SOLAR THERMAL
ALLIANCE OF COLORADO

Colorado Solar Thermal Roadmap

Our vision is to make Colorado a global leader in solar thermal adoption, installation, manufacturing, and R&D to boost Colorado's economy, generate jobs, and help build a sustainable energy future.

January 24, 2012

Houwelings Nursery, Camarillo CA, April 2009.
Photo: Jim Maguire © Schuco.

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The Solar Thermal Alliance of Colorado (STAC) is a task force under the joint leadership of the Colorado Renewable Energy Society (CRES) and the Colorado Solar Energy Industries Association (COSEIA) in collaboration with dozens of energy leaders across Colorado.

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COSEIA
Colorado Solar Energy Industries Association

CRES
Colorado Renewable Energy Society
Your Renewable Energy Resource

The organizations listed above with founders and contributors are to aid in identification of individuals only; they do not necessarily represent endorsements by said organizations of the *Colorado Solar Thermal Roadmap*. Individuals mentioned may not have reviewed all contents of the published roadmap, and may not endorse specific aspects.

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List of Acronyms

ANSI: American National Standards Institute

ASES: American Solar Energy Society

COSEIA: Colorado Solar Energy Industries Association

CRES: Colorado Renewable Energy Society

CPUC: California Public Utilities Commission

CSI: California Solar Initiative

CSP: concentrating solar power

DOE: U.S. Department of Energy

EIA: U.S. Energy Information Administration

EPA: U.S. Environmental Protection Agency

ESTIF: European Solar Thermal Industry Foundation

EU: European Union

FSEC: Florida Solar Energy Center

GEO: Colorado Governor's Energy Office

IEA: International Energy Agency

ISO: International Organization for Standardization

HVAC: heating, ventilation and air conditioning system

kW: kilowatt

kW_{th}: kilowatt thermal equivalent

kWh: kilowatt hour

kWh_{th}: kilowatt hour thermal equivalent

LPG: liquefied petroleum gas

MW: megawatt

MW_{th}: megawatt thermal equivalent

NREL: National Renewable Energy Laboratory

PACE: Property Accessed Clean Energy

R&D: research and development

SERI: Solar Energy Research Institute

ST: solar thermal

STAC: Solar Thermal Alliance of Colorado

SWH: solar water heating

TDC: thermally driven cooling

Executive Summary

Colorado is strategically poised to seize national leadership in the solar thermal industry—and the vast economic benefits that come with it. The state occupies North America's "bull's-eye" of optimal solar thermal heating performance; it is home to a cluster of cleantech and solar innovators; Colorado enjoys deep technical expertise in the field; and its citizens strongly support the development of clean energy.

Colorado is fortunate to have a natural advantage over other U.S. states. Solar thermal heating technologies perform better in Colorado than in any other state according to researchers at the National Renewable Energy Laboratory and the Florida Solar Energy Center. This advantage is due to Colorado's dramatic daily temperature swings, abundant sunshine, cold ground water, and annual heating loads.

The *Colorado Solar Thermal Roadmap* plots a course to sustained growth in the state's solar thermal industry while positioning Colorado as a leader in the research, manufacturing and installation of this renewable energy technology. This *Roadmap* outlines pragmatic goals for installed solar thermal capacity with the concurrent results for economic development, job creation and health and environmental benefits, as illustrated in the table below.

Solar Thermal Leadership: Colorado's Economic Opportunity

Solar thermal technologies are commonly used for heating purposes. Systems heat a liquid that provides hot water for residential, commercial and industrial applications, as well as for heating buildings and industrial processes. These types of heating functions represent a large majority of Colorado buildings' energy needs. Recently, innovators have pursued using this heat to drive cooling systems and electric generation during summer electric peaks. Concentrating solar thermal applications are also able to generate electricity on a utility scale, as demonstrated by two world-leading companies based in Colorado.

The 18-collector system on the Denver Federal Center Building #95. Photo: Mike Wilson.

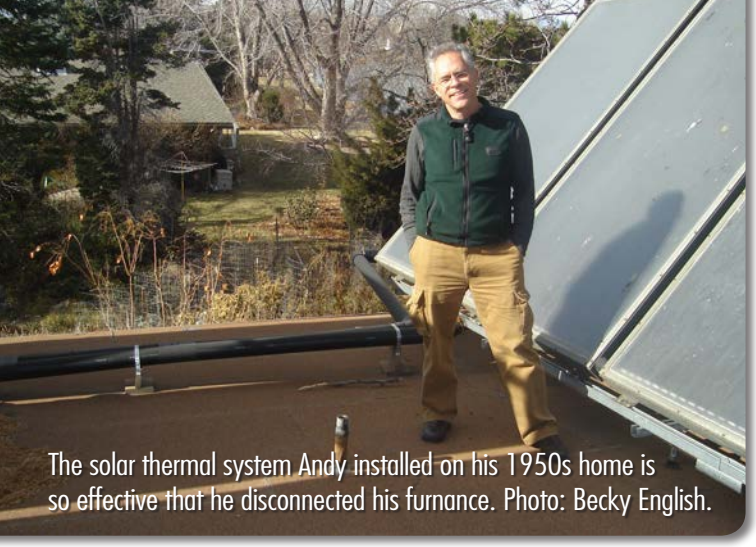
Therefore, solar thermal systems have the ability to offset or supplement fossil fuel use in both heating and electric applications, and in both distributed and central generation. Since most of the sun's energy reaches the earth's surface as heat, solar thermal systems are highly efficient: they can capture as much as 80% of the sun's energy.

Global Growth, Local Opportunities

On the international stage, solar thermal energy has seen strong growth in recent years. The U.S., however, has lagged behind in implementation of this efficient technology. And, in spite of remarkable progress with other forms of renewable energy, Colorado is noticeably behind in solar thermal deployment, especially in light of

Projected Targets from Growth Modeling in the *Colorado Solar Thermal Roadmap*

Year	Cumulative Solar Thermal Installed Capacity (MW_{th})	Annual Revenue	Total Jobs	Health & Environmental Cost Savings	CO_2 Offset (million lbs)
2010	150	$16,000,000	626	$17,000,000	89
2030	2,474	$677,000,000	15,600	$286,000,000	1,500
2050	16,595	$1,060,000,000	24,300	$1,920,000,000	9,900



The solar thermal system Andy installed on his 1950s home is so effective that he disconnected his furnance. Photo: Becky English.

its outstanding solar resource. The industry faces key barriers to growth within the state, including a lack of public awareness of the technology, a patchwork of inconsistent permitting rules, an absence of state policy, the current low price of natural gas in the region, and scarce financing mechanisms for system adopters. The *Roadmap* offers recommendations for tackling these barriers.

Implementing these concrete recommendations will fuel significant economic growth in Colorado. Using a conservative growth model, the *Roadmap* anticipates a gradual and incremental ramp up of the industry with annual growth peaking in 2022. The growth of the industry then tapers to a mature, level state industry after 2030, with a sustained installed capacity of nearly 800 MW_{th} per year by 2050. By comparison, today's capacity is only about 5 MW_{th} per year. As indicated in the previous table (Page v), such growth would result in total installed capacity of nearly 2,500 MW_{th} and 15,600 total jobs by 2030 and over 16,000 MW_{th} and 24,000 total jobs by 2050.

Our state's embrace of the *Roadmap's* recommendations will facilitate dramatic progress toward goals that state leaders have articulated well for years: energy independence, reduction in CO_2 and other emissions, reduced total life-cycle costs of fossil fuels and improved state import-export balance, to name just a few. These are factors that affect Colorado's economy, businesses and residents in profound ways.

A Path Forward

The *Roadmap* shows that growth of the solar thermal industry will be achieved by a concerted campaign involving for-profit, non-profit and governmental stakeholder collaboration, encompassing four key areas of activity:

- **Increasing consumer awareness** by developing consumer relationships, improving communication, and ensuring the quality delivered by the state's solar thermal industry.
- **Developing financing mechanisms** through collaboration with financial institutions and the deployment of pilot financing programs.
- **Leveling the state's energy policy playing field.** This effort requires rebalancing energy standards to include solar thermal and creating a stable environment to encourage long-term investment.
- **Solving local impediments**, such as development of solar friendly communities, identifying best industry practices, and creating simple, clear and consistent zoning and permitting requirements across jurisdictions.

Timely implementation of the *Colorado Solar Thermal Roadmap* will attract solar thermal customers, manufacturers, and new investment and will stimulate economies of scale in the solar thermal industry. These trends will dynamically reinforce each other, establishing Colorado as the solar thermal nerve center of the U.S. and boosting the state's natural advantage in solar resources many times over. Currently Colorado's solar thermal industry is a sleeping giant. By waking it up, the solar thermal industry can make a powerful and lasting contribution to Colorado's energy economy.

Section I

Analysis of Today's Solar Thermal Marketplace


20 kW_{th} thermal collectors working since 1981 and still going strong. Photo: Capitol Solar Energy.

Solar heating, cooling, and other thermal technologies offer tremendous potential to become major economic engines for Colorado. Because local labor can constitute up to two-thirds of total solar thermal system installation costs, deployment of the technology represents significant job generation in our state. Solar thermal technologies are highly efficient and offer an early return on investment. They're also clean, renewable, and environmentally friendly. This report provides a roadmap to optimize cost-effective solar thermal development in Colorado.

Colorado is in a unique position to optimize benefits from global trends that are accelerating interest in solar thermal. The first trend is increasing demand for finite fossil fuel supplies. This trend has led to significant price volatility and economic uncertainty over the last few decades, leading many countries to look for more sustainable alternatives. Second, environmental risks from climate change, oil drilling, hydraulic fracturing, and nuclear plants are increasing the public's interest in clean, renewable energy. Third, public sector solar thermal investment in China, Germany, the U.S. and elsewhere—in the form of tax credits, rebates and other incentives—has greatly increased during the past few years, boosting global demand and promoting economies of scale. Finally, private sector investments and growth from solar thermal manufacturers, installers, and other businesses are increasing efficiencies that promote economic development and put downward pressures on solar thermal system prices.

