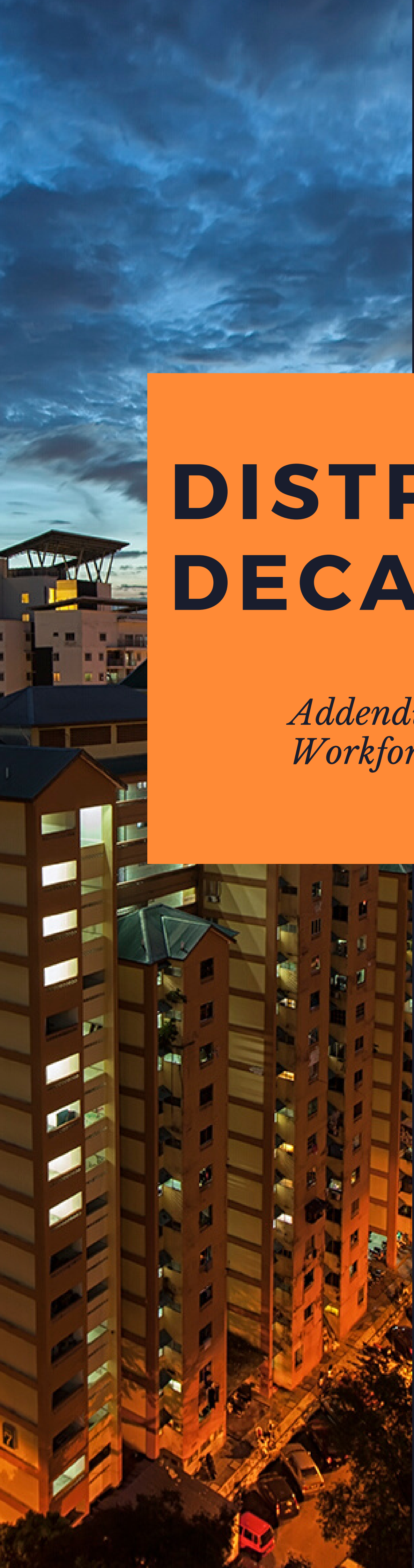

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DISTRICT ENERGY DECARBONIZATION

Addendum to California Building Electrification Workforce Needs and Recommendations

