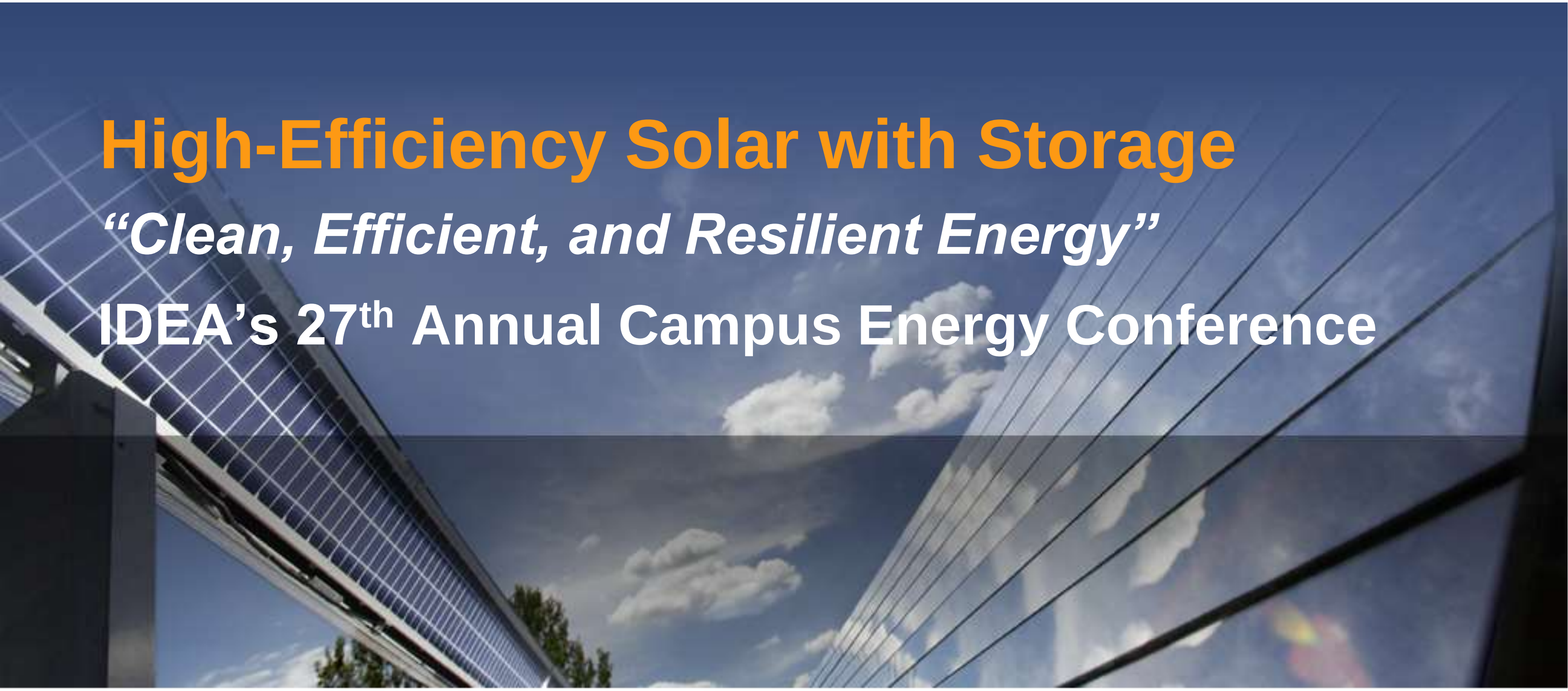


# High-Efficiency Solar with Storage

## *“Clean, Efficient, and Resilient Energy”*

## IDEA’s 27th Annual Campus Energy Conference

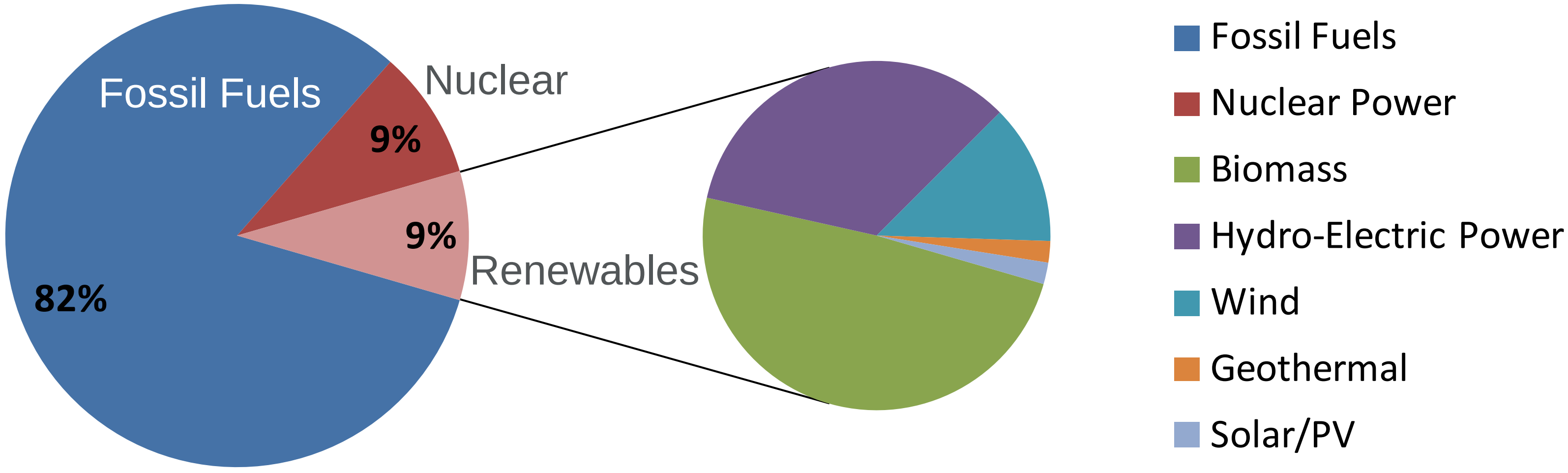
Feb 20th, 2014

# Outline

- Energy Demand and Environmental Impacts
- Solar Market and Industry Trends
- Solar Cogeneration with Waste Heat Recovery
- Case Studies
  - » University of Arizona Technology Park
  - » SolarZone at the UA Tech Park
- Solar On Demand

