Technical Feasibility of Storage on Large Dish Stirling Systems

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CONCENTRATING SOLAR POWER: SYSTEMS

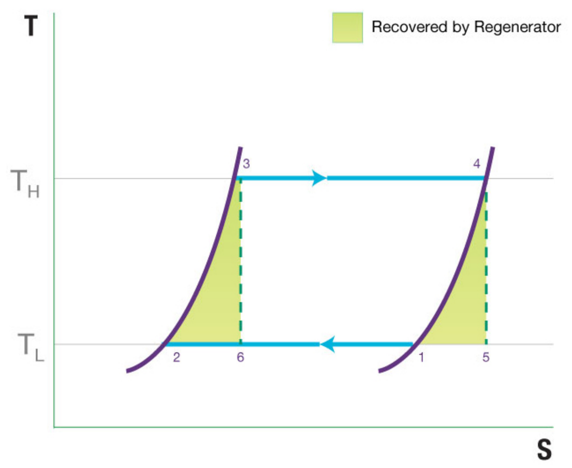
Introduction & Background

Concept

Adding up to 6 hours of storage to high-performance dish-Stirling systems has the potential to increase performance, improve capacity, and enhance interest, making dish-Stirling systems a leading candidate to meet SunShot goals

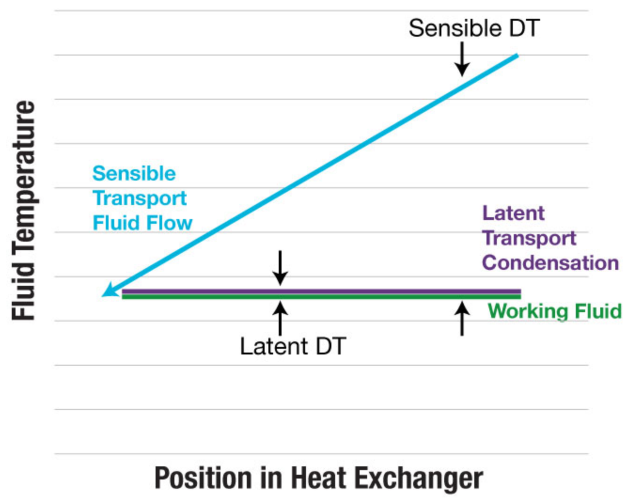
Why dish-Stirling?

- Demonstrated over 31% sun-to-grid, 26% annual
- High temperature, high concentration systems
- Highest efficiency thermodynamic cycle
- 6¢-8¢/kWh attainable with engineering and supply chain



Latent heat transport and storage

- Isothermal input to engine
- Best match to isothermal transport, isothermal storage
- High exergy efficiency
- Isothermal transport has additional demonstrated system performance improvements
- 10-20% system performance boost
- Independent optimization of receiver, storage, engine
- Heat pipe is a "thermal transformer"
- First- and second-law improvements over existing systems



