



# Novel Binderjet Additive HXs

## *A Pathway to 5¢/kWh CSP*

September 20, 2021

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# Acknowledgments

The authors wish to acknowledge the work of the following individuals, without which this research would not be possible:

John Morrison  
Bill Alberts  
Will Navojosky  
Pong Chan

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technology Office (SETO) Award Number DE-EE0008737.

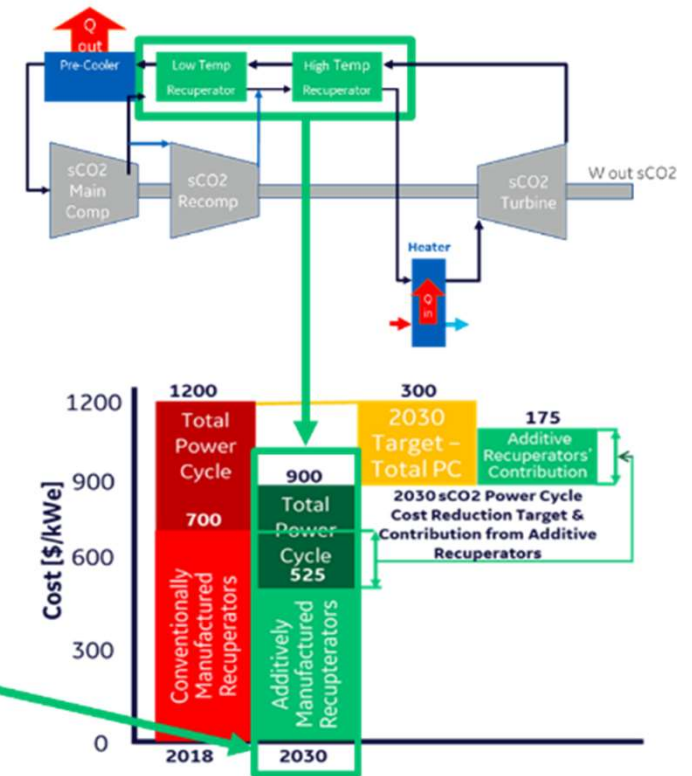
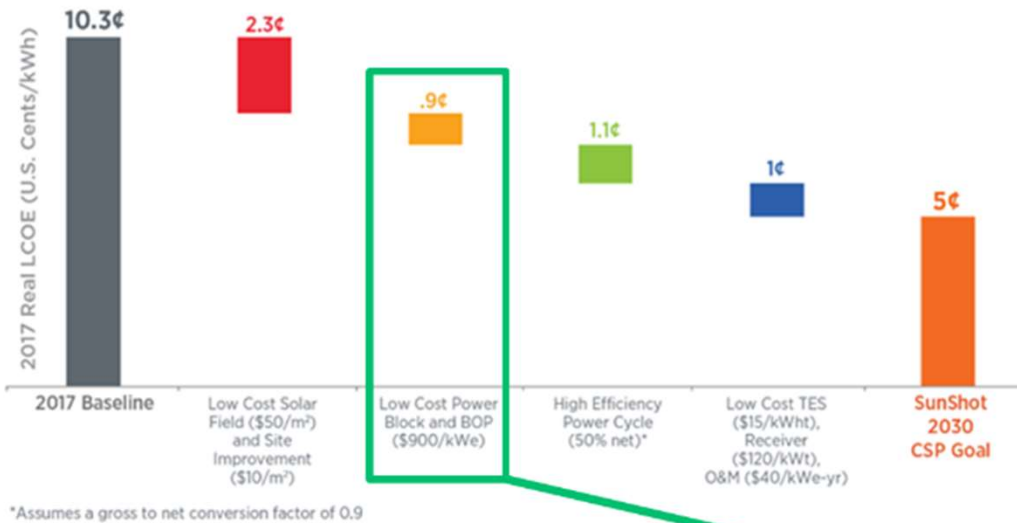
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# Heat Exchangers: CSP Power Cycle Cost Driver

sCO<sub>2</sub> Recompression Cycle: Recuperators dominate the cost

A Pathway To 5 Cents per kWh for Baseload CSP

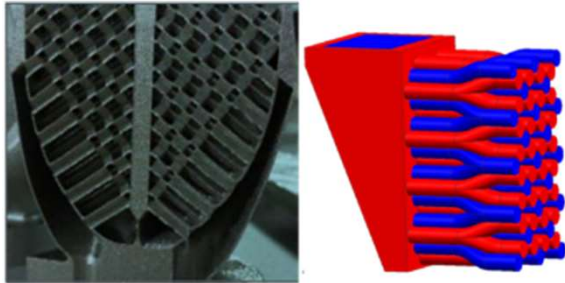


A proposed path towards \$0.05/kW-h from CSP [DOE/EERE, 2018]  
**Binderjet HX's reduce Power Block Cost**