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INCLUSIVE
ECONOMICS

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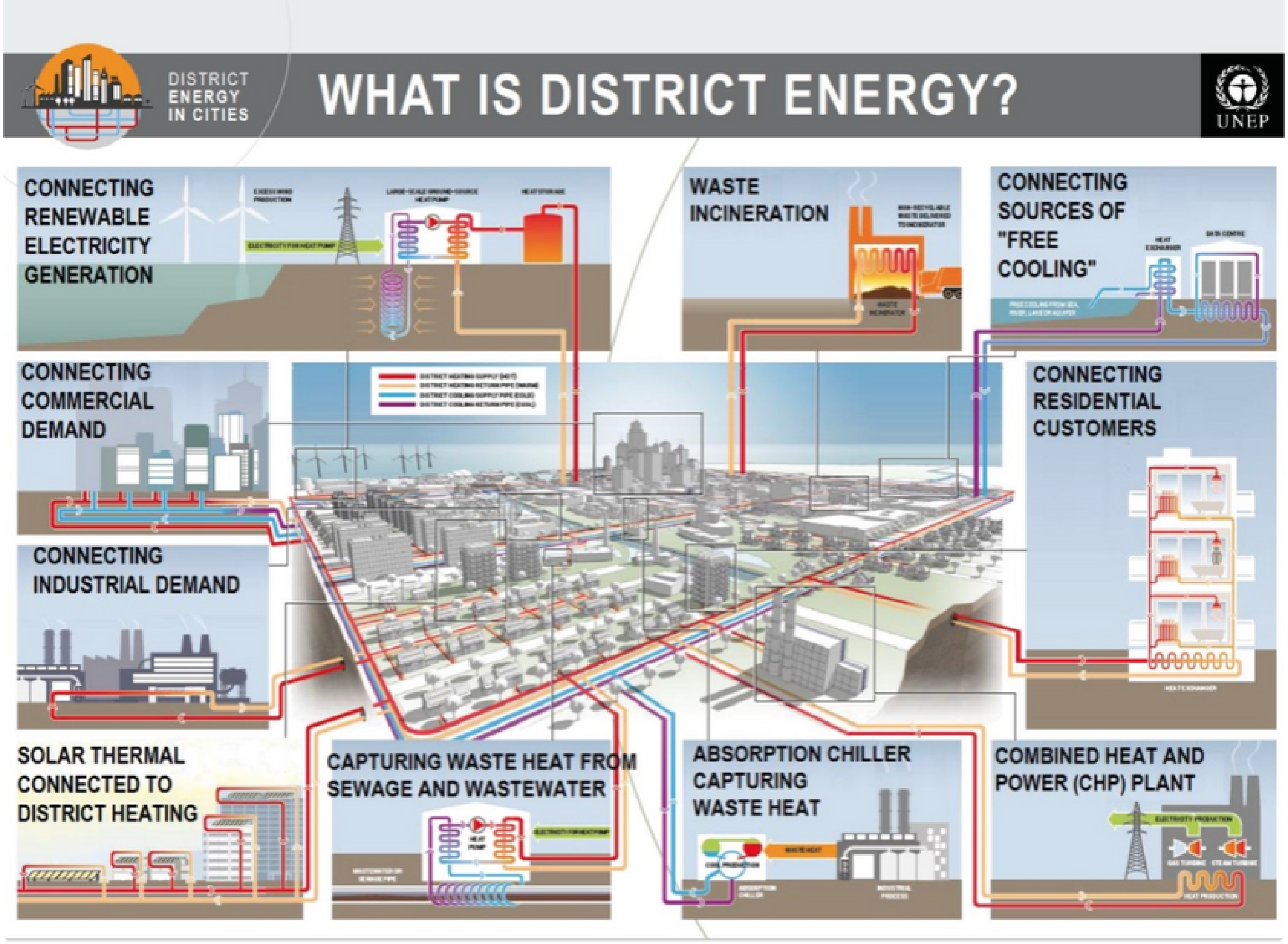
OVERVIEW

Heating, cooling, and water heating make up 80 percent of building natural gas use in California.[1] Some of this gas use can be reduced through stand-alone building electrification, but building decarbonization can also be accomplished through a centralized approach: renewable district energy systems or thermal microgrids[2]. District energy systems typically rely on combined heat and power or co-generation systems, which are used to provide both electricity and heat to large buildings or campuses. While traditionally powered by fossil fuels, these systems can be converted to run on renewable energy and provide both heating and cooling, as well as water heating to large buildings, campuses, entire neighborhoods, or commercial districts.



Source: United Nations Environment Program (UNEP). District Energy in Cities Initiative
http://www.districtenergyinitiative.org

KEY BENEFITS

In addition to the climate benefits, there are several significant co-benefits of carbon-free district energy systems.[3] When designed appropriately, district energy systems can also:

- Enhance energy resiliency and reliability by using a diversity of renewable energy sources, beyond wind and solar, such as sewer heat, geothermal, biogas, biomass, and waste heat from other buildings;
- Improve energy efficiency by moving waste heat from places where it is a nuisance or liability, such as data centers or refrigeration facilitates, to places with high demands for heat, such as private residences.
- Reduce the investment needed for new electricity generation and distribution infrastructure by providing efficient non-electric carbon-free sources of heating, cooling, and water heating;
- Reduce the overall costs of decarbonization by investing in large systems and amortizing the investment over time;
- Offer a business opportunity to utilities negatively affected by transition away from natural gas systems; and
- Provide quality job opportunities for skilled and trained workers in construction and maintenance.

