Direct Gain Consulting, LLC.

Hybrid Solar / Particle Heat Transfer Fluid Technology

Technology licensing opportunity

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Technology Licensing/Purchase Opportunity

- Direct Gain Consulting is under contract with GTI Energy to license or sell their unique solar/thermal storage technology developed over the last decade.
- GTI Energy, www.gti.energy, is a non-profit organization dedicated to advancing the economy-wide transformation needed to deeply decarbonize energy systems while supplying the energy needed to support rising standards of living and economic growth worldwide.
- One of GTI Energy's objectives is to identify and develop meaningful new energy technologies and deliver them to the marketplace; maximizing value for commercialization by others.
- This thermal storage and solar collection technology can be utilized together or separately, as a superior industrial thermal storage process, an efficient solar thermal collection process, or complete solar thermal/storage system.

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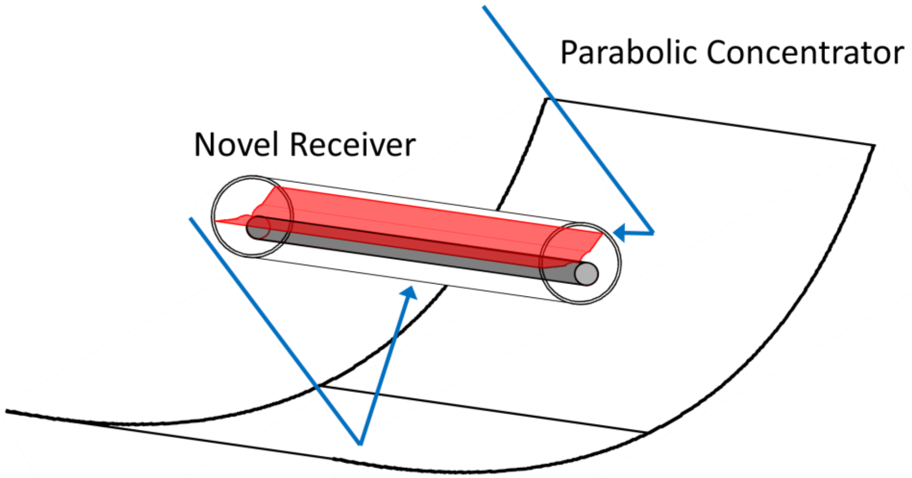
Experienced Technology Development Team

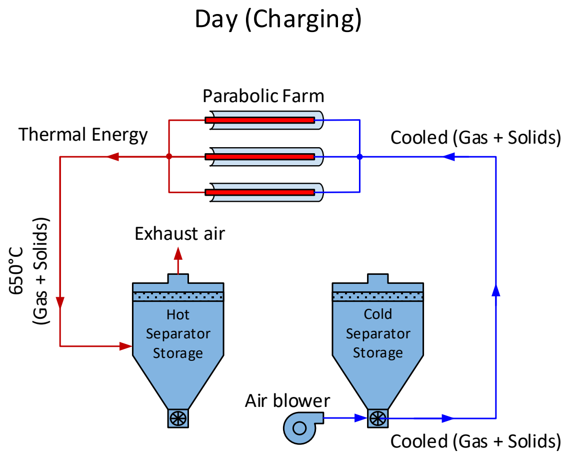
GTI ENERGY

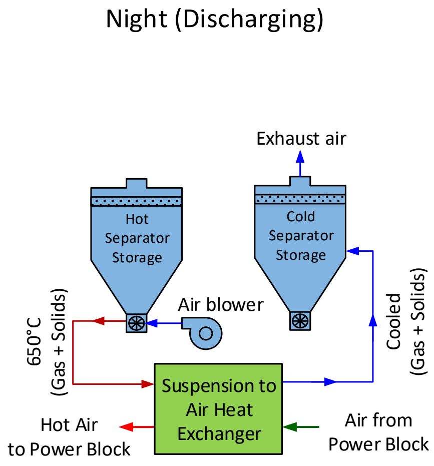
- GTI Energy: Over 80 years of technology development and commercialization for energy industry
  - Overall lead, and lead for particle system development and integrated system testing at host site
- University of California at Merced (UC Merced): Hosted UC solar - established in 2010 to develop/commercialize advanced solar systems
  - Lead for solar collector development and integrated system testing at UC Merced
- Particulate Solids Research, Inc. (PSRI): 47 years in granular-fluid systems technology advancement
  - Provide particle transport and storage expertise

High Temperature Solar Technology
(combined solar collection and thermal storage)

- Two stage collector increases solar concentration to achieve 650°C Fluid
  - Conventional primary trough with advanced receiver design
- Particle thermal fluid enables collection and storage of 650°C+ thermal energy
  - Low cost, low pressure, non-corrosive and non-flammable







