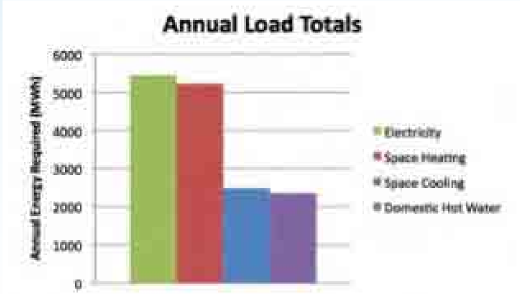
Partnership *for* Sustainable Communities



DENVER, COLORADO

South Lincoln Redevelopment Project Energy Charrette

FINAL REPORT

April 2011

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U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Office of Brownfields and Land Revitalization
Washington, DC 20460

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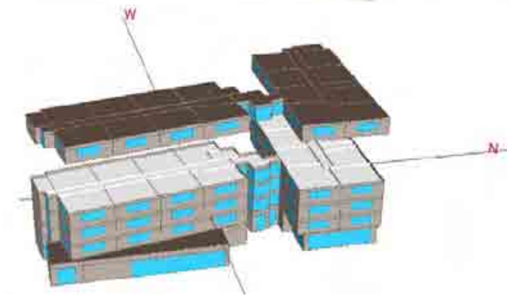
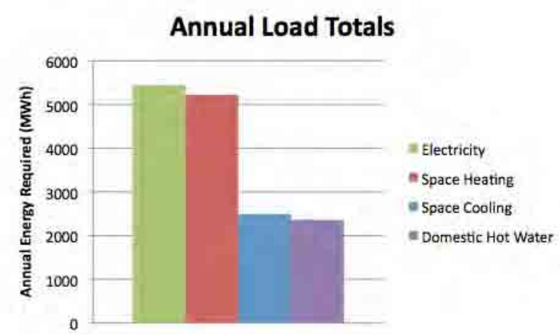




1. Executive Summary

The Denver Partnership for Sustainable Communities Brownfield Pilot is led by the U.S. Environmental Protection Agency (EPA) Office of Brownfields and Land Revitalization (OBLR) and the Office of Sustainable Communities (OSC), and is comprised of the EPA, Department of Housing and Urban Development (HUD), and Department of Transportation (DOT). These agencies are working together to ensure federal resources and policies support the development of sustainable communities. The partnership is based on “livability principles” that guide inter-agency collaboration and support the integration of safe, reliable and economical transportation; affordable, energy-efficient housing; and sustainable reuse of unoccupied or underutilized land. Pilot communities were selected by EPA’s Brownfields Program with input from HUD and DOT, and receive technical assistance and support from these agencies to build on past investments, identify opportunities to connect housing, transit and brownfields within the development, and to coordinate resources that can further the integration of sustainability.

The Denver Housing Authority (DHA) is an affordable housing provider whose South Lincoln Redevelopment Project (SoLi) was selected as a Partnership for Sustainable Communities Pilot in 2010. In recent years, the SoLi project has received much collaborative support from state, local and community stakeholders and leaders in defining and establishing its concept and goals. In 2008, prior to being selected as a Pilot project, a 3-acre portion of the SoLi site (at 10th and Osage, included as part of Phase 1 of the project) received funding from the EPA’s Brownfield Cleanup grant program to cleanup the area to unrestricted residential use cleanup standards. In addition, Phase 1 of the project received $10 million in American Recovery and Reinvestment Act (ARRA) funding from HUD to support its development. In September 2009, the DHA and key project team members finalized a Master Plan for SoLi focusing on land use, energy, transportation and public health. In addition, this Master Plan identifies sustainability goals as integral to the project vision (to view the SoLi Master Plan, go to: http://www.denverhousing.org/development/SouthLincoln/MasterPlan/Pages/default.aspx).

SoLi is a transit-oriented development that strives to be as energy efficient as possible in order to decrease utility bills for its units and reduce the project’s carbon footprint. Since the cost of housing and transportation has a direct impact to household budget, one goal of the project is to incorporate strategies that emphasize energy use reduction in order to decrease the cost of living for residents. In addition, as SoLi is a 5-phase project, the phasing of housing and development will need to be carefully evaluated in order to determine an approach that minimizes the displacement of current residents, maintains affordability and culture of the neighborhood and community, and effectively incorporates strategies that can be implemented as part of a phased-project.

Developers, designers, policy makers, and residents participated in an EPA sponsored Energy Charrette to identify opportunities and constraints of a district energy solution, specific building and occupant scale energy strategies, key partnerships and financial resources, and develop an implementation plan with DHA with a goal to create a net-zero energy development for South Lincoln residents. As part of the Pilot and charrette process, technical assistance was provided under contract by SRA International, Inc., and YRG sustainability. In addition, National Renewable Energy Laboratory (NREL) provided energy analysis based on building scale modeling to evaluate the energy impacts and feasibility of district-wide systems.

1.1 Energy Priorities

The overarching goal of the South Lincoln energy charrette was to evaluate and provide recommendations for a series of solutions that could create a net-zero energy balance for the development. This, of course, meant a discussion regarding what definition of net-zero was appropriate and what the appropriate metrics for measuring this should be.

Fundamental to this discussion was a need to identify a solution that was economically realistic – from both a first cost and life cycle cost perspective. Therefore, the metrics and priorities that eventually emerged as the driving factors were:

- Occupant comfort, health and wellness, including elements such as access to the outdoors and daylight via operable windows, natural ventilation, etc.
- First cost and net-present value
- Greenhouse gas (GHG) and fossil fuel reductions per $ spent
- Logistically and operationally manageable (shifting the operational costs from fuel to labor, in the form of job creation, was viewed as acceptable and even attractive in some cases, so long as the increase in operations didn't represent an undue burden or level of risk for failure)
- Flexibility and adaptability to future technologies, fuel prices, etc.

Much of the effort, therefore, was aimed at (a) reducing demand and (b) using less energy and GHG emission intensive modes of energy delivery. Additionally, since SoLi is a 5-phase project, strategies will need to be evaluated based on how well they can be integrated into each project phase. The electricity grid serving the project, it should be noted, represents a fairly high energy and GHG emission intensity because much of Colorado's electricity is generated by coal-fired power plants; this meant that producing as much of the project's electricity needs on-site became of paramount importance. It also meant that shifting to electric forms of heat, such as a ground source heat pump (GSHP) system, would likely not be as attractive (given the higher emissions per kilowatt of electricity) as other options, unless that electricity could be produced on-site via renewable sources. With these considerations and circumstances, the order of operations for a solution became as follows:

1. Reduce design demand as much as possible by emphasizing:
   a. Lighting reductions, including the Energy Star Advanced Lighting Package
   b. Plug Load reductions, by installing high efficiency Energy Star appliances
   c. Cooling reductions, by switching to non-compressor based alternatives such as evaporative cooling (which is an option given Denver's dry climate), or passive cooling using strategies such as shading, thermal mass, and orientation
   d. Heating reductions, by specifying advanced envelopes and allowing for passive solar heat during winter
2. Accommodate as much of the non-HVAC electrical loads, i.e. lighting, plug, and auxiliary load electricity demands from on-site sources, namely either on-site photovoltaic (PV) collectors or cogeneration (an on-site generator producing both heat and electricity)
3. Provide as much heat as possible from highly efficient boilers or cogeneration systems, or
4. To reach true on-site net-zero energy, use either biomass or solar-based heating, or shift the heat to ground source heat pumps with the electricity supplied from on-site solar.

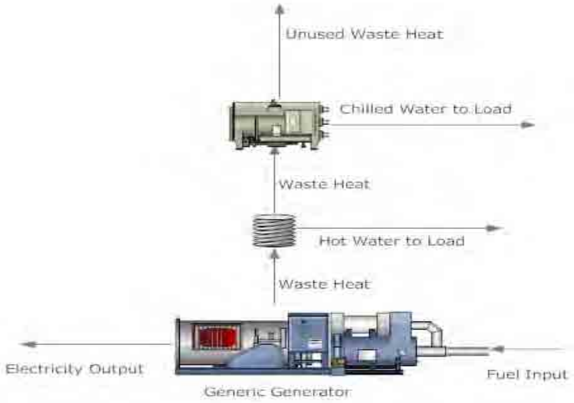
To reach the true net-zero goal would require that either the biomass option was cost and logistically acceptable (daily truck load deliveries of fuel during the winter season and weekly deliveries throughout the rest of the year), or that the on-site solar potential was enough to accommodate (a) the lighting, plug, and auxiliary loads and (b) still have enough to accommodate the electricity requirements for the GSHP or solar thermal production. Because it was later determined via a site-wide energy balance that the on-site, rooftop, solar capacity could only accommodate the lighting, plug, and auxiliary loads, the highly efficient boilers (Option 3) also became a reasonable target; i.e. not achieving net-zero, but targeting a reduction in overall GHG emissions, including those produced at the upstream power plant, on the order of 80-90%.

Photovoltaic panels

1.2 Summary of Key Findings

The results of this analysis represent a mix of economic and technical feasibility at both the building level and the district-wide level. Much of the discussion that follows deals with the supply side options at the district level, but it should be noted that this supply is intended to meet a dramatically reduced demand due to efficiency measures undertaken at the building level (see *Framing the Problem*, below). One of the main conclusions of this analysis is that because electricity represents the highest intensity of GHG emissions for the project's demand profile, finding ways to economically offset this becomes the top priority. Further, because electricity rates are relatively cheap in Colorado, installing expensive equipment to produce electricity on-site is generally a poor investment from a financial perspective. With this mind, we can draw the following conclusions about each of the supply side alternatives:

PV: Given the incentive structure that is in place in Colorado for PV (yielding between $2.50 and $3.50 per installed Watt), PV fares relatively well from a financial perspective. More importantly, because PV is an emissions-free means of producing electricity on-site, it has by far the greatest potential to reduce overall GHG emissions and fossil fuel use. It should be noted that PV may compete with other rooftop uses such as rooftop patio areas with planters for additional amenity space and potential for habitat and heat island reduction, green roof for habitat and stormwater management, or greenhouse for food production. The PV solution should support, rather than compromise, these other important rooftop uses, such as by creating shade, for example.



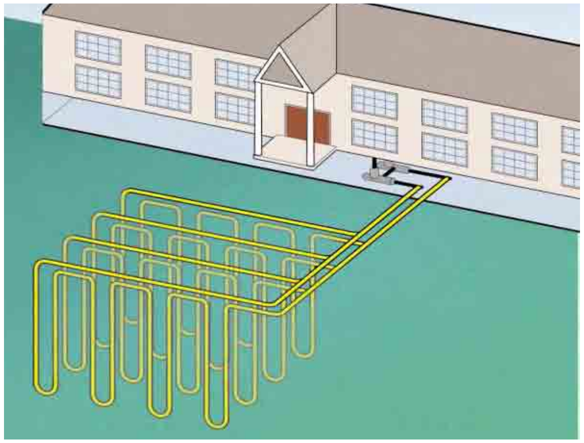
Cogeneration and trigeneration systems use waste heat.

Cogeneration: Cogeneration – the production of on-site electricity and the capture and use of the resulting waste heat – generally does well when (a) electricity prices are high, (b) there is a consistent use for as much of the electricity and heat as possible (i.e. from an economic perspective, the ideal is to run the cogeneration system at 100% capacity, 24 hours / day, 365 days / yr, but in reality, the electric and heat load profiles vary throughout the day and year). The latter is usually achieved where there exists a diverse mix of demand profiles within a development, such as residential, commercial, and industrial, because in those cases, there is a more consistent and continual demand for both electricity and heat.

Because the South Lincoln project is primarily residential and will also include a variety of mixed-used developments, a diverse mix of load profiles doesn't exist and the resulting economics are less favorable. Further, one can either size the system to offset as much of the electricity as possible (yet this would result in a huge surplus of waste heat, reducing the economic viability of such a system), or they can size the system to offset as much of the heat as possible, generally resulting in a much smaller system, since the heat output makes up 60-70 percent of the useful energy. However, a smaller system will offset a lower percentage of the project's electricity needs, resulting in a much smaller overall impact at reducing GHG emissions.

Trigeneration: The discussion of trigeneration is very similar to that of cogeneration, except that for an increase in capital cost, one can add an absorption chiller which can produce cooling from the system's waste heat in the summertime where there is no demand for that heat. This could prove to be an attractive option if there was significant cooling demand to justify the increase in first cost. However, because the cooling demand is relatively small, and it is envisioned that the buildings should be able to accommodate cooling through passive and evaporative means, there is little justification for a trigen system.

Wood chips being delivered to a biomass energy facility



Ground source heat pumps use energy drawn from the ground

Biomass: As was discussed above, the use of a biomass system is one of only three ways to achieve net-zero on-site (the others being the use of solar PV with GSHPs and PV with solar thermal for 100% of the electrical and heating load). The use of biomass in a district heating system represents a lower order priority, because it is displacing on-site natural gas combustion, which has a much lower overall GHG and fossil fuel impact than electricity production. Therefore, a biomass district system should only be employed after a solution for electricity production has been implemented. Further, the economics of biomass-based district heat is among the worst performers of the systems considered. However, there may be a role for a biomass based district heating system, either now or in the future, in the following scenario: If PV can be used to offset 100% of the lighting, plug, and auxiliary loads, and it is determined that a district heating scheme is the best option for meeting the remaining heat demand, then a biomass-based system might be attractive in-lieu of a natural gas fired boiler approach.

Solar Thermal: Along with biomass, solar thermal had the worst financial performance of the strategies considered. In part, this is due to the financial incentives that favor PV (utilities are more inclined to support on-site electrical production, especially peak production, as it helps avoid the need to build additional power plants). The economics of solar thermal are even worse when one sizes the systems to accommodate for both space heat and domestic hot water (DHW), as opposed to just DHW as the current analysis has done. The reason for this is that there is a fairly consistent demand for DHW throughout the year, whereas the demand for space heat is seasonal, and a system that is sized to produce enough heat to supply both space heat and DHW will have a very large surplus of waste heat in the summer.

There is also a competition for roofspace between PV and solar thermal, and given that PV displaces the higher GHG emissions intense electricity and has more favorable economics, PV would generally be the winner. The only exception to this would be if PV were able to accommodate the on-site electrical loads with additional roofspace to spare. In this case, solar thermal could be used to offset some of the heating load. However, it is expected that in reality, it would be unlikely there would be much rooftop to spare as the PV required to offset the on-site electrical loads would occupy the majority if not all of the available roofspace because higher density buildings (e.g., high rise buildings) have less roofspace per unit for PV.

District Ground Source Heat Pumps (GSHPs): As was discussed above, GSHP systems shift the supply of heat from gas to electric, or from a lower emissions fuel source to a higher one. Granted, the efficiency savings for GSHP systems is significant, but the overall benefit from the savings is nearly erased by the increase in emissions intensity at the power plant. Further, GSHP systems are generally economically beneficial when there is a year-round demand for space heating or cooling. Given that there is relatively little cooling demand (and it is envisioned that this demand can be accommodated by evaporative means), the economics are relatively poor for very little net gain. It should be noted, however, that if there was a surplus of roofspace for PV (after lighting, plug loads, and auxillary equipment were accounted for), then a GSHP system coupled with PV would be one of the three ways to achieve true net–zero for the project.

2. Introduction

The South Lincoln Redevelopment Project is a 17.5 acre development that seeks to revitalize South Lincoln homes by enabling residents the opportunity to enjoy the unique advantages of a holistic, transit-oriented development realized through the core attributes established during the design process: a highly green mixed-use community, focused on a healthy lifestyle, increased non-auto mobility, an integration of the resource conservation and management systems, and a diverse mix of new and existing residents. The redevelopment will include new residential units and a mix of retail, commercial and community services at the ground floor to encourage and promote activity along the streets. The project also includes planned outdoor amenities, including a new plaza and promenade, and a variety of open spaces, to enrich the neighborhood.

SoLi is a large multi-phase development project that is currently constructing the Phase 1 building and site plan in the Northwest corner of the development. Active and continuous community involvement and support has contributed to the development of the Master Plan that was created in September 2009 and the Neighborhood Plan that was approved in September 2010. An ongoing group of committed stakeholders have focused on defining the project goals and vision, and have begun to identify the design elements of the project. As the SoLi project has been selected to receive support by the Partnership agencies (HUD, DOT, and EPA), DHA plans to utilize this interagency support to execute the vision and ideals for the project. Although future phases of the project included in the SoLi Master Plan are awaiting funding and have not been designed, the scope of the Energy Charrette focused on the full development of all future phases of the SoLi development and surrounding neighborhood areas. The charrette utilized the efforts and progress to date, and allowed opportunity to further define the project's vision and next steps. Results from the charrette influenced the RFP requirements for Phase 2, and has also shifted how DHA and the project team view energy consumption by considering the strategy's CO2 emissions intensity and impact in addition to its output and efficiency.

Working group presentation during charrette

2.1 Framing the Problem

Residential development energy reduction strategies are almost always developed at the building scale on a project-by-project basis yet most options for efficient on-site energy generation do not work well, if at all, at the building scale, and are better optimized at a district scale. In addition, building energy end uses are heavily influenced by how the residents actually live in and operate the buildings. Most development projects consist of just one or two buildings and the developers do not know who will live in them. At SoLi, there is a rare opportunity to incorporate energy generation at a district scale and energy savings at the occupant scale, along with high performance strategies at the building scale.

2.2 Charrette Process

DHA is committed to making the redeveloped South Lincoln Homes project as energy efficient as possible in order to decrease utility bills and reduce the project's carbon footprint. The purpose of the charrette was to discuss the opportunities and constraints of a campus-wide energy solution and to outline key next steps such as how to leverage partnerships and identify financial resources.

The "Leadership Team" below was responsible for planning the charrette. This effort included defining the overall charrette goals, identifying the scope of any analysis needed, and ensuring that charrette outcomes and lessons learned are distributed throughout the Partnership agencies to support implementation on the SoLi project. This team included representatives from each of the Partnership agencies as well as the design and technical assistance team. The members of this team included the following:

Devon Bertram, YRG sustainability
Cindy Cody, EPA Region 8
Kimball Crangle, DHA
Jesse Dean, NREL
Stacey Eriksen, EPA Region 8
Rebecca Fox, SRA International
Narada Golden, YRG sustainability
Christian Kaitreider, NREL
Aleka Pappas, Group 14 Engineering, Inc.
Josh Radoff, YRG sustainability
Tim Rehder, EPA Region 8
Otto VanGeet, NREL

The Energy Charrette was an 8-hour session that occurred on August 10th and 11th of 2010 at the La Alma Recreation Center in the heart of the neighborhood. A charrette is an interactive meeting with a large group of stakeholders that is intended to generate innovative design ideas, identify barriers to and strategies for implementation, and build key partnerships. Energy Charrette participants were asked to focus on DESIGN and TECHNICAL solutions in the working groups and discussions by first identifying priority strategies from a full list of possible strategies (Day 1), then exploring means to achieving those priority strategies (Day 2). The following report is a summary of these discussions and working groups.

"Getting to net-zero is extremely difficult for buildings of more than 4 stories."

- Nadav Malin, EBN Article

However,
"In a community, density allows for greater walk-ability and many other attributes desired in a sustainable community."

-"Definition of a 'Zero Net Energy' Community", NREL

2.3 Energy Charrette Goal

The Energy Charrette goal was developed to guide the charrette agenda, discussions, and working groups. Charrette participants discussed and agreed to this goal at the beginning of the charrette.

To explore the goal of a net-zero energy neighborhood through an interactive dialogue on concept feasibility, strategies, and actions needed in order to develop an action plan that guides implementation through all phases of the project.

2.4 Defining Net-Zero

The goal of the Energy Charrette was to explore the concepts, strategies, and feasibility of creating a net-zero energy development at South Lincoln. Before charrette participants were able to explore the details of this challenge, it was important for the group to develop a shared definition of "Net-Zero".

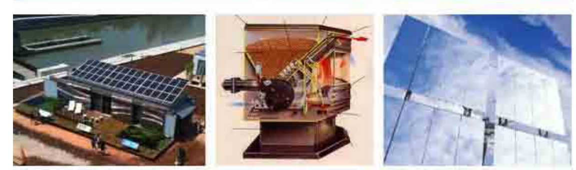
Representatives from the NREL presented four commonly accepted definitions for Net-Zero Energy Communities (NZEC) and Net-Zero Energy Buildings (NZEB) for the group to discuss. These definitions are shown below. Charrette facilitators then led a full group discussion to better understand the differences between these definitions and decide on one definition of "Net-Zero" for the South Lincoln Redevelopment project.

Net-Zero Energy Communities

NZEC Class	Least-rigorous energy source allowed
NZEC: A	Within building footprint or built enviroment or on unbuildable brownfield sites within the community
NZEC: B	Can include some generation on greenfield sites within the community or using biofuels imported from off site.
NZEC: C	Can include some off-site renewable energy credits or green power
NZEC: D	No onsite generation; all off-site renewable energy credits or green power

Net-Zero Energy Buildings

NZEB Class	Least-rigorous energy source allowed
NZEB: A	Within building footprint
NZEB: B	Within building site
NZEB: C	Generated onsite using imported biofuels
NZEB: D	Off-site renewable energy credits for green power



During the group discussion, participants identified the following key issues:

- All of the electric loads could potentially be offset with PVs, but the space heating loads for the buildings will likely require a non-electric fuel type which eliminates the possibility of achieving the NZEC-A definition.
- On-site biofuels and/or off-site carbon offsets will likely be required to achieve any definition of net-zero.
- A net-zero definition for the entire SoLI Redevelopment Project is more appropriate because there will be a number of varying building types and it would be very difficult to develop a unified net-zero definition for all of these building types.
- Further analysis of the other project loads and possible energy generation systems will be required to determine whether the project can achieve any definition of net-zero.

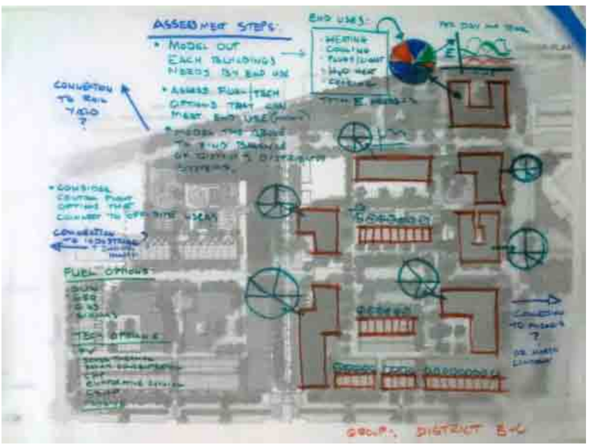
After a full discussion, the charrette participants agreed that NZEC-B was the most appropriate definition of “Net-Zero” for SoLi. This definition states the following:

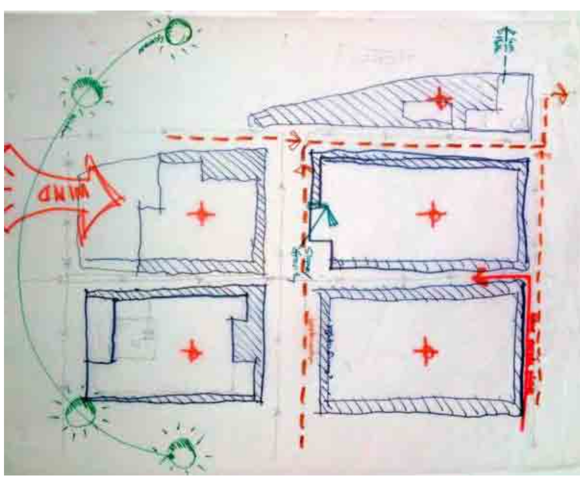
Can include some generation on greenfield sites within the community or using biofuels imported from off-site.

