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DISTRICT-SCALE ENERGY PLANNING:

SMART GROWTH IMPLEMENTATION ASSISTANCE TO THE CITY OF SAN FRANCISCO

Office of Sustainable Communities
Smart Growth Program

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EXECUTIVE SUMMARY

Communities are always looking for solutions to growth and development challenges that bring multiple benefits and use funds efficiently. Increasingly, states and municipalities are trying to reduce their greenhouse gas emissions to lessen their impact on climate change. Communities, businesses, and individuals see volatile energy prices and want a more stable, reliable, and affordable energy source. Local governments are trying to respond to the demand for more development in compact neighborhoods with a mix of uses and transportation options. District-scale energy systems – which provide heating and cooling from a central utility plant to individual buildings across a neighborhood or development district – can help communities with all of these aspirations.

District-scale energy systems can achieve economies of scale by combining the needs of multiple buildings to attain benefits for individual property owners and the larger community. Developers, property owners, and building managers can save money on energy, have a more reliable system, and avoid having to operate and maintain heating and cooling systems in each individual building. The community as a whole can benefit from these systems because they can lower greenhouse gas emissions and other pollution, use more renewable energy sources, encourage new development in existing neighborhoods, and help achieve other community and environmental goals.

> ***District-scale energy systems*** *can reduce a community's greenhouse gas emissions, provide a more affordable and reliable energy source, and facilitate compact development.*

District-scale energy is not a new concept in the United States, but it is resurging due to increased environmental awareness, volatile energy costs, technological advances, and a more robust marketplace of developers and operators. Communities are interested in how they can shape new district-scale energy systems to achieve the most benefits for the community, environment, and economy. District-scale energy systems are particularly well-suited for compact neighborhoods that have a mix of uses, where fewer and shorter pipes are needed to connect users to the system and energy demand is spread out over the day. District-scale systems also allow individual buildings to allocate more space to tenant uses when they do not have to house their own heating and cooling systems, which increases the amount of developable space and can entice developers to build in neighborhoods where the community wants to see more investment.

In 2012, the city and county of San Francisco applied to the U.S. Environmental Protection Agency's Smart Growth Implementation Assistance program for support in encouraging district-scale energy systems in two development areas of downtown San Francisco. The technical assistance project explored how the public sector could facilitate and provide incentives to establish district-scale energy systems that meet local goals. This report introduces a four-phase process for district-scale energy planning developed as part of the project:

1. Initial Assessment, in which the community defines the district's boundaries and goals and determines how future growth and land use changes could affect the system.
2. Feasibility, in which the community assesses the technical and commercial viability of a district-scale energy system in the district.
3. Project Development, in which responsibility shifts to the energy system developers and users as they begin to design and build the system.

4. Operation, Optimization, and Expansion, in which the system operator and other stakeholders, including the community, improve the system's operations and determine whether and how to expand it.

The report includes a technology filtering tool to help municipalities and their stakeholders assess various technologies to determine which can best meet the goals for the system and a parcel evaluation tool to help identify properties that might be well suited to either host the main utility plant for the district system or connect to the system.

San Francisco and other local governments can use this four-phase approach to understand the options for, and benefits of, establishing district-scale energy systems in compact, mixed-use areas. The approach can also help communities determine how to capture associated benefits such as energy conservation and resiliency, cost efficiency, and support for new investment in existing neighborhoods.

This report introduces a ***four-phase process*** *to help communities understand the options for, and benefits of, establishing district-scale energy systems in compact, mixed-use areas:*

1. ***Initial Assessment***
2. ***Feasibility***
3. ***Project Development***
4. ***Operation, Optimization, and Expansion***

INTRODUCTION

District-scale energy systems provide heating and cooling to individual buildings across a neighborhood or development district. The heating or cooling supply is produced at a central utility plant and distributed across the district through pipes or another distribution network. By centralizing the production of hot water, steam, chilled water, condenser water, or combined heat and power , also referred to as CHP (in which a power station generates both electricity and excess heat), individual buildings no longer need their own boilers, chillers, and other thermal infrastructure. District-scale energy does not refer to the basic electricity needs of a building, and buildings would still get electricity from a regular connection to the electricity grid.

District-scale energy systems benefit from the efficiencies of coordinating across several properties. Individual buildings see these benefits in the form of cost savings, system reliability, and other economic and environmental gains that come from centralizing energy production and managing a shared distribution network. The community can benefit from these systems because they help reduce greenhouse gas emissions, can use renewable energy, encourage development in existing neighborhoods, and can align with other community and environmental efforts.

District-scale energy systems are not new to the United States. Many older American cities, such as Denver and New York City, have provided district steam heating for well over 100 years. The concept is resurging due to concern about global climate change, growing energy costs, technological advances, and a more robust marketplace of developers and operators. Communities are interested in how they can shape new district-scale energy systems to encourage compact, mixed-use development and achieve the most benefits for the community, environment, and economy.

PRIVATE-SECTOR BENEFITS OF DISTRICT-SCALE ENERGY SYSTEMS

District-scale energy systems use energy and building space more efficiently and reduce capital and operating costs. Individual buildings that use district heating or cooling do not need to allocate as much space for infrastructure like boilers and cooling towers.

***District-scale energy systems** offer benefits to building developers, designers, owners, residents, and utilities.*

- By removing the need to house boilers and chillers in individual buildings, developers, architects, and engineers have more flexibility in designing new projects. Developers can also reduce upfront capital costs and get a better return on their investment.
- Property owners can use the valuable square footage that would otherwise host thermal facilities to meet tenant needs or create additional leasable space.
- Property owners no longer have to operate and maintain boilers and chillers, which can decrease costs.
- District-scale energy systems are generally more reliable because they help reduce peak energy loads that can affect energy supply and costs, and they have robust backup systems that provide reliable service even during blackouts or other disruptions. This reliability helps protect property and residents during extreme weather events.
- On-site heating and cooling can affect occupants’ health and safety. For example, older boilers might have asbestos, and fuel delivery can be dangerous for occupants. Owners remove these issues when they remove on-site heating and cooling facilities.

- District-scale energy systems have more flexibility in the type of fuel they can use than stand-alone systems. This flexibility can help customers avoid the market fluctuations of a single fuel source. For example, District Energy St. Paul in Minnesota has integrated natural gas, fuel oil, CHP, and solar energy to replace coal as the single fuel source, which has allowed the system operator to better plan its long-term budget and give customers more stable pricing.[1]
  District-scale energy systems can also integrate advanced technologies in ways that individual building owners cannot. As fuel prices change and technologies advance, district systems let communities invest in or explore fuel options that are better for the environment, more reliable, and/or less expensive.

***Compact development** can best support an efficient distribution system by creating concentrated demand for heating and cooling. **An appropriate land use plan and zoning profile** is also key to establishing a district-scale energy system that can increase efficiency and cost savings and allows the use of more renewable resources.*

PUBLIC-SECTOR BENEFITS OF DISTRICT-SCALE ENERGY SYSTEMS

Several benefits can make district energy systems attractive to local governments.

- **District-scale energy conserves energy resources** by efficiently producing, storing, and distributing thermal energy to a group of buildings. A centralized system can cool water at night during off-peak hours, store it, and deliver the chilled water to buildings for use during peak hours. These types of district energy systems not only stabilize energy costs for customers but can lower water use in buildings.

- **District-scale energy systems use energy more efficiently** because they eliminate distribution power losses; balance, share, and recover thermal energy across a community; and centralize energy supply equipment, which reduces redundancies. Using energy more efficiently can reduce what users spend on energy, which can help make housing and workplaces more affordable to low-income people or start-up businesses. It also reduces greenhouse gas emissions and other pollution, helping to protect air quality and the global climate.

- Because district-scale energy technologies can reduce the cost of developing new buildings and long-term operation costs for all buildings, **a district energy system can make a community more economically competitive and encourage compact development with a mix of uses.** District-energy systems rely on a distribution network, often in the form of underground pipes, to deliver thermal energy to properties across the district. Compact development, where buildings are located close together, can best support an efficient distribution system and create concentrated demand for heating and cooling.

  The right mix of uses is also important for realizing the benefits of a district-scale energy system. For instance, an ideal neighborhood for district energy might include uses with higher heating and cooling loads, such as hospitals, data centers, or other commercial uses, but also residential and commercial users that would need energy at different times to balance the overall system. An appropriate land use plan and zoning profile is key to successfully setting up a district-scale energy system and achieving the benefits of increased efficiency, cost savings, and the ability to use more renewable resources for energy production.

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[1] District Energy St. Paul. "The Wave – Spring 2014." http://www.districtenergy.com/press-room.

- **The reliability of a district energy system can be a selling point to attract businesses and residents**. Ensuring that the power stays on in a storm, for example, means that businesses can continue operations without disruption. If the system can keep power, heating, and cooling operating during extreme weather events and other emergencies, residents could stay in their homes instead of having to evacuate or go to a shelter, which relieves pressure on the community's emergency management resources.

THE ROLE OF LOCAL GOVERNMENT

Though some cities and counties, such as St. Paul; Nashville, Tennessee; Miami-Dade County, Florida; and Boise, Idaho, have district-scale energy systems, they are most common in the United States in campus settings, such as universities and hospitals, where there is a single owner and operator. In many U.S. cities, stakeholders are uncertain about how district-scale energy works. Planning authorities and the energy and development industries may need more education and experience to create, participate in, and manage these systems. The public sector can provide regulatory certainty, transparency among stakeholders, and incentives for participation.

Public-sector stakeholders include various agencies or departments at the local, state, and federal levels. This report focuses on the local level.

- When a system is established, a distribution network needs to be installed throughout the district, and public works departments, public utilities, capital planning, and transportation agencies that control right-of-way access need to be involved in infrastructure additions and construction projects that affect rights of way.
- Building inspection or enforcement departments need to provide new rules and regulations for properties that host central utility plants and for buildings that plan to connect to the district-scale energy system.
- City attorneys need to be at the table to ensure proper compliance with all national, state, and local rules around procurement, delivery, energy distribution and sale, and public-private partnership arrangements.

Local governments can help capture the benefits of district-scale energy systems by helping outline the goals of the system early in the process, even if the public sector does not end up owning and operating the system. The public sector might also choose to support or require district systems through policies or incentives and by establishing rules or structures for public-private partnerships. The tools in this report can help the community's planning staff and officials identify the technology that best meets the system's goals, develop an initial land use plan that identifies the best locations for the central utility plant, and assess which district parcels are the most attractive to connect to a district-scale energy system.

The tools in this report can help a community ***identify the technology*** *that best meets the system's goals,* ***develop an initial land use plan*** *that identifies the best locations for the central utility plant, and* ***assess which district parcels are the most attractive*** *to connect to a district-scale energy system.*

Communities must balance the challenges of setting up a district-scale energy system with the expected benefits. The public sector can help mitigate risks associated with implementation, connection, and operation by designing policies to support district-scale energy. Over time, the private sector will improve efficiencies, reduce costs, improve low-carbon technologies, and access capital. But as these systems are first implemented, the public sector can help establish collective buy-in among property owners, developers, investors, and energy providers.

The public sector can also help these stakeholders navigate regulatory barriers and take advantage of incentives to strategically mitigate risks and increase value. The public sector can facilitate the process by educating district stakeholders, making them aware of the opportunities and constraints of district-scale energy systems, and maintaining ongoing communication about ways to improve public regulations, permitting, and oversight. The public sector can organize this diverse set of stakeholders—property owners, developers, investors, and energy providers, as well as public agencies, residents, and other local interest groups—which are referred to throughout the report as the "project team." This team can engage at different points in the process of developing a district-scale energy system.

Table 1 lists major activities that the public and private sectors could do in each phase, whether directly or through a third-party consultant. The activities will depend on local context; The San Francisco Pilot Projects section discusses how a list like this was developed for the two pilot studies in San Francisco.

Table 1: Public and Private Sector Roles in Each Phase

Phase	Major Activities	Responsibility	
		Public Sector	Private Sector
Initial Assessment	Defining the district and goals	Leader	Supporter
	Identify barriers	Leader	Supporter
	Determine system potential	Leader	Supporter
Feasibility	Selecting appropriate technologies	Leader	Supporter
	Parcel evaluation	Leader	Supporter
Project Development	Concept design and analysis	Supporter	Leader
	Cost-benefit analysis	Supporter	Leader
	Procurement and project delivery	Supporter/Leader	Leader/Supporter
	Facilitating project implementation	Leader	Supporter
Operation, Optimization, and Expansion	Developing new projects or systems	Supporter	Leader
	Expanding operating systems and connecting separate systems	Supporter	Leader
	Optimizing based on original goals	Supporter	Leader

SAN FRANCISCO CONTEXT

The city of San Francisco asked for assistance from EPA's Smart Growth Implementation Assistance Program to plan district-scale energy systems for two pilot development areas in the city, and ultimately to create a policy in support of district-scale energy for the entire city. (For more information on the program, see Appendix A.) EPA formed a team of engineers, real estate and finance experts, and land use planners from Arup and CH2M HILL to work with staff from EPA and the city. The EPA team developed:

- Criteria for evaluating parcels of land appropriate for district-scale energy systems, as well as a set of energy generation and delivery alternatives that the city could assess for the two pilot districts.
- Near-term next steps for implementing district-scale energy systems in two local pilot projects.
- Long-term implementation steps and planning framework for future district-scale energy projects.

The multidisciplinary EPA Team helped San Francisco plan district-scale energy systems for two pilot districts by developing:

- *Evaluation criteria and alternatives*
- *Near-term implementation steps*
- *Long-term plans and framework*

These activities, as described in this report, can help San Francisco and other communities understand how to evaluate the feasibility of district-scale energy systems for compact, mixed-use areas.

Section II explains the four-phase process the EPA team developed for assessing whether and how to implement a district-scale energy system. Section III discusses specific action items and lessons the EPA team learned by applying this approach to two pilot districts in San Francisco.

FOUR PHASES OF DISTRICT-SCALE ENERGY SYSTEM IMPLEMENTATION

This report offers a four-phase implementation process that communities can use to determine the viability of starting a district-scale energy system, implement the system, and assess how to improve and expand it. District-scale energy systems, like most large-scale projects, go through several phases as they move from concept to reality. This report focuses primarily on the local government's role. However, the success of district-scale energy systems will rely on multidisciplinary coordination with the private sector. Planners, engineers, building owners and developers, energy system developers, utilities, and others need to be involved, especially as the project moves from the Initial Assessment phase to Project Development.

The four phases of district-scale energy system implementation are:

1. **Initial Assessment**
2. **Feasibility**
3. **Project Development**
4. **Operation, Optimization, and Expansion**

The EPA team applied this process in two pilot neighborhoods in San Francisco, Central SoMa and the Transit Center district. Section III discusses specific results and next steps for the two districts and gives more detail on how the city might work through each phase.