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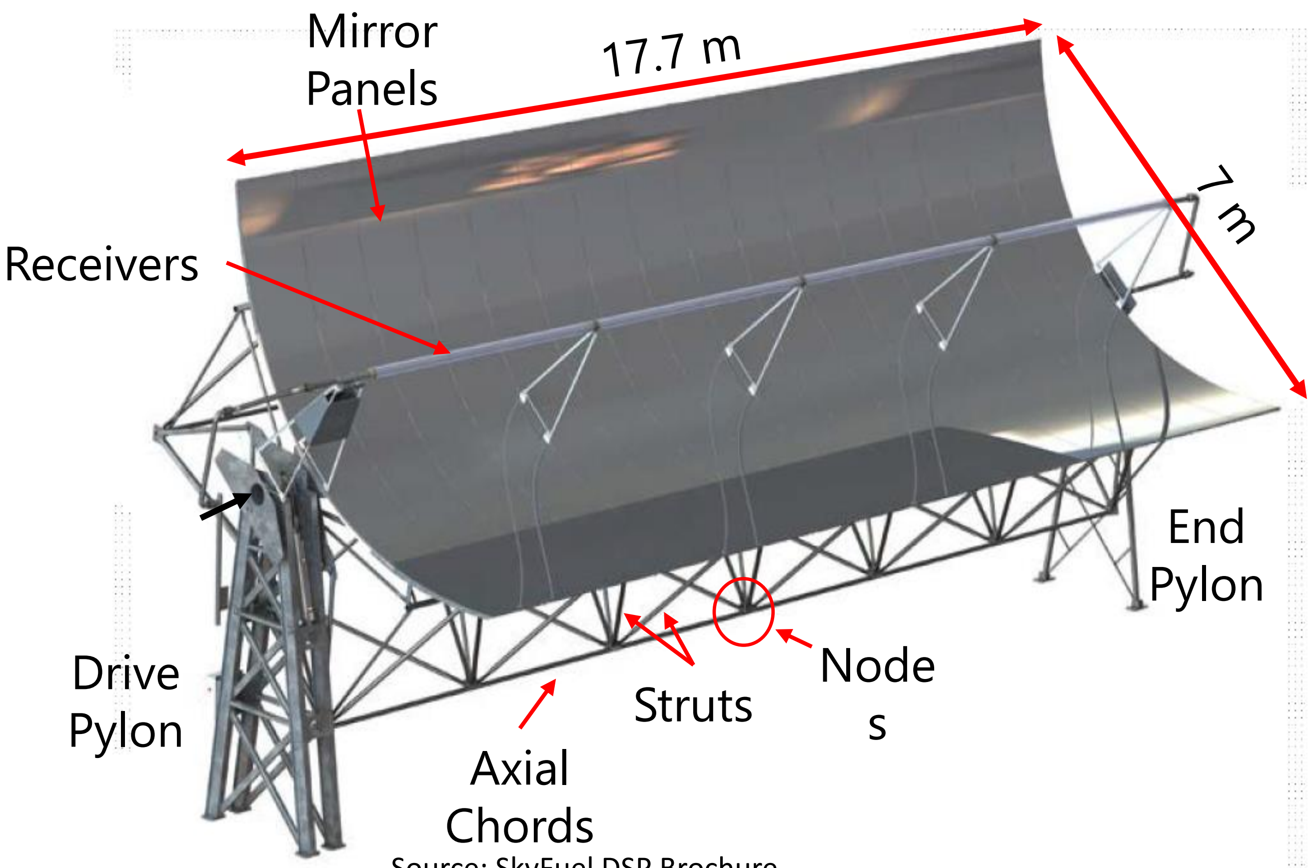
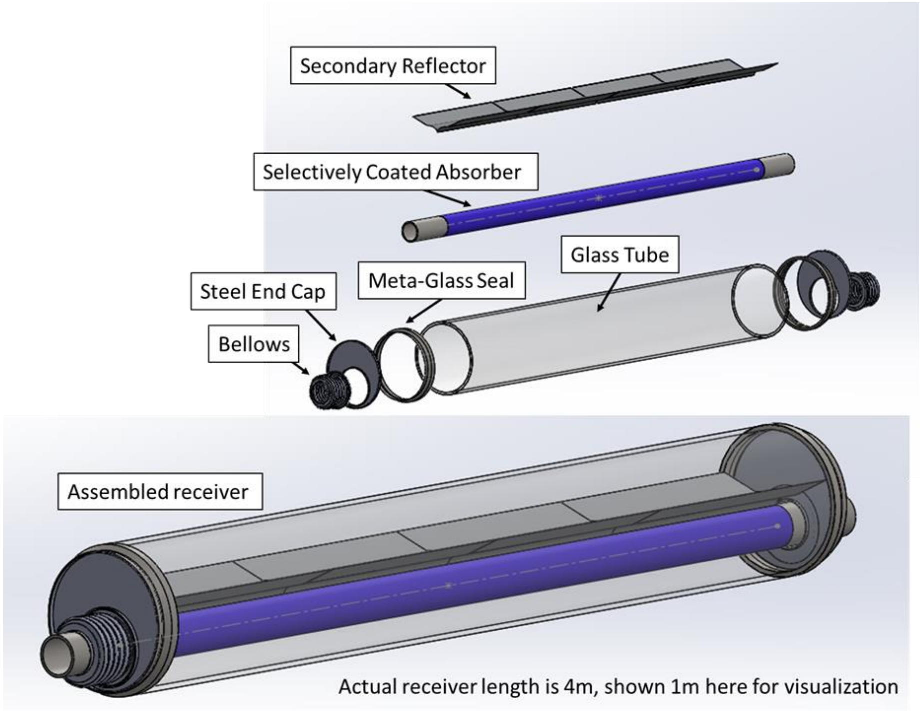
Parabolic Trough Reflector / High Temperature Receiver

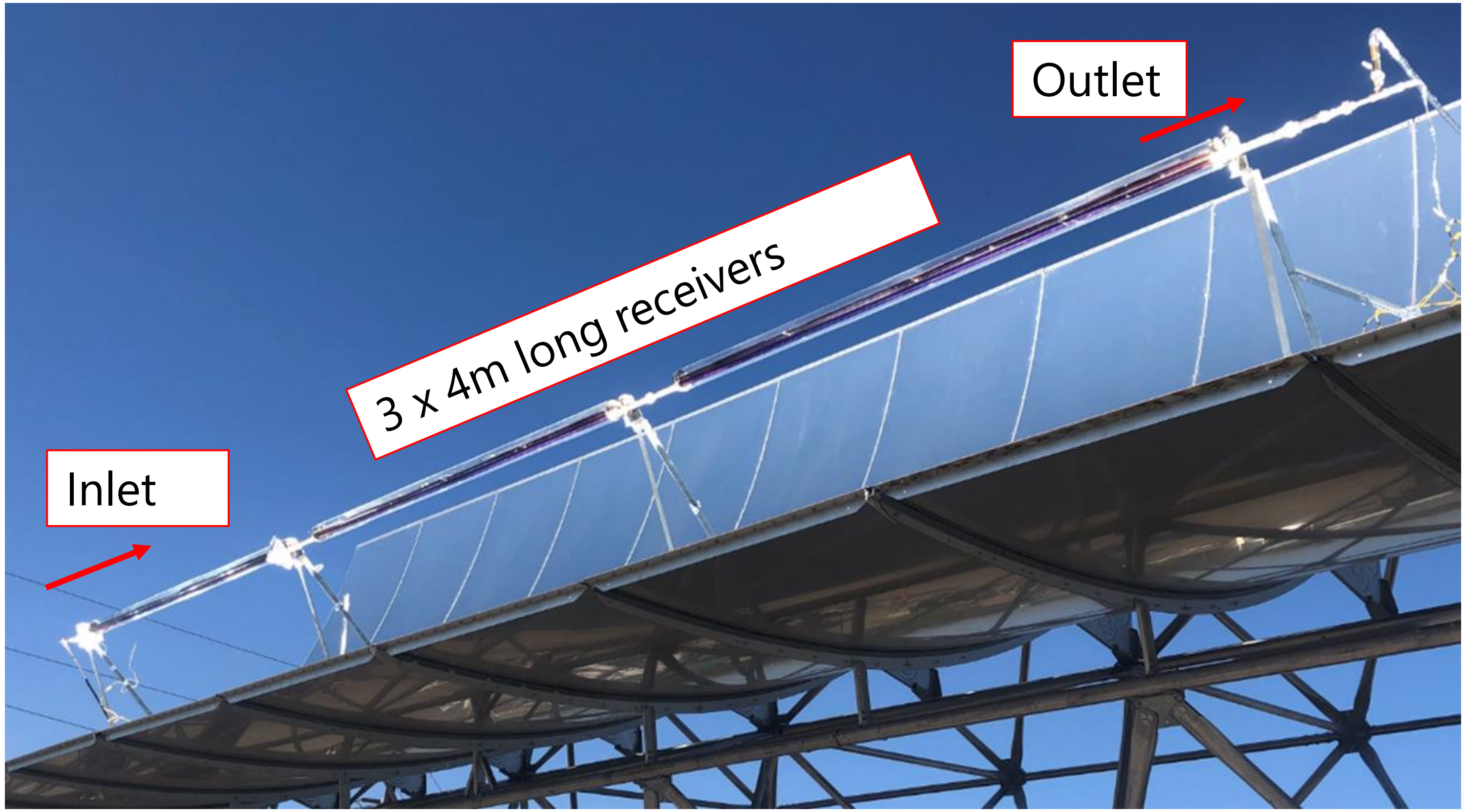


Source: SkyFuel DSP Brochure



Locally sourced components!