3. Priority Strategy Overview

Charrette participants divided into the following three self-selected working groups to identify and discuss priority strategies, major barriers for each of those strategies, and develop an implementation plan focused on addressing the major barriers and partnership opportunities for each priority strategy. Below are the priority strategies, barriers, actions, and partnerships identified by each working group.

- District Scale
- Building Scale
- Occupant Scale





3.1 District Scale Strategies

Two working groups developed a list of district scale strategies along with a series of pros and cons, feasibility challenges, and recommended next steps for implementation. The fourteen strategies below were identified as a comprehensive list of district energy strategies during the report-out for both working groups. After the report-out, all charrette participants voted for the two strategies they thought were the most important for achieving the charrette goal. The following is a tally of that vote.

We have elaborated on the three strategies that received the most votes. There is a full set of notes from the working groups in the Charrette Notes section of the Appendix.

District Strategies	Description	Votes
1. Design for multiple systems and hybrid System diversity Adapts to various seasons/use patterns	A system that incorporates various energy generation options would allow for flexibility and adaptability, especially in response to future fuel costs, maintenance requirements, and site limitations.	**16**
2. Design for Flex Fuel Complimentary fuel systems Adapt future	Similar to a hybrid system, designing a solution that utilizes various fuel types that work together or can substitute one another. This can allow for flexibility to adjust and adapt to future needs and costs.	**11**
3. Reduce energy use - Orientation	Designing SoLi utilizing passive design and optimal orientation across the development can ensure reduced loads and energy demands on the development, leading to reduced size and costs of both the district-scale and building-scale energy systems.	**8**
4. Energy use feedback	Providing a vehicle for occupant energy use feedback can allow residents to actively track and manage their energy use, and operators to more easily troubleshoot problem areas.	**7**
5. Complete energy analysis	Performing a comprehensive energy use study for the development can help identify where a district system makes sense, evaluate potential synergies, and estimate anticipated energy demand and design requirements for the system.	**7**
6. Design for the baseline Don't design district system for peak Allow for growth	Sizing a district system using the baseline demand and allowing for future growth can save first costs and reduce the risk of over-sizing the system. Alternate systems or fuel sources may be used to meet peak demands.	**5**
7. Balance loads within district	District energy systems are most cost and energy efficient when they are supplying a consistent amount of energy. At SoLi, it may make sense to supply energy to buildings outside the development to make the energy demand more consistent throughout the day.	**5**
8. Tax increment financing New financing	Identifying a financing mechanism that involves tax increment payments can support upfront and ongoing district system costs.	**5**
9. District use of right-of-way Ground source Earth tubes Denver Public Works	Utilizing the public right-of-way (ROW) can allow for strategies such as ground source heat pump and earth tubes. District system design may require collaboration and partnership with Denver Public Works if ROW is utilized.	**4**
10. Load optimization Analysis to look at load balance	Completing a load analysis can provide information on energy demands within the development and allow the design team to match strategies to the anticipated loads.	**3**
11. Solar garden	A solar garden is a cooperative ownership investment in a solar electric array. Solar gardens are typically built off-site when a project needs more land area for solar panels.	**2**
12. Recognize biggest "User/Loser" Feedback of individual use	Identifying major energy savers and users within development can help promote a culture of energy efficiency.	**1**
13. Optimizing infrastructure Eliminate redundant systems	Developing a district energy system may require some system redundancy. It will be important to minimize the unwanted redundancy due to phasing and future flexibility.	**0**
14. Virtual central plant	Some district systems can be made up of smaller distributed energy production systems. This can provide system diversity and flexibility but it is important that all of these distributed systems operate together as a "virtual central plant".	**0**

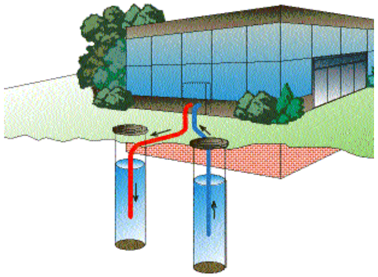
3.2 District Scale Priority Strategies

1. & 2. Design for Multiple or Hybrid, Flex Fuel District Energy Systems

Building a district energy system that relies on a single system type or fuel could create additional risk of future cost increases, system limitations, or comprehensive system maintenance challenges. One way to hedge against this future risk is to develop a district heating system that allows for various energy generation components and fuel types. One example of this would be a district hot water loop that can receive hot water from a ground source heat pump, a biofuel combustion engine, and solar hot water collectors. The following is a list of benefits, feasibility questions, and recommended next steps for this strategy*.

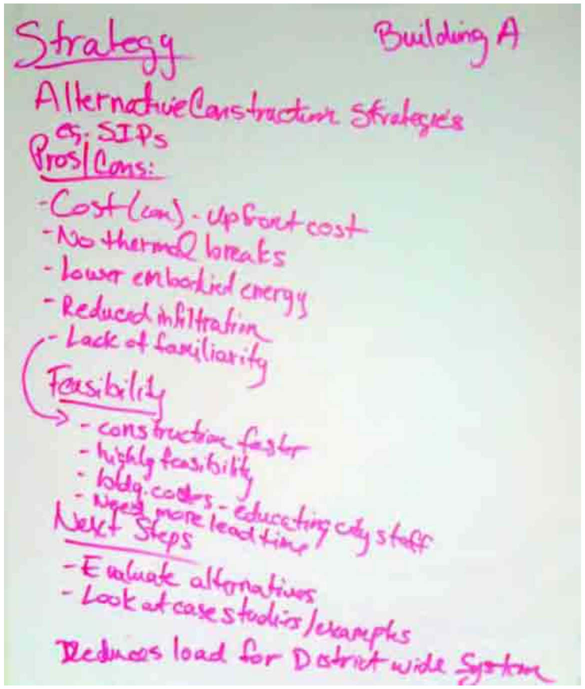
Needs	Gas	Solar Thermal	Concentrated Solar	Biomass	Ground Source Heat Pump (GSHP)	Photovoltaics (PV)
Heating	Easy, cheap now. Volatility in cost. Greater environmental impact than other options.	Highly efficient for larger scale.	Needs a lot of real estate. Railyard roof area as a resource?	Needs storage, unclear on operations and maintenance requirements and who will manage this. Need to determine training and associated costs. Not cost-effective without tax credits. Biomass gasification could be used.	Awesome, very efficient, high first cost, low maintenance	May not be best option unless heating is electric.
Cooling	X		X		X	X
Plug Loads	Combined Heat and Power (CHP)		X			X
Lighting	CHP		X			X
Hot water	X	X		X		

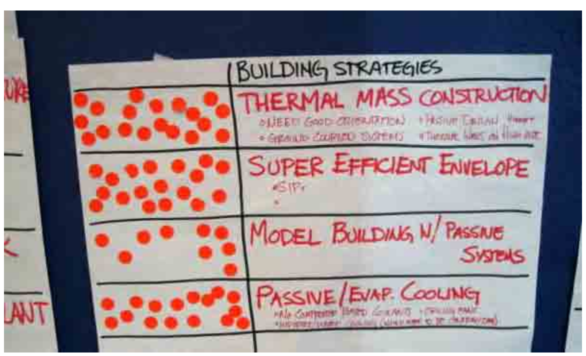
**To better convey the strategies and break-out group ideas, some text in the chart above has been revised or added to in order to clarify notes taken during the break-out group discussions.*


3. Reduce Energy Use by Optimizing Building Orientation

The size and cost of a district energy system will need to be based on the predicted heating, cooling, and electricity load of the SoLi development. Because a district energy system will likely require an additional upfront investment in energy infrastructure to work effectively, it will be important to “right size” the district energy system. If DHA can ensure that future development teams will design and construct highly energy efficient buildings, this could allow for significant reductions in the size and upfront costs of a district energy system. Thus, a feasible and cost efficient district energy system will likely be coupled with comprehensive building scale and occupant scale energy strategies.





3.3 Building Scale Strategies

Two working groups developed a list of building scale strategies along with a series of pros and cons, feasibility challenges, and recommended next steps for implementation. The five strategies below were identified as a consolidated list of building energy strategies during the report-out for both working groups. After the report-out, all charrette participants voted for the two strategies they thought were the most important for achieving the charrette goal. The following is a tally of that vote.

We have elaborated on the three strategies that received the most votes. There is a full set of notes from the working groups in the Charrette Notes section of the Appendix.

Building Strategies	Description	Votes
Super efficient envelope Structured Insulated Panels (SIPs)	A super efficient envelope can significantly reduce the external heating and cooling loads that pass through the building exterior by increasing insulation, reducing solar heat gain, and reducing air infiltration.	**21**
Passive/Evaporative cooling No compressor based coolants Ceiling fans Indirect/direct cooling (would need to be centralized)	Passive and evaporative cooling use natural airflow, evaporation, and other low energy cooling strategies to eliminate the need for compressor based cooling while greatly reducing the space cooling demands.	**17**
Thermal mass construction Need good orientation Passive design Ground coupled systems Thermal walls on four-stories-or greater high rise	Thermal mass construction increases the amount of heavy materials within the building to passively regulate and stabilize internal temperatures.	**14**
Model building with passive systems	Modeling SoLi buildings with passive designs strategies can inform the impact of these systems and overall influence on energy demand.	**10**

3.4 Building Scale Priority Strategies

1. Super Efficient Building Envelope

Significant reductions in the building energy use will be required if the project is to achieve the goal of net-zero. One of the best ways to ensure large energy savings is to reduce the amount of energy that is required to operate the buildings. Two of the largest building loads at SoLi are space heating and cooling. Both of these loads can be significantly reduced through increased efficiencies in the exterior envelope of future projects. These improvements, which include increased insulation, tighter wall construction to reduce air infiltration, high performance windows, and windows that are appropriately sized and located, will reduce the transfer of heat from the inside of the building to the outside in the winter, and vice versa in the summer.

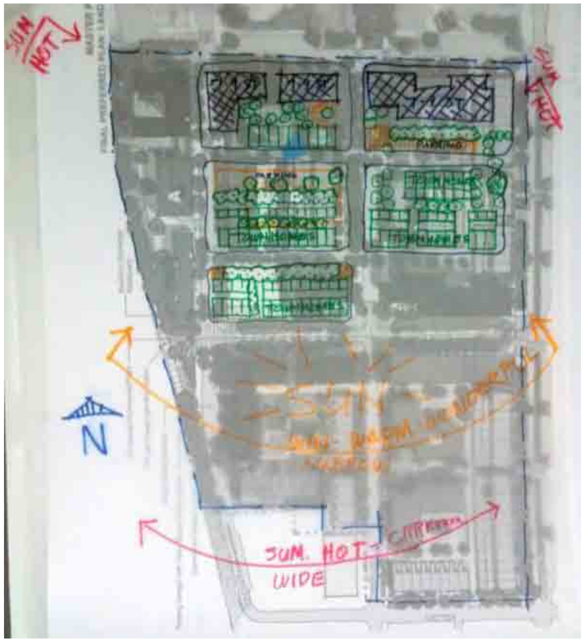
2. Passive / Evaporative Cooling

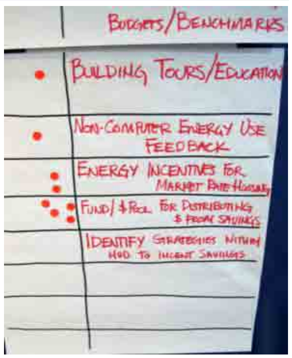
The third largest energy load at SoLi, slightly larger than domestic hot water heating, is space cooling. There are several decisions that could significantly reduce or even eliminate the space cooling load at SoLi. Two possible choices are utilizing passive cooling and/or evaporative cooling. Passive cooling would require the buildings to have an optimized building envelope (see Strategy 1 above) and be designed for natural ventilation. Evaporative cooling, which relies on the evaporation of water to provide the cooling required, could also reduce overall cooling loads beyond a traditional air conditioning system.

3. Thermal Mass Construction

The third most popular building scale strategy identified was thermal mass construction. Although the notes and discussions from the charrette did not clearly define thermal mass construction, several key points were emphasized.

- Design building with exposed concrete or masonry inside the units for thermal mass. This mass will help regulate internal temperatures.
- Thermal mass is important for optimizing passive solar heating. In order to take advantage of this strategy, the mass should be exposed to direct sunlight for most of the day during the heating season. Dark concrete floors near windows on the south side of the building would achieve this goal.
- Thermal mass can also help optimize natural ventilation strategies. Concrete ceilings in particular, can support passive cooling in the winter and "night flushing" where occupants could open windows to cool down the units at night.





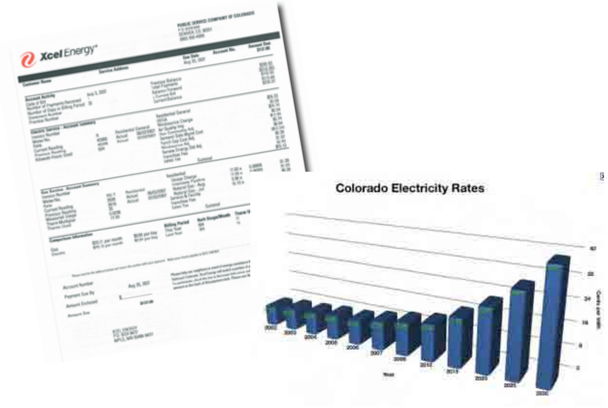
3.5 Occupant Scale Strategies

Two working groups developed a list of occupant scale strategies along with a series of pros and cons, feasibility challenges, and recommended next steps for implementation. The thirteen strategies below were identified as a comprehensive list of occupant scale energy strategies during the report-out for both working groups. After the report-out, all charrette participants voted for the two strategies they thought were the most important for achieving the charrette goal. The following is a tally of that vote.

We have elaborated on the three strategies that received the most votes. There is a full set of notes from the working groups in the Charrette Notes section of the Appendix.

Occupant Scale Strategies	Description	Votes
1. Energy Use Transparency and Incentives Vouchers for green store	Considering a strategy that allows residents to see their individual utility usage can encourage energy savings. Additionally, providing incentives for reduced energy usage can encourage residents to incorporate habits that use less energy.	**14**
2. Green store/resource room	This added amenity for the neighborhood can be a space to sell small sustainability related products and materials, as well as a community gathering point for workshops, trainings, and discussions related to energy efficiency, water savings, low-toxic building materials, and indoor health.	**12**
3. Identify benefits for residents Comfort Marketing/messaging Cultural relevance	Identifying the clear benefits of living a sustainable lifestyle can increase resident support for related efforts focused on energy efficiency, cost savings, comfort, and safety.	**9**
4. Resident champions Support/engage/represent residents DHA to Support leaders	A community member identified as the "Resident Champion" can be the point person to maintain momentum around SoLi's sustainability efforts and goals by encouraging action from the residents, and a central resource and guide for the community.	**9**
5. Focus on engagement Education Residents External partners	Involving residents through active engagement can increase their investment in the community and understanding of the sustainability initiatives. These efforts can involve educational opportunities such as workshops and discussions and identifying partners that can support the community goals.	**7**
6. Involve kids! Future leaders, they get it Help engage others New "paper boy route"	Engaging kids and younger generations can help to push sustainability efforts and initiatives forward. This can involve workshops or games around sustainability and energy use reduction, or programs around communicating community goals (creating murals, signage, etc.).	**6**
7. Internships/job opportunities Work with community colleges	Identifying internship or job opportunities can encourage relationships with neighboring academic institutions, support SoLi programs such as the green store/resource room, and resolve the need for ongoing maintenance required for some of the strategies.	**6**
8. Fund ($ pool) for distributing $ from savings	Collecting money saved from energy efficiency strategies and resident energy use reduction can be used for a money pool that supports community programs and efforts around sustainability.	**4**
9. Non-computer energy use feedback	In order for all residents to have access to feedback regarding the impact of their behavior, SoLi can provide a system that is easily and readily accessible to occupants and does not require a computer.	**3**
10. Energy incentives for market rate housing	Since some of the SoLi development will be market-rate housing, it will be important to consider how energy related efforts support these residents too.	**2**
11. Establish fair energy budgets/benchmarks	Target energy budgets will need to be established in order to create incentives for reduction. Because each resident and family is different, it will be important to create fair, flexible energy budget criteria.	**0**
12. Building tours/education	Regular building tours to highlight energy efficiency strategies and ongoing education opportunities can support and maintain ongoing discussion about the sustainability initiatives at SoLi.	**0**
13. Identify strategies within HUD to incentivize savings	Developing a system within HUD that allows residents to receive incentives for their energy usage savings can encourage energy reduction habits.	**0**

3.6 Occupant Scale Priority Strategies



1. Energy Use Transparency and Incentives

Occupants' day-to-day activities will contribute a great deal to the overall energy usage of the SoLi development, and yet this energy usage can vary drastically from household to household. SoLi should consider a strategy that includes transparency or resident-payment of utilities in order for the residents to 'see' their individual utility usage. In addition, incentivizing energy-saving actions and habits can not only allow for opportunity around education regarding energy efficiency and energy use reduction, but can also encourage occupants to reduce their overall energy usage within their home. A rewards or incentives program for reduced energy usage can link to neighborhood amenities and resources such as offering a reduced fee or free hours for childcare, free or discounted car share hours, discounted transit passes, access to a bike share program, entertainment coupons, or vouchers to a community green store. These rewards could be purchased in part with savings from the reduced energy use.

2. Green Store / Resource Room

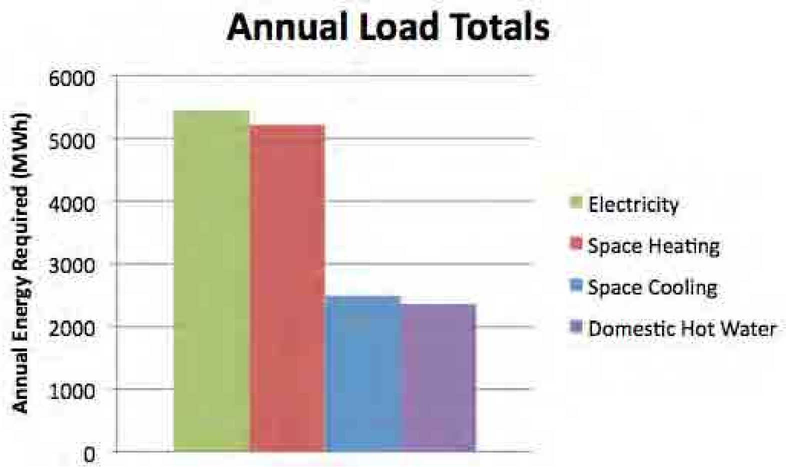
A centrally located Resource Room / Green Store can provide residents access to sustainability related products and materials (such as low VOC paints, green cleaning products, energy efficient light bulbs, guides and books related to green building, etc.). This space can also be an area where residents can rent or borrow tools related to small-scale home improvement and maintenance projects as well as be a resource for guidance and contacts to support these upgrades or improvements. Additionally, the Green Store can provide an opportunity for community building and education by hosting events, classes, workshops, and trainings around sustainability. This gathering point can generate enthusiasm and culture around the sustainability goals of the project, as well as provide jobs or volunteer opportunities for community residents.

3. Identify Clear Benefits for Residents

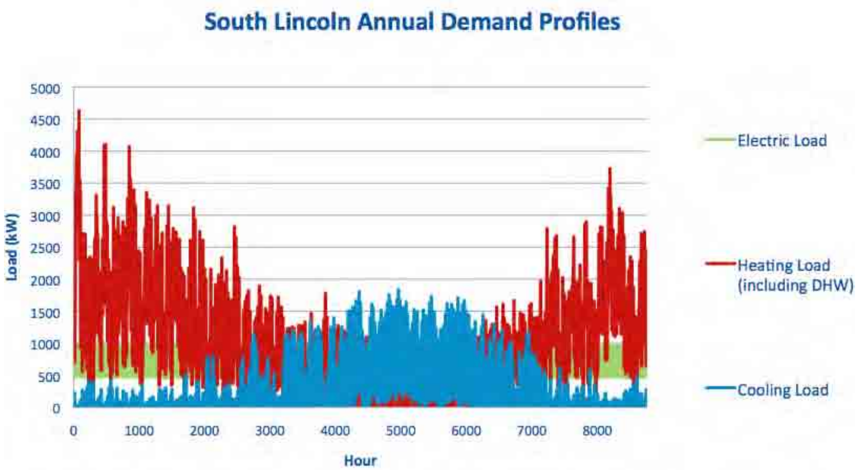
Education is an ongoing theme within the community and a clear goal of DHA, particularly when around sustainability and the environmental goals of the project. Educating occupants on the benefits of the community and its amenities and services, as well as identifying the benefits to living a sustainable lifestyle is crucial to the success of the project. Focusing on energy efficiency and cost savings, comfort and safety, and cultural relevance, this education can be demonstrated through tracking and monitoring occupant behavior, and sharing results; hosting community events and discussions around actions and benefits related to sustainability; displaying signage within resident homes and around the neighborhood that highlights key facts and figures; and providing ongoing communication of benefits and opportunities through postings and mailings.

4. Resident Energy Champions

In order for the project to excel in regards to sustainability action within the community, a Resident Energy Champion (or Champions) will need to lead the charge in order to support, engage and represent the community and resident goals. This resident champion can focus on and prioritize the energy-related initiatives and actions, as well as market and message the initiatives taking place within the community. DHA (or other partner) will need to support these leaders and provide them the resources to effectively engage and educate the community and residents.



Annual loads above are based on the total demand for electricity, space heating, space cooling, and domestic hot water across the entire SoLi development.



This demand profile graph above shows the hour demand for electricity, heating, and cooling for an entire year.

Category	Potential Systems to Analyze
District Heating/DHW	Wood Chip Boiler
District Heating and Cooling	GSHP
Cogen	NG Gas Turbine
	NG IC Engine
	NG Fuel Cell
Trigen	Same generation systems as Cogen
Electricity Only	PV
DHW Only	SHW

District systems identified for further analysis.

4. NREL Analysis and Results

The following is a summary of the ***South Lincoln Redevelopment District Systems Analysis Report*** developed by the National Renewable Energy Laboratory. See the Appendix for the full report.

4.1 Summary of Analysis

Providing heating and cooling for homes and businesses is typically done at the building level, meaning there is one system dedicated specifically to a single building. However, in many situations it may be economically and environmentally beneficial to provide these services at the community scale, in which case many buildings are served by one large district system designed for the entire community. The advantages of district systems stem from their larger scale, their ability to capitalize on load diversity within the community, their reliability and maintainability, the possibility to attain high efficiencies by combining electrical generation with heating and/or cooling, and the autonomy given to the community concerning the operation of the system and the fuel source it uses. For these reasons, it has been deemed worthwhile to analyze potential district systems for SoLi.

NREL and Group 14 Engineering, Inc. provided energy analysis for the SoLi development. Group 14 Engineering, Inc. developed building scale energy models for several typical building types using load assumptions from the Phase 1 project and additional assumptions determined by the Leadership Team. NREL used this building scale modeling to create annual demand profiles for the entire development and evaluate the energy impacts and feasibility of district-wide systems.

NREL's analysis of the potential for district systems involves estimating the hourly heating, cooling, DHW, and electric loads required by the community, investigating potential district system technologies to meet those needs, and researching available fuel sources to power such systems. The metrics used to evaluate the economic and environmental viability of each system are simple payback period (SPP), Net Present Value (NPV), and greenhouse gas (GHG) reductions.

