Analyzing the Performance of Low-Quality Graphite for High-Temperature Thermal Storage

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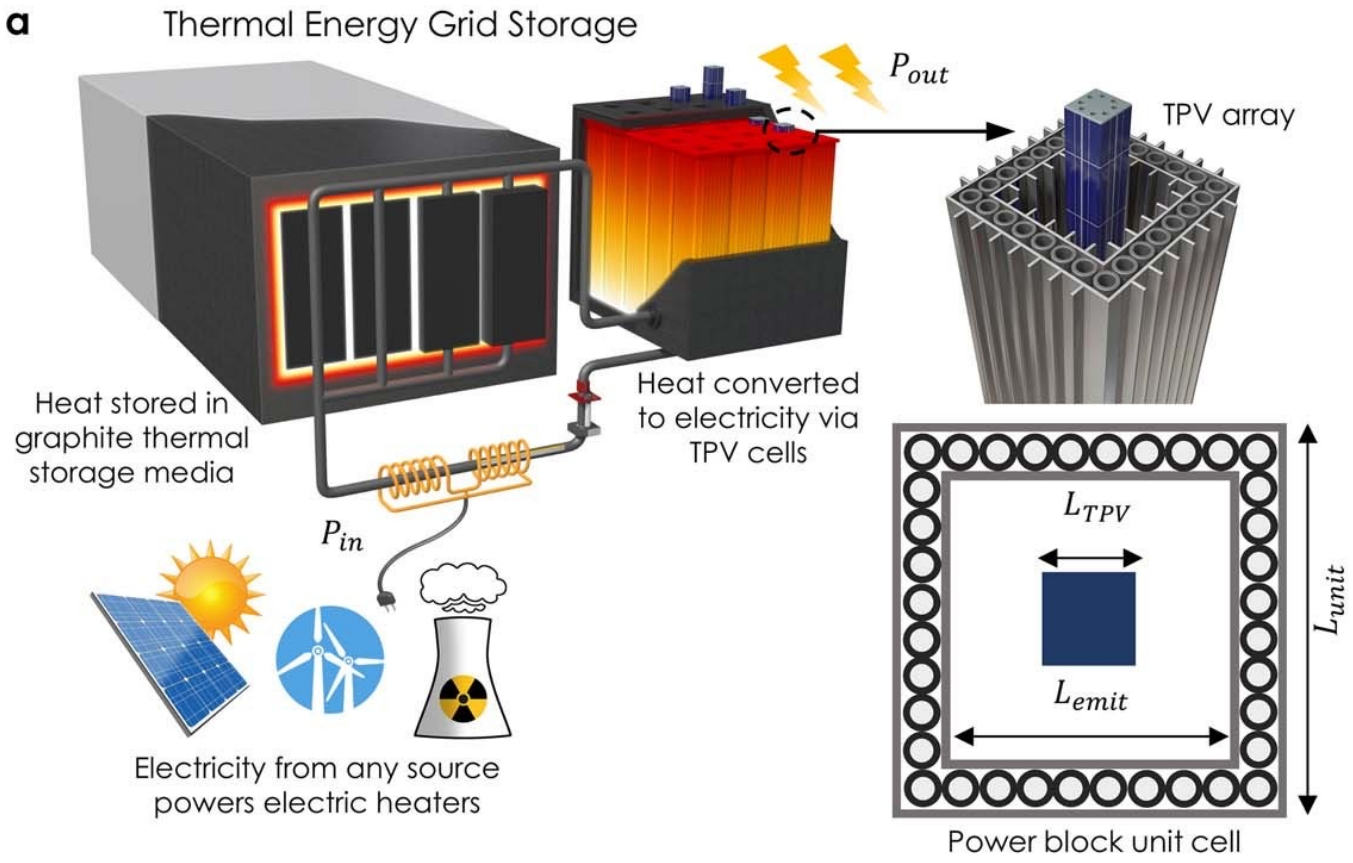
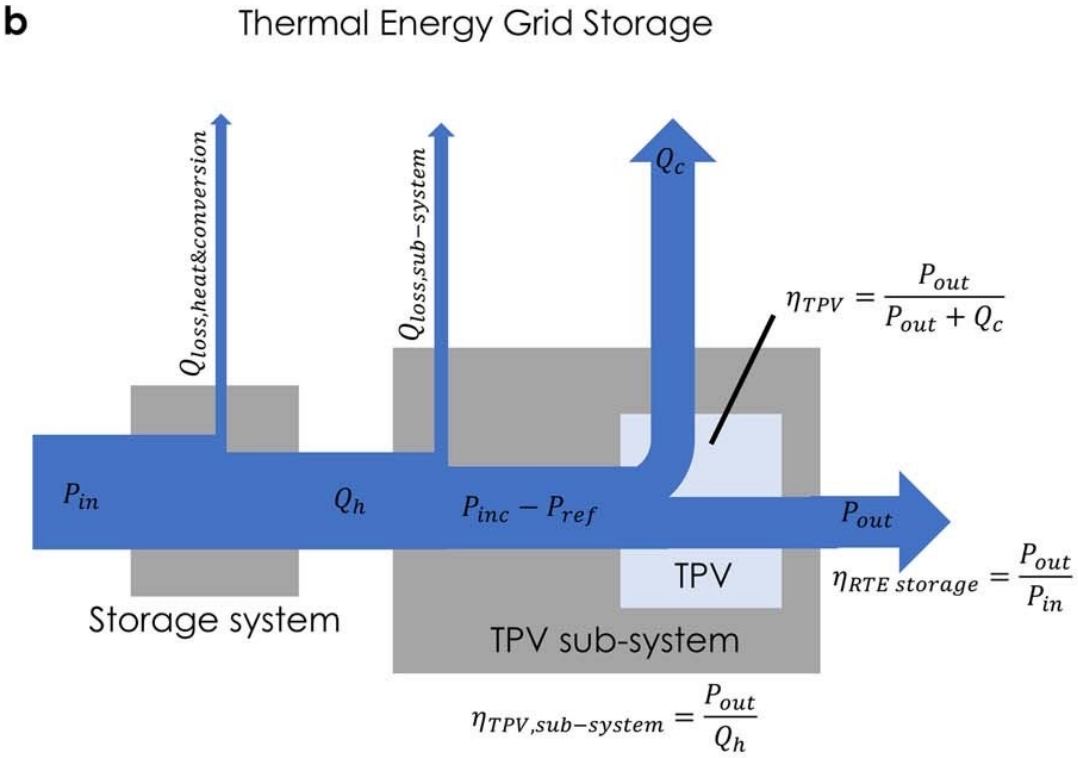
Massachusetts Institute of Technology

