SOLAR ENERGY AT RICE UNIVERSITY

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Intro

Our Big Questions

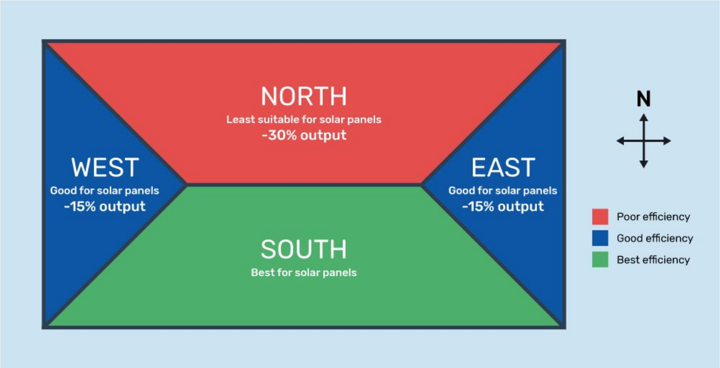
1. Can Rice meet its energy needs through solar energy alone if panels were installed in all viable areas?
2. What other considerations would/would not make this feasible and practical?

Our Approach

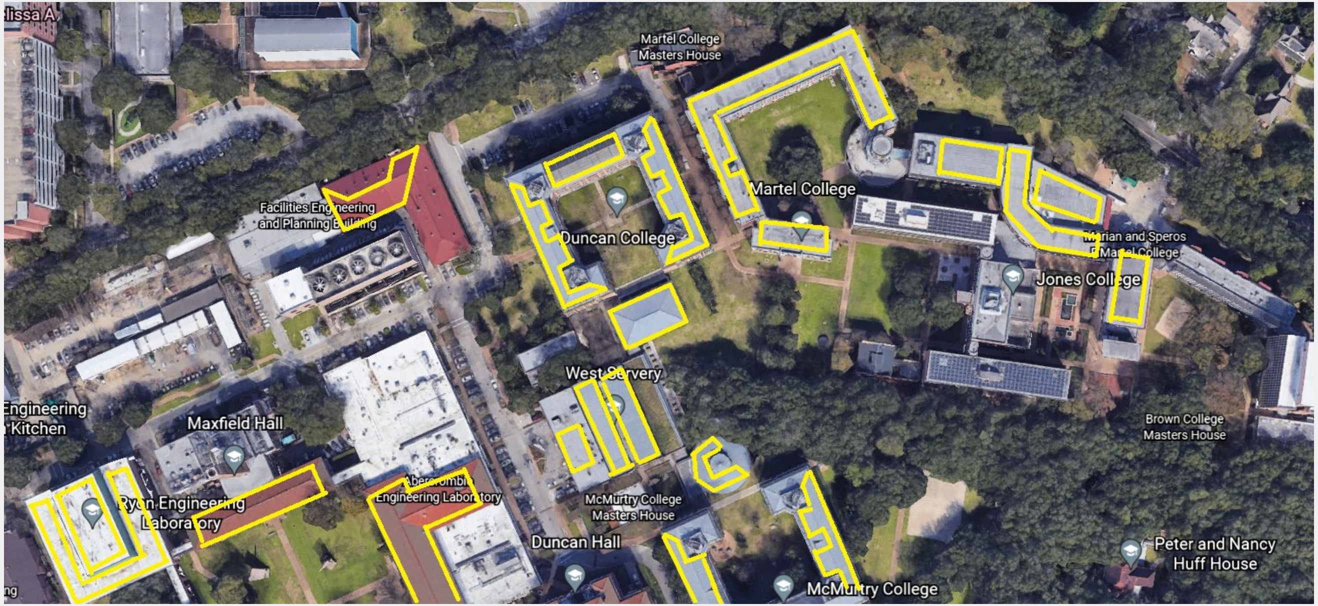
1. Mapped out viable area for solar panel installation
2. PVwatts Calculator by National Renewable Energy Laboratories (NREL) takes weather/solar radiation data, models solar power generation
3. Compared this output to Rice's use

Mapping Out Potential Solar Energy Zones

- Determined whether spaces were suitable for solar power based on following factors:
    - Sun exposure/levels of solar radiation
    - Level of shade
    - Level of cloud cover
    - Direction of solar panels (preferably south-facing)
    - Obstructions (other buildings, treeline cover, etc.)
- Utilized Google Earth to find suitable zones as well as map specific sizes of each potential area
- Ultimately, decided upon using Rice's lots to create large-scale solar canopies as well as roof space



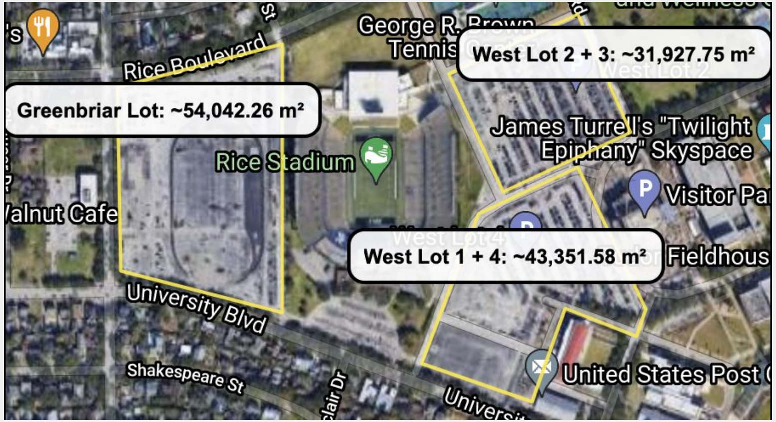
Solar Panel Areas: Roof Space



Ex: Martel College has ~1,991 m² of roof space

Campus Total is **~50,986 m²**

Solar Panel Roofing Areas: Campus Lots



Greenbriar Lot

Space at ~54,000 m^2.

West Lot 2 + 3

Space of at ~32,000 m^2.