4.2 NREL Conclusions and Recommendations

Although none of the district systems investigated for this analysis show favorable economics, some options may well make sense as integral parts of the final solution. **However, it is highly recommended that other measures be maximized before implementing any district system.** Specifically, it is vital that electrical loads, heating and DHW loads, and cooling loads in the community, are reduced as much as possible. Electrical loads can be reduced by a combination of building system design (high efficiency pumps and fans, timers on bathroom vents, daylighting design), appliance efficiency standards, occupant education, and any number of occupant incentives. Heating loads can be reduced primarily by building design, including insulation levels and window specifications. DHW loads can be reduced by educating the occupants and using low-flow fixtures.

Perhaps the greatest improvements in the baseline energy use can be found in the reduction of cooling energy use. The Denver climate is ideal for natural ventilation, direct cooling with outdoor air, night- time pre- cooling, and evaporative cooling. It is conceivable that these technologies could virtually eliminate conventional cooling methods in the South Lincoln community and significantly reduce the electricity used for cooling.

In regards to district systems for this community, the most drastic reductions in GHG emissions will best be achieved using a combination of PV for electricity and biomass for heating and domestic hot water. If cooling and other electrical loads are reduced based on the recommendations above, it may be possible for the community to reach net zero GHG emissions by installing 19% efficient solar panels on rooftops and carports and installing a biomass heating system sized to 40% of peak heating and DHW demand. In this scenario, heating and DHW will require some natural gas input. However, with the reductions in cooling and other electrical energy, the PV system is projected to produce enough of a surplus of electrical power to offset the greenhouse gas emissions from the site's natural gas usage. Although the economics of buying and owning a PV system may be prohibitive, entering into a power purchase agreement (PPA) could make such a system viable. A PPA is a legal contract between an electricity generator (provider) and a power purchaser (buyer).

An alternative to the scenario above is to install PV to offset electricity, concentrate on reducing heating/DHW loads, and utilize high efficiency natural gas systems at the building level in lieu of a central biomass plant. **While the community is not expected to reach net zero GHG emissions in this scenario, emissions savings of about 80% or higher are achievable. Furthermore, upfront costs as well as operations and maintenance costs will be significantly lower. This approach would be much simpler and less costly to design and implement phase by phase, with a relatively small loss of environmental benefit**. Considering both economics and environmental benefits, this may be the most reasonable option for South Lincoln.

A third possibility would be to use a cogeneration or tri-generation plant driven by an IC engine or a fuel cell to provide a portion of the community's heating and electricity needs. These systems show the most attractive economics of any of the systems analyzed. It would be possible to supplement a cogeneration plant with PV as a path to net zero emissions. However, implementation of a cogeneration or tri- generation strategy will require more planning and ongoing operations and maintenance effort by DHA than a PV strategy. Furthermore, while a PV system can be installed under a PPA, a cogeneration plant would require the consent of the utility for such an arrangement. Because the utility has little incentive to agree to this type of arrangement, a PPA for a cogeneration plant is very unlikely.

System Priorities

- Efficiency and Conservation First
    - Electric Loads: Building System Design, Occupant Education, Incentives, Appliance Standards, Lighting Standards
    - Heating Loads: Insulation Levels, Window Specs, Duct/Piping Design
    - Cooling Loads: Insulation Levels, Window Specs
    - DHW Loads: Low-Flow Fixtures, Distribution Design, Occupant Education
- Drastically Reduce Cooling Energy
    - Natural Ventilation, Direct Outdoor Air Cooling, Nighttime Pre-cooling
    - Evaporative Cooling

System Recommendations

4. Net Zero GHG
    a. High Efficiency PV on Rooftops and Carports (Enter into a PPA to capture government incentives)
    b. Biomass Heating and DHW
5. Significant Reduction in GHG
    a. PV
    b. High Efficiency Natural Gas Boilers (Condensing)
6. Other Options
    a. Internal Combustion (IC) Engine Cogeneration

For a full copy of the NREL South Lincoln Community District Assessment, see the Appendix to this report or go to the following link.

http://yrgsustainability.centraldesktop.com/denverscpcharrettesexternal/

Results Summary				
Technology	**Size**	**SPP (yrs)**	**NPV ($)**	**Percent Total CO_2 Equivalent Saved**
Cogeneration				
NG Gas Turbine	250 / 409	85.0	-$673,339	8%
IC Engine	300 / 300	33.1	-$282,627	12%
Fuel Cell	600 / 269	46.6	-$1,917,016	28%
Trigeneration				
NG Gas Turbine	250 / 409	83.0	-$873,275	9%
IC Engine	350 / 350	36.4	-$440,141	14%
Fuel Cell	700 / 313	48.2	-$2,399,469	33%
District GSHP				
GSHP	100% of Load	83.2	-$4,642,113	4%
Biomass District Heat				
Wood Chip Boiler	40% of Heating Demand	111.5	-$1,545,443	21%
Photovoltaics				
Solar Panels (19% efficient; Rooftops and Carports)	252,455 ft^2 (as multiple smaller systems)	66.4	-$17,720,053	76%
Solar Panels (15% efficient; Rooftops Only)	188,848 ft^2 (as multiple smaller systems)	58.0	-$9,019,400	57%
Solar Hot Water				
Flat Plate Panels	80% of DHW Load	126.8	-$12,265,323	6%

This table summarizes results for selected systems and technologies. Results here were selected based on simple payback and feasibility of size. See full NREL report for a complete list of systems analyzed.

5. Report Conclusions and Recommendations

Based on the analysis presented herein, the most economic means of achieving near-net-zero energy for the project is to maximize the production of on-site PV to offset the electrical demand, namely the lighting, plug, and auxiliary loads. If cooling is assumed to be provided by passive and/or evaporative means, the only remaining load is space heat and DHW. This can be produced either through a high efficiency boiler (building or district level), or through a cogeneration system. If the latter is used, then the PV capacity can be reduced in proportion to the expected electricity production from the cogen unit. These system combinations have the capacity to reduce the overall GHG emissions by 80-90% or more, depending on the degree to which passive design measures can be employed at the building level.

Reaching True Net-Zero: To address the remaining 10-20% of emissions and fossil fuel use on site, the project would need to either:

4. Use a biomass district heating system, despite the poor economics and logistical challenges.
5. Shift the heat to a GSHP system and add additional solar to compensate for the increased electrical load for the GSHP system.
6. Use solar thermal for DHW and space heat, despite the poor economics and lack of roof space to accommodate both the PV and solar thermal collectors (this would require either off-site PV production, or non-rooftop PV production such as collectors on the south facades).

While this is technically feasible, the marginal returns are significantly diminishing – that is, the additional costs are harder and harder to justify given the resulting benefits.

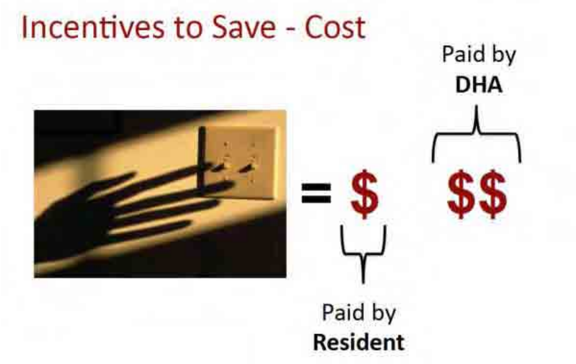
It should be noted that the results of this analysis are heavily dependent on the following factors:

3. Technical solutions, need to match the specific load profiles of the development, thus will be dictated by the Colorado climate which is heavily heating dominated, as well as building efficiency and plug load assumptions. Different climates such as Atlanta's, have a greater need for cooling and cannot easily utilize evaporative cooling.
4. The cost and rate structures of electricity and gas: The financial viability of the systems discussed would be markedly improved if the was project located in a region with higher energy prices, or if the assumptions for energy price escalation were increased from the current level of 3% annually, or even if there was a more favorable rate structure, such as a time of use structure.

Lastly, the charrette working groups and discussions identified several other general energy recommendations.

- SoLi residents are not currently incentivized to save energy because they do not pay for their own utilities. HUD and DHA should make this usage transparent to residents and develop an incentive structure that encourages residents to save energy and share their efforts with others.
- There is a tension between building higher density developments and providing adequate solar access to all buildings and most units. Planning decisions for energy savings related to solar access should also take into account transportation impacts of lower density developments.
- District energy systems will likely require a dedicated maintenance staff. DHA will need to hire and train this staff or hire contractors to provide this service.

- There could be a number of ownership options for all of the district energy system mentioned above. DHA will need to explore and negotiate an ownership structure before these systems can be built.
- District systems that include district water loops will require coordination with Denver Public Works (DPW) and other local agencies in order to be approved.



5.1 Funding and Incentive Opportunities

DHA will need to acquire additional funding to implement many of the strategies outline in this report. The following funding sources were identified to help support these strategies.

- Governor's Energy Office (GEO)
- State and federal tax incentives
- Xcel Energy

5.2 Strategic Partnerships

DHA will need to develop active working relationships with the following strategic partners in order to successfully implement the transportation strategies recommended in this report.

Housing and Urban Development (HUD) – HUD can provide support for resident programs and facilities that support energy efficiency strategies.

National Renewable Energy Laboratory (NREL) – NREL completed a district energy analysis for the SoLI project and can continue to be a technical partner as the team explores the logistics and payback of aggressive energy strategies.

Denver Community Planning and Development (CPD) – Denver CPD has developed a comprehensive neighborhood plan for La Alma / Lincoln Park and will need to be involved in many of the major decisions moving forward.

Denver Public Works (DPW) – Denver Public Works plays a critical role in the approval and development of the public right-of-way in the SoLi development and La Alma / Lincoln Park neighborhood, and may need to be involved for district-wide energy strategy decisions if these influence neighborhood transit during construction and/or operations.

La Alma / Lincoln Park Neighborhood Association (LPNA) (formally known as La Alma / Lincoln Park Planning Group (LLPPG)) – Many of the energy efficiency programs and strategies included in this report will not be successful without engaging and developing support within the LA / LP resident community.

Xcel Energy – Xcel can provide resources for the SoLi development such as building modeling analysis and incentive programs, and will need to be a partner in the design, approval, and ownership of a district energy system.

6. Appendix

6.1 Charrette Photos

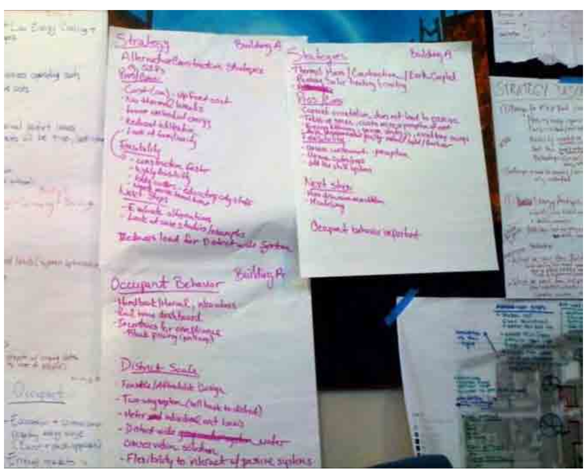
Go to the following link to see photos taken during the Energy Charrette.

http://picasaweb.google.com/yrgconsultants/PSCCharrettes?feat=directlink

6.2 Charrette Agenda, Presentations, and Handouts

The following pages include the Charrette Agenda and presentation slides in handouts format. In addition, the agenda, a PDF of the PowerPoint presentations, and all handouts for the Energy Charrette have been posted on a public website for participants and the general public to access. Go to the following website to access those documents.

http://yrgsustainability.centraldesktop.com/denverscpcharrettesexternal/



Charrette Agenda (Day 1):

Tuesday, August 10, 1:00 – 5:30 pm

Welcome and Introductions (1:00 – 1:15)

- Goals of the charrette (EPA/DHA/YRG)
- Attendee introductions

S. Lincoln Redevelopment Project Overview (1:15 – 1:45) (DHA)

- General goals and objectives for the project
- Brief overview of how Master Plan was developed, cultural context, phasing approach, funding implications
- Energy information included in the Master Plan
    - Why energy improvements are important to DHA and stakeholders and associated challenges
    - Overview of Master Plan's energy goals, metrics, and guidelines

Guiding Principles and Metrics (1:45 – 2:30) (YRG)

- Overview of project's energy design guiding principles (e.g., concepts and strategies for getting to net-zero)
- Overview of project's overarching energy goals and metrics
    - Energy metrics (net-zero, carbon neutral, EUI, reductions below code)
    - Green Building metrics (LEED NC and ND, Green Communities)
- Lessons learned from Phase I (e.g., specific Phase I energy goals, strategies used, lessons learned, and implications for future energy planning)
- Project challenges and opportunities

Stakeholder Presentations (2:30 – 3:00)

- HUD
- Governor's Energy Office
- Denver Greenprint
- NREL
- Xcel

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Break and Site Walk (3:00 – 3:30)

Concepts and Strategies (3:30-4:30) (NREL/YRG presentation and facilitated discussion)

- Overview of potential energy strategies, including case study examples and pre-charrette energy analysis information
    - District scale (e.g., centralized ground source heat pumps, co-generation and district heat and solar gardens)
    - Building scale (e.g., orientation, window to wall ratio, shell features, lighting and hvac)
    - Occupant/behavioral (e.g., occupant feedback and information, ongoing challenges and reminders to participate in the projects intent)

Goals and Outcomes Working Groups (4:30 – 5:20)

- Break out into groups to and discuss the top 3 desired outcomes for the charrette

Day Wrap-Up (5:20 – 5:30)

Social at the Buckhorn Exchange at 10th and Osage (not hosted)

Charrette Agenda (Day 2):

Wednesday, August 11, 8:00 am – 12:00 pm

Welcome / Recap (8:00 – 8:15)
- Brief review of Day 1
- Goals for day and working groups

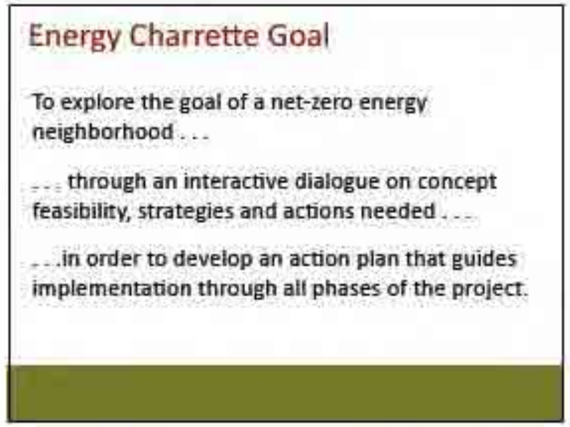
Sustainability Working Groups (8:15 – 9:45)
- Break out into three groups to develop concepts, strategies, and metrics
    - Topic 1: Building scale energy
    - Topic 2: District scale energy
    - Topic 3: Occupant / behavior energy impacts

Break (9:45 - 10:00)

Plenary to Discuss / Evaluate Working Group Ideas (10:00 – 11:15) (YRG/SRA to facilitate)
- Each group to select one member to report out to the larger plenary
- Group to discuss ideas, further brainstorm, and identify 3-5 priority concepts/strategies to move forward with

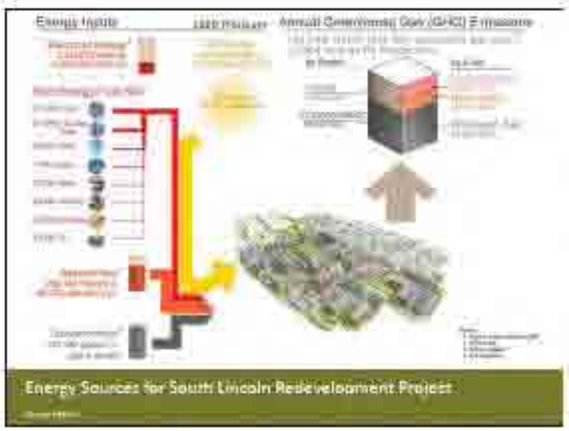
Implementation and Next Steps (11:15 - 12:00) (YRG/SRA to facilitate)
- For each of the 3-5 priority concept/strategies, the full group will discuss:
    - Next steps (e.g., additional analysis needed, partners to engage)
    - Estimated timeline
    - Funding/technical assistance opportunities
- Review any action items/next steps
- Charrette wrap up

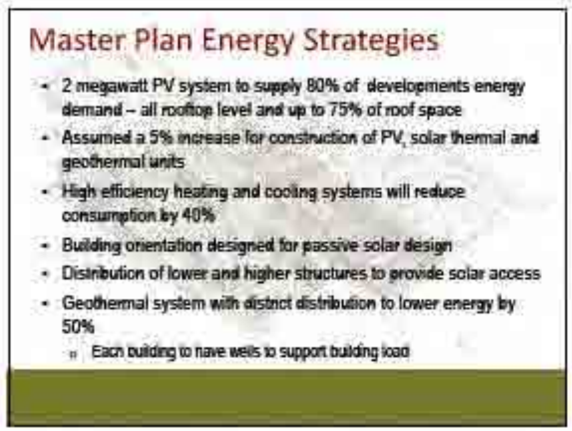
Presentation Slides



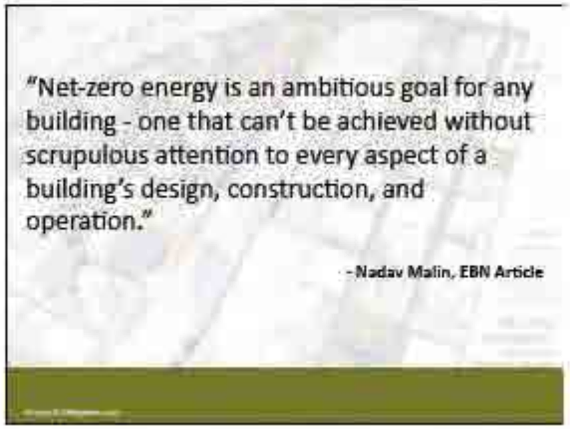

South Lincoln Master Plan
Sustainable strategies
LEED


Energy Story


Energy Sources for South Lincoln Redevelopment Project

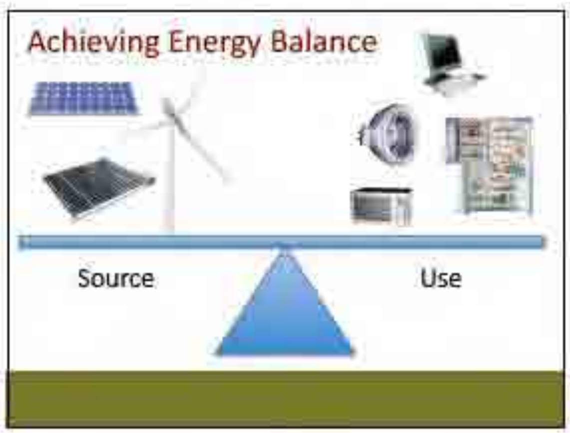

Master Plan Energy Strategies
2 megawatt PV system to supply 80% of developments energy demand – all rooftop level and up to 75% of roof space
Assumed a 5% increase for construction of PV, solar thermal and geothermal units
High efficiency heating and cooling systems will reduce consumption by 40%
Building orientation designed for passive solar design
Distribution of lower and higher structures to provide solar access
Geothermal system with district distribution to lower energy by 50%
Each building to have wells to support building load


Guiding Principles and Metrics


"Net-zero energy is an ambitious goal for any building - one that can't be achieved without scrupulous attention to every aspect of a building's design, construction, and operation."
- Nadav Malin, EBN Article


Defining Net-Zero


Achieving Energy Balance
Source
Use


Achieving Energy Balance
Source
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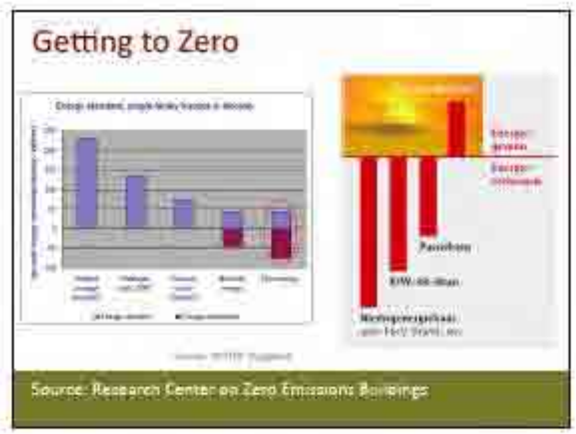
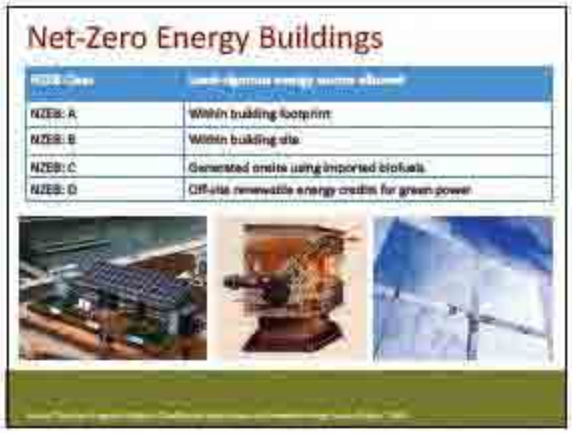
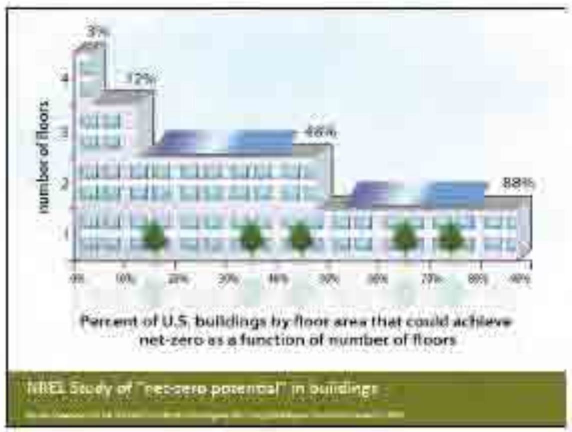

Getting to Zero
Source: Research Center on Zero Emissions Buildings

Net Zero vs. Carbon Neutral



Net-Zero Energy Buildings
NZEB: A Within building footprint
NZEB: B Within building site
NZEB: C Generated onsite using imported biofuels
NZEB: D Off-site renewable energy credits for green power

Net-Zero Energy Communities
NZEC: A Within building footprint or built environment or on unbuildable brownfield sites within the community
NZEC: B Can include some generation on greenfield sites within the community or using biofuels imported from off site.
NZEC: C Can include some off-site renewable energy credits or green power
NZEC: D No onsite generation; all off-site renewable energy credits or green power



3%
72%
48%
88%
number of floors
Percent of U.S. buildings by floor area that could achieve net-zero as a function of number of floors
NREL Study of "net-zero potential" in buildings

"Getting to net-zero is extremely difficult for buildings of more than 4 stories."
- Nadav Malin, EBN Article
However,
"In a community, density allows for greater walk-ability and many other attributes desired in a sustainable community."
- "Definition of a 'Zero Net Energy' Community", NREL
NREL Study of "net-zero potential" in buildings

South Lincoln Redevelopment Project Master Plan

Buildings by Type

Projected Energy Use

- Electricity Use: 5,458 MWh/yr
- Electricity Demand 1.4 MW
- Natural Gas Use (DHW): 25,387 MMBtu/yr

NREL Analysis

Heating and Cooling Requirements

- Cumulative annual heating load: 4,706 Mbtu
- Peak heating load: 3.49 MMBtu/hr (366 Tons)
- Peak cooling load: 506 Tons

NREL Analysis

Solar Access Study

Solar Energy Potential: Rooftop PV

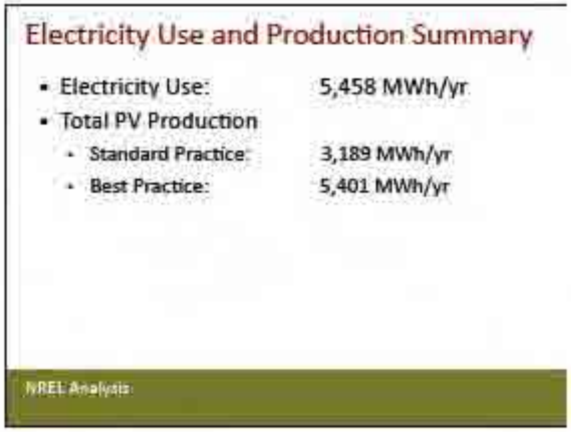
- Rooftop PV Annual Production
  - Standard Practice:
    - Annual energy production: 2,119 MWh/yr
    - System size: 1,511 kW
  - Best Practice:
    - Annual energy production: 3,973 MWh/yr
    - System size: 2,833 kW

NREL Analysis

Solar Energy Potential: Carport PV

- Carport PV Annual Production
  - Standard Practice:
    - Annual energy production: 1,070 MWh/yr
    - System size: 763 kW
  - Best Practice:
    - Annual energy production: 1,428 MWh/yr
    - System size: 1,018 kW

NREL Analysis


Electricity Use and Production Summary
Electricity Use: 5,458 MWh/yr
Total PV Production
Standard Practice: 3,189 MWh/yr
Best Practice: 5,401 MWh/yr
NREL Analysis


"Single-scale problem-solving leads to solutions that don't always make sense."

