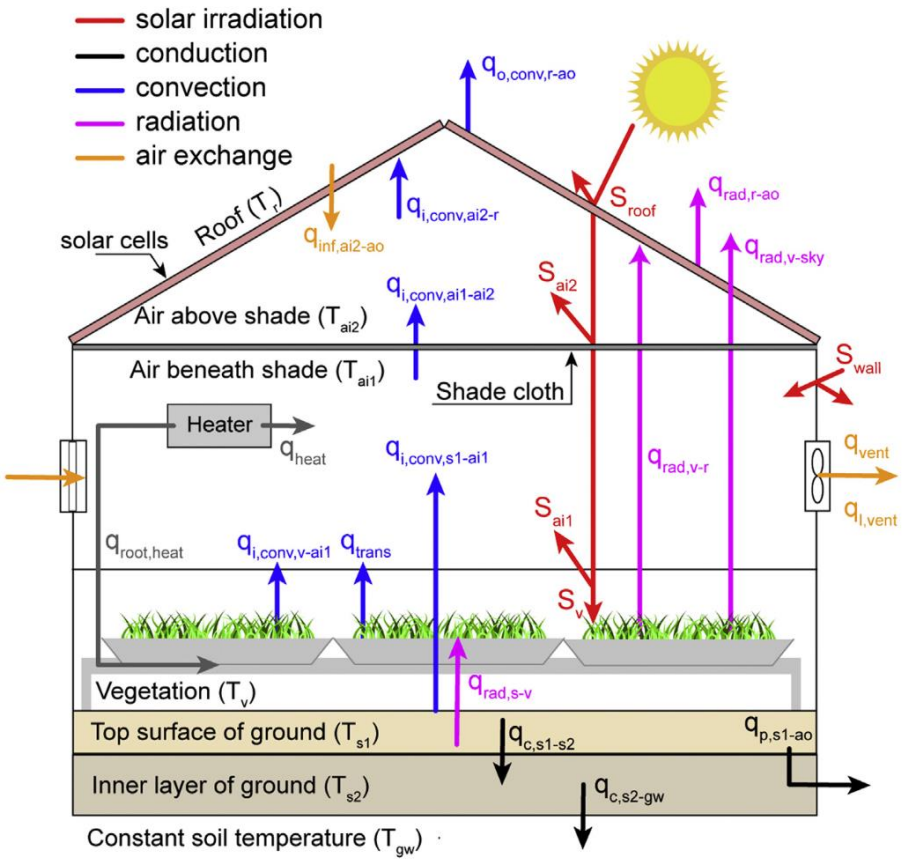
Corrado, C., et al., *J. Renewable Sustainable Energy,* (2016)