Thermal Energy Grid Storage (TEGS) Overview



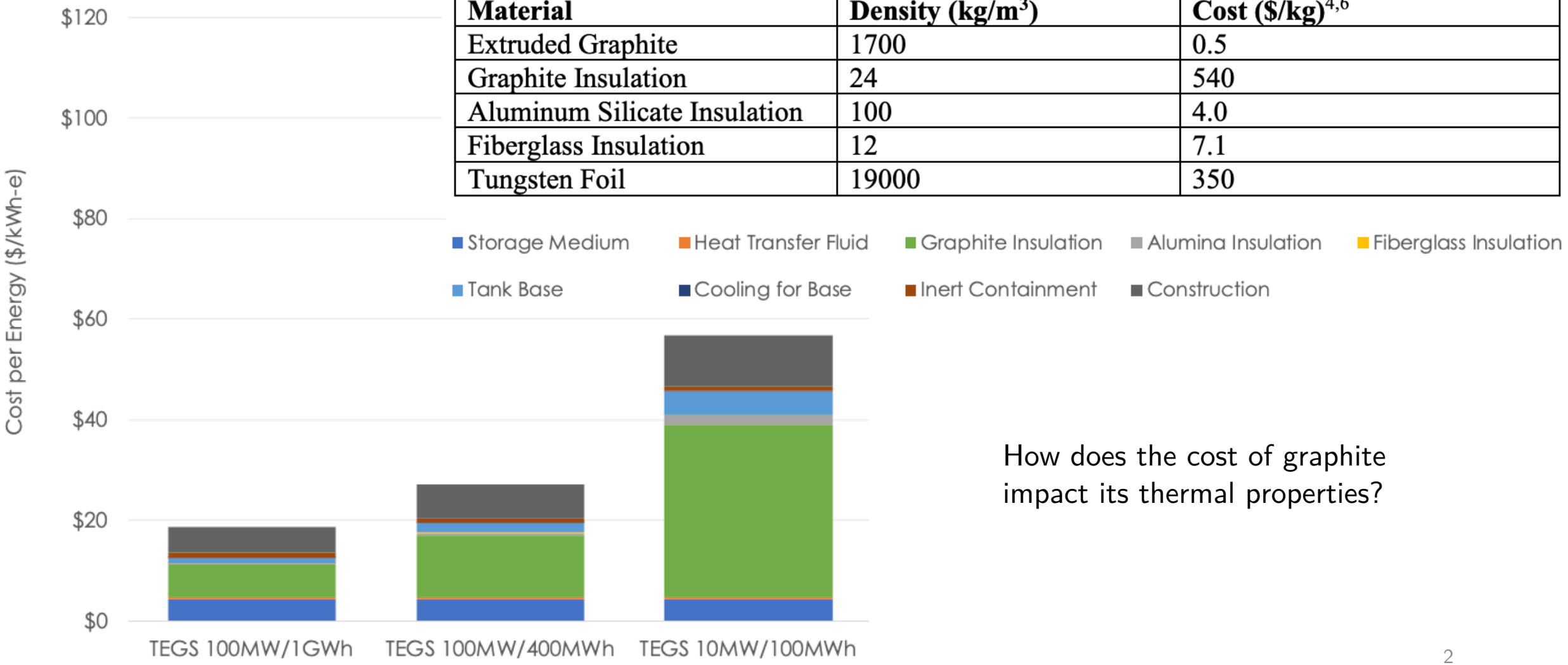


RTE = 40-50%
CPE = \$20/kWh
CPP = \$0.40/W

https://www.nature.com/articles/s41586-022-04473-y

Cost of TEGS

Material	Density (kg/m^3)	Cost ($/kg)[4,6]
Extruded Graphite	1700	0.5
Graphite Insulation	24	540
Aluminum Silicate Insulation	100	4.0
Fiberglass Insulation	12	7.1
Tungsten Foil	19000	350

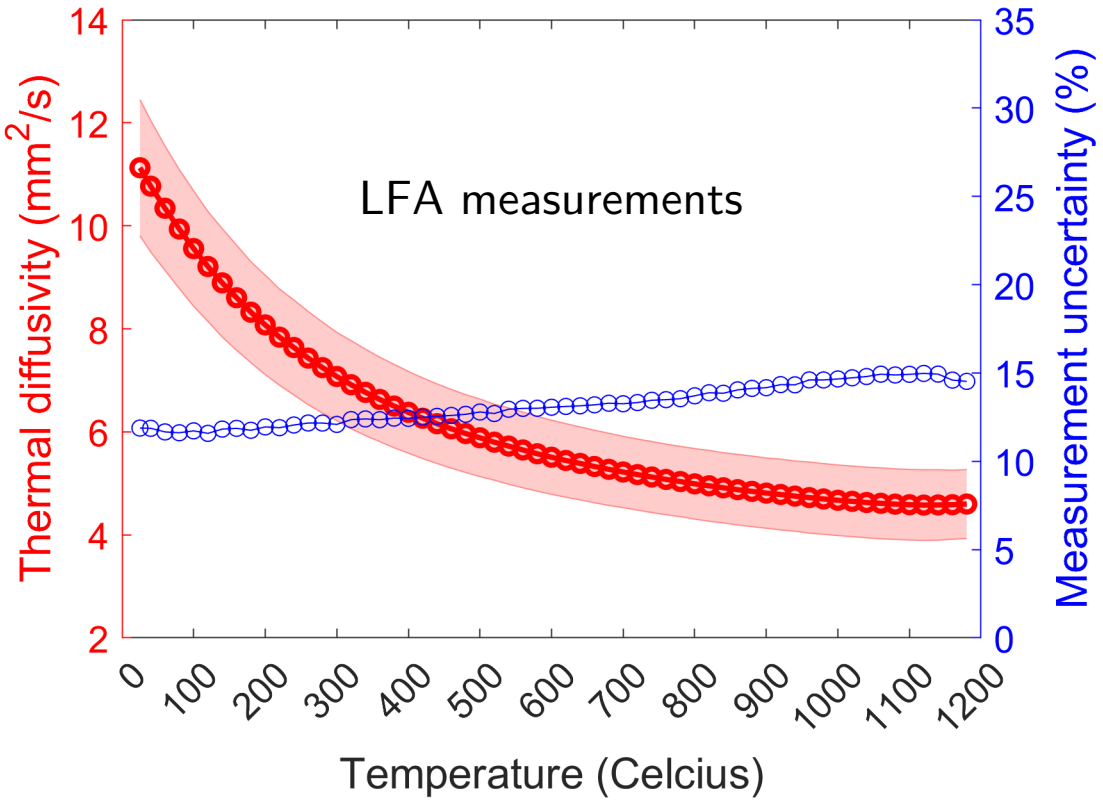


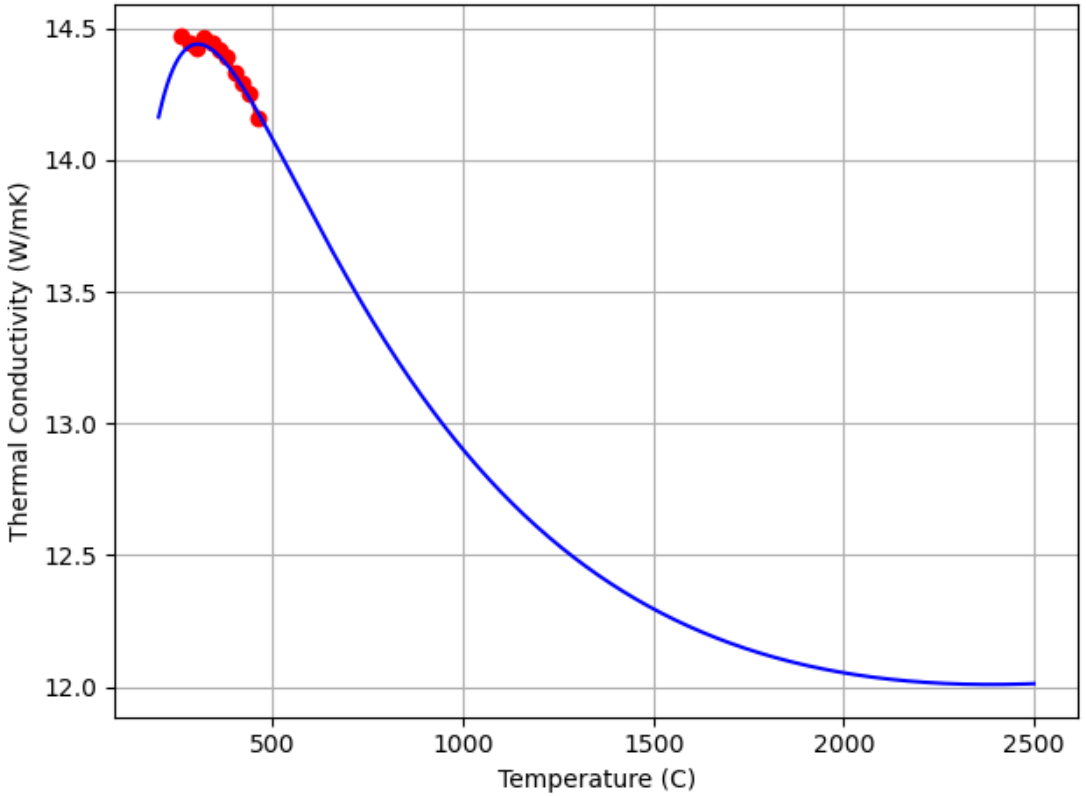
How does the cost of graphite impact its thermal properties?