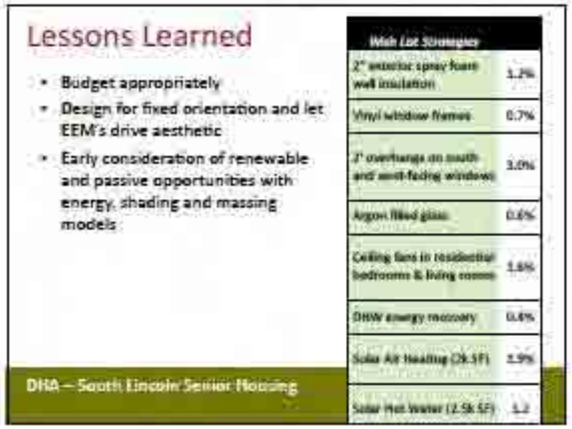

Energy Strategies at Different Scales
District Scale
Building Scale
Resident Scale


Metrics and Benchmarks
LEED-ND
NEW
architecture 2030
kW
LIVING
BUILDING
CHALLENGE


EUI : 32
National Renewable Energy Laboratory


Lessons Learned – Phase 1
Goal = 50% reduction ASHRAE 90.1, 52% achieved ($54k/yr)
Xcel EDA process for energy modeling, all-electric baseline
EUI – 40 kBtu/SF/yr (413,000 kWh & 25,000 therms per yr)
50 kW PV, 11% of energy cost (75 kW possible)
DHA – South Lincoln Senior Housing

More than 25 strategies modeled
Chosen Strategies
100% ground source heat pump with double pane low-e glass, R-19 batt wall insulation 24.9%
Add low-SHGC glass (PPG XL70 equivalent) 8.0%
Residential lighting power density of 0.50 W/SF 0.5%
20% reduction in common area LPD 0.9%
Daylighting controls in upper two-level corridors and connector spaces 0.0%
Variable speed drive pumps 2.1%
Low flow sinks and lavatories 0.2%
Energy Star refrigerators,

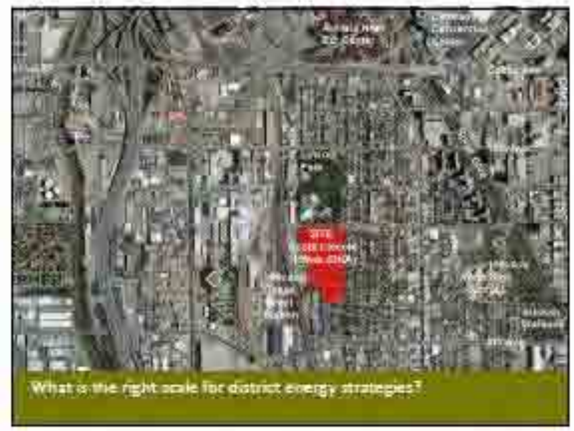


Lessons Learned
Budget appropriately
Design for fixed orientation and let EEM's drive aesthetic
Early consideration of renewable and passive opportunities with energy, shading and massing models
Wish List Strategies
2" exterior spray foam wall insulation 1.2%
Vinyl window frames 0.7%
2' overhangs on south and west-facing windows 3.0%
Argon filled glass 0.6%
Ceiling fans in residential bedrooms & living rooms 1.6%
DHW energy recovery 0.4%
Solar Air Heating (2k SF) 1.9%
Solar Hot Water (2.5k SF) 1.2
DHA – South Lincoln Senior Housing

South Lincoln Redevelopment Project

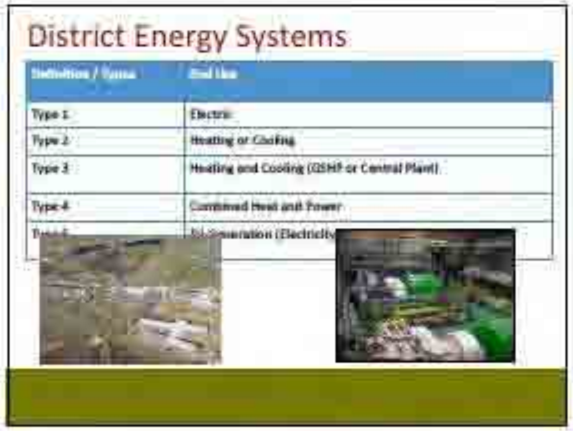
Concepts and Strategies

District Scale Strategies



What is the right scale for district energy strategies?


LEGEND: LAND USE
District Resources


District Energy Systems
Definition / Types
End Use
Type 1
Electric
Type 2
Heating or Cooling
Type 3
Heating and Cooling (GSHP or Central Plant)
Type 4
Combined Heat and Power


Electric Only Options
Renewable Energy Options:
• Photovoltaic
• Wind (not viable based on resource)
Photovoltaic Opportunities:
• Roof Mounted
• Carport
• Community Solar (Solar Gardens)
Photovoltaic Issues
• Sub-metering/billing
• Purchasing – Agency Appropriations/ Power Purchase Agreement (PPA)


Northeast Denver Housing Center
Project Description:
• Installing PV systems on 20 Low Income Housing Units (54.78 kW)
Financing
• GEO Grant Loaned to Developer
• NDHC Pays $0.08/kWh PPA (30% reduction on utility bills)
• NDHC Receives Loan Interest Payment
• Customers receive price surety and rate reduction
Organization


Heating or Cooling
Technology Options:
•Central Chilled Water Plant
•Central Heating Plant
• Biomass Combustion
• Biomass Gasification
• Boiler w/ Renewable Methane
Central Plant Issues
• Sub-metering/billing
• Incremental Infrastructure Development
• Long-term biomass contract availability / price


Renewable Fuel Heating Plant (RFHP)
• Wood fired combustion boiler that will combust urban wood waste and forest thinnings
• Displaces 75% of STM campus natural gas use
• Installed through an ESPC
• Began Operation: November, 2008

Green Acres Public Housing Complex

- **50 Unit Affordable Housing**
- **Residential District Woodchip Heating System**
  Heating Capacity (output): 0.6 MW (2.2 MMBtu/hr)
- **Year Installed:** 1992
- **Thermal Output:** Hot water

Heating and Cooling

Technology Options:
- Central Ground Source Heat Pump

GSHP Issues
- Sub-metering/billing
- LCC Effectiveness
- Infrastructure Development

Boulder County Housing Authority

Boulder County Housing Authority

Combined Heat and Power and Tri-Gen

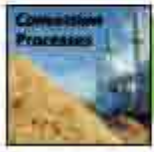
CHP Technology Options:
- Biomass Combustion or Gasification
- IC Engine
- Gas Turbine
- Fuel Cell

Tri-Gen Cooling Options:
- Absorption Chiller

Technology Issues
- Sub-metering/billing
- Fuel Supply (GHG savings or net zero?)
- Long term utility rates

Range of Bioenergy Concepts

- Trees
- Grasses
- Agricultural Crops
- Residues
- Animal Wastes
- Municipal Solid Waste
- Algae
- Food Oils, Waste Oils



- Combustion
- Gasification
- Pyrolysis
- Co-firing
- Enzymatic Fermentation
- Gas/liquid Fermentation

Products

Fuels
- Ethanol
- Biodiesel
- "Green" Gasoline & Diesel

Power
- Electricity
- Heat


Integrated Solid Waste Management Hierarchy
Source Reduction
Reuse
Donation
Recycling
Composting/Mulching
Waste to Energy (WTE)
Other forms of volume reduction
Landfilling

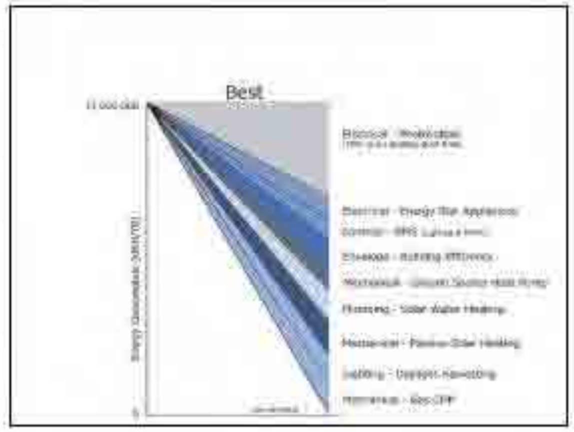

Fuel Types and Technologies
Fuel processing
Mass burn
Refuse Derived Fuel (RDF)
cubed or fluff
Technologies
Combustion
Fluidized bed
Stoker/grate
Gasification/pyrolysis
Rotary kilns
Plasma – arc and torch
Steel vessel
Digestion
Anaerobic digestion
Bioreactor
Continuous and batch processes


Must meet regulations for solid waste (ash) and air quality
Air
Modern air pollution control technology removes most contaminants
SCR, SNCR, carbon injection, ammonia injection, lime, scrubbers, baghouse, ESP
Varies by WTE technology, fuel composition, and controls used
Challenges
Labor costs for small plants nearly same as large
Higher per unit capital costs
Higher heat rates (lower efficiencies compared to large)
No commercial operating history in U.S.

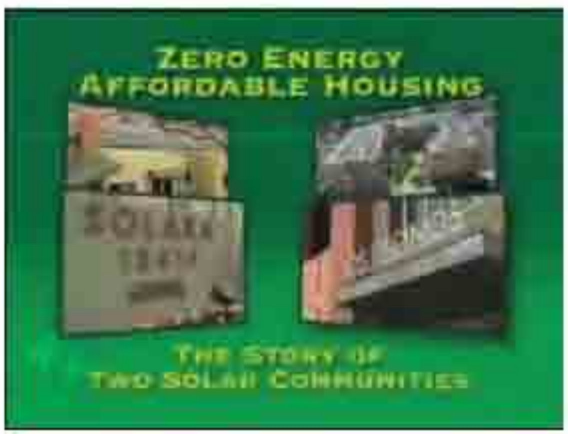

Buildings by Type


Building Scale Strategies


Optimizing Building Performance
1
2
3
4
5


Best
Electrical - Energy Star Appliances
Envelope - Building Efficiency
Plumbing - Solar Water Heating
Mechanical - Passive Solar Heating
Lighting - Daylight Harvesting


Los Vecinos Affordable Housing

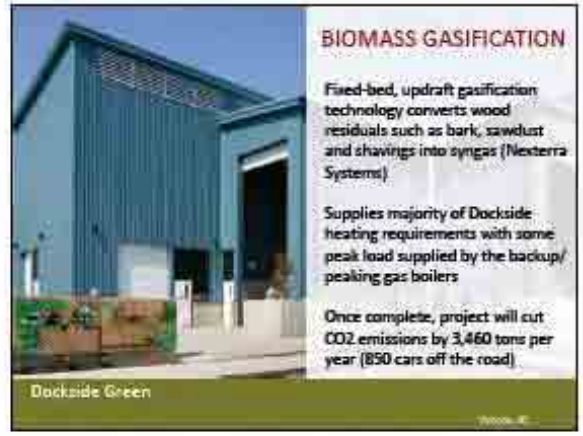

ZERO ENERGY
AFFORDABLE HOUSING
THE STORY OF
TWO SOLAR COMMUNITIES


Dockside Green
OVERVIEW
15 acre brownfield redevelopment
26 buildings with 1.3 million SF of mixed residential, office, retail and light industrial space
2,500 residents at build-out
Dockside Green is one of 16 founding projects for Clinton Climate Initiative's Climate Positive Development Program
Case Study


Dockside Green


Dockside Green


HIGHLIGHTS
Centralized biomass heat generation plant
100% of sewage treated on-site, treated water used for toilets, irrigation, and water features
66.5% water savings compared to LEED baseline
Dockside Green


BIOMASS GASIFICATION
Fixed-bed, updraft gasification technology converts wood residuals such as bark, sawdust and shavings into syngas (Nexterra Systems)
Supplies majority of Dockside heating requirements with some peak load supplied by the backup/ peaking gas boilers
Once complete, project will cut CO2 emissions by 3,460 tons per year (850 cars off the road)
Dockside Green


HIGHLIGHTS
Designed to be 47% more efficient than the ASHRAE 2007
Motorized exterior shades
LED in building corridors
Heat recovery ventilators to provide 100% fresh air to all units
Individual meters for hot water, cold water, heat and electricity
Small-scale PV, solar thermal, wind
Dockside Green


Ventilation Strategy - Typical
Dockside Green


Ventilation Strategy - Design
Dockside Green


"Solar Ship"
Solarsiedlung


Solarsiedlung


Solarsiedlung


Solarsiedlung


Solarsiedlung


Evolution

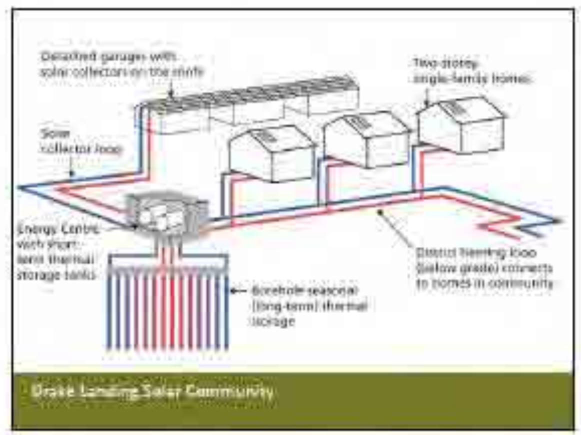

Mueller Green
Mueller Green

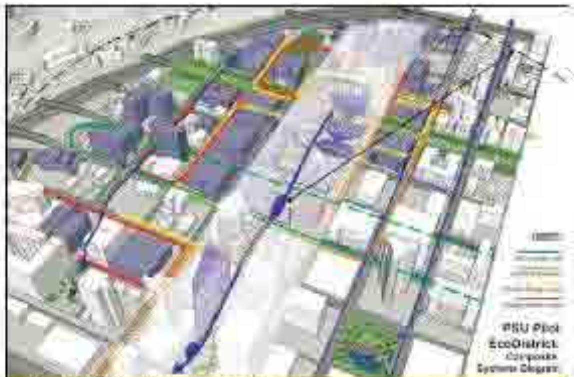

Mueller Green


Mueller Green


BedZED
BedZED


Drake Landing Solar Community


Detached garages with solar collectors on the roofs
Two storey single-family homes
Solar collector loop
Energy Centre with short-term thermal storage tanks
Borehole seasonal (long-term) thermal storage
District heating loop (below grade) connects to homes in community
Drake Landing Solar Community



Portland State University EcoDistrict

Piezoelectricity

Generate energy from walking, running, and traffic

Resident Scale Strategies

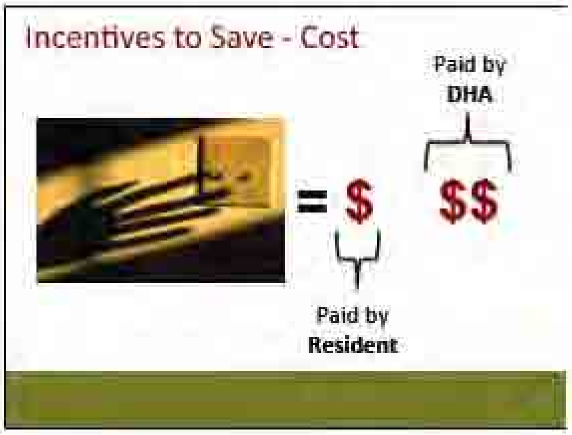
What's going on here?

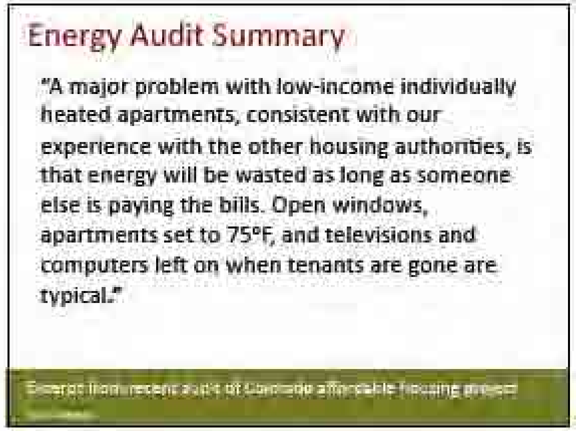
Occupant Scale Energy Strategies

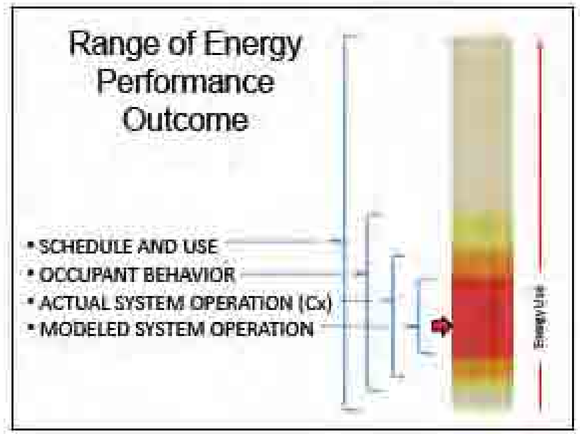
- Engaging occupants and operators
  - Mandates and Policies
  - Information and Feedback
  - Fostering Community and Identity
  - Incentives for saving energy
    - Cost
    - "Doing the right thing"
    - Peer pressure / competition
    - Rewards

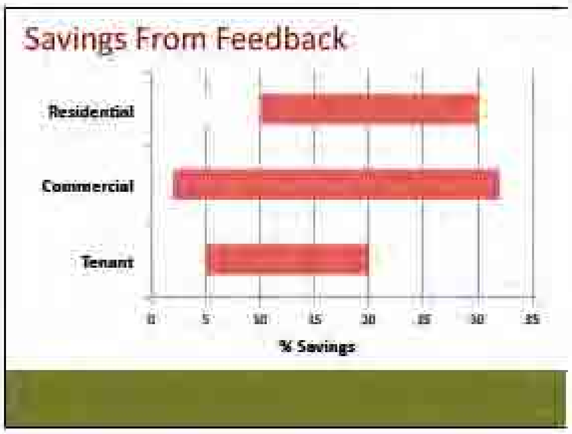
Incentives to Save - Cost

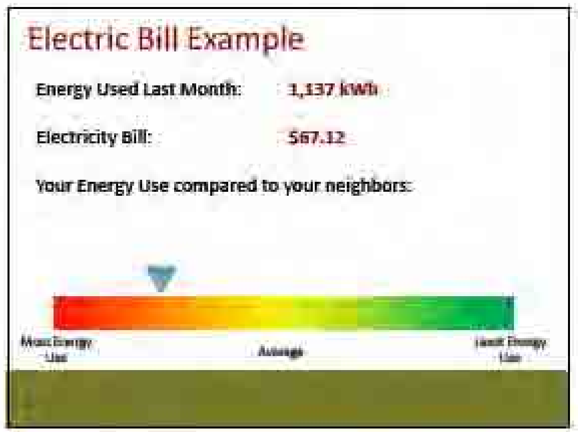
= $$$

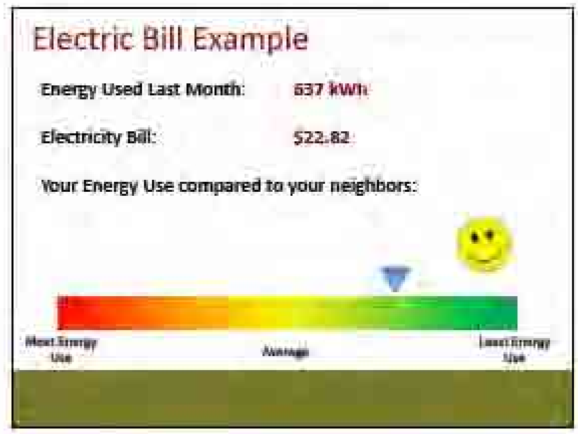

Incentives to Save - Cost
Paid by
DHA
= $
$$
Paid by
Resident


Energy Audit Summary
"A major problem with low-income individually heated apartments, consistent with our experience with the other housing authorities, is that energy will be wasted as long as someone else is paying the bills. Open windows, apartments set to 75°F, and televisions and computers left on when tenants are gone are typical."


Range of Energy Performance Outcome
• SCHEDULE AND USE
• OCCUPANT BEHAVIOR
• ACTUAL SYSTEM OPERATION (Cx)
• MODELED SYSTEM OPERATION


Savings From Feedback
Residential
Commercial
Tenant
0
5
10
15
20
25
30
35
% Savings


Electric Bill Example
Energy Used Last Month: 1,137 kWh
Electricity Bill: $67.12
Your Energy Use compared to your neighbors:
Most Energy Use
Average
Least Energy Use


Electric Bill Example
Energy Used Last Month: 637 kWh
Electricity Bill: $22.82
Your Energy Use compared to your neighbors:
Most Energy Use
Average
Least Energy Use


Occupant Feedback and Control


Lucid Design Displays


Building Dashboard


Summary of Building Systems
Building Dashboard


Budgets


End use breakdowns


Hourly usage profiles


Community comparisons


Green tips
Weather


Energy Strategies at Different Scales
District Scale
Building Scale
Resident Scale


Goals and Outcomes
Working Groups

6.3 Charrette Notes

The following pages contain all of the notes that were recorded on flip charts and taken during the discussions and working groups during the Energy Charrette.