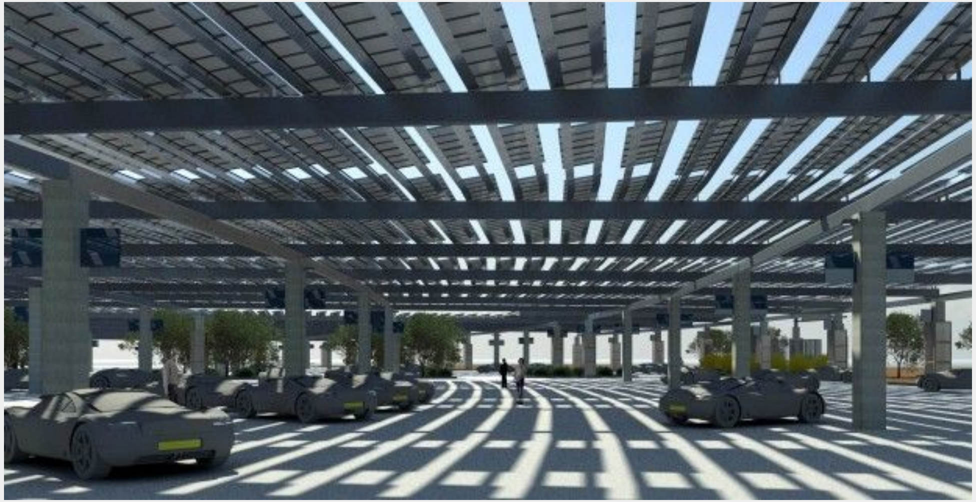
West Lots 1 + 4

Space of ~43,000 m^2.

Total Campus Lot Space: **~129,000 m^2**

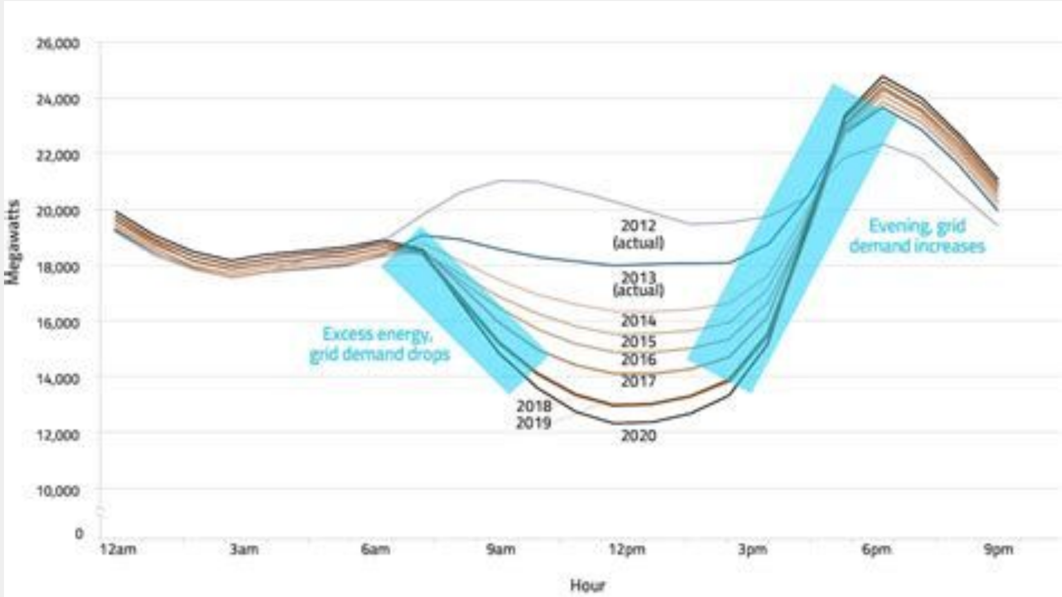
Why Solar Parking Lots ?

- Reduces costs of lighting and operation expenses from other sources on campus
- Helps mitigate substantial peak-hour energy demand created by Rice
- Saves on fuel efficiency for vehicles - Reduced need to use air conditioning in hot Houston weather
- Uses significantly less energy than a lot that relies on a power grid
- Provides increased support for electric vehicles