CONDITIONS FOR SUCCESS

District energy systems are most practical under the following conditions:

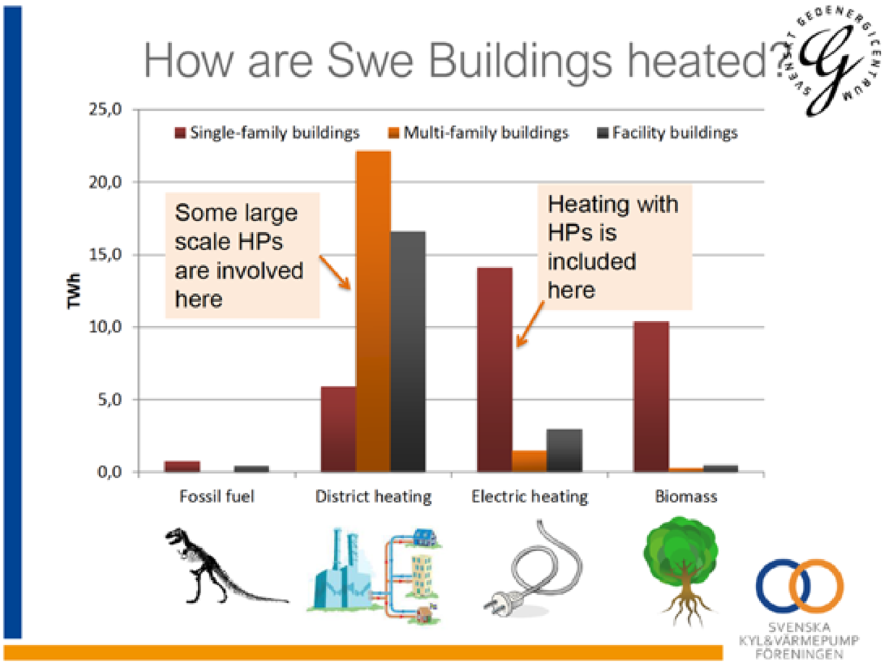
- **High load and density of buildings** where short distances of distribution piping can interconnect several buildings of reasonable size, for example, at airports, college and university campuses, large hospital complexes, large office and industrial complexes/campuses, casinos, sports stadiums and arenas, and downtown central business districts of larger urban centers;
- **Diversity of building uses** in order to balance heating and cooling loads across the connected system of buildings;
- **Developments with high capital costs** such as new developments where extending infrastructure for gas is expensive and otherwise undesirable; and
- **Ability to finance investment** with a long payback and depreciation schedules such as utilities, government facilities, airports, college and university campuses, and hospital campuses.

EXISTING PENETRATION

Outside of the United States, district heating is commonly utilized. For instance, Figure 1 shows the pervasiveness of district heating in single-family, multi-family, and other buildings in Sweden; district energy is the most common source of heat for multi-family and facility buildings. Similarly, in Denmark, 63 percent of all residential homes are connected to district heating for space heating and domestic hot water. [4]

California has over 75 district energy systems throughout the state, and there are over 5,800 in operation across the U.S., serving more than 6.5 percent of commercial buildings, downtown districts, campuses, military bases, research facilities, and even some residential locations. [5] Unlike countries in northern Europe, California and the U.S. are doing little to leverage the decarbonization potential of these systems.

Figure 1. Building heat sources in Sweden



Energy use for heating of buildings in Sweden 2015. From Energiläget i siffror 2017, Energimyndigheten 2018