https://arxiv.org/abs/2106.07624

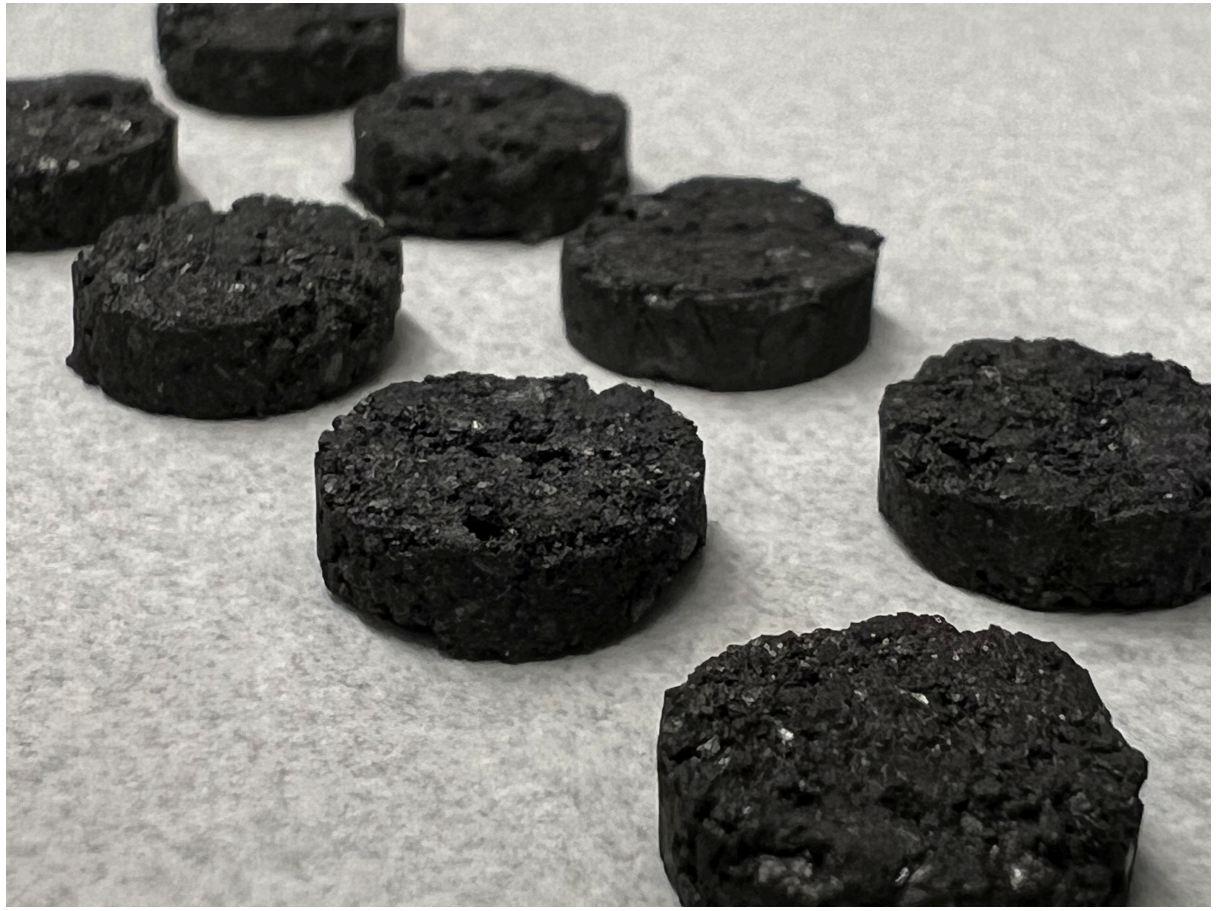
Mid-quality graphite k measurements

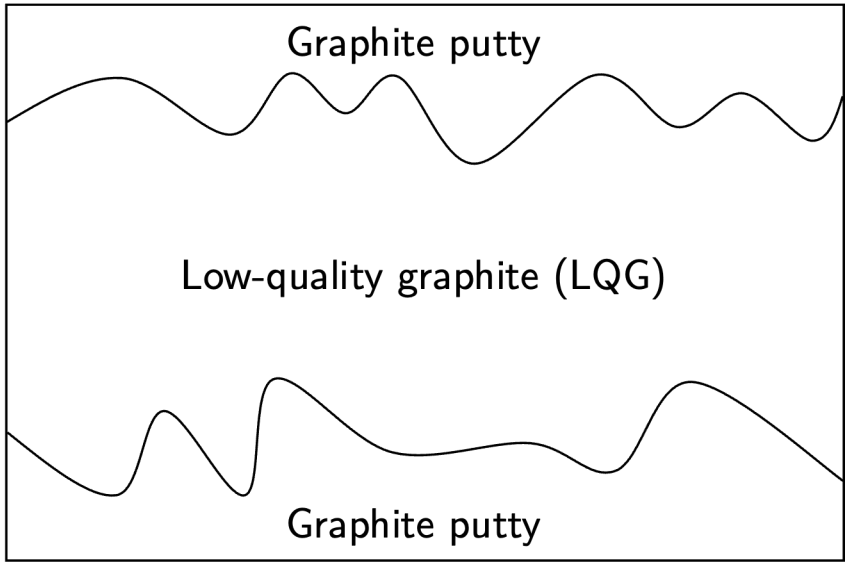
$1.5/kg graphite, $\rho = 1.6$ g/cm^3

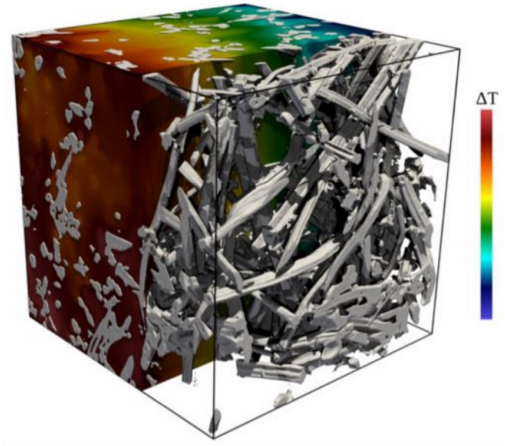




Low-quality graphite samples ($0.70/kg)