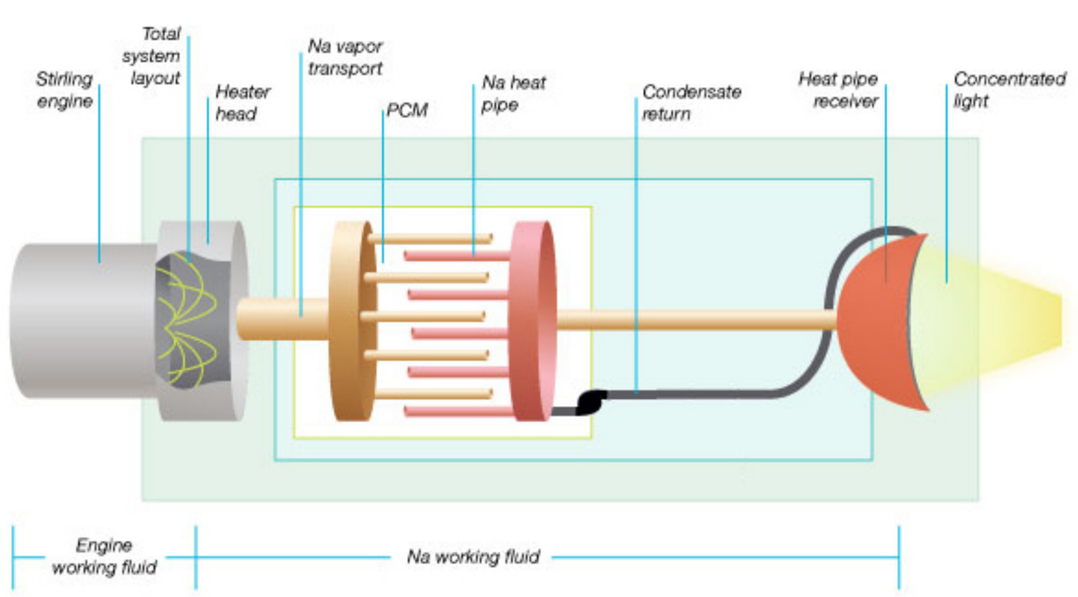
System Level Model

System layout

- Two heat pipes in series
- Metallic PCM storage

Field-level model

- Dish-to-dish shading
- Annual meteorological data (15-minute)



Financial model

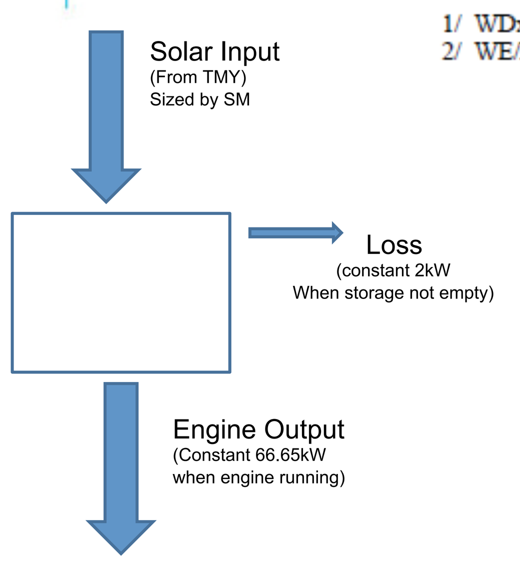
- Calculate LCOE based on 7.42% FCR
- Calculate "profit" based on SCE TOD
- Adjust dish and field size proportional to solar multiple
- Fixed and variable cost of storage
  - $3k/dish fixed
  - $20/kWhth variable with storage size
- System cost set to $2/W

Season	Period	Definition	Factor
Summer June 1 - September 30	On-Peak	WDxH[1], noon-6 pm	3.13
	Mid-Peak	WDxH, 8-noon, 6-11 pm	1.35
	Off-Peak	All other times	0.75
Winter October 1 - May 31	Mid-Peak	WDxH, 8 am-9 pm	1.00
	Off-Peak	WDxH, 6-8 am, 9 pm-midnight; WE/H[2] 6 am-midnight	0.83
	Super-Off-Peak	Midnight-6 am	0.61

1/ WDxH is defined as weekdays except holidays
2/ WE/H is defined as weekends and holidays

Storage accumulator model

- Thermal input from met data
- Thermal output when engine running
- Shed energy when full (lost)
- Input and output based on measured system data with heat pipe receiver