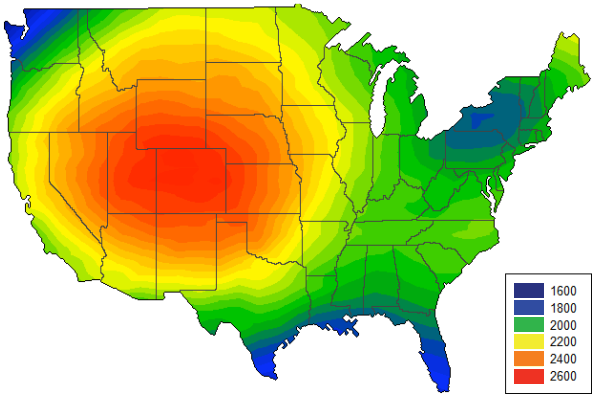


Figure 1. U.S. solar water heating performance (kWh/year; Source: Merrigan and Parker. 2010. *Solar Thermal Technology*)

1. Colorado's Competitive Advantage

In addition to these global trends, Colorado is fortunate to have a natural advantage over other U.S. states. According to researchers at the National Renewable Energy Laboratory (NREL) and the Florida Solar Energy Center (FSEC), solar thermal technologies perform better in Colorado than in any other state in the U.S. (Figure 1).[1] That's because solar thermal performance increases in proportion to the temperature difference between the liquid inside the panels and the air temperature outside the panels. Colorado's solar thermal performance advantage is due to the state's abundant sunshine, dramatic daily temperature swings day to night, cold ground water, and annual heating loads. In short, Colorado represents the bull's-eye of the U.S. solar thermal market opportunity; the state is well positioned to benefit from impressive economic growth if appropriate steps are taken.

1 Merrigan, Tim, and Danny Parker. July 8, 2010. *Solar Thermal Technology*. Presentation to the Colorado Public Utilities Commission, Denver, Colorado. National Renewable Energy Laboratory; Florida Solar Energy Center. Accessed at https://www.dora.state.co.us/pls/efi/efi_p2_v2_demo.show_document?p_dms_document_id=52870

Colorado already has a reputation as having a "cluster" of cleantech and clean energy entrepreneurship and innovation. Its solar thermal expertise is among the best in the world, due to a long history with the technology going back more than thirty years to the founding of NREL's predecessor, the Solar Energy Research Institute (SERI). In 2004, Colorado consumers made their preferences for clean energy known at the ballot box when more than a million voters supported Amendment 37, the nation's first successful citizen initiative to create a renewable portfolio standard. The measure has subsequently been reinforced through a series of state and local clean energy measures. Collectively, these competitive advantages, state-level public drivers, and global trends all point to a clear conclusion: that Colorado has a tremendous economic opportunity to be a global leader in solar thermal technologies.

2. Solar Thermal Overview

Solar thermal technology is most commonly seen today in the form of flat panels or tube collectors that heat a fluid. After decades of research and development, today's technology reaches very high efficiencies, capturing up to 80% of the sun's energy.

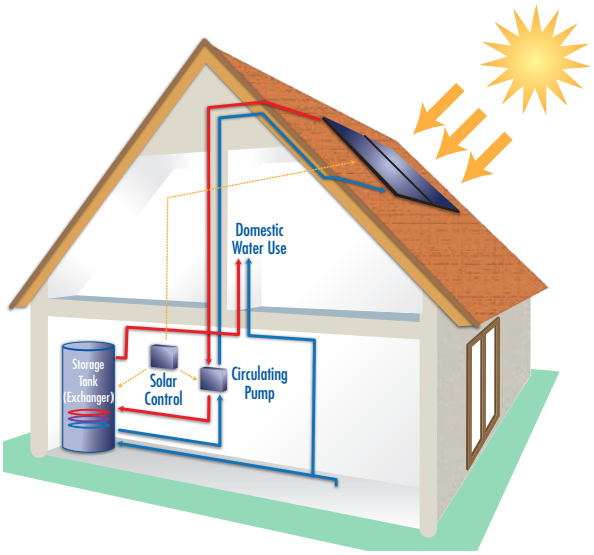


Figure 2. Residential solar water heating system schematic

All Season Energy: Cool Energy, Inc.

Since the fall of 2006, Boulder-based Cool Energy, Inc. has been developing an innovative solution called the SolarFlow® System, in which an electricity production unit called the SolarHeart® engine is used in conjunction with rooftop solar heat collectors to supply clean, cost-effective heat and grid-connected electricity to homes and commercial buildings. The system delivers solar electricity when surplus heat is available from the solar collectors. During the winter months, most of the energy from the collectors is used to heat the building's living space. In the summertime, the system's engine converts that thermal energy to electricity when it is needed the most.

The heat is usually stored in a tank—in hot water in residential and small commercial applications, and in more complex systems in industrial and utility applications. This simple storage of energy provides an important mechanism to help smooth peak energy demand on the grid.

Heated fluid from solar thermal systems provides the following services.

a. Hot Water

Solar water heating (SWH) systems can be used for both residential and commercial buildings (Figure 2). In Colorado, these systems can provide up to 90% of the energy needed for water heating.

b. Space Heating

Solar thermal systems have been used for over 30 years

to heat buildings. Solar thermal systems easily interface with buildings' existing space heating systems: forced air HVAC systems, boilers to radiant floors, radiators, or baseboard heaters. When a building does not offer an existing distribution system for solar thermal heating, fan-coil radiators can be installed at a reasonable cost.

c. Combination

These larger systems typically address a combination of functions which may include hot water, space heating, spa heating, or pool heating. In Colorado's unique climate, these systems can address up to 70% of the total heating/hot water bill of a home or building.

d. Pool & Spa Heating

Systems for pools and spas represent the earliest return on investment. Solar thermal spa heating easily offsets expensive electric or propane heating. Solar thermal pool heating typically uses flat plate solar thermal collectors for year-round heating, or affordable unglazed PVC panels for summer-only pool heating. Because pools and spas themselves store a considerable amount of heat, such systems often have little to no extra storage requirements. These systems are low-temperature applications with very high efficiencies—factors that combine to reinforce each other to offer an extremely attractive return on investment for system owners.

e. Cooling

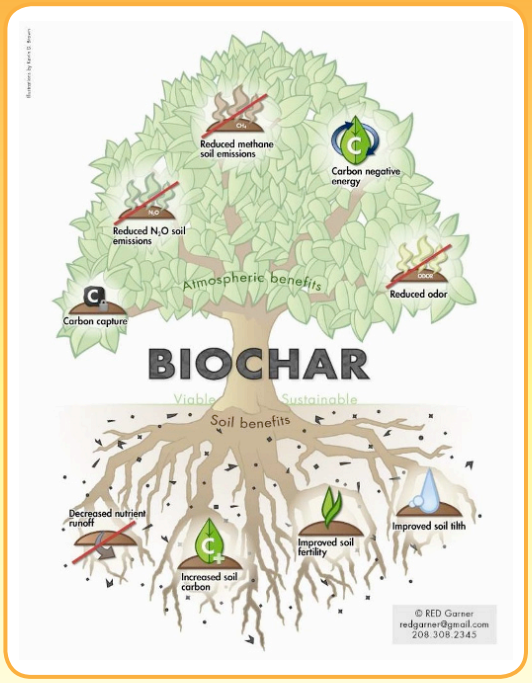
Solar thermal cooling relies on various technologies and is gaining popularity at the commercial scale. For example, NREL's thermally driven cooling system uses water vapor to produce cool air from heated liquid (Page 18), while Boulder-based Cool Energy's SolarFlow® System uses heated liquid to produce electricity for cooling (Page 2). Addressing air conditioning requirements with stored solar thermal energy presents many advantages, including reduction of summertime peak demand on the grid.

f. Solar Electric Generation

Large scale concentrating solar power (CSP) systems are currently being deployed in the southwest U.S. The sun's energy is used to create steam, which turns turbines that generate electricity. The solar resource in parts of southern

Combining Diverse, Complementary Approaches

Complementary approaches can achieve 100% clean and renewable energy. While several biomass options will likely become cost-competitive in the near future, the combination of solar thermal and biochar is a desirable portfolio. Biochar is produced by pyrolysis—partial combustion of organic matter, such as agricultural or urban waste, in a low- or no-oxygen environment. Depending upon the ratio of oxygen to fuel and the process temperature, different ratios of products—including biochar, fuels and heat—result. When combined with solar thermal, biochar production provides power generation without fossil fuel backup, carbon-negativity through biochar's fixing of atmospheric carbon, and a bonus soil improver. Some climate researchers point to the need for active atmospheric carbon dioxide removal (CDR)—and biochar provides CDR.



and western Colorado has been identified as among the most desirable locations nationwide for CSP. Newer hybrid solar-fossil fuel technology has recently been tested at the Xcel Cameo plant near Grand Junction where CSP technology is used to increase system efficiency. Lower temperature Stirling engines can also be used to generate electricity and recapture wasted heat to reduce energy costs.

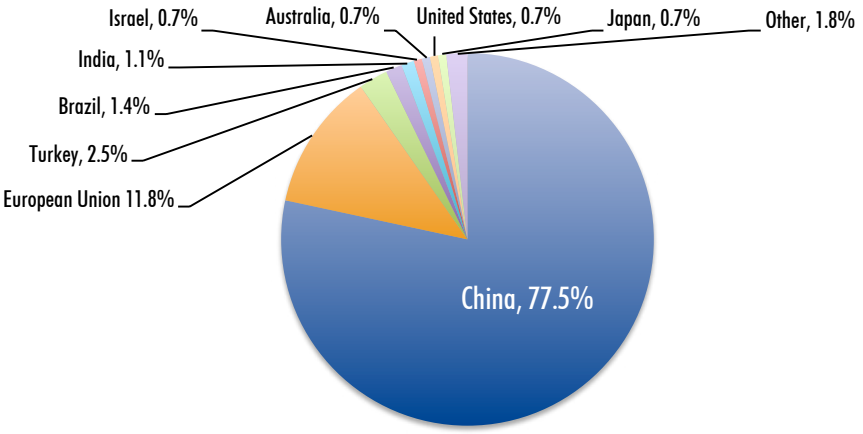


Figure 3. Solar hot water/heating capacity added by top 10 countries/regions (2008; total capacity added in 2008 = 28 GW_{th}; Source: Renewable Energy Policy Network for the 21st Century. September 2010. *Renewables 2010 Global Status Report.* 22.)