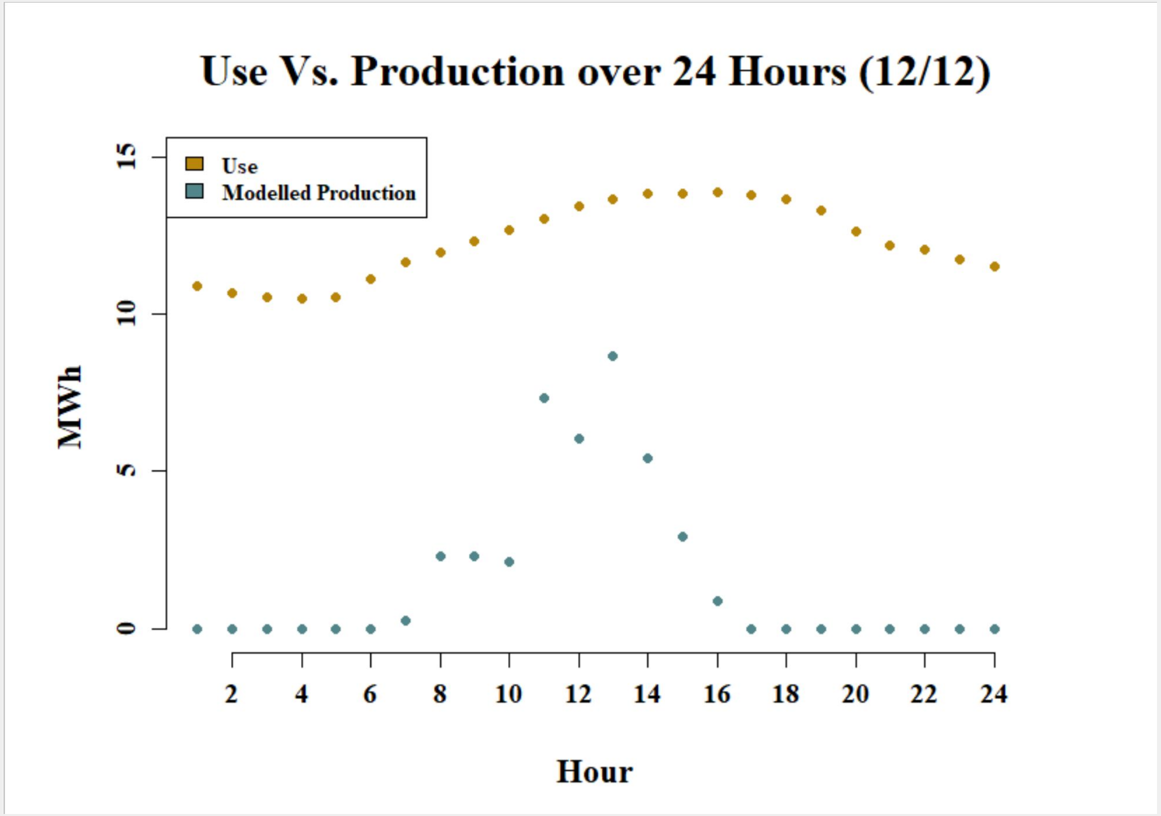
Results

Duck Curve Recap



- Lower demand in the day, with higher production
- Rapid evening demand increase, ramp need