# US Energy Portfolio

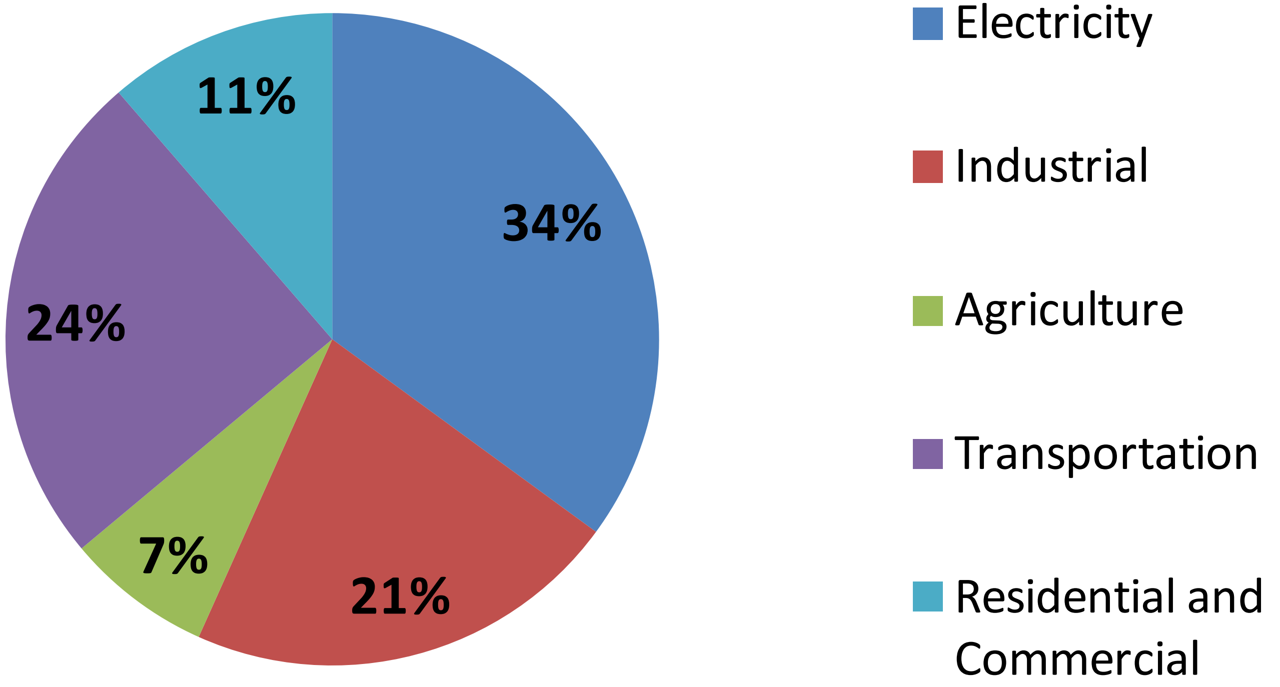
*Consumption, Quad BTU*




Source: US EIA

**Substantial Climate Impacts from Generation Mix**

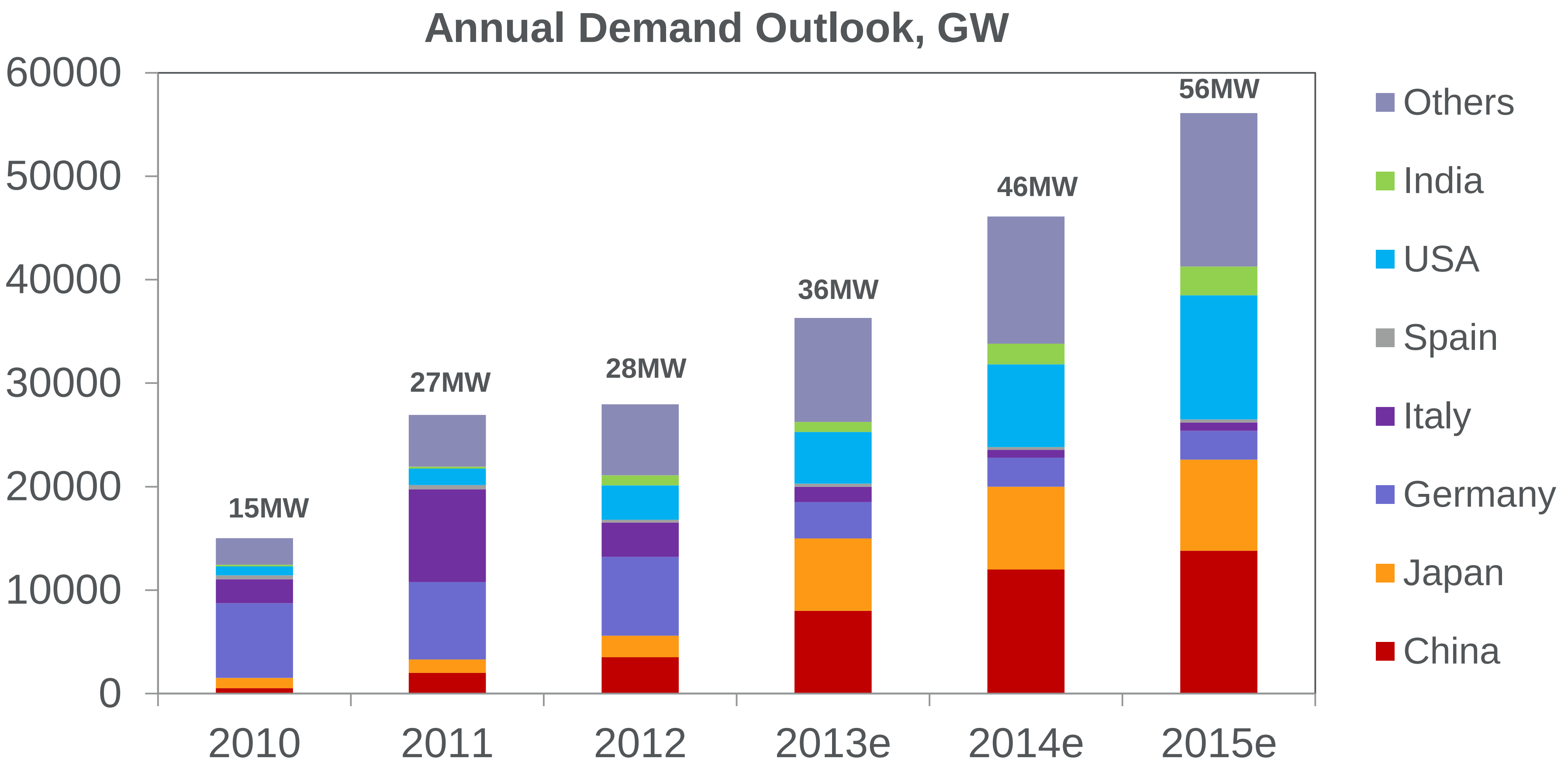
# US GHG Emissions by Sector




Source: US EIA

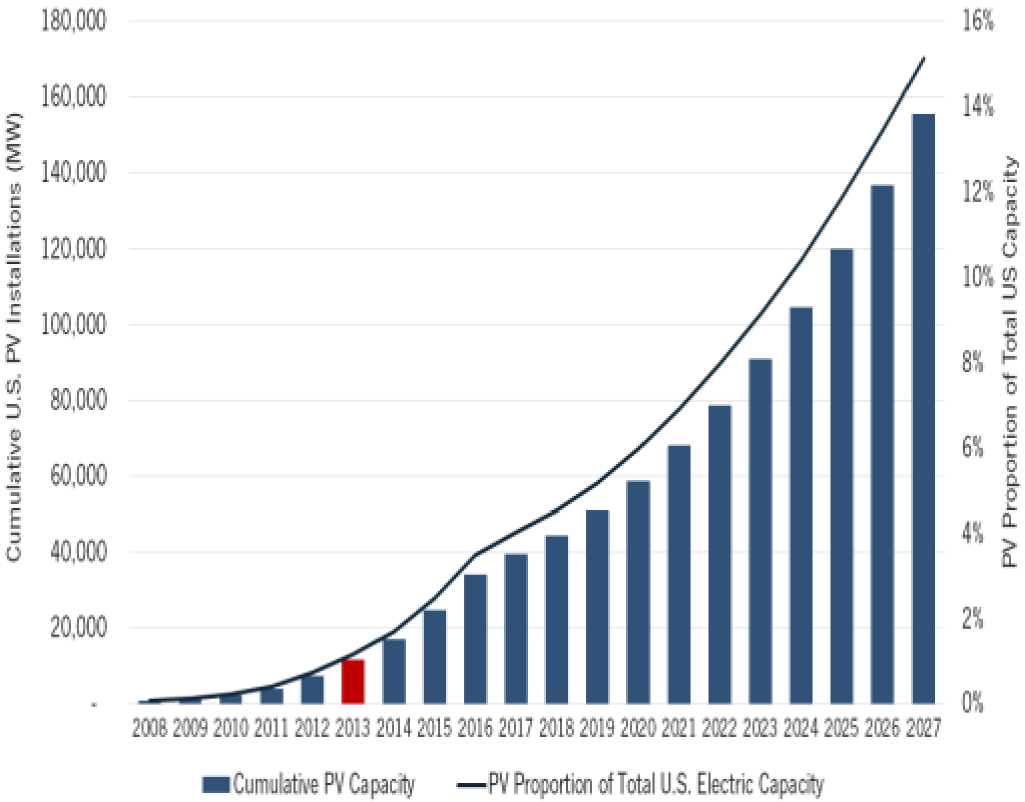
**Electricity Generation and Industrial Dominate**