Charrette Goals and Outcomes

Net Zero Definition

- Community net zero building be reviewed separately
- What PV rebates go away—rely on this
- Focus on more than just electricity—don't have all electric load
- Zero flow through community
- District wide—100% (NCECRE) within footprint
  - -Plan B—off-site source e.g. solar garden on brownfield (NZEC-B)
- NZEC-B: Can include some off-site renewable energy credits or green power
- Occupant educational important
- Lifetime—not just five-year period
- Try offset—BTU/BTU match even if different resources
- Electrical diversity vs. contained project
- OK to have natural gas input?
  - -Do through geothermal exchange and passive solar
  - -Could have geothermal ground source with or without central plant
- Remember to focus on minimizing load
- Really important to map loads over time

Suggested Outcomes

- Determine fuel sources in nearby area
- Set goals and keep buildings accountable
- Energy budgets?
- Look for partnerships and continue them long-term
- Fund to pay for first cost appliances to ensure long-term operation?
- Decision strategy—what drives decision on central plant
- Have building envelope toolbox
- How to train people
  - -Out and within (e.g. occupant behaviors)
- Model for other communities
  - -What decision making did you use
- Match funding with phases
- Occupant resp. of uses
  - -Motivation and incentives
- Ensure holistic approach (e.g. don't focus just on photovoltaics)
- Economic impact—sustainable jobs

District Scale Energy Strategies

District Group A (1)

1. DISTRICT energy strategies needed to achieve the goal of a net-zero development?

1. Community Involvement
2. Infrastructure optimization and energy use
3. Solar garden with neighborhood resources (Auraria and Denver Health)
4. Load equalization (“Big Sexy Graphs”)
    a. Block by block, phase by phase, SoLi to neighborhood
5. Sharing opportunities with “neighbors”
    a. Auraria Campus roofs for solar garden, same with Denver Health

2. Emphasis on creating energy—instead of using (electric/natural gas)

2. Pros and Cons of these strategies?

Pros

- ID inefficiencies and avoid
- District-wide approach
- Cost savings
- Lends to a phased approach (scaling)
- Neighborhood approach
- Using resources elsewhere that may not be available on our site

Cons

- Planning needs ($) - more costly near term?
- Need to co-operate
- Working among bureaucratic agencies with varying needs
- Joint funding

3. Technical and political feasibility

- Must be flexible to market/program changes
- Politically—TIF, metro district (to solidify standards)
- $$$$
- Future assets/needs
- Political—work with three large organizations
- Phasing—need to further define solar garden
- Issue—how big can the garden be? Big enough? DHA using others’ roofs
    - ID “now” need vs. “unknown” of future needs

Next Steps

Colorado Carbon Fund
Inventory energy audits: Xcel energy demand model for Master Plan/Neighborhood
Energy Tax Increment Financing (TIFs)/energy conservation district
Analyze rooftops available
Interest at Denver Health or Auraria?
MOU
ID % “allowances”

Other

Occupant behavior groups affect this strategy

District A (2)

Occupant

Smart switch
-do some things automatically/take out the ‘human’ factor
Net metering (awareness)
Education (culturally sensitive)
Community buy-in (everyone)

Building

Design—window direction for wind direction
PV canopy/parking lot
BMPs—make it simple
Building orientation/solar access
Minimum threshold of energy

District Group B & C (1)

Strategy

Design for flexfuel (central plant)

- ➔ Ground Source Heat Pump (GSHP)
- ➔ Biomass
- ➔ Solar
- ➔ Denver Water

Pros/Cons

(Pro) Hedges against volatility and allows options towards net-zero

(Con) Land/real estate

Feasibility

Residential use, real estate, financing are barriers

Distribution costs are high

Next Steps

Complete analysis to evaluate needs and feasibility—should this be balanced with what other strategies?

Partnerships—GEOtool, NREL, Xcel, Denver Water, adjacent landowners, Energy Outreach Co., Enterprise, Denver Public Schools, HUD, EPA, DOE, Colorado Higher Education Association (CHEA)

Challenges—need to expand only residential/consider beyond boundaries to South for industrial, other uses

-N. Lincoln Park
-Railroad
-Denver Health
-Auraria Campus

Strategy

Energy analysis working with building strategies

Identify where district makes sense and how many

Identify synergies

Next Steps

Evaluate energy profiles

Identify opportunities to optimize—building orientation

(Where do savings go?)

What we need from buildings

Optimal orientation, submetering, pay attention to future building code, understanding how owned properties and rental properties work together for sharing costs and savings, how to avoid energy use before systems are built (windows, passive, trees), what type of mechanical systems, will they have—needs to be hydronic or heat pump with coil, adjacent property plans, roof space

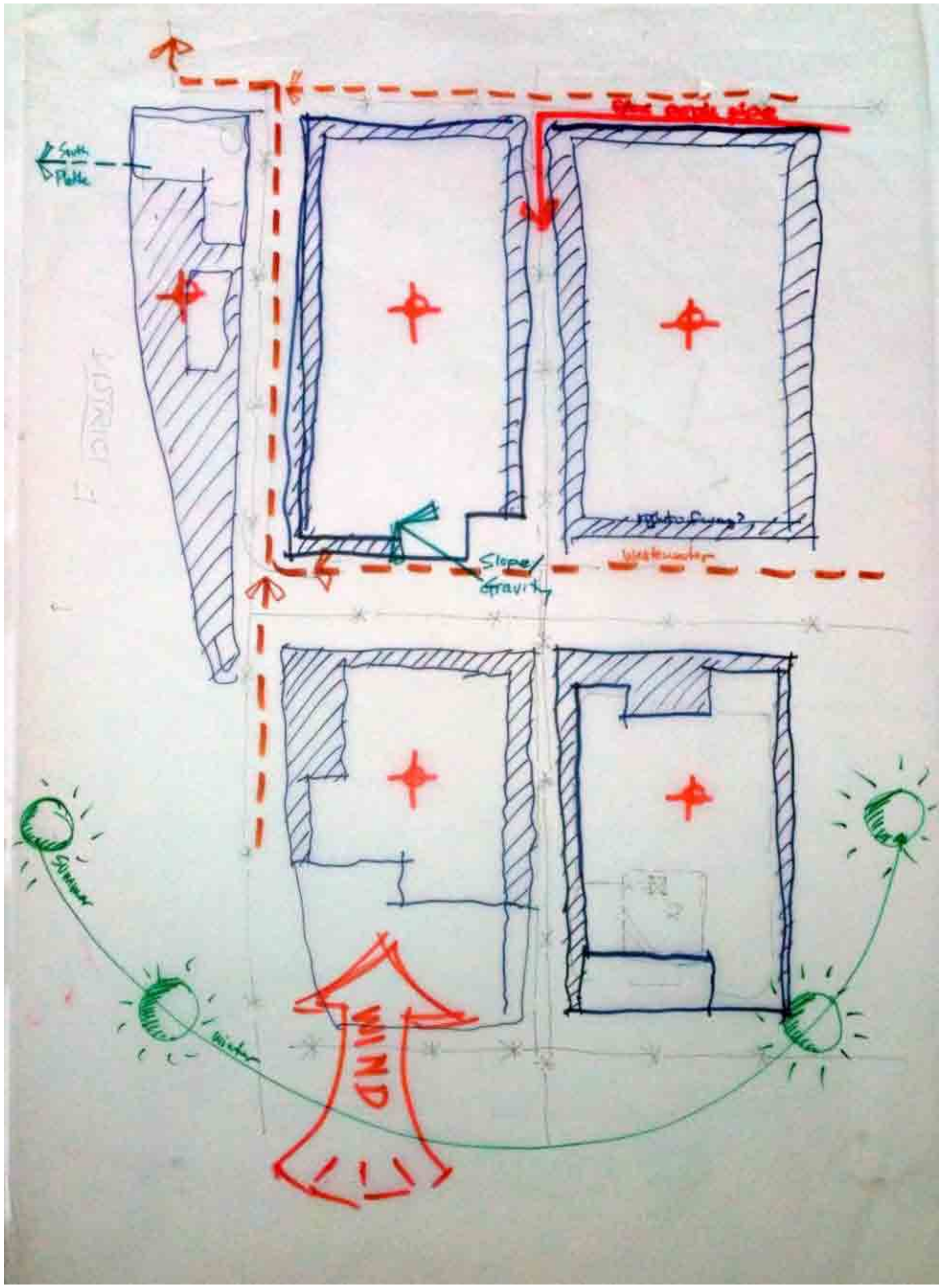
What we need from occupants

Awareness/paying own bills, develop and show incentives, education on lowering energy usage, rules and policies, financial incentives, peer pressure, start with the kids—through school

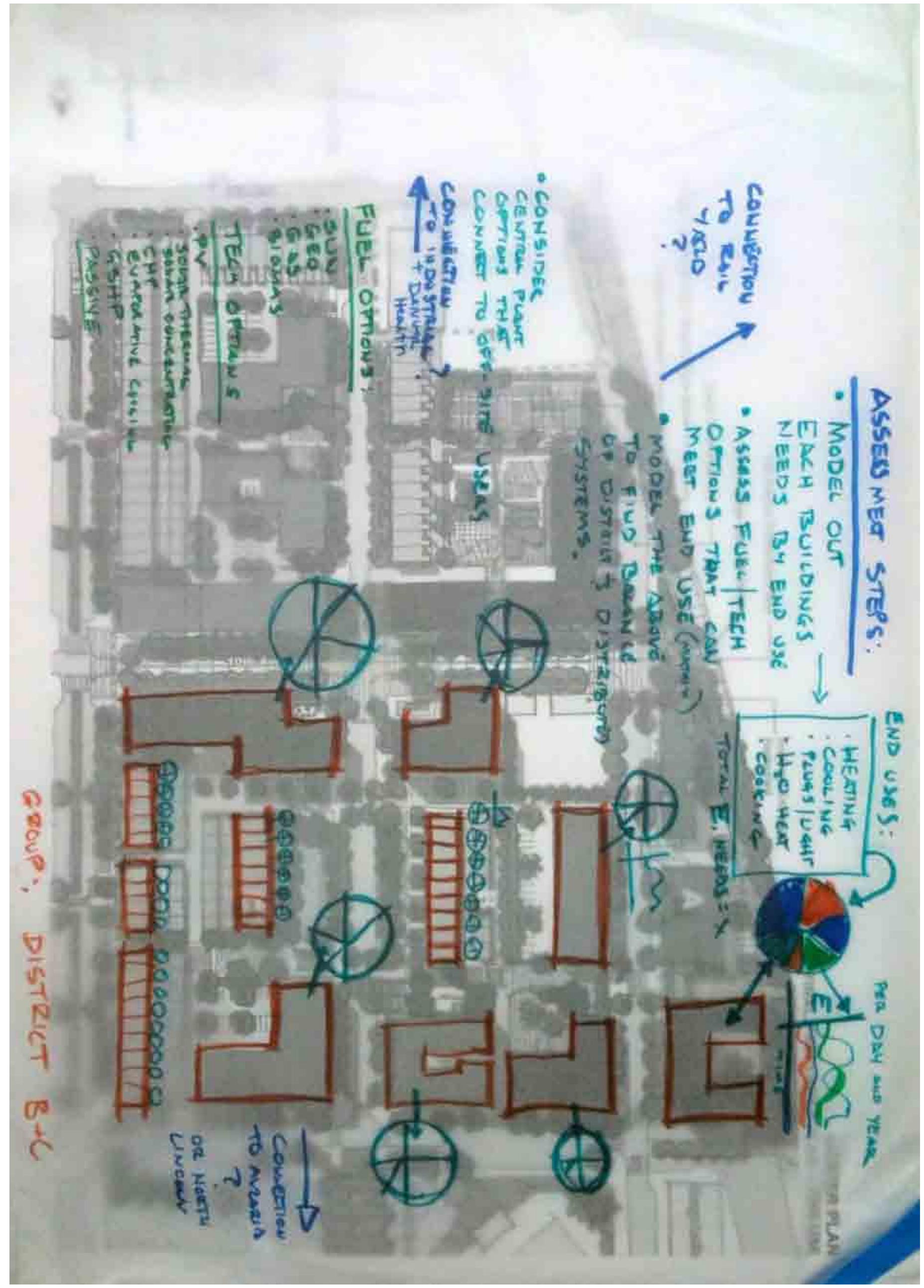
Needs	Gas	Solar Thermal	Concentrated Solar	Biomass	Ground Source Heat Pump (GSHP)	Photovoltaics (PV)
Heating	Easy, cheap now. Volatility in cost. Greater environmental impact than other options.	Highly efficient for larger scale.	Needs a lot of real estate. Railyard roof area as a resource?	Needs storage, unclear on operations and maintenance requirements and who will manage this. Need to determine training and associated costs. Not cost-effective without tax credits. Biomass gasification could be used.	Awesome, very efficient, high first cost, low maintenance	May not be best option unless heating is electric.
Cooling	X		X		X	X
Plug Loads	Combined Heat and Power (CHP)		X			X
Lighting	CHP		X			X
Hot water	X	X		X		

**To better convey the strategies and break-out group ideas, some text in the chart above has been revised or added to in order to clarify notes taken during the break-out group discussions.*

District Group Drawings



District A Drawing



District B Drawing

Building Scale Energy Strategies

Building A (1 & 2)

Strategy

- Efficient/alternative HVAC system
- Envelope—less than .2 air changes per hour
- Passive house standard as potential goal
- Passive system
- Reorientation of buildings
- Frieberg model for some buildings
- Window shading—high efficiency
- Proven products—most bang for buck
- Alternate materials strategies
- Thermal mass
- Alternative construction strategies (e.g. SIPS)

Pros/Cons

- (Con) Cost—upfront cost
- No thermal breaks
- Lower embodied energy
- Reduced infiltration
- Lack of familiarity

Feasibility

- Construction faster
- Highly feasible
- Building codes—educating city staff
- Need more lead time

Next Steps

- Evaluate alternatives
- Look at case studies/examples

Other

- Reduces load for district-wide system

Building A (3)

Strategy

- Thermal mass/construction/earth coupled passive solar heating and cooling

Pros/Cons

- Current orientation does not lend to passive
- Takes up space, costs more or perception of cost
- Energy efficiency, proven strategies, avoid temperature swings
- High environmental quality—natural light/fresh air

Feasibility

- Unsure can reorient—perception
- Unsure codes/regulations
- Off-the-shelf systems

Next Steps

- More discussion on orientation
- Modeling

Other

- Occupant behavior important

Building A (4)

Occupant Behavior

- Handbook/manual, intro class
- Real-time dashboard
- Incentives for compliance
  - Block pricing (positive and negative)

District Scale

- Feasible/Affordable design
- Two-way system (sell book to district)
- Meter individual unit basis
- District-wide water conservation solution
- Flexibility to interact with passive systems
- Landscape/site planning issues for conservation

Building B (1)

Strategy

Natural and low-energy cooling and high performance envelopes

Pros/Cons

Low energy usage, minimizes operating costs
Low upfront and maintenance costs
Incentives? (Xcel)
Better indoor air quality
Potential occupant thermal comfort issues
Education campaign to tenants will be time-, cost-intensive

Next Steps

Investigate incentive opportunities
Bring in expertise (if not available in-house)

Building B (2)

Strategy

Passive design—community and buildings

Pros/Cons

Low cost/rapid payback
Opportunity for significantly reduced loads (system optimization)
Potential code variances/issues

Feasibility

Existing, established process

Next Steps

Look into zoning and land use regulations
Use Building A as a demonstration project with ongoing data (recognize that senior population is unique to rest of project)

Building B (3)

District	Occupant
-Passive design at district scale -Integrate with existing and emerging neighborhood plans -Data collection at district scale -Engage local, proximate businesses, education institutions, community members, etc.	-Education and communication regarding energy usage (carrot and stick approach) -Engage residents in interior design process -"Tell us what you want" and how you learn via Resident Committee

Occupant Scale Energy Strategies

Occupant A (1)

Strategy
- Provide ownership & sense of pride
- Engage residence as early as possible
- Identify champions (train the trainer)
- Involve community colleges & other partners
- Job creation
- Get children involved
- Education part of cornerstone

Pros/Cons
- Culturally relevant
- Ongoing training/high turnover/burnout
- Quickly evolving technology
- Literacy/education issues
- Young engineer group

Feasibility
- Must keep it fun
- Provide incentives (hours for zipcar, childcare, vouchers for green store)

Next Steps
- Create teams for buildings
- Start engagement
- Find the champion (resident to be paid)

Other
- Occupant/community connection with Environment and Earth
- Cultural relevance
- Education
- Resident-driven

Occupant A (2)

Strategy
- Energy management system—or other low-tech option—by unit/floor/building/community
- Provide feedback in unit
- Provide incentives if they don't pay bills (childcare, zipcar hours, transit passes, entertainment, bike share)
- Children to help teach/educate

Pros/Cons
- Cost
- Access to computer/computer labs
- Technology/market

Feasibility
- Need to engage funders/donators (Honeywell?)
- Technology

Next Steps
- Research technology
- Engage funders

Other

Occupant A (3)

Strategy
- Building as teaching tool
- Continual commissioning
- Use clothesline instead of dryer
- Green cornerstone/resource room

Pros/Cons
- Will cornerstone be self-sustaining—can it generate profit if things are provided at cost?
- Provide incentive voucher to spend at green store—others to pay full cost
- Training center

Feasibility
- Depends on building type—you need different strategies for different building types

Next Steps
- Partners for cornerstone
- Retail tenants to leverage cost

Other

Occupant B (1)

Strategy
- Information & Feedback
  - Individual and building usage statistics
  - Rewarding/identifying best practice users -> trip
  - Social feedback: resident meetings
  - Non-computer based feedback: lights, flag, ice cream, letter from Obama, mayor, truck to be powered by alternative energy
- Pay-as-you-go metering

Pros/Cons
- (Con) Participation/Turnout
- (Con) Turnover/Reeducation
- (Pro) Community building/Cost effective

Feasibility
- Getting right data
- Organize meetings/leadership

Next Steps
- Identifying current meetings
- Identify strategy/system for data collection

Occupant B (2)

Strategy
- Energy Careers
  - Job shadows for monitoring/administrative/ops
  - Internships
  - Job training

Pros/Cons
- (Pro) Skills building
- (Pro) More in-depth knowledge of systems
- (Pro) Community Building
- (Con) Participation

Feasibility
- Existing program/Wage subsidies/Training funding
- Need buy-in from staff

Next Steps
- Building Program focused on Net-Zero

Occupant B (3)

Strategy

Mandate/Policy: benchmark—rewarding occupants below benchmark/outreach to occupants with "bad" consumption behavior. Reports given. Benchmark = Sft + # of occupants

Pros/Cons
- Promotes community buy-in/resistance
- Undermining behavior patterns

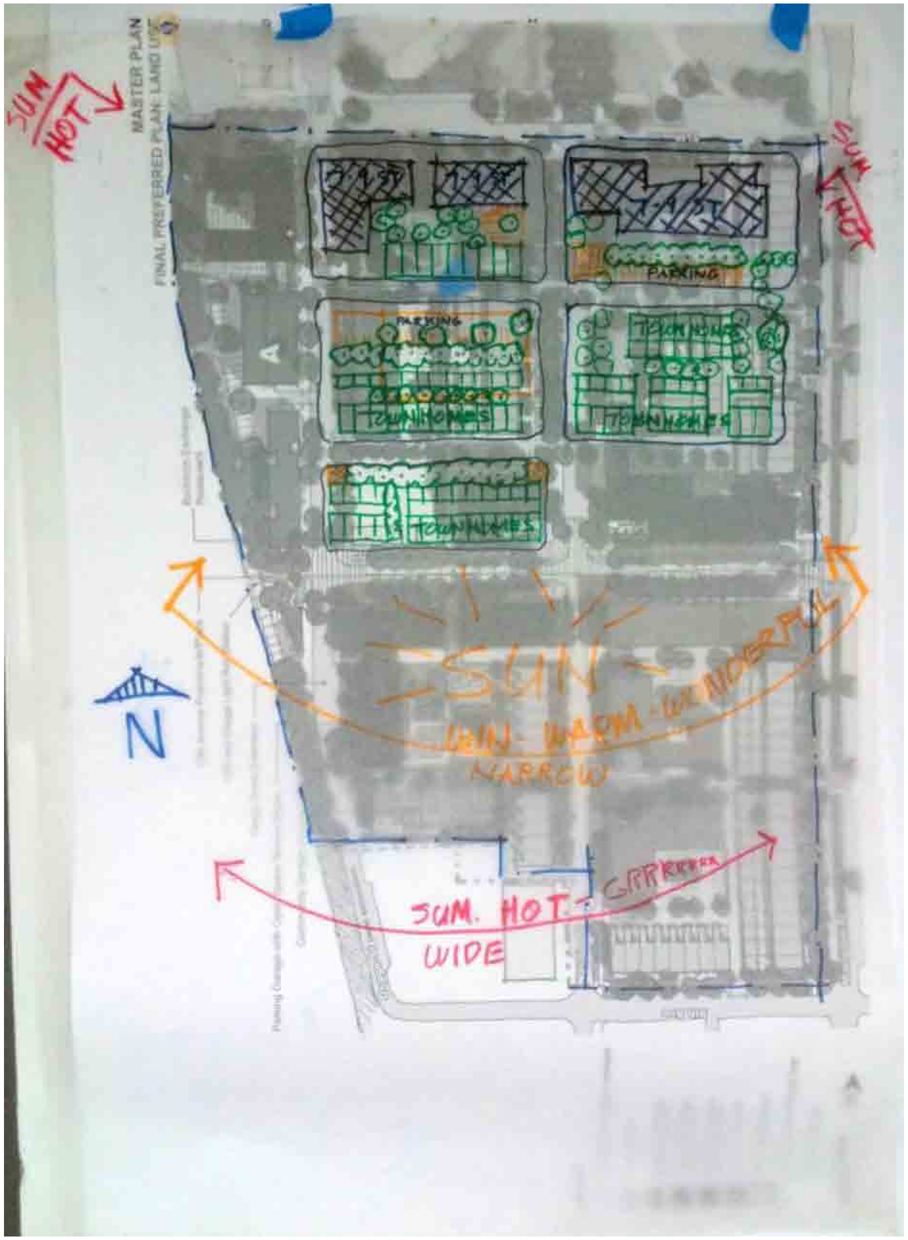
Next Step
- Research HUD funding capabilities/30%

Feasibility
- Market rate vs. Affordable
- Utilities included in all rent?