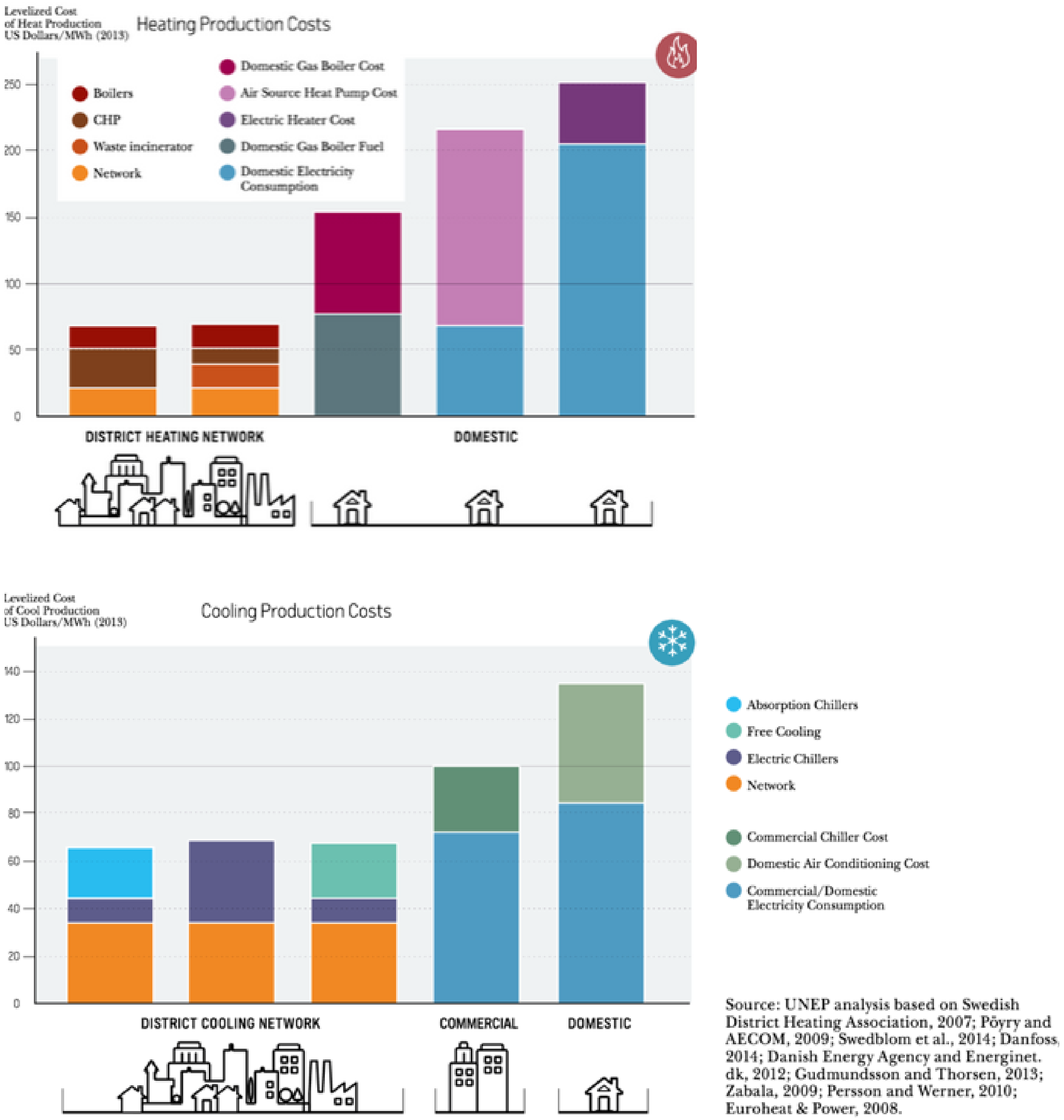
Source: Energy and Climate Academy. 2018. District Energy – Energy Efficiency for Urban Areas. https://ecacademyen.nemtilmeld.dk/18/

ENERGY BENEFITS & COST SAVINGS

District energy provides the economies of scale that are necessary for utilizing alternative heat sources that may not be accessible or affordable at the level of a single building. As with decentralized electrification solutions, decarbonized district heating and cooling applications can rely on electricity-powered heat pumps.[6] However, unlike decentralized solutions, district energy systems can use a wide range of energy sources that require scale to be cost-effective, including sewer heat, geothermal, biogas, biomass, and waste heat from other buildings. In 2011, less than 16 percent of the energy for Norway's district heating systems was provided by fossil fuels; most of the remainder was from renewables or recycled heat.[7] Tapping into year-round renewable energy sources accrues technical benefits for system resilience and helps to offset concerns about the inefficiency of wind and solar renewable energy generation in California during the winter season when heating demands are highest.