Model inputs exercised

- Size of storage
- Solar multiple
- Control modes

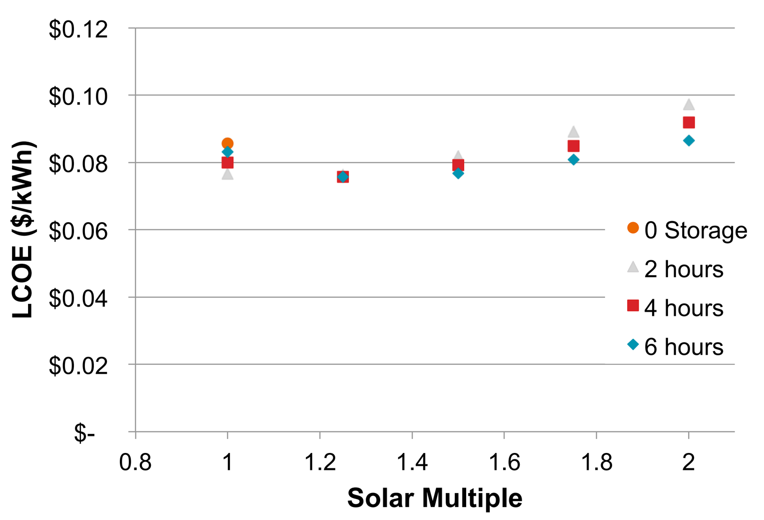
Model Results

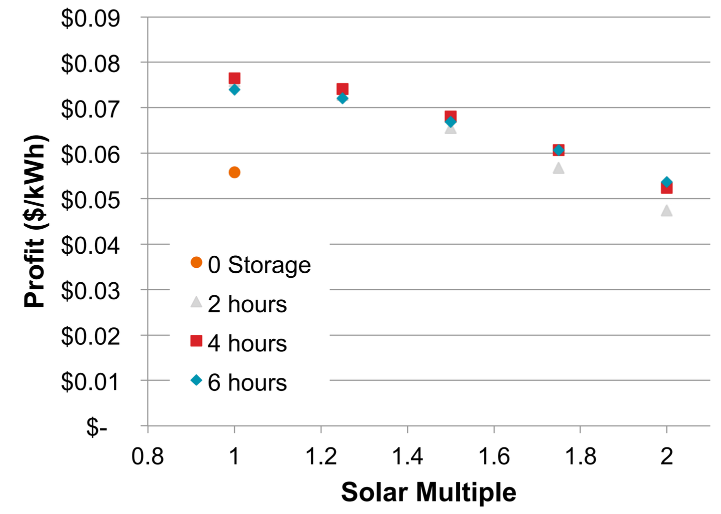
Clear financial benefit

- About 1¢/kWh LCOE
- 2 ¢/kWh profit, due to TOD mapping

Clear optimum in Solar Multiple at 1.25 for cases studied

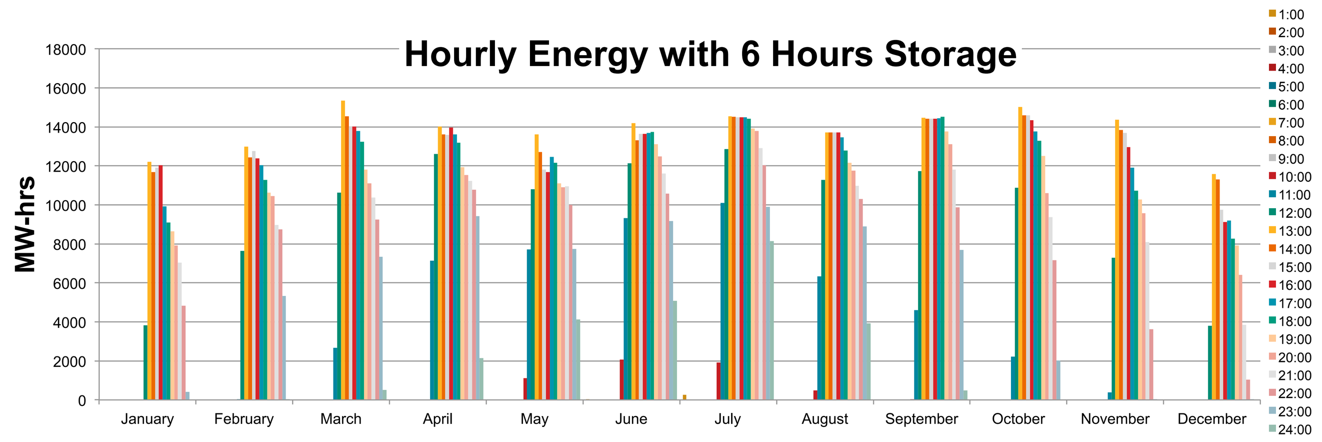
- Greater storage improves LCOE to a point
- Better amortization of equipment costs
- Too much storage cannot be consistently used