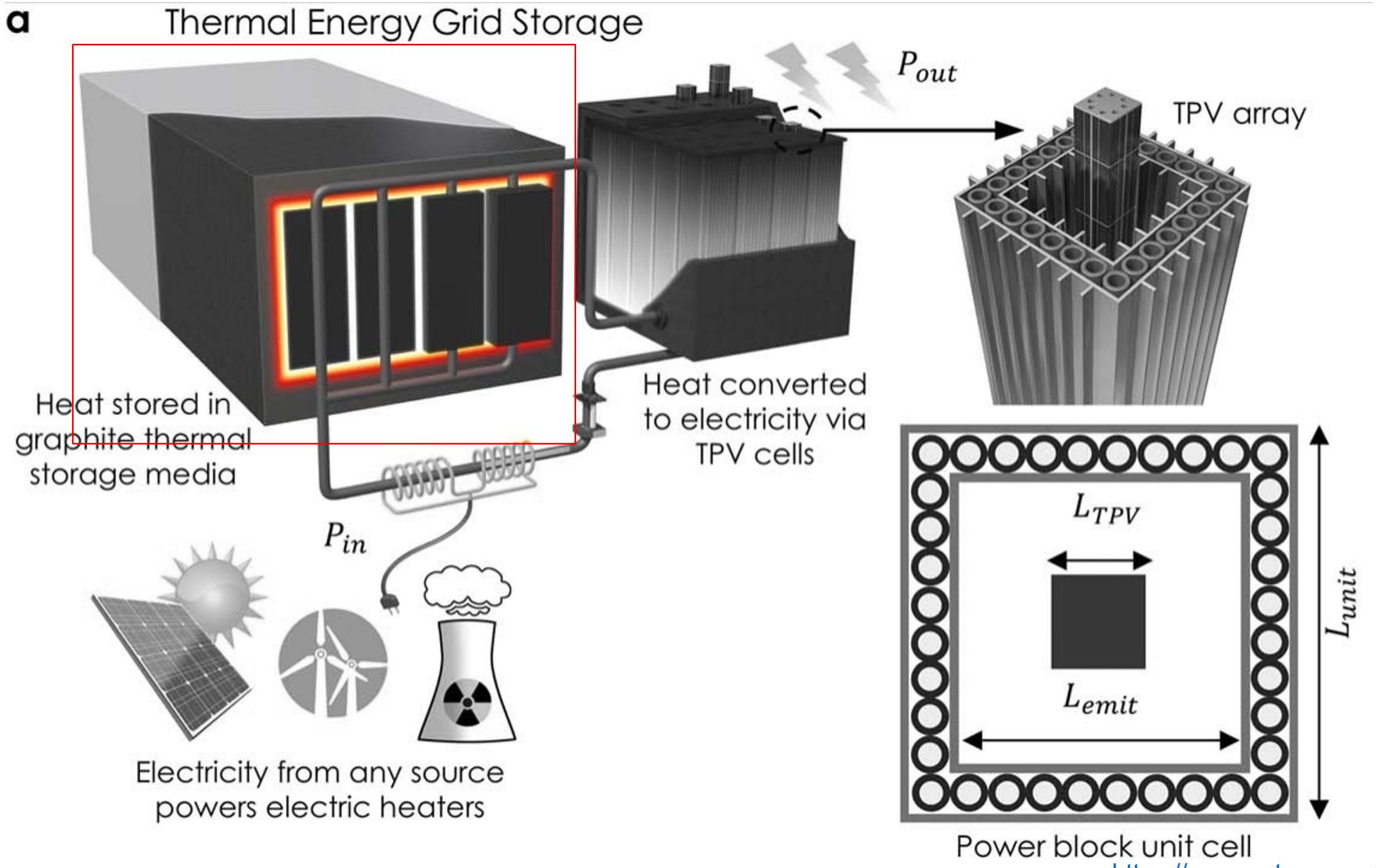






https://ntrs.nasa.gov/api/citations/20200000908/downloads/20200000908.pdf

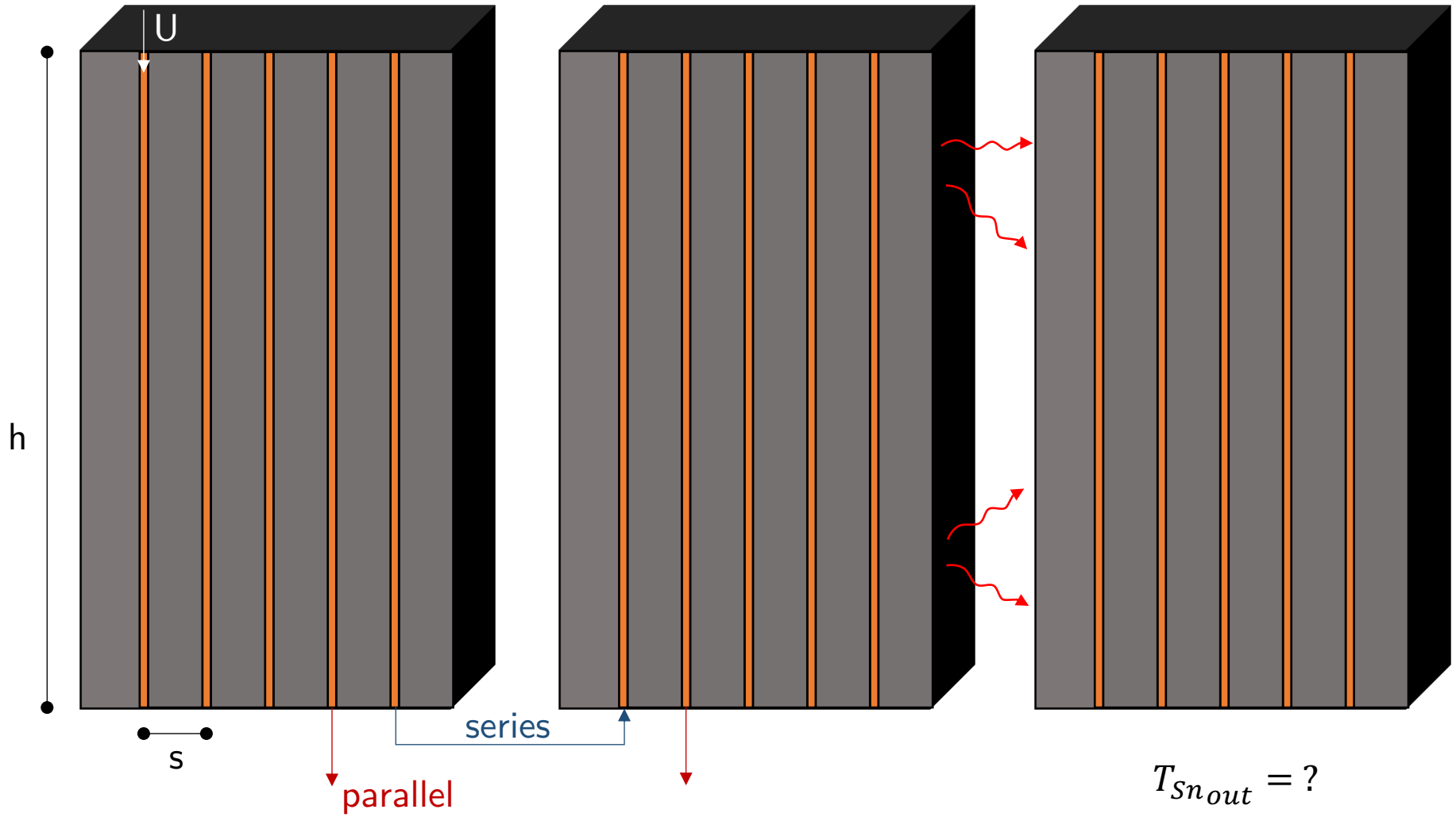
Thermal Energy Grid Storage (TEGS) Design