Parabolic Trough/Receiver Testing

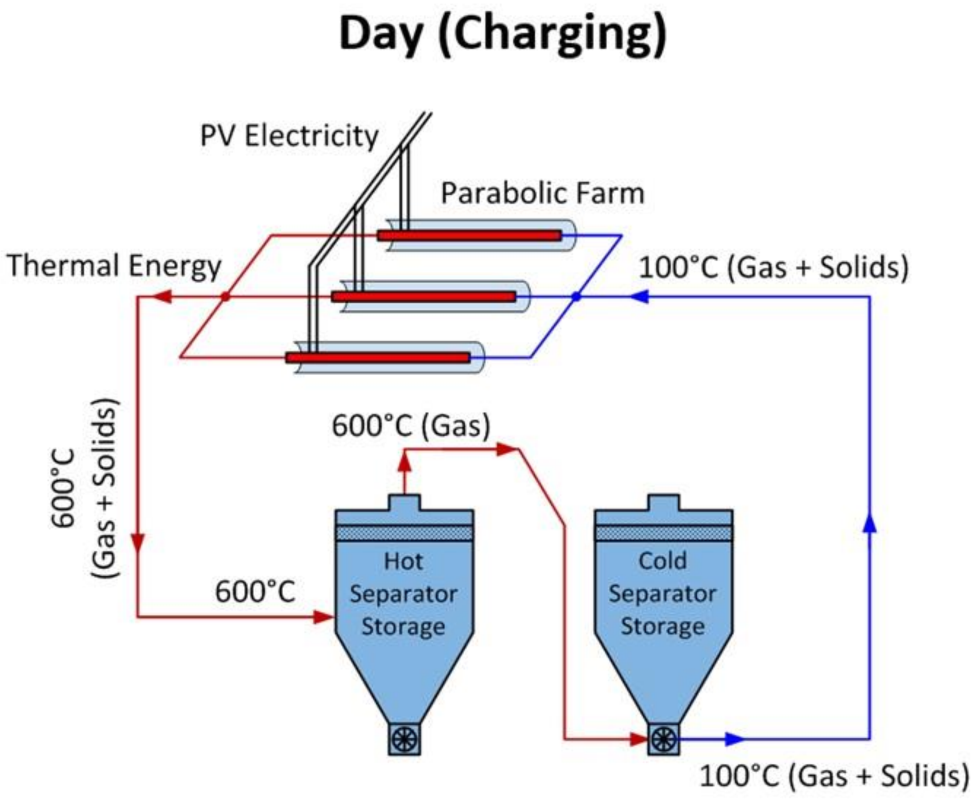


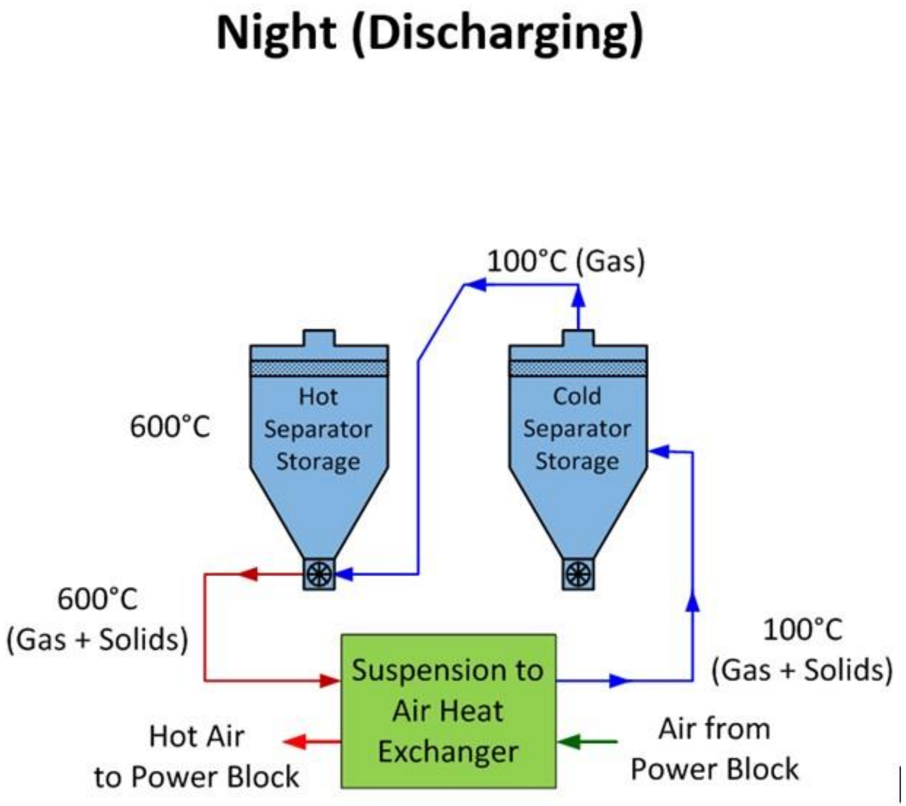
Three 4 m long prototype receivers tested on sun for optical efficiency measurement

State of the Art Thermal Storage

- Ceramic particle energy storage advantages:
  - SAFE & FLEXABLE system design
  - No-phase change required
  - Non-toxic, low-pressure operation vs. traditional synthetic heat transfer fluid or Molten Salt based systems
  - Demonstrated capability to 680^{o}C
  - Ease of operation and low maintenance
  - No thermal particle degradation

Particle Based Storage System





Enables dispatchable solar energy / high temperature process heat on demand

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Storage and Receiving/Lock Hopper Skids