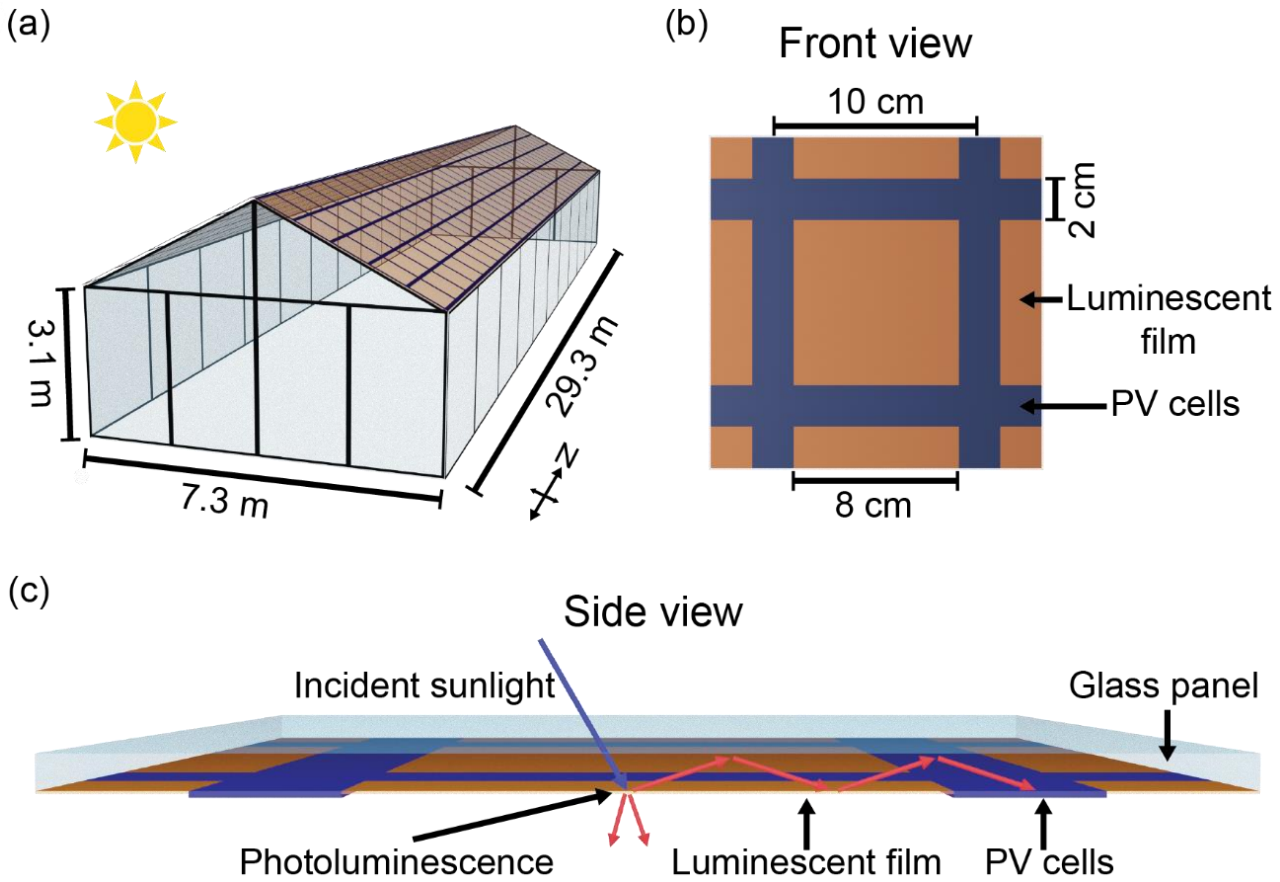
Michigan Farm Energy Program, 2021

How can we reduce the large energy demand of greenhouses?

Agrivoltaics: OSC/LSC Greenhouses

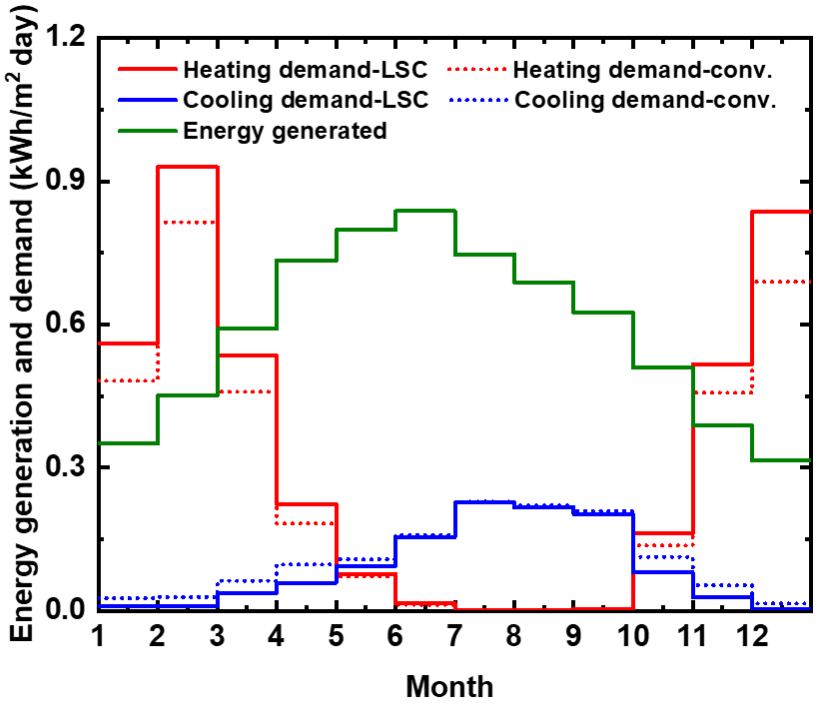


Ravishankar, E., et al., *Joule*, (2020)