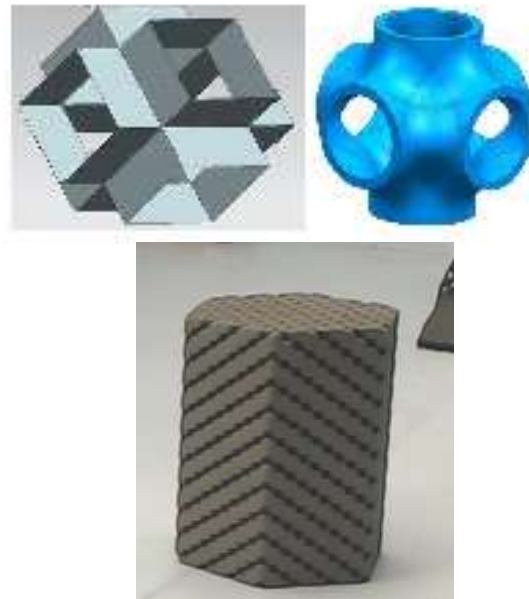


# Complex Design: A Challenge for Binderjet

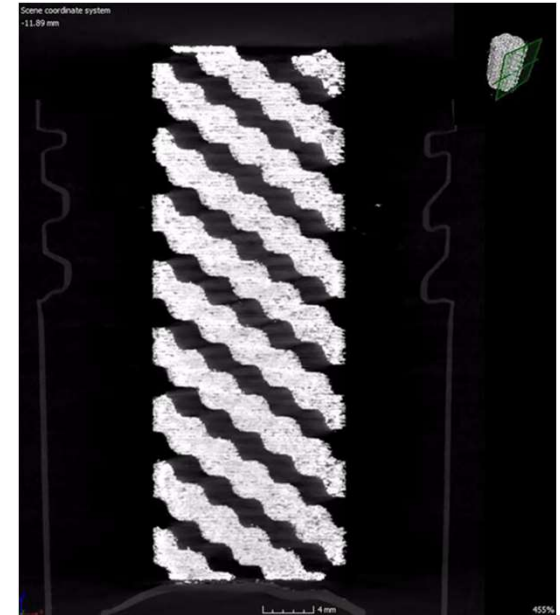
Planar Trifurcating  
HX core geometry



From Planar to curved Unit Cell:  
reduces stress >50%



Multiple small internal passages  
& powder removal



## Trifurcating flow channels

Boundary layer resets at every 1-3  $D_h$

**3x** HTC laminar flow

**1.2-1.3x** HTC turbulent flow

Massively parallel flow paths

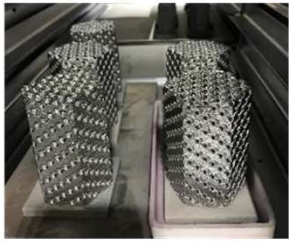
Core geometry extends into manifold



# Binderjet Process & Advantages

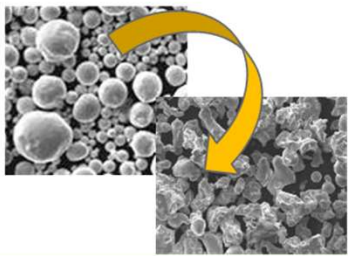
## High Throughput

- Faster print speeds compared to powder bed fusion;
- Batch processing.

