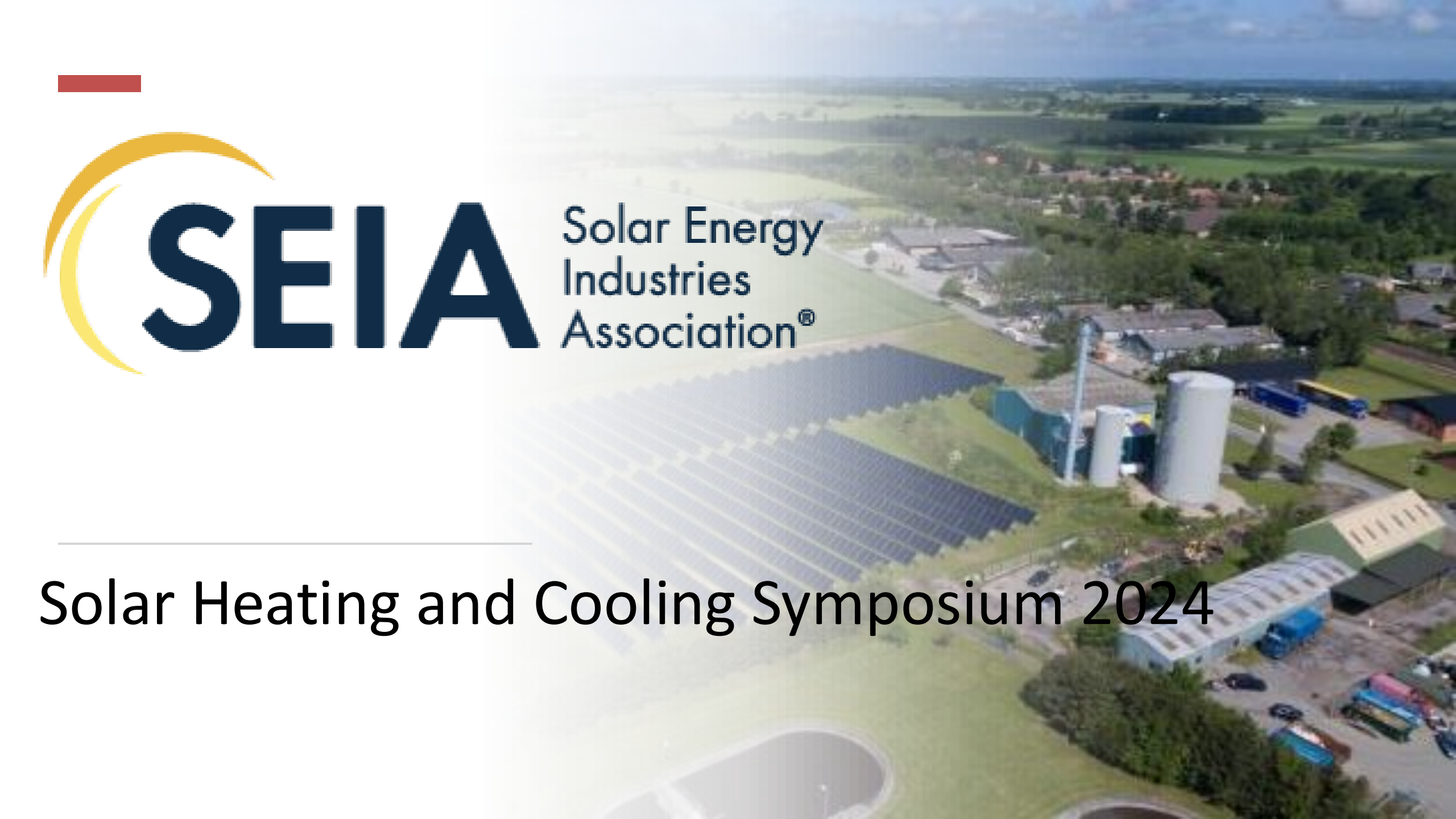
SEIA Solar Energy Industries Association®



Solar Heating and Cooling Symposium 2024

What is the Solar Energy Industries Association

- "Founded in 1974, SEIA is the national trade association for the solar and solar + storage industries, building a comprehensive vision for the Solar+ Decade through research, education and advocacy. SEIA has earned numerous awards for its work and company culture and was named by the Washington Post as a 2023 Top Workplace and a Best Nonprofit to Work For by the Nonprofit Times."
- Solar Heating and Cooling Committee works with industry and SEIA staff to impact national policy on solar thermal technology
  - Current Chair and Vice-Chair:
    - Will Giese, The Solaray Corporation
    - Tara Prieto, Alternate Energy Technologies

SEIA and Solar Hot Water

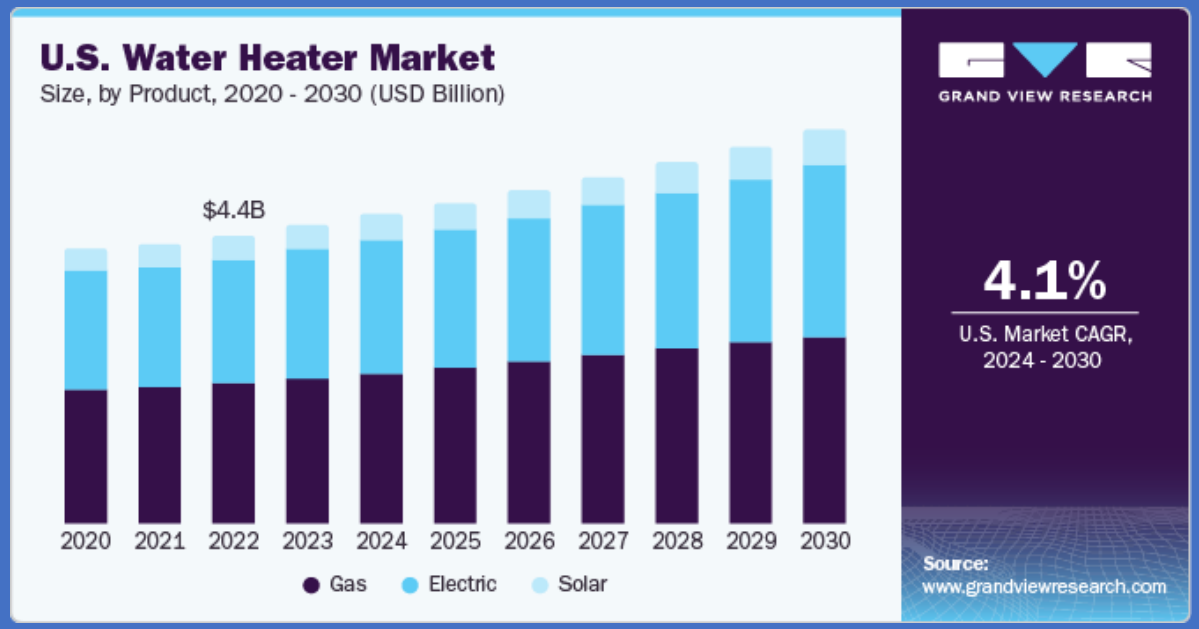
- SEIA is the main national trade advocate for the solar heating and cooling industry and advocates for national and state level policy
- Examples of advocacy:
  - Creation and inclusion of the solar universal energy factor (SUEF) in EnergyStar device standards
  - Inclusion of SHC technology in Section 48 Commercial Investment Tax Credit
  - Advocacy on solar thermal issues to federal policy makers and agencies, such as the DOE and EPA's EnergyStar
  - Publishing of case studies and white papers on solar thermal
  - Regular meetings and events for SHC industry

Joining the SHC Committee at SEIA

- SHC Committee is open to all “Basic” level SEIA members and above currently, transitions to KW+ members in 2026
- Interested companies should contact membership@seia.org or one of the SHC Committee Chairs:
  - Will Giese: wgiese@sunearthinc.com
  - Tara Prieto: tara@aetsolar.com
- Details about SEIA membership can be found here: https://www.seia.org/Join

The Water Heater Market

- Total addressable market, annually = $639 million
- Globally = $29 billion
- Projected Annual CAGR
  - 1-5YR = 4%
  - 5–10YR = 7%
- No clear solution for total electrification,
- Commercial and industrial sectors are being pushed to decarbonize; hybrid solutions favor solar

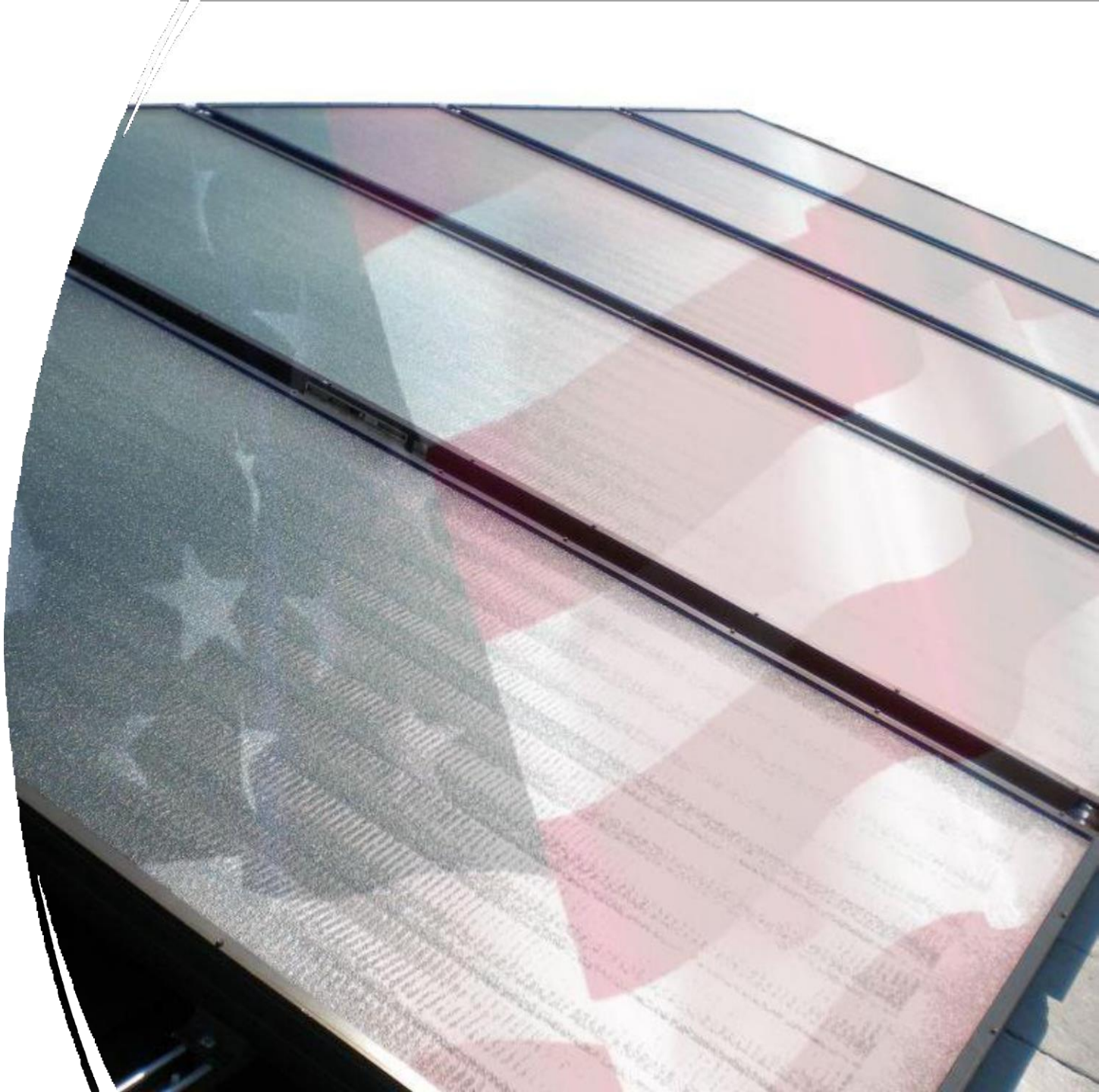


The Policy of it All

Understanding the Landscape Post-IRA

Key Provisions Impacting Solar Thermal

- Section 25C and 25D of the Internal Revenue Code
  - 25C - Energy Efficient Home Improvements
  - 25D – Residential Energy Property Tax Credits
- Section 48 of the Internal Revenue Code
  - Pre-2025 – commercial property tax credit, post-2025 Section 48E “tech neutral” credit
  - “energy community” and “domestic content” adders (2-10% based on qualification)
  - Section 48C – Manufacturing Tax Credit
- Several funds, grants, and loan programs
  - $1 Billion – Rural Electrification
  - $1 billion –REAP
  - $29 billion EPA GG Reduction Funds



Solar Thermal for Decarbonization

A Valuable Option for Building Engineers

Brad Heavner [1]
CALSSA Policy Director
October 28, 2024

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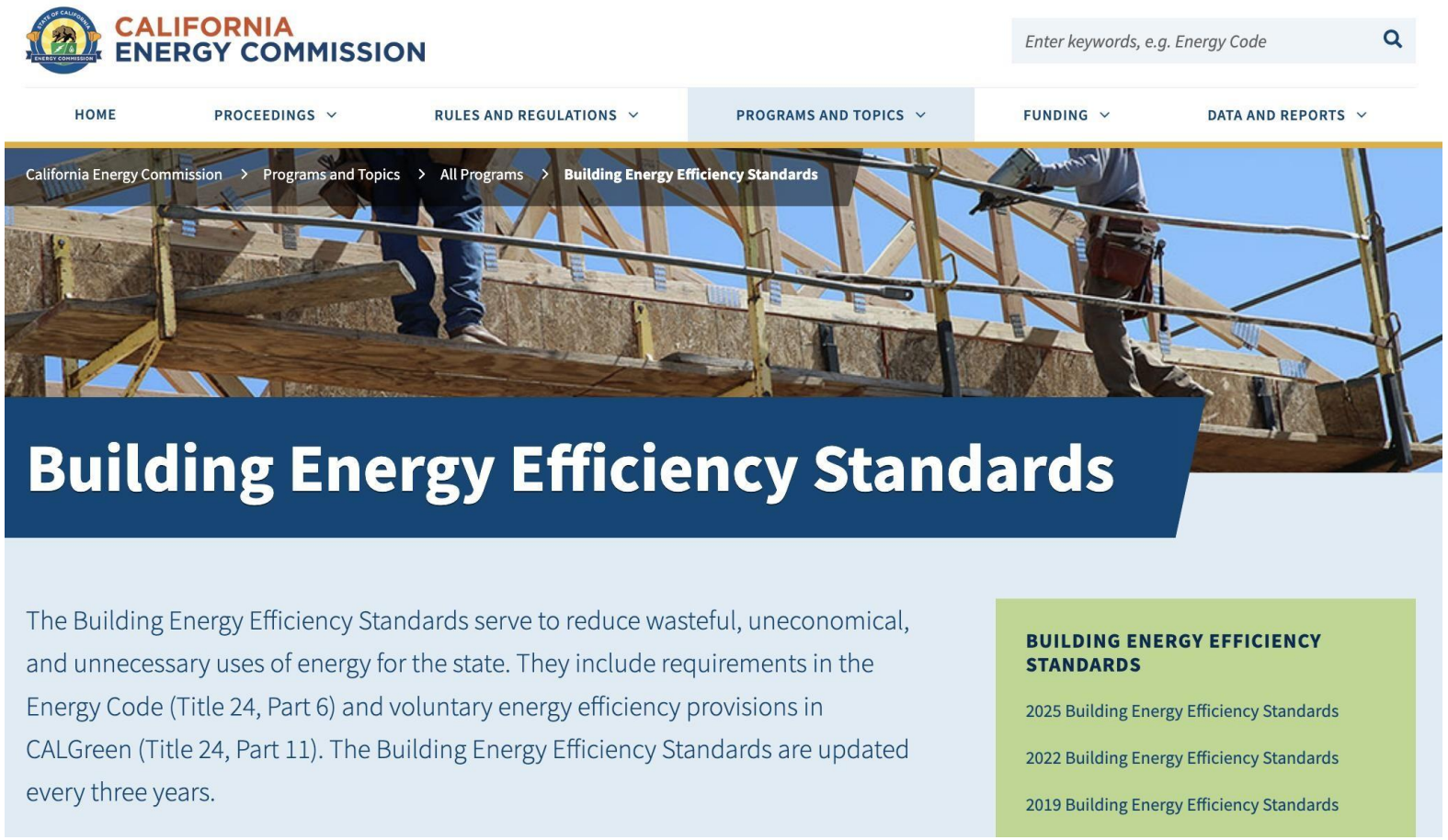
smart local energy

California Title 24



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CBECC Tool

2022 Energy Code Compliance Software

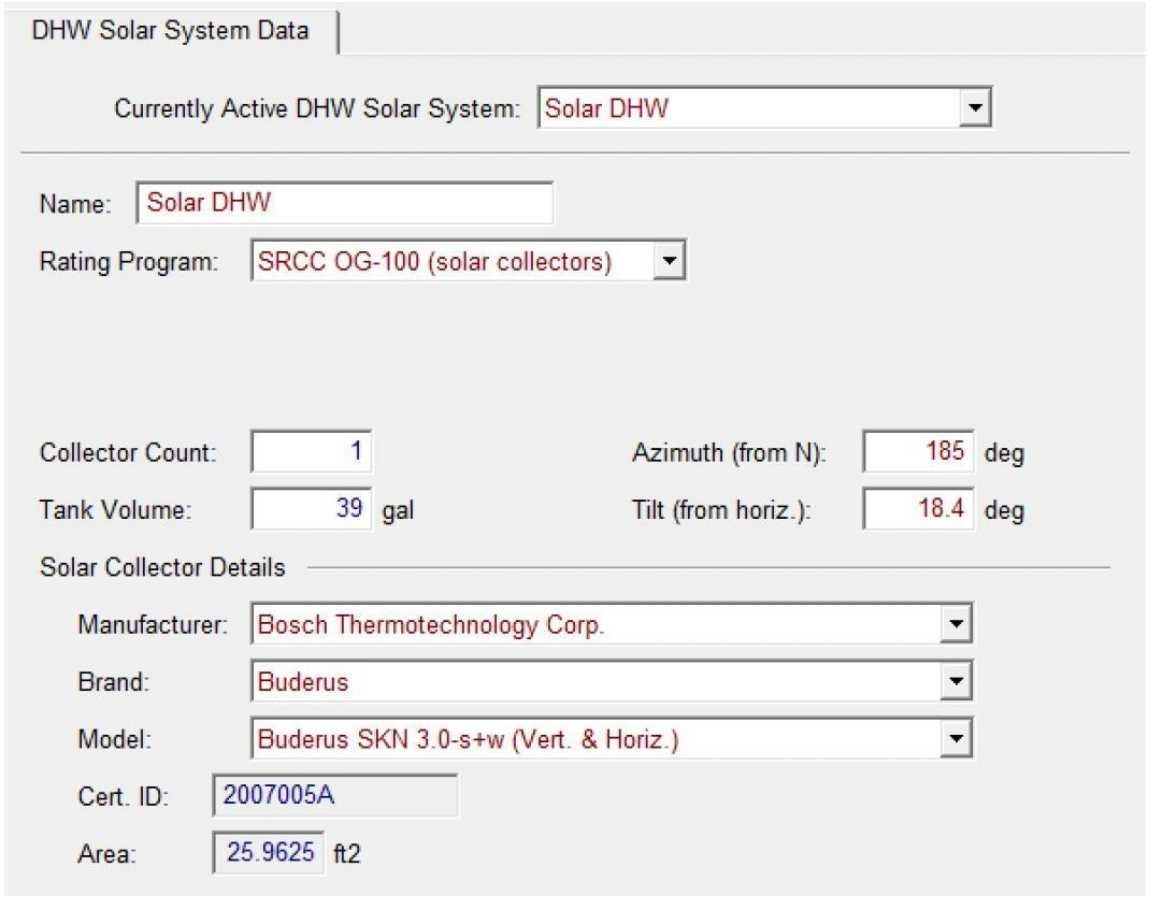
The California Energy Commission (Energy Commission) has approved the following compliance software for the 2022 Building Energy Efficiency Standards (Energy Code) in accordance with the California Code of Regulations: Title 24, Part 1, Article 1, Section 10-109.

The individual programs are listed below under specific categories, single-family residential and nonresidential and multifamily. These are the only programs authorized to be used under the performance approach (energy budget) method of compliance for the 2022 Energy Code.

Single-Family Residential, 2022 Energy Code

Program Name	Compliance Software Versions	Contact Information	Additional Information
California's Building Energy Code Compliance Software – Residential (CBECC-Res)	CBECC-Res 2022.3.1 was approved 5/3/24 for demonstrating performance compliance with the single-family residential provisions of the 2022 Energy Code. Permit applications made on or after 10/1/23 must use CBECC-Res 2022.3.0, or 2022.3.1. **Latest Version** • Download CBECC-Res 2022.3.1	California Energy Commission Building Standards Office 715 P Street, MS 37 Sacramento, CA 95814 ATTN: Thao Chau 916-776-7974 cbecc.res@energy.ca.gov	See the CBECC-Res Website for: • Quick Start Guide and User Manual (packaged with software) • FAQs • Software Archive • ACM Tests • Reference Documents

Solar Water Heating in the CBECC Tool



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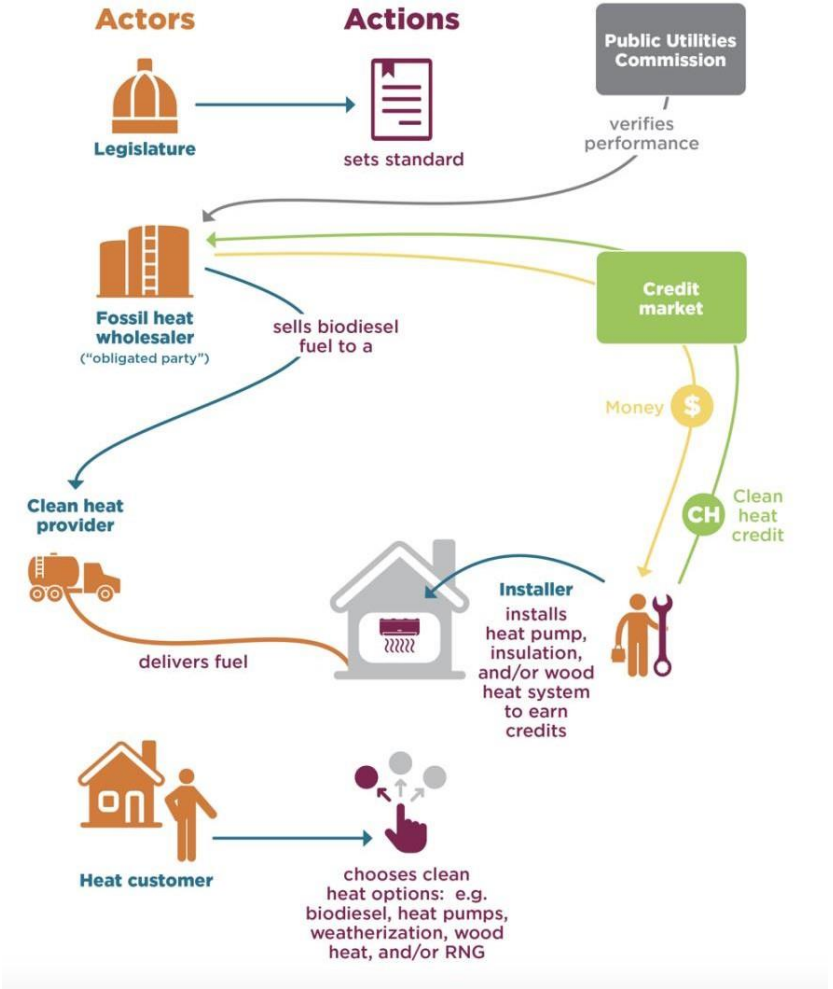
New York Decarbonization Mandate

The Climate Act requires New York to reduce economy-wide GHG emissions 40% by 2030 and 85% by 2050 from 1990 levels.