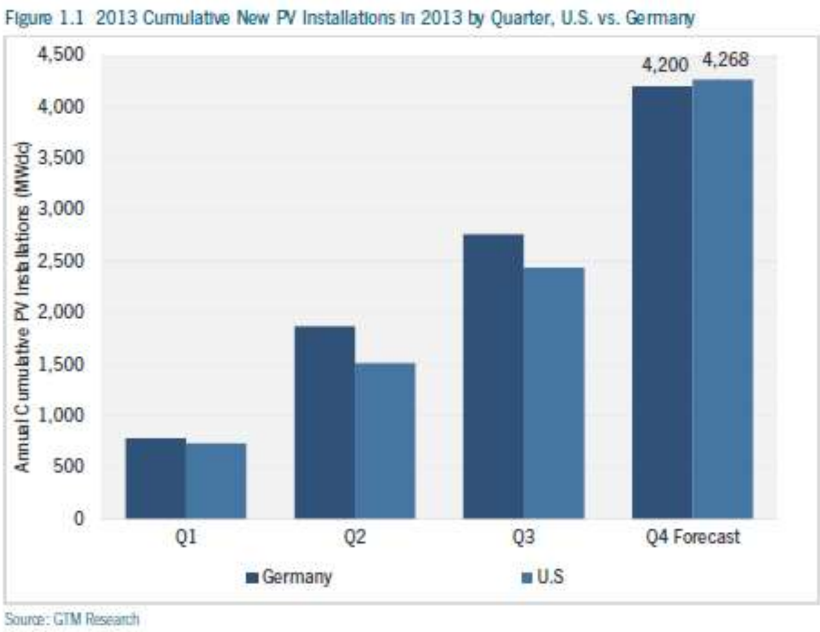
# Worldwide PV Demand Exceeding 50GW




Source: Deutsche Bank

# Growing US Market



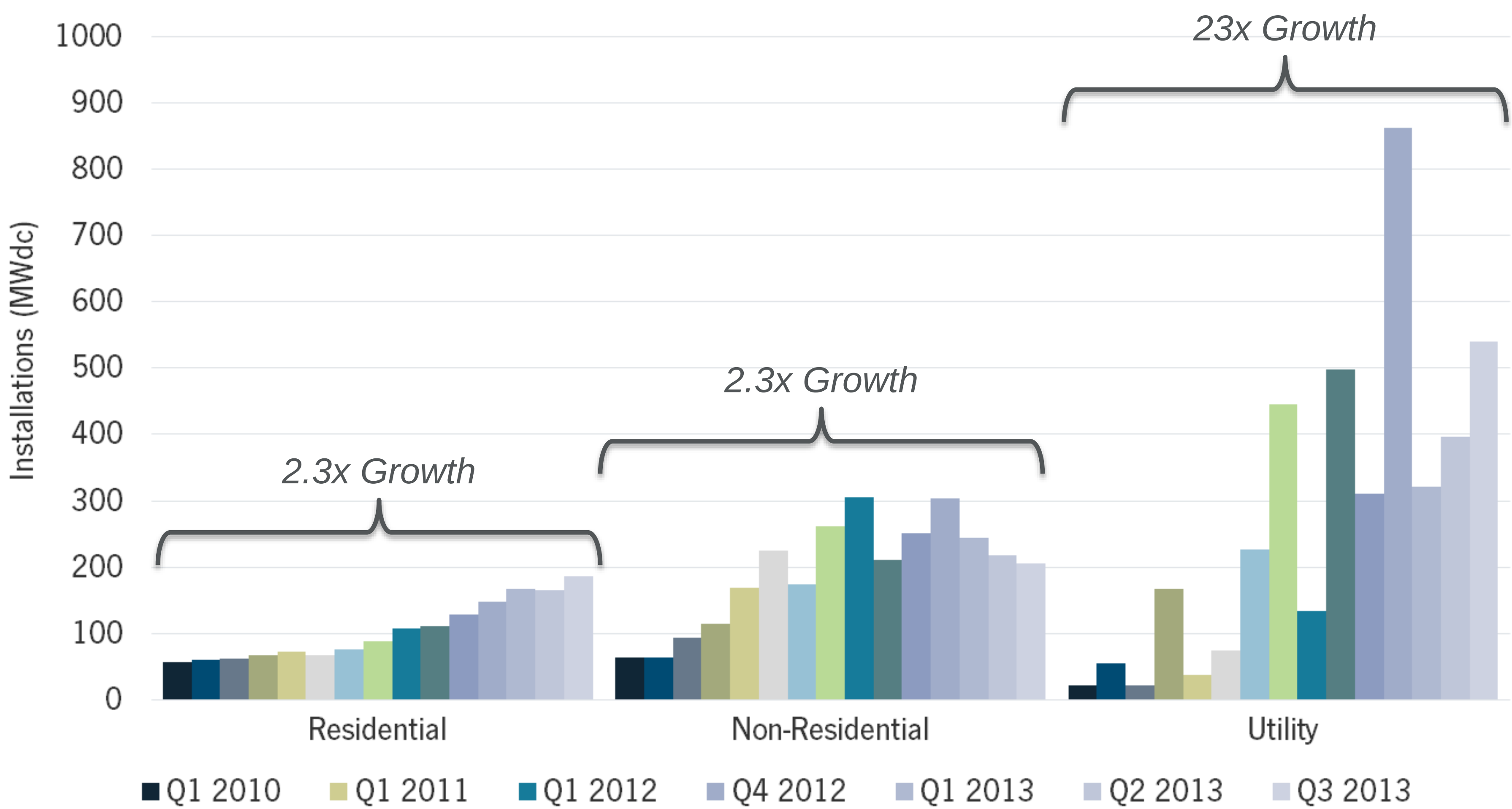




*US installations top Germany in Q4'2013*

Source: GTM Research

# US Market Segments Growth

*Utility Scale Large Ground Mount Dominates*




Source: GTM Research

# Focus on Energy Storage

*"2013 was marked by a steady march toward practical, utility-scale energy storage…"*
*IEEE Spectrum 12/18/2013*

arpa·e

"At the University of Texas-Austin today, Energy Secretary Ernest Moniz will announce $30 million in funding to 12 ARPA-E projects to develop **transformational hybrid solar energy** technologies that **deliver cost-effective power when the sun is not shining**." *– ARPA-E 2/6/2014*

"In a bold move being closely watched by utilities, environmentalists and the clean technology industry, **California on Thursday adopted the nation's first energy storage mandate**.