https://www.nature.com/articles/s41586-022-04473-y

Simplified model of TEGS

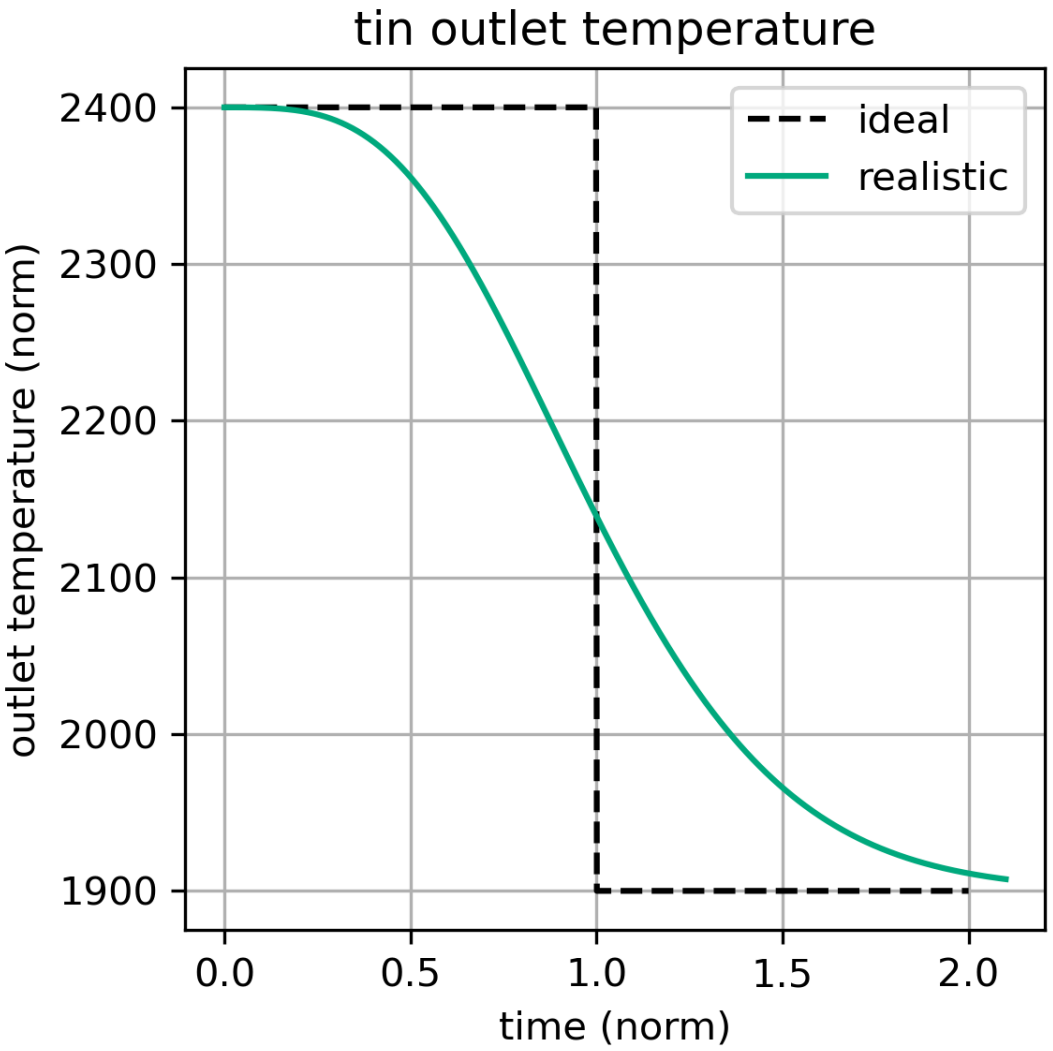
$T_{Sn_{in}} = 1900C$



$T_{C_{init}} = 2400C$

$T_{Sn_{out}} = ?$

Objective function

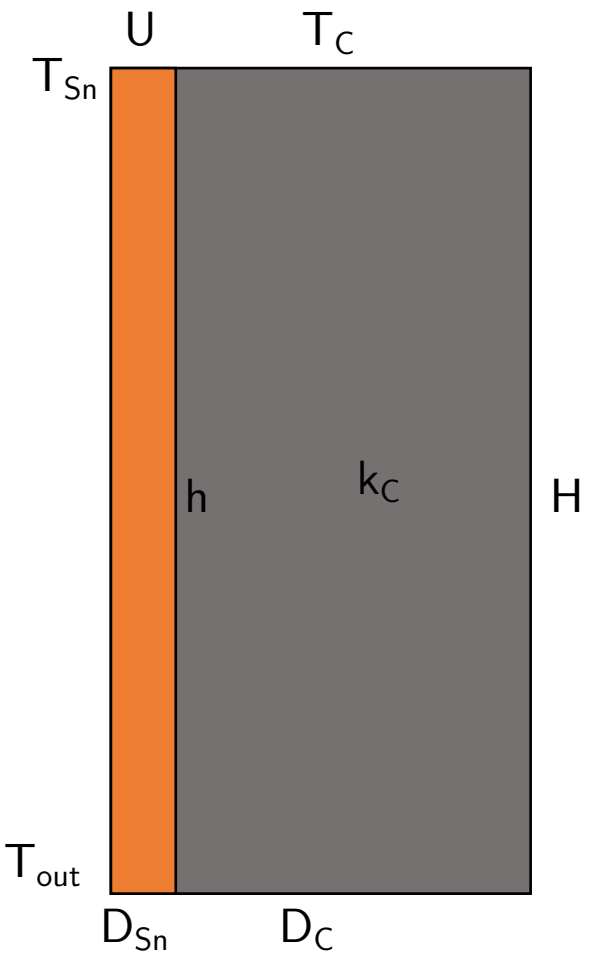


$$T_{FOM} = \int_0^1 \Theta \, dt^* \leq 1$$

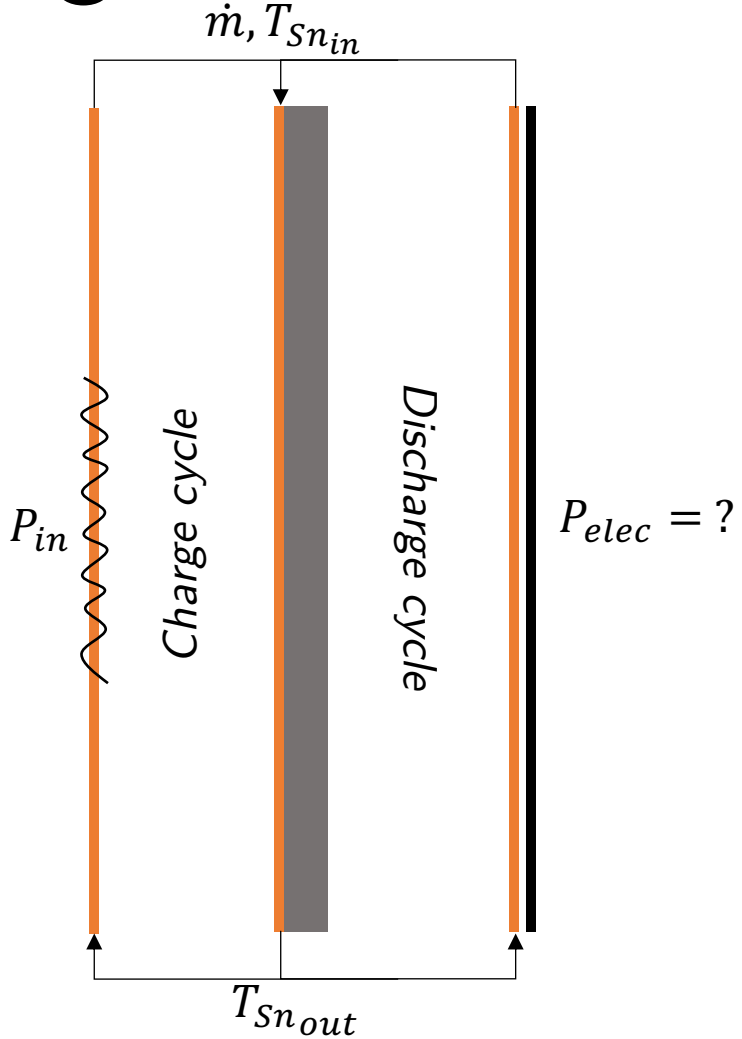
How to optimize tin outlet temperature based on:

- Block geometry
- Operation
- Block arrangement

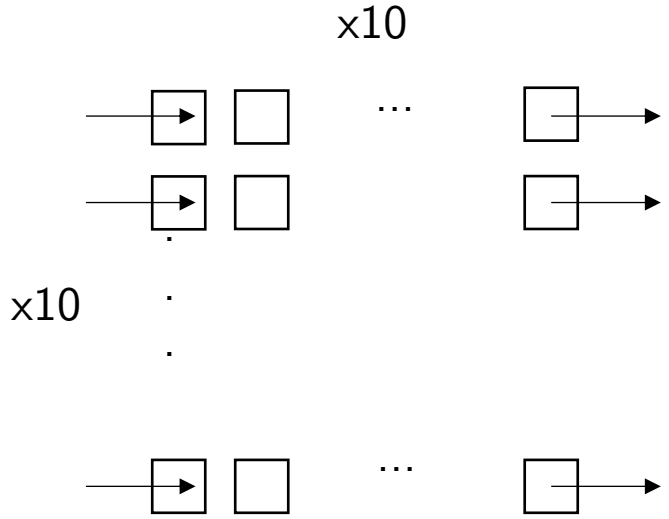
Hierarchical design



Dimensional analysis
to optimize geometry



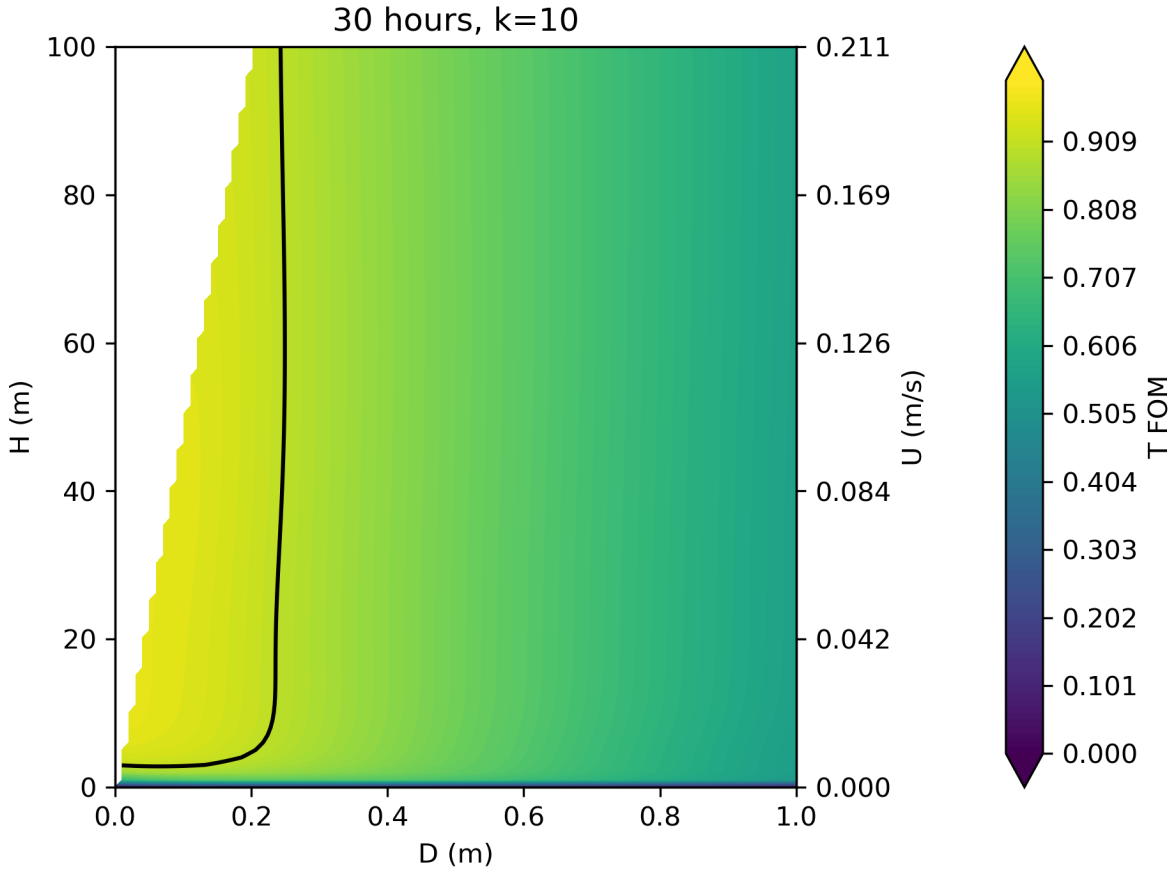
Single-block simulations
to optimize operation