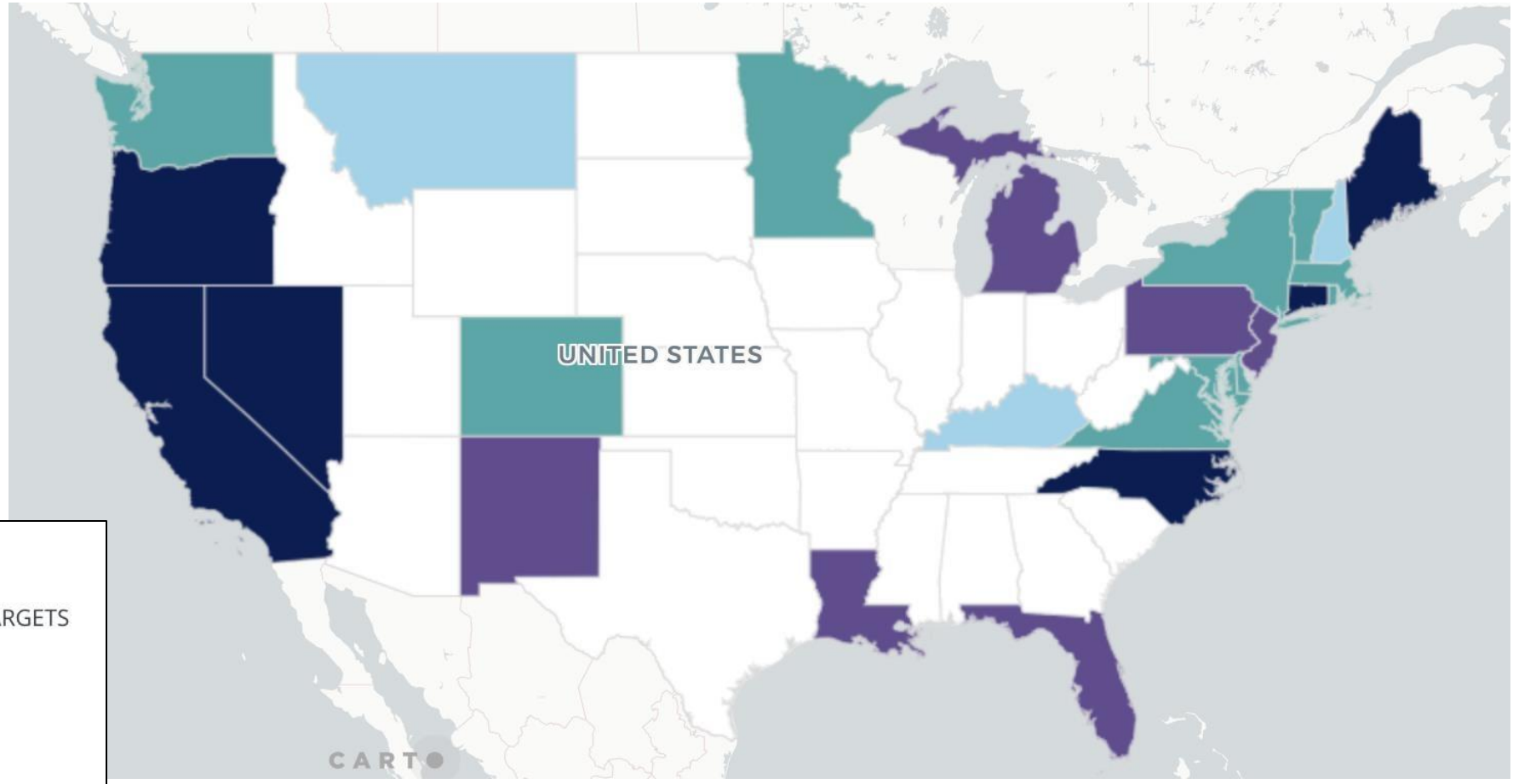
- **Adopt regulations to end on-site emissions:** DOS, NYSERDA, and the Code Council should advance code provisions that prohibit fossil fuel combustion equipment for space conditioning, hot water, cooking, and appliances. Until such codes are adopted statewide, NYSERDA should encourage local governments to adopt NYStretch Energy Code.

Vermont Clean Heat Standard

- Vermont Act 18 of 2023 became effective on May 24, 2023. It directs the Vermont Public Utilities Commission to prepare a Clean Heat Standard by January 2025.
- The CHS is a performance standard, applied to the providers of fossil heating fuels in Vermont, requiring them to deliver a gradually-increasing percentage of low-emission heating services to Vermont customers.



State Greenhouse Gas Reduction Targets



State GHG Targets

- STATUTORY AND EXECUTIVE TARGETS
- STATUTORY TARGET
- EXECUTIVE TARGET
- RECOMMENDED TARGET
- NO TARGET

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Challenge of Low-Emission Water Heating at Large Scale

Installation Costs

- Large heat pumps are relatively unproven
- Can solar reduce installation costs and performance risk by enabling smaller heat pumps

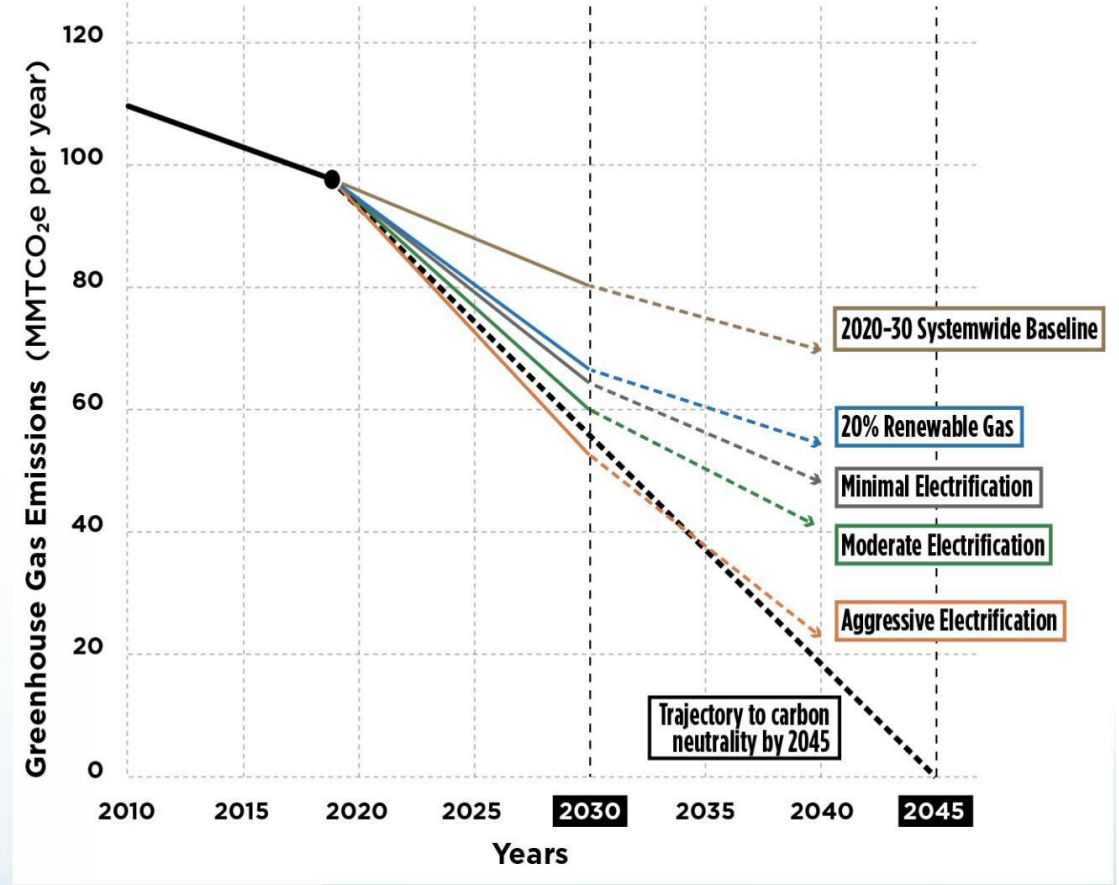
Operating Costs

- Large scale water heating requires massive storage tanks.
- If you install large, stratified thermal storage for an industrial heat pump, adding solar thermal collectors is a low-cost option that can greatly reduce fuel costs

Decarbonization – Reduce or Eliminate Gas

Should decarbonization efforts focus exclusively on zero gas strategies or should some short term gas reduction strategies be included?

- California is focused on 100% gas elimination.
- Will other states allow solutions that reduce gas usage by 80% as part of decarbonization efforts?



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SoCalGas Incentive Program

Solar Thermal WH Information

Purchase Date *

Installation Date *

Manufacturer Name *

OG-300 Certification # *

Solar Thermal Collector Manufacturer Name *

ENERGY STAR® Solar Thermal Water Heating System

From October 1, 2024, until November 30, 2024, all qualifying energy-efficient residential appliance purchases will receive an extra 50% rebate. Eligibility requirements apply.

Only the Account Holder, Spouse (authorized on account) or Property Owner can apply for the rebate. Payments are always payable to the Account Holder.
Note: If you are an owner applying on behalf of your tenant and you want the rebate payment payable to you, please apply here. You will need to provide proof of property ownership.

Rebate will not exceed the purchase price of the unit. Purchase price does not include sales tax or other taxes, installation, shipping or delivery, or any associated costs.

"Incomplete and Incorrect applications will need to reapply."

SoCalGas Incentive Program

ENERGY STAR solar thermal water heating system with an ENERGY STAR Tankless Gas Backup (.95 UEF or above) replacing a Tankless Gas Water Heater - $4,500 Rebate

ENERGY STAR Solar Thermal Water Heating System with an ENERGY STAR Tankless Gas Backup (.95 UEF or above) replacing a Storage Gas Water Heater - $4,500 Rebate

ENERGY STAR Solar Thermal Water Heating System with an ENERGY STAR Storage Gas Backup (up to 55 gallons) replacing a Storage Gas Water Heater - $3,500 Rebate

ENERGY STAR Solar Thermal Water Heating System with a NON-ENERGY STAR Tankless Gas Backup (.82 UEF or above) replacing a Tankless Gas Water Heater - $3,000 Rebate

ENERGY STAR Solar Thermal Water Heating System with a NON-ENERGY STAR Tankless Gas Backup (.82 UEF or above) replacing a Storage Gas Water Heater - $3,000 Rebate

ENERGY STAR Solar Thermal Water Heating System with a NON-ENERGY STAR Storage Gas Water Heater (up to 55 gallons) backup replacing a Storage Gas Water Heater- $2,500 Rebate

IMPORTANT: To qualify for the rebate, certified ENERGY STAR Solar Water Heating Systems must have a Solar Uniform Energy Factor (SUEF) of 1.8 or greater. In addition, a new installation of an ENERGY STAR certified Natural Gas Storage Water Heater (up to 55 gallons) or an ENERGY STAR certified Natural Gas Tankless Water Heater with a UEF (Uniform Energy Factor) of .82 or above (serving as the backup unit), in conjunction with the Solar installation is required. Limit one per household. Current Solar Water Heater Rebates - Effective 11/22/2022:

Thank You!

Brad Heavner
Policy Director
brad@calssa.org

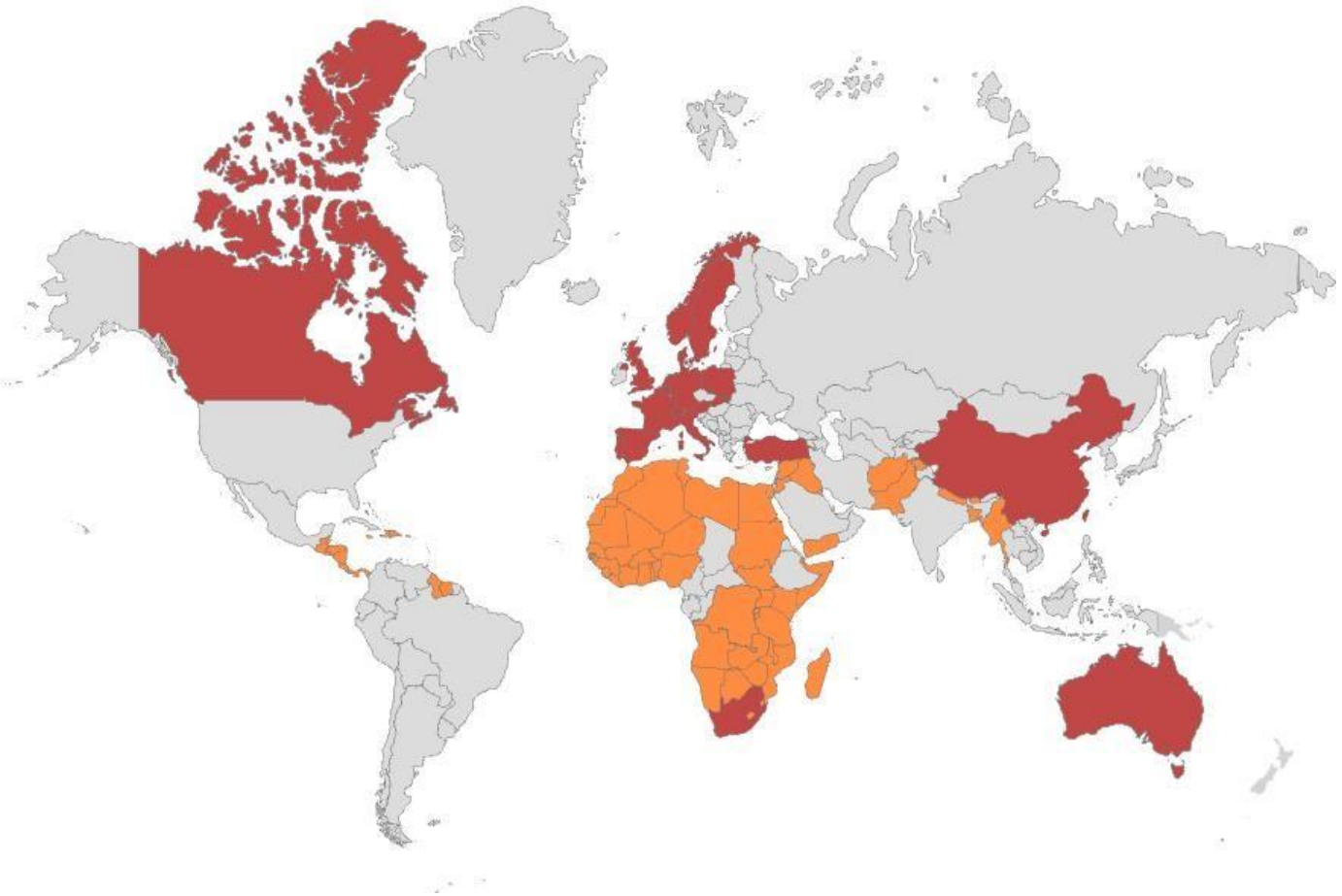
CALIFORNIA SOLAR + STORAGE ASSOCIATION
smart local energy

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Key Solar Thermal Market Trends

Lucio Mesquita, Chair
SEIA Solar Thermal Symposium, October 28, 2024

Who We Are



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area

21 Contracting Parties

Australia
Austria
Belgium
Canada
China
Denmark
European Commission
France
Germany
Italy
Netherlands
Norway
Poland
Portugal
Slovakia
South Africa
Spain
Sweden
Switzerland
Türkiye
United Kingdom

9 Sponsor Members

International Solar Energy Society

Solar Heat Europe

UNIDO GN-SECs *(Global Network of Regional Sustainable Energy Centers)*

- CCREEE (Caribbean)
- EACREEE (East Africa)
- ECREEE (West Africa)
- RCREEE (Arab States)
- **ICIMOD/REEECH (Himalayans)**
- SACREEE (Southern Africa)
- SICREEE (Central America)

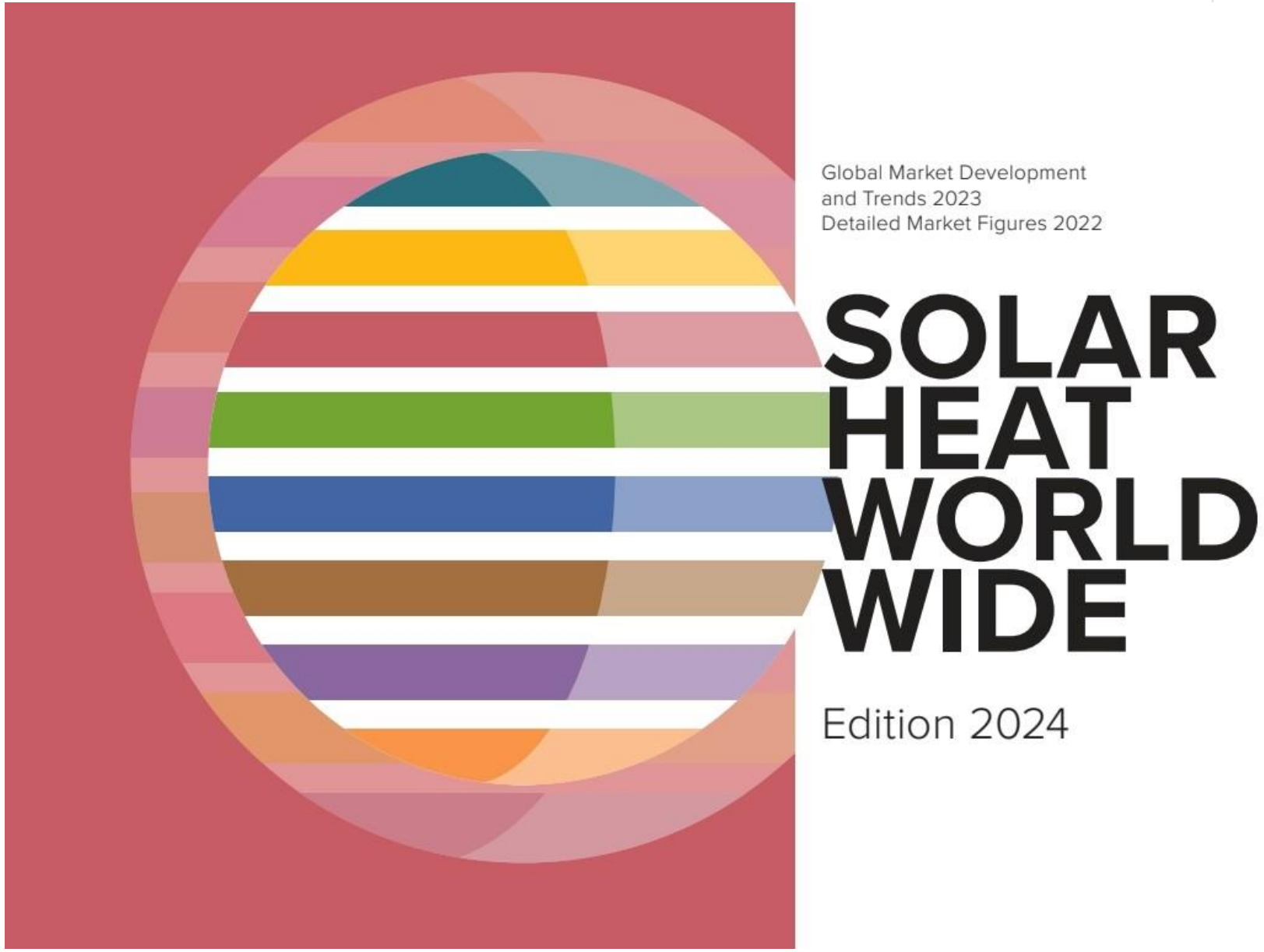
Limited Sponsor

Ergsol (US)

What we do and how we do it

- Collaborative R&D through Tasks (projects), usually running for 3 to 4 years
- Information dissemination and data gathering:
  - Training – Solar Academy (webinars and onsite training)
  - Joint Eurosun Conference with ISES
  - National days
  - Solar Award
  - Task Reports and White Papers
  - Website/Newsletter/Linkedin/X/YouTube/solarthermalword.org/direct mailing
  - Solar Heat Worldwide

www.iea-shc.org


Global Market Development
and Trends 2023
Detailed Market Figures 2022
SOLAR
HEAT
WORLD
WIDE
Edition 2024