Storage hopper

Receiving (top) and lock hoppers

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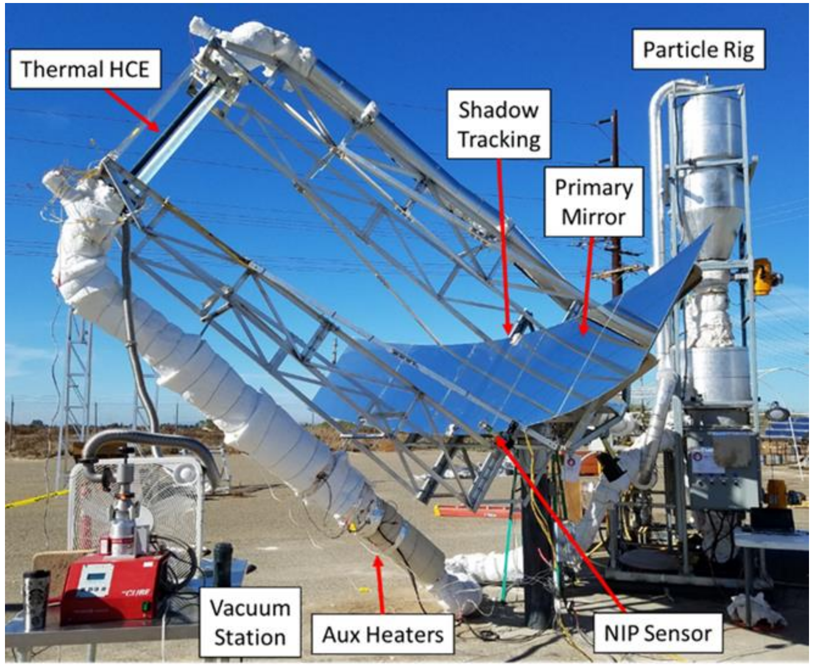
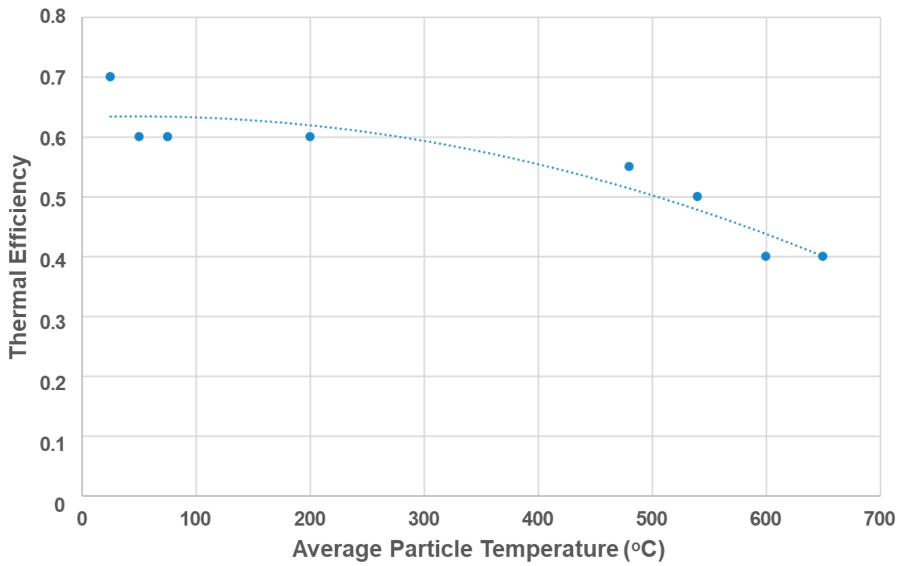
Demonstration Project

- Designed, built and tested 12 m long nominal 60 kW collector at UC Merced
- Designed, built and tested 650°C particle transport and storage loop at GTI
- Tested integrated system at UC
  - Achieved 685°C at receiver outlet and 500°C at process heat exchanger
  - No accumulation of particles
  - Over 40% of collected energy to process
  - System accommodates multi-day operation and expected solar radiation and process changes





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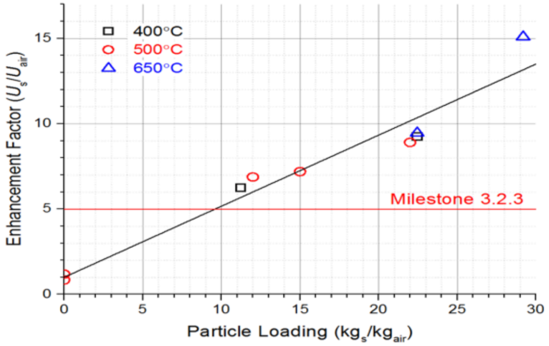
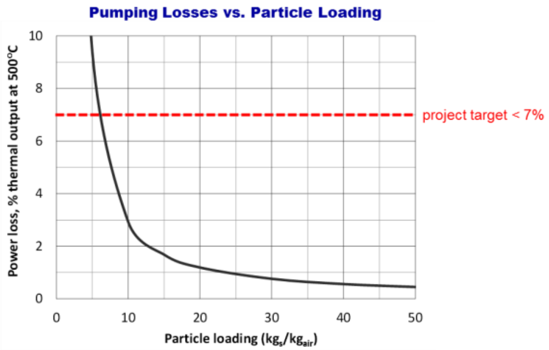
Demonstration Proved Effectiveness of Thermal Storage

- No particle degradation, heat transfer and pressure drop impacts for over 4000 heating cooling cycles (100°C to 650°C) representing 11-year system operation
- Low pumping loss - <1% of thermal output at 500°C
- Excellent Heat transfer coefficient – ~350 to 400 W/m^2-K; 15 times that of air alone





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Patented Heat Transfer Fluid Advantages

- **Higher Temperatures**
  - Enables full thermal conversion to 1200°F/650°C
  - Conventional thermal fluids limited to 1050°F/565°C
- **Safe and Stable**
  - Non-Toxic
  - Not susceptible to freezing
  - Low pressure
  - Non-corrosive
  - Non-flammable
- **Cost Effective**
  - Allows for locally sourced - standard materials of construction
  - $16/KWh compared to $20/KWh (molten salt) and $53/kWh (best synthetic heat transfer fluids)

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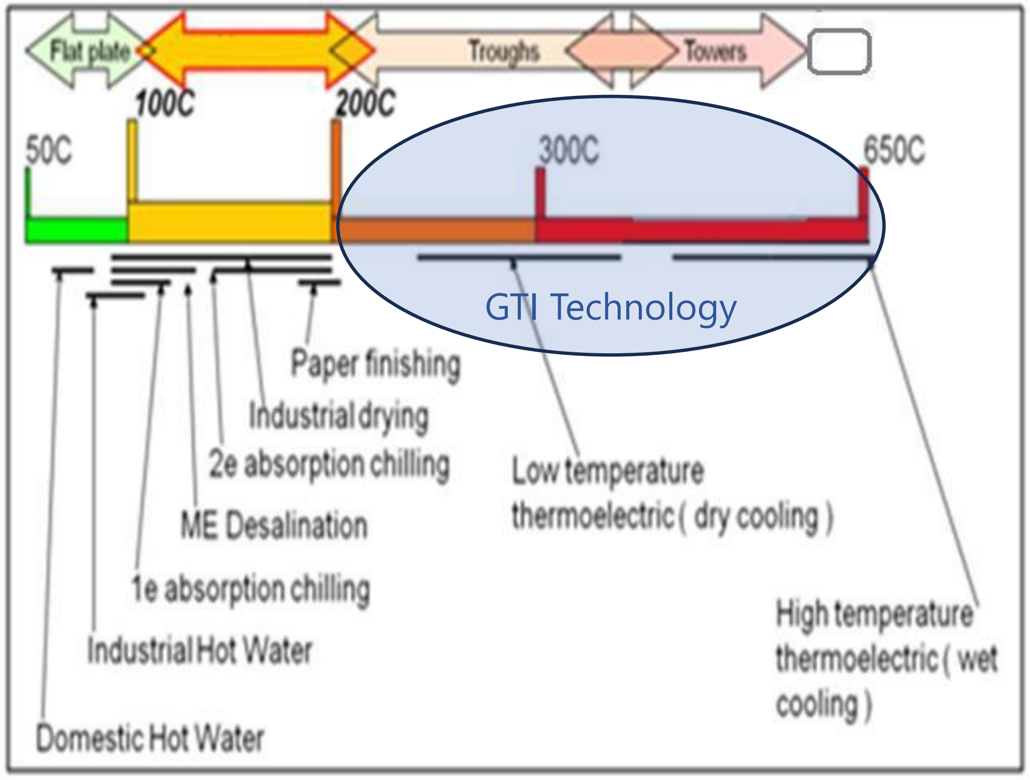
Our Technology provides a *critical solution* for Solar Thermal Process Heating