In addition to energy savings, there is some evidence in Europe that indicates heating and cooling with district energy is more cost-effective per unit of energy than decentralized solutions because they have lower levelized costs, which represents the net present value of the unit-cost of electrical energy over the lifetime of the energy source.[8] Figure 2 depicts the levelized cost of district heating and cooling relative to conventional domestic solutions. Levelized costs show that even if upfront costs appear to be high, the cost over the life of the district heating and cooling system is substantially lower than decentralized heating and cooling systems.

Figure 2. Levelized costs of district heating and cooling compared to decentralized production



Source: UNEP analysis based on Swedish District Heating Association, 2007; Pöyry and AECOM, 2009; Swedblom et al., 2014; Danfoss, 2014; Danish Energy Agency and Energinet.dk, 2012; Gudmundsson and Thorsen, 2013; Zabala, 2009; Persson and Werner, 2010; Euroheat & Power, 2008.

Source: See graphs on p. 40-41. United Nations Environment Program. (2015). District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy. https://wedocs.unep.org/bitstream/handle/20.500.11822/9317/-District_energy_in_cities_unlocking_the_potential_of_energy_efficiency_and_renewable_ene.pdf?sequence=2&isAllowed=y

WORKFORCE BENEFITS

Finally, district energy systems require skilled and trained workers to install and maintain equipment and infrastructure, which generates the labor-market conditions that create quality employment opportunities for workers. Given the high upfront capital investment, utilities or municipalities that can amortize their investments are more likely to own and operate district energy systems. District energy systems could offer a high-road path to building decarbonization in California and serve as a replacement industry for workers facing job loss in from declining natural gas demand. For example, Stanford University's overhaul of their district energy system employed 72 different signatory subcontractors and created union jobs across the skilled construction trades, including jobs for insulators, pipefitters, boilermakers, among others.

In 2011, Norway's district energy industry employed 1,600 full-time workers across 120 district heating systems. This network of systems generated 65 TWh of heating power (almost half of it serving the residential sector) and 123 GWh in cooling.[9,10] In total, district energy systems covered six percent of the country's heating and cooling market. Equivalent district energy penetration in California could sustain 12,800 full-time utility workers, more than the 7,200 workers currently involved in distribution of gas to residential and commercial buildings in the state.

EXAMPLES

There are thousands of examples of district energy systems serving business districts, universities, hospitals, and neighborhoods across the country.

- The City of Detroit has a district energy system providing heating and cooling to over 100 buildings in its downtown and midtown core.[11]
- The City of West Union in Iowa, recently implemented a central ground-source geothermal district energy system to which downtown commercial buildings connect using heat pumps.[12]
- In British Columbia, a 460-acre golf course community installed a central district energy system using geothermal heating and cooling. This system provides heating and cooling to all the commercial buildings plus 2,000 homes.[13]
- In Seattle, Amazon's new headquarters—five million square feet of office space—will be heated by siphoning the equivalent of 5 MW of waste heat from an adjacent data center.[14]

The following three examples illustrate innovative district energy solutions at different stages of planning, design, and implementation in California.

1/ University of California, Davis Planning for Carbon Neutrality

In 2013, the University of California (UC) began the Carbon Neutrality Initiative to move all campuses to zero-carbon energy production by 2025.[15] To reach these goals, the UC Davis campus intends to convert its steam district heating powered by natural gas to hot water powered by electricity. Steam production at the Central Heating and Cooling Plant at UC Davis is responsible for about a third of the campus's carbon footprint. The system is made up of 30 miles of pipes underground, many of which are over 50 years old and very leaky. UC Davis currently spends $20-25 million annually to run this plant and provide heating and cooling to eight million square feet of building space.[16]