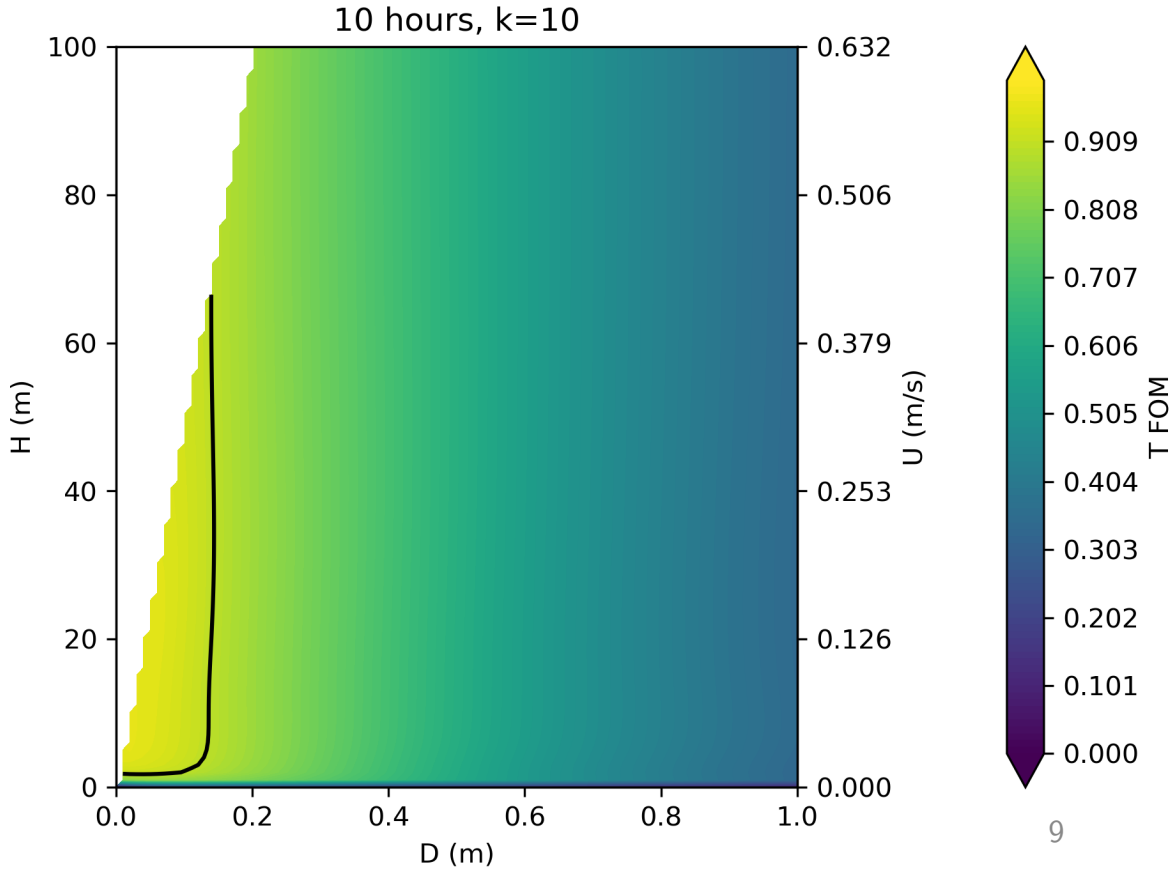


Multi-block simulations
to optimize arrangement

Dimensional analysis model results

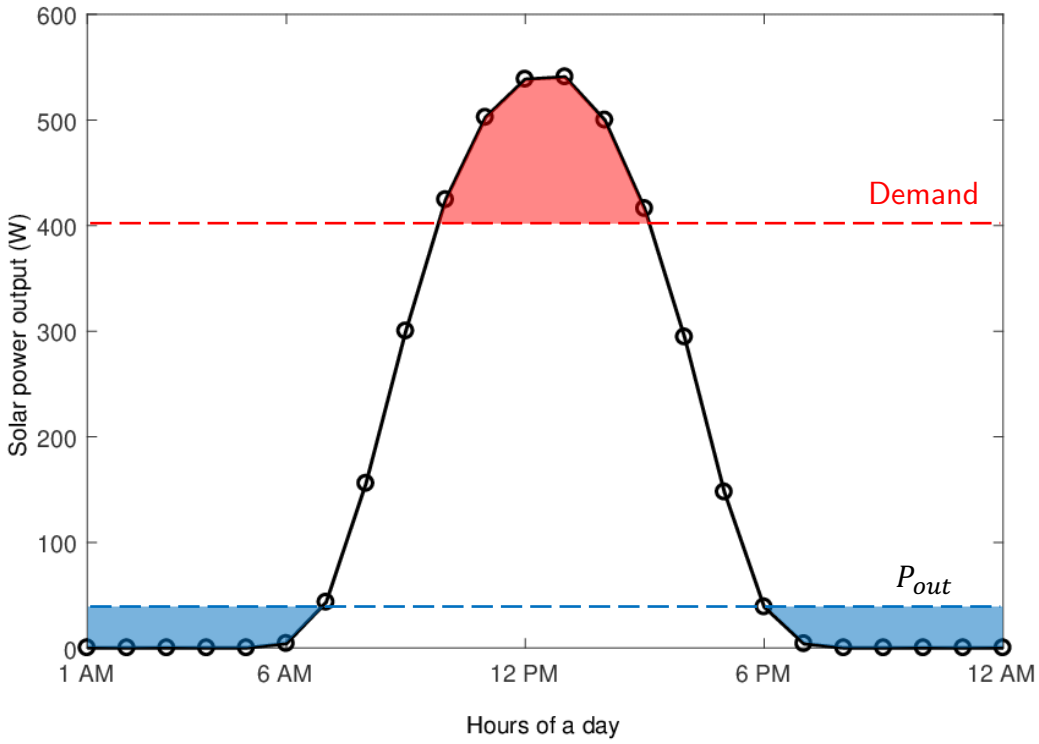
- Given: hours, k, can calculate H, D.
- D $=$ 0.2m, H $>$ 10m gives optimal results





Operational objectives

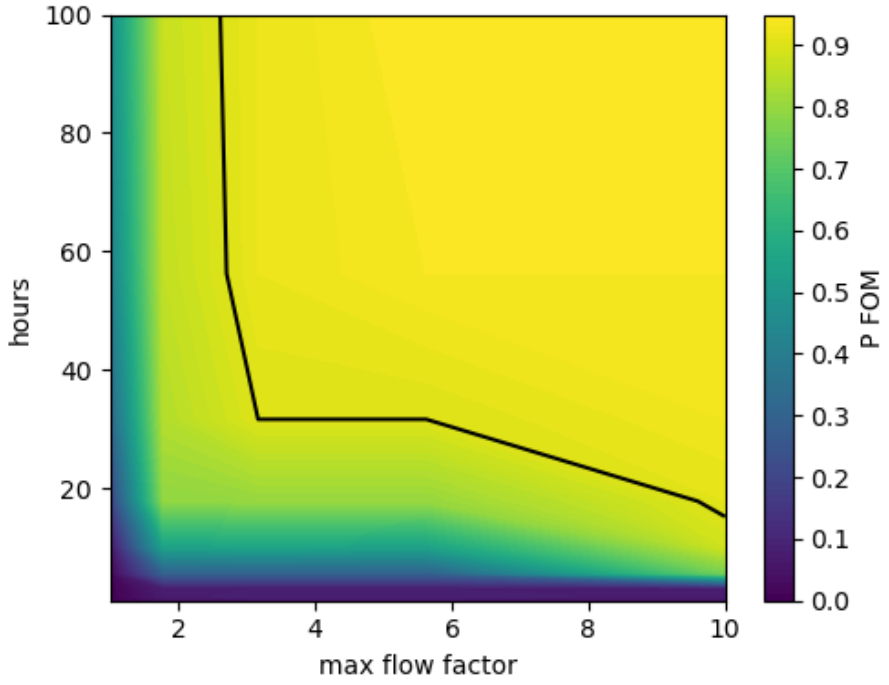
- Constant power output when required
- Fast charging to take advantage of VRE