INITIAL ASSESSMENT

The Initial Assessment phase involves three major activities:

1. **Defining the district and its goals.**
2. **Identifying barriers.**
3. **Determining the system's potential based on local context, both present and future.**

After assessing the land use potential, local goals, potential barriers, and overall system viability, the municipality can assess the suitability of district-scale energy and can determine what strategies are required to make a district-scale energy project more viable. Such strategies could include revising the boundaries, changing land use regulations, amending building codes, finding funding, and seeking partners. The city can also assemble the project team, including property owners, developers, local government, utilities, system developers, and regulators.

Defining the District and Its Goals

In this initial step, the municipality and its partners identify areas or districts where a system might be located. To define the district's boundaries, the project team can use information such as political boundaries, physical barriers (e.g., highways or rivers), assessment districts (e.g., business improvement districts), large planned developments, or single high-energy users (i.e., "anchor" users or loads). At the beginning, the boundary should be flexible while the city gathers information about potential participating parcels in and near the district. This flexibility will allow the city to redraw the boundaries, as needed, to take advantage of opportunities during later phases.

At the outset, project boundaries should be fluid to accommodate evolving opportunities and stakeholder input on goals and priorities.

First, the project team defines a district geographically, determines relevant goals and priorities for the area, and collects data such as future planned density, zoning, presence of utilities and other infrastructure, and location and use of any permitted developments. To determine suitability, the municipality and/or utility should assess available energy resources, including local renewable resources, the current energy source, and typical heating and cooling technologies.

After roughly defining the district's geographic area, the community and stakeholders set the goals for that district, accounting for local, regional, state, and federal policies, laws, and goals. Sample goals might include setting targets for energy efficiency, greenhouse gas emissions reduction, financial performance (e.g., capital expenses and energy rates), use of alternative energy sources, and/or energy resilience and energy independence. The project team might find that it needs to redraw the district boundaries to add more development area and increase the scale and diversity of uses. San Francisco's Central SoMa Eco-District was set into motion by a task force that included almost 30 stakeholders from neighborhood groups, nonprofits, utilities, real estate developers, property owners, engineers and architects, and city agencies. This group established shared goals and devised a plan for how stakeholders and the city would work together to implement and manage projects over time.[2]

Identifying Barriers

Concurrent with defining the goals and priorities in the district, the project team should also identify major barriers. The team identifies more specific barriers in later phases, but at this point, three questions can help determine if certain district-scale energy technologies are even feasible:

1. **Is distribution possible?**
   Typically, a network of underground pipes distributes thermal energy. Freeways, rivers, or rights of way can pose challenges to or even prevent the installation of these pipes, as can areas with long histories of development that have abandoned or crowded utility infrastructure. Though technically feasible, aboveground thermal energy distribution is generally more difficult: in addition to facing the same potential physical constraints as underground systems, aboveground systems are more visible and have to consider aesthetic impacts.
2. **Is there a regulatory framework for distributing locally generated energy (thermal and/or power)?**
   For a district energy system to work, it must be legal to sell locally produced energy to participating parcels. This process can require franchise agreements for underground distribution or require that the energy generator become a legal utility. If a district-scale energy system already exists in the municipality or state, that system's operators and participating utilities can advise on how to set up a new system. In San Francisco, NRG has managed steam heat since 1999 and was a great resource for the city as it began exploring options for establishing and managing a district energy system.
3. **Is there potential interest and demand from multiple property owners over multiple blocks to connect to the system?**
   Local energy generation and distribution requires connecting multiple buildings, usually over multiple blocks, to attain the needed economies of scale in cost and energy efficiency. The city should determine the energy demand from individual buildings, as well as what stakeholders want from a district-scale system. As discussed in Section I, building owners might be motivated to participate for many reasons: lower life-cycle costs, system reliability, elimination of operation and maintenance for thermal energy, occupant safety, energy efficiency, and greater cost certainty.

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[2] San Francisco Planning Department. *Central SoMa Eco-District: Task Force Recomm*endations. Nov. 2013. http://www.sf-planning.org/ftp/files/plans-and-programs/emerging_issues/sustainable-development/CentralSoMa_EcoDTaskForceReport_112513.pdf.

Determining the System's Potential

A demand load profile helps the city assess the energy demand necessary to host a district-scale energy system. The profile should consider how future growth and land use changes might impact demand and affect the system's size and design over time.

After defining the district's boundary and goals and assessing major barriers, the city can estimate whether the district has the energy demand necessary to host a district-scale energy system. Further, the city may consider how future growth and land use changes might impact demand and affect the system's size and design over time.

Demand load "is the amount of energy consumed in a given building or development"[3] and varies according to a building's size, age, use, daily and annual use profile, and local climate. The city can combine building-level demand loads to determine the current district's demand load. The project team should then examine planned development for the district and develop an energy demand load that reflects the system's future potential. This energy demand profile would show demand for heating and cooling in the district graphed over an entire day and then combined to show a demand profile for the year.

Initially, the team can distinguish between energy demands for existing uses and future uses. As the project is refined, the city should apply a timeline to modify the whole district energy demand profile based on future development and replacement or refurbishment of existing buildings.

These steps give the municipality the foundation it needs to move on to the second phase, Feasibility.

FEASIBILITY

During the Feasibility phase, the city assesses the technical and commercial viability of a district-scale energy system based on plans for future development in the district. The Initial Assessment phase ended with estimated energy demand, which is a good starting point for selecting potential energy generation technologies. In addition, Feasibility involves identifying buildings in the district that could initially support or connect to the system. The goal of the Feasibility phase is to determine if these projects would provide enough demand to warrant the capital investment required to begin developing the system.

The Feasibility phase includes two major steps:

1. **Selecting appropriate technologies**
2. **Evaluating parcels**

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[3] King, Michael. *Community Energy: Planning, Development and Delivery*. International District Energy Association. 2012. http://www.districtenergy.org/assets/pdfs/Community-Energy-Dev-Guide-US-version/USCommunityEnergyGuidehi.pdf.

Selecting Appropriate Technologies

The first step in the Feasibility phase is to identify and filter a list of potential district-scale energy technologies, as they will begin to define the physical design of the system and the political, financial, and regulatory support needed to meet the goals. Appendix B gives more information about the following technologies that the San Francisco pilots considered:

- Central heating
- Central cooling
- Central heating and cooling
- Central condenser water system
- Central heat recovery chillers
- Ground source heat exchange
- Bay-water cooling
- Combined heat and power (cogeneration)
- Combined cooling, heating, and power (trigeneration)
- Photovoltaics and solar thermal
- Biofuels

The project team can use the goals and priorities established in the Initial Assessment phase to narrow down the list of potential technologies.

Tables 2 and 3 on pages 16 and 17 provide a sample tool that could help users evaluate technologies based on local goals and priorities. Users can weight each criterion to prioritize goals and accommodate differences in climate conditions. To summarize the results, users aggregate the scores so that they can evaluate the technologies equally based on their ability to meet both demand and goals. The two tables below break out these scores by “Primary Score” for the top local goals, “Load Opportunity” for the ability of the technology to meet energy demand, and “Secondary Score” for lower priority goals. An “Opportunity Score” adds all these together. The tool can be customized for different district-scale systems. Some questions that can narrow the list of candidate technologies include:

- **Primary Technology Considerations**
    - **Greenhouse gas reduction potential**: What is the technology’s ability to reduce greenhouse gas emissions by not generating energy from on-site combustion?
    - **Regulatory impacts**: Are there laws and policies that could exclude or encourage the use of a specific technology? If there are restrictive regulations, can the regulators change them?
    - **Risk**: Does the technology create financial or legal problems? Is the technology too new to evaluate effectively?
- **Energy Generation**
    - **Heating, cooling, and power**: How well does the technology meet the district’s heating, cooling, and power requirements?

- **Secondary Considerations**
  - **Ease of distribution**: Would additional pipes or conduits need to be installed in existing or new streets?
  - **Life-cycle costs**: What is the total cost of ownership over time, including energy costs?
  - **Central utility plant footprint**: How much space would a utility plant need?
  - **Capital costs**: What is the initial cost of the system?
  - **Operating costs**: What are the ongoing maintenance and operations costs?
  - **Water impact**: What is the potential for integrating with water and wastewater systems and conserving and reusing water?[4]

The EPA team populated Tables 2 and 3 with these considerations because they were important for the two San Francisco pilots. Other communities might find that other considerations are more important and could list those in the appropriate order. Table 2 shows specific scores for each consideration; Table 3 is a simplified version of the same information to give users a visual representation of which technology types perform well or poorly for each consideration.

These technology selection tools can also help planners and other stakeholders identify and review regulations that can either help or hinder the technology options under consideration and sale of power to the grid. For example, early in the San Francisco project, the EPA team thought cogeneration would be the best technology type to meet the two pilot districts' energy needs. After the EPA team used the tool to prioritize technologies that meet state and local goals for reducing greenhouse gas emissions, cogeneration ranked much lower than other technologies like photovoltaics and solar thermal, which have greater greenhouse gas reduction potential. At the same time, photovoltaics may not be feasible in downtown San Francisco where surface area may be too limited to achieve the necessary generation amounts. This tool helps stakeholders weigh the considerations for each technology type.

In the process of selecting appropriate technologies, the project team can also identify policy changes or incentives that can help overcome barriers. For example, if the public sector can reduce regulatory restrictions or make distribution easier, the private sector might be able to use certain technologies more easily and cheaply, perhaps improving their rating.

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[4] In San Francisco, some buildings may be able to collect and reuse foundation drainage water for non-potable purposes, and the district-energy system may also be able to use collected foundation drainage for shared heating and cooling functions. San Francisco Planning Department. *Central SoMa Eco-District: Task Force Recommendations*. Nov. 2013. http://www.sf-planning.org/ftp/files/plans-and-programs/emerging_issues/sustainable-development/CentralSoMa_EcoDTaskForceReport_112513.pdf.

Table 2: Sample Technology Selection Tool. This tool ranks technologies based on their abilities to generate energy and meet district goals and priorities. The weighting row at the bottom can be used to weight the considerations from 1 to 5, with 5 being the most important.

	Primary Technology Considerations				**Energy Generation**				**Secondary Considerations**							
	GHG REDUCTION POTENTIAL	**REGULATIONS**	**RISK**	**PRIMARY SCORE**	**HEATING**	**COOLING**	**POWER**	**LOAD OPPORTUNITY SCORE**	**DISTRIBUTION**	**LIFE CYCLE COST**	**CUP SIZE**	**CAPEX**	**OPEX**	**WATER INTEGRATION POTENTIAL**	**SECONDARY SCORE**	**OPPORTUNITY SCORE**
DISTRIBUTED HEATING & COOLING	1.0	5.0	5.0		3.0	3.0	1.0		5.0	1.0	5.0	1.0	1.0	1.0		
CENTRAL HEATING	2.0	2.0	4.0		4.0	1.0	1.0		3.0	4.0	4.0	4.3	4.0	2.0		
CENTRAL COOLING	3.0	2.0	4.0		1.0	4.0	1.0		3.0	4.0	4.0	4.0	4.3	2.0		
CENTRAL HEATING & COOLING	3.3	3.0	3.0		4.0	4.0	1.0		2.5	4.5	3.0	3.5	5.0	2.0		
HEAT RECOVERY CHILLERS	3.0	3.0	3.0		5.0	4.0	1.0		2.5	4.0	3.0	3.0	4.0	3.0		
CENTRAL CONDENSER WATER	3.5	4.0	4.0		4.0	4.0	1.0		4.0	5.0	4.0	5.0	4.0	3.5		
GROUND SOURCE HEAT REJECTION	2.0	1.5	3.0		5.0	5.0	1.0		2.0	2.0	3.0	3.0	4.0	5.0		
BAY WATER COOLING	2.0	1.0	3.0		5.0	5.0	1.0		2.0	2.0	3.0	3.0	4.0	5.0		
COGENERATION	3.8	1.5	2.0		4.0	1.0	4.0		1.5	4.0	2.0	2.0	3.0	3.0		
TRIGENERATION	4.3	1.5	1.0		4.0	3.0	4.0		1.5	4.0	1.8	1.8	3.3	3.0		
FUEL CELLS	3.0	2.5	2.5		2.0	1.0	5.0		2.5	3.0	2.0	1.0	2.5	2.0		
PHOTOVOLTAICS	5.0	5.0	5.0		1.0	1.0	4.0		4.0	3.0	5.0	3.0	4.0	1.0		
SOLAR THERMAL	5.0	5.0	4.0		5.0	2.0	1.0		4.0	4.0	5.0	4.0	5.0	2.0		
WIND	5.0	2.0	3.0		1.0	1.0	2.5		4.0	2.0	4.0	2.0	4.0	1.0		
BIOFUEL (AVG OF NAT GAS USERS)	3.8	3.8	2.8		3.1	2.4	2.4		2.7	3.3	3.1	2.3	3.0	2.1		
Weighting																

Table 3: Sample Technology Filter. This tool includes the same information as the filter in Table 2, but it color codes the results to make the relative performance of the technologies more visible. The red boxes indicate relatively poor performance on the criterion compared to the green boxes, which indicate relatively strong performance. The weighting row at the bottom can be used to weight the considerations from 1 to 5, with 5 being the most important of the filter.

	Primary Technology Considerations				Energy Generation				Secondary Considerations							
	GHG REDUCTION POTENTIAL	REGULATIONS	RISK	PRIMARY SCORE	HEATING	COOLING	POWER	LOAD OPPORTUNITY	DISTRIBUTION	LIFE CYCLE COST	CUP SIZE	CAPEX	OPEX	WATER INTEGRATION POTENTIAL	SECONDARY SCORE	OPPORTUNITY SCORE
DISTRIBUTED HEATING & COOLING	🟥	🟩	🟩		🟨	🟨	🟥		🟩	🟥	🟩	🟥	🟥	🟥		
CENTRAL HEATING	🟧	🟧	🟢		🟢	🟥	🟥		🟨	🟢	🟢	🟢	🟢	🟧		
CENTRAL COOLING	🟨	🟧	🟢		🟥	🟢	🟥		🟨	🟢	🟢	🟢	🟢	🟧		
CENTRAL HEATING & COOLING	🟨	🟨	🟨		🟢	🟢	🟥		🟧	🟢	🟨	🟨	🟩	🟧		
HEAT RECOVERY CHILLERS	🟨	🟨	🟨		🟩	🟢	🟥		🟧	🟢	🟨	🟨	🟢	🟨		
CENTRAL CONDENSER WATER	🟨	🟢	🟢		🟢	🟢	🟥		🟢	🟩	🟢	🟩	🟢	🟨		
GROUND SOURCE HEAT REJECTION	🟧	🟧	🟨		🟩	🟩	🟥		🟧	🟧	🟨	🟨	🟢	🟩		
BAY WATER COOLING	🟧	🟥	🟨		🟩	🟩	🟥		🟧	🟧	🟨	🟨	🟢	🟩		
COGENERATION	🟢	🟧	🟧		🟢	🟥	🟢		🟧	🟢	🟧	🟧	🟨	🟨		
TRIGENERATION	🟩	🟨	🟥		🟢	🟨	🟢		🟧	🟢	🟧	🟧	🟨	🟨		
FUEL CELLS	🟩	🟥	🟥		🟨	🟥	🟩		🟢	🟩	🟧	🟥	🟢	🟧		
PHOTOVOLTAICS	🟩	🟩	🟩		🟥	🟥	🟢		🟢	🟨	🟩	🟨	🟢	🟥		
SOLAR THERMAL	🟩	🟩	🟢		🟩	🟧	🟥		🟢	🟢	🟩	🟢	🟩	🟧		
WIND	🟩	🟧	🟨		🟥	🟥	🟧		🟢	🟧	🟢	🟧	🟢	🟥		
BIOFUEL (AVG OF NAT GAS USERS)	🟢	🟢	🟨		🟨	🟧	🟧		🟨	🟨	🟨	🟧	🟨	🟧		
Weighting																

Parcel Evaluation

In this step, the project team evaluates each building parcel to determine its potential role in the system either as a central utility plant or as a customer that connects to the district-scale energy system and relies on the utility plant for service. Similar to the technology selection, parcel evaluation is a comparative analysis that should be followed by a more in-depth technical study of whether and how a parcel can connect to the system. The project team can conduct the parcel evaluations with generalized assumptions about the district, such as information from the planning department about the land use profiles of different parcels.