Liu, Y., et al., *In Preparation*

LSC Greenhouses: NZE in AZ

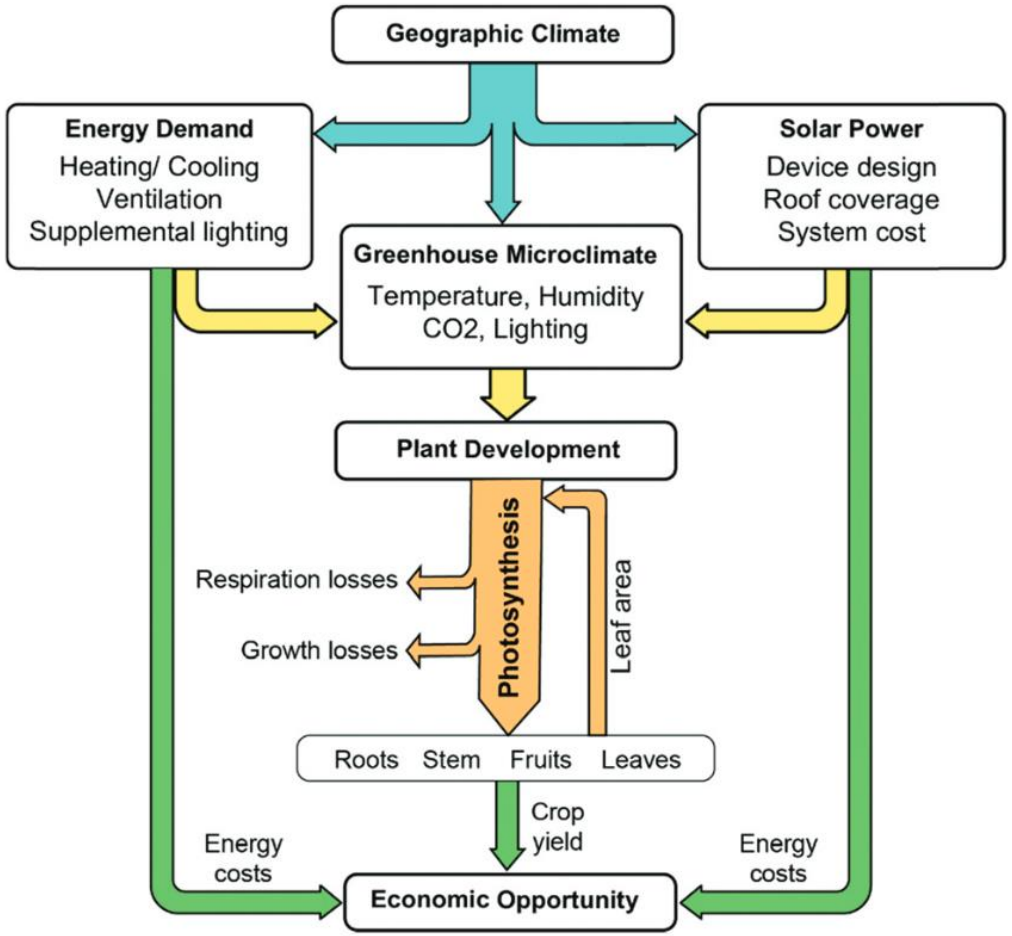


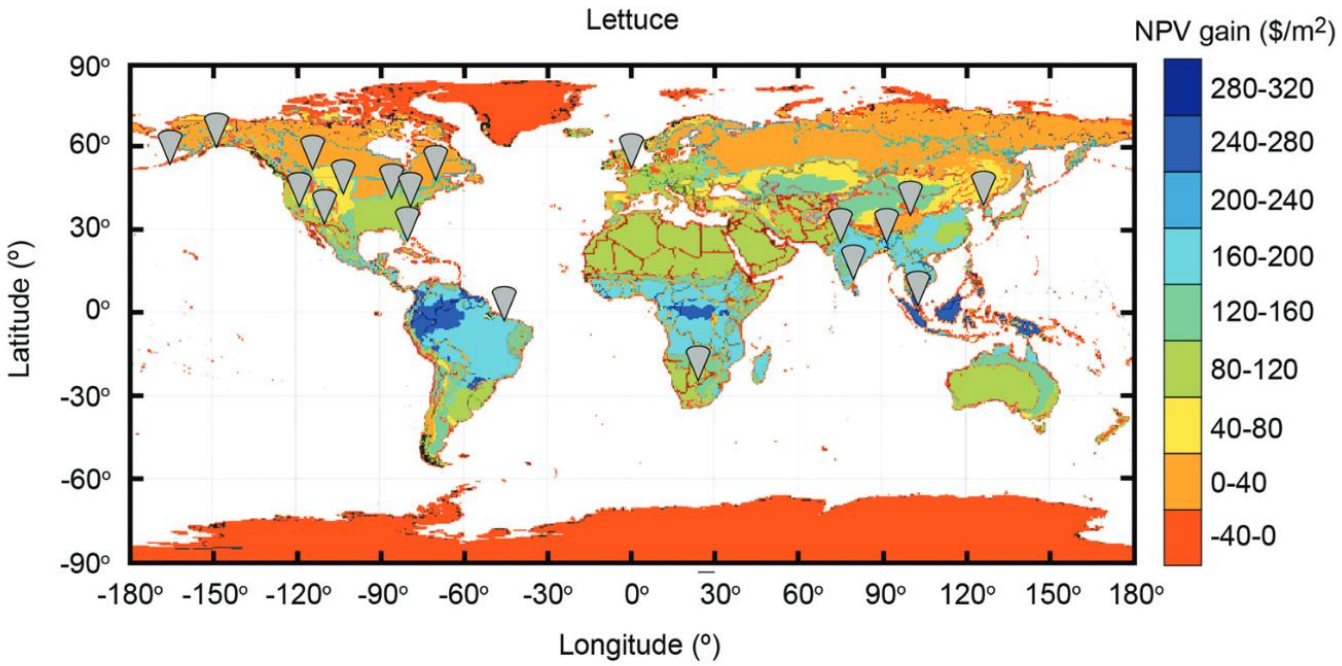
Location	Period	Greenhouse	Heating demand (kWh/m^2)	Cooling demand (kWh/m^2)	**Total demand (kWh/m^2)**	**Energy generation (kWh/m^2)**
AZ	Annual	Conv.	99.5	40.4	139.9	-
		LSC	116.2	34.3	**150.5**	**214.1**

- LSC greenhouses can generate enough annual energy to power a greenhouse in AZ and provide surplus energy
- Advantageous over conventional greenhouses by controlling incident light and temperature (lowers cooling demand)

- How do LSCs affect plant growth?