- No commercial technologies exist above 1050°F/565°C
- Temperature spectrum under served
    - Flat plates up to 212°F/100°C
    - Evacuate tubes 212°F/100°C to 392°F/200°C
    - Troughs 392°F/200°C to 743°F/395°C
    - Towers 662°F/350°C to 1050°F/565°C; not suitable for industrial applications
- **GTI particle-based technology can serve all industrial and power applications in the 200ºC-680ºC range with potential extension to 1000ºC**



Summary

- Decarbonizing thermal energy is critical
- Solar heat generation provides for replacement of fossil fuel industrial heat and power sources
- Particle transport and thermal storage enables:
  - Demonstrated productivity improvement and emissions reduction
  - Low-loss transfer and storage of thermal energy at temperatures >650^{o}C
  - Highly efficient and cost-effective heat transfer and storage based on a mature technology
  - Safe (non-flammable, non-toxic, non-freezing) storage media

Backup Slides

Potential Applications of Technology

- Process heat & power generation
- Air permit limits/ restrictions
  - Augment fuel consumption
  - Offset fuel consumption
- Without solar collectors – transfer heat from one process to another
- Increase production without increasing emissions
- Decarbonization
  - Efficiencies
  - Fuel switching
- Dispatchable renewable energy

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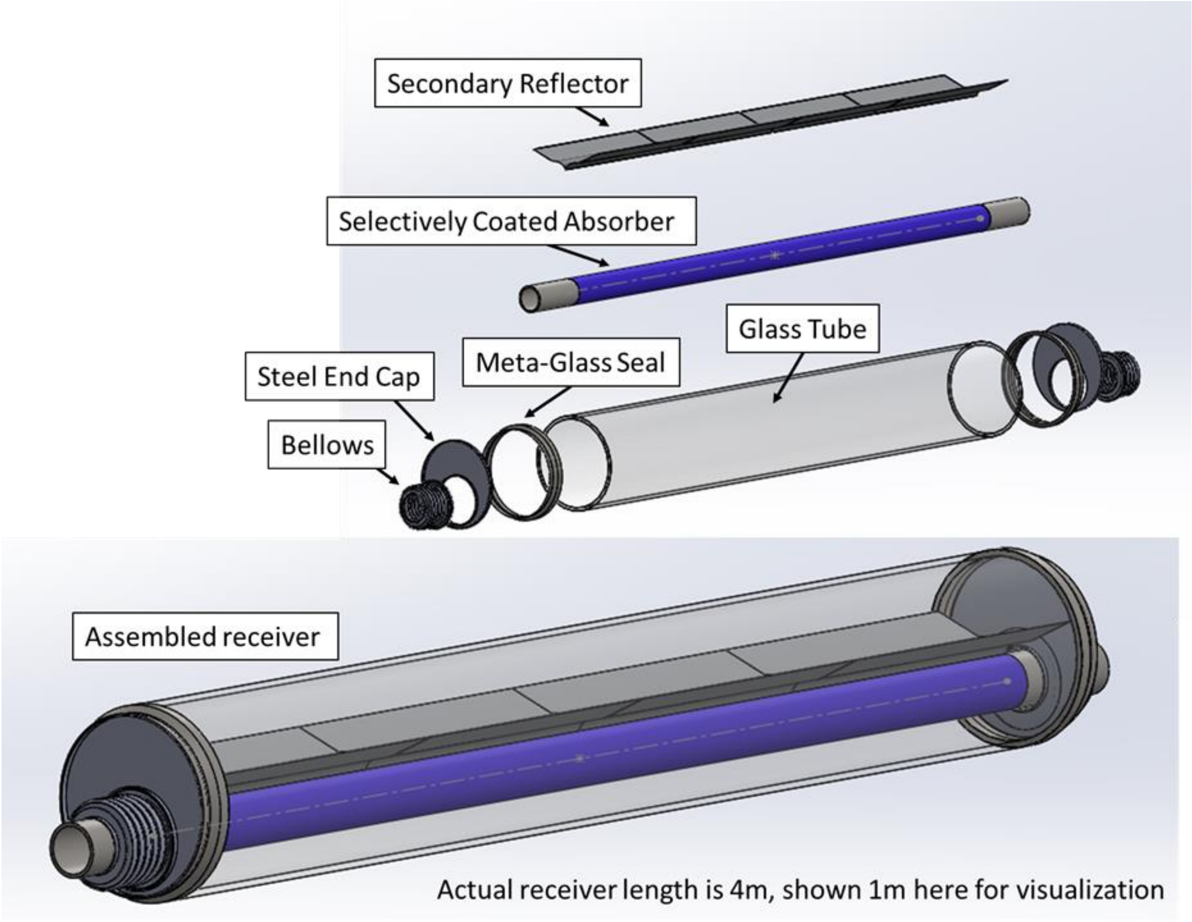
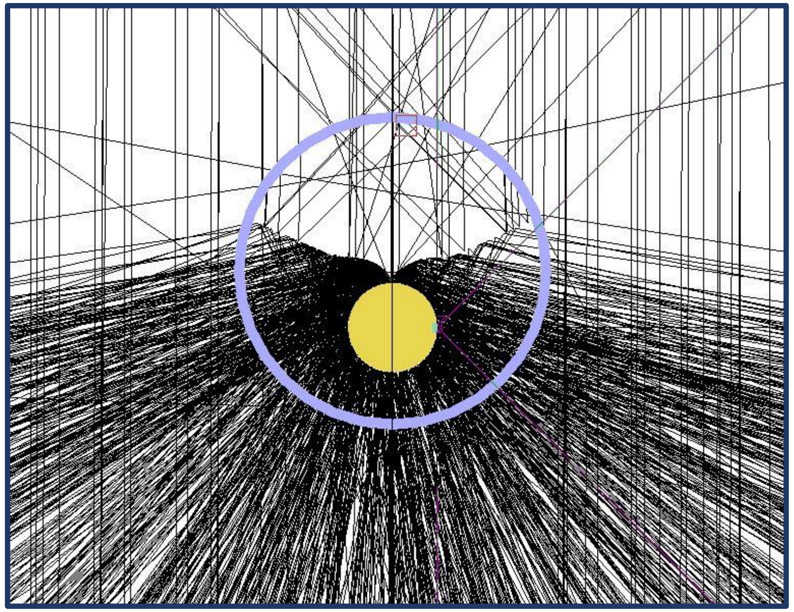
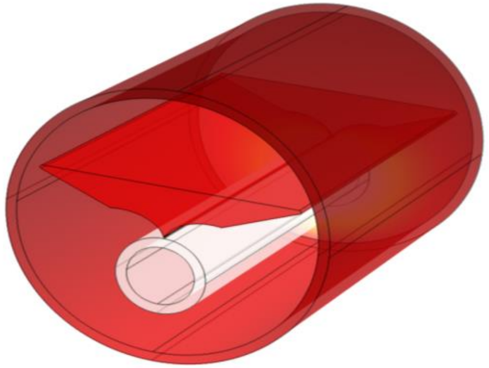
High Temperature Receiver







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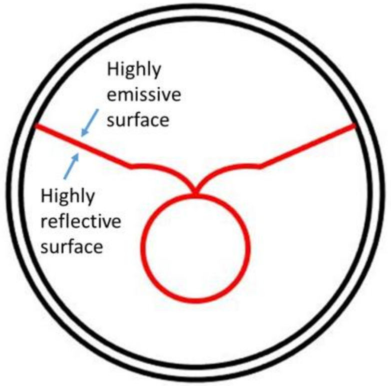
60 kW Collector

- Design confirmed with optical and thermal simulation




Source; SkyFuel Inc.