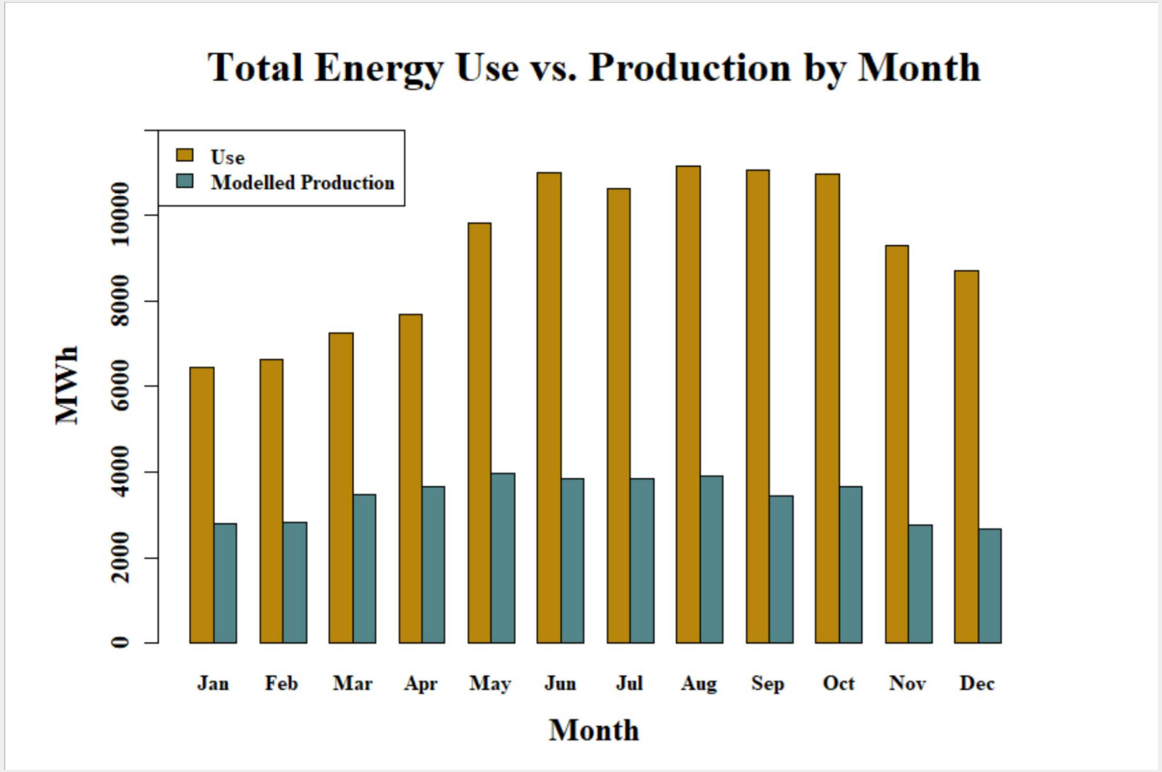
Production vs. Use over 1 Day



-Right now Rice doesn't face a severe Duck Curve

- We would still need storage or other sources to meet daily needs

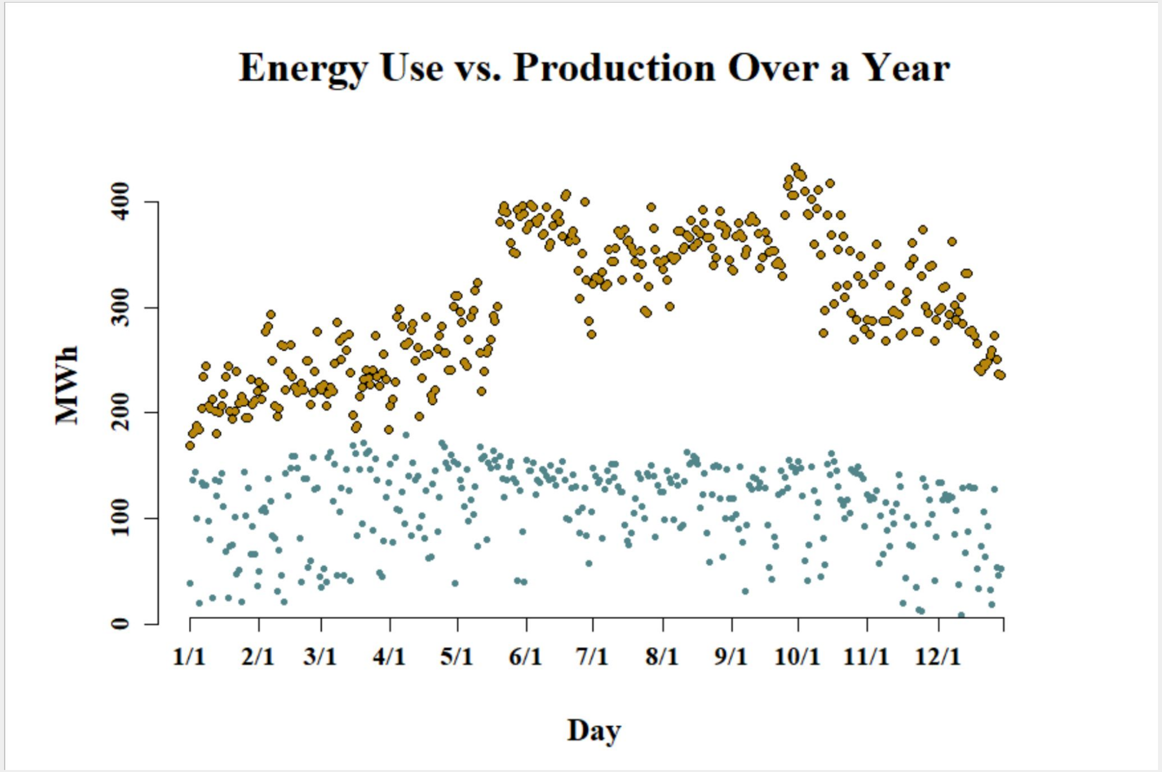
Production vs. Use by Month



-Yellow = Rice's use
- Green = modelled solar production

- Rice would fall far short of its energy needs if only powered by solar

Production vs. Use Over One Year

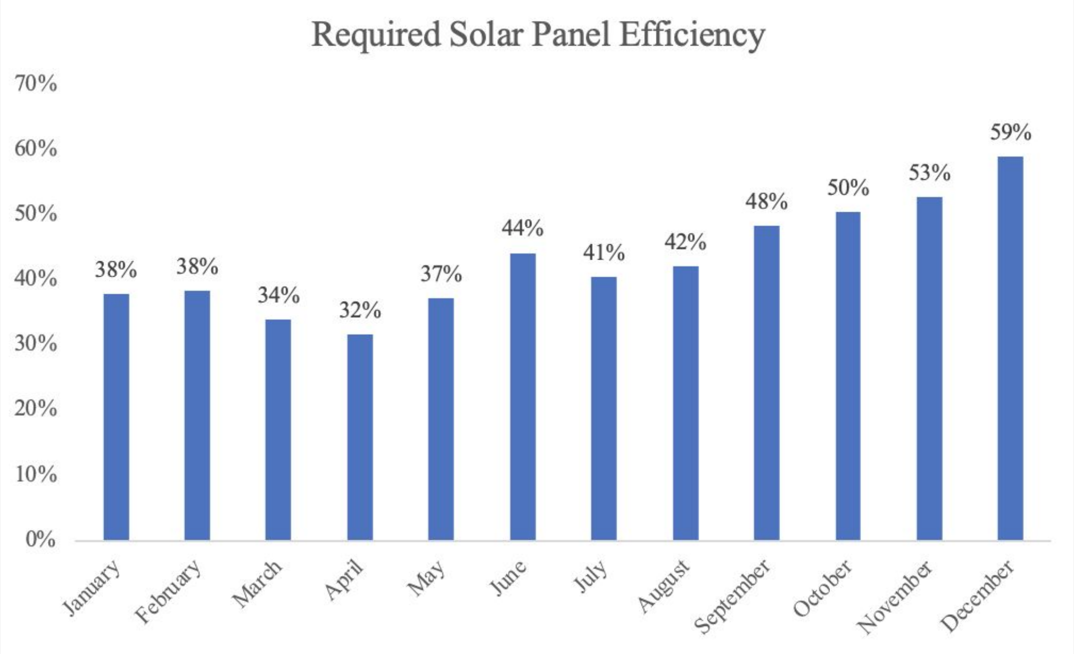


-Yellow = Rice's use
- Green = modelled solar production

Key Takeaway:

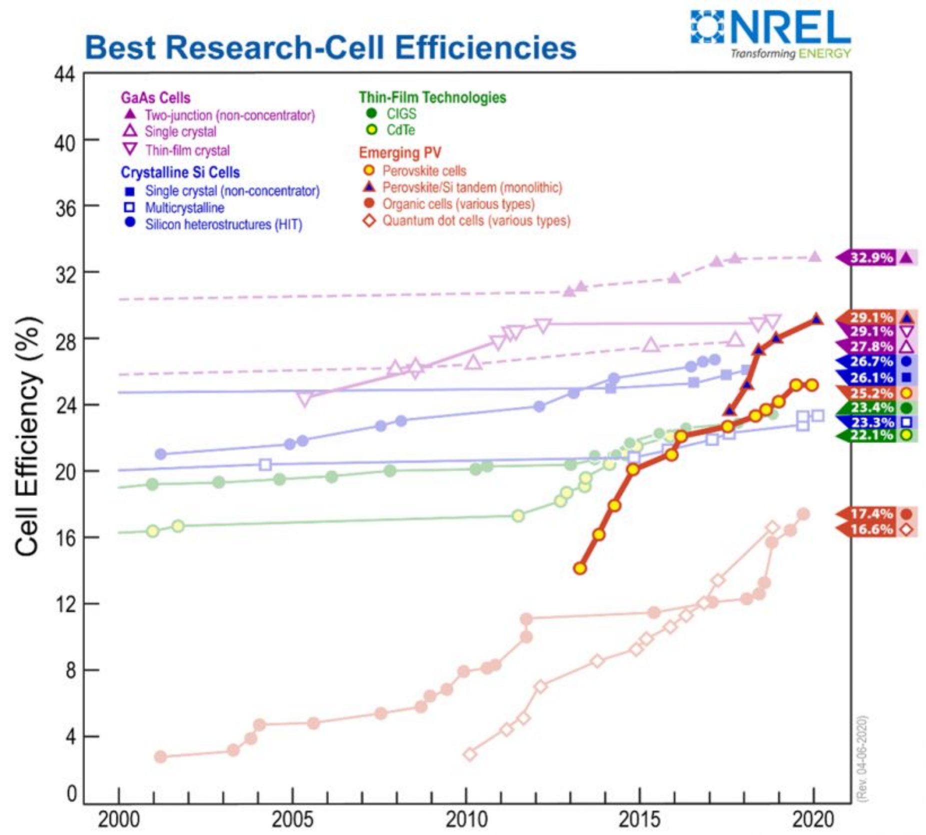
Rice would fall far short of its energy needs if only powered by current solar technology