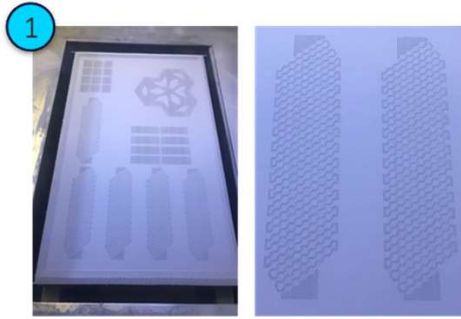


## Lower Cost Print Process (\$/cc)

- Gas atomized → water atomized powder;



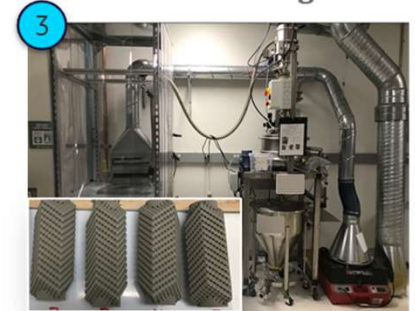
## 1 Binder Jet Print



## 2 Binder Curing



## 3 De-Powdering



## 6 Finished Part



## 5 Heat Treatment (Optional)

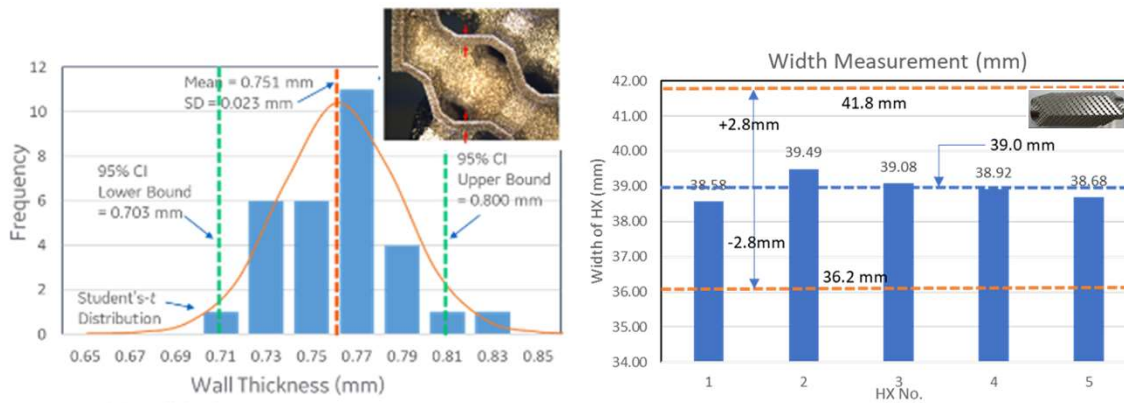


## 4 Debind & Sintering



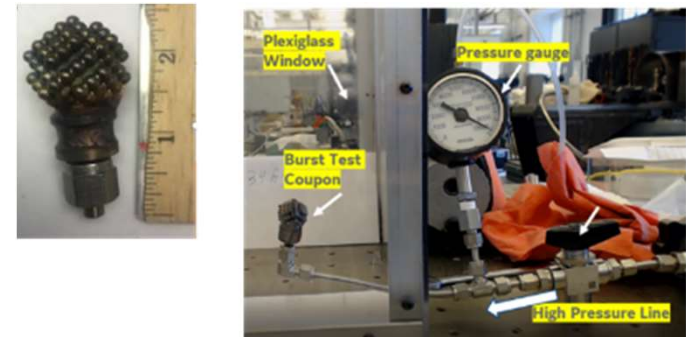
# Builds demonstrate control and high quality

## Dimensional control



- At 0.75 mm, wall thickness within target range of  $\pm 0.2$ mm
- Hole diameters within  $\pm 0.25$  mm
- Overall dimensions within target within  $\pm 5$  mm

## Burst pressure

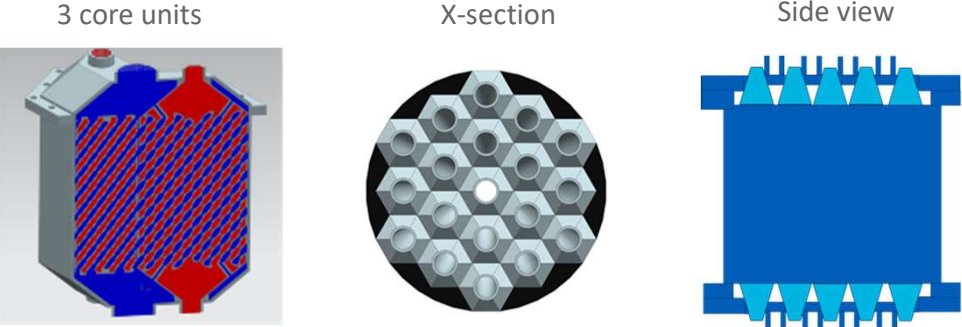


- Core sections subjected to high pressure on one side
- Successful demo of pressure sustainability @ 10,000 psi