The state's three investor-owned utilities must collectively buy **1.3 gigawatts** -- or 1,325 megawatts -- **of energy storage capacity** by the end of 2020." *– San Jose Mercury News 10/17/2013*


COGENRA SOLAR    Johnson Controls

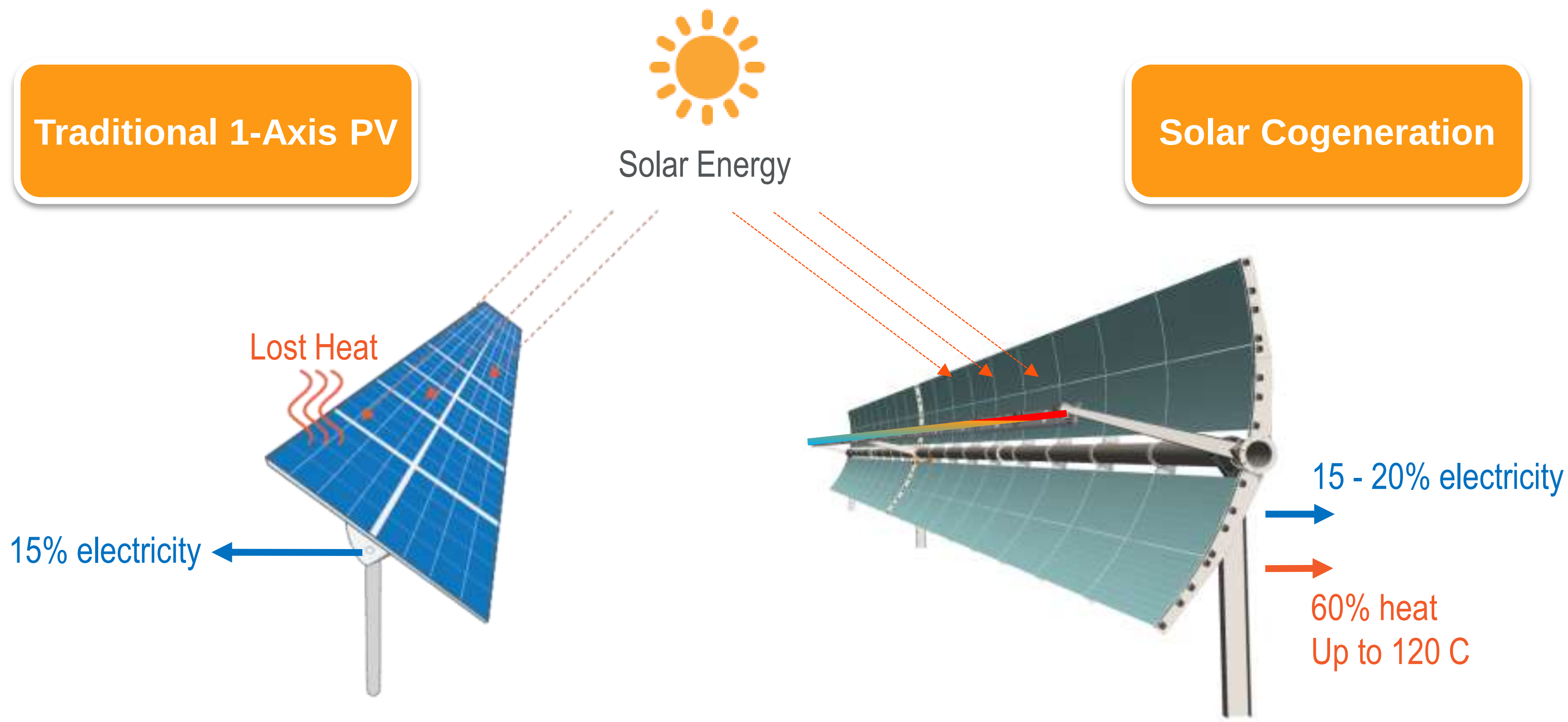
# Combined Heat and Power

**COMBINED HEAT AND POWER (CHP) describes a system that simultaneously generates electricity and useful thermal energy from a single fuel source**

- 8% of US Electric Power – 80 GW
- Prime movers: Combustion Gas Turbines, Internal Combustion Engines, Fuel Cells, Micro-turbines