- Established primary mirror from SkyFuel lowers costs, increases reliability
- Reduced primary mirror to receiver distance simplifies support structure, improves aesthetics
- Greater receiver acceptance angle increases collection efficiency
- Higher concentration ratio on receiver increases solar flux, temperature
- Commercially applied low emissivity absorber coating reduces heat losses
- PVD coated stainless steel secondary reflector improves reflectivity and structural integrity and reduces heat losses

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Solar/Storage Benefits to Industry

- Delivers highest, long-duration thermal storage efficiency in its class
- Provides significant environmental benefits
- Environmental awareness/safeguards
- Technological innovations
- Expands renewable portfolio
- Reduces fossil fuel consumption and CO_2 emissions
- Reduces waste heat for industrial processes
- Contributes to sustainability and resilience
- Improves peak fuel demand

Technology Patent Portfolio

- **Air Cooling Day Cycle-Based Processing and Systems**
  - Processes and systems applying day cycle temperature changes in conjunction with cool storage are provided. A thermal energy storage material is placed in heat transfer communication with lower temperature nighttime air resulting in a cooled thermal energy storage material. The cooled thermal energy storage material is subsequently utilized to cool an item such as a supply of higher temperature air, such as daytime air, or a cooling medium.
  - Patent No. US 10,488,120 - Filed: February 16, 2017

- **Hybrid Solar System**
  - A hybrid solar system including a hybrid solar collector using non-imaging optics and photovoltaic components and a heat transfer and storage system in thermal communication with the hybrid solar collector, the heat transfer and storage system using particle laden gas as thermal media to simultaneously generate and store electricity and high temperature dispatchable heat
  - Patent No. US 10,777,724 - Filed: December 4, 2015

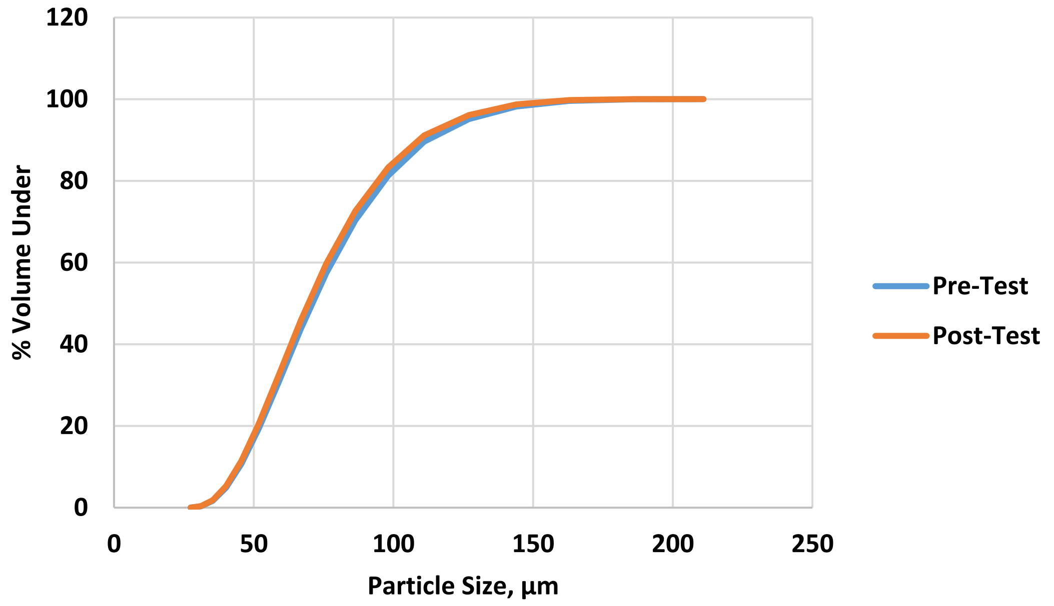
- **Process and System for Hot and/or Cold Energy Transfer, Transport and/or Storage**
  - A thermal conveyance system and process for absorbing, transporting, storing, and recovering thermal energy (both hot and cold energy) over a wide range of temperatures from up to 2,100° F., or higher, or cool energy at subzero temperatures in inert and stable particles without the need to maintain a minimum temperature or requiring high system pressures. The process involving the transferring thermal energy to a first transfer fluid and recovering thermal energy from a second transfer fluid wherein the first and the second transfer fluids comprise a two phase thermal media including a gaseous carrier containing a quantity of micron to millimeter sized solid particles.
  - Patent No. US 11,255,575 – Filed: March 20, 2017

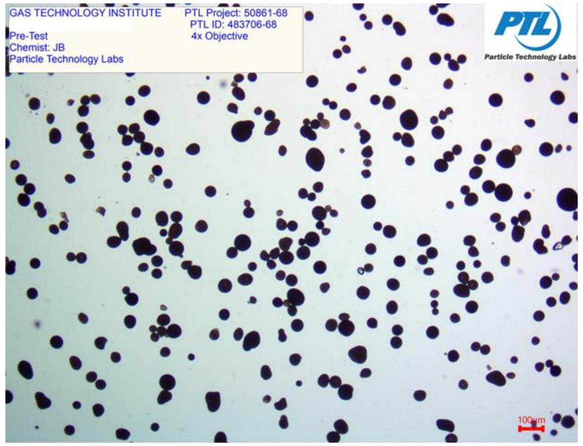
- **Solar-Infrared Hybrid Collector**
  - A system and method for improving solar collector design to provide thermal and electric output during times of low or no solar intensity. The improved solar collector design includes an infrared heater to supplement energy provided by the sun during time of low or no solar intensity.
  - Patent No. US 11,296,645– Filed Date: May 29, 2015

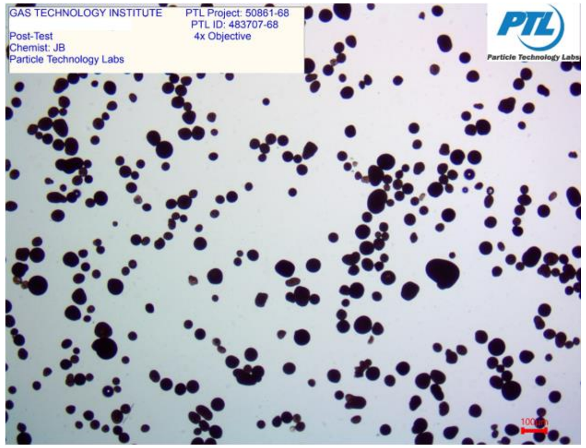
System Advantages

- Dispatchable renewable energy (storage)
- Synergy with the environment
  - Environmental awareness / safeguards
  - Technological innovations
- Expands renewable portfolio
- Reduces fossil fuel consumption and CO_2 emissions
- Contributes to sustainability and resilience
- Manage peak fuel demand
- Mature technology
- Standard materials and means of construction
- Waste heat capture opportunity