3. Adoption of Solar Thermal Technology

a. International

Solar thermal technologies have already been shown to positively impact a wide range of economies and environments. The technology is widely implemented globally, with China and Europe far ahead of the U.S. (Figure 3). Solar thermal systems are already installed on more than 60 million Chinese homes and 10 million European homes. In the U.S. the total is fewer than 1 million homes.

The European solar thermal industry powers 37,500 full-time jobs and more than $4 billion in annual revenues. In 2008, the European Union (EU) and Switzerland saw the solar thermal market grow by over 60% to an annual installed level of 3,300 megawatts of thermal capacity (MW_{th}) per year. Despite the impact of the recent global economic crisis, Denmark, Hungary, Netherlands, Portugal, and Switzerland each saw significant solar thermal market growth in 2009, and the European solar thermal marketplace significantly outpaced the overall economy. These experiences demonstrate that the technology provides consumer choices and decreases energy costs. In Europe, solar thermal systems displaced the equivalent of more than 1.2 billion barrels of oil, and avoided 7,000,000 metric tons of CO_2 emissions in 2009.[2]

These levels of adoption and market growth are a result of many factors, including energy costs, aggressive marketing, educational programs, government regulations, and incentive programs. Canada provides aggressive solar thermal incentives aimed at solar air and solar water heating technologies in the commercial/industrial sector and for residential consumers. In the fall of 2010, the United Kingdom launched a feed-in tariff that includes incentives to spur rapid adoption of solar thermal technology. Ontario has adopted a feed-in tariff to boost its use of renewable energy. Its program manager has since advocated for inclusion of solar thermal systems in the city's review of the program.

While energy costs and incentive programs can be drivers for adoption of solar thermal systems, other factors such as stable, sustained governmental policy and targeted educational and marketing campaigns also spur the market. The EU has developed a long-range energy goal that includes solar thermal technology as a key contributor to its energy portfolio. The goal is to provide 50% of heating requirements through solar thermal by 2050.

2 U.S. Energy Information Administration (EIA). *World Energy Consumption 2009.* 53, 335, 336. Accessed at http://www.eia.doe.gov/aer/pdf/aer.pdf and http://www.eia.doe.gov/aer/pecss_diagram.html

The EU has developed a comprehensive strategy to meet these ambitious goals, including investing in technology advancement (R&D), supporting policy via renewable energy requirements and educating the public.

b. United States

While more than $1.1 trillion is spent on energy per year in the U.S.,[3] renewable energy is still only a small portion of the portfolio, generating approximately 4% of the total energy use (excluding biomass).[4] Despite the challenging economic landscape, SWH sales have grown in the U.S. for each of the past five years, with collector shipments increasing about 10% to 147 MW_{th} in 2009.[5] The greatest growth has been seen in the industrial sector and in process heating. The largest decreases were seen in the solar pool-heating sector, which is closely tied to the struggling housing market.

Solar thermal sales recently have been strengthened by expanded federal incentives, including a 30% federal investment tax credit which took effect in 2009 and runs through 2016 (but excludes pool and spa heating). The economic development impacts have been impressive. For example, the number of U.S. jobs in solar thermal manufacturing facilities more than doubled from 2007–2009,[6] and retail distribution of solar thermal collectors increased more than 40% during 2009 alone.[7]

Several U.S. states are taking advantage of global economic growth and increased interest in solar thermal. In late 2010, the California Solar Initiative (CSI) Thermal Program launched an initiative to install 200,000 SWH systems by

Installation of a residential solar water heating system in Golden. Photo: Mike Wilson.

2017.[8] Currently the program offers cash rebates of up to $1,875 for residential solar water heating systems and up to $500,000 for commercial and multifamily properties.[9] According to the CSI program assessment, for every $1 spent on incentives by the state, there has been $2.62 invested in the state from other sources.[10]

In 2011, the state of New York introduced a program to install 46 MW_{th} of solar thermal capacity by the end of 2015.[11] North Carolina offers cash for solar renewable energy certificates to help meet state requirements. Arizona currently offers solar thermal utility rebates, a 25% state tax credit and includes solar thermal in its renewable energy standard.[12] Hawaii's tax credits and requirements to install solar thermal on new buildings have led to the installation of more than 80,000 solar

3 EIA. *World Energy Consumption 2009.*

4 Rocky Mountain Institute. 2011. "Reinventing Fire." Accessed at http://rmi.org/ReinventingFireinfographic

5 EIA. January 2011. "Solar Thermal Collector Manufacturing Activities 2009." Accessed at http://www.eia.gov/cneaf/solar.renewables/page/solarreport/solar.pdf

6 EIA. December 2010. "Solar Thermal Collector Manufacturing Activities 2009." 25.

7 EIA. December 2010. "Solar Thermal Collector Manufacturing Activities 2009." 18.

8 State of California, California Energy Commission, California Public Utilities Commission (CPUC). 2011. "California Solar Initiative: CSI-Thermal Program." Accessed at http://www.gosolarcalifornia.org/solarwater/

9 CPUC. January 2011. *California Solar Initiative—Thermal: Program Handbook.* 15, 17. Accessed at http://www.cpuc.ca.gov/NR/rdonlyres/528DD03E-4D07-4D76-ACB2-B671E-F33137A/0/CSIThermalHandbook_Jan_022811.pdf

10 CPUC. June 2010. *California Solar Initiative Annual Program Assessment June 2010.* 8. Accessed at http://www.cpuc.ca.gov/NR/rdonlyres/CE1D2316-405C-4C94-A805-A68A1988D640/0/2010APA_final.pdf

11 Solar Thermal Consortium. *New York's Solar Thermal Roadmap.* Accessed at http://www.clarkson.edu/camp/NYS_SolarThermal_Roadmap.pdf

12 APS. 2011. "Solar Water Heater Technology." Accessed at http://www.aps.com/main/green/choice/solar/Residential/Water/VideoWater.html

water heating systems.[13] Clearly, there is competition among states to attract private investment and jobs. The window for Colorado to position itself as a leader will not be open for long.

Lack of focus on solar thermal deployment is the most glaring gap in Colorado's clean energy economy.

c. Colorado

While Colorado is a leader in many areas of the renewable energy and energy efficiency marketplace, for a variety of reasons the state has lagged behind in taking advantage of its world-class solar thermal resource. Solar thermal was not included in renewable energy policy measures like HB10-1001, which increased Colorado's renewable energy standard for investor-owned utilities to 30%, and other major legislation.[14] Therefore, despite solar thermal's low costs and high efficiencies, it has been at a disadvantage relative to solar photovoltaics and wind energy—technologies for which incentives are more widely available. Solar thermal also is not included in most utility demand-side management programs, despite its clear role in energy efficiency and conservation.

Lack of focus on solar thermal deployment is the most glaring gap in Colorado's clean energy economy. In addition to these issues, financing for solar thermal projects is not widely available. At the same time, natural gas—which shares the building-heating and water-heating "applications space" with solar thermal—currently has prices approaching historic lows.

Despite these challenges, there are currently more than 150 solar thermal-related businesses in Colorado, about a third of which are contractors exclusively focused on solar thermal. The other two-thirds are involved with both solar thermal and solar electric technologies.[15] Colorado solar thermal employers range from global utility-scale manufacturers such as Lakewood-based Abengoa Solar and Arvada-based SkyFuel, to small entrepreneurial manufacturers, distributors, contractors and education facilities. While energy expenditures in Colorado exceed $14 billion per year, the solar thermal marketplace currently accounts for only a fraction of 1%.[16] This differential offers tremendous room for growth in the solar thermal sector.

4. Market Barriers to Growth

STAC research has identified five major barriers limiting solar thermal growth in Colorado.

a. Lack of Awareness

One of the biggest barriers to solar thermal growth in Colorado is lack of public awareness about what the technology is and its many benefits. An exceedingly large percentage of people simply are not aware that there is more than one type of solar technology. Many Coloradans lack even rudimentary understanding of solar thermal's advantages.

b. Patchwork of Local Permitting Rules

Solar thermal regulations are fragmented and inconsistent across the state. Colorado is a home-rule state where many jurisdictions make their own regulations regarding construction-related permits. For example, Colorado's

13 Yonan, Jr., Alan. March 17, 2011. "Solar water heater rebate to double." *Star Advertiser.* Accessed at http://www.staradvertiser.com/business/20110317_Solar_water_heater_rebate_to_double.html?id=118155259

14 Colorado. 2010. HB10-1001. Accessed at http://www.leg.state.co.us/CLICS/CLICS2010A/csl.nsf/fsbillcont3/47C157B801F26204872576AA00697A3F?Open&file=1001_enr.pdf

15 Colorado Solar Energy Industries Association. n.d. "Member Directory." Accessed at http://www.coseia.org/join-coseia/member-directory/

16 EIA. June 30 2011"Primary Energy, Electricity, and Total Energy Expenditure Estimates, 2009." SEDS: State Energy Data System, 1960–2009 Estimates (Full Report (1960–2009)). Accessed at http://www.eia.gov/state/seds/seds-data-complete.cfm

Atop the Adams 12 Schools' Veteran's Memorial Aquatic Center in Thornton, 102 collectors provide up to 60 % of pre-heating for an Olympic pool. Photo: Mike Wilson.

Fairplay community categorizes solar thermal as an appliance and does not require permits. Denver and other jurisdictions require a plumber's license. Others require multiple licenses and permits. The local rules change frequently, and they are complicated for consumers and solar thermal providers to navigate, due to their inconsistent approaches.