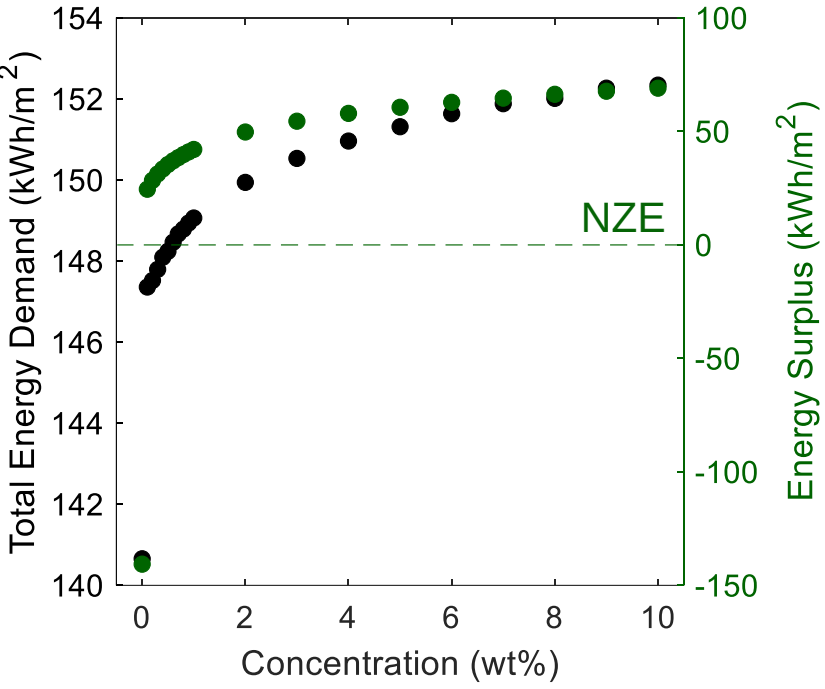
OSC Greenhouses: Crop Growth Modelling

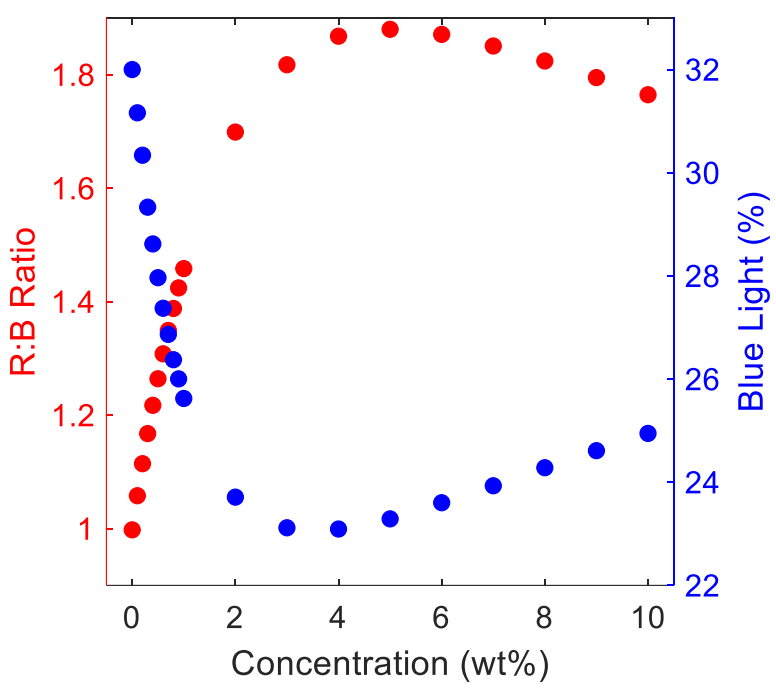


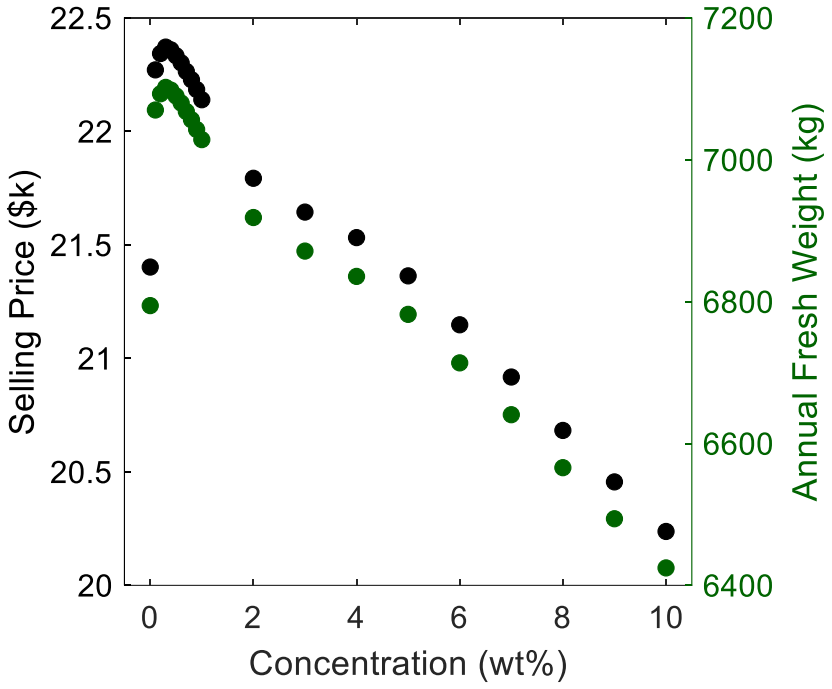


How can we optimize LSC greenhouses to successfully produce crops?