2/ San Francisco Designing a Neighborhood with District Energy

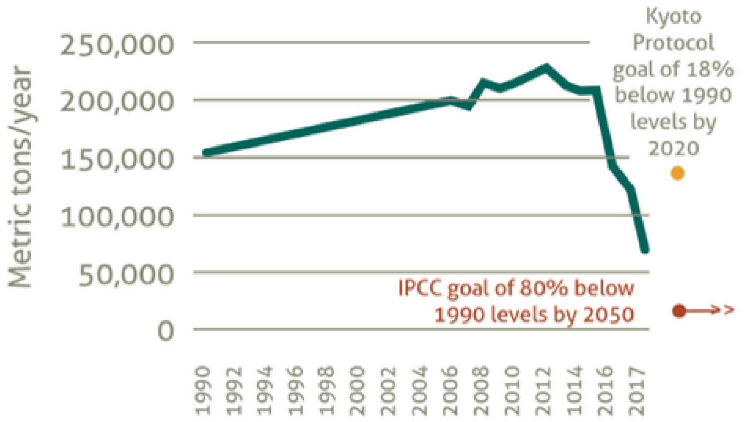
The City of San Francisco Planning Department is pursuing a district energy system in the Transbay Redevelopment Area to take advantage of dense mixed-use development in the district.[17] The project would require new buildings to be designed to plug into such a system, avoiding the need for individual buildings to have their own heating and cooling equipment. Customers will use the hot and chilled water from a central plant to meet their water heating, space heating, and air-conditioning needs through a closed-loop piping system.

3/ Stanford University Creates Union Jobs and Reduces Greenhouse Gas Emissions by 70 Percent

Stanford University recently invested $468 million into a four-part effort to decarbonize its campus.[18] The Stanford Energy System Innovations (SESI) project replaced an aging 50-MW natural gas-fired co-generation plant with a new heat-recovery system to provide heating and cooling to the campus.[19] The cost of this new plant was about $200 million. The construction required 72 subcontractors, and the entire plant, except for the thermal storage tanks, was built with union labor from the Central Valley and Southern California.

Stanford also spent about $180 million to convert 155 campus buildings from steam to hot-water distribution and installed a 22-mile-long network of new pipe to move hot water. The system captures 57 percent of building waste heat, reusing it to meet 93 percent of campus heating needs.[20] Heat and Frost Insulators and Allied Workers Local 16 completed much of this work. As a foreman concisely explained, “The University is replacing steam radiators with water pumps. Warm water heating is more efficient. It is a pretty cool project. The Heat Recovery Plant recovers the heat that is usually expelled through the exhaust tower and uses it to heat up the water. It costs a lot of money to build a system like this, but the energy savings will pay for itself.”[21]

Figure 3. Stanford GHG Emissions From 1990 to 2017, Showing Steep Reductions After SESI Project Completion



Source: Stagner, Joseph. (2016). Stanford University’s “fourth generation” district energy system: Combined heat and cooling provides a path to sustainability. ttps://sustainable.stanford.edu/sites/default/files/IDEA_Stagner_Stanford_fourth_Gen_DistrictEnergy.pdf.

Stanford also built a new 80-megavolt-ampere electrical substation to connect with grid-scale renewable energy resources.[22] In addition, Stanford executed a long-term contract with SunPower Corp. for 68 MW of solar photovoltaic built near Mojave, California, and 5 MW on on-campus solar.[23]This massive infrastructure effort caused Stanford's greenhouse gas (GHG) emissions to plummet about 70 percent from 2016 to 2017 when the project was completed (as shown in Figure 3), and emissions will continue to decrease as Stanford increases the percent of electricity procured from renewable sources. In addition to these environmental benefits, the university expects to reduce energy expenditures relative to the business-as-usual scenario.

Large infrastructure projects like these require a highly skilled workforce and are therefore more likely to hire union or other highly-trained workers than single-building projects with simpler systems. One journeyman on the SESI project commented, "I like the guys I work with. They want to do good-quality work... The trick to doing good work is having a lot of experience. It starts with training in the apprentice school and then getting hands-on experience working with guys who have done it before." And an apprentice commented, "I did earthquake retrofitting, electronics, and a lot of other stuff. There was no future in any of it. Not enough money to sustain myself. This time I'm working with a great group of guys. We have fun working together. It makes you want to come back the next day. This time I feel like I finally found a home."[i]

> *The trick to doing good work is having a lot of experience. It starts with training in the apprentice school and then getting hands-on experience working with guys who have done it before."*
>
> --Journeyman working on SESI project

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