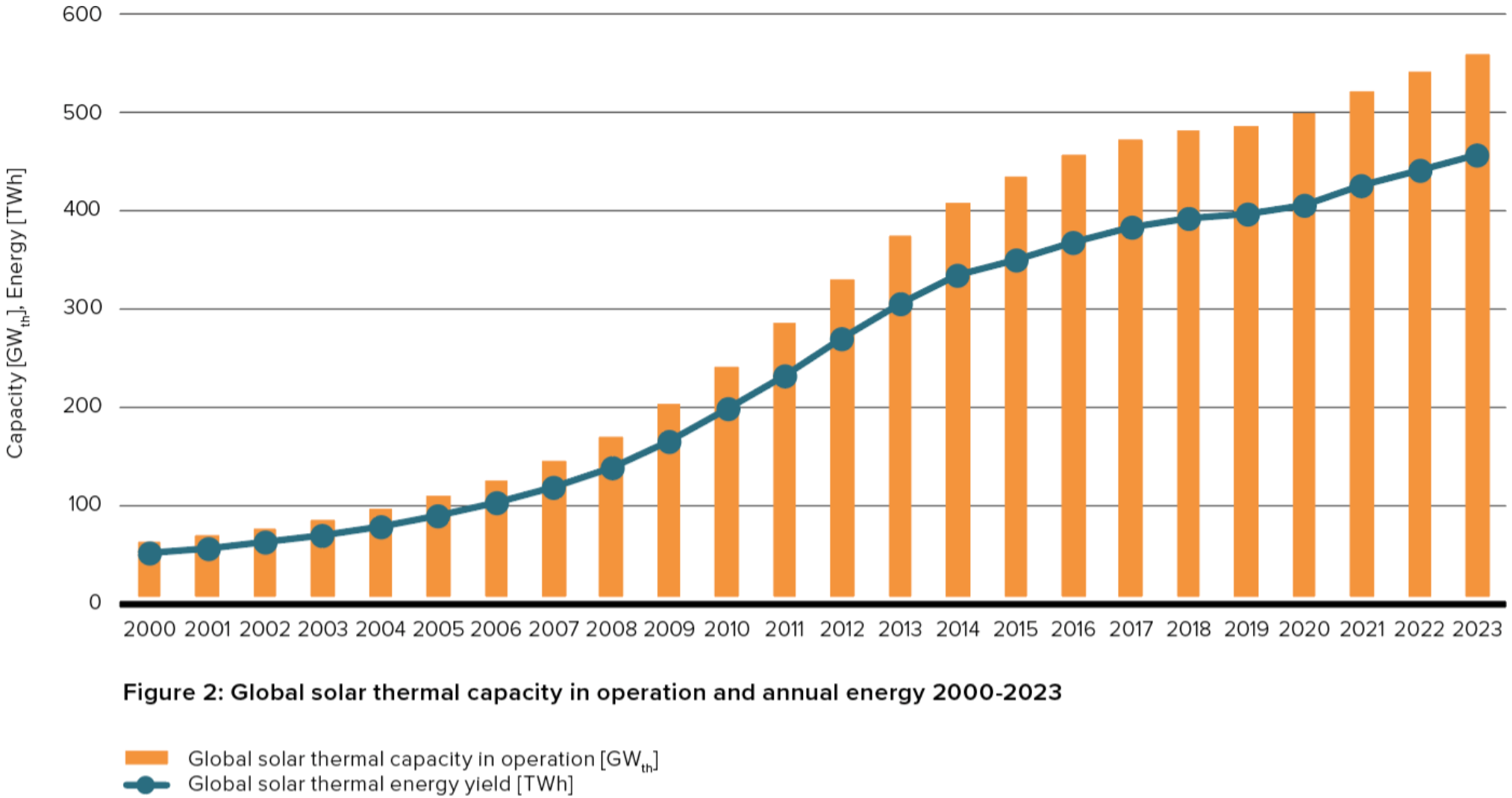


Figure 2: Global solar thermal capacity in operation and annual energy 2000-2023

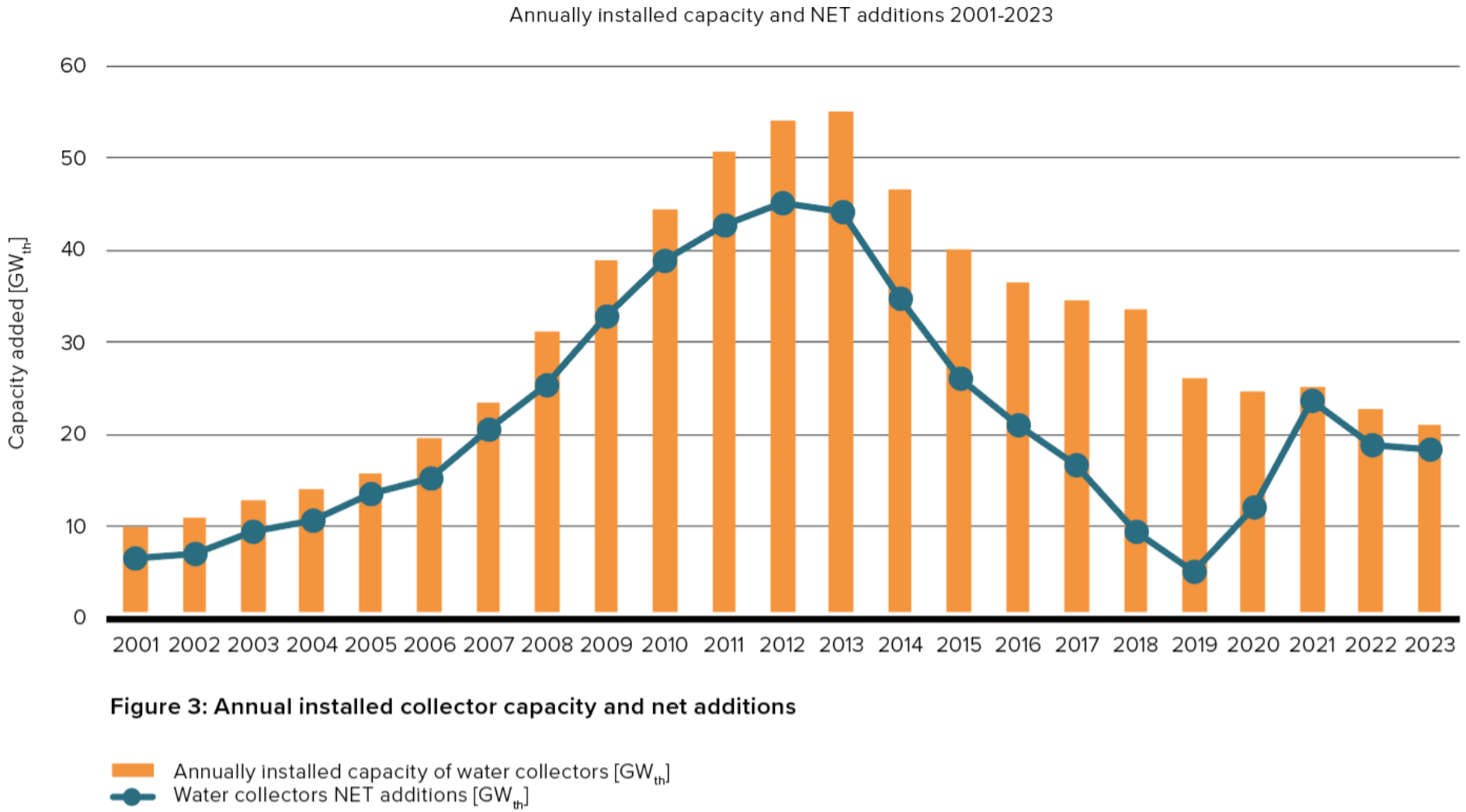


Figure 3: Annual installed collector capacity and net additions

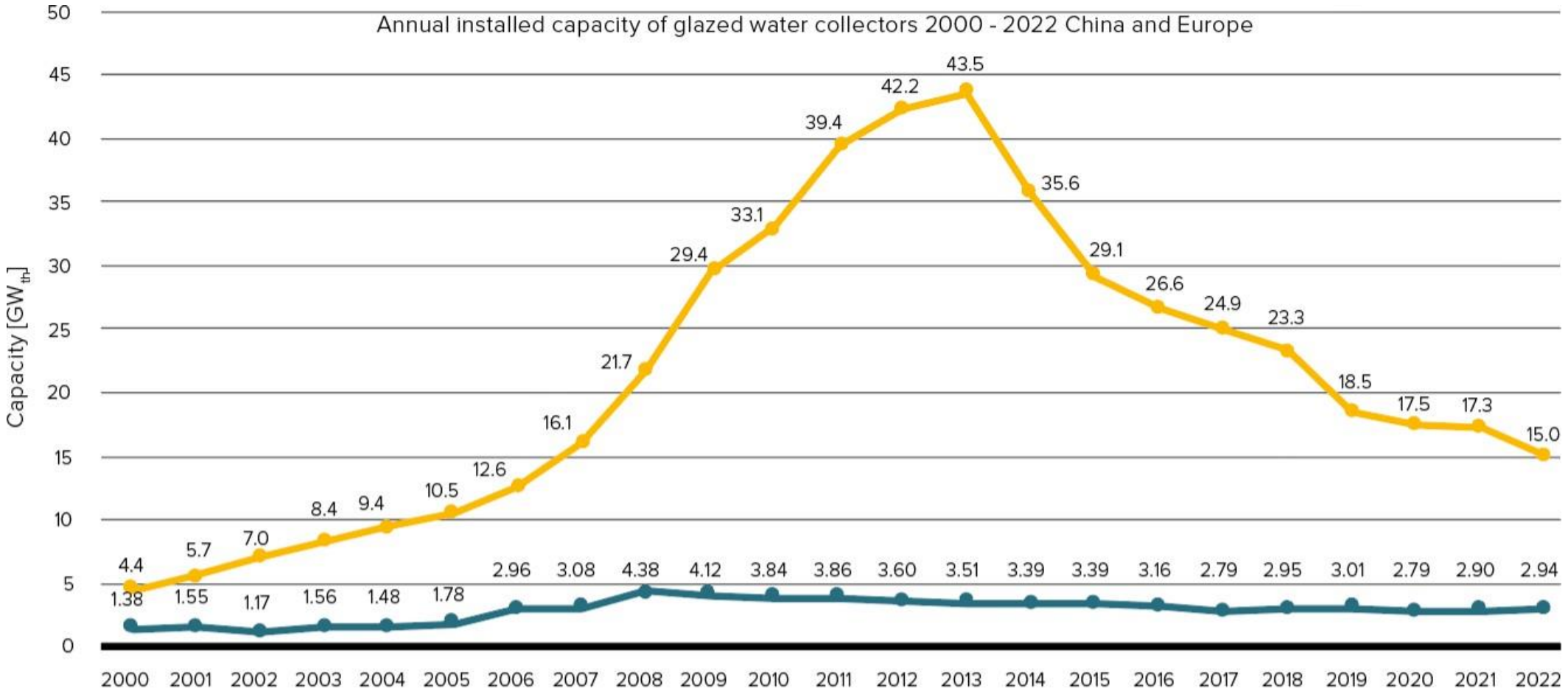


Figure 43: Market development of glazed water collectors in China and Europe 2000-2022

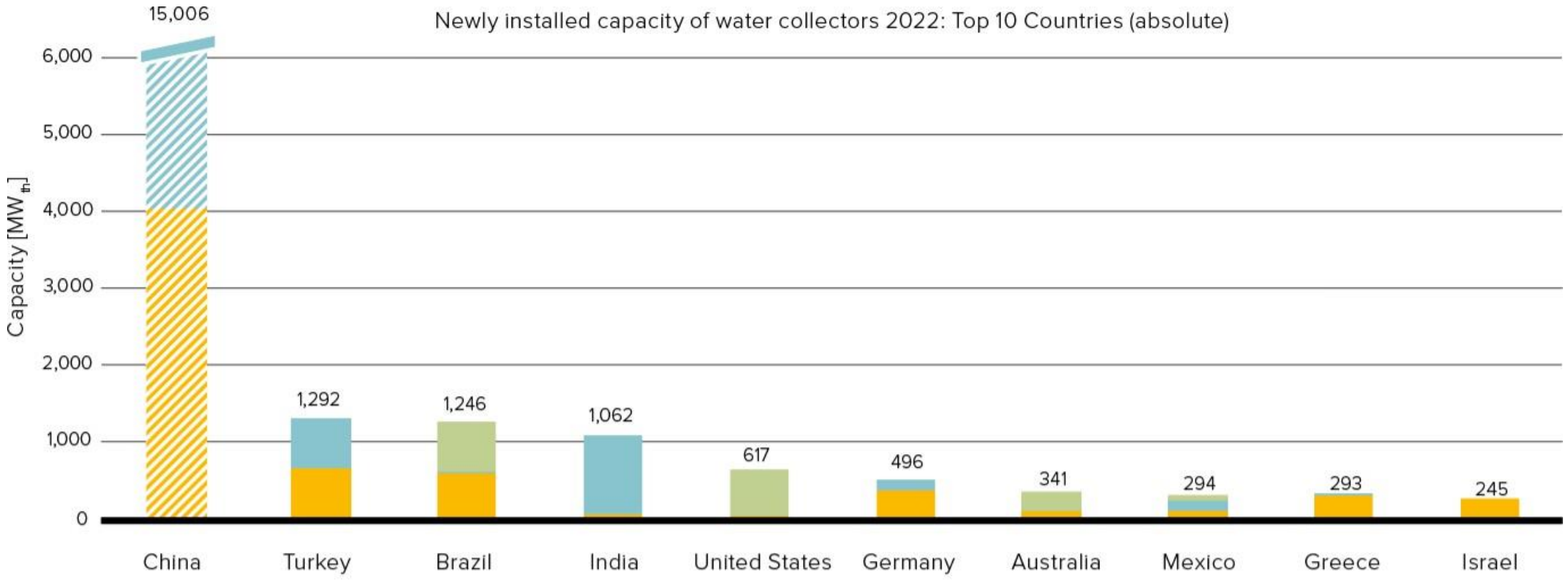


Figure 36: Top 10 markets for glazed and unglazed water collectors in 2022 (absolute figures in MW_{th})

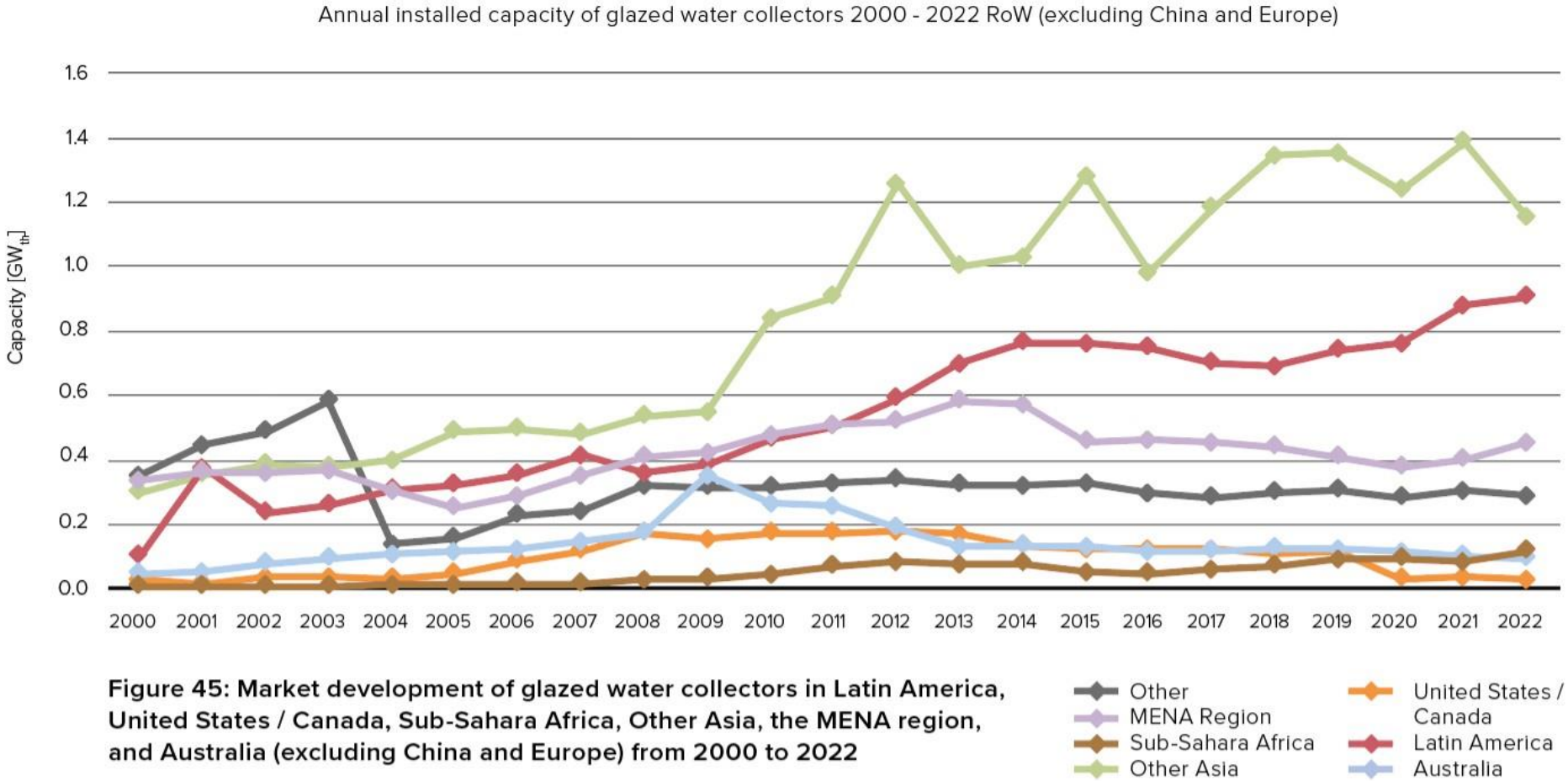


Figure 45: Market development of glazed water collectors in Latin America, United States / Canada, Sub-Sahara Africa, Other Asia, the MENA region, and Australia (excluding China and Europe) from 2000 to 2022

Other Asia: Bhutan, India, Japan, Nepal, South Korea, Chinese Taipei, Thailand
Latin America: Argentina, Brazil, Chile, Mexico, Panama, Uruguay
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia
Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe

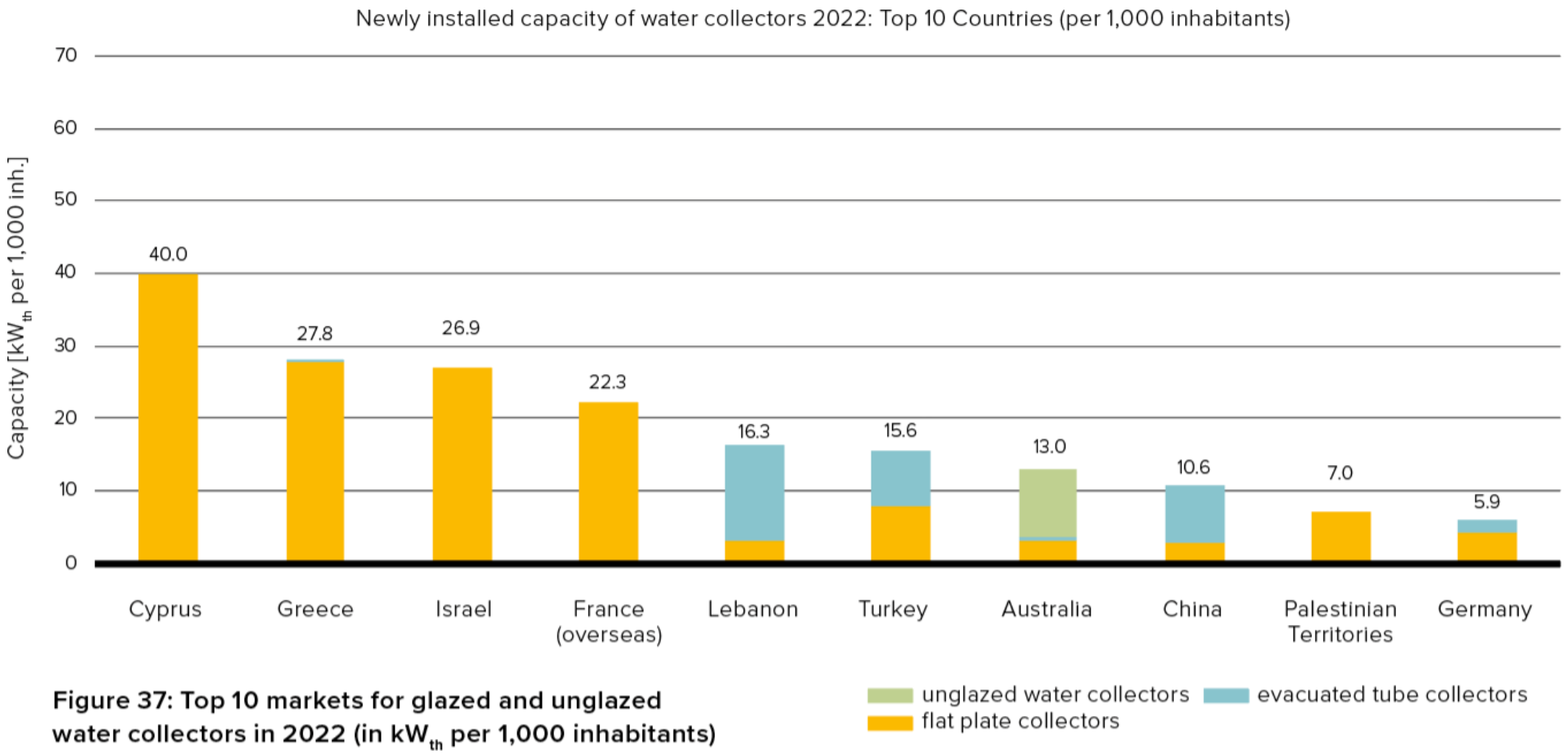


Figure 37: Top 10 markets for glazed and unglazed water collectors in 2022 (in kW$_{th}$ per 1,000 inhabitants)

Thank You!

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

www.iea-shc.org

IEA Solar Heating and Cooling Programme (group 4230381)

@IEASHC

RENEWABLE THERMAL COLLABORATIVE

Decarbonizing Industrial Heat with Solar Thermal

Ruth Checknoff

October 28, 2024

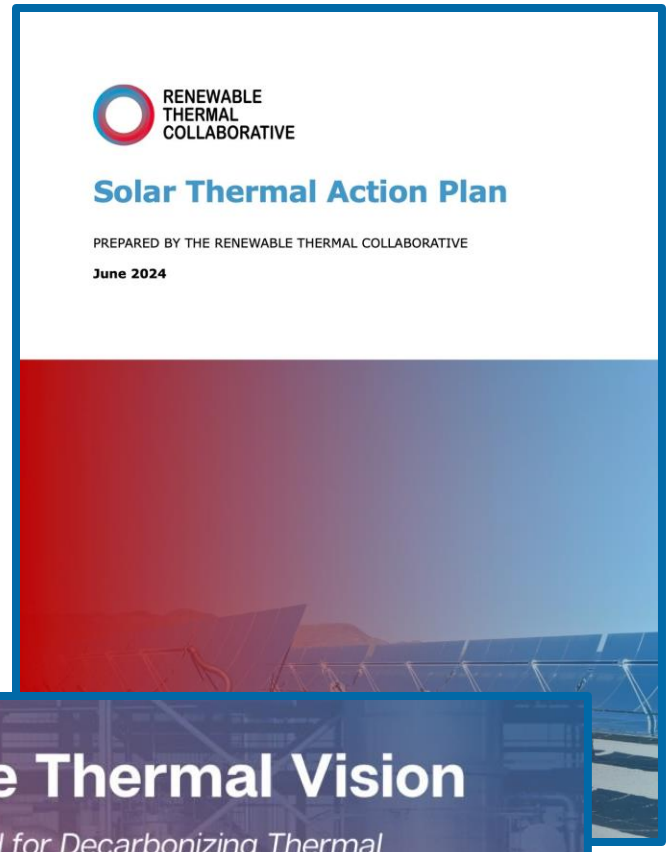
What is the RTC?

The RTC is the only global, buyer-led coalition focused on decarbonizing thermal energy with renewables.

We focus our work across the intersecting issues of **technology**, **market development**, and **policy**.

RTC Members (buy-side) and Solutions Providers (supply-side) are invited to participate in multiple RTC workstreams to:

- Identify and address barriers;
- Accelerate solutions;
- **Implement** projects and policies.