On the zoning side, despite multiple state laws enacted to prohibit regulations limiting solar installations based on aesthetics, many communities still have complex and restrictive rules. Denver's zoning code is 50 pages thick, while Vail currently dictates that all panels must be flush with the roof and at least two feet from any roof's edge. Local government regulations have become one of the biggest barriers to driving down the cost of solar thermal deployment.

c. Inconsistent State Policy

Although Colorado has passed close to 60 renewable energy and energy efficiency bills over the past five years, few of these bills have included solar thermal. Solar thermal is not included in the state's renewable energy standard, which is being achieved primarily by deploying solar electric and wind electric systems. Solar thermal also is missing from demand-side management legislation, which invests upwards of $80 million annually in Colorado towards energy efficiency programs that offset consumption. Often, new energy legislation in Colorado focuses on electricity only, leaving out other important forms of energy from the outset. Many of these programs only target large investor-owned utility regions, leaving more than one-third of the state's population without major programs to help take advantage of these technologies.

The occasional solar thermal programs that have come online are generally inconsistent across the state, and often have lasted for just a few months—conditions that create roller coaster boom and bust cycles. It takes a stable environment with a longer time horizon to attract investment, and to promote continued economic development.

d. Lack of Financing Alternatives

A number of factors have limited the financing of solar thermal, including lack of awareness in the banking sector, difficulties of measuring energy collection on small systems, inconsistent policy, and the near-absence of solar thermal power purchase agreements nationwide. In Colorado and much of the U.S., solar thermal organizations are primarily, though not exclusively, small businesses. Most financial institutions have not focused on thermal-specific programs as worthy of investment and loans. However, "green" bank loans are becoming more common. US Bank recently launched its green loan program in Colorado as a pilot test for the country. Currently, however, the interest rates for these loans often are not as competitive as those in other sectors. Property Assessed Clean Energy (PACE) bonds for low-interest loans for renewable energy and energy efficiency improvements are stalled at the national level due to legal challenges that, unfortunately, have coincided with the numerous controversies in the mortgage market.

e. Current Low Cost of Natural Gas

Natural gas is a primary resource used for heating buildings and water in Colorado. Historically, the Colorado and Wyoming region has benefited from both abundant

The Eagle-Vail Community Pool, opened in 2010, hosts year-round and summer-only solar thermal for a summer capacity of 118 kW_{th}. Photo: Capitol Solar Energy.

natural gas and relatively low demand. Natural gas suppliers are therefore incentivized to export local gas to other parts of the country, where some out-of-state utilities pay two to four times what Colorado's largest investor-owned utility, Xcel Energy, and other natural gas wholesalers and retailers pay locally. Large pipelines including the Rockies Express continue to be built. Prices rose to $1 per therm retail in Xcel territory two years ago, while the national average was $1.35 per therm.

More recently, extraction methods called horizontal drilling and hydraulic fracturing, or "fracking," has made access to additional natural gas resources more economic. This access has caused Colorado prices to temporarily fall to as low as $0.50 per therm. Fracking, in which water, sand or other propants and chemicals are pumped into shale layers at high pressure, has raised public concerns about contamination of aquifers and surface waters, seismic activity and air quality due to releases of methane (a potent greenhouse gas) and other chemicals. The EPA is in the midst of a major investigation of the technique.[17] The EPA has also undertaken a secondary study at the request of the residents of Pavillion, Wyoming and has offered preliminary conclusions linking fracking to groundwater contamination.[18] The final results of this investigation, combined with increasing global demand, may lead to increased regulation and cost increases for natural gas throughout the country.

The price of natural gas in our state has swung between $0.50 and $1.00 per therm over the last two years. It is currently priced around $0.75. In past decades, prices have been very volatile; most stakeholders agree that it is likely that the volatility will continue in the years ahead. Solar thermal can be used to help diversify Colorado's energy mix and reduce the inherent risk of over-dependence on any one energy source.

Colorado can promote economic development and position itself as a national leader in the clean energy economy by addressing these five major barriers to growth. The next section of the *Colorado Solar Thermal Roadmap* analyzes the economic opportunity available to Colorado by exploiting the state's natural advantages. Colorado can become a global leader in solar thermal; this roadmap provides a clear path of how to do so.

17 U.S. Environmental Protection Agency (EPA). December 23, 2011. "EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources." Accessed at http://www.epa.gov/hfstudy/

18 EPA. December 8, 2011. "EPA Releases Draft Findings of Pavillion, Wyoming Ground Water Investigation for Public Comment and Independent Scientific Review." Accessed at http://yosemite.epa.gov/opa/admpress.nsf/931381dfcd9a5c308525779700424ccd/ef35bd26a80d6ce385257960065c94e!opendocument

Section II

Goals for Solar Thermal Growth


The National Water Testing Lab at Denver Federal Center Building #95 uses this 18-collector system for domestic water usage. Photo: Mike Wilson.

This section of the *Colorado Solar Thermal Roadmap* presents conservative long-term numerical objectives for solar thermal installed capacity and consequent offset energy consumption. It then reviews calculations of the economic impact, including the job creation impacts. Finally, it surveys the basic environmental and health impacts of implementing these objectives.

Based on the global trends and Colorado's competitive advantages identified in Section I, STAC analysis suggests that adoption of the recommendations of this roadmap will increase statewide solar thermal installed capacity from its current estimated level of just 150 MW_{th} to more than 16,000 MW_{th} by 2050. Achieving this goal will create over 24,000 new jobs (Figure 4) and $22 billion in cumulative direct sales revenue in Colorado.

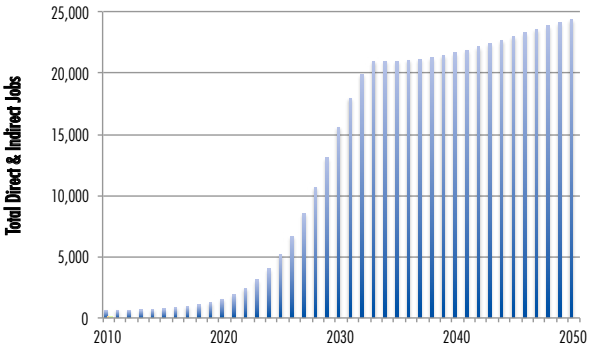


Figure 4. Forecast of new jobs generated under the *Roadmap*

1. Background Factors

Many variables were carefully weighed in developing the conservative mathematical model behind these projections.

Basic metrics of equivalence[19] between square footage of panels, kW_{th} capacity and kWh_{th} of offset energy consumption were developed in partnership with NREL, through a Technical Assistance Program grant secured by the Colorado Governor's Energy Office (GEO). Population and energy consumption growth projections are based on historical data published by the Energy Information Agency (EIA) and the Colorado State Demography Office. EIA released Colorado-specific data for its residential energy survey for the first time in 2010. The *Colorado Solar Thermal Roadmap* explains selected metrics for revenue, jobs, health and environmental cost reductions, and CO_2 offsets.

a. Factors Influencing Growth

A variety of factors will impact Colorado's future solar thermal marketplace. The factors include the following:

- the future price of natural gas,
- how economies of scale lower the cost of solar thermal technology,
- technological innovations,
- balance-of-system costs,
- regional population growth rates,
- policy considerations,

19 To make numbers easier to understand, solar thermal capacity is expressed in kilowatts thermal (kW_{th}), and energy consumption offset is expressed in kilowatt hours thermal (kWh_{th}). NREL vetted a capacity of 0.7 kW_{th} per square meter, as established by the IEA SHC Programme, and 1,298 kWh_{th} of annual energy consumption offsets per 1 kW_{th} capacity. For example, a typical 4 by 10 foot panel has a 2.5 kW_{th} capacity. The 1,298 kWh_{th} per kW capacity is calculated using a representative mix of fuels used in Colorado to address heating loads, as well as a representative mix of heating applications and subsequent solar thermal efficiencies.

- availability of financing,
- success of promotional campaigns, and
- other factors.

While any report that considers growth projections is inherently an estimate based on reasonable assumptions, this section explores specific impacts of various factors and assumptions on Colorado's solar thermal market development.

b. Population Growth and Energy Consumption

Over the last 40 years, Colorado has experienced an explosion in the number of inhabitants, becoming one of the fastest growing states in the country. According to the Colorado State Demographer, the state's population will likely grow to 7.1 million residents by 2030, with no end to population growth in sight.[20] Colorado's energy consumption has grown even faster than its population.[21] Roughly three-fourths of the energy consumption of Colorado residences is for heating (hot water and indoor space heating). A majority of commercial and industrial energy usage is also for heating functions. At present, the burning of fossil fuels generates most of the heat for Colorado's hot water and space heating requirements (Figure 5).

c. Colorado Energy Costs

Coloradans currently burn more than $2.3 billion worth of fossil fuels each year for heating purposes and this number is likely to increase over time.[22] Based on conservative estimates, Colorado families and businesses will easily spend more than $200 billion in heating costs between 2012 and 2050. With a heating market this size, many customers will seek the freedom and independence of lowering their utility bills with solar thermal technologies.

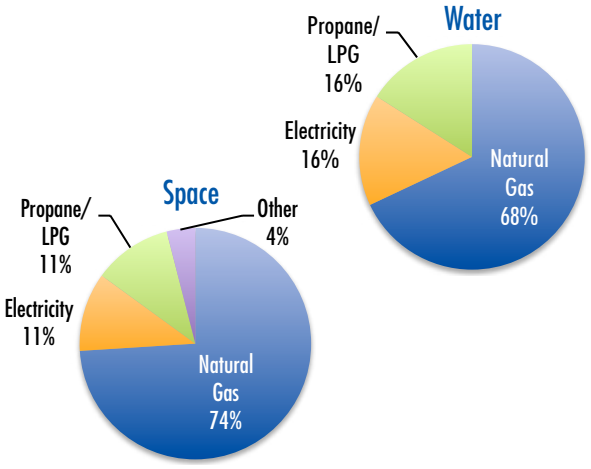


Figure 5. Fuels used for water heating (upper right) and space heating (lower left) in Colorado (2009; Source: EIA. 2009. "Residential Energy Consumption Survey." Tables HC6.11 & HC8.11.)