Required Solar Panel Efficiency



Required solar panel efficiencies:
32%-59%

Required Solar Panel Efficiency



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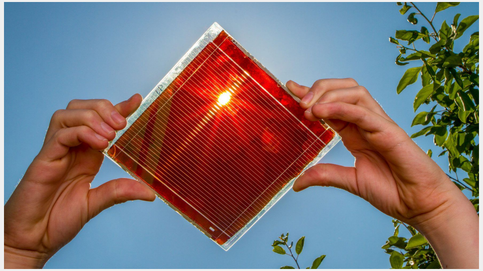
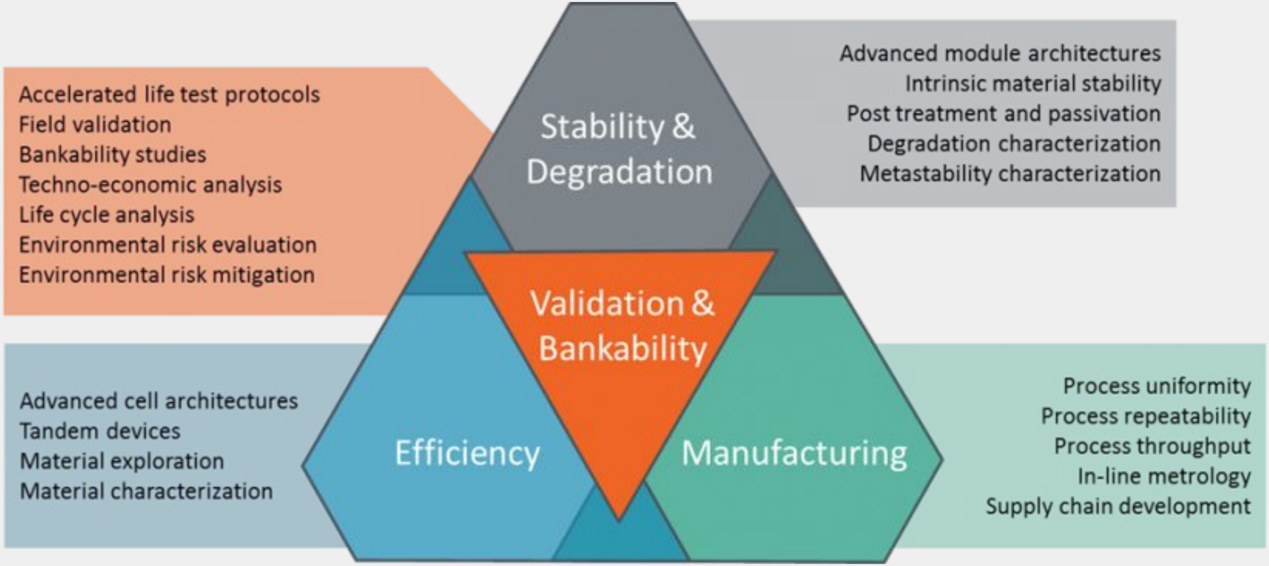
Required Solar Panel Efficiency



Perovskite Cell R&D Challenges:



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Required Solar Panel Efficiency

Key Takeaway:

Rice's energy needs require solar panel efficiencies that are unrealistic in the near future

Cost

The Costs

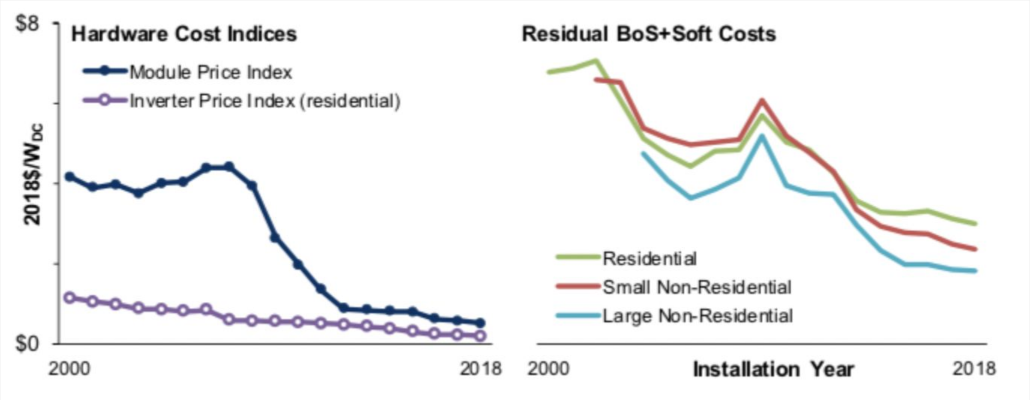
- 19.4 MW car lot solar: $2.40/Watt installed,
- 7.7 MW Rooftop Solar: $2.00/Watt installed
- Total cost: **$62,000,000**
  - Not economically practical

- Solar is growing, new tech is being developed: how might we expect cost to change in the future?

Change of Solar Panel Cost Over Time

- Solar PV prices expected to drop by **34%** by 2030 (BNEF New Energy Outlook 2019)
- By 2050, prices should drop by approximately **63%**,
- Thus, utility-scale PV will cost approximately 2.5 cents per kWh

- From these projections, we can estimate that the total cost of solar panel implementation to be at least **halved** by 2050 (~**$31,000,000**)