Table 4, a Hosting and Connecting Questionnaire, can help project teams evaluate whether a parcel should host a central utility plant or connect to the overall system. Evaluative criteria include current and future building area, centrality in the district, willingness to participate, heating and cooling demand, and potential barriers. This kind of information will help a city estimate how different parcels would connect to the system based on their heating and cooling needs.

Table 4: Hosting and Connecting Questionnaire

Evaluation Criteria	Is the parcel suitable for hosting a central utility plant?	Is the parcel suitable for connecting to a district energy system?
Current Gross Lot or Building Area	A central utility plant's space requirements depend on the chosen generation technology and desired capacity (based on projected demand). The project team will need to analyze a number of factors to find the best location, but larger parcels are more likely to be able to fit a utility plant.	The building's size and use, combined with local climate information, will help determine base and peak loads for electricity, heating, and cooling. The building's age and (if available) historical energy use data can help refine energy demand estimates. Buildings with more demand are generally the most desirable participants in a district energy system. Without more detailed information, the team assumes that larger parcels have greater energy demand and are, therefore, more likely to connect to the system.
Future Gross Building Area	Any site that might host a utility plant would see a reduction of square footage available for other uses. Owners must consider this loss of developable area.	Future gross area and use (determined by zoning) indicate the potential energy demand of a particular parcel. The team can update information as the development gains entitlement and the district becomes more defined. Buildings with larger demands are generally the most desirable participants in a district energy system.
Centrality or Proximity	The primary factor to consider is how easily the parcel can connect with other parcels. • Where is the parcel located in the district (e.g., center, fringe, or somewhere in between)? • Can the parcel easily access the planned distribution network? • Are there barriers, such as freeways, water bodies, or building foundations that would restrict transmission lines between the parcel and potential participating parcels? • Does the parcel have high on-site demand, or is it near an anchor load (a building or development with high energy demand)?	The parcel's suitability depends on how easily it can connect to the distribution network. Questions include: 1. Where is the parcel located in the district (e.g., center, fringe, or somewhere in between)? 2. How far away is the parcel from the central utility plan? The further away, the more expensive it will be to run transmission lines. 3. How far is the parcel from any existing distribution network? 4. How far is the parcel from other "attractive" parcels, meaning parcels that are relatively large, central, willing, and

Evaluation Criteria	Is the parcel suitable for hosting a central utility plant?	Is the parcel suitable for connecting to a district energy system?
		have a high baseload,[5] or parcels with complementary loads (e.g., residential loads to balance commercial loads)? 5. Is there access (underground right of way) to connect distribution lines to the parcel?
Willingness	The project needs a clear and legal commitment by the owner of the central utility plan site; involvement by the owner early in the process is essential. A publicly owned parcel might be the easiest to pursue, particularly as a first central utility plan host in a phased project. The owner may have his or her own sustainability goals, such as a desire to attain green building certification, or by financial implications, such as the loss of leasable space.	A parcel owner's willingness to connect to a district system depends on several factors, including: - Do regulations require it? - Is the parcel publicly or privately owned? - Could the building occupants save money on energy by participating in the system? - Could the owner earn green building credits or other development bonuses? - Does the property owner own multiple parcels in the district?
Thermal and Electrical Baseloads	Thermal and electrical baseloads determine the size and quantity of equipment in a central plant. If these baseloads are not yet determined, it is prudent to oversize the distribution infrastructure (since modifying distribution can be prohibitively expensive) and undersize central plant equipment (since it is straightforward to add additional generation capacity). Buildings with high loads are good potential hosts.	A building's daily load profile is determined by the change in energy demand over a 24-hour period. The type of building occupant and use and local climate conditions can help create an estimate of a building's load profile. Building uses with large baseloads include health care, public assembly, manufacturing, and hospitality.[6]
Potential Barriers	The list of potential barriers will largely depend on the size of the utility plant, the technologies under evaluation, local regulations, and community concerns. - Are there energy generation regulations that govern considerations such as air and water quality, noise, or proximity to particular building uses such as schools? - Would there be community resistance to this parcel's hosting a utility plant because of noise and emissions? - Would the parcel be more valuable economically or socially if it were developed, or is the parcel generally undesirable (e.g., under a freeway), and, therefore, more suitable for a utility plant?	Existing property owners might be concerned about the sunk costs of existing heating and cooling systems, the reliability of the district system, and the loss of control over managing their own on-site heating and cooling. For new developments, concerns might include the risk or uncertainty that the property will be completed before the district system is up and running, as well as uncertain costs of creating a new district system.

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[5] A baseload is the minimum continuous amount of power a building needs to meet basic heating and cooling demands of tenants.

[6] For a simple breakdown of baseload significance, see Table 5. Find specific benchmarks using EPA's ENERGY STAR Portfolio Manager® (http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager) and the U.S. Energy Information Administration's Commercial Buildings Energy Consumption Survey (http://www.eia.gov/consumption/commercial/).

The next tool in the Parcel Evaluation process is the Baseload Table (Table 5), which shows hypothetical baseload energy usage for different building types in San Francisco. The table assigns a score of 1 to 5 to building types based on their typical heating and cooling baseloads, with 5 being the best score in terms of a building's ability to support a district energy system because it requires more heating and cooling. The next tools in Parcel Evaluation, Tables 6 and 7, use this combined baseload score that accounts for both heating and cooling needs.

Table 5: Baseload Table. This table gives sample scores for certain building uses in San Francisco based on hypothetical baseloads and intensities. In the heating and cooling baseload columns, the darker colors indicate larger baseloads. In the total baseload column, green indicates larger collective baseloads while red indicates smaller baseloads.

Building Type	Heating Baseload	Cooling Baseload	Total Baseload (for scoring)
Health Care	4	5	5
Public Assembly	2	5	5
Residential	5	1	4
Hospitality	5	1	4
Food Service	2	4	3
Office	1	4	3
Education	3	3	2
Retail	3	3	2
Food Sales	1	3	1

Next, Tables 6 and 7 build off of the Hosting or Connecting Questionnaire and further assess parcels for either hosting a central utility plant or connecting to the system. The two tables include criteria based on a scoring legend that planners can customize for each district. For example, in the Current Gross Area column, a score of 1 should be based on the smallest building in the district, while a 5 should be based on the largest building. These sample tables include hypothetical scores for all criteria, but if the project team does not know or need to prioritize a given criterion, the weighting can be set to 1.

Table 6 shows the Hosting Evaluation Tool, which follows the same approach as the Connection Evaluation Tool in Table 7 but uses different criteria and scoring legend. The project team can weight each criterion depending on its importance to each individual district. For instance, the project team weighted "Willingness" because finding an owner willing to host the plant is paramount even to centrality of the parcel.

Table 6: Hosting Evaluation Tool. This tool can help the project team evaluate which parcels might host a utility plant in a district energy system. The scores are based on the customized scoring legend

Parcel	Lot Area (Sq.Ft.)	Future Gross Area (Bldg Sq.Ft.)	Sensitive Location (subjective)	Centrality/ Proximity	Willingness	Connection Score (from Parcel Evaluation Table)	Utility Plant Score
H	4	4	4	5	5	5	77
J	4	4	5	4	4	4	72
D	4	2	4	4	3	4	62
G	5	4	2	4	2	5	57
C	5	1	2	4	1	4	48
I	1	2	5	1	3	2	44
A	1	4	1	2	4	5	43
E	1	2	3	4	2	2	41
K	1	2	3	1	3	4	40
F	1	3	3	3	1	1	33
B	1	3	1	1	3	1	27

Typical Priority/Weighting	*3*	*1*	*4*	*3*	*4*	*2*

Scoring Legend						
1 (minimum)	*<2,000*	*>450,000*	*Very*	*Fringe*	*Low (often private)*	*45 to 50*
2	*2,000 to 8,000*	*300,000 to 450,000*				*39 to 44*
3	*8,000 to 14,000*	*150,000 to 300,000*	*Somewhat*	*In-between*	*Medium*	*32 to 38*
4	*14,000 to 20,000*	*5,000 to 150,000*				*26 to 31*
5 (maximum)	*>20,000*	*<5,000*	*Not at All*	*Center*	*Innovative or Public*	*20 to 25*
units	*Sq.Ft.*	*Sq.Ft.*	*Sq.Ft.*	*subjective*	*subjective*	*(Linked)*

Table 7: Connect Evaluation Tool. This tool can help the project team evaluate which parcels are good candidates to connect to a district-scale energy system. The scores are based on the customized scoring legend.

Parcel	**Current Gross Area (Bldg Sq.Ft.)**	**Future Gross Area (Bldg Sq.Ft.)**	**Centrality/ Proximity**	**Willingness**	**Baseload Score (based on land-use)**	**Connection Score**
A	5	3	2	4	5	44
H	3	3	5	5	1	44
G	4	3	4	2	5	42
K	5	4	1	3	5	40
J	3	3	4	4	1	38
C	4	5	4	1	2	37
D	2	4	4	3	2	37
E	1	4	4	2	1	30
I	3	4	1	3	1	28
B	1	4	1	3	1	24
F	1	4	3	1	1	24
Typical Priority/Weighting	***2***	***2***	***3***	*3*	***2***	

Scoring Legend

1 (minimum)	*<3,000*	*<5,000*	*Fringe*	*Low (often private)*	*1*
2	*3,000 to 100,000*	*5,000 to 150,000*			*2*
3	*100,000 to 200,000*	*150,000 to 300,000*	*In-between*	*Medium*	*3*
4	*200,000 to 300,000*	*300,000 to 450,000*			*4*
5 (maximum)	*>300,000*	*>450,000*	*Center*	*Innovative or Public*	*5*
units	*Sq.Ft.*	*Sq.Ft.*	*subjective*	*subjective*	*(See Exhibit 21)*

The project team can illustrate the information about hosting and connecting in an energy demand map. See Figure 2 for an example energy demand map, which shows relative energy loads per parcel and then scores each parcel for its ability to host a central utility plant. The team can generate the map using basic information about the locations of high-energy loads, new development, existing systems, and right-of-way access. The main purpose of this map is to identify ideal locations for the central utility plan based on known or likely base and peak loads in the district and availability of right of way for distribution lines. The central utility plan should be close to buildings with high energy demands and peak loads to make the system as efficient as possible.

Figure 1: Sample Energy Demand Map. This map shows how a city might assign each parcel a color that reflects its energy demand, by heating and cooling, and then assign each parcel a score for how well it might host the central utility plant.

The project team can use the map to reach out to parcel owners, energy operators, and other stakeholders to discuss potential locations for key parts of the system. This outreach can help the team identify specific development sites that can be initial projects in the district-scale energy system. The project team may later develop a business case to help property owners understand the costs and benefits of connecting to the district energy system. Items that might be important to communicate are changes to property owner's building costs, internal space requirements, operational and maintenance costs, and impact on energy resiliency.

If the city wants to further encourage district energy systems, local departments should review zoning regulations to identify opportunities to encourage more compact development and a land use mix that supports district-scale energy systems. An example of an attractive mix would be multifamily and commercial uses because of their complementary loads—demand is highest at different times of day for residences and commercial buildings—alongside a hospital complex due to its large baseload.

The city could also develop incentives and/or mandates for buildings to connect to a district-scale energy system. For example, Vancouver, British Columbia, requires all new developments to conduct a district energy feasibility study. For any mandate, local agencies will need to oversee regulations to ensure reasonable rates. Incentives or mandates might include amending local building codes and development permits or agreements to encourage or require district-scale energy system connection.

PROJECT DEVELOPMENT

After the Feasibility phase, the responsibility largely shifts from the municipality to energy system developers (private or public) and users (property owners). The municipality can continue to facilitate implementation using its various authorities, such as land use and building codes, infrastructure management, and access and authority over rights of way. **The Project Development phase includes four steps:**

1. **Concept design and analysis**
2. **Cost-benefit analysis**
3. **Procurement and project delivery**
4. **Facilitating project implementation**

Concept Design and Analysis

To understand the economic potential of a district energy system, the project team will need to work with a system developer or engage an expert in developing and operating district systems to conduct the following activities:

- Concept design: The expert would match the anticipated energy demands of specific buildings to several energy-generating technologies, like those discussed in Appendix B. To encourage a system that can grow, concept design could include the modularity, additional space, equipment, and distribution capacity sufficient for future expansion.
- Life-cycle cost analysis: Each concept design's initial capital and ongoing operating costs, as well as business-as-usual systems that buildings would have in the absence of a district system, are put into a financial model to quantify the long-term business case. This financial model should take into account issues such as environmental and regulatory risk, including potential of carbon regulation and changing energy costs.
- Qualitative value: The expert would compare the different concept designs using qualitative criteria important to stakeholders, which might include resiliency (e.g., to grid or equipment failures), required building space, and timing.

Cost-Benefit Analysis

The energy provider, whether the municipality or a utility, can then conduct an additional analysis for the project stakeholders to understand the full costs and benefits of the district energy system by factoring in financing, risk, and project delivery and operations. This additional analysis could include:

- Risk analysis: Stakeholders might need to identify what risks they each want to hold, share, or transfer. Risks might include not enough customers connecting to the system, future regulation that might undercut the system's benefits, potential increases in future energy and labor costs, and build-out costs potentially being higher than expected. The energy provider can work with the municipality and property owners to identify the best approach to efficiently distribute the risks. The energy provider can also quantify these risks, such as potential cost overruns for building out the system, and fold them into the financial analysis.
- Market research, if applicable: Since the energy provider will likely need outside designers, contractors, and operators to develop the system, it should learn about the market for developing district energy systems and the various partnership and contractual arrangements that are available.
- Financing strategy, if applicable: Depending on the business model and operational agreement, overall costs can vary significantly. For each potential project delivery arrangement and investment strategy (e.g., debt or equity), the energy provider would need to generate different cash flows. Most funding arrangements will fall into one of two scenarios:
    - Design-bid-build: The user bears most of the upfront responsibilities and costs but reaps all associated benefits throughout the system's operation.
    - Build-own-operate: End users make little upfront investment but pay back the third-party developer over time through an energy contract.
- Final financial analysis: Putting all of the cost-benefit analyses together will produce an economic comparison between varying project delivery mechanisms. If the costs of risks are also incorporated, then the comparison will be "risk adjusted."