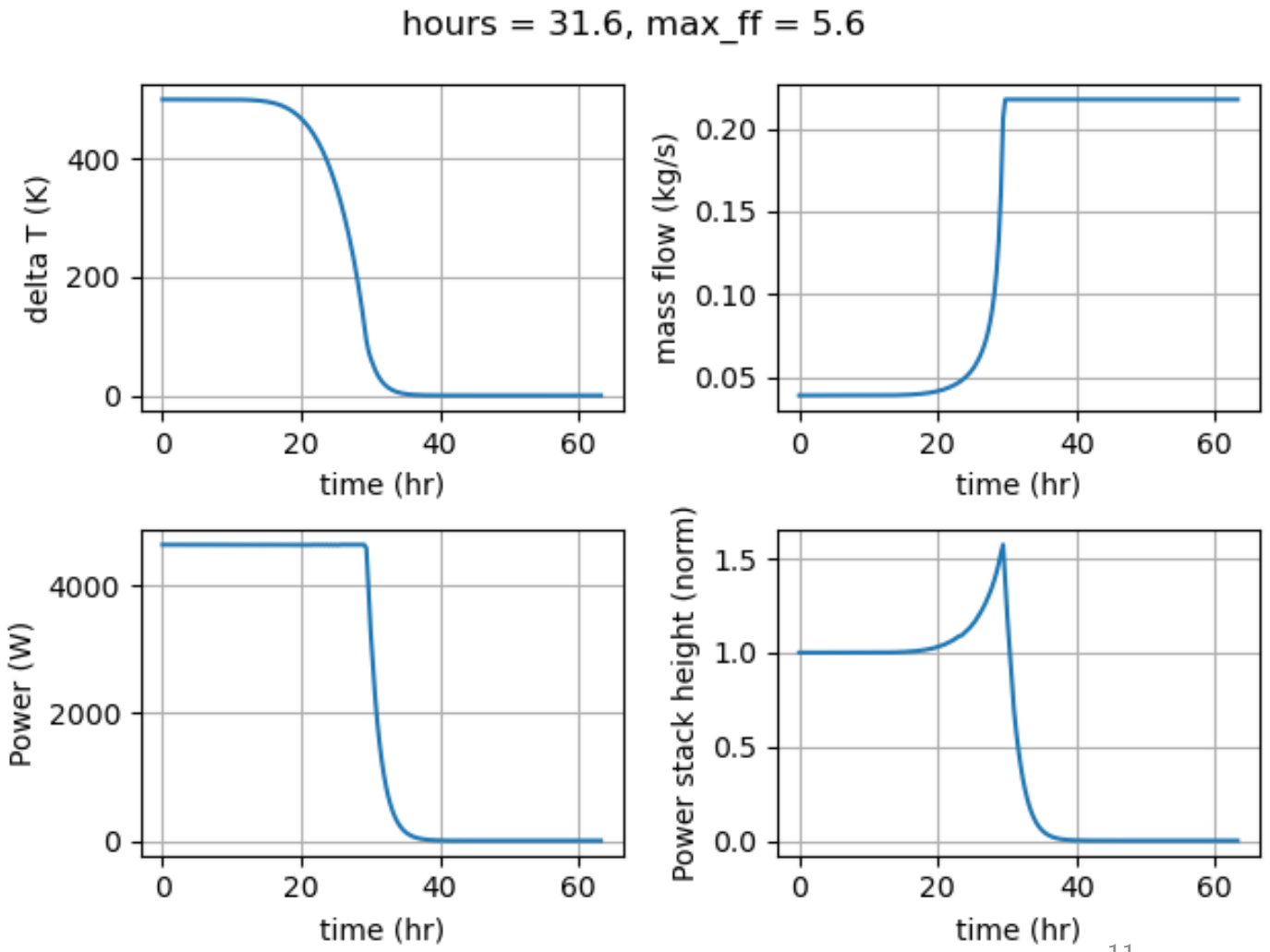


https://www.tandfonline.com/doi/full/10.1080/15435075.2018.1529593

Single-block analysis: constant power out

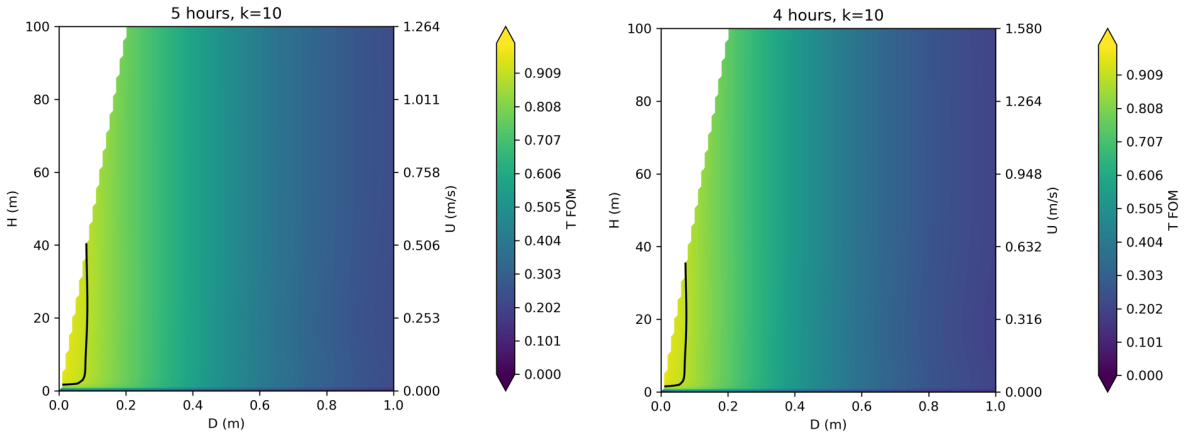
- Vary $\dot{m}$
  - Define P FOM as $\frac{t_{P_{max}}}{hours}$



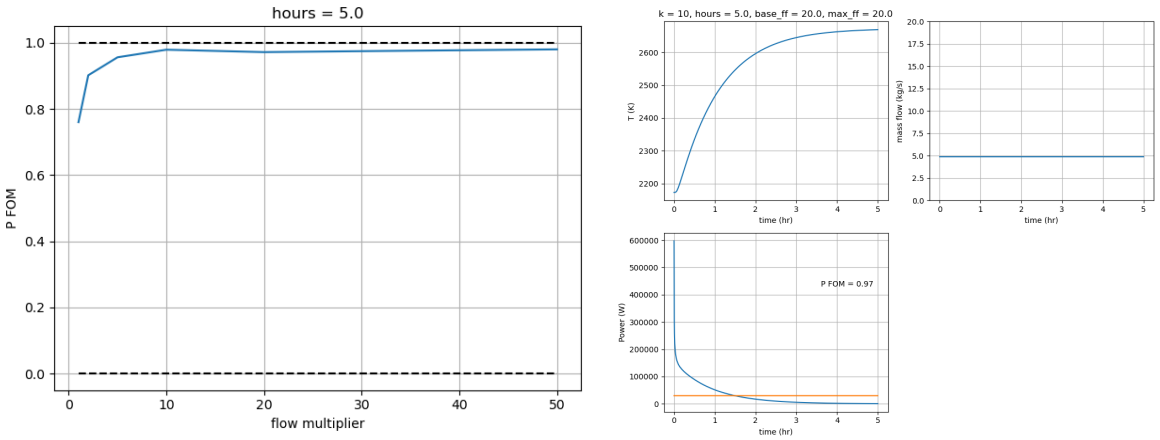


Single-block analysis: fast charging

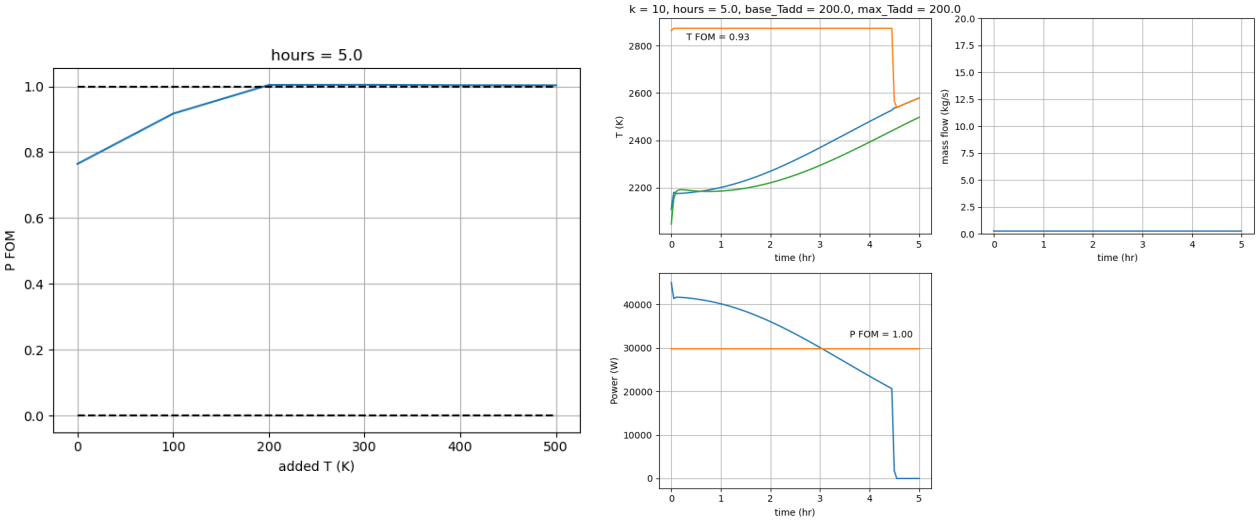
Re-size the system



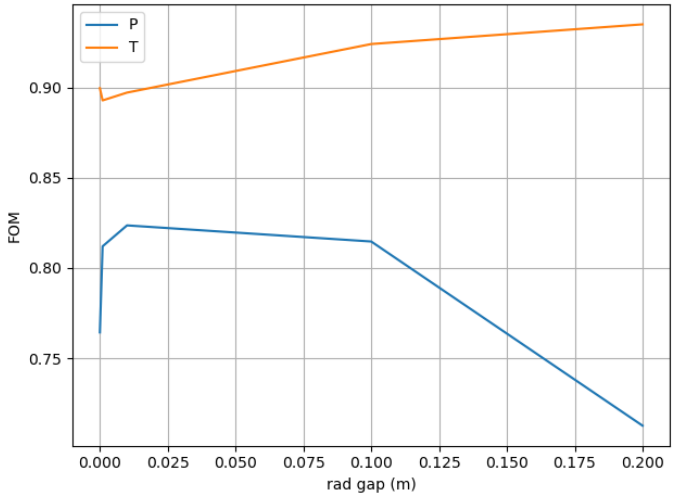
Vary flowrate



Supercharge tin

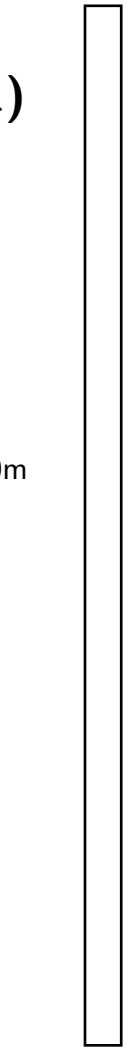


Exploit low radiative resistance



Multi-block analysis: 5 layouts

(1)