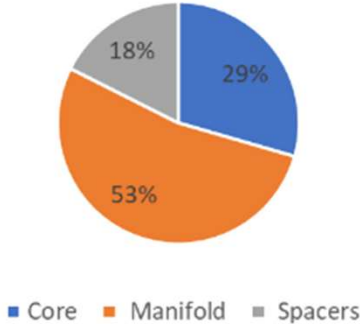


# Modular HX Concept & Cost Breakdown

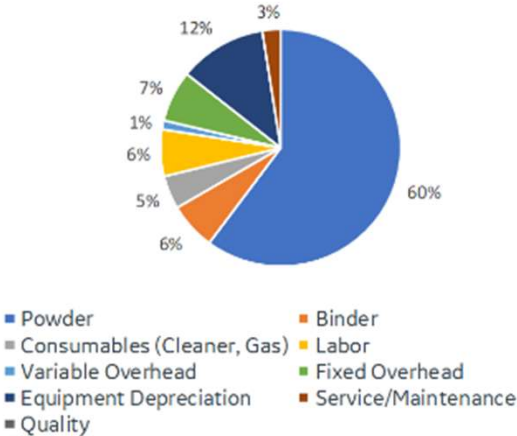
Concept for Full Size Heat Exchanger  
 Binderjet HX Cores Combined into Modular Units



Total HX Cost



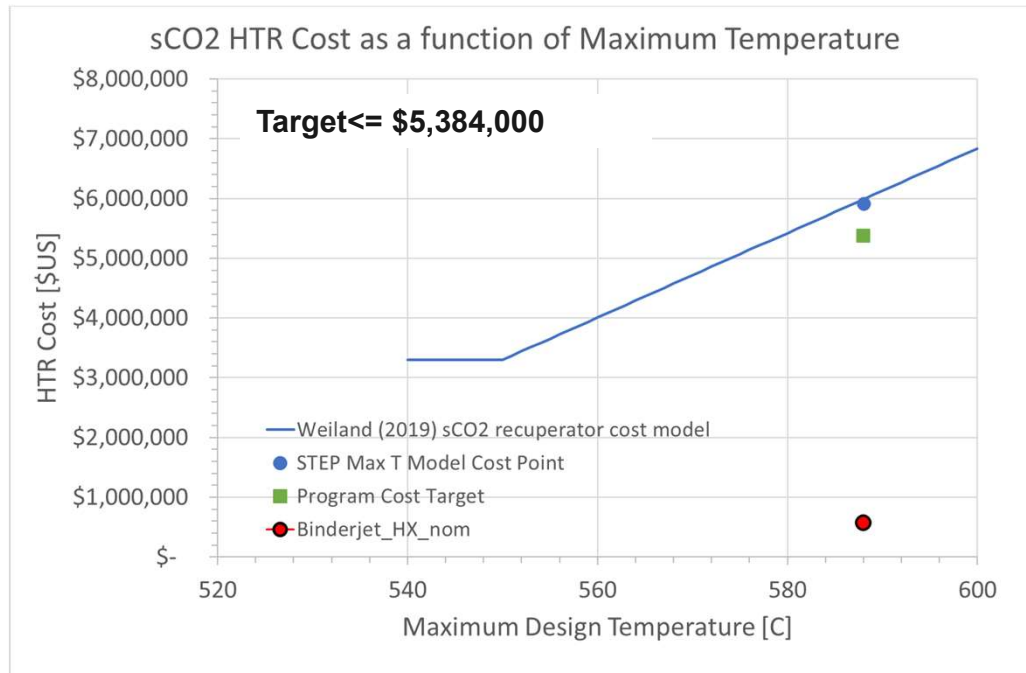
Core cost breakdown



Powder cost is a significant cost driver



# Cost Target < 90% Weiland Model



## Cost estimates well within target

Estimate does not include assembly and inspection but have significant margin

## Additional cost reduction potential

- HX core size & build orientation
- Modular HX design
- Power cost etc.





# Summary

- CSP sCO<sub>2</sub> Power Cycle Cost is limited by Recuperator Cost
- Binderjet – Technology with High Throughput and Low Cost
- **Complex Core Geometry** – Successful builds using Binderjet demonstrated *within targets and tolerances*
- **HX cost within targets** with potential for additional reduction