As explained in Section I, the boom and bust cycles of natural gas price volatility over the past 40 years have demonstrated a compelling economic case against Colorado's over-dependence on any one energy resource. Solar thermal technology provides important diversification for the energy mix. As population growth and energy consumption continue to increase, it will be possible to address some of the new energy loads with solar thermal technologies. As a bonus, increasing the use of solar thermal for homes and businesses will result in lower energy costs over time, thanks to solar thermal's zero fuel cost.

2. Colorado's Solar Thermal Model

The target goal for the *Colorado Solar Thermal Roadmap* is to achieve total installed capacity of nearly 2,500 MW_{th} and 15,600 total jobs (direct and indirect) by 2030, and over 16,000 MW_{th} and 24,000 total jobs by 2050. These goals are outlined in Table 1 (Page 11).

These goals are achievable based on conservative assumptions. As a benchmark, the energy consumption offset by this cumulated installed capacity represents only 3% of projected consumption of natural gas for hot water and space heating in Colorado by 2030, and 13% by 2050. This is a small fraction of the potential for

20 Garner, Elizabeth. March 2011. "Housing Colorado's Future: A Demographer's Perspective."Colorado State Demography Office: Denver, Colorado. Accessed at http://www.colorado.gov/cs/Satellite?c=Document_C&childpagename=DOLA-Main%2FDocument_C%2FCBONAddLinkView&cid=1251593309262&pagename=CBONWrapper

21 EIA. June 30, 2011. "Energy Consumption Estimates for Major Energy Sources in Physical Units, 1960-2009, Colorado."

22 EIA. 2009. "Residential Energy Consumption Survey."

these conventional heating applications of solar thermal, so export opportunities for the products of Colorado's extraction businesses will continue to thrive. Further, these conservative goals do not take into account other solar thermal applications mentioned in this report, such as nascent technologies like cooling applications that displace electricity or CSP displacement of fossil fuels used for power plant electric generation or for industrial heating processes. The objectives above represent just a fraction of the viable potential of applied solar thermal technologies over the next four decades.

The *Solar Thermal Roadmap* model indicates that Colorado's solar thermal marketplace will benefit greatly from the activities of increasing public outreach and promotion campaigns, increasing availability of financing, and lowering balance-of-system costs. All of these efforts are beginning to get underway. Colorado will also benefit from global competition. Rising global demand, economies of scale, and continued R&D will reduce solar thermal costs as greater efficiencies are achieved throughout the supply chain. Concurrently, increases in drilling and fracking are likely to stabilize natural gas prices through much of the current decade. Then, in the 2020s, rising global demand for natural gas combined with supply and delivery constraints will likely drive natural gas prices up. These developments will further boost demand for solar thermal technologies.

Contrary to the boom and bust cycles of the past, the current model uses a modest progressive bell curve in the *Roadmap's* growth model. Current industry growth is measured at 5% per year. The roadmap model ramps up gradually to a peak annual growth rate of 35% in 2022, leveling off to a stable industry size past 2030, as illustrated by the steady gains in installed capacity in Figure 6. This curve takes into account the need for developing sufficient numbers of competent manufacturing and installation professionals to meet demand, as well as progressive market adoption. It is certainly possible that demand will ramp up faster and that growth will peak sooner than expected, but again the roadmap model purposely incorporates conservative estimates.

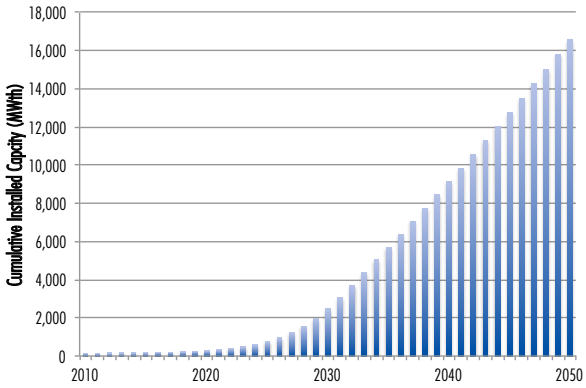


Figure 6. Projected cumulative installed capacity of solar thermal (MW_{th}) from the *Roadmap* model

Because heating with electricity or propane costs more than heating with natural gas, customers who now use electricity or propane to heat their buildings and hot water will invest more heavily in solar thermal in the first phase. Commercial customers with high year-round hot water and heating requirements, such as hotels, car washes, breweries, restaurants, and fitness centers also will be

Table 1. Solar thermal capacity, revenue and jobs goals outlined in the *Roadmap*

Year	Annual Installed Capacity (MW_{th})	Total Solar Thermal Installed Capacity (MW_{th})	Annual Revenue	Total Jobs
2010	5	150	$16,000,000	626
2020	35	289	$57,000,000	1,500
2030	500	2,474	$677,000,000	15,600
2040	700	9,140	$944,000,000	21,700
2050	780	16,595	$1,060,000,000	24,300

likely early adopters. Sustained growth of solar thermal deployment over the long term is necessary in order to achieve a meaningful proportion of the total load of Colorado buildings through this clean, renewable energy.

3. Economic Development and Job Creation

In today's unsteady economic environment, the redevelopment of the U.S. job market, our manufacturing sector, and our economy in general are top priorities. The solar thermal industry provides a uniquely elegant solution because its development will necessarily proceed in lockstep with the parallel development of large numbers of qualified local design, manufacturing, sales, distribution, and installation professionals. Solar thermal is a labor-intensive business that provides significant job creation benefits.

a. Generating Jobs

Achieving the *Solar Thermal Roadmap's* goals will add more than 24,000 new jobs in Colorado by 2050, including positions in sales, distribution, manufacturing, and over 10,000 jobs in solar thermal installation. These data are based on European Solar Thermal Industry Federation (ESTIF) figures indicating that one full-time job is generated per 80 kW_{th} of newly installed capacity,[23] plus increasing demand for suppliers, accountants, lawyers, transportation, permitting, and other ancillary services, resulting in a total jobs multiplier effect of 2.43 jobs/80 kW_{th} installed.[24] Attracting additional solar thermal manufacturers to Colorado can also quickly increase job growth further, which will become more likely thanks to Colorado's existing cluster of solar manufacturers, expected to grow as a result of the favorable market conditions.

b. Economic Development

Successful implementation of this roadmap will increase annual sales revenue from an estimated $16 million in 2010 to more than $670 million in 2030, and over $1 billion in 2050, based upon annual installation targets. These economic benefits will increase dramatically if we manufacture a higher percentage of the equipment used in local installations and boost exports of manufactured solar thermal equipment out of state. Cumulative direct revenues from 2011 to 2050 are projected to be $22.5 billion, before taking multiplier or rollover effects into consideration, just to be conservative. Accordingly, there's little doubt that development of the solar thermal market will expand the state's tax base considerably.

c. Current Success

Colorado is the location of the National Renewable Energy Laboratory, leading research universities, the Renewable Energy Collaboratory (a strategic collection of research,

23 European Solar Thermal Industry Federation (ESTIF). June 2010. *Solar Thermal Markets in Europe Trends and Market Statistics 2009*. 15. Accessed at http://www.estif.org/fileadmin/estif/content/market_data/downloads/2009%20solar_thermal_markets.pdf

24 American Solar Energy Society (ASES). January 2009. "Green Collar Jobs in the U.S. and Colorado." Accessed at http://www.ases.org/images/stories/ASES/pdfs/CO_Jobs_Rpt_Jan2009_summary.pdf

Table 2. Solar thermal capacity, health and environmental cost savings and carbon dioxide offsets outlined in the *Roadmap*

Year	Total Solar Thermal Installed Capacity (MW_{th})	Health & Environmental Cost Savings	CO_2 Offset (million lbs)
2010	150	$17,000,000	89
2020	220	$33,000,000	170
2030	2,400	$286,000,000	1,500
2040	9,100	$1,050,000,000	5,400
2050	16,600	$1,920,000,000	9,900

technology, industry, agency, and testing entities), several established worldwide leaders in CSP and numerous startups in the solar thermal industry. The community college system and training organizations such as Solar Energy International, based in Carbondale, have been teaching solar thermal technologies for decades. A number of established small business owners have acquired the expertise to design, install and service systems since the 1980s. A steady solar thermal program will position Colorado as an attractive central manufacturing platform for the U.S. and beyond, with enhanced growth rate potential in comparison to large states like California, due to relatively low Colorado real estate costs.

d. New Vision

By positioning itself as a leader in solar thermal, Colorado will create impressive activity in installation work, manufacturing, teaching, training, and maintenance and service jobs. Colorado's cluster of organizations in research, education, innovation, installation and manufacturing will create resonance in the broader economy, creating multiplier effects in the billions of dollars through 2050. However, again out of an abundance of conservative caution about assumptions, this well-known multiplier effect was not included in the annual revenue goals listed earlier.

4. Heath And Environmental Benefits

The concepts of lifestyle sustainability and legacy—along with many associated precepts ranging from economic independence to global environmental responsibility—are becoming increasingly important. It is becoming more and more evident that all of our decisions must include considerations for the interest of this and future generations. Table 2 (Page 12) outlines the projected benefits of the *Roadmap* goals in terms of health and environmental cost savings and carbon dioxide offsets.

a. Reduced Emissions

Solar thermal has a large impact on the reduction of our fossil fuel emissions. STAC analysis suggests that the implementation of this roadmap will lead to a reduction in Colorado's carbon dioxide emissions of 1.5 billion pounds by 2030, and 10 billion pounds by 2050 (Figure 7). Many other associated emissions and particulates from displaced technologies are also reduced, such as carbon monoxide, methane, mercury, and coal ash.