# Solar Cogeneration

## *Or Solar Combined Heat and Power*



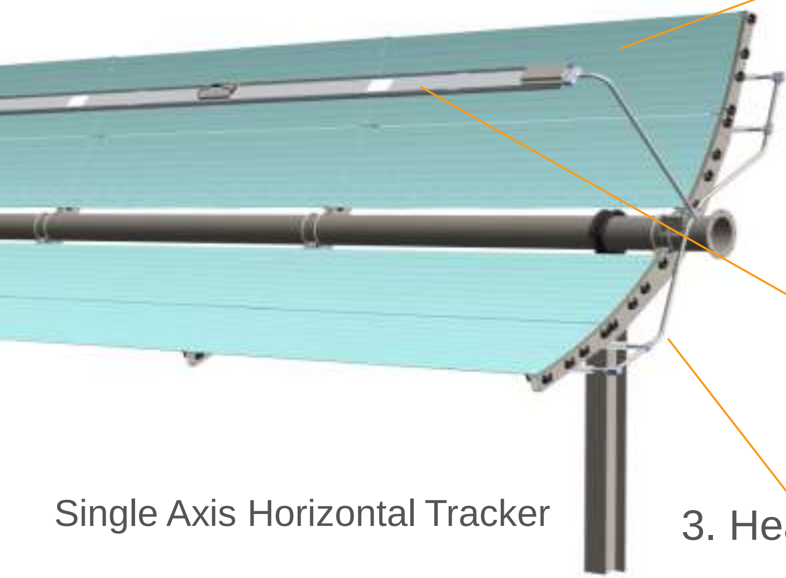

**PV Electricity + Waste Heat Recovery**

# Solar Cogeneration
## *PV + Waste Heat Recovery*

1. Flat-Glass Concentrator

C-Si

*80% area cost reduction*



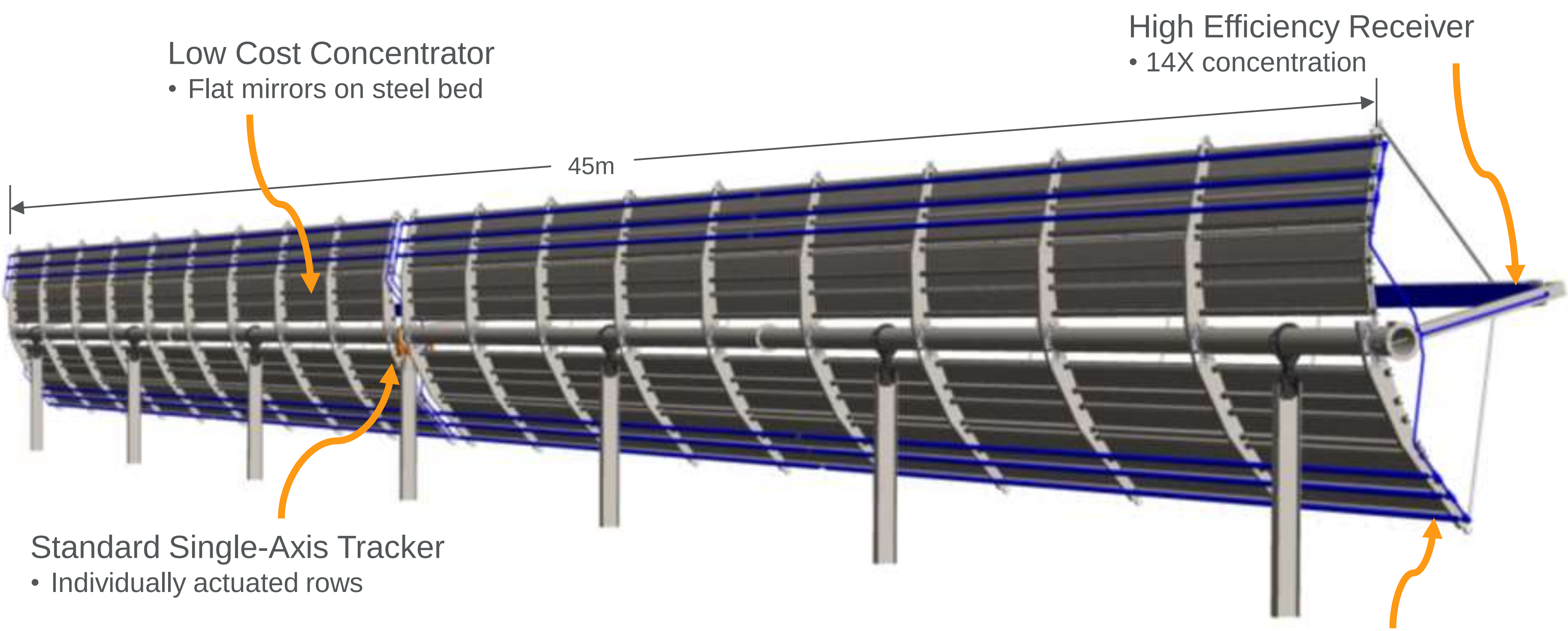
Single Axis Horizontal Tracker

3. Heat Dissipation

2. 1/14th Area → High Efficiency c-Si Module

# Solar Cogeneration

*PV + Waste Heat Recovery*

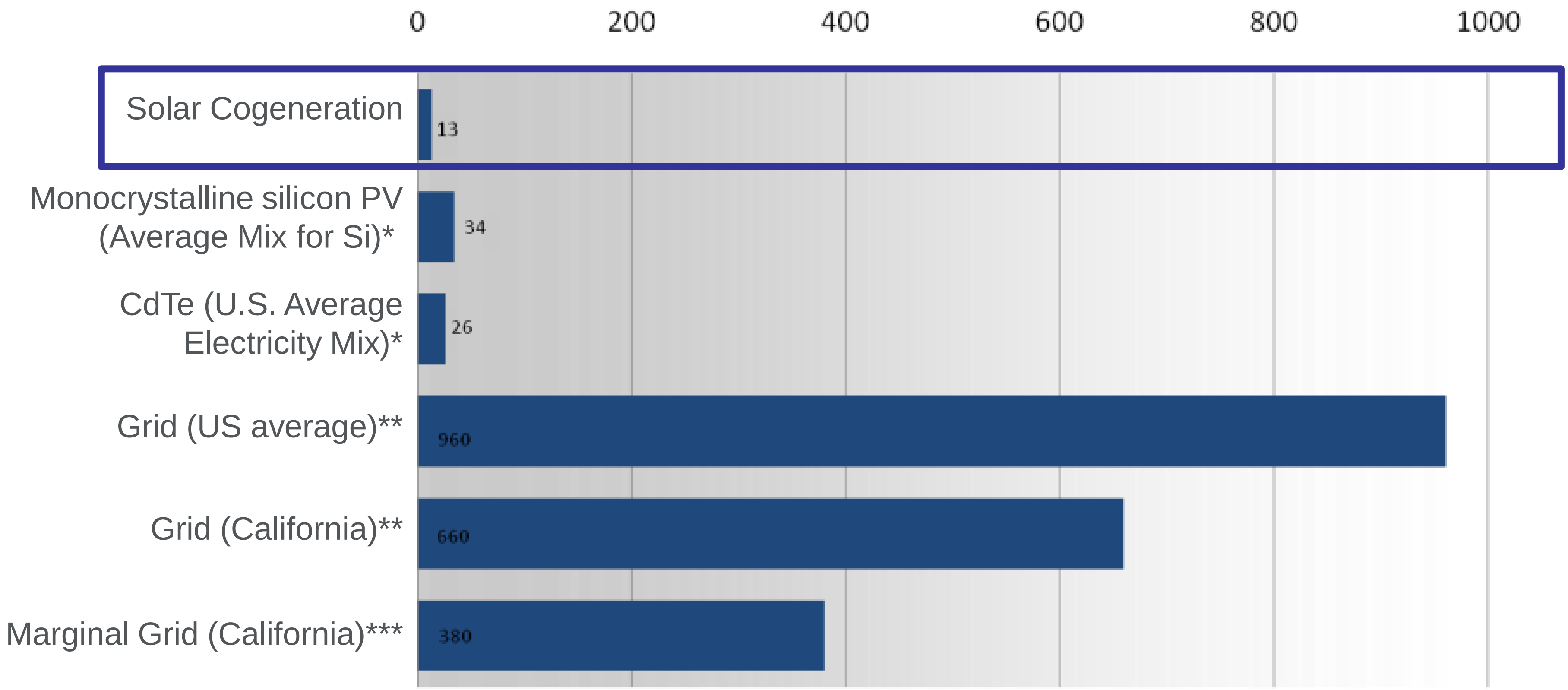



COGENRA SOLAR

Johnson Controls

# Lifecycle GHG Emissions

## g CO2 per kWhe Delivered



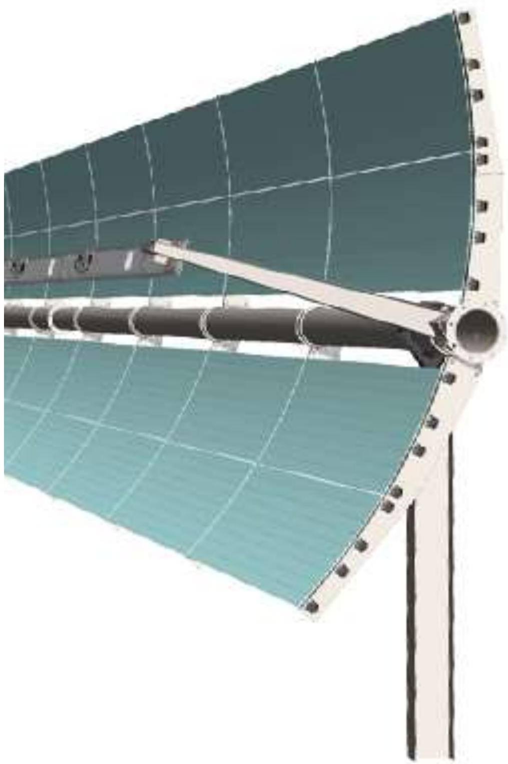

* Fthenakis, et al., "Emissions from Photovoltaic Lifecycles", Environmental Science and Technology, 2008, 42, 2168, 2172.

** Indirect emission reduction factors from U.S. Department of Energy, EIA. Voluntary Reporting of Greenhouse Gases Program. See: http://www.eia.doe.gov/oiaf/1605/pdf/Appendix%20F_r071023.pdf, including emissions avoided from generation at the margin (from fossil-fuel sources) and indirect transmission and distribution losses.