If the project maintains its commercial viability, the market has shown interest in developing the system, and the project stakeholders understand their roles and commitments, then the stage is set for procuring a system developer who will build the project.

Procurement and Project Delivery

The project team can engage energy developers or operators via a request for qualifications (RFQ) or request for proposals (RFP) unless the property owner or municipal utility chooses to provide the energy itself. Based on responses and subsequent negotiations, the team can establish and implement the agreement for project delivery. The steps to go from a potential project to a delivered project are:

- Procurement (if a third-party developer is desired): As part of the RFP, portions of the concept design, cost-benefit analysis, and district development plan should be paired with the Initial Assessment and Feasibility phase products. The business case for the initial project should be enough to encourage developers and operators to invest in developing the system, but if the RFP also identifies expansion opportunities, more companies might be interested.
- Energy developer or operator business case: Using the information in the RFP, the respondents will analyze the design and other system conditions and conduct their own business case analyses. Using their internal costs and industry experience, they will propose an energy rate that will be the

basis of an agreement. In many instances, a public utility will need to approve this rate and the city should investigate this on a case-by-case basis. At this stage, the developer should include additional partners, such as lenders and investors, system designers, and operators.

- Selecting a project winner and project delivery: The energy developer or operator will select a project winner and work with them to finish design and construct their respective portions of the project.

Facilitating Project Implementation

While much of the project responsibility transfers to the energy producer and users at this point, the public sector could continue to facilitate the district energy system in several ways:

- Permitting distribution and generation: If the initial phase of building the district energy system requires distribution using public rights of way,[7,8] the municipality could help identify routes, expedite permitting, arrange franchise agreements, and otherwise support easier right-of-way crossing. The public sector could also facilitate utility plant construction and operation by streamlining permitting and making regulations clear and predictable. One of the greatest risks to a project is that energy will not be available when the building needs it. The public sector could mitigate this risk by providing clarity on requirements and timing.
- Incentives: Costs for developing the business case and the upfront capital costs are often barriers to system development. The public sector could leverage its low cost of capital to provide debt to projects (or portions of projects), use grants to fund project feasibility studies, provide land for a utility plant, or coordinate distribution costs with other capital projects to minimize costs to energy developers.
- Connection: The public sector can increase the number of users connecting to the system through financial incentives, building code or district-based requirements for new development, and volunteering to connect its own buildings to the new system.
- Short-term expansion opportunities: The public sector could leverage its work in the Initial Assessment and Feasibility phases to communicate the progress and potential of the developing district-scale energy system to local stakeholders and property owners. The public sector can also identify and reserve distribution pathways and have conversations with potential users to provide clarity and build interest in the system.
- Additional financing: The city could earmark funding or apply for grants that would pay for a more detailed feasibility study; identify public finance strategies such as bonds, grants, and tax abatement that could provide low-cost capital for design and construction; and identify sources of capital financing for infrastructure such as the distribution system or central utility plan.
- Zoning: If the district is properly zoned for a range of users and parcel sizes, load size and diversity of users will increase as development continues to advance in the district. This increased demand and diversity could bring more likelihood of project success and expansion for both the project stakeholders and system developers.

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[7] In California, the California Public Utilities Commission regulates the distribution of electricity. There are significant barriers to transmitting electricity in public rights of way and selling energy to more than two adjacent properties. If the buildings are not under a common ownership, which will often be the case in communities, sharing electricity is not feasible between more than two property owners on contiguous land parcels.

[8] In San Francisco, running thermal and electric distribution systems using public rights of way requires a franchise agreement with the municipality, according to the San Francisco Administrative Code Chapter 11 (http://www.sfbos.org/ftp/uploadedfiles/bdsupvrs/ordinances00/o0058-00.pdf).

- Building codes: The municipality can ensure that building codes encourage or require connection to district energy systems, and then work to enforce codes and maintain compliance.

OPERATION, OPTIMIZATION, AND EXPANSION

Once a district-scale energy system is up and running, the system operator will work with stakeholders, including the municipality, to maintain operations, optimize the system's efficiency, and expand it to new properties in the district. Depending on how oversight, regulation, and governance are arranged, the public sector could monitor operations to ensure the district's goals and priorities are being met, work with property owners to generate business cases for system connection, and help negotiate terms between the energy operator and new customers. On the private-sector side, building owners and energy operators can work to minimize costs, expand revenues, and improve overall performance to expand and optimize the system.

In some states, including California, utility providers are "decoupling," or separating profits from consumption of energy. Instead of basing profits on sales, utilities now set rates based on revenue needs, which means that utilities are no longer motivated to sell more energy. On top of decoupling, California also offers financial incentives for utilities to sell less energy, which, in turn, encourages customers to use less energy.

District-scale energy systems could follow the same path in their districts. Building-level energy efficiency could allow district systems to expand their service area without installing additional capacity. This expansion could eventually enable multiple district systems to connect, which could result in further energy efficiency and supply resiliency. Additionally, as a greater diversity of users connect to a district system, several things become increasingly feasible: supplying energy-using utility plants with more sustainable generation technologies; serving critical zones with redundant distribution capable of handling a singular failure more effectively; and meeting district goals.

SAN FRANCISCO PILOT PROJECTS

EPA's Smart Growth Implementation Assistance to the city of San Francisco developed the four-phase process described in Section II after considering how to develop systems for the two potential Eco-Districts identified by the city: the Central SoMa and Transbay Transit Center districts. The city defines Eco-Districts as "neighborhood scale public-private partnerships that can strengthen the economy while creating a stronger sense of place. Creating eco-districts can help achieve the goals of city's Climate Action Plan, Electricity Resource Plan, and Green Building Ordinance."[9]

To fine tune and vet criteria for parcel evaluation, technology types, and options for next steps, the EPA team held a half-day workshop in May 2013 to share findings to-date with stakeholders and elicit their feedback. The stakeholders included public-sector representatives from the San Francisco Planning Department, Capital Planning Committee, San Francisco Department of Public Works, San Francisco Department of the Environment, and San Francisco Public Utilities Commission (SFPUC). Private-sector stakeholders included technical experts, property owners, building developers, and local energy providers Pacific Gas & Electric (PG&E) and NRG. The workshop solicited stakeholders' feedback on the four-phase process and helped develop specific actions the city and other public entities could take to further facilitate district-scale energy in the Central SoMa and Transbay Transit Center districts.

This section describes how each of the four phases could apply in San Francisco, including ideas for public-sector actions. Appendix C includes tables of possible action items, with lead agencies and supporting organizations for each action. For the Feasibility phase, the EPA team provided cursory parcel evaluation scores for the two Eco-Districts. Communities should not use the scoring on these tools to evaluate other districts.

This section also identifies strategies and actions that could help the city and its partners further implement district-scale energy system in the two pilot areas.

INITIAL ASSESSMENT

Defining the district and its goals

In 2013, two major transportation projects were underway in San Francisco—the Central Subway and the Transbay Transit Center. As part of this work, the San Francisco Planning Department began a zoning update to the surrounding Central SoMa and the Transit Center districts. The department identified these two districts as potential Eco-Districts because the neighborhoods are being upzoned for more compact development, receiving transit and pedestrian improvements, adding landscaping, and expecting significant job growth.

The combined area is well positioned to become a center of the region's high-tech industry. With the construction of the Central Subway (scheduled to begin operations in 2018) and the Transbay Transit Center, undeveloped or underdeveloped parcels in the area offer major development opportunities. The area will be upzoned from low-intensity industrial use to compact commercial and residential uses. Public realm and transportation improvements will encourage building owners to upgrade their buildings to meet market demand.

San Francisco's Planning Department defines an Eco-District as "neighborhood scale public-private partnerships that strengthen the economy and reduce environmental impacts while creating a stronger

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[9] San Francisco Planning Department. "The Sustainable Development Program." http://www.sf-planning.org/index.aspx?page=3051. Accessed Feb. 2015.

sense of place and community."[10] Since compact development is a critical component in making district energy systems feasible, the planning department was eager to explore implementing district energy as part of the Eco-District program.

Figure 2: Central SoMa Plan Area.
Source: Central SoMa Eco-District Task Force Recommendations. Nov. 2013. http://www.sf-planning.org/ftp/files/plans-and-programs/emerging_issues/sustainable-development/CentralSoMa_EcoDTaskForceReport_112513.pdf.

Central SoMa is a large neighborhood with diverse uses, including industrial, that is becoming a home to high-tech industry. The Central SoMa Plan proposes to rezone the district for compact, transit-oriented, mixed-use growth, and the city wants to incorporate more efficient and resilient infrastructure in this growth.

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[10] San Francisco Planning Department. "The Sustainable Development Program." http://www.sf-planning.org/index.aspx?page=3051. Accessed Feb. 2015.

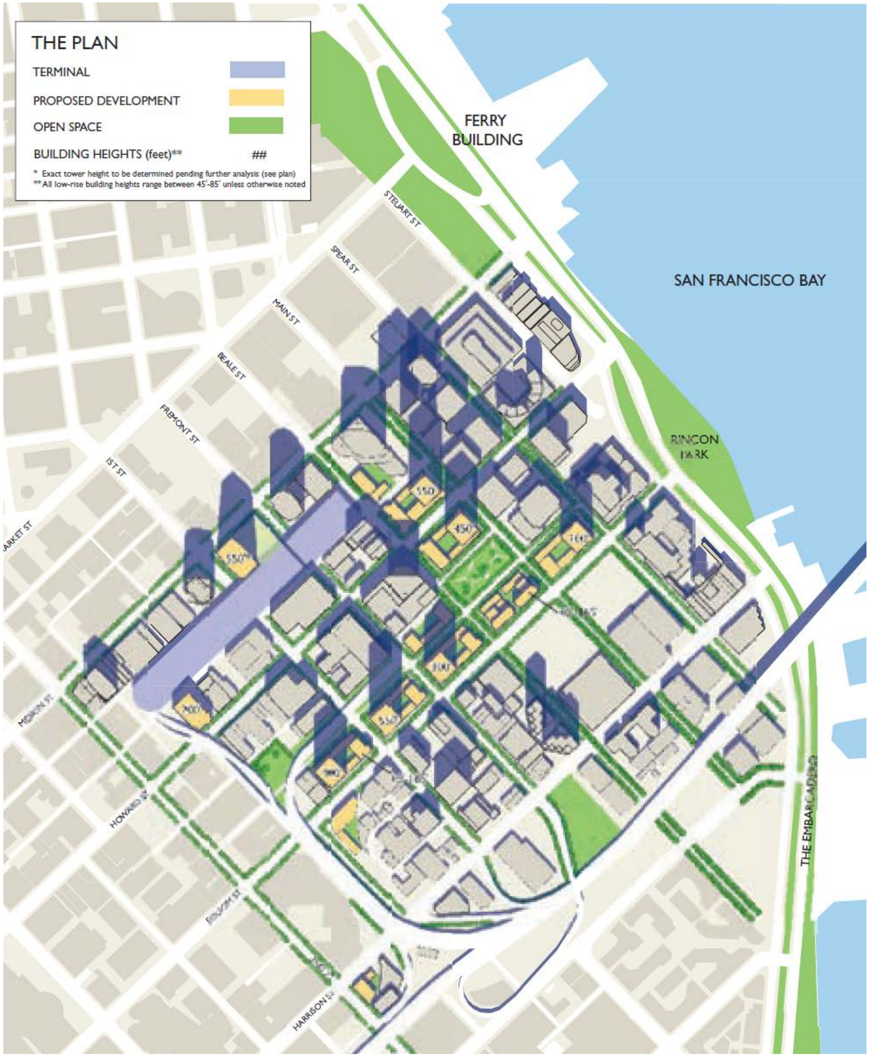

Figure 3: Transbay Redevelopment Area. This area is located in downtown San Francisco in the midst of the city's greatest concentration of transit service. Source: Transbay Redevelopment Area Design for Development.

The Transit Center District is a few blocks east of the Central SoMa District. This neighborhood surrounds the Transit Center, which began construction in 2010. The anticipated new development in this area includes construction of more than 7 million square feet of office space, more than 4,500 new housing units, hundreds of hotel rooms, 200,000 square feet of retail, and 11 acres of new open space. The city outlines the future development for this area in two planning documents: the Transit Center District Plan and the Transbay Redevelopment Plan.

The Central SoMa Task Force and the Transit Center District Plan both set energy-related goals. The Transit Center District Plan states: "There is a great opportunity with the Transit Center Plan to establish a highly energy efficient district-scale approach to energy procurement and consumption, including combined heat and power (CHP), setting up the area to be an exemplar low carbon development. This will help the City to achieve its Climate Action Plan, Electricity Resource Plan and carbon reduction goals."[11]

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[11] San Francisco Planning Department. "Transit Center District Plan." P. 60. http://www.sf-planning.org/ftp/General_Plan/Transit_Center_District_Sub_Area_Plan.pdf. Accessed Jan. 2015.

The Transit Center District Plan's goals include:

- Increase energy efficiency, reduce carbon-intensiveness of energy production, and enhance energy reliability in the district.
- Capitalize on the balanced, dense, mixed-use development in the Transit Center District and Transbay Redevelopment Areas to enact district-scale energy measures.
- Streamline potential implementation of a district energy distribution network by phasing major streetscape and utility works in line with new building development in the Transit Center District and Transbay Redevelopment Areas.

The Central SoMa Eco-District Formation Task Force created a vision for the area to be a "future ready neighborhood." The task force also made the recommendation to "Establish a net zero carbon energy district" using the following strategies:

- Prioritize energy efficiency in existing and new developments.
- Encourage community-scale clean energy systems in areas with intensive infill capacity and anticipated growth.
- Develop incentives to encourage the implementation of community-scale clean energy projects.
- Explore the potential of renewable energy generation and procurement."[12]

San Francisco has identified district-scale energy systems as an important way to meet state and citywide goals and priorities listed below.