RTC Members


AMGEN
Ansell
AstraZeneca
Bristol Myers Squibb
Campbell's
Cargill
charles river
city of CINCINNATI
CISCO
COLGATE-PALMOLIVE
CORNING
DIAGEO
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gm
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International Paper
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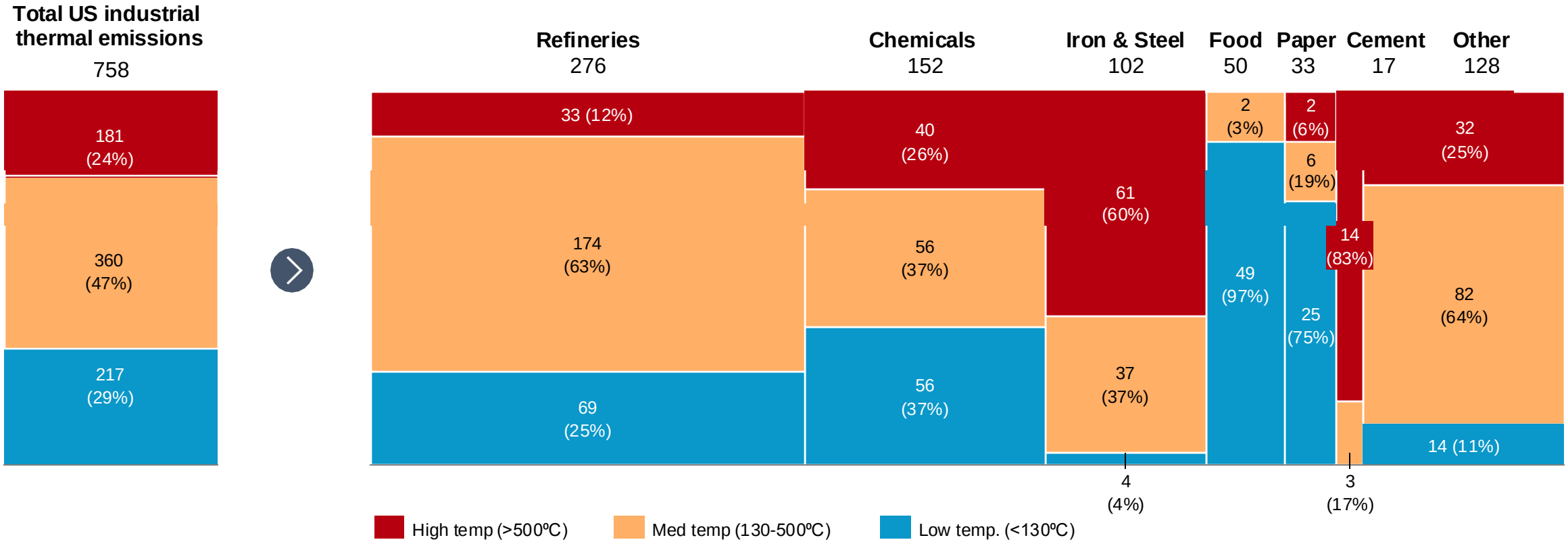
KAISER PERMANENTE
kenvue
Keurig DrPepper
Kimberly-Clark
KraftHeinz
LACTALIS US YOGURT
L'ORÉAL USA
MARS
Tomorrow starts today
Nestlé
NEW BELGIUM BREWING
THE ORIGINAL OATLY!
PEPSICO
City of Philadelphia
THE CITY OF PITTSBURGH
CITY OF PORTLAND, OREGON 1851
P&G
Roche
SAINT-GOBAIN
SAVENCIA FROMAGE & DAIRY
SDI Steel Dynamics, Inc.
stryker
ThermoFisher SCIENTIFIC
Unilever
UNIVERSITY OF CALIFORNIA
OEI Wisconsin Office of Energy Innovation

RTC Solutions Providers

Low & medium heat processes dominate industrial thermal emissions and account for ~76% of total

Estimated share of 2018 thermal emissions by temperature range (million tonnes of CO2e)



Notes: Energy usage by temperature range was used as a proxy for thermal emissions by temperature range, most of industrial heat is fueled by natural gas across low, medium, and high temperature processes; certain sector emissions (e.g. Iron & Steel, Cement) may skew more towards the higher temperature range as these sectors combust fuels with higher carbon intensity for high temperature processes (e.g. coal in steel making) Source: NREL Manufacturing Thermal Energy Use in 2014 (provides thermal energy use by temperature); EIA Outlook 2019 (provides 2018 energy consumption by fuel); EPA emissions intensity by fuel

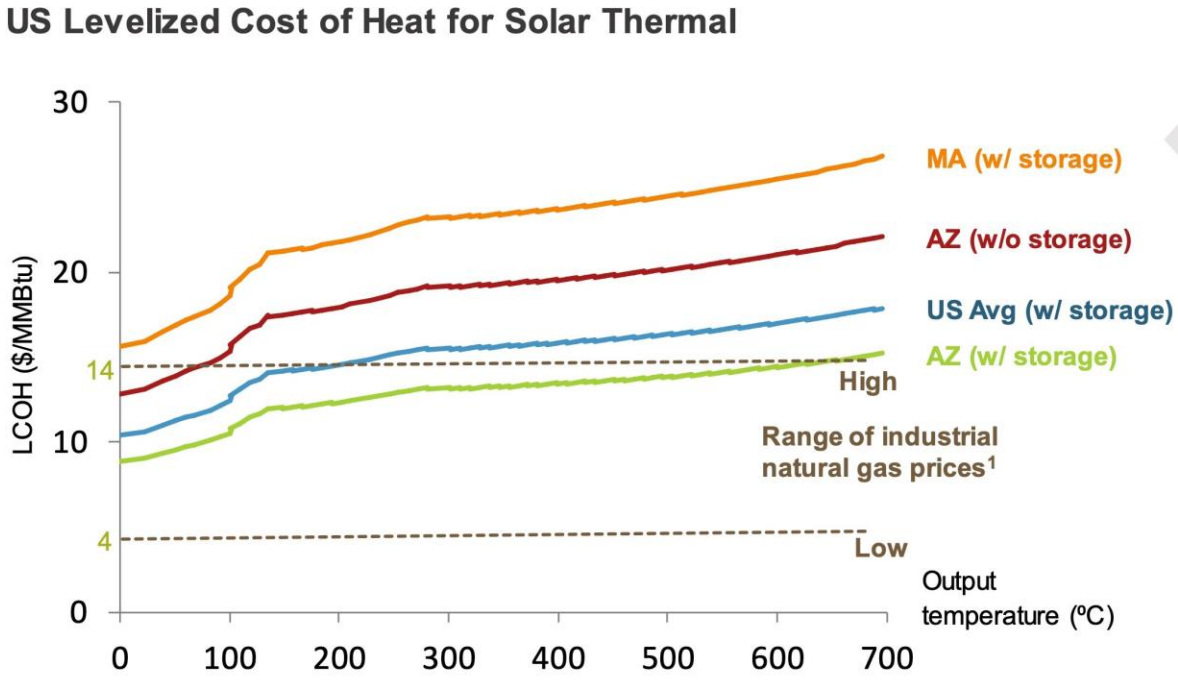
Solar Thermal Technologies and Temperature Ranges

Solar thermal technology	Description	Operating temperatures
Non-concentrating	Any design without optic elements	<100 ºC
Parabolic trough	Sun-tracking concave mirror with individual receiver tube	260-400 ºC
Linear Fresnel	Numerous sun-tracking mirrors concentrated on single receiver	260-400 ºC
Power tower	Array of heliostats focused on a molten salt receiver tower	600-1,000 ºC
Parabolic dish	Sun-tracking concave dish focused on individual receiver	500-1,200 ºC
Molten salt storage	Thermal storage technology	<560 ºC

The Deployment Opportunity

Solar thermal could scale to meet up to 25% of total industrial heating demand in the U.S.

- Solar thermal can **decarbonize most low- and medium-temperature** industrial process heating applications and **can be cost effective** depending on the configuration and location.
- Solar thermal economics and applicability improve when **paired with thermal energy storage**.



1. EIA May 2022 end-user prices

Notes: Does not include cost for land use. Uses solar thermal power plant estimates (central receiver tower with heliostats) with power generation equipment removed for LCOH calculation.

Source: NREL; Lazard; IRENA; DOE, AIP Conference Proceedings; BCG analysis

Key Challenges

The Knowledge Gap

Prospective buyers often have incomplete information about the full range of opportunities for solar thermal to decarbonize industrial processes and achieve energy cost savings.

The Policy Gap

Federal and state policies to support solar thermal adoption, including financial incentives and compliance markets, are inconsistent, short-term, low-impact, or nonexistent.

Actions to Accelerate Deployment

Actions to fill the knowledge gap

- Convene buyers and suppliers
- Develop case studies & resources
- Highlight key insights in webinars
- Create decision support tools

Actions to bridge the policy gap

- Support funding for RD D&D
- Extend & establish tax incentives
- Cultivate legislative champions
- Implement state-level policies

Solar Thermal at Colgate-Palmolive Factory

Location: Athens, Greece

Technology: Rooftop parabolic trough (264 m^2 array)

Application: Delivers pressurized hot water at 50°C (122°F) to fabric softener reactor

Motivation: Compared to electrification with solar PV, solar thermal offered better economic returns and displaced more natural gas use with the available rooftop space

Key Outcomes:

- Meets 70% of the fabric softener reactor's thermal energy demand with 163 MWh/year output
- Avoids 39 tons of CO_2 emissions annually
- Achieved a double-digit rate of return on Colgate-Palmolive's investment

Source: https://www.renewablethermal.org/cp-absolicon-case-study/

Decarbonizing Industrial Process Heat at California Dairies, Inc.

Location: Visalia and Turlock, California

Technology: Flat plate solar thermal + heat recovery

Application: Preheats boiler feedwater up to 82°C (180°F) for use in dairy processing

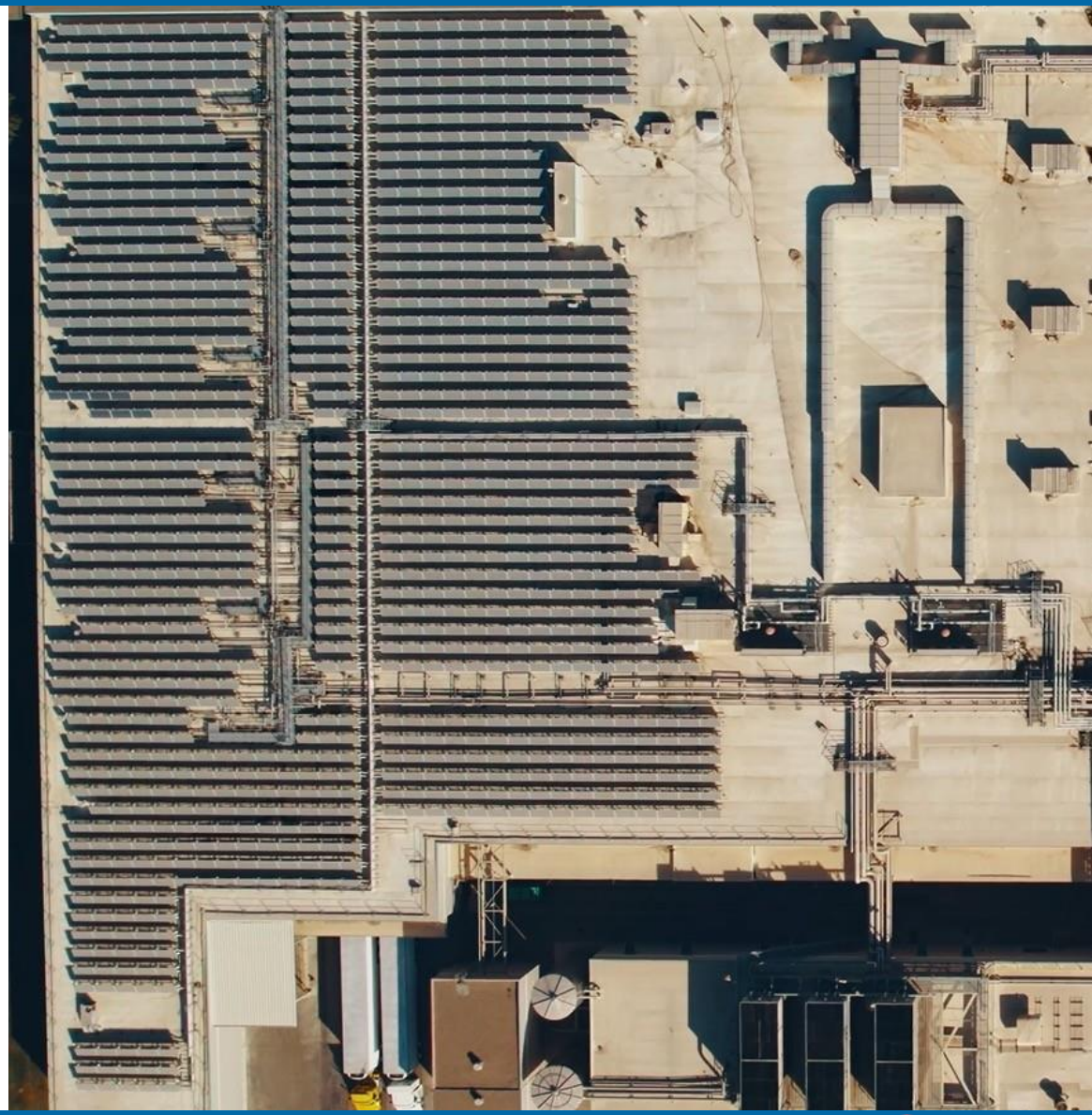
Motivation: Progress towards CDI's 30% GHG reduction by 2030 goal

Financing Model: Energy-as-a-Service, with $9M of CapEx from California Energy Commission FPIP grants, plus utility incentives and third-party investors

Key Outcomes:

- Avoids 7,000 metric tons of CO_2 emissions and 110,000 MMBtu of natural gas usage annually
- Delivered $419,659 in net savings to CDI to date

Source: https://www.renewablethermal.org/skyven-cdi-case-study/



Solar Thermal at Boortmalt Malting Plant

Location: Issoudun, France

Technology: Flat plate (14,252 m^2 array) + storage

Application: Preheats air in the malthouse up to 67°C (153°F) for barley drying

Motivation: Reduce exposure to volatile natural gas prices and make progress on Boortmalt's 50% GHG reduction by 2030 goal

Financing Model: Energy-as-a-Service, with 60% of total €6M CapEx from French government

Key Outcomes:

- Meets 10% of the malting plant's thermal demand with 8.5 GWh/year output
- Avoids 2,100 metric tons of CO_2 emissions per year

Source: https://www.boortmalt.com/thermal-solar-power-plant

Policies to Support U.S. Solar Thermal Deployment

- Extend Sec. 48 investment tax credit for solar thermal
- Expand Sec. 45X Advanced Manufacturing Production Credit
- Establish new industrial heat production tax credit
- Expand funding for RDD&D through Department of Energy programs

RTC Resources

Publications:

Congressional Policy Priorities to Enhance American Manufacturing Competitiveness:
https://www.renewablethermal.org/policy-priorities-2024/

Solar Thermal Action Plan:
https://www.renewablethermal.org/solar-thermal-action-plan/

Solar Thermal Technology Assessment:
https://www.renewablethermal.org/solar-thermal-technology-assessment/

Solar Thermal Report in Brief:
https://www.renewablethermal.org/report-in-brief-solar-thermal-technology-assessment/

Renewable Thermal Vision Report:
https://www.renewablethermal.org/vision/

Case Studies:
https://www.renewablethermal.org/category/publications/case-studies/

Tools:

Policy Finder:
https://www.renewablethermal.org/policy-finder/

Partner Locator:
https://www.renewablethermal.org/partner/

Heat Pump Decision Support Tools:
https://www.renewablethermal.org/heat-pump-decision-support-tools/

Communications:

Monthly newsletter:
https://www.renewablethermal.org/contact-us/

LinkedIn:
https://www.linkedin.com/company/renewable-thermal-collaborative/

Questions?

Contact:

Ruth Checknoff

RTC Project and Research Director

Ruth@dgardiner.com

Sign up for our newsletter at renewablethermal.org

Follow us on LinkedIn

Solar Thermal Symposium

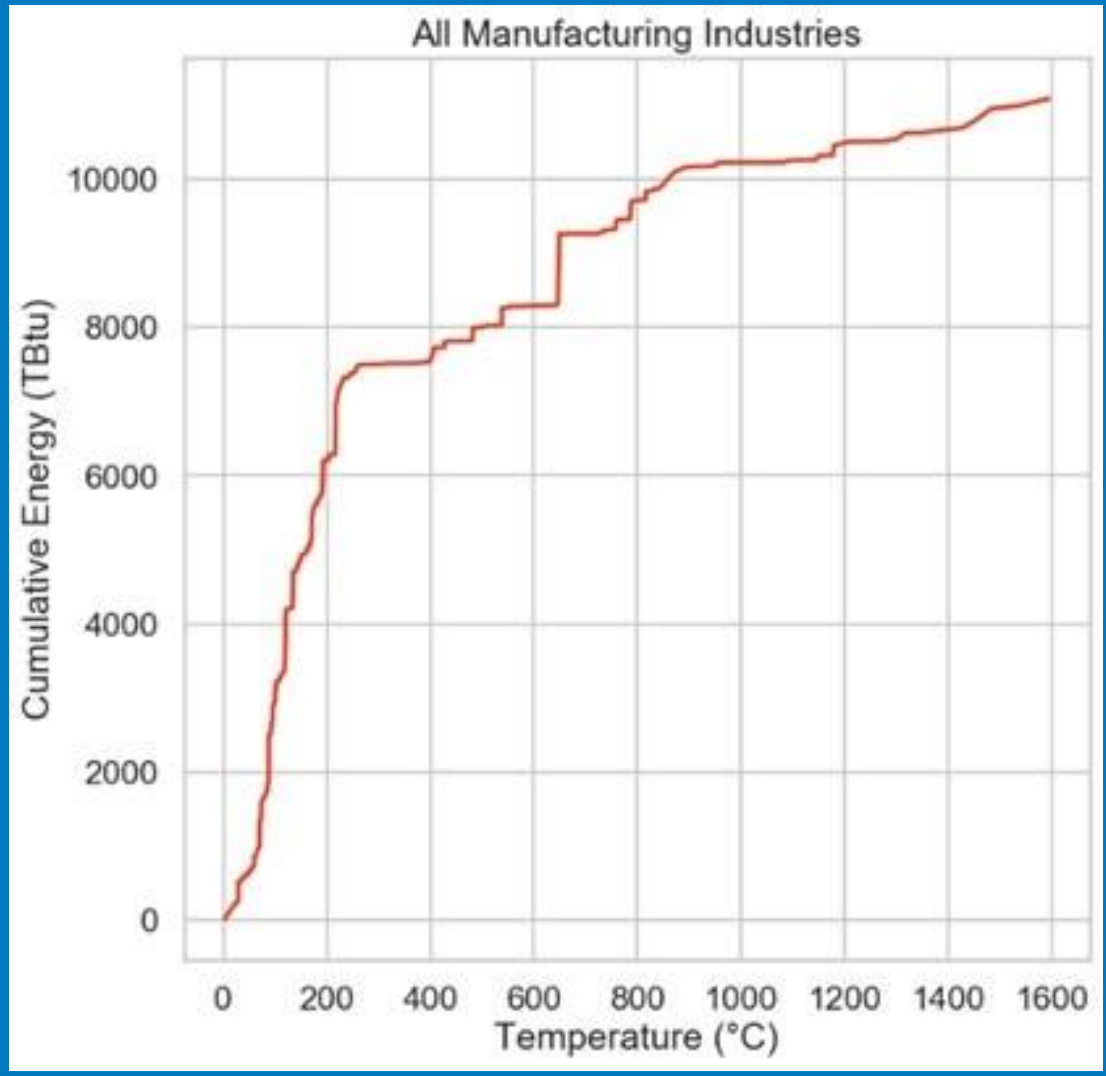
October 28th 2024

Parthiv Kurup

Photo by Dennis Schroeder, NREL 55200

Solar Thermal Technologies and Tools

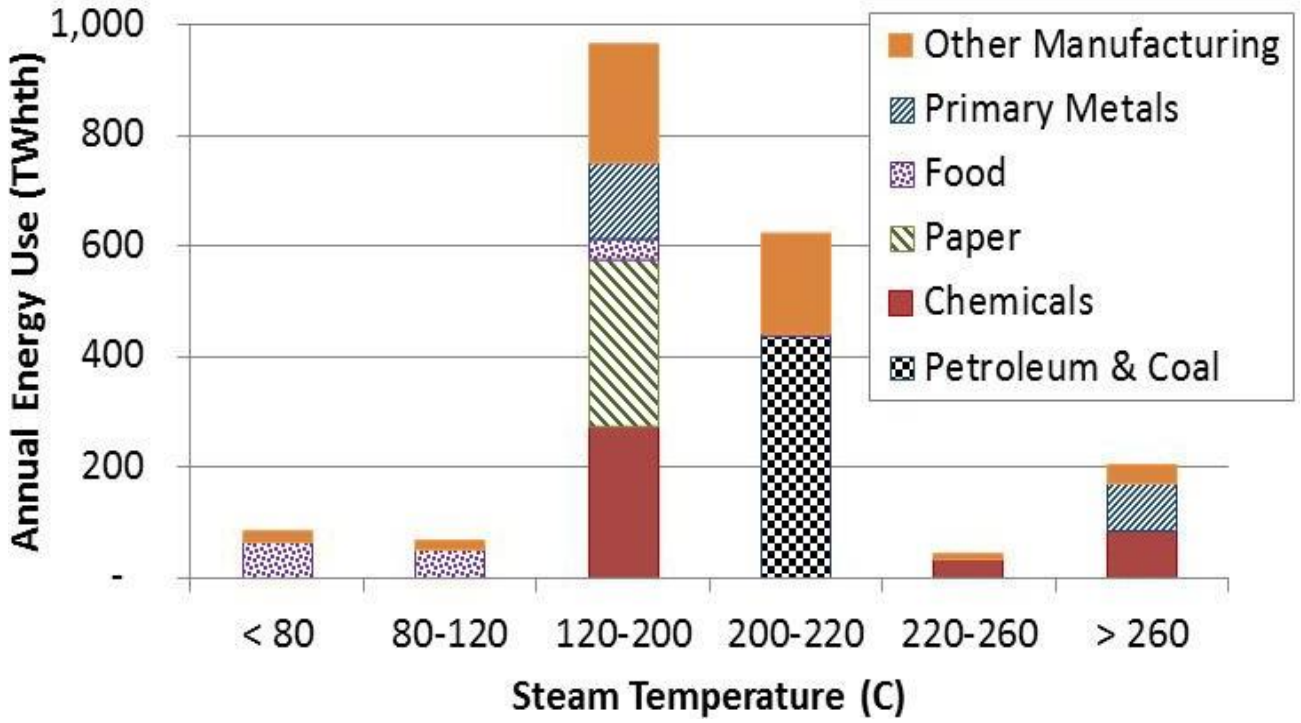
- Heat in Industry
- Solar Thermal Technologies Overview
- Research Areas
- Modeling Tools



Cumulative process heat demand by temperature in 2014. *Illustration by Colin McMillan, NREL* - https://www.nrel.gov/analysis/solar-industrial-process-heat.html

Heat in Industry

Steam use in the U.S. by Temperature



"Initial Investigation into the Potential of CSP Industrial Process Heat forthe Southwest United States" – NREL Report
https://www.nrel.gov/docs/fy16osti/64709.pdf

- Biggest steam users in the U.S.:
  - Petrochem
  - Chemicals
  - Paper
  - Food
  - Primary Metal and Manufacturing
- Majority of steam use is <250°C!
  - Largest steam demand in <220°C
  - Steam is used to transfer heat, but is not the most efficient way
    - E.g., steam used for <100°C demands
- **120-220 °C steam is target for Solar IPH e.g.,** Flat plates, Troughs, Heat pumps, (Biomass)

Industries and Temperatures

Industrial Sector	Unit Operations	Temperature Range	
		Celsius	Fahrenheit[62]
Food	Drying	30-90	90-210
	Washing	60-90	150-210
	Pasteurizing	60-80	150-190
	Boiling	95-105	220-140
	Sterilizing	110-120	250-270
	Heat Treatment	40-60	110-150
Beverages	Washing	60-80	150-190
	Sterilizing	60-90	150-210
	Pasteurizing	60-70	150-170
Paper Industry	Cooking and Drying	60-80	150-190
	Boiler Feed Water	60-90	150-210
	Bleaching	130-150	190-330
Metal Surface Treatment	Treatment, Electroplating, etc.	30-80	90-190
Bricks and Blocks	Curing	60-140	150-310
Textile Industry	Bleaching	60-100	150-230
	Dyeing	70-90	170-210
	Drying, De-greasing	100-130	230-290
	Washing	40-80	110-190
	Fixing	160-180	350-390
	Pressing	80-100	190-230
Chemical Industry	Soaps	200-260	430-550
	Synthetic Rubber	150-200	330-430
	Processing Heat	120-180	270-390
	Preheating Water	60-80	150-190
Plastic Industry	Preparation	120-140	270-310
	Distillation	140-150	310-330
	Separation	200-220	430-470
	Extension	140-160	310-350
	Drying	180-200	390-430
	Blending	120-140	270-310
Flour By-Products	Sterilizing	60-90	150-210
All Industrial Sectors	Pre-heating of Boiler Feed Water	60-90	150-210
	Industrial Solar Cooking	55-180	140-390
	Heating of Factory Buildings	30-80	90-190

- Majority of industries use low temperature heat e.g., 30-150°C
- Other key considerations:
  - Cost! But fuel/energy costs vary by site and industry
  - Heat is needed normally at constant rate and therefore reliable sourcing is key
  - Heat has a quality i.e., the higher the waste heat temperature the better use
  - Heat is needed quickly e.g., firing and baking
  - Heat is vital for the process and product
- Key sectors of process heat use
  - Food, Paper, Beverages, Textiles
  - Chemicals and Plastics
- What agricultural processes use significant heat and steam?
  - Drying, washing, pasteurization
  - Steam sterilization, line cleaning, preheating tanks
  - Processing of material, curing, biowaste treatments