*** Marginal electricity factor from California Environmental Protection Agency Air Resources Board, Detailed California-Modified GREET Pathway for California Average and Marginal Electricity. Version 2.1, February 27, 2009

# Added Value Opportunities

**Solar Cogen PLATFORM**



**APPLICATIONS**

**PV**

\+

Recovered Heat

**District Heating**

**Thermal Desalination**

**Waste-Water Treatment**

**District Cooling**

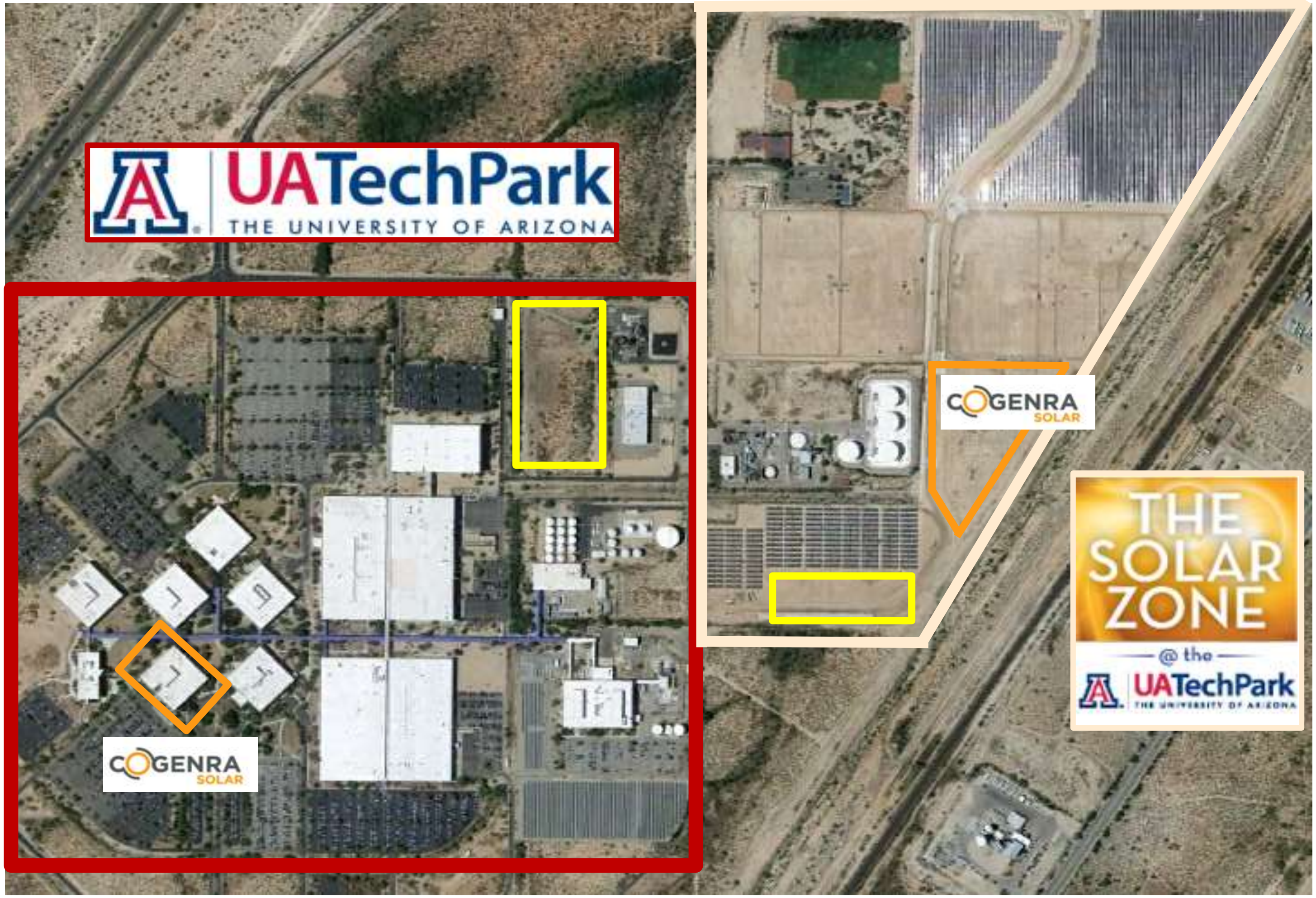
**Energy Storage**

Solar Leadership.