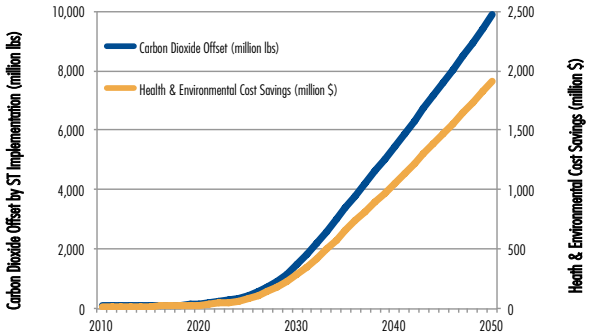


Figure 7. Annual offset CO_2 emissions and healthcare savings from projected solar thermal capacity

b. Reduced Health and Environmental Costs

A recent Harvard Medical School study published in the *Annals of the New York Academy of Sciences* assesses the health and environmental cost savings of reduced coal consumption.[25] Counting natural gas displacement at half the cost of coal displacement, and discounting the percentage of Colorado buildings using electric heat, the avoided costs from the implementation of this roadmap are estimated to exceed $280 million by 2030, and $1.9 billion annual by 2050, based upon the projected total installed capacity reached in each year (Figure 7). These estimates are difficult to quantify with precision, as our society is just beginning to develop the metrics to calculate these impacts. Yet, at a time when healthcare funding is an issue for many Americans, it is relevant to take into consideration the health cost savings of avoided pollution, not to mention the associated quality-of-life

25 Epstein, Paul. February 2011. "Full Cost Accounting for the Lifecycle of Coal." *Annals of the New York Academy of Sciences: Ecological Economics Reviews.* 1219:73–98.

issues that everyone understands but that are difficult to quantify.

c. Preservation of Natural Wonders

From Rocky Mountain National Park to the Great Sand Dunes, our National Park Service has been led since its founding by individuals who appreciate nature's beauty and the necessity of preserving it for future generations. The mission of our National Park Service is "to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." It is natural that our grandchildren, who will be impacted by today's energy choices, will want to enjoy not just token protected lands, but all of our lands, water, air, sunshine and energy.

The full range of health and environmental consequences from fossil fuels is emerging slowly, as humanity becomes aware of its responsibility towards future generations on a fragile, limited planet. The numbers above enable a first estimate of the magnitude of the impacts avoided by adoption of solar thermal in Colorado. We anticipate that the real outcomes, including currently unforeseen benefits, will exceed considerably these modest projections.

We must have the sense of urgency to seize the low-hanging fruit that saves tax payer money, preserves the environment and creates economic opportunity.

—Governor John Hickenlooper

5. A Complete Vision of The Impacts

In terms of economic benefits, and in particular with regard to job creation, Colorado is uniquely positioned to optimize solar thermal performance and competence. Our dynamic and efficient labor force and central logistical position present objective advantages for national manufacturers and distributors. If Colorado continues to build its leadership, these factors can combine and leverage each other to greatly exceed the job projections above.

Furthermore, these economic benefits flow across the Colorado economy. Because space heating is the largest energy usage in Colorado buildings, and because natural gas prices can be volatile, solar thermal participates in creating stable operating costs for energy consumers in many industrial sectors, as well as for Colorado families.

Solar thermal creates an attractive asset to strengthen Colorado tourism. Most visitors to the state seek the pristine environment and sunshine of the Rocky Mountains. Creation of a solar thermal market will help to preserve the cleanliness of our air, water, and other habitats valued by hunters, anglers, and other outdoor recreationists. As we harvest our sun's energy, we also free up our limited fossil fuel supplies for export, and reduce our imports of other fossil fuels. Improving our state's and the country's import-export balance has far-reaching benefits for job creation, the economy, and for geopolitical balance of trade and balance of power.

Solar thermal fits well with the priorities identified by Governor John Hickenlooper in his inaugural speech: "We will protect our land and water and preserve the natural beauty that helps define Colorado… We will help businesses protect and expand the jobs we have, we will attract new jobs, and we will harness the entrepreneurial spirit that has always defined Colorado through her history."

However, the full potential of solar thermal's role in the state may be best illustrated by another phrase from Governor Hickenlooper when he served as Denver's Mayor: "We run the risk of being the first generation in history to leave the next generation a problem for which there is no solution. We must have the sense of urgency to seize the low-hanging fruit that saves tax payer money, preserves the environment and creates economic opportunity."

Solar thermal is that large ripe fruit, hanging low on Colorado's renewable energy tree, with far-reaching benefits for generations to come.

Section III

Establishing Colorado's Global Solar Thermal Leadership

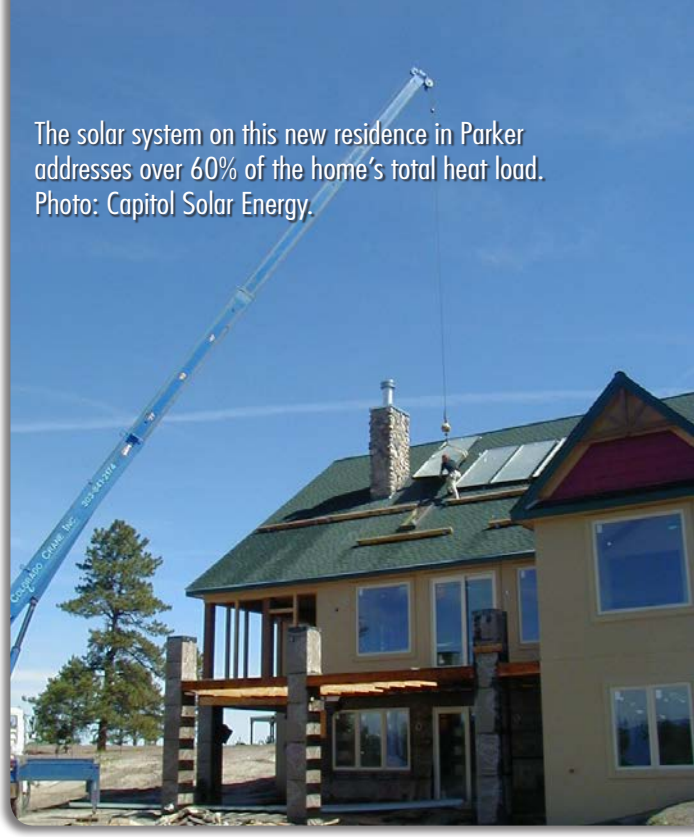
Colorado's solar thermal marketplace is well positioned for new development and significant growth. The analysis presented above demonstrates that the economic opportunity for Colorado can accurately be described as extraordinary. Local businesses are capable of designing, manufacturing, marketing, selling and installing the thermal products and services that meet a variety of needs for Colorado energy consumers.

What's missing? This report identifies four main opportunities for addressing barriers to growth in order to drive the expansion of the solar thermal marketplace in Colorado:

- increase consumer awareness
- develop financing mechanisms
- level the policy playing field
- resolve local impediments

1. Increase Consumer Awareness

One of the biggest barriers to solar thermal growth in Colorado is a lack of public awareness about this technology and the many benefits it provides. While there has been a recent expansion of the solar photovoltaic marketplace, many people are simply not aware that there is more than one type of solar technology. According to a recent independent national survey by Gotham Research Group, more than one-third (37%) of Americans were unaware that solar energy can be utilized both to generate electricity and for heating purposes.[26] Most Coloradans



The solar system on this new residence in Parker addresses over 60% of the home's total heat load. Photo: Capitol Solar Energy.

lack the basic understanding of the positive impacts that solar thermal can have on the hot water and space heating demands of their homes and businesses. The establishment of a major campaign with a solar thermal focus will draw attention to this technology.

a. Develop Consumer Relationships

STAC has identified the urgent need to communicate the benefits of solar thermal as a top priority. Working with a range of nonprofit, for-profit, and governmental organizations, a multi-pronged "Go Solar Colorado!" campaign to communicate and educate solar thermal's tremendous benefits for homeowners, businesses and utility providers can be implemented. The internet and social media should be utilized to communicate a simple message that speaks to the hearts and minds of each energy consumer. Integrating the message throughout the state's solar thermal stakeholder community will help to leverage public education well beyond those communities to the general public.

The energy advantages of solar thermal technology are

26 Gotham Research Group. October 17, 2011. "Public Perceptions of Solar Water Heating Systems: Survey Findings." 1. Accessed at http://www.seia.org/galleries/pdf/2011_SHC_Survey_Results_10.17.11.pdf

Harvesting Savings

In 2008, Steve and his wife installed a combination solar thermal system on their home. The system included eight panels totaling 320 square feet of collectors, a 670 gallon tank in the garage, and interfaces with the home's forced air system and hot water heater.

The couple carefully measured and compared their propane bills before and after the installation of the system. The result? "We have eliminated two thirds of our propane bill! We received a 30% federal tax credit, as well as $3,000 from the 2008 GEO–United Power solar thermal pilot program. Our net system cost was $15,000. Our system saves us close to $2,500 of propane every year! These savings will have paid off our system in 6 years, and we look forward to another 25 years or more of additional savings."

The family has since opened their home to visitors from various governmental and non-profit groups to help promote what Steve calls, "this amazing technology." And, they are personally delighted with the results, "from breathing cleaner air to being more energy-independent." Steve sums up the family's feelings about the system: "We are registered Republicans. Frankly, we can't believe there isn't a long-term program so all Coloradans can take advantage of this technology!"

many, yet the focus on the consumer's savings will play a leading role in the marketing efforts of these organizations. There is a compelling economic argument: fossil fuels are expensive; solar fuel is free. The only way to ensure our children will have lower energy costs than we do is to switch to free fuels like solar thermal. Smart branding, clean graphics, compelling communication, and relevant design of all communications—which past efforts have lacked—will lead to an improved and consistent brand identity for the technology.