"Electrifying U.S. Industry: A Technology- and Process-Based Approach to Decarbonization" – Global Efficiency Intelligence Report
https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/6018bf7254023d49ce67648d/1612234656572/Electrifying+U.S.+Industry+2.1.21.pdf

Solar Thermal Technologies Overview

Solar Thermal Technology Overview

- Utilizes the sun's energy to **generate heat**
  - Can be harnessed for various industrial applications, such as water desalination, enhanced oil recovery, food processing, chemical production, and mineral processing.
- Two types of Solar Thermal
  - Non-Concentrating
  - Concentrating
- Benefits of **solar heat for industry**
  - Reduces impact of fuel-price volatility
  - Increases product value (green marketing)
  - Reduces emissions
  - Increases sustainability
  - Increases resilience

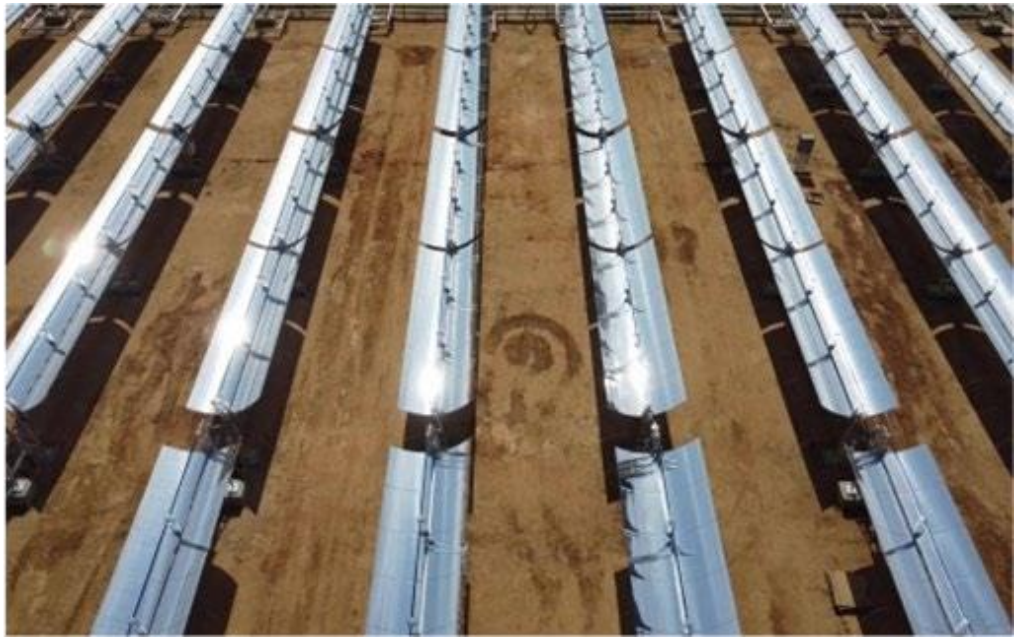


Figure 1 Solar Thermal Example: Sunvapor's solar collectors
Source: Solar Energy Technology Office

Solar Thermal Technologies

Non-concentrating
1. Flat plate
2. Evacuated tube
3. Integral collector storage
4. Thermosiphon collector

Concentrating
1. Parabolic trough
2. Parabolic dish
3. Power tower
4. Linear Fresnel

Temperature Ranges
1. Non-concentrating can provide up to 100°C (212°F)
2. Concentrating can provide up to 1200°C (2200°F)

Zero emissions technology

Heat Transfer Fluid e.g., water, steam, molten salt, synthetic oil

Flat plate

< 80°C (180°F)

Evacuated tube

< 80°C (180°F)

Parabolic trough

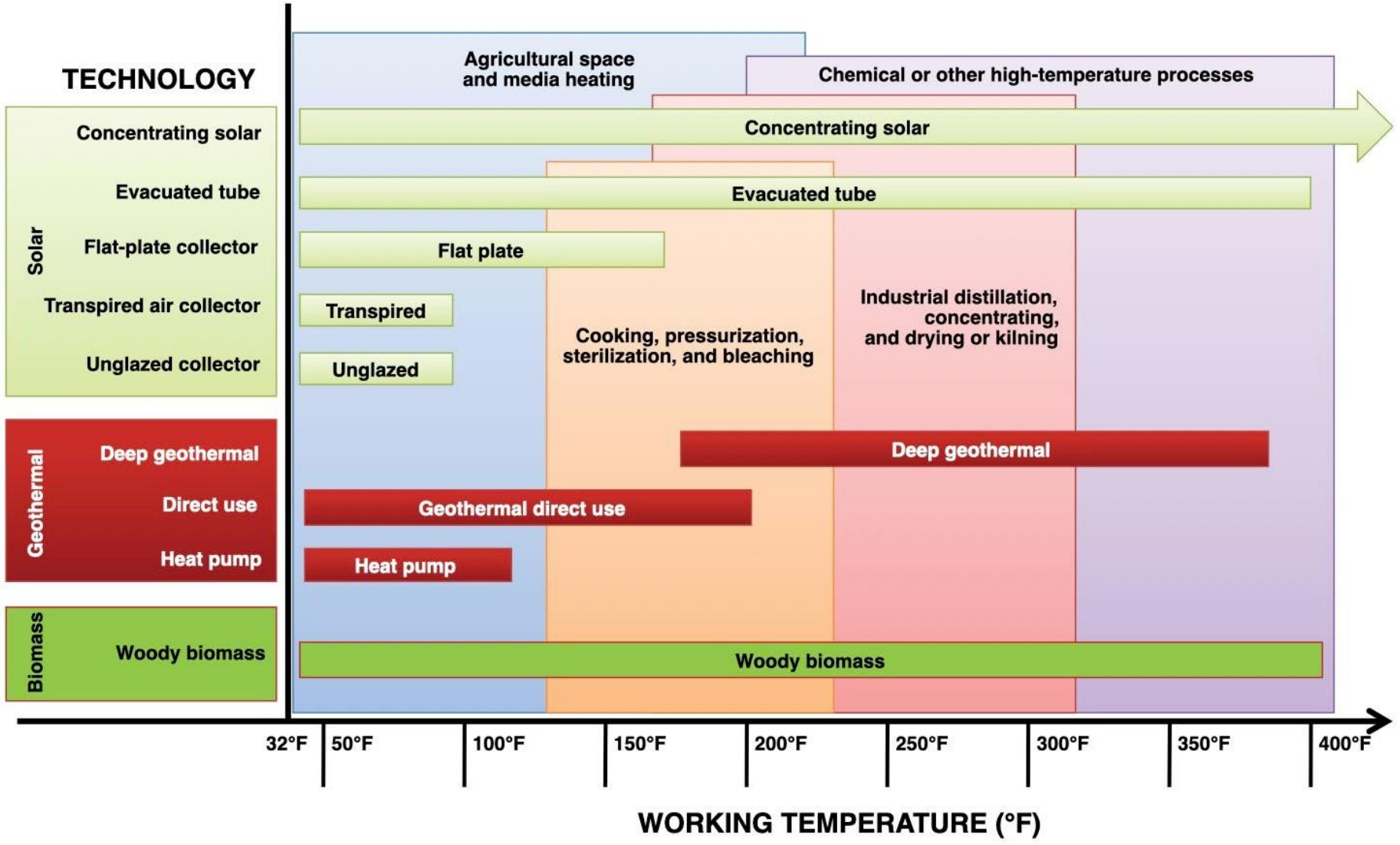
< 400°C (750°F)

Linear Fresnel

Power Tower

> 400°C (750°F)

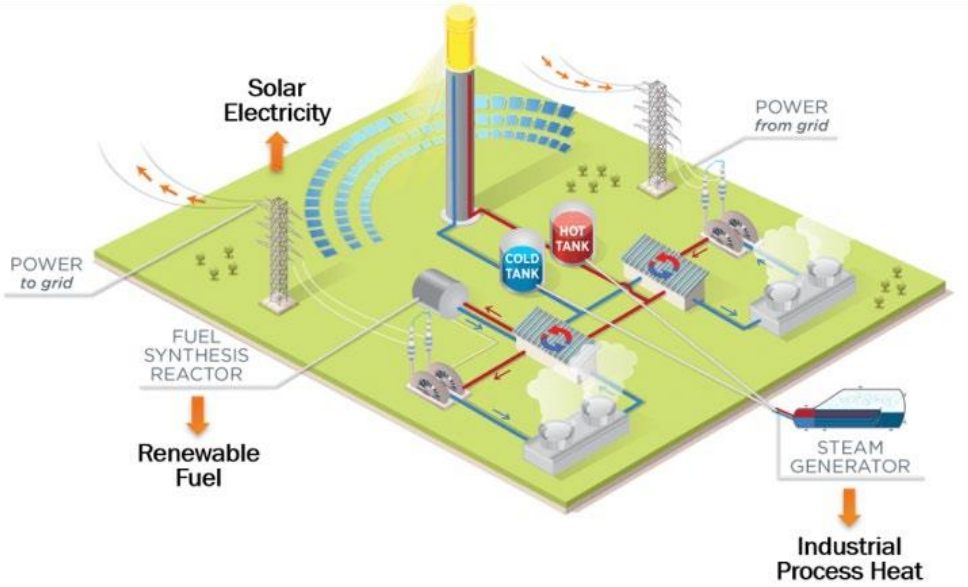
Industry Applications



Source: EPA

Concentrating Solar Thermal (CST)

- Use mirrors (e.g., heliostats) to concentrate sunlight onto a receiver
- Large electricity plants e.g., 50 – 250MWe
- Concentrated energy heats the fluid in the receiver to high temperatures
  - Can be used for various industrial applications
  - Can generate electricity
  - Built in thermal energy storage (TES)
- CST power systems have historically been used for utility-scale electricity projects but are now transitioning to industrial heat.

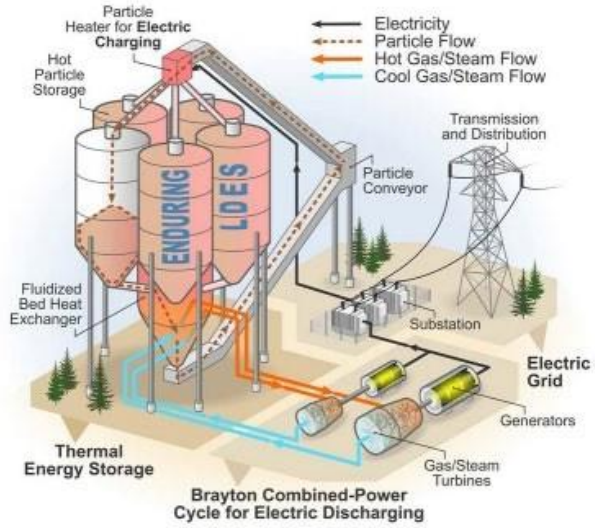


Source: Solar Energy Technologies Office

Research Areas

Research Areas

- Research areas:
  - Particle-based TES to replace salts
  - CST for IPH applications
    - Costs, barriers, integration
  - Heliostats e.g., HelioCon
    - Component performance, metrology…
  - Materials
    - Higher-reflectivity mirrors
    - Better thermal-absorbing receivers
    - More corrosion-resistant materials
    - Increasing material durability
  - Establish guidelines and standards
- Central receiver systems have greatest potential for improvements
  - Super critical CO_2 cycles
- DOE Solar Energy Technologies Office (SETO)



Economic Long-Duration Electricity Storage by Using Low-Cost Thermal Energy Storage and High-Efficiency Power Cycle (ENDURING). Ma, Zhiwen. 2023

Heliostats at the Ivanpah Solar Project, owned by NRG Energy, Bright Source Energy, Bechtel and Google. *Photo by Dennis Schroeder / NREL.*

Modeling Tools

NREL's Solar Modeling Tools Overview

Established software tools

System Advisor Model™ (SAM™) – Free desktop application for annual TEA simulations using physics-based component models:

- TES (hot water, molten salt, packed bed, pressured water)
- Thermal generators (non-concentrating water heating, linear collectors, towers, and electric heating)
- Thermal load profiles
- Electric generators (PV, wind, thermo-electric power cycles)

REopt® – Free web application to evaluate the economic viability of distributed energy systems, expanding in industrial loads. Currently, no solar thermal technology.

In development software tools

First Solar Thermal Energy Planner (STEP 1)

- Online tool being developed with Sandia
- Lower barriers to entry for those considering solar+storage solutions for industrial process heat decarbonization
- TES (hot water, molten salt, packed bed, pressured water)
- Thermal generators (Solar PV and linear collectors, towers,

REHeat – Desktop tool to evaluate costs and performance of hybrid systems (e.g., heatpump and flat plate collectors) to determine site level feasibility and optimization.

Thank you!

Parthiv.Kurup@nrel.gov

www.nrel.gov

Acknowledgements

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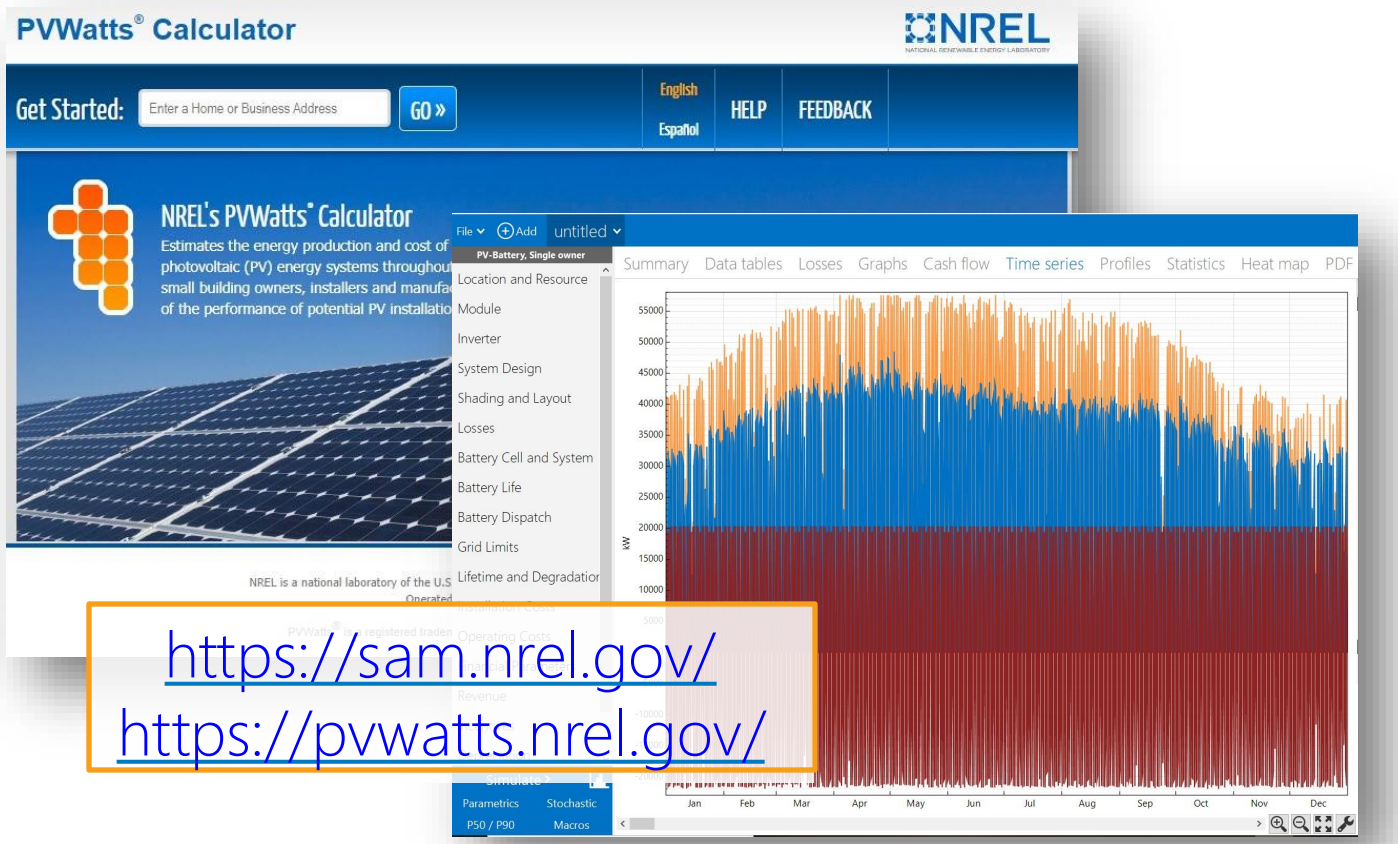
U.S. DEPARTMENT OF ENERGY

NREL Transforming ENERGY

Backup

System Advisor Model (SAM) & PVWatts

Free software that enable detailed performance and financial analysis for renewable energy systems

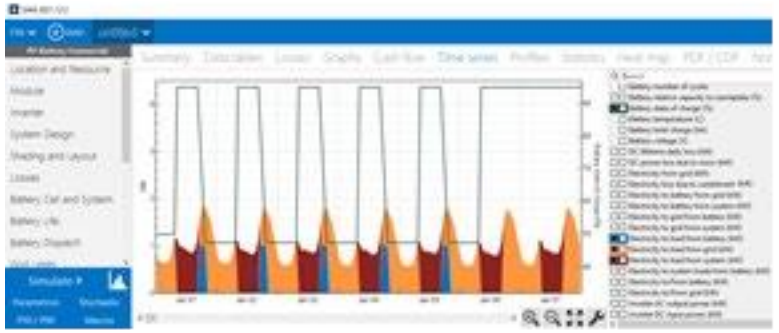


https://sam.nrel.gov/
https://pvwatts.nrel.gov/

- ✓ Desktop application
- ✓ PVWatts web tool & API
- ✓ Software development kit
- ✓ PySAM Python package
- ✓ Open source code
- ✓ Extensive documentation
- ✓ User support

System Advisor Model (SAM)

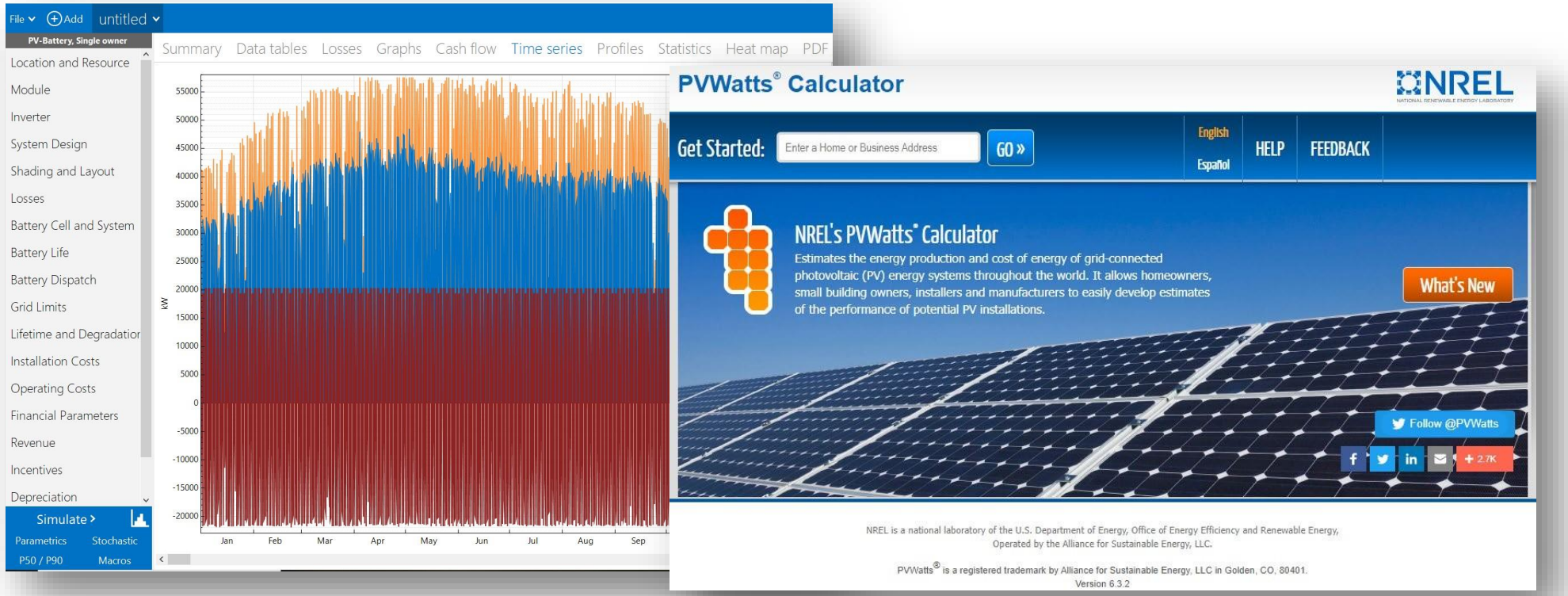
- Free software for modeling renewable energy projects
- Developed by NREL with funding from DOE
- Desktop app for Windows, Mac, Linux
- Software Development Kit (SDK) with PySAM Python package
- Documentation and user support
- Code is open source on GitHub.com
- One or two new versions per year



https://sam.nrel.gov

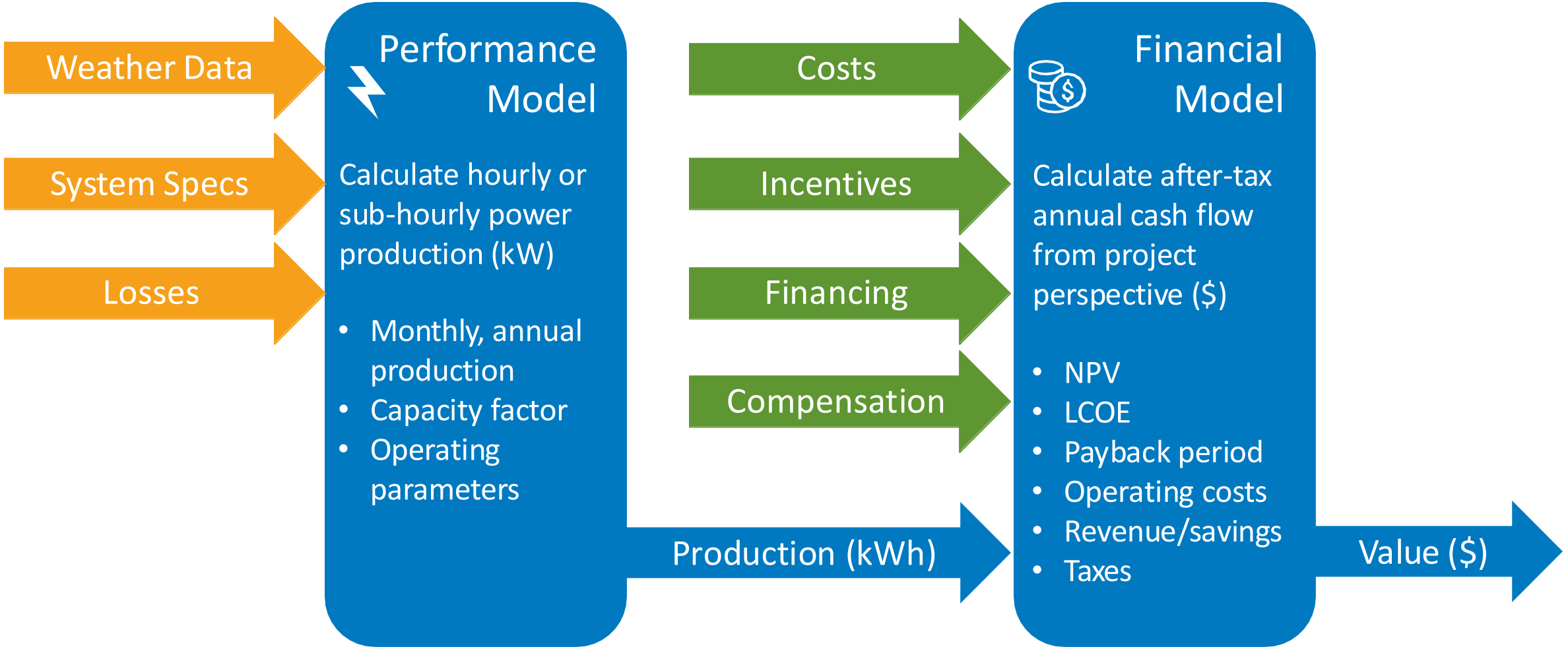
System Advisor Model (SAM) & PVWatts

Free software that enable detailed performance and financial analysis for renewable energy systems



http://sam.nrel.gov/download
https://pvwatts.nrel.gov

Model Structure



Technologies

- Photovoltaic
- Energy storage
  - Electric battery
  - Electric thermal storage
- Concentrating solar power
- Industrial process heat
- Marine energy
- Wind power
- Fuel cell
- Geothermal power
- Solar water heating
- Biomass combustion
- Generic system