California Goals

- Meet net zero energy goals for all new residential construction by 2020 and commercial construction by 2030.[13]
- Achieve 12,000 megawatts of local, renewable distributed generation by 2020.[14]
- Achieve net zero energy for new construction.[15]

San Francisco Goals

- Achieve a greenhouse gas-free citywide electricity system by 2030 using renewable and zero-greenhouse gas energy sources.[16]
- Use 100% renewable electricity for all residential buildings and 80% of commercial buildings.[17]
- Achieve 2.5% annual increase in energy efficiency in the commercial and residential building sectors.[18]

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[12] San Francisco Planning Department. *Central SoMa Eco-District: Task Force Recommendations.* Nov. 2013, p. 7. http://www.sf-planning.org/ftp/files/plans-and-programs/emerging_issues/sustainable-development/CentralSoMa_EcoDTaskForceReport_112513.pdf.

[13] State of California. *California Energy Action Plan, 2008 Update.* 2008. http://www.energy.ca.gov/2008publications/CEC-100-2008-001/CEC-100-2008-001.PDF.

[14] California Governor's Office of Planning and Research. "Renewable Energy in California." http://www.opr.ca.gov/s_renewableenergy.php. Accessed Jan. 2015.

[15] California Energy Commission. "2007 Integrated Energy Policy Report." http://www.energy.ca.gov/2007_energypolicy/. Accessed Jan. 2015.

[16] San Francisco Public Utilities Commission. "2011 Updated Electricity Resource Plan." http://sfwater.org/index.aspx?page=700. Accessed Jan. 2015.

[17] San Francisco Department of the Environment. "San Francisco Climate Action Strategy Update." http://www.sfenvironment.org/cas/milestones. Accessed Jan. 2015.

[18] Ibid.

Identify barriers

Compact, central districts might encounter barriers to implementing district energy systems at this phase of planning. Typical barriers include limited space under streets for additional distribution pipework and the challenge of engaging and aligning building owners into committing to a common vision. The Central SoMa District and the Transit Center District illustrate locally specific challenges.

Central SoMa District

In the Central SoMa District, the initial barriers for successful district-scale energy system implementation are:

- The Central Subway tunnel will run through the middle of the district, which could make it difficult to connect the energy distribution system across the entire district.
- The district's ownership pattern is very complex, with multiple property owners and parcels at various stages of redevelopment. This situation could make it difficult for the city to understand and address the interests of all the key property owners and other stakeholders in the area and could reduce certainty about the overall energy requirements of the proposed district-scale energy system. Engaging property owners early could improve the city's chances of success.

Transit Center District

The three primary obstacles that the city would need to overcome to successfully implement a district-scale energy system in the Transit Center District are:

- As in Central SoMa, there is limited space under the streets, especially near the Transbay Terminal, to run utilities.
- The district has few parcels that could host a larger, centralized utility plant due to development demand, which suggests several smaller, distributed utility plants might be the preferred solution to a central utility plant.
- Development might happen too quickly for the city's implementation of a district energy system to keep pace. Given this, developers could make the buildings ready to accept district energy, though they would also presumably require interim on-site heating and cooling systems as well.

Determining the system's potential based on local context, both present and future

The city has not conducted a formal feasibility analysis for the Central SoMa District. However, with the area's current and future development, there is likely enough demand to continue with the Initial Assessment phase. In the Transit Center District, a formal feasibility analysis commissioned by the city recommended combined heat and power as the preferred generation technology.[19] The assumed development program and phasing would generate sufficient demand. However, natural gas-driven CHP runs counter to the city's goal of reducing greenhouse gas emissions. Using renewable fuels with a CHP system could help meet environmental goals, though it might also be more expensive and have a less certain fuel supply.

During the workshop, stakeholders helped identify actions the city could take to complete the Initial Assessment phase of developing district-scale energy systems for the Central SoMa and Transit Center districts.

- Despite strong momentum and multi-departmental government involvement, a few information gaps remain that present risks to implementing a district-scale energy system. The city might identify these barriers and appropriate agencies or departments that can begin to overcome the barriers and close information gaps.
- The city could estimate the potential customer base and energy demand for each district by using current and future development programs to estimate the total heating, cooling, and electrical loads now and over time.
- The city could use the information from the Initial Assessment phase to determine if the district should expand, shrink, or be divided, as well as revisit the goals and priorities to ensure they remain relevant.

FEASIBILITY

Although the city has not completed the Initial Assessment phase, it has conducted some parts of the Feasibility phase, including some technology selection and communicating with potential energy operators and local developers about the project's potential.

Key public-sector stakeholders include city departments, including the San Francisco Planning Department, Capital Planning Committee, San Francisco Department of Public Works, San Francisco Department of the Environment, San Francisco Public Utilities Commission, and the cross-departmental eco-districts working group. External stakeholders include potential energy developers, independent consultants, building owners and developers, PG&E, NRG, the California Energy Commission (CEC), and potentially many more.

In the May 2013 workshop, the EPA team explained the four-phase approach to the stakeholders and asked for candid feedback, which it incorporated throughout this report. This feedback also helped city staff fill in gaps in ongoing decisions about investing in district energy in the two districts.

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[19] URS/Simon Associates Joint Venture. *Final Summary Report: Planning-Level Options Appraisal Study, Combined Heat and Power—Transbay District*. Dec. 2010.

Selecting Appropriate Technologies

Using the criteria and tools presented on pages 11-27, the EPA project team conducted a preliminary analysis to identify technologies most likely to succeed in the pilot districts. The team customized the load weightings for San Francisco but not for each of the pilot districts because the goals, priorities, and loads were so similar. Tables 8 and 9 show the results.

Parcel Evaluation

Although a few key future real estate developments have been identified as potential anchors and a few property owners considered hosting sites for a utility plant, the city has not yet conducted a formal parcel evaluation for either district. Because one of the challenges with testing district energy feasibility is the uncertainty surrounding the size, type, and timing of future development parcels, the city might want to make parcel evaluation the next step to help identify catalytic projects that could be the basis of either district's energy system.

Central SoMa District

As part of the Central SoMa planning process, the city has conducted a very thorough public outreach and engagement process,[20] including a task force to engage key public and private stakeholders to collaborate and advise on district-scale, environmentally sustainable development projects for the district. The Central SoMa Eco-District Task Force established an Eco-District vision, recommendations, and implementation strategies.[21]

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[20] San Francisco Planning Department. "The Central SoMa Plan 2013." http://www.sf-planning.org/index.aspx?page=2557. Accessed Jan. 2015.

[21] San Francisco Planning Department. "Central SoMa Eco-District: Task Force Recommendations." Nov. 2013. http://www.sf-planning.org/ftp/files/plans-and-programs/emerging_issues/sustainable-development/CentralSoMa_EcoDTaskForceReport_112513.pdf.

Table 8: Technology Selection Tool. The EPA project team applied this technology filter to the Central SoMa and Transit Center districts. The criteria are scored from 1 to 5, with 5 being the most favorable, and the criteria are weighted from 1 to 5, with 5 being the most favorable, and the criteria are weighted from 1 to 5, with 5 being the most important to users of the filter. This scoring is specific to the Central SoMa and Transit Center districts and should not be used for other projects.

	Primary Technology Considerations				Energy Generation				Secondary Considerations							
	GHG REDUCTION POTENTIAL	REGULATIONS	RISK	PRIMARY SCORE	HEATING	COOLING	POWER	LOAD OPPORTUNITY SCORE	DISTRIBUTION	LIFE CYCLE COST	CUP SIZE	CAPEX	OPEX	WATER INTEGRATION POTENTIAL	SECONDARY SCORE	OPPORTUNITY SCORE
PHOTOVOLTAICS	5.0	5.0	5.0	60.0	1.0	1.0	4.0	25.0	4.0	3.0	5.0	3.0	4.0	1.0	42.0	127.0
SOLAR THERMAL	5.0	5.0	4.0	56.0	5.0	2.0	1.0	21.0	4.0	4.0	5.0	4.0	5.0	2.0	49.0	126.0
CENTRAL CONDENSER WATER	3.5	4.0	4.0	46.0	4.0	4.0	1.0	25.0	4.0	5.0	4.0	5.0	4.0	3.5	52.5	123.5
CENTRAL HEATING & COOLING	3.3	3.0	3.0	37.0	4.0	4.0	1.0	25.0	2.5	4.5	3.0	3.5	5.0	2.0	41.0	103.0
HEAT RECOVERY CHILLERS	3.0	3.0	3.0	36.0	5.0	4.0	1.0	27.0	2.5	4.0	3.0	3.0	4.0	3.0	38.5	101.5
BIOFUEL (AVG OF NAT GAS USERS)	3.8	3.8	2.8	41.3	3.1	2.4	2.4	25.7	2.7	3.3	3.1	2.3	3.0	2.1	33.8	100.8
CENTRAL COOLING	3.0	2.0	4.0	36.0	1.0	4.0	1.0	19.0	3.0	4.0	4.0	4.0	4.3	2.0	43.3	98.3
DISTRIBUTED HEATING & COOLING	1.0	5.0	5.0	44.0	3.0	3.0	1.0	20.0	5.0	1.0	5.0	1.0	1.0	1.0	32.0	96.0
TRIGENERATION	4.3	1.5	1.0	27.0	4.0	3.0	4.0	37.0	1.5	4.0	1.8	1.8	3.3	3.0	29.8	93.8
WIND	5.0	2.0	3.0	40.0	1.0	1.0	2.5	17.5	4.0	2.0	4.0	2.0	4.0	1.0	35.0	92.5
CENTRAL HEATING	2.0	2.0	4.0	32.0	4.0	1.0	1.0	16.0	3.0	4.0	4.0	4.3	4.0	2.0	43.5	91.5
FUEL CELLS	3.0	2.5	2.5	32.0	2.0	1.0	5.0	32.0	2.5	3.0	2.0	1.0	2.5	2.0	27.0	91.0
COGENERATION	3.8	1.5	2.0	29.0	4.0	1.0	4.0	31.0	1.5	4.0	2.0	2.0	3.0	3.0	30.5	90.5
GROUND SOURCE HEAT REJECTION	2.0	1.5	3.0	26.0	5.0	5.0	1.0	30.0	2.0	2.0	3.0	3.0	4.0	5.0	33.0	89.0
BAY WATER COOLING	2.0	1.0	3.0	24.0	5.0	5.0	1.0	30.0	2.0	2.0	3.0	3.0	4.0	5.0	33.0	87.0
Weighting	*4.0*	*4.0*	*4.0*	*1.0*	2.0	3.0	5.0	*1.0*	*3.0*	*3.0*	*2.0*	*2.0*	*1.0*	*1.0*	*1.0*	

Demand for San Francisco

Table 9: Color-coded Technology Selection Tool. This version of the technology filter for the Central SoMa and Transit Center districts is identical to Table 8 except that it is color-coded to highlight how well the technologies meet the criteria. Red indicates a relatively low score, suggesting potential barriers, while green suggests more appropriate technologies. The weighting ranges from 1 to 5, with 5 being the most important to users of the filter.

	Primary Technology Considerations				Energy Generation				Secondary Considerations							
	GHG REDUCTION POTENTIAL	REGULATIONS	RISK	PRIMARY SCORE	HEATING	COOLING	POWER	LOAD OPPORTUNITY SCORE	DISTRIBUTION	LIFE CYCLE COST	CUP SIZE	CAPEX	OPEX	WATER INTEGRATION POTENTIAL	SECONDARY SCORE	OPPORTUNITY SCORE
PHOTOVOLTAICS	🟩	🟩	🟩	🟩	🟥	🟥	🟩	🟨	🟩	🟨	🟩	🟨	🟩	🟥	🟩	🟩
SOLAR THERMAL	🟩	🟩	🟩	🟩	🟩	🟧	🟥	🟧	🟩	🟩	🟩	🟩	🟩	🟧	🟩	🟩
CENTRAL CONDENSER WATER	🟨	🟩	🟩	🟩	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟩	🟩
CENTRAL HEATING & COOLING	🟨	🟨	🟨	🟨	🟩	🟩	🟥	🟨	🟧	🟩	🟨	🟩	🟩	🟧	🟩	🟨
HEAT RECOVERY CHILLERS	🟨	🟨	🟨	🟨	🟩	🟩	🟥	🟨	🟧	🟩	🟨	🟨	🟩	🟨	🟨	🟨
BIOFUEL (AVG OF NAT GAS USERS)	🟩	🟩	🟨	🟨	🟨	🟧	🟧	🟨	🟨	🟨	🟨	🟧	🟨	🟧	🟧	🟨
CENTRAL COOLING	🟨	🟧	🟩	🟨	🟥	🟩	🟥	🟧	🟨	🟩	🟩	🟩	🟩	🟧	🟩	🟨
DISTRIBUTED HEATING & COOLING	🟥	🟩	🟩	🟩	🟨	🟨	🟥	🟧	🟩	🟥	🟩	🟥	🟥	🟥	🟧	🟨
TRIGENERATION	🟩	🟧	🟥	🟥	🟩	🟨	🟩	🟩	🟧	🟩	🟧	🟧	🟨	🟨	🟧	🟧
WIND	🟩	🟥	🟨	🟨	🟥	🟥	🟧	🟥	🟩	🟧	🟩	🟧	🟩	🟥	🟨	🟧
CENTRAL HEATING	🟥	🟥	🟩	🟧	🟩	🟥	🟥	🟥	🟧	🟨	🟨	🟩	🟨	🟥	🟩	🟧
FUEL CELLS	🟨	🟧	🟧	🟧	🟧	🟥	🟩	🟩	🟧	🟨	🟧	🟥	🟧	🟧	🟥	🟧
COGENERATION	🟩	🟧	🟧	🟧	🟩	🟥	🟩	🟩	🟧	🟩	🟧	🟧	🟨	🟨	🟧	🟧
GROUND SOURCE HEAT REJECTION	🟧	🟧	🟨	🟥	🟩	🟩	🟥	🟩	🟧	🟧	🟨	🟨	🟩	🟩	🟧	🟥
BAY WATER COOLING	🟧	🟥	🟨	🟥	🟩	🟩	🟥	🟩	🟧	🟧	🟨	🟨	🟩	🟩	🟧	🟥
Weighting	*4*	*4*	*4*	*1*	*2*	*3*	*5*	*1*	*3*	*3*	*2*	*2*	*1*	*1*	*1*	

Demand for San Francisco

Transit Center District

With the Transit Center District Plan adopted in July 2012, the city is moving forward with its vision for developing a new commercial corridor and establishing a highly energy-efficient district heating and power network for the district. The city has identified necessary amendments to city codes, as well as the need for an analysis for pipe and utility sizing that would inform these amendments.

Because of the intensive development planned for this district, the city's eco-districts working group has prioritized a district-scale energy system here. San Francisco owns several parcels in the district and could require future users of those sites to connect to and/or host a utility plant. The Transit Center, currently under construction, would not be a near-term user of a district-scale energy system but is helping to bring new development in the area.

City Actions

Based on the Initial Assessment and Feasibility phases, the following actions could help the city identify other locations for district-scale energy system projects.