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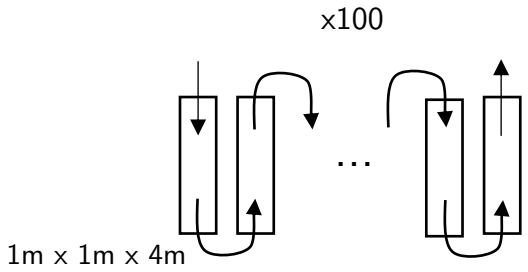
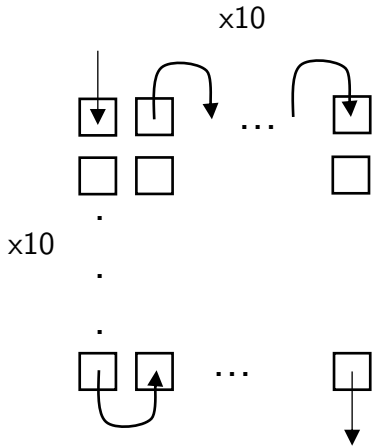


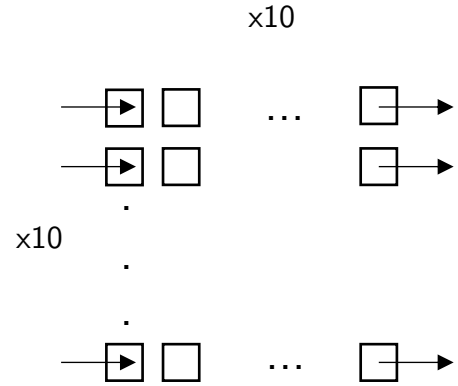
String arrangement

(3)

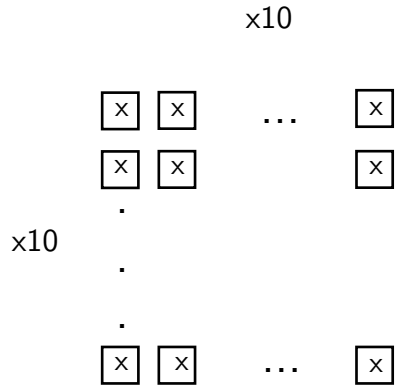


Grid arrangement

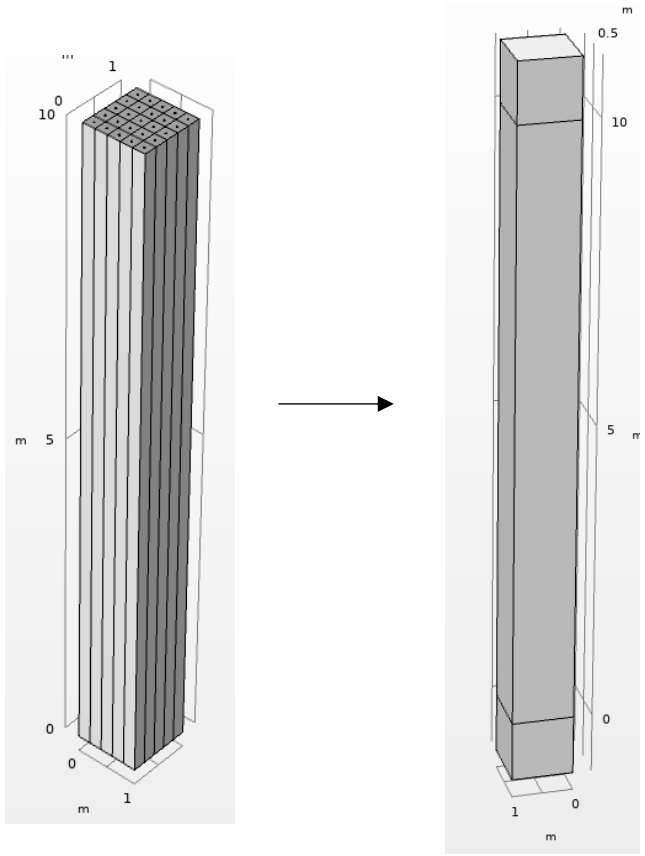
(4)



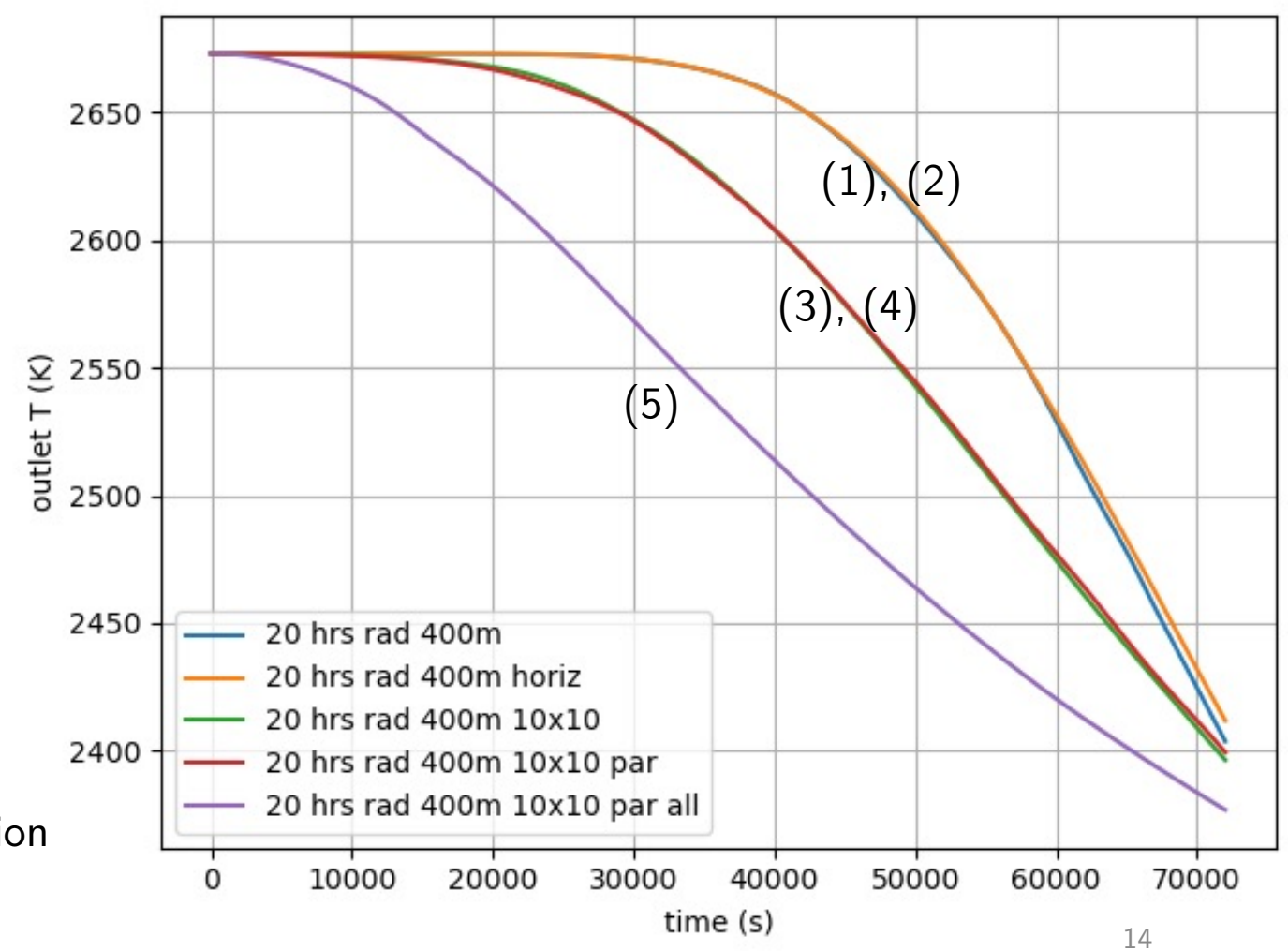
(5)



Comparison of configurations



Porous media approximation enables fast computation
Radiation between blocks included



Summary

- LFA for graphite thermal properties
- Hierarchical approach for TEGS system design
  - Geometry: D=0.2m, H>10m
  - Operation: Vary flowrate, reverse flow
  - Arrangement: String better
- Cheap, efficient, long-duration storage

Thanks!
Questions?

Acknowledgements

MIT
- Colin Kelsall
- Alina LaPotin
- Kyle Buznitzky
- Bryan Sperry
- Mary Foxen
- Asegun Henry

Georgia Tech
- Michael Adams
- Shannon Yee