Financial Models

- Power purchase agreements
  - Single owner
  - Partnership flips
  - Sale leaseback
- Residential
- Commercial
- Third party ownership
- Merchant plant
- Community solar
- Simple LCOE calculator

Data from: 2020

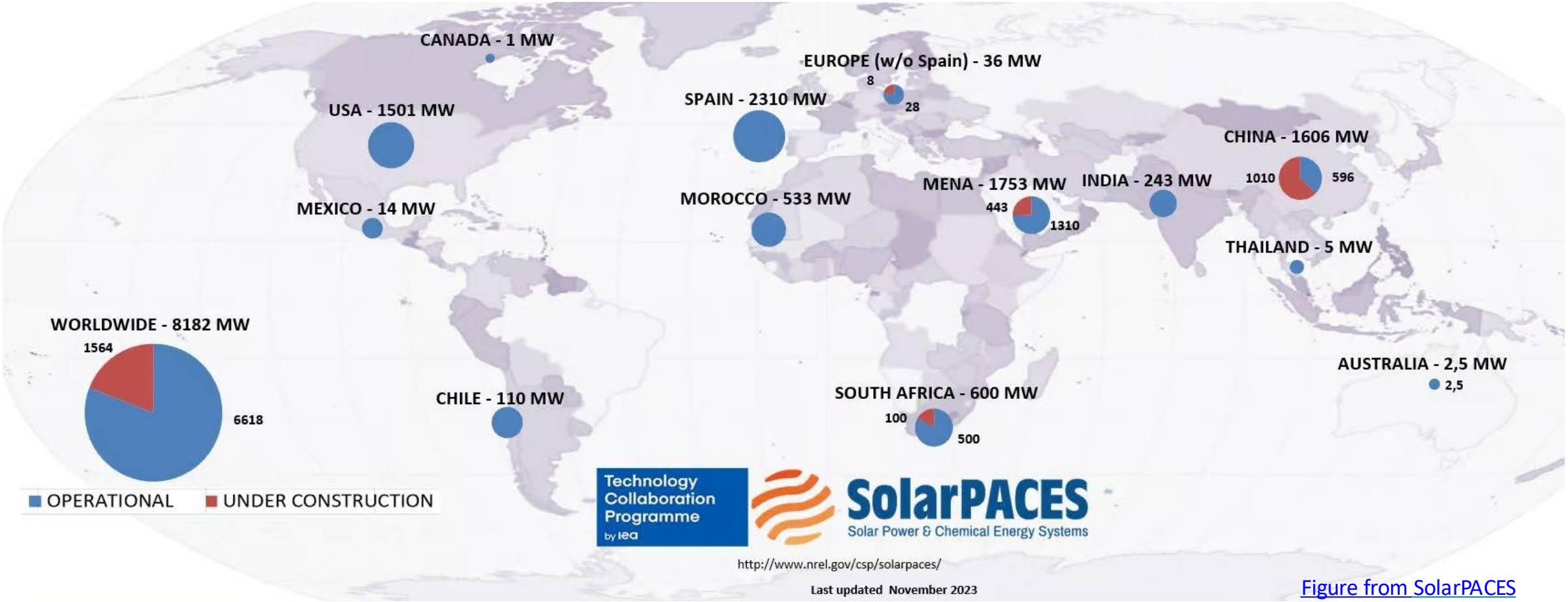
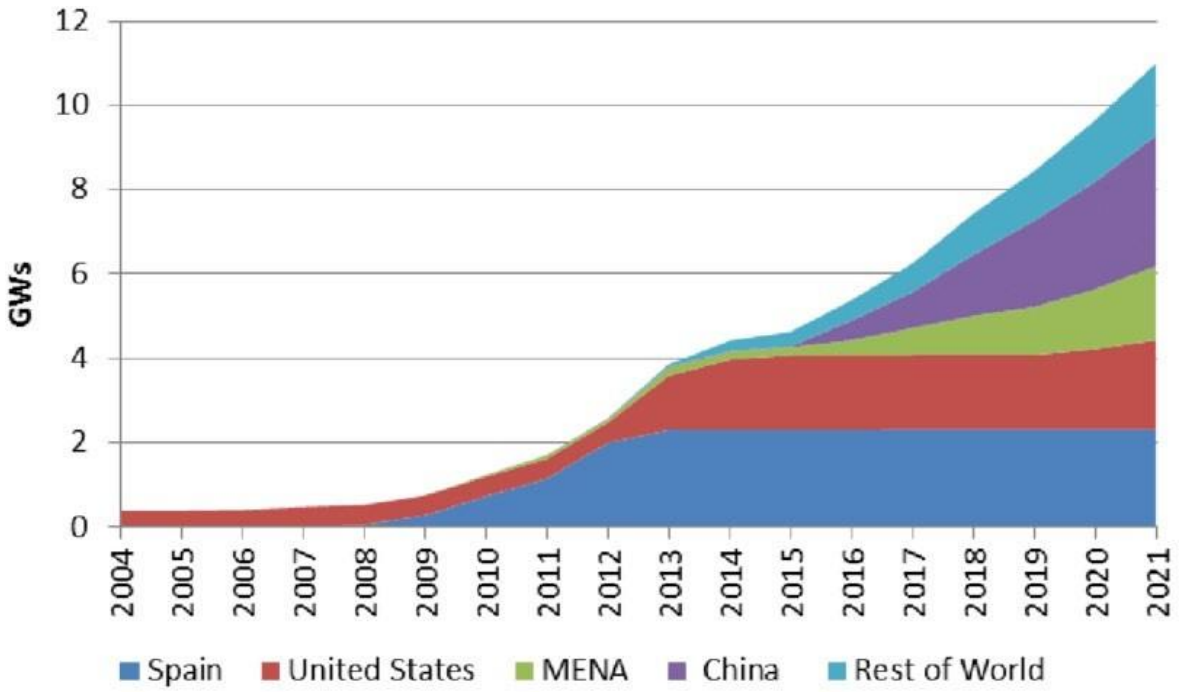


Figure from SolarPACES

Current Market Snapshot

CSP

- Greatest installations are in the U.S. and Spain, but stalled around 2014
- More recent development activity in Middle East, South Africa, and China



Actual and projected global cumulative growth of CSP capacity (source: IEA).

A Selection of U.S. and International CSP Companies	
BrightSource Energy, Inc. (USA)	Heliogen (USA)
Abengoa Solar (Spain)	Atlantica (UK)
Acciona (Spain)	Masen (Morocco)
ACWA Power (Saudi Arabia)	Megalim Solar Power (Israel)
ALTO Solution (France)	Shams Power Company (UAE)
Cosin Solar (China)	Vast Energy (Australia)

Current Market Snapshot

CSP

CSP is **more expensive than solar PV without storage** but can be cheaper than solar PV + storage as a function of storage duration.

Global weighted average LCOE and auction/PPA prices for PV and CSP

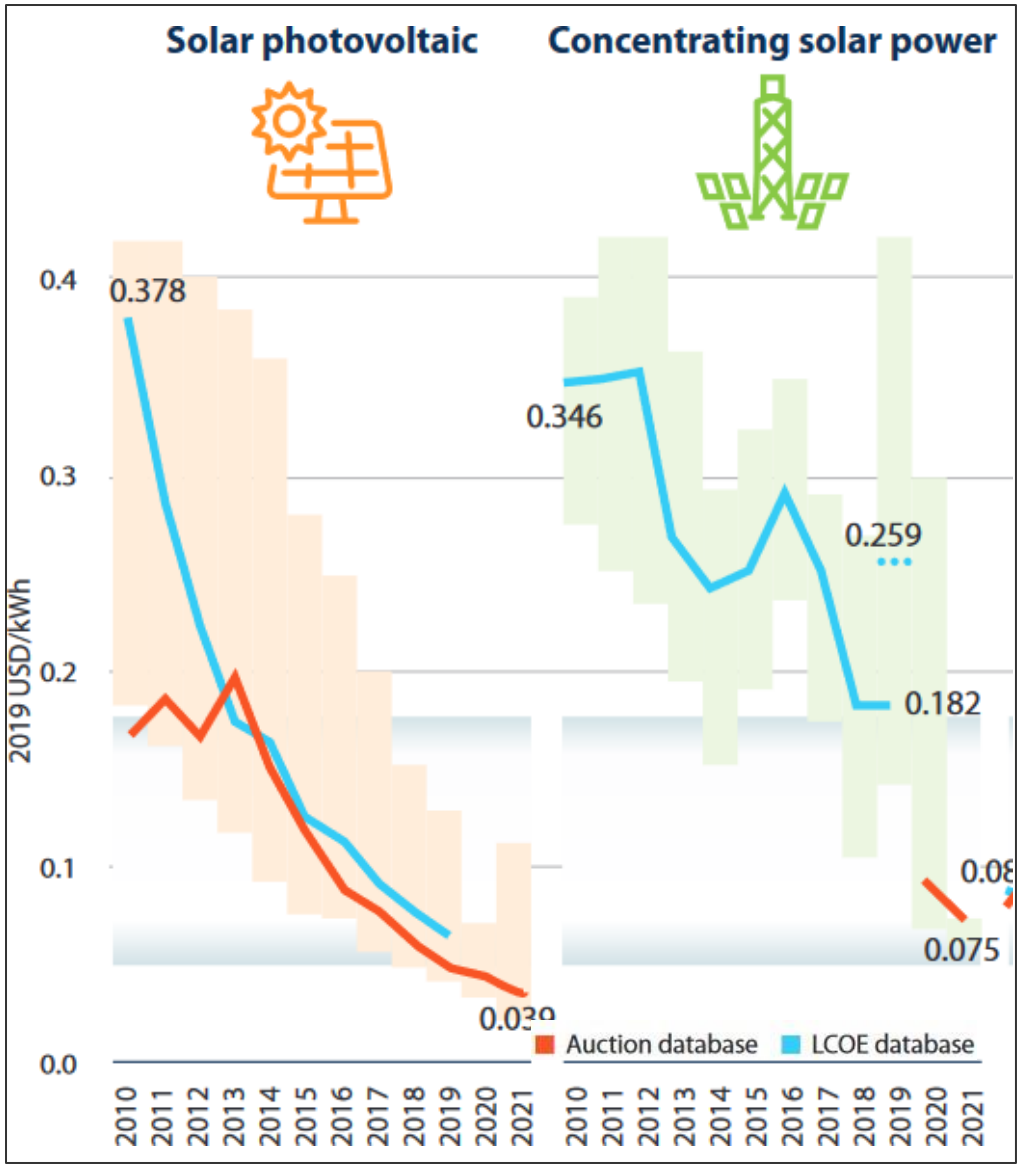
Source: IRENA 2020.

Note: The thick lines are the global weighted average LCOE, or auction values, by year. The shaded bands, which vary by year, are the cost/price range for the 5th and 95th percentiles of projects. For the LCOE data, the real weighted average cost of capital is 7.5% for China and members of the Organisation for Economic Co-operation and Development, and 10% for the rest of the world. The grey band that crosses the entire chart represents the fossil-fuel-fired power generation.

For CSP, the dashed blue bar in 2019 shows the weighted average value including projects in Israel.

LCOE = levelized cost of electricity; PPA = power purchase agreement; USD/kWh = US dollars per kilowatt-hour.

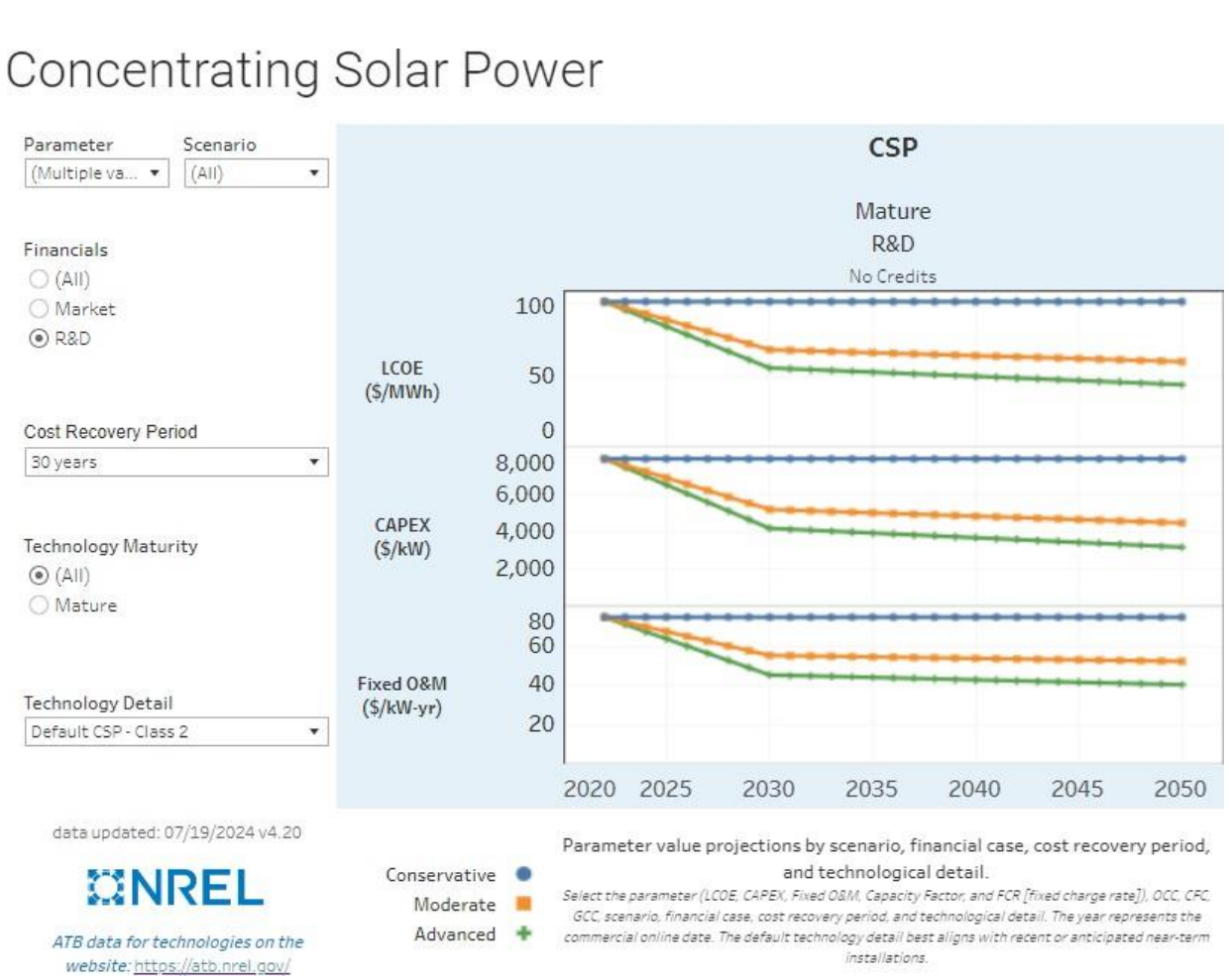
Figure from: [The World Bank 2020]



Current Market Snapshot

CSP

NREL Annual Technology Baseline (ATB) Costs / Trends



Source: https://atb.nrel.gov/electricity/2024/concentrating_solar_power

Key assumptions*:

- CSP costs are based on Central Receiver / Power Tower technology available in the System Advisor Model (SAM)
- Moderate Scenario assumes molten salt TES operating at current temperatures of 565°C with a transition to a supercritical-CO_2 power cycle, advanced coatings on the receiver, improved tanks, pumps, and component configurations for the thermal storage unit, and improved heliostat installation and learning that are due to deployment in the solar field
  - Moderate based on projections from other research for today's 2 tank molten salt tower
- The Advanced Scenario assumes higher-temperature sCO_2 ; a higher-temperature receiver; advanced storage compatible with higher temperatures; and low-cost, modular solar fields with increased efficiency.
- Inflation Reduction Act tax credits begin phasing out in 2038

*from: Annual Technology Baseline: The 2024 Electricity Update

Current Market Snapshot

CSP

Technology Readiness Levels (TRLs) and Level of Deployment*

- High technology readiness level (commercial deployment)
- Deployments are less prevalent compared to other renewable energy technologies due to costs and present lack of need for 12-h energy storage.
- <10 CSP plants in the U.S. as of 2023

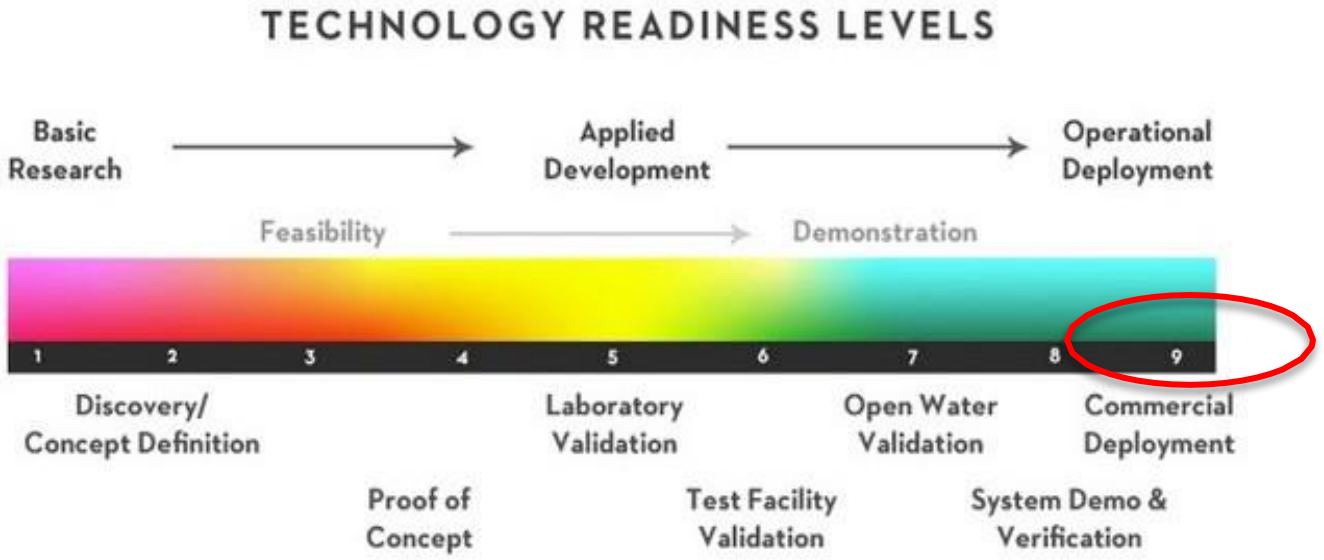
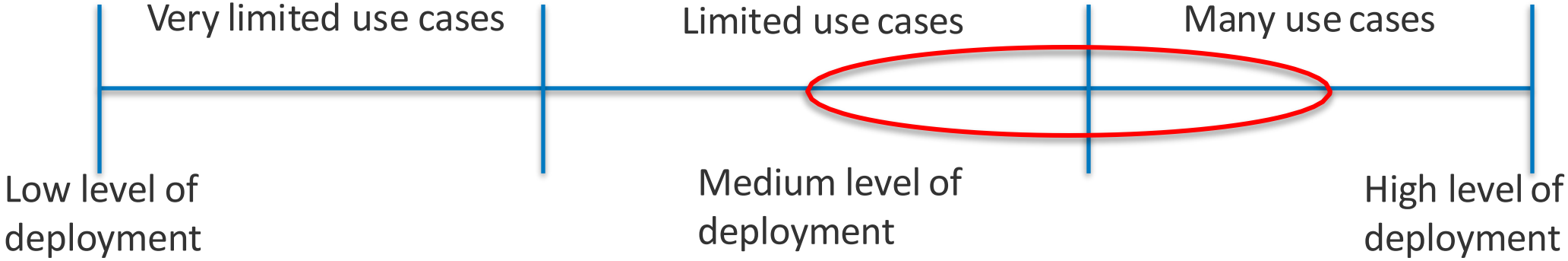


Figure from SNMREC



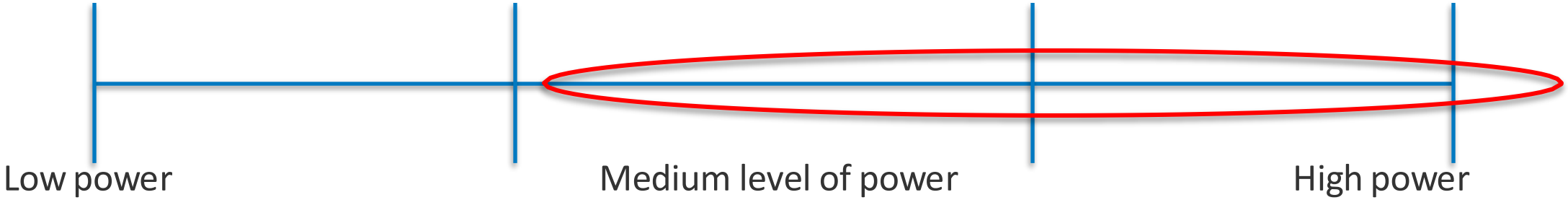
*These are estimated scale placements based on literature reviews and discussions with subject matter experts and are subject to change as the field evolves.

Current Market Snapshot

CSP

Scale of Power Capacity*

- CSP is economical at medium-to-high power levels
- Most utility-scale CSP plants range in capacity from 50 – 300 MW_e (as of 2024)



*These are estimated scale placements based on literature reviews and discussions with subject matter experts and are subject to change as the field evolves.

Summary: Benefits and Challenges

CSP

Benefits	Challenges
Cost effective energy storage. (LCOE is *lower* when energy storage included)	Cost higher than wind or solar PV if long duration storage (~12 h) not required.
Thermal power system easy to integrate in electric grid; shares attributes with other turbine-based systems.	Constrained by water availability (dry cooling is common but adds cost). Water and O&M cost to clean mirrors.
Energy storage allows dispatchable power day or night. Power output not affected by abrupt changes in solar input.	High land use (albeit comparable to utility-scale PV)
	Most suited to desert Southwest, i.e., regions of high direct normal irradiance (DNI)

Solar Thermal Pool Heating

Helping pool owners to live green, and swim warm.