Enable More Technologies to Meet Goals and Priorities

The technology-filtering process that the EPA team undertook suggests that the energy generation technology with the most potential to generate cost-effective energy does not meet San Francisco's overarching goals and priorities for the two Eco-Districts. That technology is fossil fuel-powered combined heat and power, which would source electricity and hot water locally but would also increase greenhouse gas emissions. To encourage electricity-generation technologies that help meet city and state environmental and community goals (e.g., non-fossil fuel combined heat and power, trigeneration, fuel cells, photovoltaics, and wind), the city could work with partners to find feasible and affordable implementation strategies.

To encourage technologies that meet goals and priorities, cities can:
- *Work with partners.*
- *Talk to potential district-scale energy operators.*
- *Support regulatory changes.*
- *Help identify plant sites.*
- *Review local goals and priorities.*

The city could also use findings from the technology filter and parcel evaluation exercises to talk with potential district-scale energy operators about which technologies could meet both demand and district goals. The city could support changes to state regulations for electricity distribution, or SFPUC could agree to purchase electricity generated through technologies that meet city goals. City planning staff could help identify large parcels in each district that are willing to host a utility plant for technologies that require more space, such as trigeneration and cogeneration. Finally, the city and stakeholders might decide to reassess how appropriate district energy is for a given neighborhood, or based on given local goals and priorities.

Identify Initial Projects

The city can help identify potential catalytic projects using the parcel evaluation and energy demand mapping process described in Section 0. By mapping the rights of way in the district and overlaying right-of-way improvement plans, the city can better understand existing space and capacity for new infrastructure, as well as future opportunities for adding energy distribution infrastructure. As the city scores parcels based on connection and hosting potential, the city can overlay the energy demand map with the right-of-way map to better understand how the network's capacities and limitations intersect with parcel opportunities. This understanding will help the city engage owners of prime sites for hosting or connecting to the system.

The public sector should review or create a framework for franchise rights, energy purchase agreements, and connection standards.

In San Francisco, NRG Thermal already runs a district steam system. The city can work with NRG to understand how they can expand or integrate the existing steam loop with other thermal networks for future district-scale energy systems.

Reduce Implementation Barriers and Encourage System Connection

In complex projects, such as initiating a district-scale energy system, the government can provide clarity and minimize unknowns around legal issue and regulations. Energy regulations and rules about distribution can be an opportunity for the public sector to improve district-scale energy system viability. For example, the public sector could develop district-based regulations for all new buildings and major retrofits of existing buildings with central plants that require them to connect to and use the district energy system. San Francisco has a similar ordinance in place requiring the use of recycled water. If the city cannot modify the building code, it could create a business case to help building owners make the decision about whether to connect to the district system.

A viable district-scale energy system must create certainty for property owners and provide economies of scale. The system's user base has to be large and diverse enough to make the project feasible and to attain economies of scale. Local and state regulation changes that could encourage district energy include:

- Local building codes could be adapted to encourage connection to more efficient district energy supplies. Connection would need to be cost effective under California's Title 24, as was done for the "solar ready" provisions of Title 24 and locally adopted versions of the Title 24 Reach Code.[22]
- Adjustments to the Title 24 Building Energy Efficiency Standards (specifically the alternative calculation methods) to properly credit the energy benefits of procuring energy from a district-scale system.

Initially, there will be many unknowns, such as right-of-way capacity or thermal distribution regulations, but by moving through Initial Assessment and Feasibility, stakeholders can identify major barriers, collect necessary data, and work to change policy or the project plans to minimize barriers and uncertainty.

Create a Legal Framework for District-Scale Energy Distribution

An energy developer will need to understand the legal and regulatory framework to distribute electricity and thermal energy, and building owners that might connect to the system will need the same clear understanding of their legal rights and risks. Unless current regulations change for electricity distribution across public rights of way, the SFPUC would likely need to purchase any excess electricity generated and not used within a district. Energy developers would gain certainty from clear pricing and franchise agreements with the SFPUC. In general, the district will need a legal framework for franchise rights, energy purchase agreements, and connection standards.

Other regulatory obstacles that the public sector might need to address include:

- The California Public Utilities Commission (CPUC) regulates electrical district-scale energy systems and would face much more complicated regulatory barriers than heating and cooling systems. There are significant barriers to transmitting electricity in public rights of way and selling energy to more than two adjacent properties. If the buildings are not under a common ownership, which will often be the case in communities, sharing electricity is not feasible between more than two property owners on contiguous land parcels.

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[22] San Francisco Department of Building Inspection. "Green Building Requirement." www.sfdbi.org/index.aspx?page=268. Accessed Feb. 2015.

- Unless a parallel electrical distribution network is created, the only likely way to move electricity across public rights of way throughout these two districts is on PG&E's electricity network. This could be done through the following mechanisms:
    - Using the feed-in tariff rules for on-site generation and subsequent resale of the electricity by PG&E.
    - Using the net energy metering rules: Both the feed-in tariff rules and net energy metering rules now in effect are unlikely to still be in effect as the Eco-District comes to fruition. Due to the long development timeline for the Eco-District, a long-term agreement with PG&E specifically on "wheeling" electricity (i.e., transporting it over transmission lines) might be advisable. This agreement would be the functional equivalent of establishing vested development rights before proceeding with development plans or investments.
    - Using San Francisco's Community Choice Aggregation program: The city could explore Community Choice Agreement power purchasing rules, net metering rules, and feed-in tariff rules within the program's service territory.
- In addition to following current regulatory processes for obtaining approval, project sponsors could tie this district-scale energy project to the broader goal of helping achieve the CPUC's net zero energy goal. The city and other stakeholders could work with the commission's net zero energy leadership to help streamline the approval process.
- Stakeholders should consider overlaps between the district-scale energy system's potential for expansion and city mandates for renewable portfolio standards, which require the use of renewable sources in energy production. In 2013, CEC awarded the city a Community Integrated Renewable Energy grant, which provides additional support to understand the links between district-scale energy systems and renewable mandates. The city's project team is working closely with PG&E, NRG, and Arup to assess the feasibility of a community energy center in the Central SoMa District. The center would integrate renewable energy and enabling technologies, such as district heating and cooling, renewable electricity, waste-derived biogas, geothermal heat pumps, regenerative braking energy from public transportation, demand response, and smart distribution technology, to serve multiple community members outside of a single-owner campus environment.

Although it would be difficult, local and state agencies could amend regulations to establish a formal Eco-District boundary in which the vested interests in the Eco-District could substantially restructure the energy procurement and delivery rules and regulations. Any new or revised rules would need to benefit established utilities and simultaneously meet city objectives, state efficiency goals, and state renewable procurement goals.

PROJECT DEVELOPMENT: A POSSIBLE SCENARIO FOR SAN FRANCISCO PILOTS

The incumbent utilities in San Francisco are PG&E and SFPUC. They provide natural gas, electricity, and/or water services, and neither provides thermal energy. The incumbent thermal utility in San Francisco is NRG Thermal LLC. This report assumes, for planning purposes for the Central SoMa and Transit Center pilots, that any district thermal utility would likely be a private entity such as NRG Thermal rather than a city agency.

The district-scale energy system will likely start with a new development that is large enough to become the first customer of a utility plant. Additional customers, either new construction or existing buildings, would need to be added so that the load served by the district-scale energy system makes business sense to the provider. This initial demand node would preferably be contained within a large city block so minimal public right of way would be required to provide or build transmission infrastructure. The energy center would be in the basement or another suitable location in or near this new development. The property owner would need to designate space in the development that it could lease to the private utility for access and maintenance of the utility plant. Depending on the technology used and the size of distribution network, some buildings might need to be required to host a utility plant while others would simply be required to connect to it.

The private utility provider would be responsible for system growth and management, including outreach to property owners in the district to sign up for thermal services. New developments are likely to represent much of the growth potential of the system since they do not have existing building systems and can design buildings to more easily connect to a district-scale energy system. As new developments move through the design and permitting processes, the city has the opportunity to influence design decisions and encourage district-scale energy system connection to help achieve code compliance. The utility provider would need to install sufficient supply and return pipes to reach new customers. When advantageous, the provider could negotiate the creation of additional nodes, much like the initial node was created, to serve clusters of new customers and provide a source of energy to the larger district loop when created.

The private utility would be responsible for distributing the thermal service from the utility plant to the heat exchanger of each customer. Distribution pipes in the public right of way would require a franchise agreement with the city. This piping could be the most expensive component of a district-scale energy system, and, therefore, investment and installation of the network must be made carefully and could require assistance from city agencies. Assistance could take the form of public financing, assisting with dig permits, cost sharing, or other incentives and in-kind assistance.

City Actions

The private utility that owns and operates the system could take several actions to ensure that participation and maintenance of the district-scale energy system is commercially viable:

- Private stakeholders would select a preferred generation and distribution concept that balances energy demand with capital and operating costs and with project goals and priorities.
- The operator could put the concept design costs and benefits into a financial model to assess the system’s initial financial viability.
- The private-sector representatives would identify relevant financial, legal, or environmental risks and figure out how to distribute those risks among the stakeholders.
- The utility would likely set up a process of procurement and negotiations to design, build, finance, own, operate, and maintain the district-scale energy system.

- The public sector might need to provide approvals at different points in the process, and local agencies may want to set up a transparent process to work smoothly and efficiently to make it easy for the private sector to meet city environmental, economic, and community goals.

OPERATION, OPTIMIZATION, AND EXPANSION

In this phase, both San Francisco districts would likely have at least one building that provides an anchor load. Private- and public-sector stakeholders would continue to be involved in any anchor-load building project to ensure expansion, optimization, and expansion of the district-scale energy system. If the city and stakeholders want to, any planned right-of-way work or new building development can be an opportunity to expand the system or connect separate systems. As technologies change or new energy sources identified, the city could consider adapting the system and regulations to take advantage of technological advances. Long-term success will depend on other property owners in the district providing feedback to the utility and the city, followed by necessary system adjustments and policy changes to improve the system and help meet local and state goals and priorities.

APPENDIX A: EPA SMART GROWTH IMPLEMENTATION ASSISTANCE

Communities around the country are looking to get the most from new development and to maximize their investments. Frustrated by development that gives residents no choice but to drive long distances between jobs and housing, many communities are bringing workplaces, homes, and services closer together. Communities are examining and changing zoning codes that make it difficult to build neighborhoods with a variety of housing types. They are questioning the fiscal wisdom of neglecting existing infrastructure while expanding new sewers, roads, and services into undeveloped areas. Many places that have been successful in ensuring that development improves their community, economy, and environment have used smart growth principles (see box). Smart growth describes development patterns that create attractive, distinctive, and walkable communities that give people of varying age, wealth, and physical ability a range of safe, convenient choices in where they live and how they get around. Growing smart also means that we use our existing resources efficiently and preserve the lands, buildings, and environmental features that shape our neighborhoods, towns, and cities.

Smart Growth Principles

Based on the experience of communities around the nation, the Smart Growth Network developed a set of 10 basic principles:

- Mix land uses.
- Take advantage of compact building design.
- Create a range of housing opportunities and choices.
- Create walkable neighborhoods.
- Foster distinctive, attractive communities with a strong sense of place.
- Preserve open space, farmland, natural beauty, and critical environmental areas.
- Strengthen and direct development towards existing communities.
- Provide a variety of transportation choices.
- Make development decisions predictable, fair, and cost effective.
- Encourage community and stakeholder collaboration in development decisions.

Source: Smart Growth Network. "Why Smart Growth?" (2006) **www.smartgrowth.org/why.php.**

However, communities often need additional tools, resources, or information to achieve these goals. In response to this need, EPA launched the Smart Growth Implementation Assistance (SGIA) program to provide technical assistance—through contractor services—to selected communities.

The goals of this assistance are to improve the overall climate for infill, brownfields redevelopment, and the revitalization of non-brownfield sites—as well as to promote development that meets economic, community, public health, and environmental goals. EPA and its contractor assemble teams whose members have expertise that meets community needs. While engaging community participants on their aspirations for development, the team can bring their experiences from working in other parts of the country to provide best practices for the community to consider.

Since 2009, EPA has engaged staff from the U.S. Department of Transportation (DOT) and the U.S. Department of Housing and Urban Development (HUD) in SGIA projects. This collaboration is part of the HUD-DOT-EPA Partnership for Sustainable Communities, under which the three agencies work together to help improve access to affordable housing, more transportation options, and lower transportation costs while protecting the environment in communities nationwide. Using a set of guiding livability principles and a partnership agreement, this partnership coordinates federal housing, transportation, and other infrastructure investments to protect the environment, promote equitable development, and help to address the challenges of climate change.

For more information on the SGIA program, including reports from communities that have received assistance, see *www.epa.gov/smartgrowth/sgia.htm*. For more information on the Partnership for Sustainable Communities, see *www.sustainablecommunities.gov*.

APPENDIX B: DISTRICT-SCALE ENERGY TECHNOLOGIES

This appendix describes some district-scale energy technologies that may be applicable to both San Francisco Eco-Districts. Each technology type includes an overview description and a table with general guidelines that cities might use to evaluate each technology type to the local context and needs.

CENTRAL HEATING

Central heating systems have heat generation equipment, such as boilers, that serves a district's space and/or water heating needs. Central heating generation is well-suited to compact communities in cold (heating-dominated) climates, but it can also work in regions with seasons that require a lot of cooling and heating, and/or have year-round water heating loads. The heat generation source converts primary fuel into thermal energy, which is then distributed to the point of use through a pipe network (typically underground). Figure B-1 illustrates a sample central heating system.

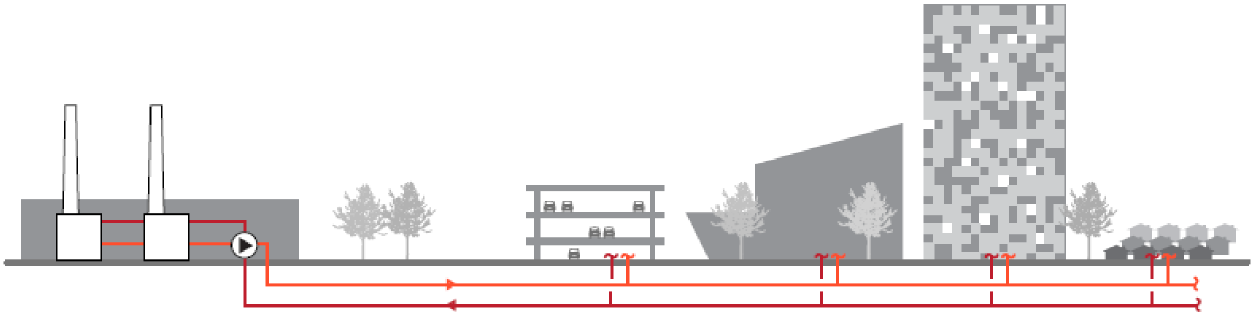

Figure B-1: This schematic diagram of a centralized heating system shows a central plant that delivers hot water or steam (bright red) to connected buildings through a pipe network that returns cooler water or condensate (dull red) to the central plant.