Berkeley Lab

Storing Energy

Methods of Storing Energy

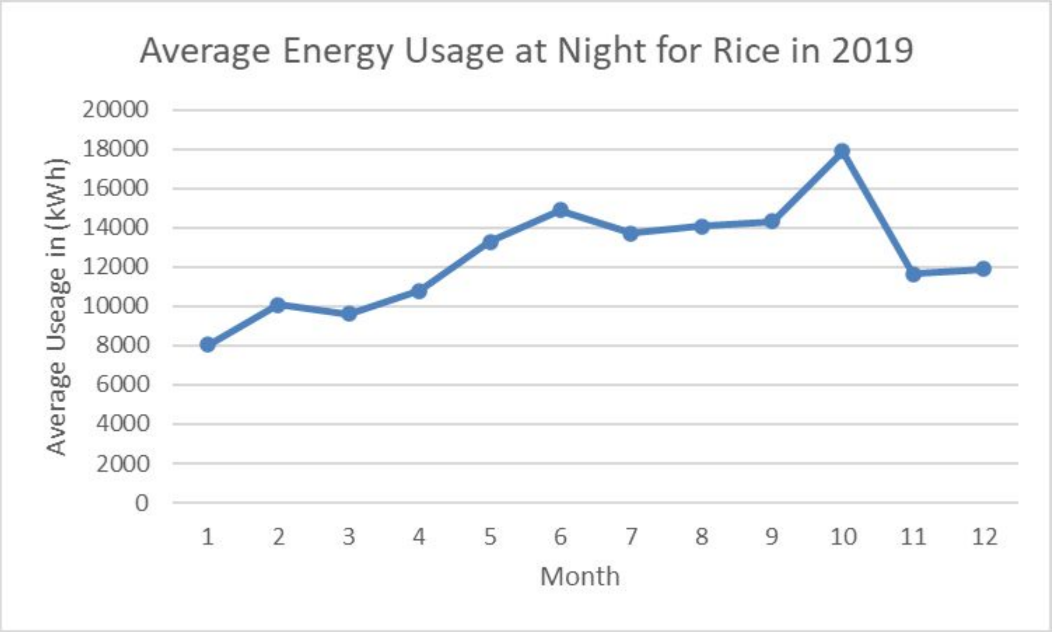
Batteries

Flow Batteries are a common way to store energy and have a lot of room for advancement

Cold Water Storage

Cold water storage is a cheaper way to run air conditioning

The Problem



- This is per hour usage so ideally we need to be able to store 12 times this amount of energy
- This assumes 12 hours of daylight, but this is a high estimate for winter hours
- Need to be able to store between 216,000 and 250,000 kW of energy

Types of Batteries

1. Lithium-ion
2. Flow Batteries

Lithium Ion Battery Chemistry

Advantages

- Lithium-Ion batteries are a type of dry cell battery
- Most energy dense batteries available on the market (150 watts/ kg)
- Can handle the most charge discharge cycles for dry cell batteries

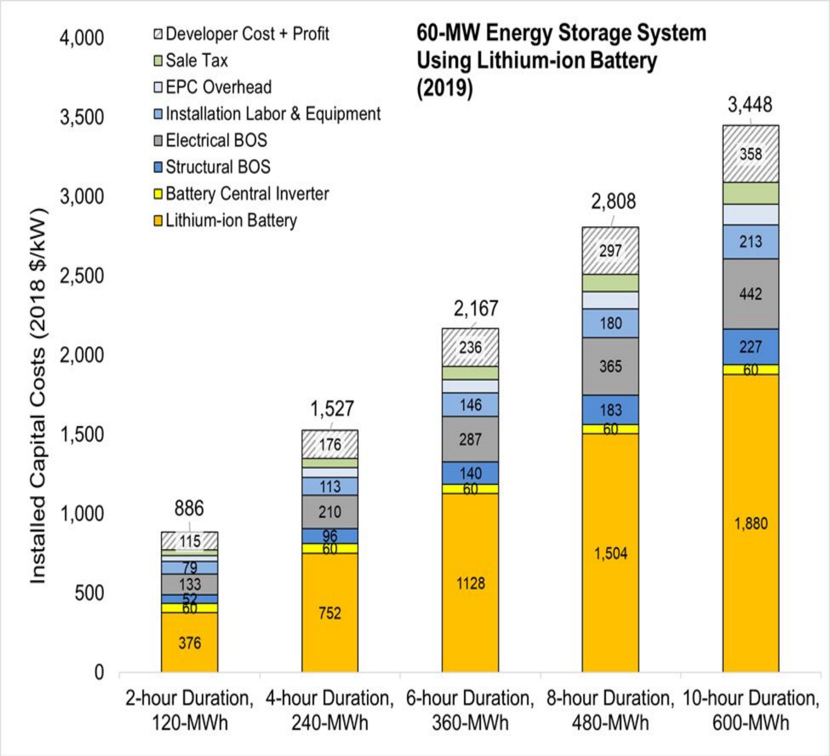
Disadvantages

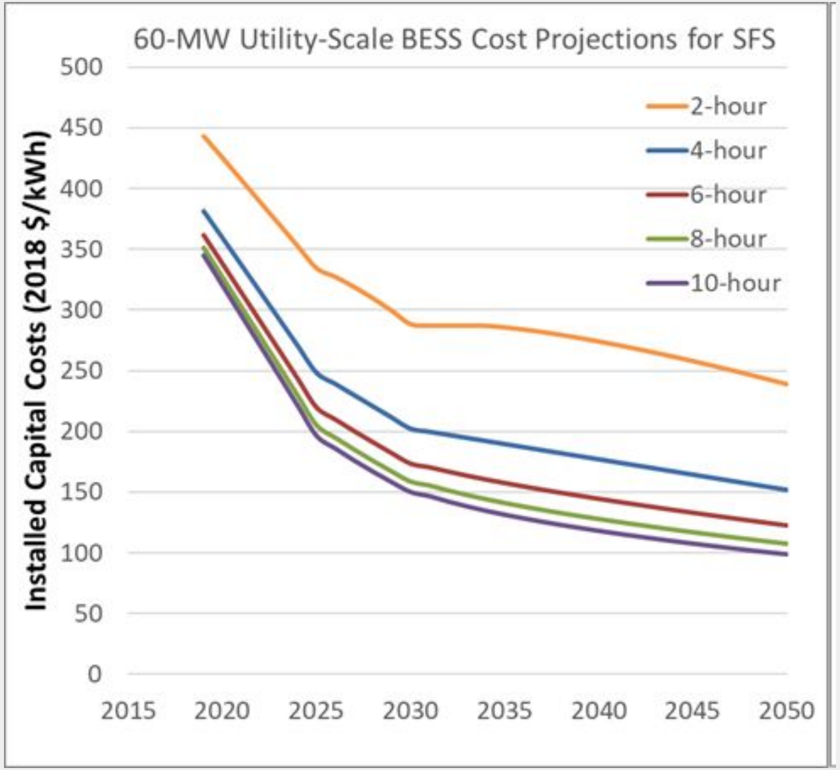
- Degrade within 8 years
- Can't be fully discharged or they will be ruined
- Batteries get hot easily and if the membrane that separates the ions gets punctured, the electrolyte can catch fire