Preliminary Results: LSC Greenhouses in AZ

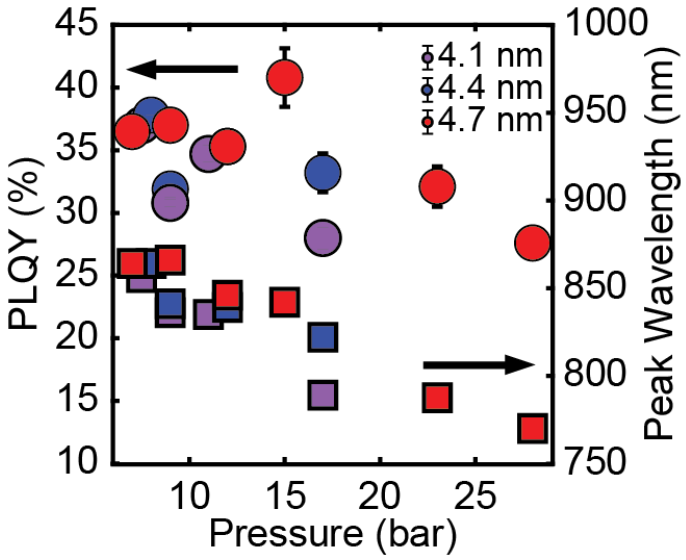


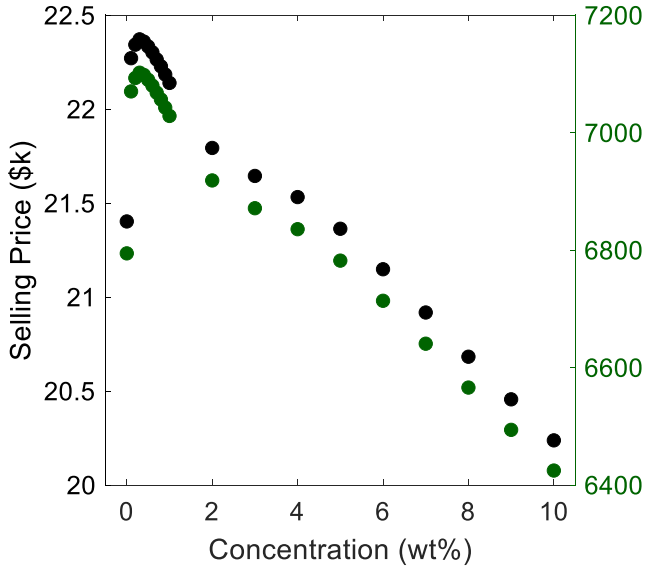


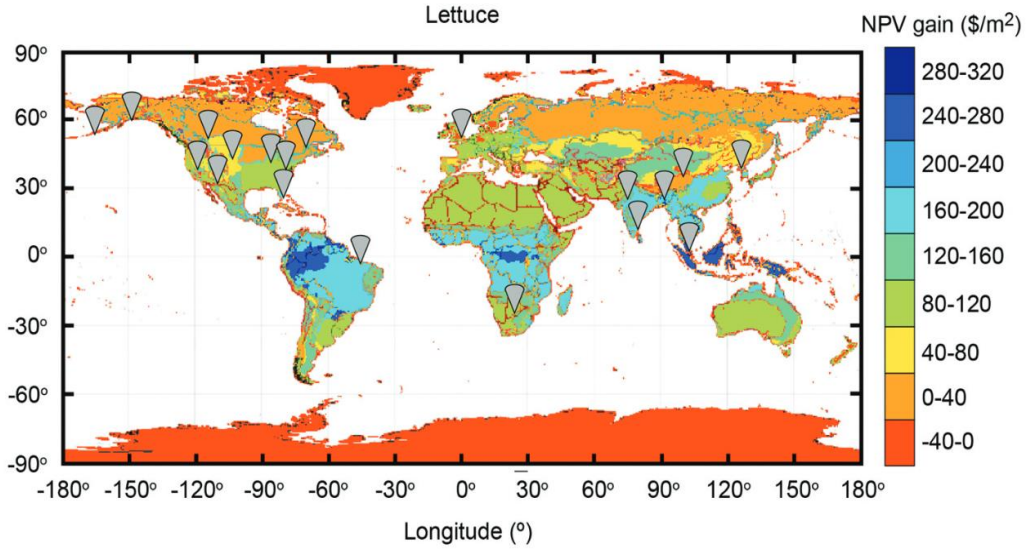


- LSC Greenhouses can supply their own energy demands
- Changing the roof material can influence the transmitted light
- Changes in transmitted light affect plant growth – optimization is possible!

Conclusion and Next Steps







Changing steam pressure can produce stable Si QDs with high PLQY and tunable colors

Si QD LSC Greenhouses can improve crop growth while supplying solar energy

Next steps: where would Si QD LSC greenhouses be most beneficial?

Thank you! Questions?