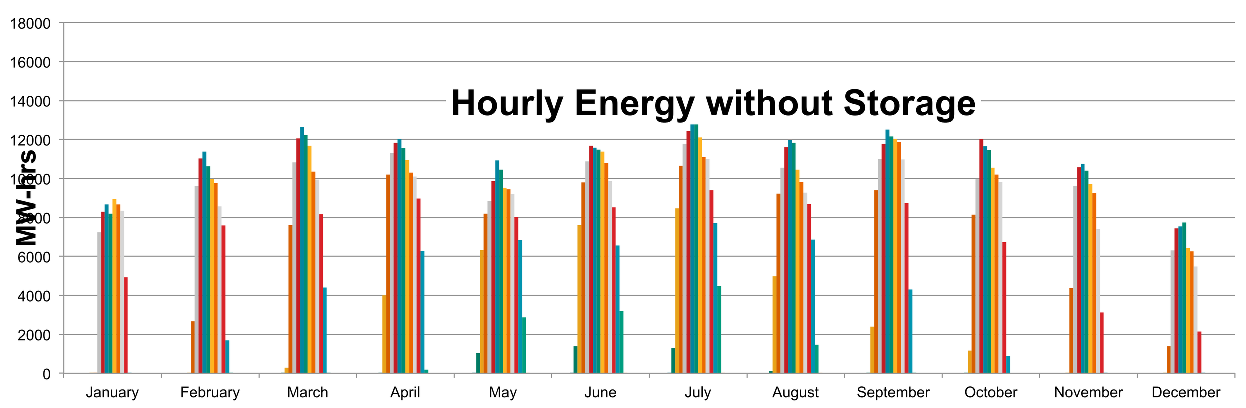




Substantial shift into evening hours

- Maximized lucrative summer PM hours
- Generation to midnight in summer

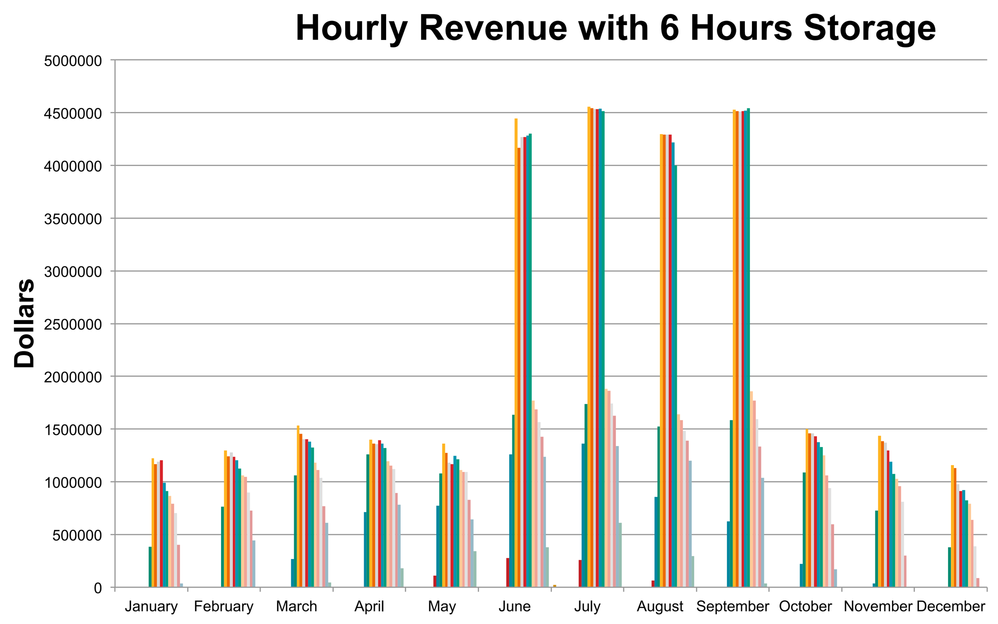




Total energy increase

- Greater collection area (solar multiple)
- Higher efficiency (always at design point of engine)