Implementing Lithium Ion Batteries

- With 150 watts/kg , need 200 metric tons worth of pure battery storage
- Need to add on computer that monitors the temperature, sensors that monitor voltage, and a voltage tap for each cell
- Must be kept at 59 degrees

Cost of Lithium-Ion Batteries





NREL

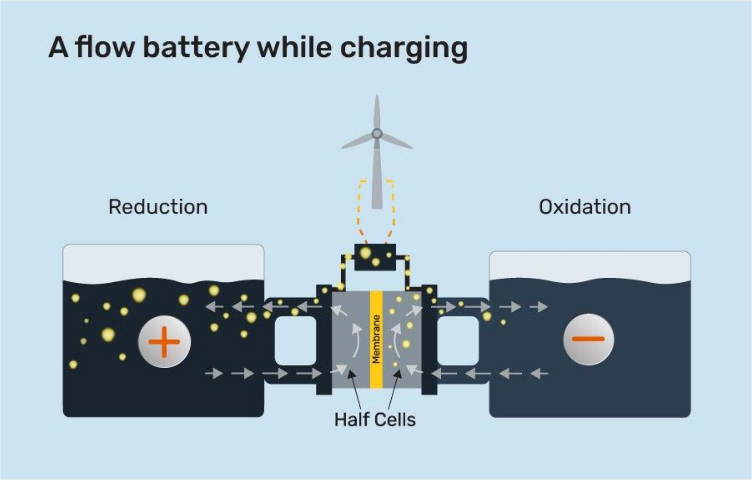
Flow Battery Chemistry

Advantages

- Long Lifespan (up to 30 years right now)
- They can be discharged over spans of 10 or more hours

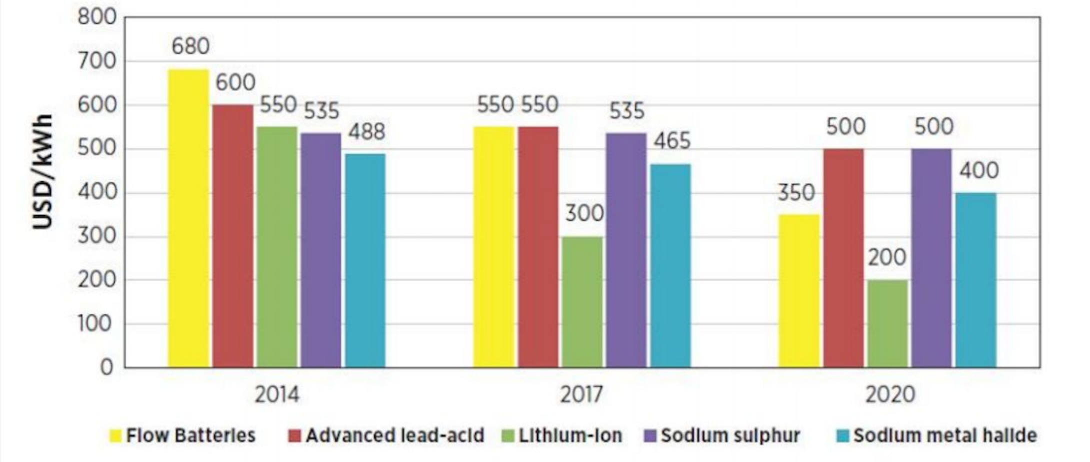
Disadvantages

- Energy less dense
- Naturally require a large surface area for oxidation and reduction to occur



Cost of Flow Batteries

- Cost ends up being higher than Lithium-Ion Batteries with current technology
  - -No large scale industry production for flow batteries
- $367 kWh based on current technology
- Vanadium costs about 2 cents per kWh but quinone costs ¼ cent per kWh



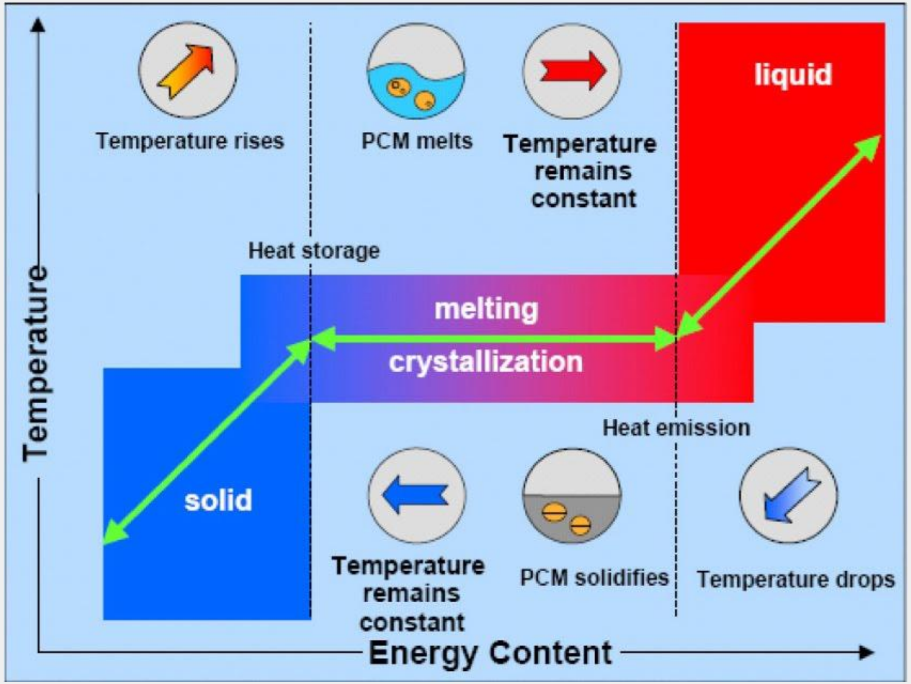
AECOM

Cold Water Storage

- Cold Water Storage for a very different problem
- Cold Water can be stored during times of low energy demand
- Used during times of high energy demand
- Dampens the duck curve