# UNIVERSITY OF ARIZONA & TUCSON ELECTRIC POWER

# Case Study Site Overview

*Utility PV + District Heat, Future Storage Potential*



# UA Tech Park

## *District Space Heating*

ARIZONA | UATechPark
Office of University Research Parks

**System Size**
227 kW

**Industry**
Education

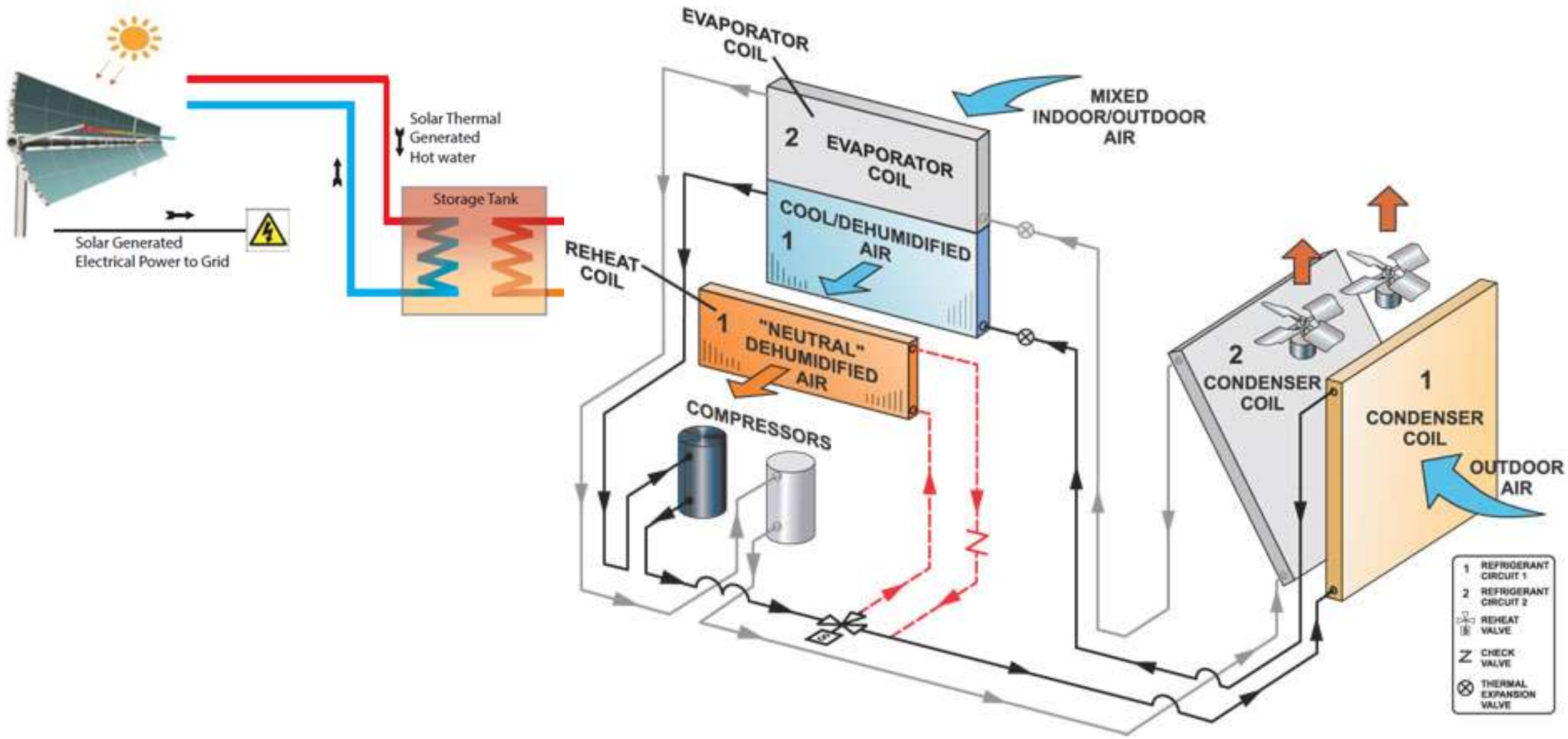
**Installation Date**
Q2 2012

**Application**
Space heating (reheat)

COGENRA SOLAR Johnson Controls

# Solar Space Heating: Reheat

*Humidity & Temperature Control*




**Solar Reheats Dehumidified Air for Comfort AC**

# SolarZone
## *Utility Solar Farm in Construction*


**Host Site**
UA TechPark, Tucson, AZ

**Installation Size**
1.1MW

**Energy Off-taker**
Tucson Electric Power (TEP)

**Project Financing**
3rd Party Construction Financing & Project Capital

**Project Economics**
20 year PPA

**Expected Completion**
Q2 2014

# Added Value Opportunities

**Solar Cogen PLATFORM**

**APPLICATIONS**

**PV**

\+ Free Heat

**District Heating**

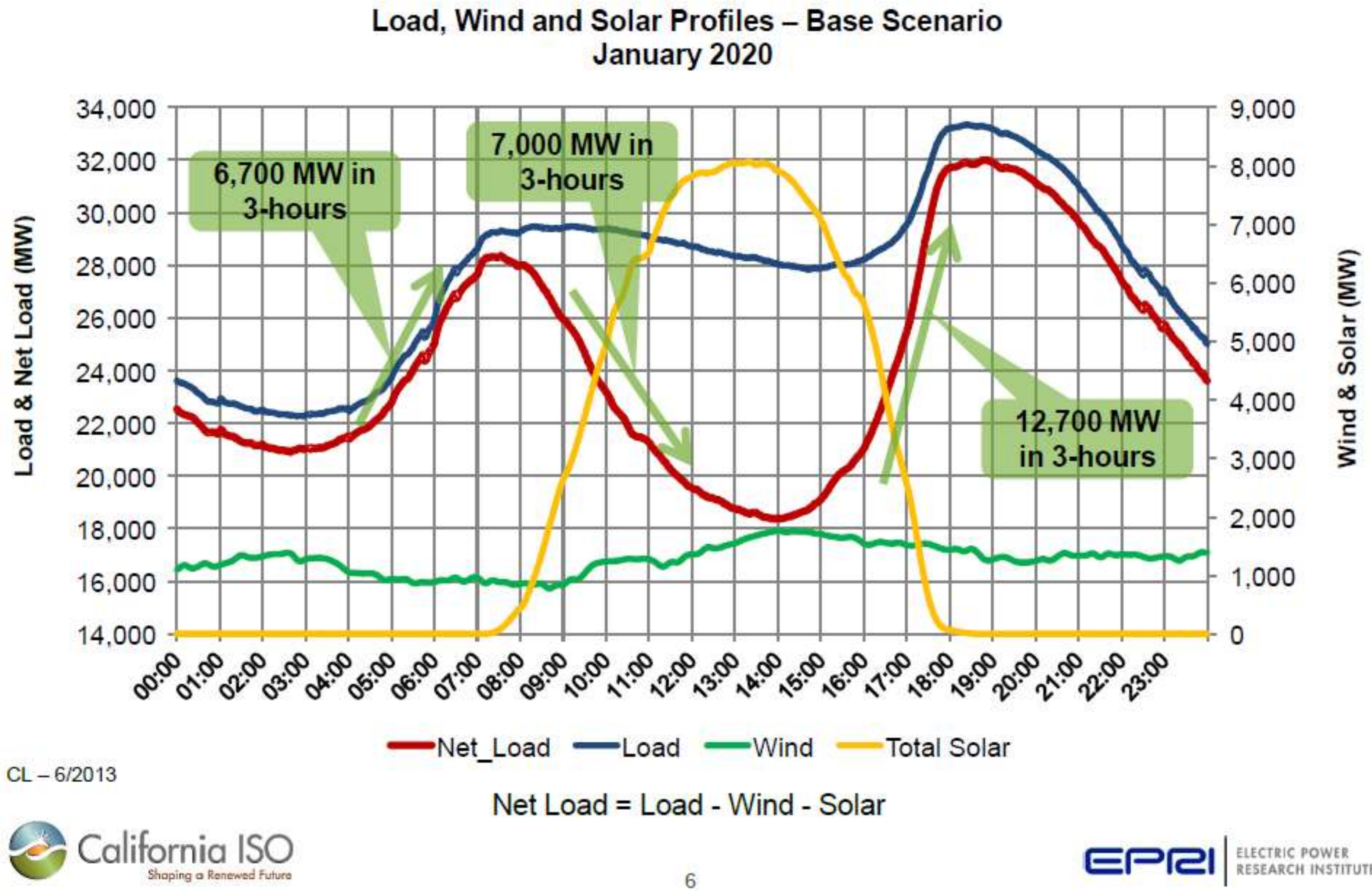
**Thermal Desalination**

**Waste-Water Treatment**

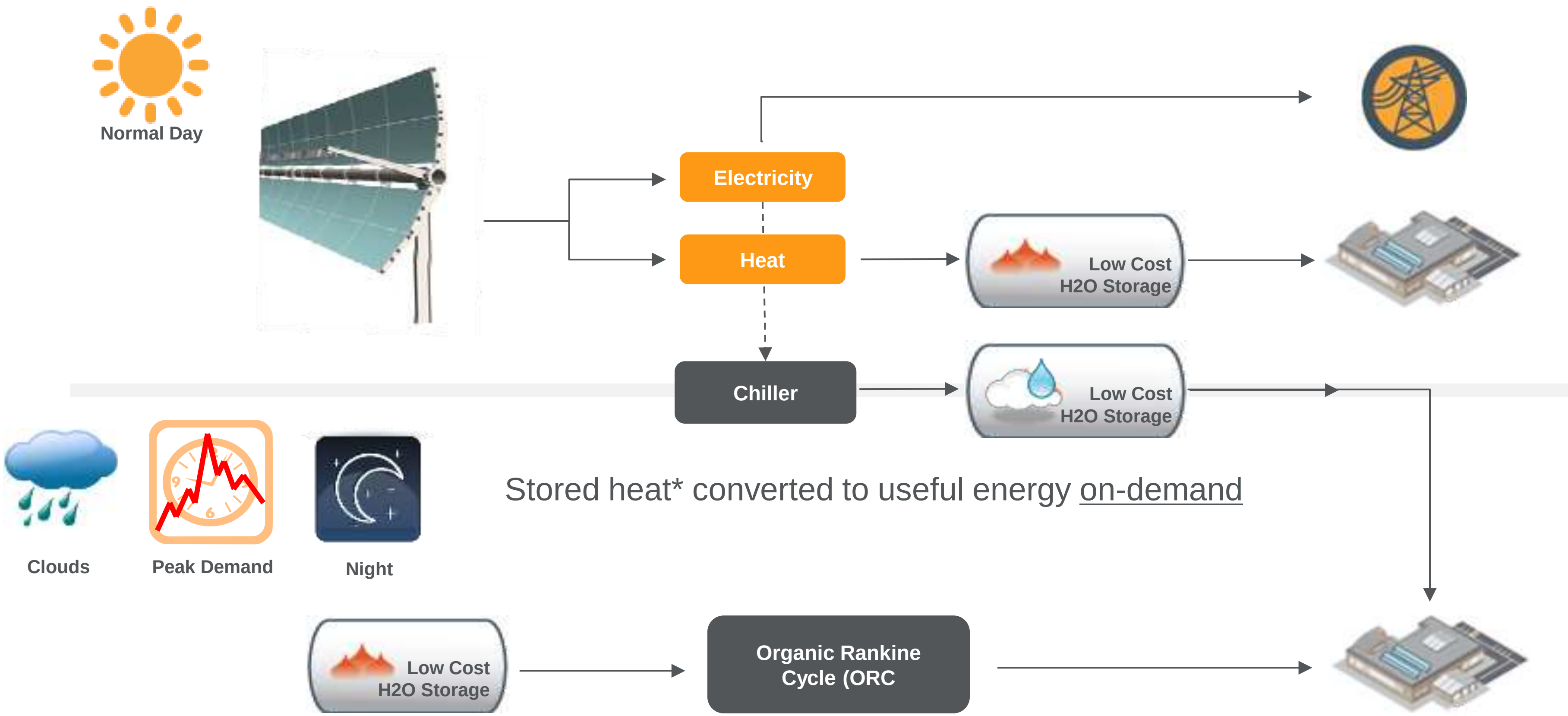
**District Cooling**

**Energy Storage**

# Why Storage Matters



# Solar Energy On-Demand




- Infinite charge / discharge cycles
- 25Yr lifetime