GREENHOUSE GAS REDUCTION POTENTIAL	Generally favorable compared to distributed heating plants located throughout the district. Central plants are more efficient because they have larger machines with enhanced controls, monitoring, and stack treatment. Using renewable, low-carbon fuels and an efficient distribution network can further reduce greenhouses gas emissions.
REGULATIONS	Varied. Central heating can run into opposition and permitting hurdles because the plants concentrate emissions and might not fit the aesthetics of the neighborhood.
CENTRAL UTILITY PLANT SIZE	Smaller footprint than multiple district supply technologies such as cogeneration and central heating and cooling. A central plant is usually smaller than the aggregate of distributed heating plants.
DISTRIBUTION	Generally more favorable than multiple district supply technologies such as cogeneration and central heating and cooling. An exception is a central system that uses a two-pipe system that can supply either heating or cooling, but not both simultaneously. Central heating scores less favorably compared to the sum of distributed heating plants.
RISK	Generally minimal. Fuel storage, if any, and local emissions should be considered.

CENTRAL COOLING

Central cooling systems have equipment, such as chillers, that serve a district's space and/or process cooling needs common in industrial and manufacturing facilities. Central cooling is typically well-suited to compact communities in warm (cooling-dominated) climates, but it can also work in regions with significant cooling and heating seasons. The cooling generation source converts the primary fuel into thermal energy and distributes the cooling to users through a pipe network (typically underground). Figure B-2 illustrates a sample central cooling system.

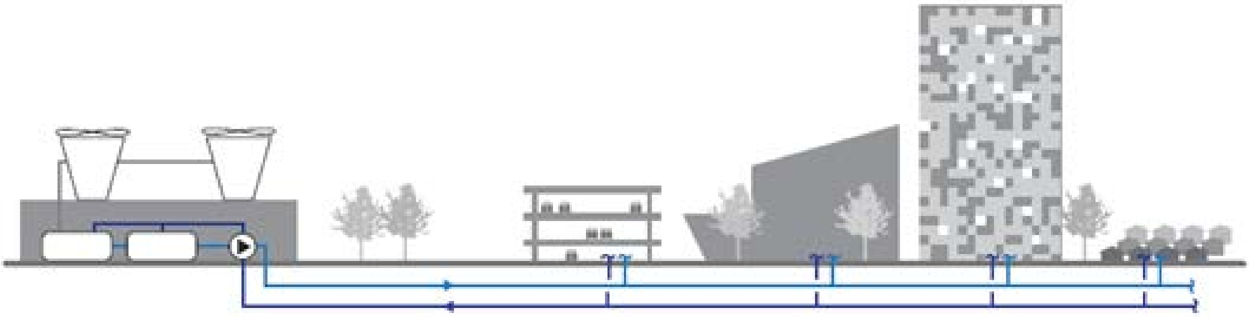

Figure B-2: This schematic diagram of a centralized cooling system shows chillers and cooling towers in a central plant that delivers chilled water (light blue) to various connected buildings through a pipe network that returns warmer water (darker blue) to the plant.

GREENHOUSE GAS REDUCTION POTENTIAL	Generally favorable compared to distributed cooling plants. Central plants are more efficient because they use larger machines with enhanced controls and monitoring. Using low-carbon fuels to generate energy can further reduce greenhouse gas emissions.
REGULATIONS	Varied. While centralizing cooling equipment can reduce net emissions and required floor space across the district, central cooling plants can spark opposition and possibly permitting delays because they are not attractive.
CENTRAL UTILITY PLANT SIZE	Smaller footprint than multiple district supply technologies such as cogeneration and central heating and cooling. A central plant is usually smaller than the aggregate of distributed cooling plants.
DISTRIBUTION	Generally more favorable than multiple district supply technologies such as cogeneration and central heating and cooling. One exception would be a central system that uses a two-pipe system that can supply either heating or cooling, but not both simultaneously. More extensive distribution network required than in a system with several cooling plants.
RISK	Minimal. Cooling towers create water condensation in the air that some people think is smoke, which may pose a public perception problem.

CENTRAL HEATING AND COOLING

Central heating and cooling systems serve a district's space and/or residential heating and space and/or industrial process cooling needs. Central heating and cooling systems are well-suited for compact communities in regions with hot summers and cold winters.

GREENHOUSE GAS REDUCTION POTENTIAL	Generally positive compared to distributed heating and cooling plants. Central plants are more efficient because of larger machines with enhanced controls, monitoring, and stack treatment. Using low-carbon, renewable fuels can further reduce emissions.
REGULATIONS	Varied. While centralizing heating and cooling equipment can reduce net emissions and required floor space across the district, it can run into opposition and permitting hurdles because the plants concentrate emissions and might not fit the aesthetics of the neighborhood.
CENTRAL UTILITY PLANT SIZE	Generally larger footprint than single district supply technologies such as central cooling and central heating. One exception would be a two-pipe system that can supply either heating or cooling, but not both simultaneously. A central plant is usually smaller than the aggregate of distributed heating and cooling plants.
DISTRIBUTION	Less favorable than single district supply technologies such as central cooling and central heating. Less favorable than the sum of distributed heating and cooling plants.
RISK	Combined risks of central heating and central cooling.

CENTRAL CONDENSER WATER SYSTEM

Central condenser water systems have a centralized thermal reservoir that serves a district's space heating and cooling needs. In some instances, a central condenser water system can partially meet a district's residential heating and industrial process cooling needs as well. Condenser water systems are typically well-suited to compact, mixed-use communities in mild climates, such as San Francisco. In a central condenser water system, distributed reversible thermal systems, such as heat pumps, add heat to the district from the thermal reservoir, or remove heat from the district and reject it to the thermal reservoir. The thermal reservoir can be the district pipe network (typically underground), but it could also include thermal energy storage in a welded steel tank containing water. Figure B-3 illustrates a sample centralized condenser water system.

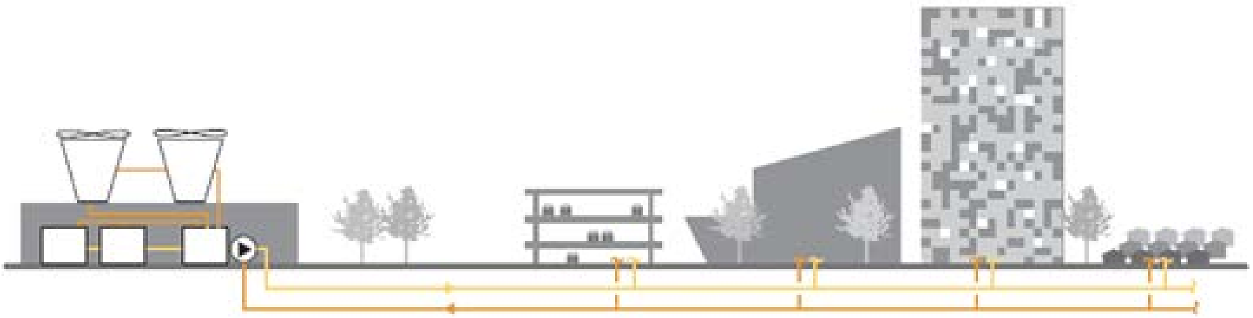

Figure B-3: This schematic diagram of a centralized condenser water system shows cooling towers in a central plant that delivers condenser water (yellow) to various connected buildings through a pipe network and returns water at a higher or lower temperature (dark orange), depending on whether it is being used for heating or cooling, to the plant.

Communities well suited for central condenser water systems have balanced demand for the amount and timing of heating and cooling, requiring no net heat add-on or removal from the reservoir. However, this perfect balance in loads rarely occurs, and central condenser water systems, therefore, typically use supplemental centralized or distributed heat addition or rejection systems such as boilers and cooling towers.

GREENHOUSE GAS REDUCTION POTENTIAL	Varies depending on district density, fuel source, and climate. An efficient distribution network and renewable, low-carbon fuels can further reduce emissions.
REGULATIONS	Varied. While centralizing heating and cooling equipment can reduce net emissions and required floor space across the district, it can run into opposition and permitting hurdles because the plants concentrate emissions and might not fit the aesthetics of the neighborhood.
CENTRAL UTILITY PLANT SIZE	Less favorable than single district supply technologies such as central cooling and central heating. Comparable to multiple district supply technologies. More favorable than the sum of distributed condenser water and/or heating and cooling plants.
DISTRIBUTION	Comparable to single district supply technologies such as central cooling and central heating. Generally more favorable than multiple district-supply technologies. An exception is a central heating and cooling system that uses a dual-temperature two-pipe system with a seasonal switchover comparable to the sum of distributed condenser water, and/or heating and cooling plants dependent primarily on density.
RISK	Minimal.

CENTRAL HEAT RECOVERY CHILLERS

Central heat recovery chillers, or large centralized heat pump chillers, generate heating and cooling simultaneously by recycling unwanted heat from the district cooling loop and using it in the district heating loop. These systems are well-suited for compact communities that demand cooling and heating at the same time.

Communities best suited for heat recovery chiller systems have balanced demand for the amount and timing of heating and cooling, requiring no net heat add-on or removal. However, this perfect balance in loads rarely occurs, and heat recovery chiller systems typically also use centralized heat addition and cooling and rejection systems such as boilers, chillers, and cooling towers.

GREENHOUSE GAS REDUCTION POTENTIAL	Varies based on primary fuel source and the degree to which heating and cooling loads overlap. An efficient distribution network and renewable, low-carbon fuels can further reduce emissions.
REGULATIONS	Varied. While centralizing heating and cooling equipment can reduce net emissions and required floor space across the district, it can run into opposition and permitting hurdles because the plants concentrate emissions and might not fit the aesthetics of the neighborhood.
CENTRAL UTILITY PLANT SIZE	Less favorable than single district supply technologies such as central cooling and central heating. Comparable to multiple district supply technologies. More favorable than the sum of distributed condenser water and/or heating and cooling plants.
DISTRIBUTION	Less favorable than single district supply technologies such as central cooling and central heating. Comparable to other multiple district-supply technologies such as central heating and cooling. An exception is a central heating and cooling system that uses a two-pipe system that can supply either heating or cooling, but not both simultaneously. Less favorable than the sum of distributed condenser water and/or heating and cooling plants.
RISK	Minimal.

GROUND SOURCE HEAT EXCHANGE

Ground source heat exchange refers to the rejection of heat to and the extraction of heat from the ground. Ground source heat exchange systems require exchanging an equal amount of heating and cooling energy over a year. However, thermal demand is not always coincident and equal to supply, so ground source heat exchangers typically use supplemental central or distributed heat rejection and/or additional systems such as boilers and cooling towers.

Ground source heat exchange systems typically consist of vertical or horizontal buried piles, tubing, or other forms of heat exchangers. These are connected to the district thermal network through additional heat exchangers typically located in the central utility plant building.

GREENHOUSE GAS REDUCTION POTENTIAL	Positive. The heating and cooling energy reduction in a well-designed system typically outweighs the additional pumping energy, reducing greenhouse gas emissions.
REGULATIONS	Stringent. Though building foundations often require piling and boring work similar to that required by ground source heat exchange systems, people might be unfamiliar with the technology and might oppose it, causing delays in permitting.
CENTRAL UTILITY PLANT SIZE	Less favorable than single district supply technologies such as central cooling and central heating. Comparable to multiple district supply technologies. More favorable than the sum of distributed condenser water and/or heating and cooling plants. A “bore field” (where the pipes go into the ground) is needed in addition to the central utility plan.
DISTRIBUTION	Less favorable than single district supply technologies such as central cooling and central heating. Less favorable than the sum of distributed heating and cooling plants.
RISK	The operator should identify where underground water contamination exists in the district and avoid putting tubing or wells in places where they might penetrate plumes of contaminated water.

LAKE, BAY, OR SEAWATER COOLING

Cooling systems that use deep lake water, bay water, or seawater is similar to ground source heat exchange except that a body of water (in the case of San Francisco, the San Francisco Bay) is used as a heat source and a heat deposit. The balance of heating and cooling demands is usually less important as long as the body of water is large enough not to change temperature dramatically over time. However, since agencies typically regulate natural water cooling systems for environmental reasons, the system’s capacity and effectiveness could be compromised, rendering it infeasible. A detailed study including local environmental effects is always necessary when using a body of water for heat exchange. Also, like ground source heat exchange systems, users may need supplemental or backup systems.

GREENHOUSE GAS REDUCTION POTENTIAL	Positive. The heating and cooling energy reduction in a well-designed bay-water cooling system would typically outweigh the additional pumping energy, reducing greenhouse gas emissions.
REGULATIONS	Stringent. Water bodies are thriving ecosystems that can be disrupted by a change in temperature. Depending on the system's thermal demands, the water body's temperature would increase while the system is operating and then equalize when it is not operating. The amount of the change in temperature of the water is often heavily regulated.
CENTRAL UTILITY PLANT SIZE	Less favorable than single district supply technologies such as central cooling and central heating. Comparable to multiple district supply technologies. Smaller than the sum of distributed condenser water and/or heating and cooling plants. The larger physical requirements of a bay-water cooling system are pumps and heat exchangers in the water body.
DISTRIBUTION	Less favorable than single district supply technologies such as central cooling and central heating. Greater than the sum of distributed heating and cooling plants.
RISK	Effects on local water ecosystems due to temperature changes and maintaining adequate capacity in the long term.

COMBINED HEAT AND POWER (COGENERATION)

Combined heat and power systems simultaneously generate heat and power from small or medium centralized energy plants located close to the energy consumers. These systems generally require compact development and a constant heating demand such as space and/or water heating. The combined heat and power approach captures heat released during power generation and distributes it to a district network. These systems typically use fuel more efficiently, lose less electricity in distribution, and are more economically feasible compared to conventional boiler and grid electricity. However, combined heat and power systems rarely meet a district's entire heating and/or electrical needs, and additional heating systems such as boilers and supplemental connection to power stations is typically required. Exhibit B-4 shows a diagram of a combined heat and power system.

GREENHOUSE GAS REDUCTION POTENTIAL	Varies based on district density and greenhouse gas emissions of local power grid. An efficient distribution network and renewable, low-carbon fuels can further reduce emissions.
REGULATIONS	Combined heat and power can run into opposition and permitting hurdles because the plants concentrate emissions and might not fit the aesthetics of the neighborhood.
CENTRAL UTILITY PLANT SIZE	Less favorable than single district supply technologies such as central cooling and central heating. Comparable to other multiple district supply technologies. Comparable or smaller than the sum of distributed heating plants and power interconnection spaces within the district.
DISTRIBUTION	Less favorable than single district supply technologies such as central cooling and central heating. Comparable or larger than multiple district-supply technologies. Larger than the sum of distributed heating and electrical distribution.
RISK	Combined heat and power can create local air pollution emissions from the combustion process, even when using low-carbon fuels that reduce greenhouse gas emissions. Central combined heat and power plants should be located away from sensitive uses, such as schools.