Minimal Particle Degradation





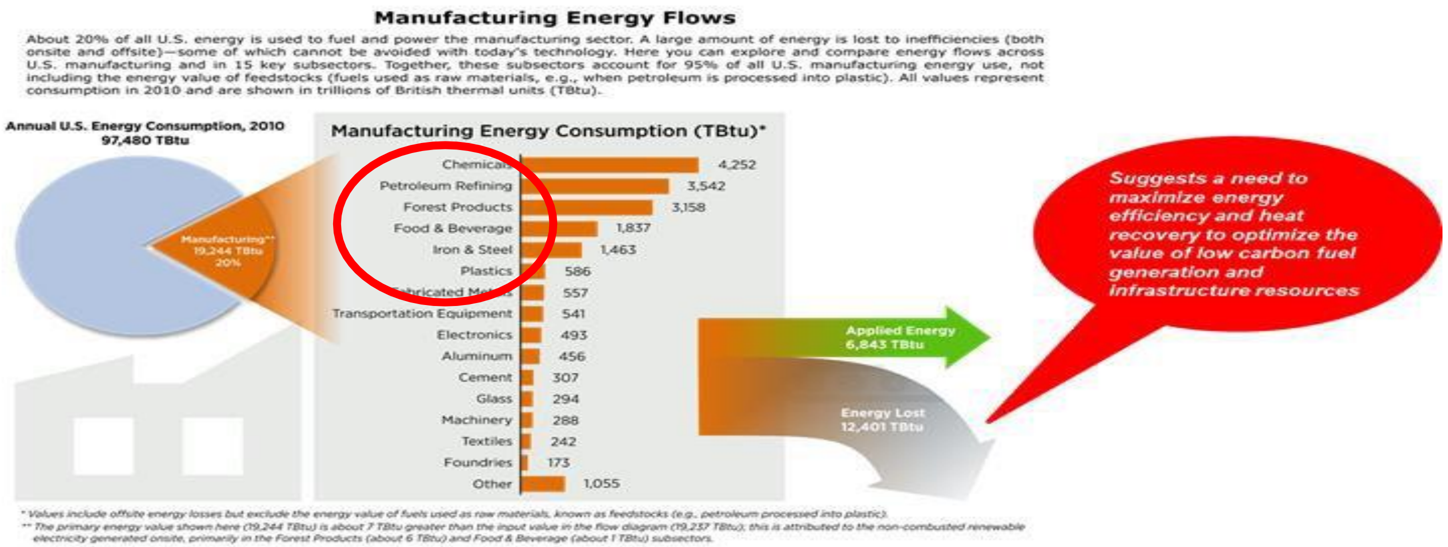


Sample ID	Cumulative volume			Surface weighted mean dia.	Volume weighted mean dia.
	10 % below	50 % below	90 % below		
Pre-Test, µm	44.9	70.9	113	75.4	66.9
Post-Test, µm	44.3	69.9	109	73.8	65.7
Difference, %	1.3	1.4	3.5	2.1	1.8

U.S. Industrial Sector Energy Consumption

- A large portion of energy used in manufacturing is lost to inefficiencies with today's technologies
- 15 key subsectors account for 95% of all manufacturing energy use
- Technology offers opportunity for significant CO_2 reductions

Manufacturing Energy Flows

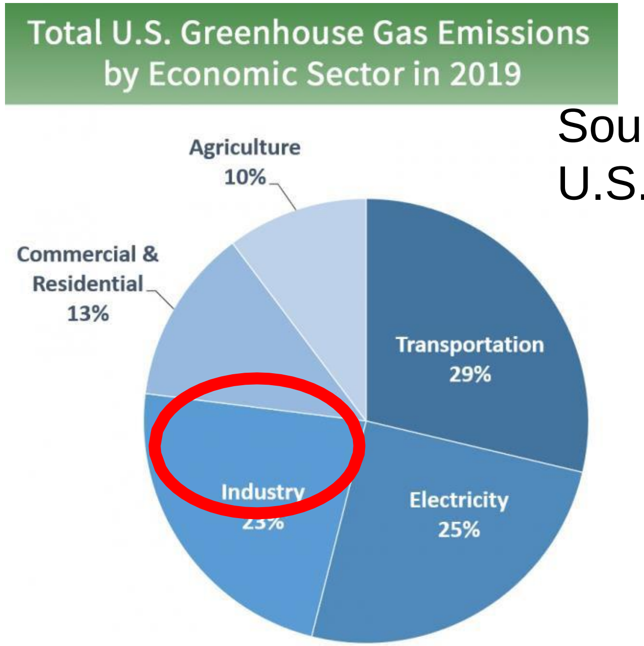


US DOE – AMO Dynamic Manufacturing Energy Sankey Tool (https://www.energy.gov/eere/amo/maps/dynamic-manufacturing-energy-sankey-tool-2010-units-trillion-btu)

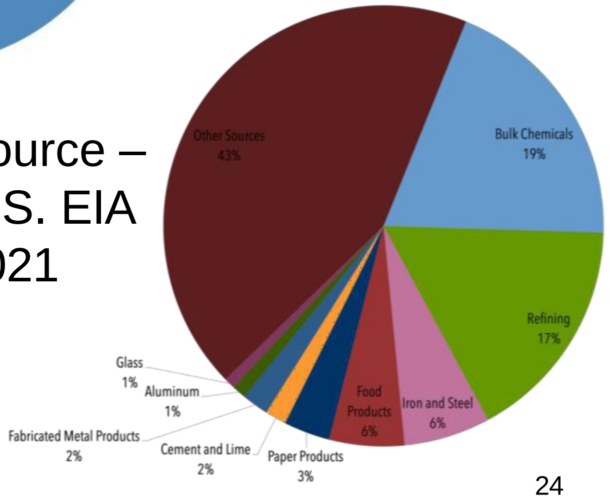
Top 5 subsectors account for 74% of Industrial Sector energy consumption

Industry is the Largest CO_2 Producing Sector in U.S.