**Addressing Intermittency and Demand Charges**

# Solar On Demand
## *Proven and Reliable Equipment*

### Hot/Cold Thermal (Water) Storage

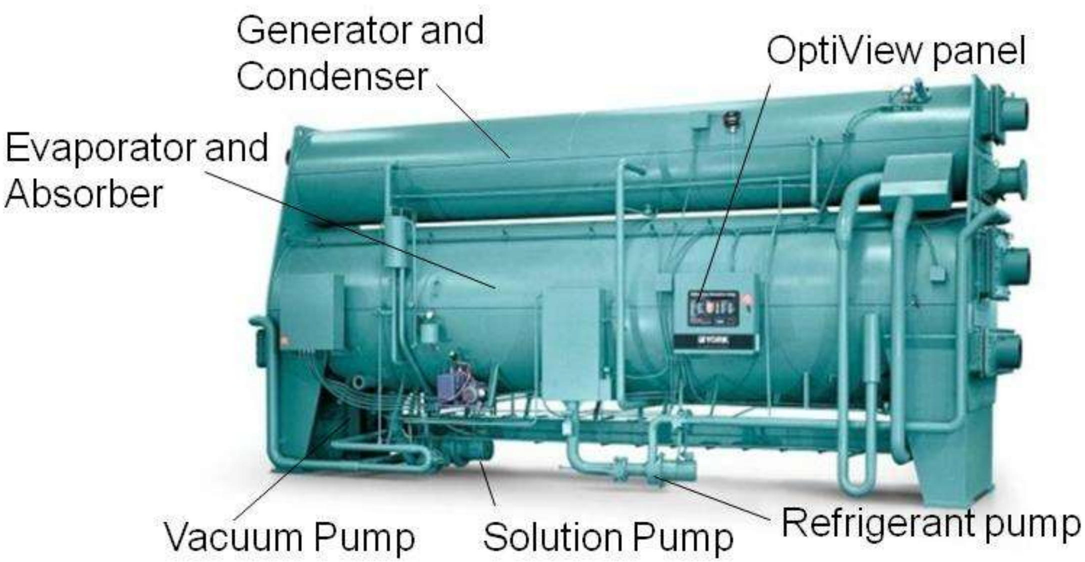
Photo from Pacific Tank, installation at Stanford University

Tanks: Steel Water Tanks
Hot water volume: 560,000+ Gallons
Cold water volume: 460,000+ Gallons
Suppliers: Pacific Tank, CST Industries

Cost: $\$50/kWh_{el}$
Enough storage for 6 hours of ORC operation and pressurized to 2 bar.

# Solar On Demand
## *Proven and Reliable Equipment*

Absorption Chiller




Generator: *Low pressure steam (15 psig) or hot water* (180° F -266° F)
COP: *0.7 – 1.2*

Minimum Leaving Chilled Water Temp: *40° F (4° C)*

Minimum Entering Condenser Water Temperature: *45° F (7° C)*

Typical Condenser Water Flow Rate: 3.6 GPM/ton

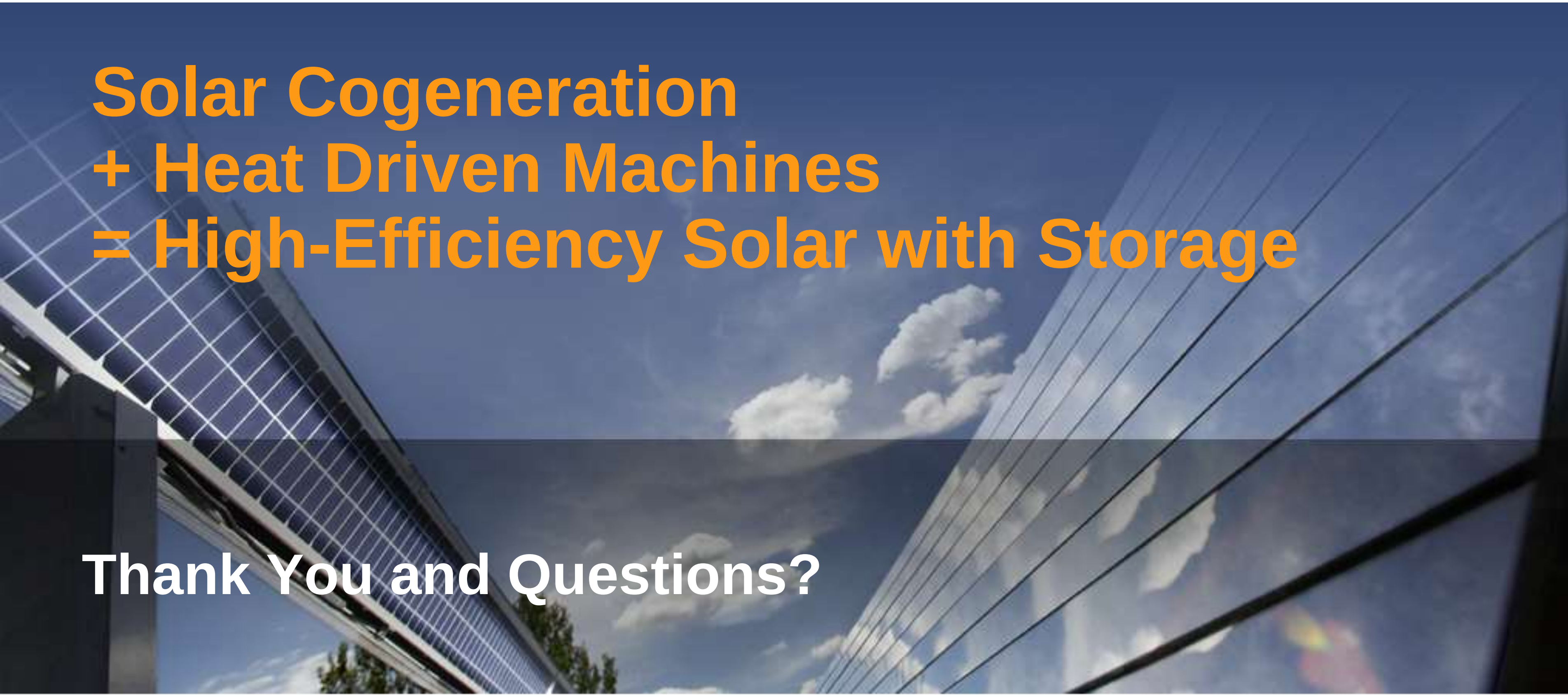
# Solar On Demand
## *Proven and Reliable Equipment*

### Organic Rankine Cycle (ORC)


Evaporator Temperatures: *110-120C*
Condenser Temperatures: *2-12C*
Power Output: *500+ kW*
Efficiency: *~14%*
Evaporator Flow Rate: 1500+ GPM
Condenser Flow Rate: 1300+ GPM

Based on 1 MW PV installation, 6 hours ORC operation and 4 hours of chiller operation

# Solar Cogeneration
# + Heat Driven Machines
# = High-Efficiency Solar with Storage



## Thank You and Questions?

Feb 20$^{th}$, IDEA 27$^{th}$ Annual Campus Energy Conference