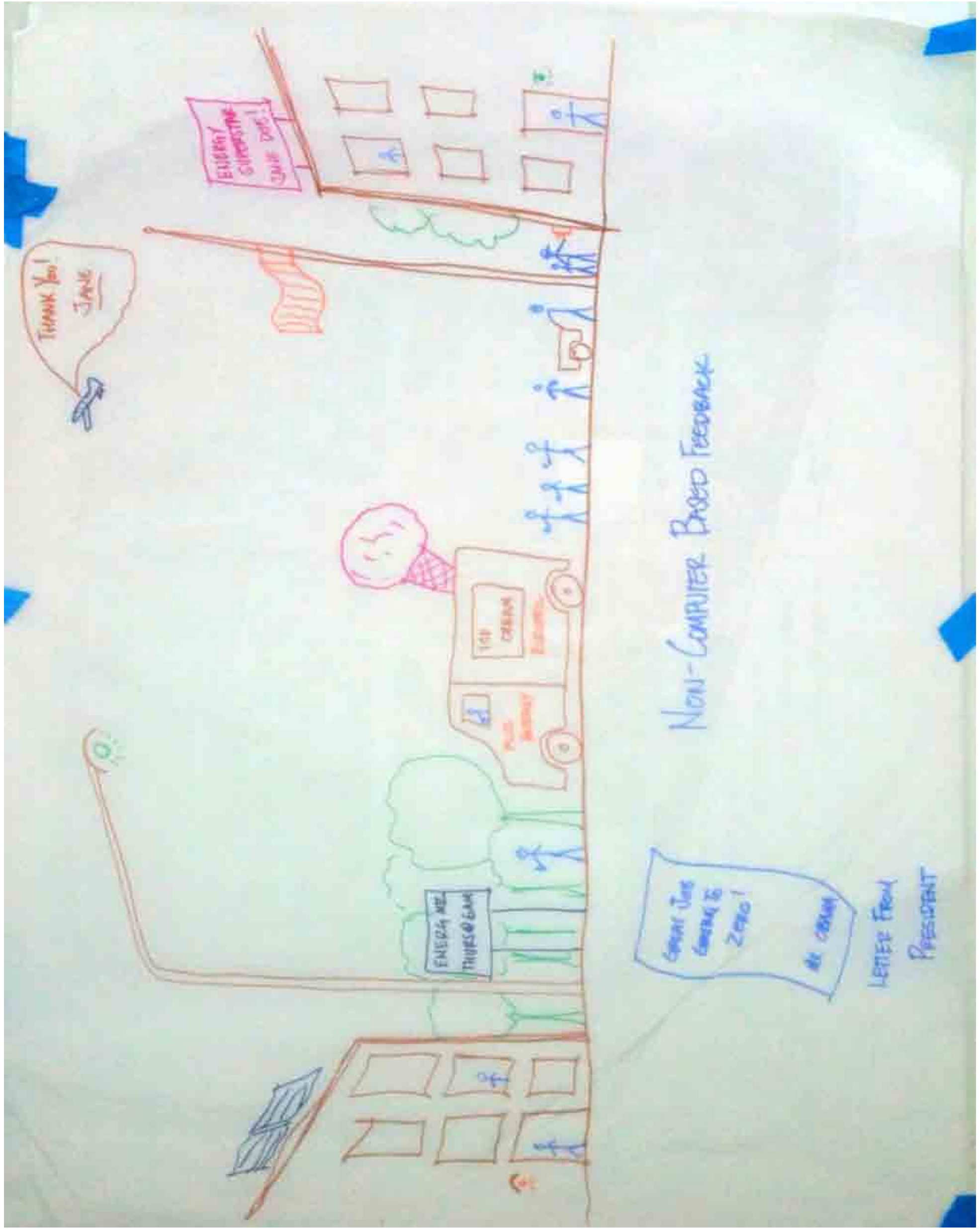
Occupant B (4)

Building Group	District Group
"Catchy" Display Panel/Lobby Units Meters at Unit Level Educational Display	Energy Flags District-scale Feedback -Newsletter -Lights -Community Board Policy for Non-DHA Developers for Energy Monitoring

Occupant Group Drawings:



Occupant A Drawing



Occupant B Drawing

Summary

Voting on Strategies

See Strategy sections above.

Questions

How will ownership be structured for a district system? What are the ownership options and possible partners?
What strategies enable DHA to obtain tax credit?
Will it be possible to dictate appliance selection across all income levels?
What is the budget for insulation and air sealing?
To what degree can we control occupancy behavior?
Has any thought been given to installing smart grid technology to allow homeowners energy use monitoring capabilities?

Ideas

Property Assessed Community Energy (PACE)
Recognition from President every year net-zero is achieved
& Ice cream truck to be powered by alternative energy – symbol of net-zero efforts and successes
& Street party
Anonymous feedback at occupant level
Building scale feedback
Street lights turn colors to indicate use (Red, White, Green)
Payback for (Soli bucks?)
Energy Cop?
Control of occupant behavior more feasible with long-term leasing, not sales?
Scaled rate thresholds for KWh usage (like current water billing)

Suggestions

Pros	Cons
-Everyone's' comments were respected -Like 2-day format	-Add glossary of key terms -Make clear how it will feed into development process -Talk more about financing (more time?) -Add homework before

Miscellaneous Page

No central gas/coal power plant
On/off site solar for electricity
Geothermal
Effective insulation/appliance/windows

Pros	Cons
-Low to no carbon -Decrease residents' utilities	-Expensive -Space—roof to building area ratio

Certain permits are needed

Multiple fuel sources:
Different usage times
Heating vs. electricity
Could be put in single plant
Decide fuel service from usage needs
Using surrounding buildings for additional solar area or additional DHA-owned Housing
Using extra energy at night to freeze ice to use for cooling during the day

Heating

Domestic water
Solar hot water—high efficiency

6.4 Charrette Attendees:

First Name	Last Name	Organization
Fred	Andreas	UNiT Design Studio
Joel	Asreal	Governor's Energy Office (GEO)
Devon	Bertram	YRG sustainability
Cindy	Bosco	Denver Greenprint
Shayne	Brady	HUD
Matt	Brady	South Lincoln Steering Committee
Cindy	Cody	EPA Region 8
Hope	Connors	Green Home Denver
Kimball	Crangle	Denver Housing Authority (DHA)
Jesse	Dean	National Renewable Energy Lab
Steven	Egglestond	HUD
Stacey	Eriksen	EPA Region 8
Laura	Farris	EPA Region 8
Rebecca	Fox	SRA International
Leslie	Fraley	Xcel
Dana	Fulenwider	Urban Venture
Abby	Fulton	EPA Region 8
Elaine	Gallagher Adams	Rocky Mountain Institute
Narada	Golden	YRG sustainability
Dave	Goldenberg	Conundrum Energy
Shannon	Gray	YRG sustainability
Elizabeth	Gundlach Neufeld	Aurora Housing
Jack	Hidinger	EPA Region 8
Doug	Houdson	Metro West Housing Solutions
Abby	Hugill	HUD
Peter	Hynes	South Lincoln Steering Committee
Ron	Johnson	Xcel
Christian	Kaltreider	National Renewable Energy Lab
Paul	Kriescher	Lightly Treading
Dan	LeBlanc	YRG sustainability
Stephen	Loppnow	YRG sustainability
Karly	Malpiede	Representative Diana DeGette's Office

First Name	Last Name	Organization
Matthew	Marshall	Denver Environmental Health (DEH)
Joe	McCabe	Sentech
Ryan	McCaw	Metro West Housing Solutions
Conor	Merrigan	Governor's Energy Office (GEO)
Nat	Miullo	EPA Region 8
Melissa	Nelson	Coldwell Banker Residential
Jason	Newcomer	Diversified Consulting Solutions
Steve	Nowack	Colorado State University (CSU)
April	Nowak	EPA Region 8
Christopher	Parr	Denver Housing Authority (DHA)
Chuck	Perry	Perry Rose LLC
John	Plakorus	CO Housing and Finance Authority
Susan	Powers	Urban Venture
Josh	Radoff	YRG sustainability
Barret	Ramey	Conundrum Energy
Tim	Rehder	EPA Region 8
Sue	Reilly	Enermodal Engineering, Inc
Peter	Riedo	EPA Region 8
Cathy	Rock	Red Rocks Community College
Phillip	Saieg	Alliance for Sustainable Colorado
Eddie	Sierra	EPA Region 8
Joan	Smith	Red Rocks Community College
Laura	Sneeringer	SRA International
Chris	Spelke	Denver Housing Authority (DHA)
Tami	Thomas-Burton	EPA Region 8
Ryan	Tobin	Denver Housing Authority (DHA)
Mike Vail	Vail	Water Legacy
Michael	Van Dalsem	CSU
Otto	Van Geet	National Renewable Energy Lab
Jonathon	Walker	CSU
Jaronam		Roman Remodel and Restoration

6.5 Acronyms List:

Acronym	
CPD	Denver Community Planning and Development
CHEA	Colorado Higher Education Association
CHP	Combined Heat and Power
DHA	Denver Housing Authority
DHW	Domestic Hot Water
DOE	Department of Energy
DOT	Department of Transportation
DPW	Denver Public Works
EPA	Environmental Protection Agency
GEO	Governor's Energy's Office
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
HUD	U.S. Department of Housing and Urban Development
IC	Internal Combustion
LA / LP	La Alma / Lincoln Park
LPNA	La Alma Lincoln Park Neighborhood Association
NPV	Net Present Value
NREL	National Renwable Energy Laboratory
NZEB	Net Zero Energy Buildings
NZEC	Net Zero Energy Communities
OBLR	EPA Office of Brownfields and Land Revitalization
OSC	Office of Sustainable Communities (formally the Office of Smart Growth)
PPA	Power Purchase Agreement
PV	Photovoltaics
SIPs	Structured Insultated Panels
SoLi	South Lincoln Redevelopment Project
SPP	Simple Payback Period
TIF	Tax Increment Financing

South Lincoln Redevelopment District Systems Analysis Report

National Renewable Energy Laboratory

February 7, 2011

Background

Providing heating and cooling for homes and businesses is typically done at the building level, meaning there is one system dedicated specifically to a single building. However, in many situations it may be economically and environmentally beneficial to provide these services at the community scale, in which case many buildings are served by one large district system designed for the entire community. The advantages of district systems stem from their larger scale, their ability to capitalize on load diversity within the community, their reliability and maintainability, the possibility to attain high efficiencies by combining electrical generation with heating and/or cooling, and the autonomy given to the community concerning the operation of the system and the fuel source it uses. For these reasons, it has been deemed worthwhile to perform an analysis of district systems for use in the South Lincoln community development in Denver, CO.

The analysis of the potential for district systems involves estimating the hourly heating, cooling, domestic hot water (DHW), and electric loads required by the community, investigating potential district system technologies to meet those needs, and researching available fuel sources to power such systems. The metrics used to evaluate the economic and environmental viability of each system are simple payback period (SPP), Net Present Value (NPV), and greenhouse gas (GHG) reductions.

Energy Sources

The source of energy used in buildings and district systems affects the economics, environmental impact, and feasibility of any proposed project. Several options are discussed here to address local availability, economic implications, environmental considerations, and any pros or cons specific to this project.

Utility-Supplied Electricity

The utility grid is ubiquitous as a consistent source of energy and will almost certainly play a part in the South Lincoln redevelopment. Though very attractive based on its convenience and relatively stable costs, electricity from the local utility carries with it significant environmental impacts.

The electricity costs incurred at the building level are highly dependent on the rate structure imposed by the local utility. Residential rates tend to have a fairly high electricity consumption ($/kWh) charge, and typically no demand charge ($/kW). Commercial rates in the state of Colorado, on the other hand, typically have low charges for electricity consumption and significant demand charges. The current rates for the South Lincoln Community are discussed more in the 'Economic Analysis' section of this report.

Because most of the electricity in Colorado is generated by coal-fired power plants, the emissions associated with electricity are high. Of the typical fuel sources for generating electricity, coal has the most significant GHG emissions. Furthermore, the efficiency of a power plant and its distribution lines is typically around 35%. As a result, one kWh of electricity used in a building requires about three kWh of energy from coal. The CO_2 emissions from electricity must take this multiplying effect into account. More information GHG emissions is provided in the 'Emissions Analysis' section of this report.

Natural Gas

Natural gas is the conventional fuel source for heating in the Denver area, but it can also be effectively used for electrical power generation. It is in ready supply and many of the systems that it can fuel are well-established, off-the-shelf technologies.

Current natural gas rates are relatively low by historical standards. Furthermore, Colorado has some of the lowest natural gas rates in the nation, as can be seen in Figure 1. The cost of natural gas for the South Lincoln community in the past year averaged to about $0.673/therm. Natural gas prices however, are very volatile. Figure 2 shows prices tripling between the years 2000 and 2006. Use of natural gas in this project would expose the neighborhood to potentially high fuel prices in the future.

Burning natural gas releases significantly less CO_2 than burning coal. Thus, producing electricity using natural gas will generally show sizeable savings in CO_2 emissions. However, like coal, natural gas is a non-renewable resource and it is not a carbon neutral fuel source.

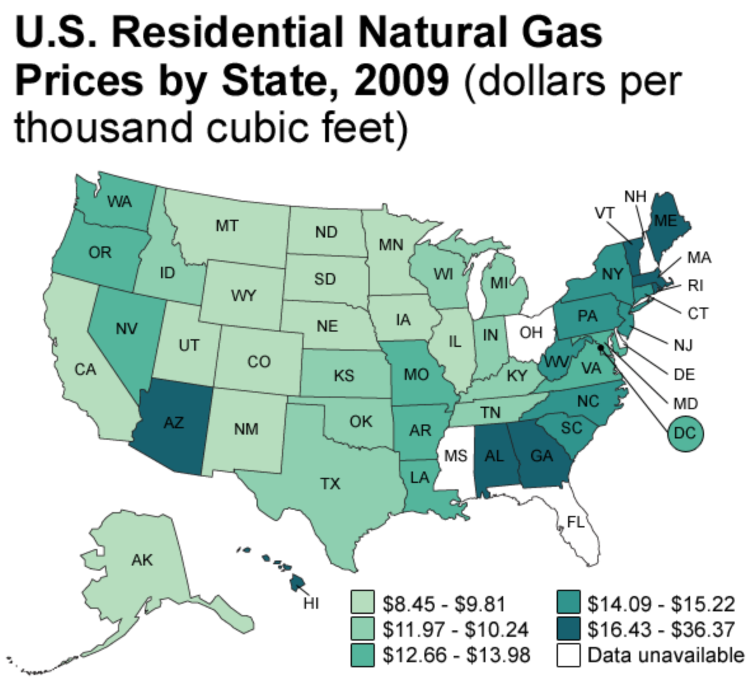


Figure 1: U.S. Residential Natural Gas Rate

(Source: http://www.eia.doe.gov/energyexplained/index.cfm?page=natural_gas_prices)

Figure 2: Historic Natural Gas Rates in Colorado
(Source: http://www.eia.doe.gov/dnav/ng/hist/n3020us3M.htm)

Biomass

Biomass fuel is produced from organic materials such as plants, agricultural residues, forestry by-products, and municipal or industrial wastes. In the Denver area, the most viable biomass options for the purposes of the South Lincoln community are coarse-ground wood, wood chips, and wood pellets. The primary source for all three of these is beetle-killed pine, but standard forest thinning, forest fire mitigation, and urban wood waste can provide sources for these fuels as well. Beetle killed pine is a plentiful biomass source and is projected to be a stable resource for decades (Source: Chris Gaul, NREL biomass plant operator). Figure 3 shows the forest residue biomass resource in and around Denver. The Denver area currently has a handful of biomass suppliers which could be relied upon for a consistent fuel supply.

Figure 3: Forest Residue Resource (shown in light green) in the Denver Area

(Source: http://rpm.nrel.gov/biopower/biopower/launch)

Wood pellets are the most expensive of these options, followed by wood chips and then coarse-ground wood. Table 1 gives approximate current costs for each of these fuels. The primary driver for cost is the amount of processing required. Consequently, the most consistent and easiest to use fuels are also the most expensive options. While coarse-ground wood is attractive from a cost standpoint, any equipment chosen must be capable of processing the relatively larger and less consistent wood pieces.

Table 1: Approximate Costs of Biomass Fuels

(Source: Chris Gaul, NREL biomass plant operator)

Biomass Fuel Type	Approximate Cost ($/MMbtu)
Pellets	12.2
Wood Chips	4.4
Ground Wood2.3	2.3

In contrast to natural gas and other fossil fuels, biomass is a renewable fuel source. It is also generally considered to be ‘carbon neutral’, meaning the fuel has no net CO_2 emissions. This is because the organism that the fuel is derived from absorbs approximately the same amount of CO_2 while it is living as it will release during combustion or decomposition. Assuming that the resource is being replaced at the same rate as it is being consumed, the rates of CO_2 emission and absorption will be approximately equal, resulting in near net zero carbon emissions. However, the transportation used energy to move the fuel from the source to the point of use results in a minor carbon emission. This is not accounted for in this analysis.

Solar

Colorado has a particularly abundant solar resource. As seen in Figure 4, only the southwest has a better solar resource in the continental U.S. There are generally few overcast days in Colorado and the higher elevation reduces the amount of solar radiation lost while filtering through the atmosphere. A benefit of using the sun for power is that there is no monetary or environmental cost associated with fuel use throughout the life of the system.

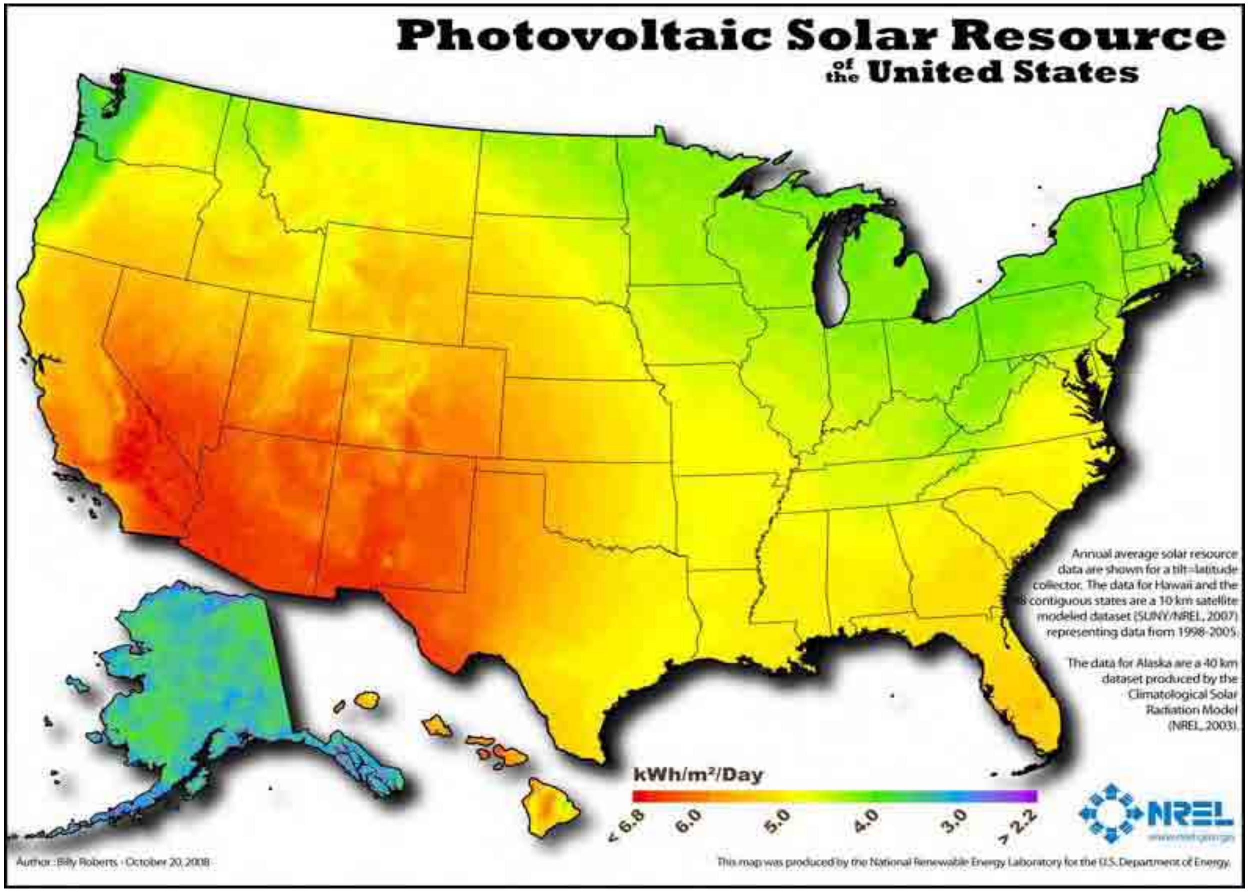


Figure 4: U.S. Solar Resource

(Source: http://www.nrel.gov/gis/solar.html)

Community Energy Requirements

In order to investigate potential district systems, it is vital to predict the hourly heating, cooling, DHW, and electric energy load and demand for the South Lincoln community once redevelopment is complete. Heating, cooling, DHW, and electrical load refers to the total annual energy needed by the community for space heating and cooling of the buildings, hot water for domestic use, and electricity used in the buildings. For the purposes of this analysis the electric load includes all building level uses except for those associated directly with heating and cooling. This includes lighting, plug loads, and HVAC fans and pumps. Estimating the load of the community allows a prediction of the amount of fuel expected to be used in a typical year. Load is expressed in units of energy, such as kWh or MWh.

Heating, cooling, DHW, and electric demand refers to the amount of heating, cooling, DHW, or electricity needed by the community at any one instant in time. Peak demand is the maximum demand experienced on an hourly basis for the entire year. For instance, peak heating demand would be determined by the amount of heating required to meet the needs of the community on the coldest night of the year. Demand is expressed as a rate of energy production such as kW or Btu/hr. Estimating the maximum demand of the community allows a prediction of how large a district system has to be so that it is capable of keeping up with the community's needs during periods of peak demand.

To estimate the energy requirements of the proposed community, building energy models were created to simulate the expected energy usage of each type of building in the community. These simulations predict hourly energy load and demand for each building type. Simulation results were scaled up to represent the usage of the entire community.

All of the building areas on the campus were represented with three models: One of the high-rise residential spaces (1099 Osage), one of the low and mid-rise flats, and one of the townhouse units. The Table 2 gives details of these models; information on floor area by space use, number of residential units, and number of bedrooms for the campus was taken from the Block-by-Block Analysis from DHA.