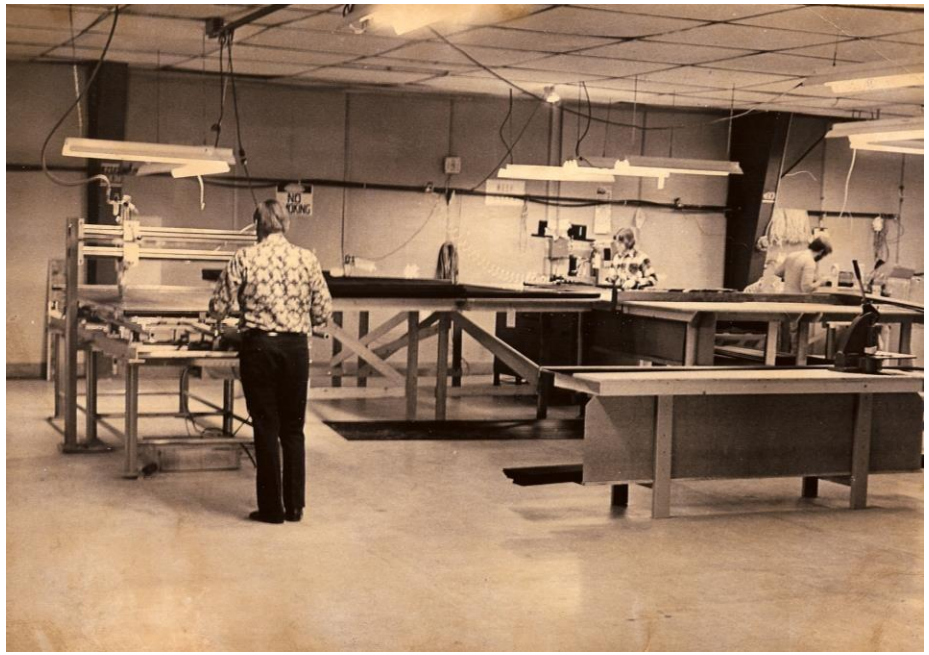
35 1989 2024 aquatherm INDUSTRIES, INC. LIVE GREEN. SWIM WARM.

Dan Sizelove

Vice President of Sales & Marketing

Aquatherm Industries, Inc.

Nearly 50 years in the making…



C. 1976
Solar Industries, Inc.
Manasquan, New Jersey

TODAY
Aquatherm Industries, Inc.
Lakewood, New Jersey

US Market Overview - Residential

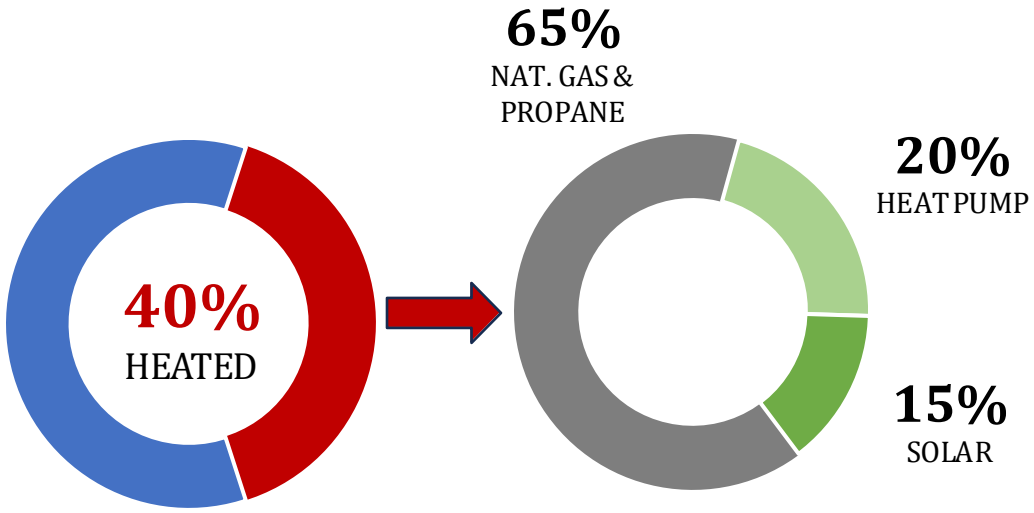
8,800,000 Residential Pools

5.4 million

PERMANENT
INGROUND

3.4 million

SEMI-PERMANENT
ABOVE GROUND



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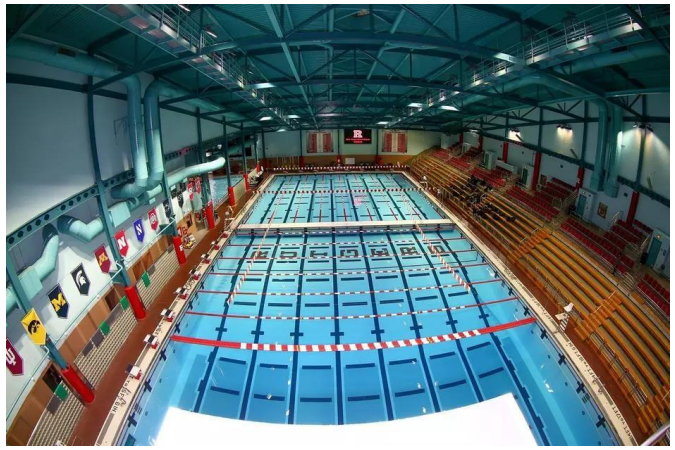
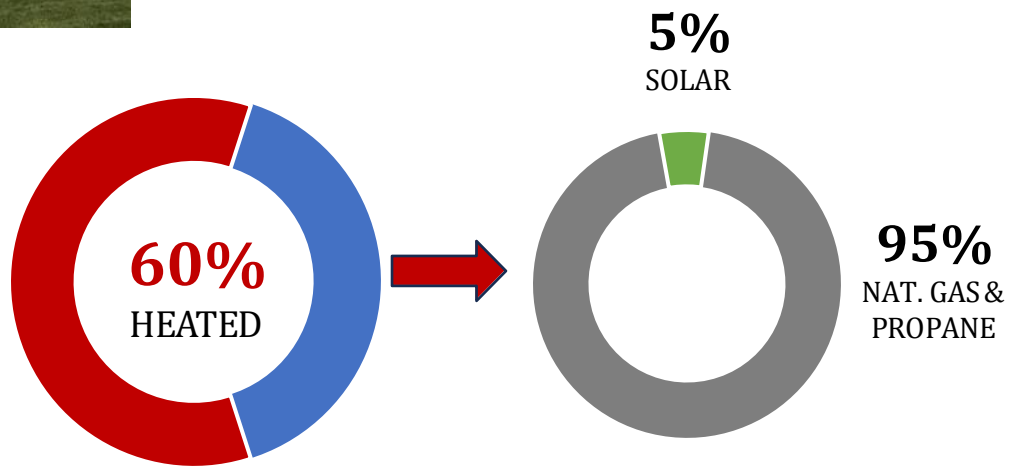
US Market Overview - Nonresidential

400,000 nonresidential pools

220,000
OUTDOOR

160,000
INDOOR





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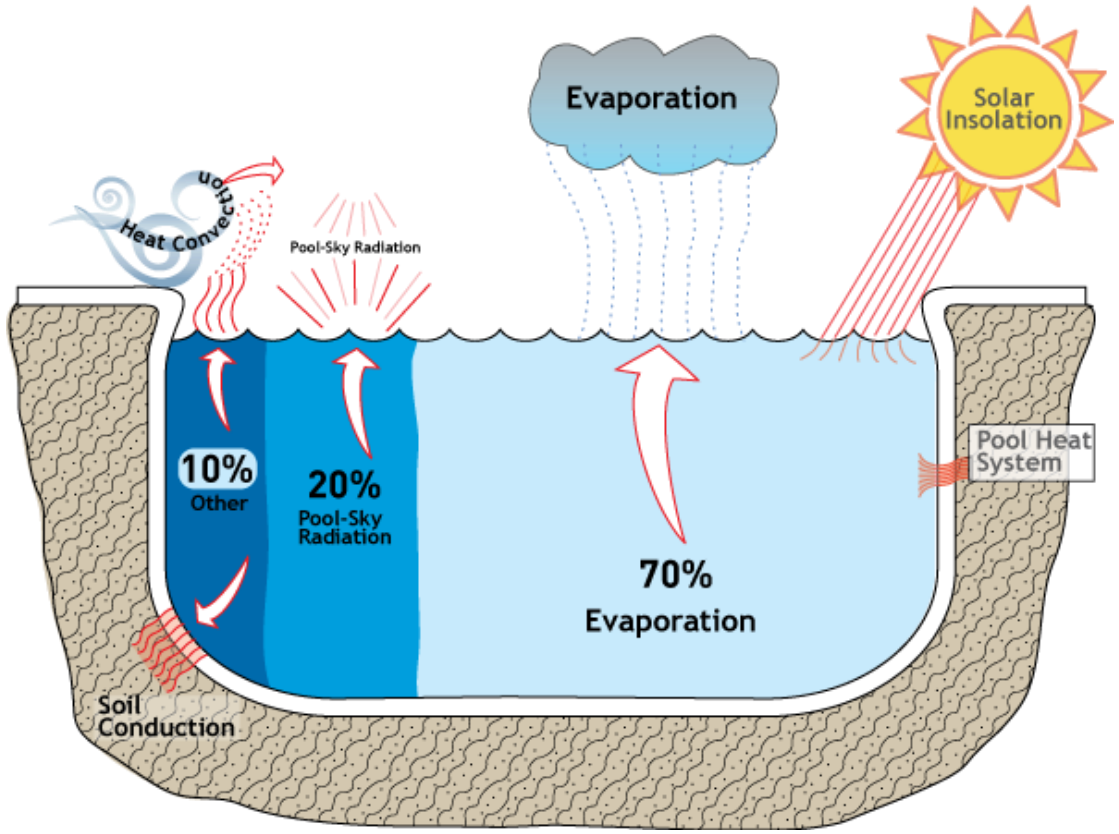
Why Heat Swimming Pools?

Natural Heat Gain

A pool is a black body, absorbing hundreds of thousands of Btus per day through its surface.

Heat Loss

A pool is a large open tank, losing hundreds of thousands of Btus per day, mostly through its surface.



Up to 80% of natural heat gain is lost!

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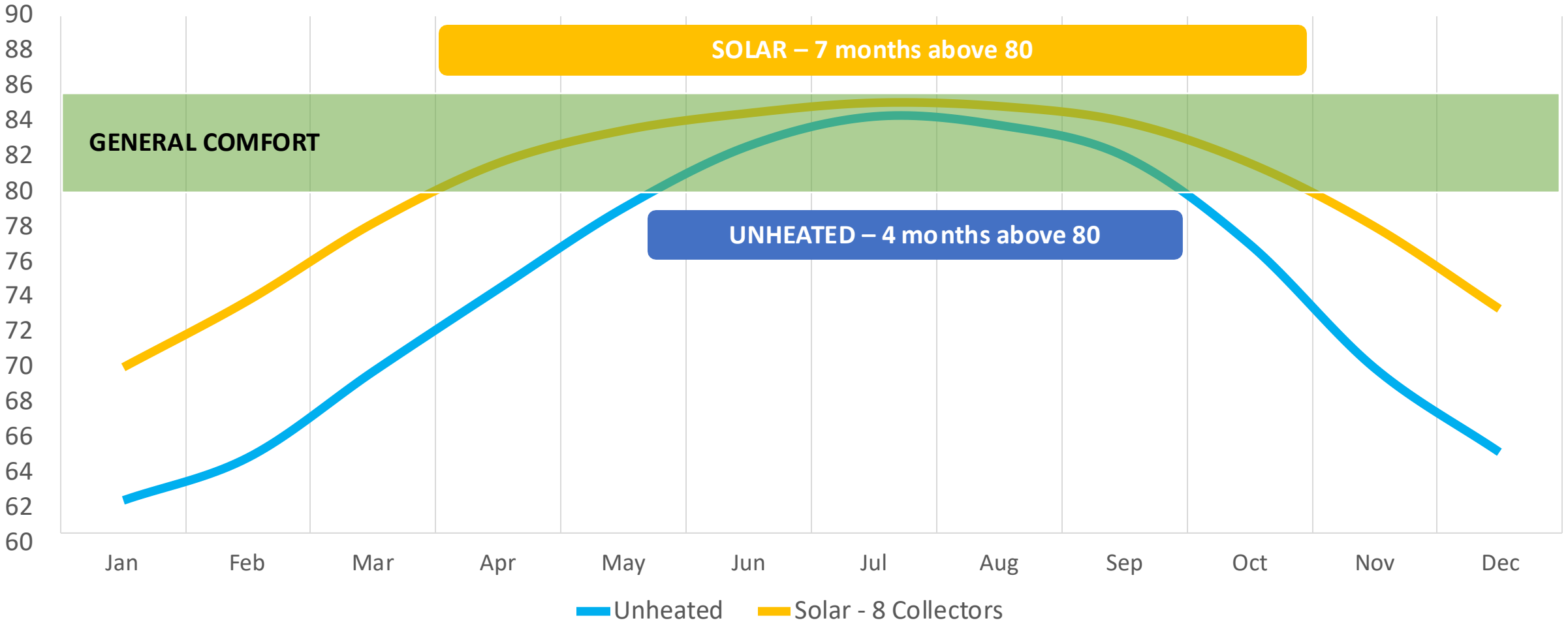
Why Heat Swimming Pools?

400 ft² (13,000 gallon) Inground Pool in Orlando, FL



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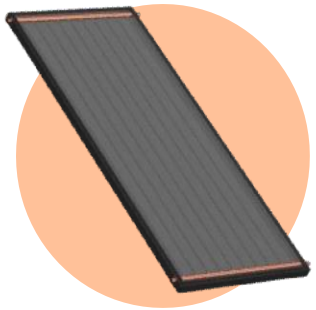
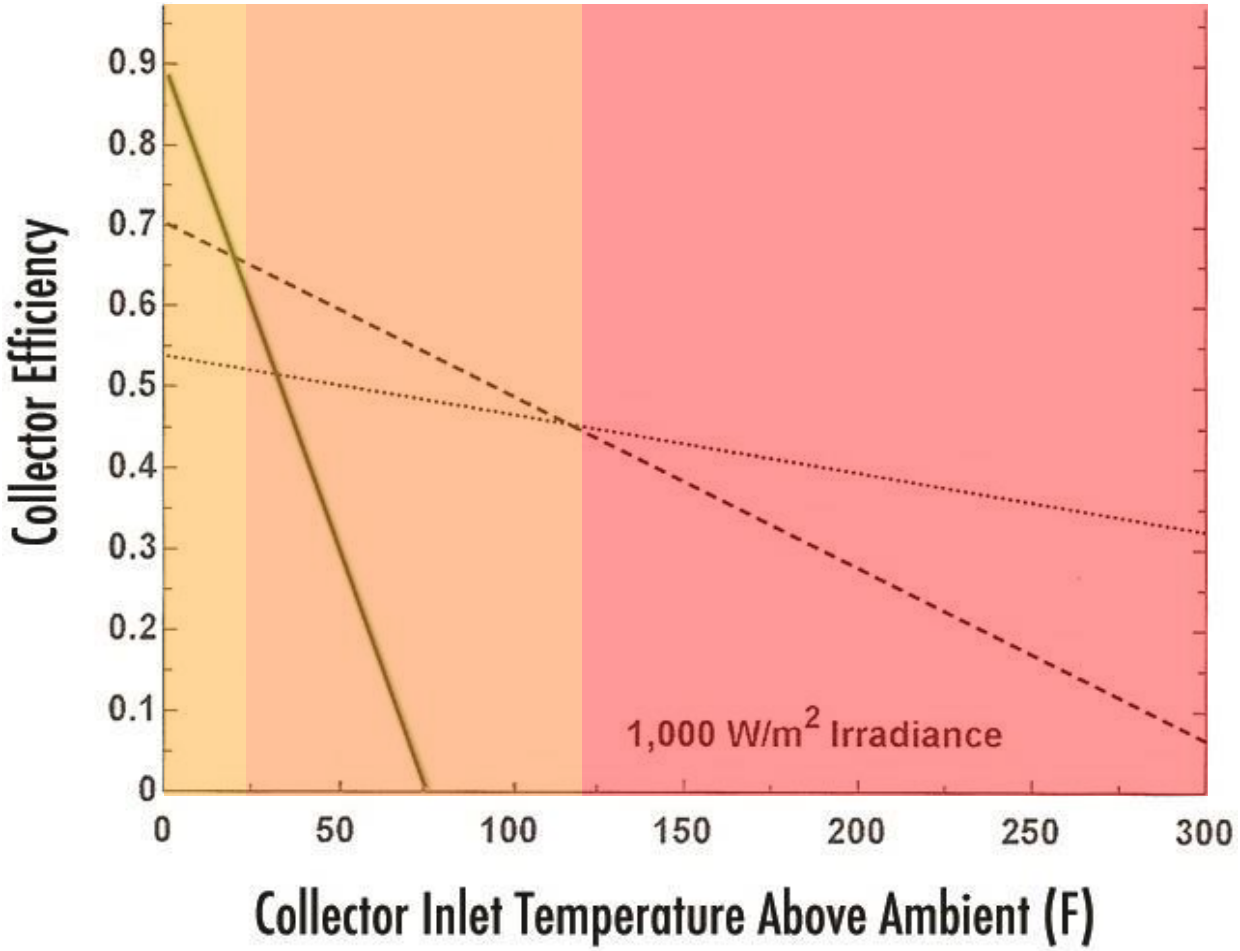
Collector Efficiency ($T_i - T_a = 0$)

Unglazed Flat Plate
Up to 93% efficient



Glazed Flat Plate
70% efficient

Evacuated Tube
55% efficient



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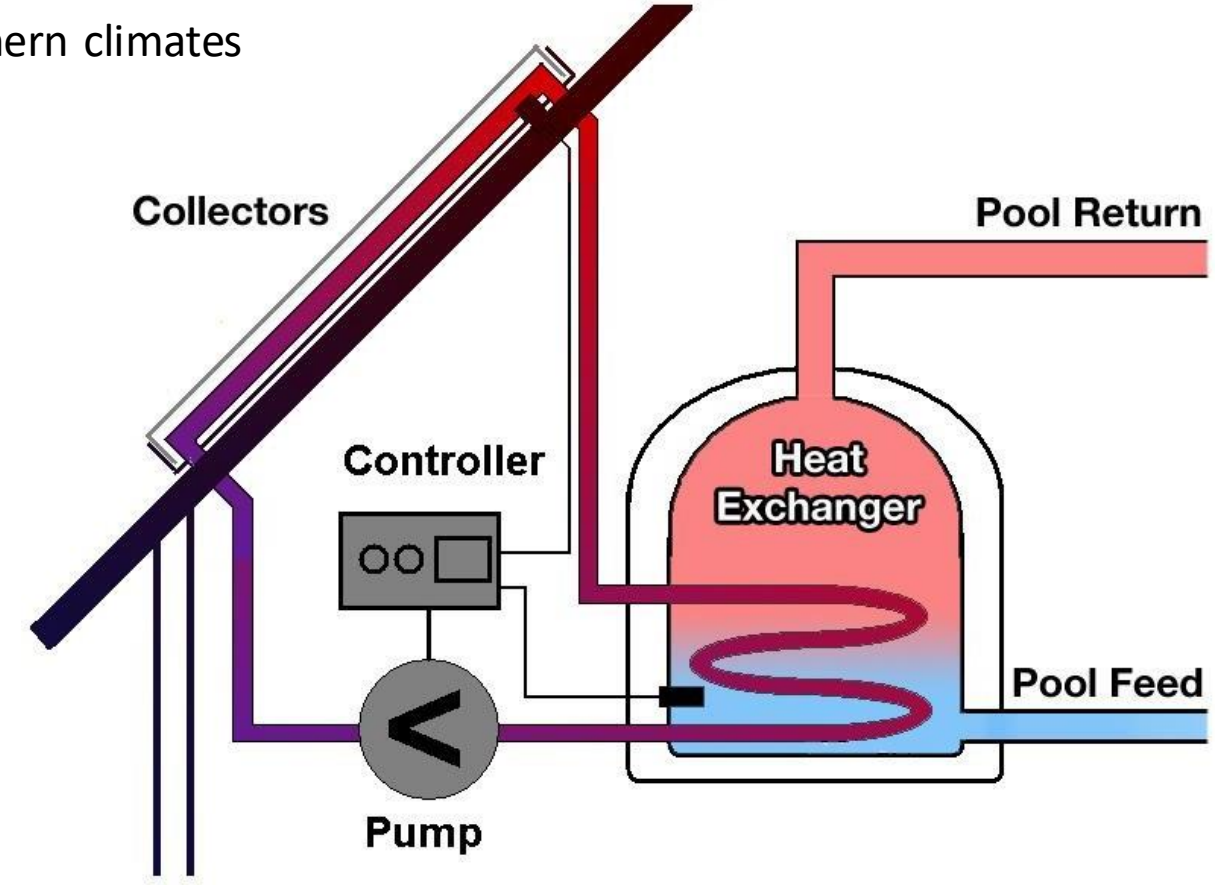
Closed Loop using Glazed Collectors

Advantages

- Good year-round performance, especially in northern climates
- Less sensitive to cool prevailing breezes

Considerations

- Efficiency losses of 17-25% due to glazing and use of a heat exchanger
- Additional balance of system components extend payback period
  - Insulated copper piping
  - Circulation pump
  - Heat exchanger
  - Expansion tank



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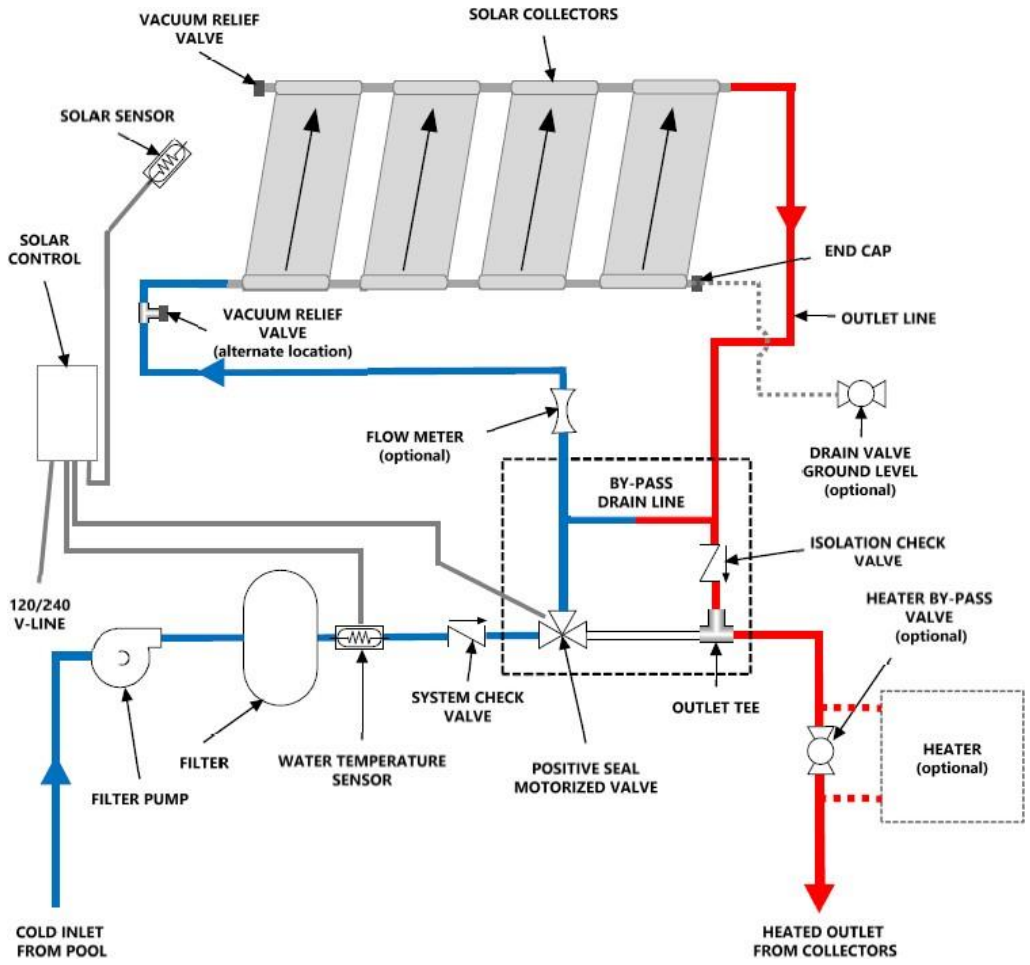
Open Loop using Unglazed Collectors