- Industry is responsible for 23-30% of the U.S. CO2 emissions using different estimation approaches
- Most CO_2 emissions are from combustion, with natural gas the largest fuel source
- Bulk chemicals and refining combined account for >35% of industrial CO_2 emissions in the U.S.
- The remaining 65% of CO_2 emissions are widely distributed



Source – U.S. EPA



Source – U.S. EIA 2021

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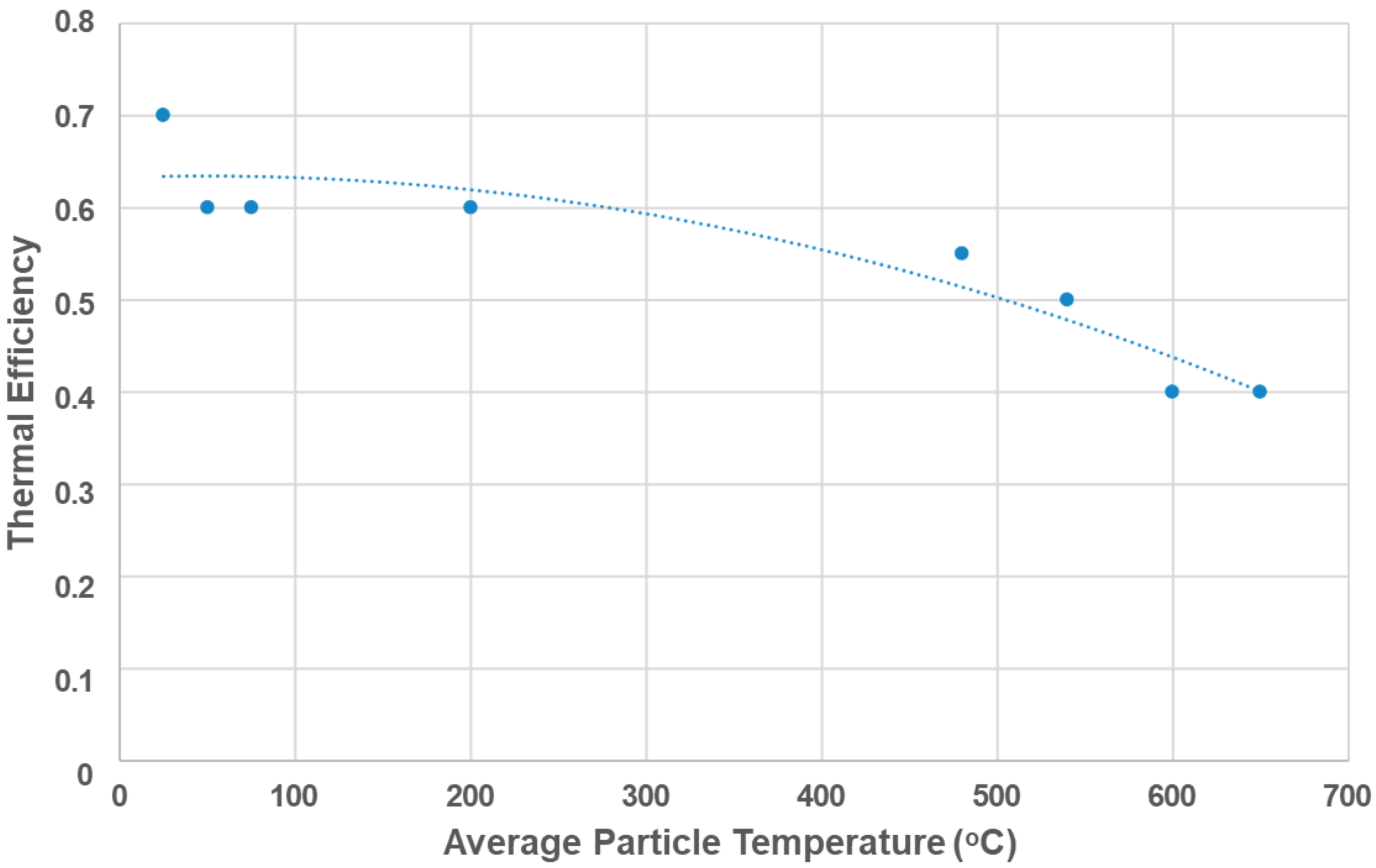
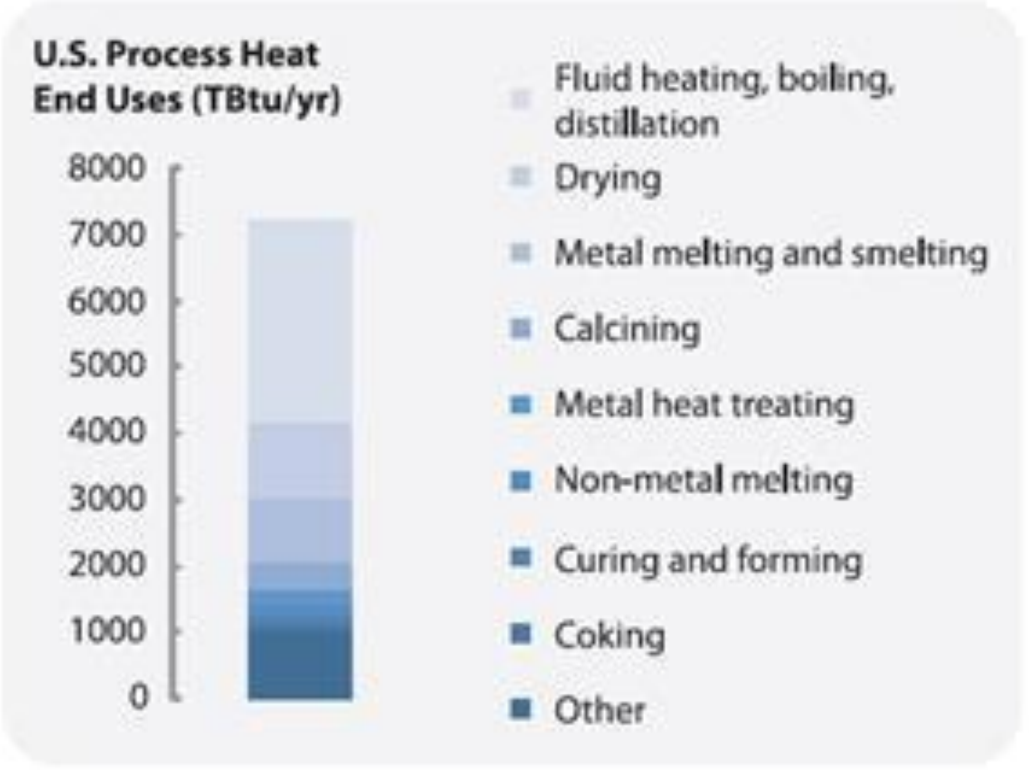
Optical One-Sun Testing Solar Collector

- Designed, built and tested a nominal 5 kW, 1 m long collector at UC Merced
- Low temperature testing with water achieved 70% efficiency
- One-sun testing with particle laden air achieved 40% efficiency at>650°C



Industrial Thermal Energy

- Thermal energy is used directly to provide heat for the process
- Or indirectly, for example via steam, to drive numerous processes like fluid heating, distillation, drying and chemical reactions
- Process temperatures range from 100's to 1000's °F
- In the U.S., ~30% of thermal energy is generated to make steam; the remainder is directly used in furnaces, ovens, kilns and other equipment



Source – U.S. Department of Energy

Techno-Economics of Thermal Energy

- For any zero-carbon heating technology to be viable, it must fulfill the end user's thermal energy demand at a competitive cost
- Demand can be characterized by two variables - temperature and load
  - Temperature is set by the nature of the process and can exceed 1000's °F (steelmaking and cement production)
  - Load is the rate of thermal energy transfer required by the process

Distribution of thermal loads as a fraction of facilities in 14 top greenhouse gas emitting industrial subsectors in the U.S.

Facility annual average load (MWth)	Fraction of facilities (%)
0 to 1	39.6
1 to 10	26.5
10 to 100	18.9
100 to 1000	2.1
Unreported	13.0

Source – McMillan and Ruth