Table 2: Building Energy Model Details

Model	Space Use	SF	Number of Residential Units	Number of Bedrooms per Unit: One	Two	Three	Four	Total Bdrms	Model Description
A	High Rise Flats (1099 Osage)	97,000	100	70	30	0	0	130	Model was completed for Phase 1 of redevelopment.
B	Townhouses (Stand-alone and Modular)	183,400	109	4	16	76	13	316	One model of a strip of two-story townhouses with 8 units @ 1,683 SF each with 23 total bedrooms (occupants). 8 is the average length of a strip of units shown in drawings; this will let us model ratio of end units/ interior units accurately. This model accurately represents the building SF, number of residential units, and number of bedrooms.
C	Low & Mid Rise Flats (3 - 6 stories)	657,731 SF residential units + 144,500 SF circulation/ support	680	439	241	0	0	921	All of this building area is represented with one model. The model consists of a 'mid-rise' with 5 stories of flats above a ground level of retail, community, and lobby space. Each residential level contains 20 residential units (& 27 bedrooms) configured in an 'L' shape around a central corridor: 19,350 SF of residential + 4,250 SF corridor/circulation (18% of floor plan assumed) = 23,600 SF footprint. The ground level consists of 3,630 SF of retail space, 3,680 SF of community space, 1,600 SF of lobby space, and 735 SF of 'other' space to make the multiplier consistent.
	Retail	24,700	-	-	-	-	-	-	
	Community	25,000	-	-	-	-	-	-	
	Lobby	10,850	-	-	-	-	-	-	
	Other	5,000	-	-	-	-	-	-	
	Totals	1,003,681	889	513	287	76	13	1,367	

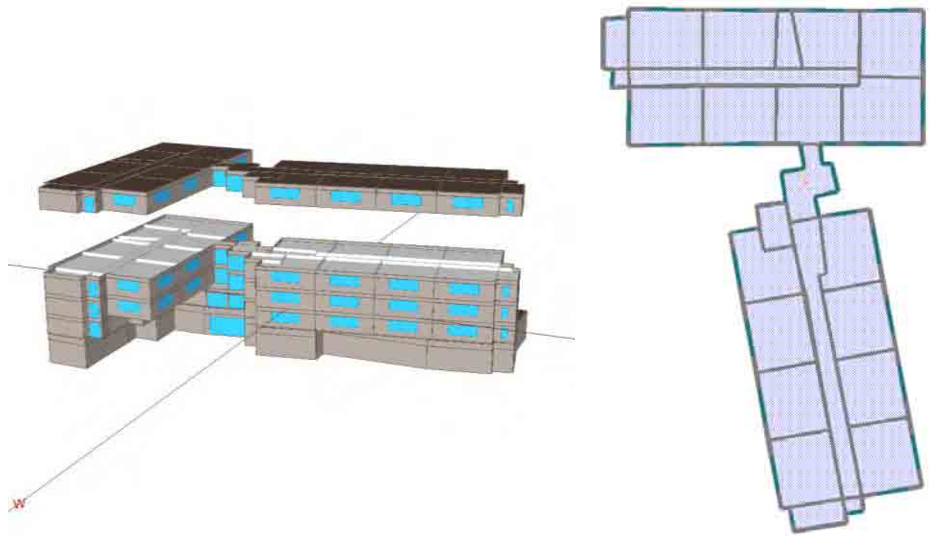


Figure 5: High Rise Building Energy Model 3D View and Floor Plan

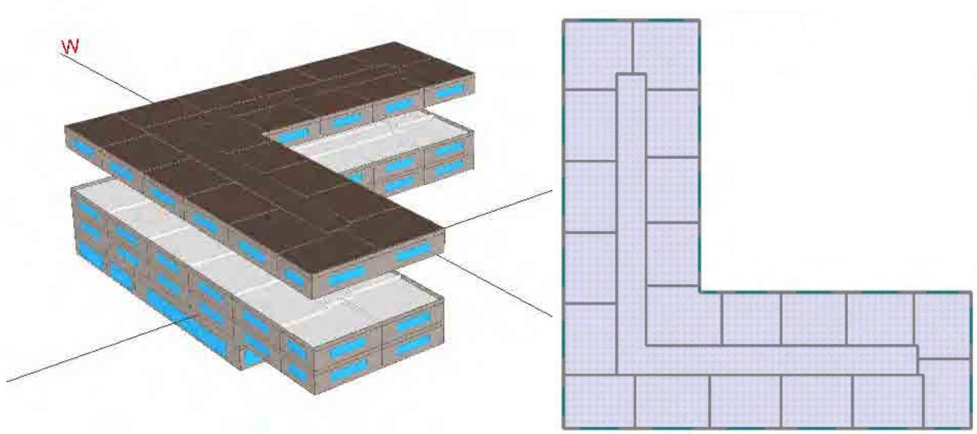


Figure 6: Mid Rise Building Energy Model 3D View and Floor Plan

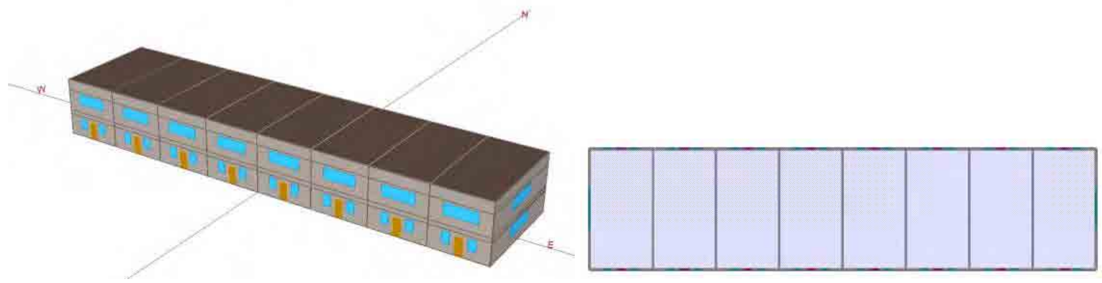


Figure 7: Townhouse Building Energy Model 3D View and Floor Plan

The results of the models indicate that electricity and space heating are the largest community loads, each requiring approximately 5000 MWh/yr. Cooling and domestic hot water require approximately 2500 MWh/yr apiece. Figure 8 compares these annual loads.

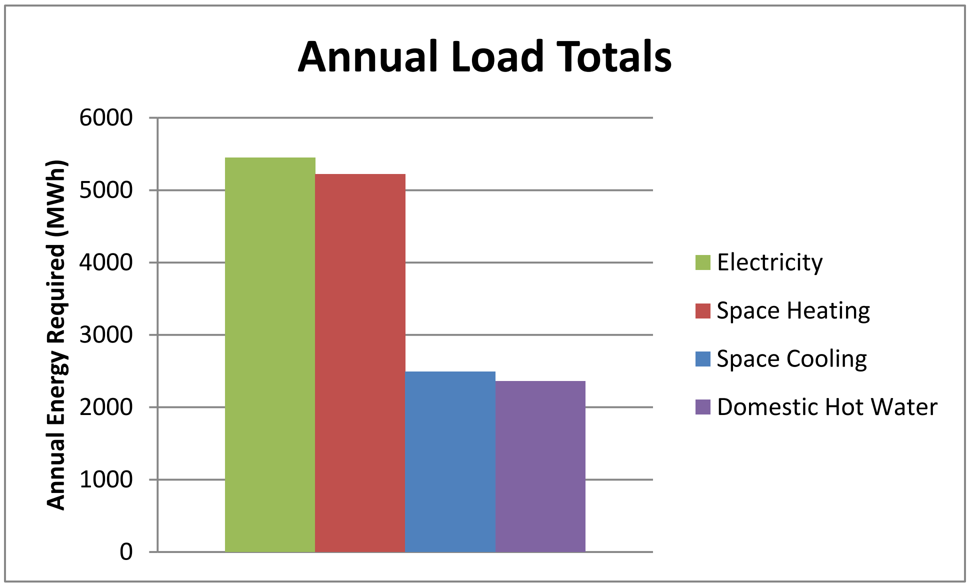


Figure 8: Predicted Annual Energy Load Requirements

Space heating and domestic hot water are often lumped together as one thermal load when served by a tri-generation, cogeneration, or district heating system. Table 2 shows the annual energy requirements of the site when space heating and domestic hot water are considered together. As can be seen, heating/DHW is the dominant load. Table 3 gives the peak demand for each of these three loads. Again, heating/DHW is dominant. Figure 9 shows the load profiles over the course of a typical year.

Table 2: Predicted Annual Energy Load Requirements

Annual Energy Requirements (MWh)		
Electricity	Heating (including DHW)	Space Cooling
5446	7582	2491

Table 3: Predicted Peak Energy Demand

Peak Demand (kW)		
Electricity	Heating (including DHW)	Space Cooling
994	4,636	1,839

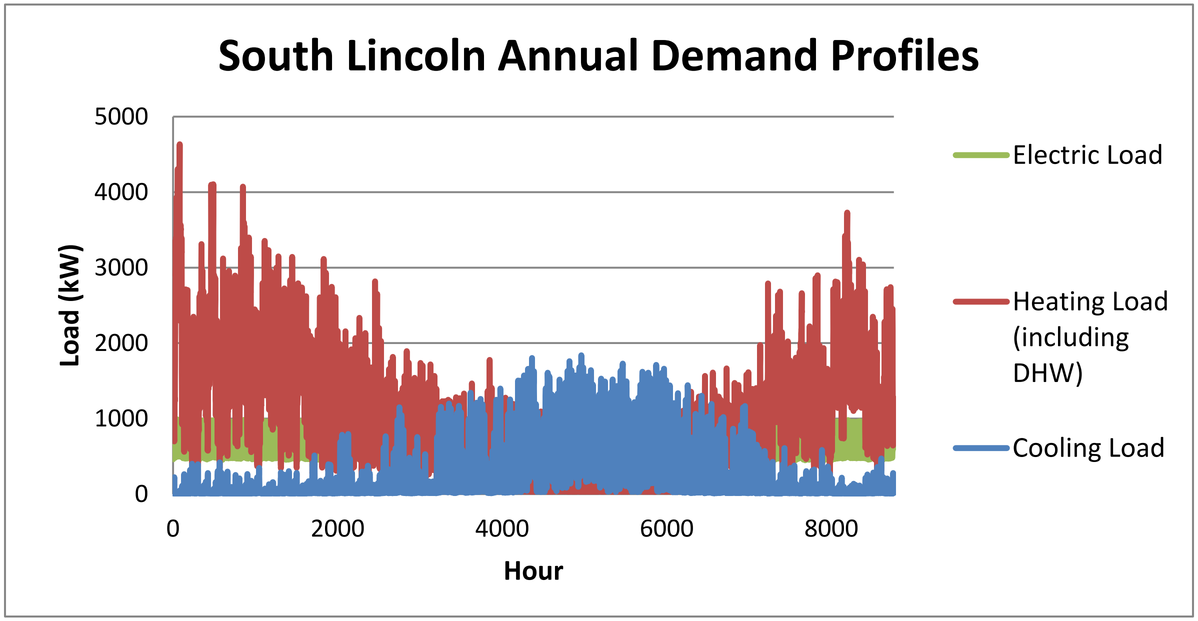


Figure 9: Predicted Annual Energy Demand Profiles

Economic and Emissions Assumptions

Economic Analysis

An economic analysis was performed that follows the federal life cycle costing requirements developed by the National Institute of Standards and Technology (NIST), using federal guidelines for discount rate, electricity escalation rate, and fuel escalation rates. The discount rates for 2010 are valid from April 1, 2010 to March 31, 2011.

The appropriate escalation rates from the Energy Escalation Rate Calculator were applied to natural gas and electricity rates. The values given in the Energy Escalation Rate Calculator are based on projections from the Energy Information Administration. The escalation rates were calculated assuming the project came online in 2012 and had an overall lifetime of 25 years.

The electricity and natural gas rates for this analysis were calculated based on a sampling of energy bills for the existing South Lincoln community. DHA typically uses a commercial utility rate structure for its larger buildings and a residential utility rate for its smaller units. Because the South Lincoln redevelopment is expected to have buildings on both structures, average rates were calculated to apply to the entire site. Table 4 lists the parameters used for all energy use and economic analyses.

Table 4: Economic Parameters Used in This Analysis

Parameters Used in Economic Analysis	
Project Lifetime	25 yrs
Real Discount Rate	3%
Electricity Escalation Rate	0.50%
Natural Gas Escalation Rate	0.40%
Blended Residential Electricity Rate	0.104 $/kWh
Commercial Electricity Rate (Energy only)	0.033 $/kWh
Summer Commercial Electricity Demand Rate	20.24 $/kW
Winter Commercial Electricity Demand Rate	27.24 $/kW
Natural Gas Rate	0.673 $/therm

A Federal Investment Tax Credit (ITC) is available for photovoltaics, solar hot water, biomass, cogeneration and tri-generation, and ground-source heat pump installations. For photovoltaics, solar hot water, and systems powered by fuel cells, the credit is worth 30% of the initial cost of the system. For ground-source heat pumps, biomass, and cogeneration or tri-generation systems not powered by fuel cells, the credit is worth 10% of the initial cost of the system. Results for cases including these incentives as well as cases without the incentives are given for each analysis in this report.

Green House Gas Emissions

Electricity emissions data were taken directly from the U.S. Energy Information Administration's publication of Colorado's electricity profile. Natural gas emissions data are from the EPA's Climate Leaders program. Table 5 summarizes this data. Notice that CO_2 is by far the dominant GHG emission for both electricity and natural gas. Note also that the emissions associated with utility-supplied electricity are nearly 5 times greater than those from natural gas. This fact plays a major role in the final results of this analysis.

Table 5: Greenhouse Gas Emissions of Electricity and Natural Gas

Energy Source	**Emission Compound**	**Equivalent CO_2 Emissions** (lbs/MWh)
Electricity (Generated in Colorado)	Carbon Dioxide	1,883
	Methane	0.0228
	Nitrogen Oxide	0.02875
Natural Gas	Carbon Dioxide	399
	Methane	0.0376
	Nitrogen Oxide	0.0008

(Sources:
Electricity: US Energy Information Administration, 2008 Colorado Electricity Profile Statistics, http://www.eia.doe.gov/cneaf/electricity/st_profiles/colorado.html;
Natural Gas: Natural Gas Emissions Data, Environmental Protection Agency, http://www.epa.gov/climateleaders/documents/resources/comm_boiler_proto.pdf)

District Systems Analysis

Base Case

It is necessary to create a base case for the community in order to generate a baseline energy usage profile for the South Lincoln community. This baseline is used as the starting point for each energy, economic, and emissions analysis. It is important to note that the base case chosen has a large impact on the analysis results.

The base case used here assumes that heating is supplied by natural gas boilers with an overall thermal efficiency of 85%. Cooling is assumed to be provided by chillers with an overall coefficient of performance (COP) of 3.1. Table 6 gives the efficiencies and total costs assumed. Electricity is assumed to be provided by the local utility. These efficiencies were applied to the energy requirements predicted by the building energy models to determine the baseline energy usage of the community. The annual energy costs and GHG emissions were based on this baseline energy usage. Figure 10 shows the annual energy usage profile for the base case. Figure 11 shows the annual GHG emissions profile for this case. Note the disproportionate role that electrical energy usage, including that used for cooling, plays in the overall emissions profile.

Table 6: Base Case Heating and Cooling Efficiencies and Total Costs

Parameter	Value
Overall Boiler Efficiency	85%
Total Boiler Costs	$491,129
Overall A/C Efficiency	3.1 (COP)
Total A/C Costs	$2,581,907

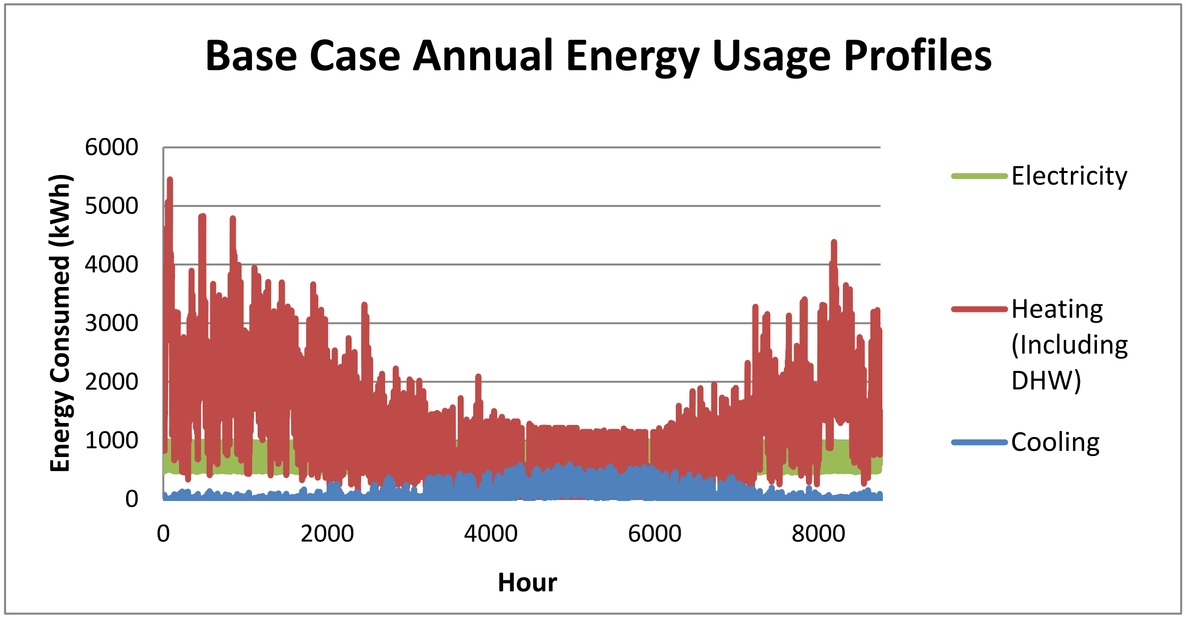


Figure 10: Predicted Annual Base Case Energy Usage Profiles

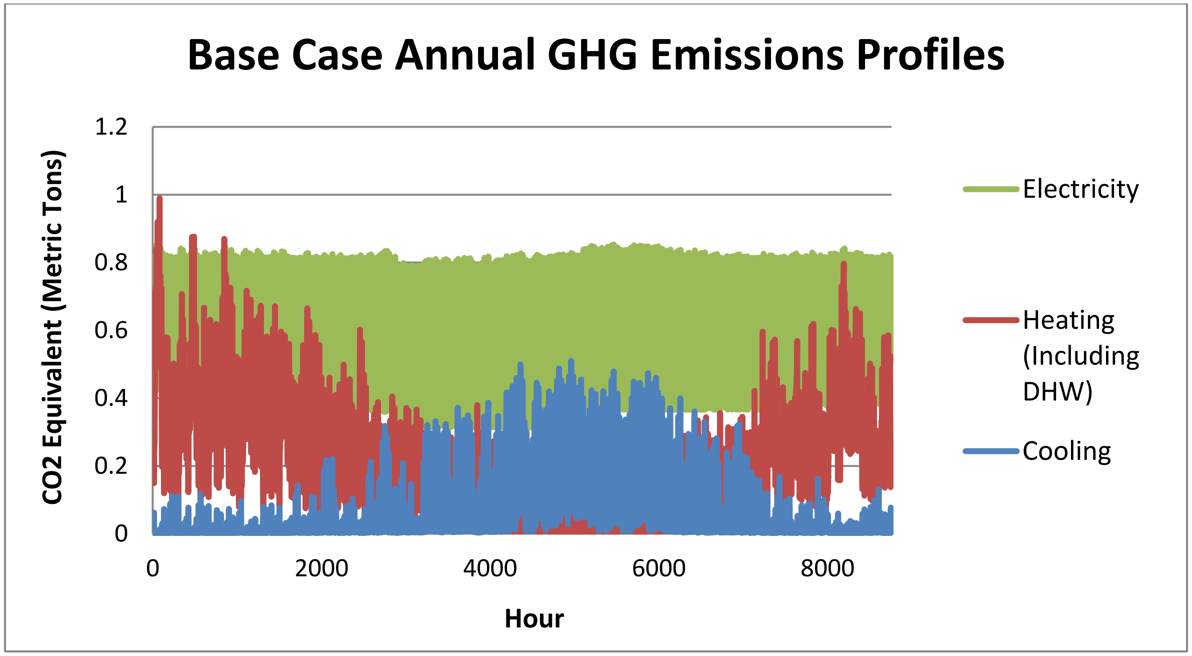


Figure 11: Predicted Annual Base Case GHG Emissions Profiles

District Heating

Clean district heating can be achieved using a central biomass boiler. The heat from a central plant can be applied to both space heating and domestic hot water.

Figure 12: Central Biomass Heating Plant on the NREL Campus

(Source: NREL Pix Photo Library)

A central biomass plant will require infrastructure such as a building to house the boiler and the fuel. A road must be built to allow easy access for fuel delivery trucks. Furthermore, a natural gas fueled back-up system should be installed. This significantly increases the upfront cost as well as the simple payback of such a system. A central biomass plant will also typically require an operator much of the time, resulting in high operation and maintenance costs and further increasing the payback period of the system.

Because a district biomass system will require the delivery of large volumes of fuel on a regular basis, the site must be prepared for this increased traffic. An initial analysis was performed to determine the approximate number of tractor-trailer loads of wood chips required per week to meet the South Lincoln community's heating and DHW loads. During the peak heating season, it was found that about 6 tractor-trailer loads per week would be sufficient. During other times of the year, the number of loads needed would be less. Table 7 shows the results of this analysis.

Table 7: Approximate Quantities of Wood Chip Fuel Required for Heating and DHW

	Base load Heating Month	Average Heating Month	Peak Heating Month
(MMBtu/month)	938	3,423	6,971
(lb/month)	137,940	503,372	1,025,118
(Trailerloads/month)	3	11	23
(Trailerloads/week)	**1**	**3**	**6**

The analysis for a central system using biomass fuel was performed for three system sizes based on the heating demand of the community. An optimal system size was determined based on simple payback period. Note that, although the system sizes range from 80% to 30% of the community's maximum demand, the percent of annual heating energy needs met by each system only vary from about 100% to 80%. This is because the community heating demand only rarely reaches levels close to its peak demand. The majority of heating energy needed by the community occurs during times when the demand is at a small fraction of the peak. Thus, smaller systems are capable of meeting these needs most of the time. Wood chips were assumed to be the fuel used for the entire analysis. Table 8 gives the results of this analysis.

Table 8: Analysis Results for District Heating with Biomass

Biomass District Heat (Wood Chip Boiler)							
Percent Heating and DHW Capacity	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total Heating and DHW Supplied	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
80%	$3,399,489	$16,976	200.3	-$3,103,881	99.8%	23%	$2,101
80% (with 10% ITC*)	$3,048,395	$16,976	179.6	-$2,752,786	99.8%	23%	$1,884
40%	$1,831,518	$16,429	111.5	-$1,545,443	91.4%	21%	$1,238
40% (with 10% ITC*)	$1,637,221	$16,429	99.7	-$1,351,146	91.4%	21%	$1,106
30% (lowest spp)	$1,439,525	$13,734	104.8	-$1,200,373	81.8%	19%	$1,085
30% (lowest spp with 10% ITC*)	$1,284,428	$13,734	93.5	-$1,045,275	81.8%	19%	$968

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Cogeneration

Cogeneration refers to a system which performs two functions simultaneously. The most common cogeneration system is combined heat and power (CHP), in which the waste heat created during electricity generation is used to meet space heating, domestic hot water, or industrial needs. All systems analyzed here are CHP systems. The main benefit of cogeneration is that waste heat can be recovered and made useful, greatly increasing to total efficiency of the system. Figure 13 shows a diagram of a CHP system.

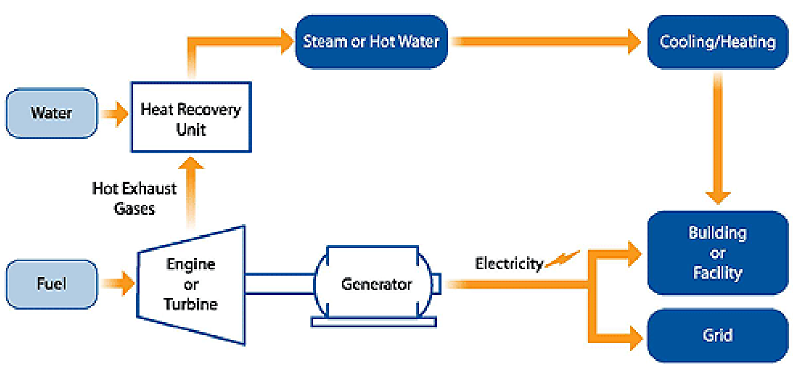


Figure 13: Schematic of a Cogeneration or Tri-generation Plant

(Source: http://www.epa.gov/chp/basic/index.html)

A cogeneration plant can be driven by gas turbines, Internal Combustion (IC) engines, or fuel cells. For the South Lincoln site, natural gas is the most appropriate fuel for all of these technologies.

The size, or capacity, of a system can have a high impact on its economic viability. If a system is too large then it will likely produce more thermal energy or electricity than the community can consume at a given time. This results in wasted energy and money. However, smaller systems suffer from economies of scale. This is because the upfront cost of the distribution system will be virtually the same for large and small cogeneration plants. This cost becomes significant in relation to the smaller savings seen with smaller systems. For these reasons, each technology is analyzed based on three different capacities: A larger size which is projected to meet most of the community's thermal loads, a smaller size based on the lower size limits of most technologies, and an optimal size based on the simple payback analysis. Note that the optimal size based on simple payback may be smaller than is commonly available.