To complete the solar thermal story in Colorado, it will be important to follow and report specific statewide results of market growth at regular intervals, and to track the associated economic development. These developments can be easily communicated across the state and beyond via mass media, special interest media, and social media.

b. Improve Communication

The general public learns about their energy choices through a wide range of sources: state agencies, utilities, local government outreach, businesses, non-profits, broadcast media, and social media. A renewed effort from all stakeholders should be made to ensure that discussions around solar are expanded to highlight a range of solar technologies, not just solar photovoltaics. When it comes to solar thermal performance, Colorado's climate provides a competitive advantage over every other state in the U.S., but the general public and business community will be left in the dark about our state's advantages unless those benefits are communicated consistently, effectively, and frequently.

c. Ensure Quality

As the consumer base grows, the solar thermal industry will need greater numbers of well-trained individuals to keep pace. The Colorado Renewable Energy Collaboratory and the state's community college system are poised to work with industry to develop the highly competent solar thermal energy workforce necessary to meet the needs of communities and employers across the state. Several training programs are in place already; new ones will be adaptively created to respond rapidly to shifting functional capability and growing market capacity requirements.

Installer certification should be promoted along with education and training. Certification can be achieved utilizing classroom participation, and should be comple-

mented by on-the-job experience to increase competence and the public's confidence in the quality of workmanship that solar thermal installations require. Colorado is well advised to consider adjusting insurance regulations to make it more feasible for employers to conduct on-the-job training. Training programs and continuing education must be part of ongoing certification in order for employees to stay abreast of the latest industry science, trends, and best practices.

In workforce development curriculums for twenty-first century careers, the industry will realize collateral promotion of education and training in solar thermal, as workers see the opportunity to retrain for new careers, and trainees spread the good word to friends and neighbors.

2. Develop Financing Mechanisms

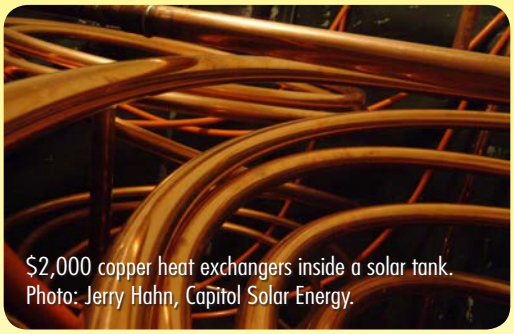
Relatively few organizations in the financial services sector have developed or targeted products for solar thermal businesses or customers, due in large part to the same awareness issues that face energy consumers. Further, while energy monitoring devices are decreasing in price and increasing in accuracy, quantifying thermal system performance in terms of its economic benefits has not been highlighted as clearly or consistently as it should be. Despite decades of experience, solar thermal businesses have not attracted the attention of lenders until recently. Thermal product offerings continue to lag other "green financing" programs, a conundrum that will change as solar thermal awareness grows in Colorado.

a. Develop Pilot Programs.

Feedback from members of the financial services community highlights the opportunities for collaboration between financial and solar businesses. Responses included recognition from some lenders that making minor adjustments to existing loan products and services could greatly improve how customers perceive their needs are being met. While acknowledging that the market is relatively small, the positive impacts of developing pilot programs for green financial products have exceeded expectations. Offering loans for solar thermal systems and related technologies can serve as a powerful market differentiator for generating new revenue and boosting the brands of financial organizations.

Driving Equipment Costs Down

One goal of the U.S. Department of Energy (DOE) has been to reduce the installed cost of solar thermal technology at least 50%. Since conventional metal-based systems are very mature with relatively small manufacturing costs and high materials costs, there is little opportunity for radical cost reduction in such solar thermal components. The DOE strategy has been far-reaching, considering a range of innovative materials and system designs. NREL has been working with industry partners to develop collectors and tanks that can reduce component costs by at least a factor of 3. One potential pathway is to use low-cost polymeric materials and manufacturing technology. Unglazed and glazed polymeric collectors have potential to reduce collector costs roughly 10 times and 5 times, respectively. An active system with an unglazed polymer collector is being marketed now, with a cost less than ½ that of conventional systems (but performance of only 2/3 that of a glazed/selective system—a glazed collector is needed for colder climates especially). Unpressurized tanks with load-side heat exchangers also have high cost-reduction potential. One contractor is developing a thin-film-based, integrated thermosiphon system with a light-weight, low-cost polymeric heat exchanger, with total system hardware cost projected at ~$350. According to Jay Burch, NREL senior solar thermal researcher, "With proper funding from DOE and economies of scale in the marketplace, systems with total installed costs ranging from $2,000 to $3,000 can be fielded in the next five years."



$2,000 copper heat exchangers inside a solar tank. Photo: Jerry Hahn, Capitol Solar Energy.

The finance industry often looks to its peers for examples of renewable products and services. Many are now eager to collaborate with the solar thermal industry to assess the needs of the market. There is a clear need to convene additional informational meetings to define the needs of each side of a solar thermal system lending transaction. Following this assessment, both industries can expand their reach to broader communities to engage colleagues on how to best participate in the burgeoning market.

According to the American Appraisal Institute, for every $1 in reduced annual operating cost of a home, its value rises by $20.[27] After the 30% federal tax credit, the net price of a solar thermal system therefore often approximates the increased value of the home. Recent research by the national real estate giant CoStar Group confirms these findings: "sustainable 'green' buildings outperform their non-green peer assets in key areas such as occupancy, sale price and rental rates, sometimes by wide margins."[28] As such information circulates widely, people will understand the benefits of solar retrofits as part of the value chain for owners and lessees of buildings. The collateral value of a solar thermal system can be calculated using production data from the Solar Rating and Certification Corporation showing that the performance of solar thermal systems far outlasts typical amortization schedules of loan products.

27 Nevin, Rick and Gregory Watson. October 1998. *The Appraisal Journal.* "Evidence of Rational Market Valuations for Home Energy Efficiency." 401–408; October 1998. "More Evidence of Rational Market Values for Home Energy Efficiency." 454–460. Accessed at http://www.solardepot.com/pdf/Appraisal-Journal.pdf

28 Burr, Andrew C. March 26, 2008. "CoStar Study Finds Energy Star, LEED Bldgs. Outperform Peers." CoStar Group. Accessed at http://www.costar.com/News/Article/CoStar-Study-Finds-Energy-Star-LEED-Bldgs-Outperform-Peers/99818.

Versatile Solar Thermal Can Cool: Thermally Driven Cooling

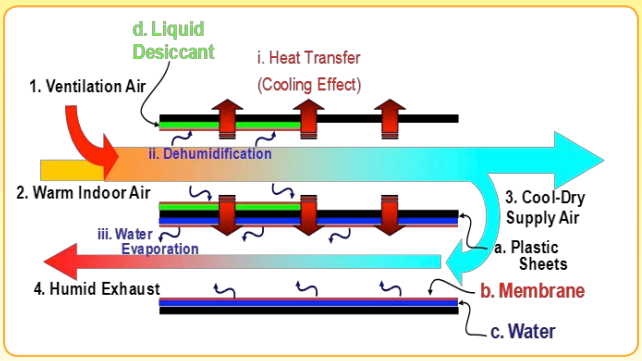
Because solar thermal systems can support such applications as cooling, they are capable of offsetting electricity loads, especially during peak demand. Thermally driven cooling (TDC) technology is one such example. TDC enables a solar thermal system to cool air used in a building's space conditioning. Dehumidifying materials can drive processes using water vapor; those materials are then regenerated with heat from the solar thermal system.

TDC is a broad field that includes absorption chillers, absorption solid desiccant systems, and liquid desiccant systems. NREL is developing an atmospheric pressure liquid desiccant cooling system that—requiring only a fan—eliminates about 90% of the electrical energy required for typical air conditioning systems. In dry climates like Colorado's this system can reduce source energy by up to 85%.

In the first stage, this unit dries the air with a liquid desiccant. A different set of channels takes away the heat generated by dehumidification with evaporatively cooled outdoor air. The second stage captures a portion of the cooled air, uses it to dehumidify or "recharge" the desiccant and exhausts the now humid vapor. The remaining cooled air is used to cool the building. The desiccants can be regenerated with temperatures as low as 160°F, making this system adaptable to solar thermal cooling in the summertime.

One ton prototypes have been successfully built and tested, reaching 90–100% of modeled performance. Discussions with partners are underway, and first models can be expected out in 2 to 3 years.

(Source: Burch, Jay. December 25, 2011. Personal communication.)



It is only a matter of time until the value of solar thermal technology is more widely recognized and rewarded in the real estate financial markets. As the financial services sector begins to offer and advertise specific products for solar thermal customers, this activity will further strengthen solar thermal marketing and education programs in a positive feedback loop dynamic.

3. Level the Policy Playing Field

According to the International Energy Agency (IEA), fossil fuel industries currently receive more than six times the subsidies that renewable energy industries do.[29] Solar thermal has been generally excluded from most renewable energy legislation in Colorado, including the initial Renewable Portfolio Standard in 2004. Such exclusion is surprising as the sun's energy arrives at Earth primarily in the form of heat. Solar thermal technology collects, stores and distributes that heat most efficiently. This heat can then be used to power a range of functions including traditional heating, cooling, and generation of electricity. Segregating heat energy from renewable energy programs has represented considerable lost opportunity for Colorado.

a. Balance Energy Standards

Thirteen states currently include solar thermal as an energy resource eligible for meeting their Renewable Portfolio Standards. Colorado is not one of those states, and is missing a major economic opportunity. The state's energy standard should explicitly include solar thermal, especially considering that solar thermal technologies perform better here than in any other state. Colorado energy officials frequently publicize their desire to explore a balanced statewide portfolio among coal, natural gas, and renewables. A balanced energy standard that includes solar thermal would better position the state as a national leader to help Coloradans take advantage of the economic opportunities ahead. Utilizing solar thermal's heat capture, storage and distribution functions helps consumers save money, promotes economic development, and diversifies the region's energy mix to reduce risks of over-dependence on any one energy source.