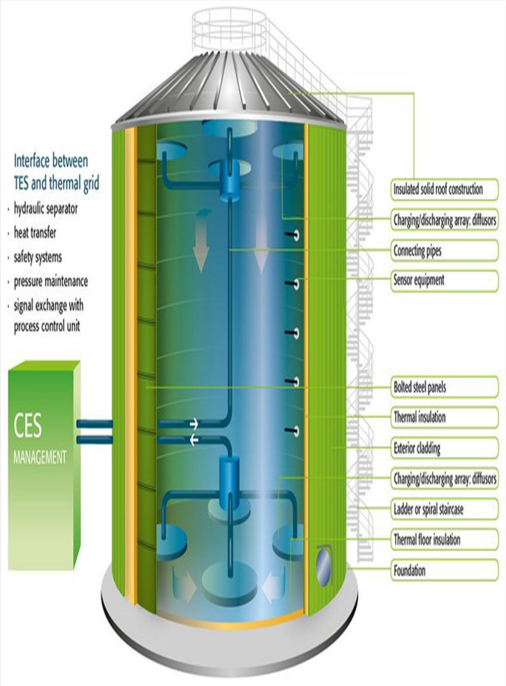
Cold Water Storage

- Cold Water Storage (12 kWh/m^3)
- Ice (73 kWh/m^3)
- PCM Storage (25-70 kWh/m^3)



Cold Water Storage Costs

- Ice storage had most available data
- Lifespan of 50 years
- $203/ kWh



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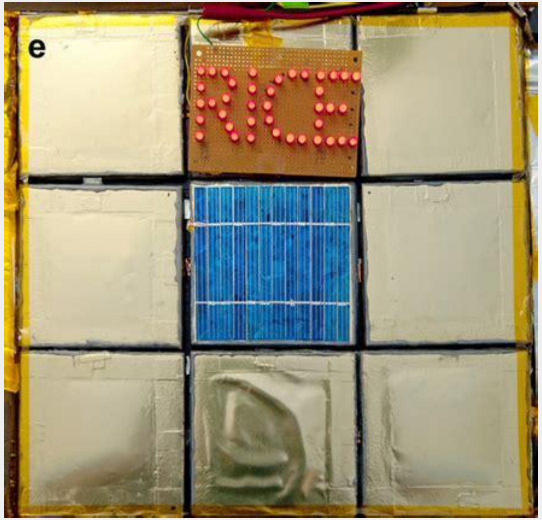
Conclusions

- Lithium-ion batteries are the most viable right now
- Solar enthusiasts are optimistic about flow-batteries



Maintenance

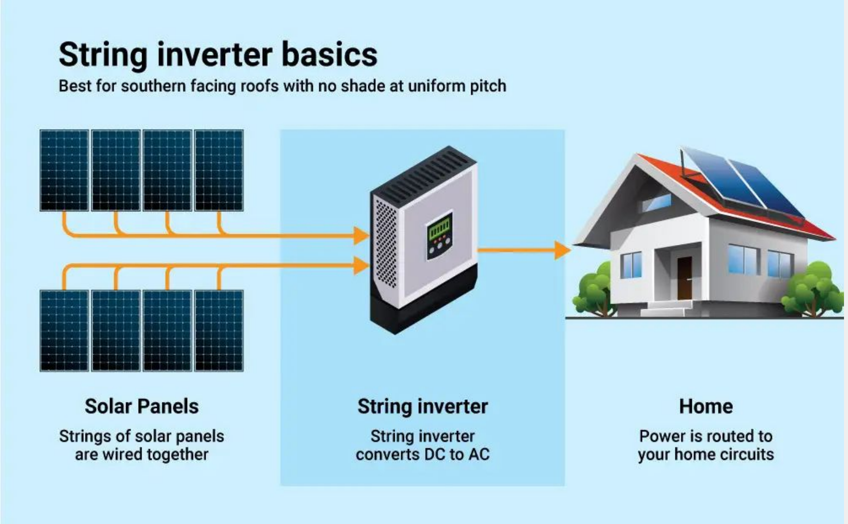
Solar Panels Require Little Maintenance

- Debris is cleared by rainfall
- Light cleaning 2-4 times a year
- Rice could just expand current cleaning arrangements
- Common Repairs ~$100 per hour

https://www.solarreviews.com/blog/solar-panel-maintenance-everything-you-need-to-know

Unexpected Damages

- Structurally strong, but can be damaged by weather
- Inverter malfunctions
  - ~$2,000 to replace a string inverter, ~$300 to replace a micro inverter



https://www.sunnova.com/watts-up/most-common-solar-maintenance

Unexpected Damages

- Arc faults - heat from high electricity discharge breaks down wires
    - Panels have protection against this - fault mode
- Wiring damage
    - May need to replace the whole panel
- Replacements
    - Cost varies by location, roof grade, panel type
    - Roof panels cost more to replace/repair than ground panels

https://www.paradisesolarenergy.com/blog/the-cost-and-frequency-of-solar-maintenance

Conclusion

Our Big Questions

1. Can Rice meet its energy needs through solar energy alone if panels were installed in all viable areas?
2. What other considerations would/would not make this feasible and practical?

Key Takeaways

- Rice would fall far short of its energy needs if only powered by solar
- Rice's energy needs require solar panel efficiencies that are unrealistic in the near future
- Other considerations further support the idea that it would be unrealistic to depend on solar alone

Thank You!

Sources

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How Cheap Can Energy Storage Get? Pretty Darn Cheap – Ramez Naam

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Will Solar Panels get Cheaper?’

Factors that Affect Solar Panel Efficiency

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