COMBINED COOLING, HEATING, AND POWER (TRIGENERATION)

Combined cooling, heating, and power (trigeneration) simultaneously produces power and thermal energy, including varying amounts of cooling and heating supply. Similar to combined heat and power, trigeneration typically requires mixed-use, compact development. A continuous cooling demand differentiates the two systems. This constant cooling demand, or “base cooling load,” is typical for buildings such as data centers and hospitals with operating suites. Like combined heat and power, trigeneration also requires constant electrical demand, which can be from an on-site use or an off-site customer such as the local utility grid.

Users can simultaneously supply heating and cooling in parallel or in series depending on the trigeneration system, configuration, and primary mover technology. The system uses an absorption chiller for cooling.

Combined cooling, heating, and power systems still require supplemental district cooling technologies such as traditional vapor compression chillers to supply non-baseload cooling demands (much like top-up boilers in a combined heat and power system). Furthermore, absorption chillers create more waste heat than electric chillers, and require greater heat rejection capacity. Cooling towers will use more water. Often, air-cooled heat rejection systems use water-cooled systems.

GREENHOUSE GAS REDUCTION POTENTIAL	Varies for heating and electrical components based on district density and greenhouse gas emissions of the local power grid. Typically less favorable because of cooling component. In cases where heat is being “wasted” by an existing process and can instead be captured and used to drive an absorption chiller to generate cooling, these systems would reduce greenhouse gas emissions. An efficient distribution network and renewable, low-carbon fuels can further reduce emissions.
REGULATIONS	Somewhat stringent. Combined heat and power can run into opposition and permitting hurdles because the plants concentrate emissions and might not fit the aesthetics of the neighborhood.
CENTRAL UTILITY PLANT SIZE	Larger than single district supply technologies such as central cooling and central heating. Comparable to other multiple district supply technologies such as combined heat and power and central heating and cooling. Comparable or smaller than the sum of distributed heating plants and power connection spaces within the district.
DISTRIBUTION	Less favorable than single district supply technologies such as central cooling and central heating. Comparable or larger than multiple district-supply technologies. Less favorable than the sum of distributed heating, cooling, and electrical distribution.
RISK	Trigeneration can create local air pollution emissions from the combustion process, even when using low-carbon fuels that reduce greenhouse gas emissions.

PHOTOVOLTAICS AND SOLAR THERMAL

Photovoltaic and solar thermal systems harness and convert solar energy into useful electric or thermal (hot water or steam), or both. This energy can help meet a district’s electric and/or thermal demands, reducing the need for conventional energy sources for these purposes. Solar resources are not always available or adequate to meet energy demand during peak times. Solar resources can also exceed energy requirements at non-peak energy use times such as weekend afternoons. As a result, operators usually connect solar arrays to a traditional electrical grid, in some cases incorporate net energy metering policies that feed excess solar energy to the grid for a credit against the overall electricity bill.

In some communities, solar energy could fully meet demand without a connection to the grid. These communities typically store the energy for use during non-sunlight hours.

Solar energy and storage are typically most suitable in regions with a lot of sun, where other sources of energy such as petroleum or natural gas are expensive, where communities are trying to reduce greenhouse gases and other pollution, and in locations with little shading and where rooftop or other solar collector space is plentiful.

GREENHOUSE GAS REDUCTION POTENTIAL	Positive. The magnitude of the reduction depends on the region's climate and the amount of sunlight it gets.
REGULATIONS	Generally negligible. Though solar energy systems are generally highly visible, they typically have no (or very slowly) moving parts, such as wind power, and can sometimes even reduce other project permitting hurdles because solar is seen as an amenity for a development.
CENTRAL UTILITY PLANT SIZE	Generally not relevant. Solar energy systems typically use available space on rooftops or on other structures.
DISTRIBUTION	Photovoltaic: Generally more favorable than single and multiple supply district systems.
	Solar thermal: Generally more favorable or comparable to a single supply district system. Smaller than a multiple supply district system.
	Solar thermal and electric: Generally more favorable or comparable to a single supply district system. Smaller than a multiple supply district system.
RISK	Minimal.

BIOFUELS

Biofuels are fuels derived from plants or raw materials and can come in the form of solids, liquids, or gases. Ethanol biofuels, derived from fermentation of raw crops, are controversial because they displace crops used for food and do not necessarily decrease greenhouse gas emissions. Biodiesel is made from vegetable oils and animal fats and can be used in emergency generators and other diesel engines.

The most relevant biofuel for typical district-scale energy systems is biogas. Systems produce biogas by breaking down organic matter in the absence of oxygen. Biogas is a renewable energy source. Using biogas in place of natural gas in heat and/or power generation technologies can reduce greenhouse gas emissions.

GREENHOUSE GAS REDUCTION POTENTIAL	Different biofuels have different emissions reduction potential. Biogas has the greatest greenhouse gas emission reduction compared to fossil fuels.
REGULATIONS	Production is regulated.
CENTRAL UTILITY PLANT SIZE	Generally integrated into a waste facility, but the biogas would be used in a central heating, cogeneration, or trigeneration plant. Refer to the descriptions of those technologies for central utility plant sizes.
DISTRIBUTION	The biogas needs to be distributed to the central utility plan and buildings in the district, typically underground.
RISK	Relatively low.

APPENDIX C: SAN FRANCISCO PILOT ACTIONS

This appendix provides possible actions that public and private entities could take as they decide whether and how to implement district energy systems in the two San Francisco pilot areas, Central SoMa and the Transit Center District. The actions are categorized as:

1. Actions to complete the Initial Assessment phase.
2. Actions to enable more technologies to realize district goals and priorities.
3. Actions to identify initial projects.
4. Actions to reduce implementation barriers.
5. Actions to create a legal framework for district-scale energy system distribution.
6. Actions to develop a well-informed and commercially attractive district-scale energy project.
7. Actions to implement, expand, optimize, and maximize systems.

Each action includes a short description and the key stakeholders that could either lead or support the effort. These potential roles of different stakeholders are suggestions based on input from the May 2013 workshop. This list of actions and roles is simply an option for how this process could work moving forward. Potential lead and support entities include:

- City and county of San Francisco
- San Francisco Department of the Environment (SFE)
- San Francisco Planning Department (Planning)
- San Francisco Department of Public Works (DPW)
- San Francisco Department of Building Inspection (DBI)
- Capital Planning Committee (Capital Planning)
- San Francisco Public Utilities Commission (SFPUC)
- Pacific Gas & Electric (PG&E)
- California Public Utilities Commission (CPUC)
- California Energy Commission (CEC)
- Others as described

These public and private entities may choose to work together to take the next steps, as determined by the city and the stakeholders, toward implementing district-scale energy projects in Central SoMa and the Transit Center District.

Note that in the tables of actions below, “L” indicates those stakeholders that might lead the effort and “S” those stakeholders that could provide support.

I. ACTIONS TO COMPLETE INITIAL ASSESSMENT PHASE

		Stakeholders			
Actions	Description	SFE	Planning	DPW or Capital Planning	SFPUC
Calculate the potential energy demand of each of the systems	Using the current and future development programs for each of the districts, estimate the total heating, cooling, and electrical loads in the districts now and over time by multiplying the building areas by their use-specific energy consumption numbers.	S	L		S
Identify initial barriers	List barriers and potential actions to overcome those barriers.	S	L	S	S
Reassess district boundaries and goals and priorities	Reassess the district boundaries (expand, shrink, or divide) and revisit the goals and priorities to ensure they remain relevant.	S	L	S	S

2. ACTIONS TO ENABLE MORE TECHNOLOGIES TO REALIZE DISTRICT GOALS AND PRIORITIES

		Stakeholders							
Actions	Description	SFE	Planning	DPW or Capital Planning	SFPUC	District-Scale Energy System Operator	Property Developer	PG&E	CPUC or CEC
Support refined electricity distribution policy	Support new regulations regarding electricity distribution or ensure that the SFPUC would purchase electricity. Electricity generation technologies such as cogeneration, trigeneration, fuel cells, photovoltaics, and wind would benefit from more flexible regulations.	L			S			S	S
Understand the potential of SFPUC as electricity purchaser					L			S	S
Discuss findings from selecting appropriate technologies	Use the findings in Section 0 to ask potential district-scale energy system operators about their preferred generation technologies given demand and the goals and priorities.	S	S		L	S			
Identify complementary infrastructure and better fuels	Identify other infrastructure investments, such as those that could support recycled water or anaerobic digestion and that could improve the performance of some of the technologies. Identify local source(s) for biogas to replace natural gas-based technologies (particularly relevant to trigeneration, cogeneration, and fuel cells).	L			S				S
Minimize other regulatory barriers	Use scientific data and completed projects to encourage the use of bay water for heat rejection and to encourage drilling for ground-source heat pumps, if these technologies seem to be good fits for the district.	L							
Identify parcels that could host a utility plant	Identify large parcels or a group of contiguous parcels that are willing to host a utility plant. Larger sites would make it easier to use technologies that require more space, such as trigeneration and cogeneration.		L			S	S		
Coordinate right-of-way capacity with distribution system	Identify right-of-way capacity to assess the feasibility of different types of distribution system and energy generation technology.			L					
Reassess goals and priorities	Continue to reassess project goals and priorities as policies change or project costs become clearer, especially in the process of selecting appropriate technologies.	S	L						

3. ACTIONS TO IDENTIFY INITIAL PROJECTS

		Stakeholders						
Actions	**Description**	**SFE**	**Planning**	**DPW or Capital Planning**	**SFPUC**	**Mayor's Office**	**District-Scale Energy System Operator**	**Property Developer**
Map space in rights of way	Determine where rights of way have space, capacity, and access.			**L**	**S**			
Overlay right-of-way plans	Identify opportunity areas to lay a distribution network in coordination with other underground infrastructure projects.			**L**	**S**			
Score district parcels on connection	Identify parcels that could connect to a district-scale energy system using the parcel evaluation tool in Section II.	**S**	**L**					
Score district parcels on distributed plant hosting and connection	Using the tool in Section II, identify parcels that could both host a utility plant and connect to it.	**S**	**L**					
Create energy demand map using parcel scoring	Show connection and hosting opportunities in each district.	**S**	**L**		**S**			
Overlay right-of-way mapping on energy demand map	Understand how the network capacities and limitations intersect with ideal parcels for connecting and hosting.	**S**	**L**	**S**				
Identify and engage owners of top 10 users and hosting sites	Get preliminary agreement from owners and users that could anchor the system to either host or connect.	**S**	**L**			**S**		**L**
NRG integration assessment	Explore how the existing steam loop might integrate with other thermal networks.	**S**	**L**		**S**	**S**	**S**	

4. ACTIONS TO REDUCE IMPLEMENTATION BARRIERS

		Stakeholders						
Actions	**Description**	**SFE**	**DBI**	**SFPUC**	**City Attorney**	**District-Scale Energy System Operator**	**PG&E**	**CPUC or CEC**
Require system connection	Develop district-based regulations for all new buildings and major retrofits of existing buildings with central plants that require them to connect to and use district energy. The regulation could be similar to San Francisco's recycled water ordinance.	**L**	**S**	**S**	**S**	**S**	**S**	**S**
Develop building-level business cases for different building sizes and uses	If the city cannot modify the building code, it could create a business case to justify a building owner and design team's decision to connect to a district-scale energy system. This case could include energy, operations, space, and capital cost savings, as well as more qualitative aspects such as aesthetics.	**L**				**S**		
Create thermal energy measurement legislation	Building on San Francisco's energy disclosure ordinance and California AB 1103, San Francisco could encourage sub-metering of heating and cooling to help the city implement and potentially expand thermal energy generation within the districts.	**S**	**S**	**S**	**S**	**S**	**S**	**L**

5. ACTIONS TO CREATE A LEGAL FRAMEWORK FOR DISTRICT-SCALE ENERGY SYSTEM DISTRIBUTION

		Stakeholders							
Actions	**Description**	**SFE**	**DPW or Capital Planning**	**City Attorney**	**SFPUC**	**District-Scale Energy System Operator**	**Property Developer**	**PG&E**	**CPUC or CEC**
Create electricity purchasing framework	Clear pricing and franchise agreements would provide certainty for energy developers. Clarify regulations regarding energy distribution across public rights of way.	**S**		**S**	**L**	**S**	**S**	**S**	**L**
Create legal framework for thermal distribution	Develop a legal framework for thermal distribution within districts. This framework would include franchise rights, energy purchase agreements for various timeframes, and connection standards.	**S**	**S**	**S**	**L**	**S**	**S**	**S**	**L**

6. ACTIONS TO DEVELOP A COMMERCIALLY ATTRACTIVE DISTRICT-SCALE ENERGY PROJECT

		Stakeholders					
Actions	**Description**	**DBI**	**Planning**	**DPW or Capital Planning**	**SFPUC**	**System Operator or Developer**	**Property Developer**
Concept design	Identify a preferred technology type and distribution concept that balances energy demand with capital and operating costs.	**S**		**S**			**L**
Life-cycle cost analysis	Put the concept design costs and benefits into a financial model to understand the initial viability of a district-scale energy system.						**L**
Qualitative assessment	Balance the quantitative assessment with non-financial factors such as the goals and priorities of the system and its users.		**S**				**L**
Risk analysis	Identify applicable risks and determine how to appropriately distribute risks to various stakeholders.						**L**
Third-party engagement	Understand the different business models and partnerships in the market.					**S**	**L**
Financing strategy	Identify a strategy that balances risk and commercial performance for the system.					**S**	**L**
Final financial analysis	Incorporate the cost of the various risks and financing strategies to provide a summary financial perspective on potential project delivery options.						**L**
Procurement	Develop a request for proposals that incorporates the concept design and project goals.					**S**	**L**
Energy developer or operator business case	Develop an energy rate, based on design and operating conditions. This rate will likely require approval from either SFPUC or CPUC.					**L**	
Identifying project winner and negotiation	Reach agreement with an operator to design, build, finance, own, operate, and/or maintain the district-scale energy system.					**L**	**L**
Project Delivery	Work with all relevant stakeholders to construct the project.	**S**	**S**	**S**	**S**	**L**	**L**

7. ACTIONS TO OPERATE, OPTIMIZE, AND EXPAND SYSTEMS

		Stakeholders						
Actions	**Description**	**SFE**	**DBI**	**Planning**	**DPW or Capital Planning**	**SFPUC**	**Energy Developer**	**Property Developer**
Expansion	Continue to identify opportunities to initiate new district-scale energy systems and expand existing systems.	**S**		**S**	**S**		**L**	
	Coordinate with right-of-way work and new building development to expand the operating systems and/or connect separate district-scale energy systems.	**S**		**S**	**S**		**L**	
Optimization	Continue to improve the district-scale energy system to meet the original and evolving goals. As technologies change or new energy sources are identified, the city could consider adapting the system to take advantage of technological advances.	**S**	**S**	**S**	**S**	**S**	**L**	**S**
	Consider how building efficiency programs and energy regulations might reduce demand for energy from the district systems or allow more users to connect to the systems without needing expansion.	**L**	**L**				**S**	

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