The 2 solar thermal panels on the left have a kW_{th} capacity of half the entire 40-panel PV array on the rest of the roof. Photo: Capitol Solar Energy.

b. Promote Economies of Scale

Renewable energy and other cleantech businesses constituted the only major sector of the Colorado economy to generate a net increase in new jobs in 2010.[30] But Colorado is competing in a global marketplace to attract new investment and create jobs. With California, New York, Arizona, Hawaii, North Carolina, and other states investing in growing their solar thermal marketplaces, Colorado needs to "up its game," or it will be left behind. Whether as a state investment tax credit which can serve as a simple and efficient mechanism to spur growth, or as a performance-based incentive, renewable energy purchase price, or other mechanism, the prudent use of incentives for solar thermal technologies can attract investment and promote economies of scale to drive down costs and promote new job growth. It is important for Colorado citizens and leaders to recognize that as with any such effort, incentives should be developed with a primary focus on promoting market stability and sustainable growth to

29 International Energy Agency (IEA). 2011. "World Energy Outlook 2011 Factsheet." 6. Accessed at http://www.worldenergyoutlook.org/docs/weo2011/factsheets.pdf

30 Pankratz, Howard. May 23, 2011. "Employment in Colorado's clean-tech industry grew more than 32 percent in past 5 years." *The Denver Post.* Accessed at http://www.denverpost.com/breakingnews/ci_18120539

attract new investment and should, therefore, be long-term. The importance of developing a competent labor force over time makes it all the more important to create and maintain this long-term stability.

c. Remove Conflicts of Interest

A stable marketplace is also key to attracting private sector investment and creating jobs. As Coloradans increasingly take advantage of the benefits of solar thermal, there is a clear need to ensure that implementation of solar thermal programs is done in a way that promotes local economic development and stability. Based on the experiences of recent utility-run programs, implementation of any future solar thermal incentive programs in Colorado should be managed and administered by an independent entity such as the Public Utilities Commission, the Governor's Energy Office, Recharge Colorado, or a similarly impartial entity, to remove any potential or perceived conflicts of interest, and to make best use of limited funds.

d. Attract Manufacturers

In 2010, Colorado was one of the few states in the nation to see an increase in manufacturing jobs, primarily from renewable energy-related manufacturers. The number of manufacturing jobs will increase with GE's new $300 million solar manufacturing facility in Aurora. The lesson from Colorado's success in attracting GE and others is that encouraging state and local collaboration, promoting the region's talented workforce, negotiating tax incentives, and specifically targeting industry clusters (including solar thermal) can make a big difference in attracting new investment and jobs.

4. Resolve Local Impediments

Zoning and permitting inconsistencies can significantly increase costs to solar customers. The inconsistencies across Colorado communities represent delays and increased cost to consumers, which present difficulties for achieving economies of scale. Colorado can recognize the benefits

Leading in Solar Thermal Manufacturing: Abengoa

Abengoa Solar Inc. is a world leader in manufacturing and installation of concentrating solar power (CSP) technology for large-scale solar thermal systems which can be used to produce heat or electricity. Abengoa Solar is headquartered in Lakewood with other offices in Phoenix, Arizona and San Francisco and Victorville, California. Since 2006, employment in Lakewood has grown to about 150 people—mostly engineers, as well as some support, manufacturing and management staff. The Lakewood office manages over $3 billion of solar thermal electric projects in Arizona and California, where Abengoa projects employ 1,000 people directly. This employment is growing rapidly, not counting workers in support industries making components such as reflectors, receiver tubes and metal structures, as well as construction materials, concrete, steel, etc. Abengoa also supports a large R&D effort in Lakewood aimed at developing the next generation of solar technologies, processes and thermal storage technology that will make solar even more competitive in the marketplace. About 20 production workers, supported by engineering and sales, are building solar concentrators for thermal applications at locations out of state and overseas. Unlike in California, Arizona and overseas, market conditions in Colorado are not currently as favorable to CSP and are hindering Abengoa Solar's growth in its home state.

At right, Abengoa parabolic trough collectors generate steam at a California plant.

of this technology in an efficient and consistent manner only by addressing jurisdictional concerns collaboratively.

a. Develop Solar Friendly Communities

Despite the ongoing efforts across Colorado to become a national leader in solar, fragmented permit processes and installation requirements continue to increase costs among the state's more than 200 municipalities, 64 counties, and 65 utilities. Issuing permits for a standard residential solar installation can add up to 20 days to solar thermal project time lines in some Colorado communities, while others complete the processes in less than one day. Licenses required to pull a solar thermal permit are inconsistent, ranging from none, to test-based mechanical licenses, to master plumber state licenses, to special licenses created by a local jurisdiction. Some permits are easy to complete over the counter, while others are not easily available online. Dealing with such varied processes can significantly increase costs for solar customers. In some cases the delays can push a project out of reach financially. Surveys of solar businesses across Colorado consistently rank permit processes and fragmentation of rules across local governments among their top pain points.

One of the fastest ways to streamline solar-related processes across local governments is to provide a compelling reason to do so and to make it easy to implement. These goals can be achieved by recognizing cities and counties that follow clearly defined best practices to make clean solar energy cost competitive in their communities, and by providing education and support for lagging communities. Such recognition, education, and support programs would create a measurable improvement in market conditions for solar thermal deployment by making it simple, clear, and compelling for cities and counties to become "Solar Friendly Communities," a DOE priority with federal grant support in Colorado.

b. Identify Best Practices

To jump-start this effort,he Colorado solar thermal community has embarked on a review of best practices and procedures that follow code and are increasingly standardized across the industry. Codes drive the permit process. Work has begun with the Rocky Mountain Chapter of the International Code Committee to ensure that newer codes meet the demands of today's solar thermal technologies. As codes are revised periodically, the solar thermal industry should remain involved in the process to keep up with emerging applications.

Using the latest codes that embody best practices will add to the comfort level of permitting professionals and their colleagues who conduct inspections. Easier, faster permitting processes will reduce expenses for industry and government. In turn, these standardized practices will drive down the turnkey price for solar thermal customers. Several organizations at the national and international levels have begun addressing the processes involved in raising building standards in communities around the globe. The American National Standards Institute (ANSI) and the International Organization for Standardization (ISO) have begun to include solar thermal in their discussions on improving building performance.

c. Zone with Clarity

As building officials begin collaborating with solar thermal stakeholders and become more familiar with solar thermal technologies, it's important that they share their knowledge with their colleagues in the zoning department. Recognizing the technical requirements of solar thermal systems will assist zoning departments in setting form-based guidelines that accommodate the needs of the local community. This collaboration will have the added benefit of showing neighbors of solar thermal adopters that solar thermal systems benefit their neighborhoods with lower energy costs and increased home values.

By implementing coordinated strategies that overcome the identified barriers to growth, Colorado can achieve—and exceed—the goals and benefits defined in this *Roadmap*. Colorado is uniquely positioned to take advantage of solar thermal and, through this industry, significantly contribute to our economic future, local job market and environment.

SOLAR THERMAL
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The STAC Vision

Our vision is to make Colorado a global leader in solar thermal adoption, installation, manufacturing, and R&D, to boost Colorado's economy, generate jobs, and help build a sustainable energy future.

STAC Vision Endorsers

The following individuals have endorsed the vision of the Solar Thermal Alliance of Colorado.[31]

Mike Bowman, 25 x '25 and Sturman Industries

Laurie Campbell, AC Solar

Beth Hart, AC Solar

Paul Gipe, Alliance for Renewable Energy

Nichole Goodman, Policy Director, Alliance for Sustainable Colorado

Piper Foster, Amatis Controls

Susan Greene, President, American Solar Energy Society (ASES)

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Valentin Philippens, ArgenSolar

Mike Tierney, Aspen Solar

Jim Welch, Owner, Bella Energy

Will Toor, Commissioner, Boulder County

Clara "Sam" Burnham, Owner, Burnham Beck Sun

Bruce Padgett, President, Capitol Solar Energy

Keith Frausto, Center for Resource Conservation

Bill Ritter, former Colorado Governor, Director, Center for the New Energy Economy

Alice Laird, Director, Clean Energy Economy

Leslie Weise, Principal, Cleantech Business Solutions, LLC

Dickey Lee Hullinghorst, State Representative, Colorado House of Representatives, District 10

Max Tyler, State Representative, Colorado House of Representatives, District 23

Randy Fischer, State Representative, Colorado House of Representatives, District 53

Doug Hoff, Aide, State Representative Randy Fischer (D), Colorado House of Representatives, District 53

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David Hiller , Colorado Renewable Energy Collaboratory

Thom Johnson, Colorado Renewable Energy Society (CRES)

Gail Schwartz, State Senator, Colorado Senate, District 5

Fred Kirsch, Community for Sustainable Energy

Sam Weaver, Cool Energy

Jason Haber, Energy Programs Manager, CORE—Aspen

Jon Klima, PE, Owner, Conifer Solar Consulting

Willie Mein, Custom Solar

31 The organizations mentioned in the list of Endorsers are to aid in identification of individuals only; they do not necessarily represent endorsements by said organizations of the *Colorado Solar Thermal Roadmap*. Individuals mentioned have not reviewed all contents of the published roadmap, and may not endorse specific aspects.

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Brandon Williams, Iron Edison

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Thornbloom, Kelelo Engineering

Kyle Webb, principal, KH Webb Architecture

Bud Elliott, Mayor, Leadville

Gerry Todd, Founder, Legacy Economy

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Jo Bourg, President, Millennium Energy LLC

Tony Renfrow, Noonday Solar

Don Marostica, Loveland Commercial)

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Jason Morley, R.A. Nelson

Ted Lowe, Executive Director, Radiant Panel Association

Mike Morton, Real Goods Solar Colorado

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Lee Swenson, Rocky Mountain Farmers Union

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This publication may be accessed from the following locations:

http://www.coseia.org/insights/thermal.html • http://www.cres-energy.org/pubs/solarthermalroadmap.pdf

SOLAR THERMAL
ALLIANCE OF COLORADO

Colorado Solar Thermal Roadmap

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a collaboration of the Colorado Solar Energy Industries Associations
and the Colorado Renewable Energy Society.

COSEIA
Colorado Solar Energy Industries Association

CRES
Colorado Renewable Energy Society
Your Renewable Energy Resource

100% recycled ♻ 50% post-consumer