Advantages

- Extremely efficient when heating water to a relatively low temperature
- Uses existing filtration pump as circulation pump
- No heat exchanger or expansion tank
- Inexpensive Sch. 40 PVC piping

Considerations

- Efficiency drops dramatically when Ti-Ta ≥ 25°F
- Sensitive to cool prevailing wind



Residential Applications

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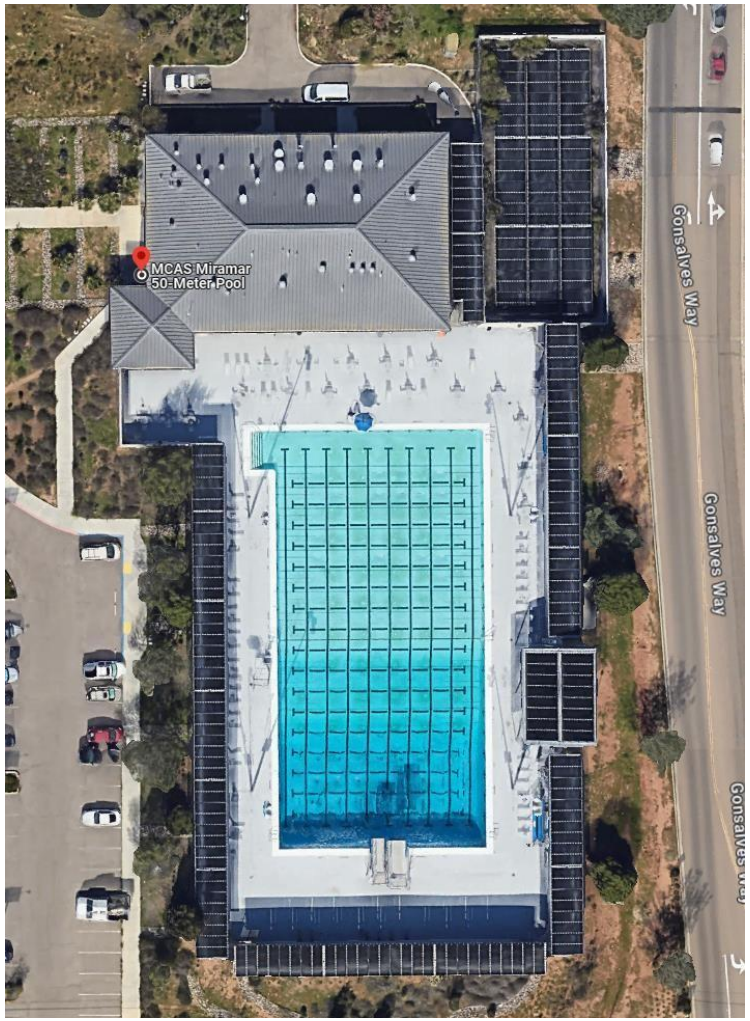
Multi-family Applications

- Apartment complexes
- Condominiums
- Community (HOA)

Nonresidential Applications

- Public/Municipal
- Hotels & Motels
- Schools & Universities
- Gyms & Health Clubs
- Aquatic Centers
- Military Bases



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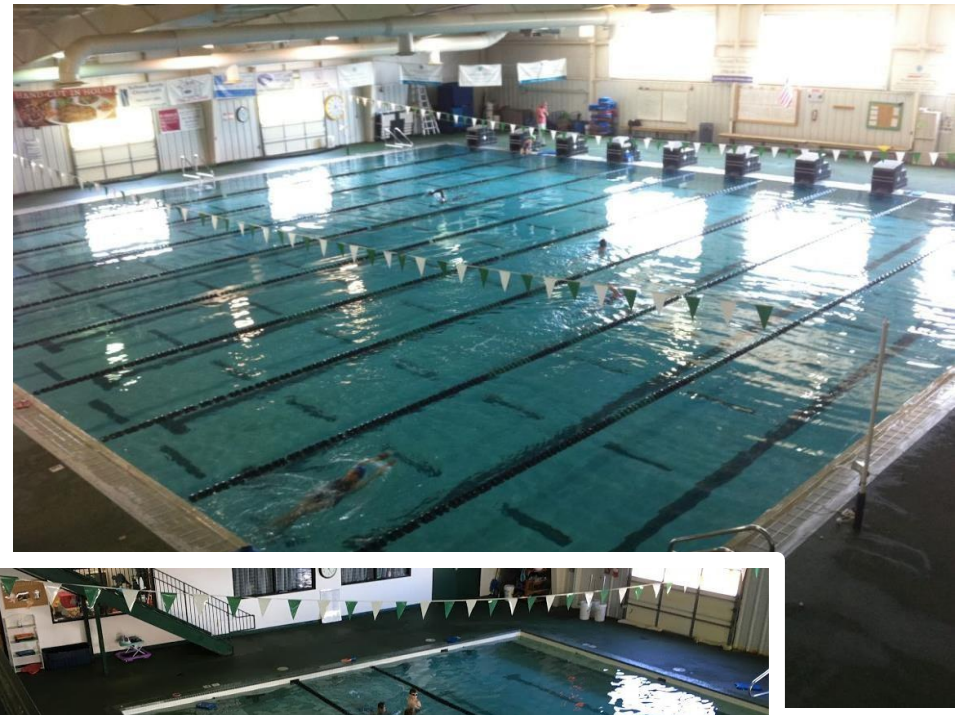
Case Study: NOMAD Aquatic Facility (Huntersville, NC)

- 30,000 ft2 facility w/ 4,000 members
- Pool 1: 5,900 ft^2 indoor
  - Heated to 79 F (C) w/ natural gas
  - Lap swimming for members
  - Competitive swim meets and practices
- Pool 2: 2,700 ft^2 indoor
  - Heated to 85 F (29 C) w/ natural gas
  - Instructional “warm” pool; learn-to-swim



- Combined modeled consumption: 22,500 therms/yr
- Combined modeled emissions: 13.2 metric tons CO2e/yr
- Owners cited monthly gas bills of up to $12,000

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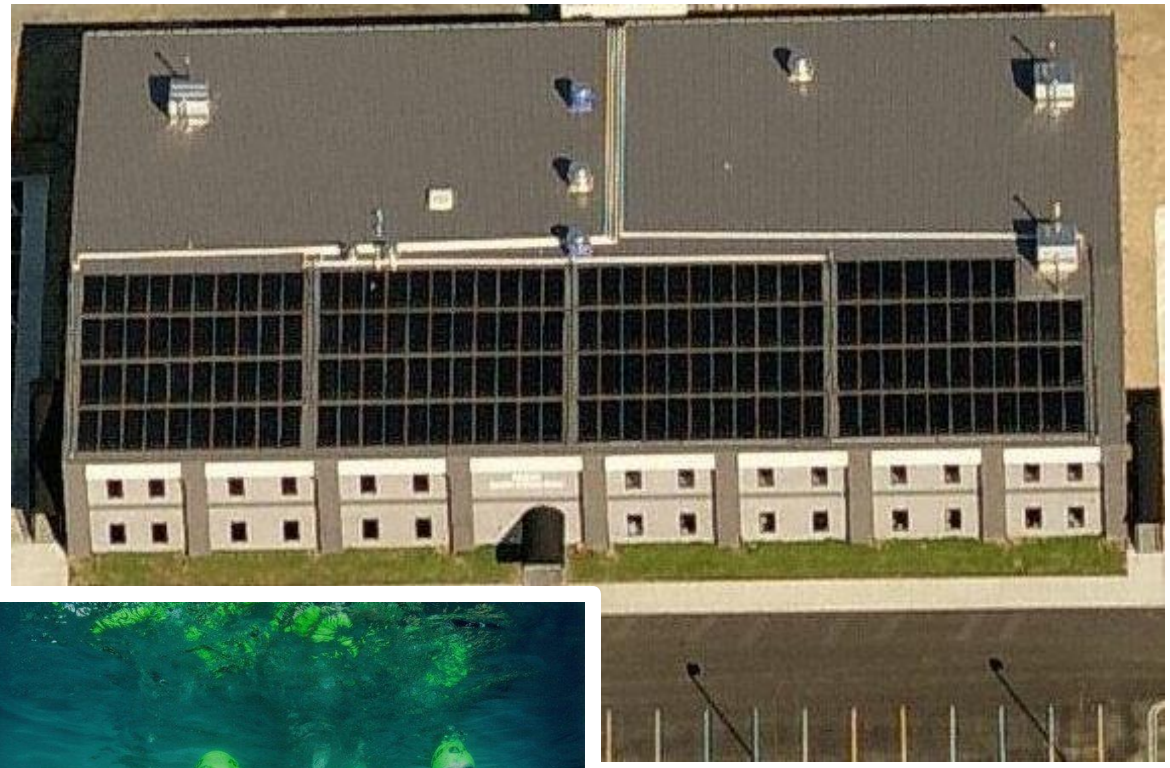
Case Study: NOMAD Aquatic Facility

- (264) 4’ x 12’ collectors (12,672 ft^2)
- Installed in 2007; total project cost $200,000
- Solar handles 100% of the load from March through October
- Less than 2-year payback

- Qualified for 35% NC state tax credit ($70,000)
- ISTEC energy meter measures total BTU output
- Facility received $40,000/yr in SRECs
- Savings and SRECs financed a backup wood pellet heater for December & January
- Gas heater no longer used



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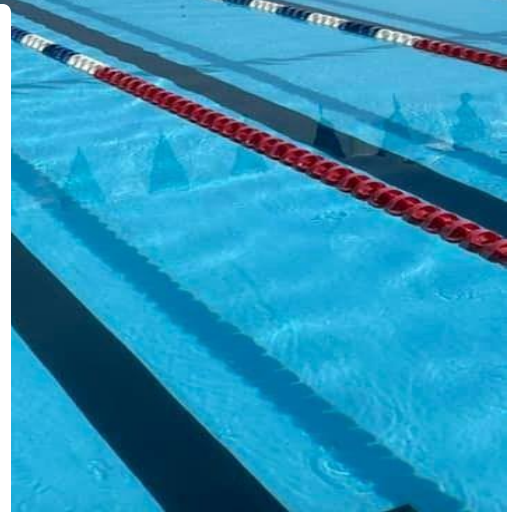
Case Study: Eglin AFB (Valparaiso, FL)

- 14,000 ft^2 outdoor pool; open year-round
- Recreational use and Water Survival Training

- Heated to 82° F (27.7 °C) with natural gas
  - Shared gas meter
- Modeled consumption: 92,000 therms/yr
- Modeled emissions: 487 metric tons CO2e/yr



Case Study: Eglin Air Force Base

- (164) 4’ x 12’ collectors; total of 7,872 ft^2
- Installed 2011; total project cost $177,175
- Solar handles 100% of the load March through November
- Displaces 328 metric tons CO2e/yr
- Savings of $24,000/yr (7.5-year payback) @ 2011 rates

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Case Study: Red Lion High School (Red Lion, PA)

- 3,000 ft^2 indoor swimming pool
- Swim team practice and meets
- Red Cross Learn-to-Swim lessons

- Heated to 85° F (29 °C) with natural gas
  - Shared gas meter
- Modeled consumption: 12,700 therms/yr
- Modeled emissions: 67 metric tons CO2e/yr

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Case Study: Red Lion High School

- (64) 4’ x 12’ unglazed collectors
- Sized to 100% of pool’s surface area
- Closed loop system (1:1 water to glycol mix)
- Custom titanium plate heat exchanger

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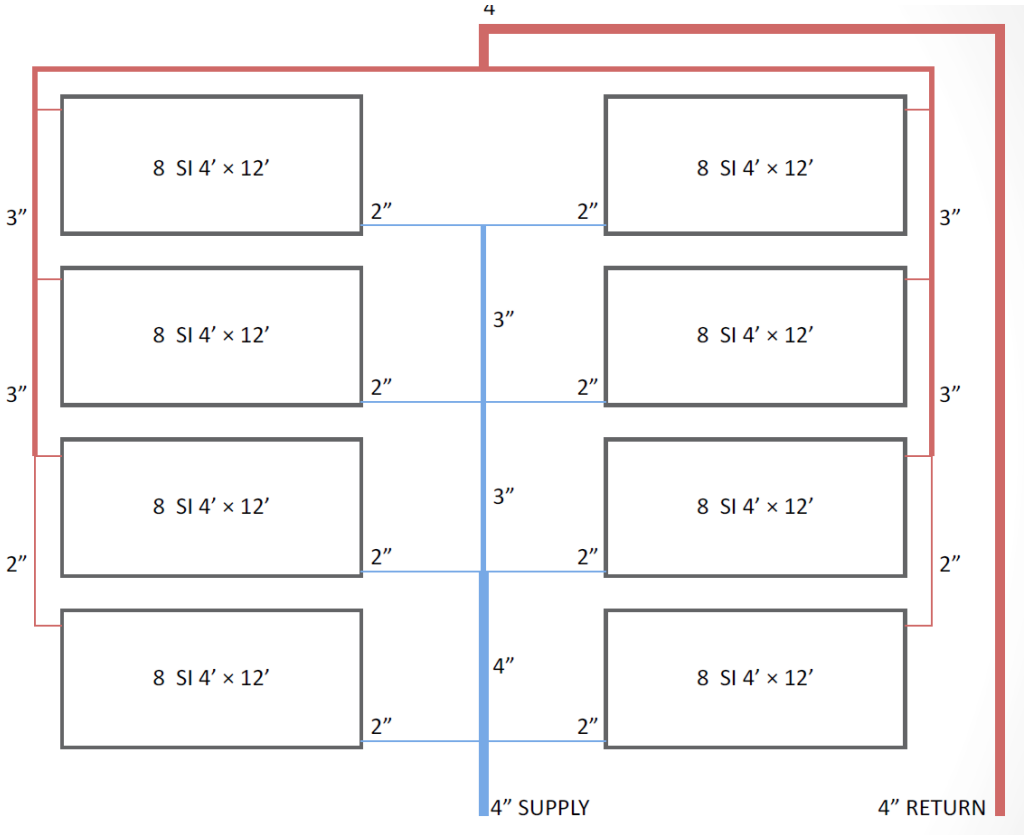
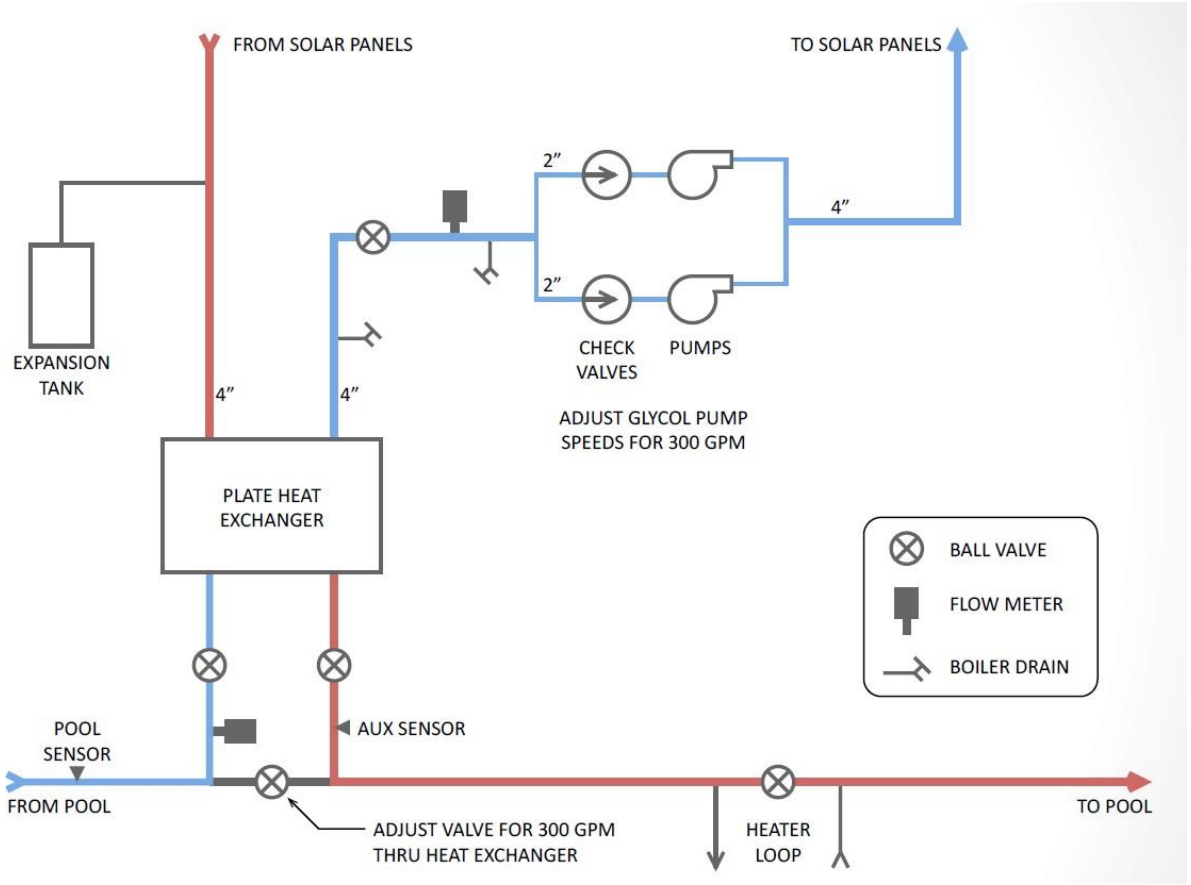
Case Study: Red Lion High School





Case Study: Red Lion High School

Date / Time	July 6, 2012 11:00am
Sky Conditions	Clear & Sunny
Ambient Air Temp.	85° F (29° C)
Pool Temp.	85° F (29° C)
Roof Temp.	128° F (53° C)
Solar Panels Inlet	91° F (33° C)
Solar Panels Outlet	105° F (41° C)
Water From Pool	85° F (29° C)
Water Return To Pool	92° F (33° C)
Water Flow Rate	270 GPM
Energy Delivered	270 GPM × 8.33 × 7° × 60 **=944,622 Btu / hr (276kW)**

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(Ultra) Low-temperature SHIP Applications

Nestlé Toluca Coffee Processing Plant

Unglazed collectors supply 20-30°C water for “wet-washing” coffee beans

Policy & Incentives: Past & Present

1979-1985: Federal Solar Tax Credit

- 30% tax credit on qualified solar energy equipment
- Up to $2,000 per system
- Pool heating included

2013-2017: CSI-Thermal Rebate Program

- Applied to commercial pools in California
- Included multi-family residential
- Ratepayer-funded rebate of $7 per displaced therm (calculated)
- No cap at first, then 50% cap added in 2014

2006 - Present: Investment Tax Credit / Inflation Reduction Act

- 30% tax credit on qualified solar energy equipment
- Pool heating excluded

January 1, 2026

2025 CA Building Code, Title 24

- Applies to new and previously unheated existing pools where a gas pool heater is going to be installed
- A solar thermal pool heater *or* heat pump pool heater must be installed in combination with the gas heater
- Residential - solar must be equal to 60% of the pool's surface area
- Nonresidential – solar must be equal to 65% of the pool's surface area
- Alternative pathways to compliance

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LIVE GREEN. SWIM WARM.

THANK YOU!

Dan Sizelove

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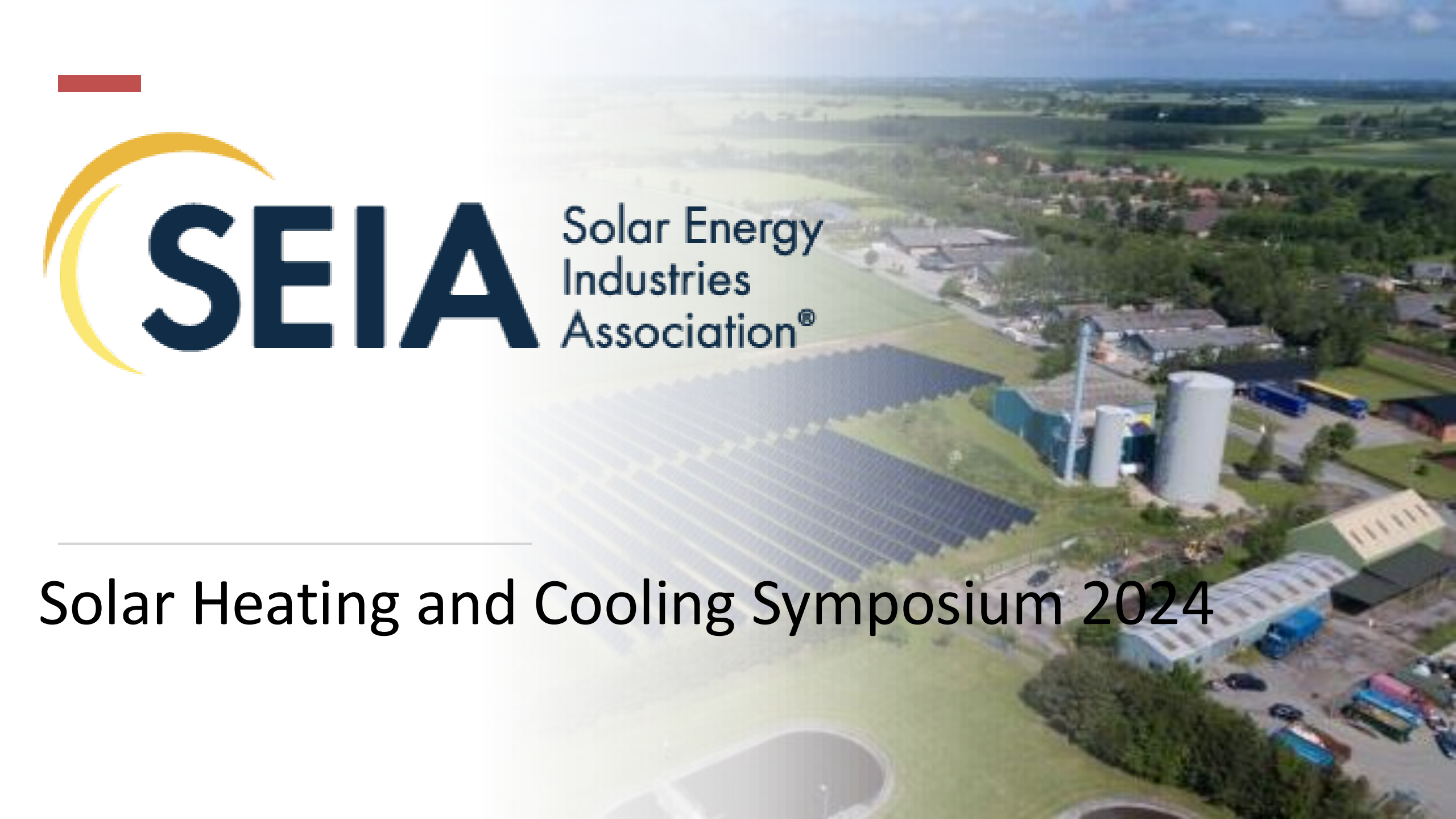
SEIA Solar Energy Industries Association®



Solar Heating and Cooling Symposium 2024