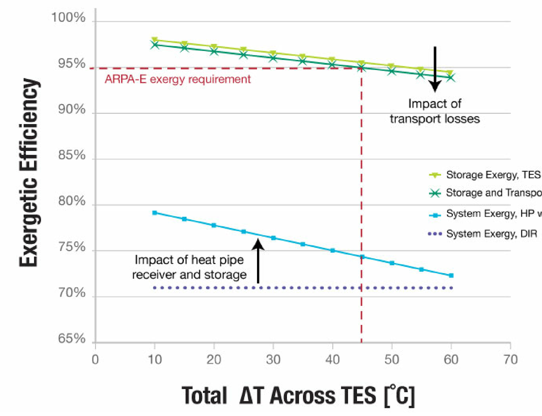
Summer afternoon critical to profit



Summary and Future Work

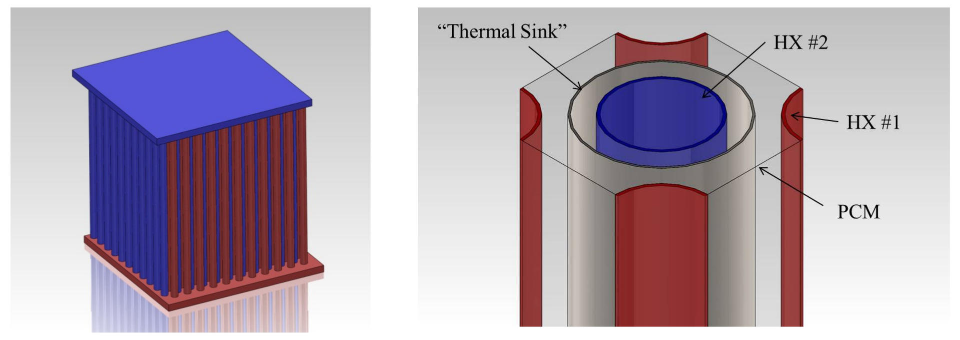
Key findings

- Dish storage can improve LCOE and Profit
- Receiver and engine performance improves
- Full utilization of summer peaks
- Amortize system costs over more energy
- Storage size and solar multiple feasible
- Cloudy days are not overcome by storage
- Design and control strategies must account for profit, TOD pricing, capacity payments, and transmission requirements

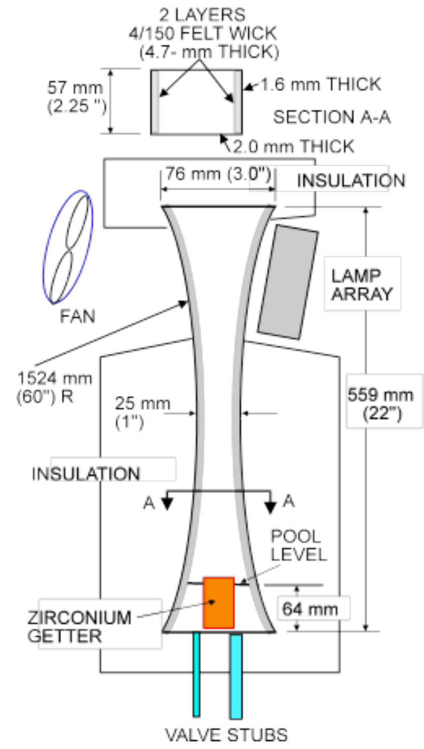


Path forward

- Demonstration of key hardware components
- High performance heat pipe receivers
- High conductivity PCM thermal storage
- Materials compatibility and durability
- Integration with leading dish systems
- Optimize PCM interface design



PCM Interface Modeling



Bench-scale heat pipe durability test rig

SunShot U.S. Department of Energy

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