The monetary and environmental savings seen with cogeneration systems are mostly tied to the production of electricity. This is because electricity from the utility tends to be fairly expensive and is primarily generated using a high-emissions fuel such as coal. Thus, the efficiency with which a cogeneration system can produce electricity is very important. Overall efficiencies, which include the useful thermal energy produced, are generally of secondary importance. A summary of the efficiencies and upfront costs used in this analysis is given in Table 9.

Table 9: Efficiency and Cost Assumptions Used in this Analysis

	Gas Turbine	IC Engine	Fuel Cell
Electrical Efficiency	28%	35%	45%
Thermal Efficiency	47%	35%	20%
Overall Efficiency	75%	70%	65%
Cost ($/kWelec) (CoGeneration)	$2,500	$1,500	$5,000
Cost ($/kWelec) (TriGeneration)	$3,550	$2,020	$5,320

<u>Gas Turbine:</u> A gas turbine uses the combustion of a gaseous fuel, such as natural gas, to drive a high pressure flow of air through a turbine. The turbine then generates electricity.

The primary advantage of a gas turbine is its high overall efficiency. Of the three technologies considered, the gas turbine will generally have the highest efficiency when considering both electricity and useful thermal energy. However, gas turbines have relatively low efficiencies when considering only electric production at smaller capacities (less than 5 MW). This is a severe disadvantage. Furthermore, gas turbines have fairly high upfront costs at smaller capacities. The analysis results for cogeneration using a natural gas turbine are given in Table 10.

Table 10: Analysis Results for Gas Turbine Cogeneration

Cogeneration (Gas Turbine)								
Capacity (kWelec/ kWtherm)	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total Electricity Supplied	Percent Total Heating and DHW Supplied	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
800 / 1310	$2,263,547	-$24,969	---	-$2,636,044	74%	66%	20%	$1,617
800 / 1310 (with 10% ITC*)	$2,026,047	-$24,969	---	-$2,398,544	74%	66%	20%	$1,447
250 / 409	$888,547	$10,454	85.0	-$673,339	23%	29%	8%	$1,528
250 / 409 (with 10% ITC*)	$788,547	$10,454	75.4	-$573,339	23%	29%	8%	$1,356
150 / 246 (lowest spp)	$638,547	$8,929	71.5	-$461,160	14%	19%	5%	$1,726
150 / 246 (lowest spp with 10% ITC*)	$563,547	$8,929	63.1	-$386,160	14%	19%	5%	$1,523

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

IC Engine: Internal combustion refers to the method in which electricity is generated by the system. An IC technology relies on the combustion of a fuel such as natural gas to power an engine or generator. Although the fuel is combusted, an IC engine uses a different thermodynamic cycle than a gas turbine. Internal combustion is a common and well established technology with well understood maintenance and performance issues.

The two main advantages of the internal combustion engine are its relatively low initial cost and high electrical efficiency. Furthermore, this technology tends to have the lowest operation and maintenance costs of the three technologies considered. The analysis results for cogeneration using a natural gas IC engine are given in Table 11.

Table 11: Analysis Results for IC Cogeneration

Cogeneration (Internal Combustion)								
Capacity (kWelec/ kWtherm)	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total Electricity Supplied	Percent Total Heating and DHW Supplied	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
800 / 800	$1,463,548	$28,174	51.9	-$847,895	89%	51%	28%	$758
800 / 800 (with 10% ITC*)	$1,306,048	$28,174	46.4	-$690,395	89%	51%	28%	$677
250 / 250	$638,548	$18,954	33.7	-$261,804	28%	21%	10%	$934
250 / 250 (with 10% ITC*)	$563,548	$18,954	29.7	-$186,804	28%	21%	10%	$825
300 / 300 (lowest spp)	$713,548	$21,579	33.1	-$282,627	33%	24%	12%	$880
300 / 300 (lowest spp with 10% ITC*)	$631,048	$21,579	29.2	-$200,127	33%	24%	12%	$778

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Fuel Cell: A fuel cell utilizes an electrochemical cycle to produce electricity. The mechanism used to produce power is similar to that for a typical battery, but a fuel cell uses an open cycle in which the fuel can be continuously supplied. Fuel cells can use hydrocarbon fuels such as natural gas, but the fuel is not burned as in an IC generator or gas turbine.

Fuel cells generally have the highest electrical efficiencies of the technologies considered. However, they typically have the highest upfront cost as well. Overall efficiencies are on par with IC engines. The analysis results for cogeneration using a natural gas fuel cell are given in Table 12.

Table 12: Analysis Results for Fuel Cell Cogeneration

Cogeneration (Fuel Cell)								
Capacity (kWelec/ kWtherm)	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total Electricity Supplied	Percent Total Heating and DHW Supplied	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
800 / 358	$4,238,5 48	$90,250	47.0	- $2,521, 175	84%	26%	37%	$1,629
800 / 358 (with 30% ITC*)	$3,063,5 48	$90,250	34.0	- $1,346, 175	84%	26%	37%	$1,177
250 / 112	$1,488,5 48	$29,978	49.7	- $919,62 4	26%	9%	12%	$1,799
250 / 112 (with 30% ITC*)	$1,138,5 48	$29,978	38.0	- $569,62 4	26%	9%	12%	$1,376
600 / 269 (lowest spp)	$3,238,5 48	$69,532	46.6	- $1,917, 016	63%	21%	28%	$1,405
700 / 311 (lowest spp with 30% ITC*)	$2,713,5 48	$69,532	33.9	- $1,190, 616	63%	21%	33%	$1,177

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Tri-generation

A tri-generation plant provides electricity, heating, and cooling. The cooling from a tri-generation plant is typically provided by an absorption chiller, which utilizes heat as its energy source rather than electricity. A tri-generation system will typically be able to use more waste heat than a cogeneration system, but the upfront costs will be higher.

Similar to cogeneration, a tri-generation plant can be driven by gas turbines, IC engines, or fuel cells. Again, natural gas is the most appropriate fuel for all of these technologies.

Like cogeneration, system size and efficiency of electricity production have a large effect on the economics of a given installation. However, tri-generation systems have a greater ability to use the thermal energy provided by a system. Furthermore, when a tri-generation system is using thermal energy to provide cooling, it is effectively replacing the electricity that would otherwise have been used for that purpose. Thus, larger system sizes become more feasible.

The same advantages and disadvantages listed above for gas turbines, IC engines, and fuel cells apply when these technologies are used for tri-generation. Tables 13, 14, and 15 give the results of the analysis for each technology.

Table 13: Analysis Results for Gas Turbine Tri-generation

Tri-generation (Gas Turbine)								
Capacity (kWelec/ kWtherm)	**Initial Cost ($)**	**Annual Cost Savings ($)**	**SPP (yrs)**	**NPV ($)**	**Percent Total Electricity Supplied**	**Percent Total Heating and DHW Supplied**	**Percent Total CO_2 Equivalent Saved**	**Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)**
800 / 1310	$3,103,547	-$1,555	---	-$3,046,196	83%	66%	27%	$1,638
800 / 1310 (with 10% ITC*)	$2,782,047	-$1,555	---	-$2,724,696	83%	66%	27%	$1,468
250 / 409	$1,151,047	$13,861	83.0	-$873,275	24%	29%	9%	$1,761
250 / 409 (with 10% ITC*)	$1,024,797	$13,861	73.9	-$747,025	24%	29%	9%	$1,568
200 / 328 (optimal)	$973,547	$12,331	79.0	-$728,908	19%	24%	8%	$1,858
200 / 328 (lowest spp with 10% ITC*)	$865,047	$12,331	70.2	-$620,408	19%	24%	8%	$1,651

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Table 14: Analysis Results for IC Tri-generation

Tri-generation (Internal Combustion)								
Capacity (kWelec/ kWtherm)	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total Electricity Supplied	Percent Total Heating and DHW Supplied	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
800 / 800	$1,879,548	$42,908	43.8	-$993,397	95%	51%	32%	$838
800 / 800 (with 10% ITC*)	$1,680,448	$42,908	39.2	-$794,297	95%	51%	32%	$750
250 / 250	$768,548	$20,370	37.7	-$365,806	28%	21%	10%	$1,077
250 / 250 (with 10% ITC*)	$680,548	$20,370	33.4	-$277,806	28%	21%	10%	$954
350 / 350 (lowest spp)	$970,548	$26,666	36.4	-$440,141	40%	28%	14%	$973
350 / 350 (lowest spp with 10% ITC*)	$862,348	$26,666	32.3	-$331,941	40%	28%	14%	$865

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Table 15: Analysis Results for Fuel Cell Tri-generation

Tri-generation (Fuel Cell)								
Capacity (kWelec/ kWtherm)	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total Electricity Supplied	Percent Total Heating and DHW Supplied	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
800 / 358	$4,494,548	$93,205	48.2	-$2,722,930	86%	26%	38%	$1,687
800 / 358 (with 30% ITC*)	$3,242,748	$93,205	34.8	-$1,471,130	86%	26%	38%	$1,217
250 / 112	$1,568,548	$30,231	51.9	-$994,993	26%	9%	12%	$1,884
250 / 112 (with 30% ITC*)	$1,194,548	$30,231	39.5	-$620,993	26%	9%	12%	$1,435
700 / 313 (lowest spp)	$3,962,548	$82,269	48.2	-$2,399,469	75%	24%	33%	$1,400
850 / 378 (lowest spp with 30% ITC*)	$3,428,948	$98,586	34.8	-$1,554,614	75%	24%	41%	$1,211

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

District Ground Source Heat Pump

A Ground Source Heat Pump (GSHP) uses the stable temperatures of the ground or ground water to extract heating or cooling for space conditioning. It pulls heat out of the ground when in heating mode, and dumps heat into the ground when in cooling mode. GSHPs typically have high efficiencies for both heating and cooling, and use electricity as the only fuel source. Closed loop GSHP systems circulate a fluid through tubes which are buried in the ground, typically in holes drilled 100 to 500 feet deep. Open loop GSHP systems exchange heat directly with ground water by pumping it through the above-ground heat pump and then discharging the water back down to the water table from which it came. See Figure 14 for schematics of closed and open loop systems. GSHPs are sometimes referred to as geothermal heat pumps; the two terms are synonymous.

In order to accurately assess the thermal potential of the soil at a project site, test boreholes have to be drilled and thermal testing performed. This was done for Phase 1 of the South Lincoln redevelopment, and the results may be able to be used for the rest of the site. Also, boreholes were drilled to determine the structural characteristics of the subsurface for the high rise project at 1099 Osage, and it was found that groundwater can be reached at about 25 ft below grade. This relatively easily accessible groundwater may make an open loop GSHP system a viable option for heating and cooling. Local laws on groundwater use could prevent this as a possibility, however.

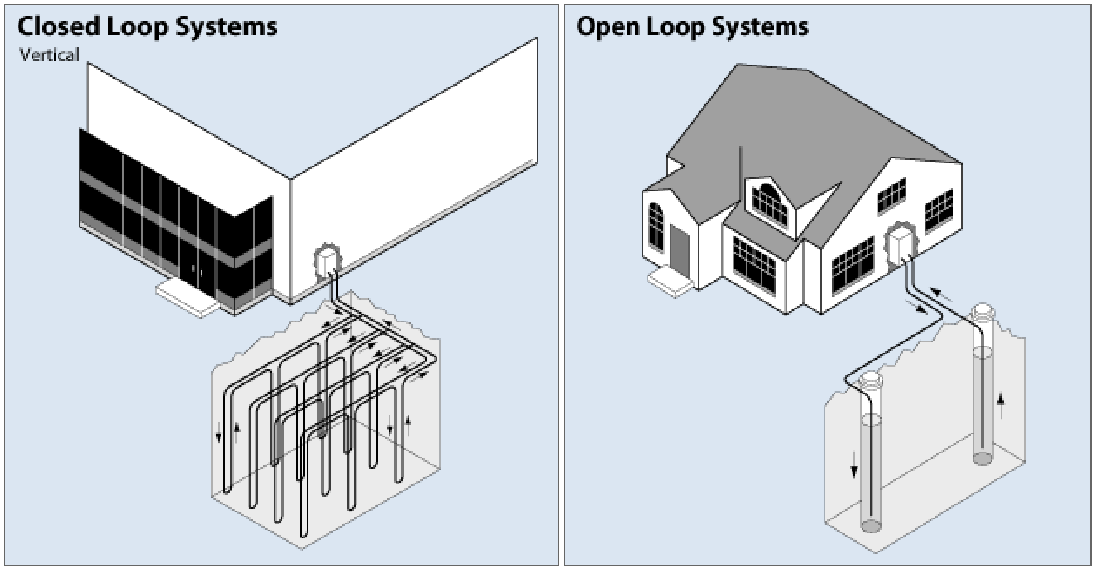


Figure 14: Closed Loop and Open Loop GSHP Systems

(Source: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12650)

GSHP systems are most effective when the heating and cooling needs of the community are well balanced over the course of a year. This allows the ground to 'recharge' and avoid a slow increase or decrease in soil temperature over time. The South Lincoln site presents a challenge in that the heating needs of the community are far greater than the cooling needs.

Although GSHP systems are highly efficient, the fact that they use electricity as the fuel source for both heating and cooling can often result in marginal greenhouse gas reductions. While CO_2 emissions are typically reduced when the heat pump is being used for cooling, in heating mode the emissions can actually increase. This is due to the fact that, in the absence of a GSHP, heating is typically provided using natural gas as the fuel. Because the emissions associated with electricity are so much higher than those for natural gas, heating with electricity, even at the high efficiencies seen from GSHPs, will often result in increased CO_2 emissions. Because South Lincoln will require significantly more heating than cooling, the net greenhouse gas savings from using a district GSHP will be marginal. The results from the district GSHP analysis are given in Table 16.

Table 16: Analysis Results for a District Ground-Source Heat Pump

District Ground-Source Heat Pump						
Percent Heating and Cooling Loads Met	Initial Cost ($)	Annual $ Savings	SPP (yrs)	NPV ($)	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
100%	$5,904,672	$70,945	83.2	-$4,642,113	4%	$22,282
100% (with 10% ITC*)	$5,006,901	$70,945	70.6	-$3,744,342	4%	$18,894

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Photovoltaics

Photovoltaic (PV) systems use only sunlight as a fuel source and produce only electricity. A residential community rooftop PV installation is shown in Figure 15. PV is a well-established and reliable source of electricity which tends to have fairly high upfront costs and low operation and maintenance costs. However, installed costs for photovoltaics have dropped dramatically in the last decade, and the trend is continuing. Table 17 gives approximate values for current costs based on actual installations. Successful implementation of PV at South Lincoln will require thoughtful design of rooftops and parking areas to maximize solar access.

Figure 15: Rooftop Solar PV Installation at the Solar Siedlung in Freiburg, Germany

Table 17: Approximate Current Costs of PV

System Type	Approximate Cost ($/W)
Standard Efficiency Panels	5
High Efficiency Panels	5.25
Carport System	6.50

(Source: Xcel Energy Solar Rewards Program http://www.xcelenergy.com/Colorado/Residential/RenewableEnergy/Solar_Rewards/Pages/home.aspx)

In addition to federal and state incentive programs, utility incentives for installing PV systems play an important role in a system's economic viability. The available incentives from Xcel Energy's Solar Rewards Program depend on the size of the system. The program offers a rebate of $2/W with a maximum rebate of $200,000. In addition, for systems between 10 kW and 500 kW, the system owner will receive a production credit of 2.5 cents for every kWh produced over a 20 year period. For systems above 500 kW, the incentives are the same except that the amount of the production credit is determined through an RFP process.

There are a number of possible models for funding PV installations. For this analysis, it is assumed that DHA will purchase and own the system. In this scenario, DHA could take advantage of Xcel Energy's Solar Rewards incentive program as well as the 30% ITC on the upfront cost of the system.

As an alternative to purchasing the PV system, the site could host the system under a third-party power purchase agreement (PPA) structure. In this structure, a private entity (or entities) installs, operates, maintains, and owns the PV system installed on the site property. The site would sign a PPA and commit to purchasing electricity from this third party for a fixed amount of time - usually 10 to 25 years. The PPA could include a price escalator that will increase the cost of the electricity at a fixed rate each year over the life of the contract - this rate is usually between 0% - 4%.

The contract would be set up such that the DHA would sign a 20-year contract with the third party, and the third party would in-turn sell the electricity to the site. DHA would have the option to "buy out" the PPA and become the system owner at any point after year 6. The third party would benefit from the 30% federal investment tax credit as well as any state and utility incentives. The impact of these tax benefits and incentives is a reduction in the installed cost of the PV system which will translate into competitive electricity rates for DHA.

This PV analysis investigates two primary scenarios: One in which all suitable rooftop area is used for PV and carports are built for the purpose of mounting solar panels, and one in which only the suitable rooftop area is used. Each of these options was investigated for both 15% efficient panels and 19% efficient panels. Furthermore, analyses were done to investigate the effect of installing the photovoltaics as one large project versus multiple smaller projects. The advantage to dividing the installations into several smaller projects comes from the ability to enter a lower tier in the Solar Rewards Program and to take greater advantage of the program's upfront rebates. The results of the analysis are given in Table 18.

Table 18: Analysis Results for PV Systems

Photovoltaics								
Project Description	Efficiency	Percent Electric Load Met	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
Rooftop and Carport Systems (252,455 ft^2)								
One Large System	15%	93%	$19,343,324	330,949	67.7	-$14,837,727	62%	$4,466
One Large System (w/ 30% ITC*)	15%	93%	$13,492,114	$330,949	47.2	-$8,986,800	62%	$3,115
8 Smaller Systems	15%	93%	$18,343,324	330,949	64.2	-$13,837,727	62%	$4,235
8 Smaller Systems (w/ 30% ITC*)	15%	93%	$12,092,114	$330,949	42.3	-$7,586,800	62%	$2,792
One Large System	19%	113%	$24,635,993	405,154	70.4	-$19,120,053	76%	$4,647
One Large System (w/ 30% ITC*)	19%	113%	$17,185,195	$405,154	49.1	-$11,669,255	76%	$3,241
8 Smaller Systems	19%	113%	$23,235,993	405,154	66.4	-$17,720,053	76%	$4,383
8 Smaller Systems (w/ 30% ITC*)	19%	113%	$15,800,817	$405,154	45.2	-$10,284,877	76%	$2,980
Rooftop Systems Only (188,848 ft^2)								
One Large System	15%	69%	$13,386,714	247,566	62.7	-$10,019,400	46%	$4,132
One Large System (w/ 30% ITC*)	15%	69%	$9,318,904	$247,566	43.6	-$5,948,721	46%	$2,876

Photovoltaics								
Project Description	Efficiency	Percent Electric Load Met	Initial Cost ($)	Annual Cost Savings ($)	SPP (yrs)	NPV ($)	Percent Total CO_2 Equivalent Saved	Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)
6 Smaller Systems	15%	69%	$12,386,714	247,566	58.0	-$9,019,400	46%	$3,823
6 Smaller Systems (w/ 30% ITC*)	15%	69%	$8,318,904	$247,566	38.9	-$4,948,721	46%	$2,568
One Large System	19%	85%	$17,326,870	303,074	66.2	-$13,200,692	57%	$4,369
One Large System (w/ 30% ITC*)	19%	85%	$12,068,809	$303,074	46.1	-$7,942,631	57%	$3,043
6 Smaller Systems	19%	85%	$16,326,870	303,074	62.4	-$12,200,692	57%	$4,117
6 Smaller Systems (w/ 30% ITC*)	19%	85%	$11,068,809	$303,074	42.3	-$6,942,631	57%	$2,791

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Solar Hot Water

Solar hot water (SHW) systems are designed to produce useful thermal energy using only the sun as the energy source. An auxiliary heat source is typically needed for a consistent supply of hot water for domestic use. An SHW system requires rooftop space to mount the solar collectors, as does a PV system. Thus, any area which is used for SHW cannot be used for PV, and vice versa. An analysis was done to determine the optimal mix of SHW and PV under the assumption that all viable rooftop area with solar access would be utilized. Figure 16 shows the total energy production and greenhouse gas reduction of every combination of systems, from 100% of the roof being covered with PV (on the left of graph) to 100% of the roof being used for SHW (on the right of the graph). It was found that using 100% PV and 0% SHW gave the highest net present value and the highest greenhouse gas savings. However, the economics of these technologies are highly dependent on incentives and methods of funding.

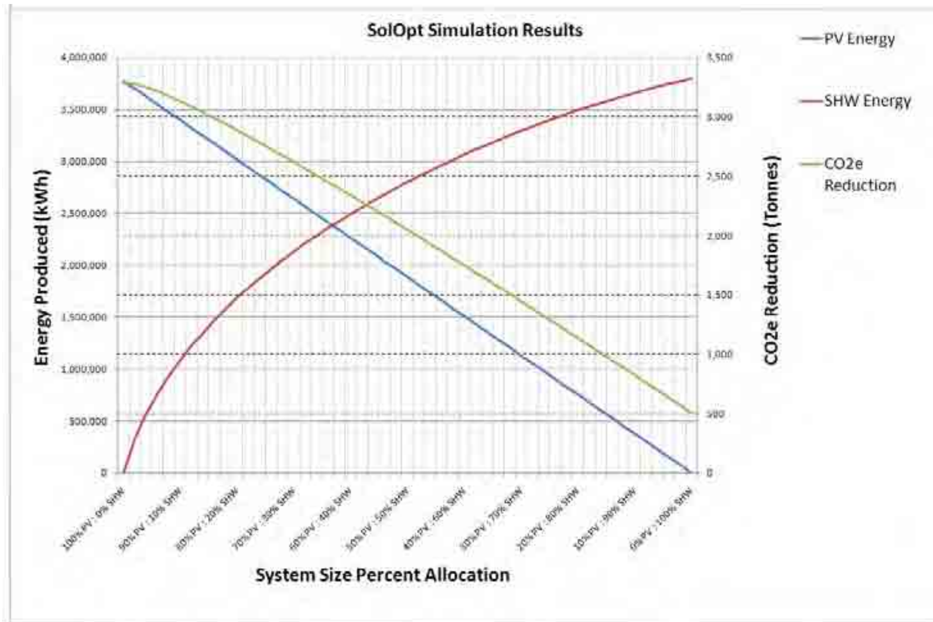


Figure 16: Rooftop PV/SHW Optimization Results based on Greenhouse Gas Reduction

As a SHW system increases in size, its overall effectiveness generally diminishes because it begins producing more hot water than the building can use at certain times in the year. For this reason, SHW systems are typically sized to meet 70%-80% of the total domestic hot water load for the building they are serving. An energy and economic analysis was performed assuming a SHW system sized to meet 80% of the South Lincoln community's annual domestic hot water load. This system would require about 90% of the total roof area deemed suitable for solar panels. The results of this analysis are given in Table 19.

Table 19: Analysis Results for a Solar Hot Water System

Solar Hot Water						
Percent DHW Load Met	**Initial Cost ($)**	**Annual Cost Savings ($)**	**SPP (yrs)**	**NPV ($)**	**Percent Total CO_2 Equivalent Saved**	**Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)**
80%	$10,647,000	$83,949	126.8	-$12,265,323	6%	$26,354
80% (with 30% ITC*)	$7,452,900	$83,949	88.8	-$8,196,679	6%	$18,448

**Federal Investment Tax Credit. See the 'Economic Analysis' section of this report*

Conclusions and Recommendations

Table 20 summarizes the results for selected systems from each of the technologies analyzed. The results shown here were selected based on simple payback and feasibility of size. While all results are not reported in this table, it gives a representative comparison of the various district systems.

Table 20: Summary of Analysis Results for Selected District Systems (all results shown include the ITC)

Selected Results Summary (All Results Include the ITC)					
Technology	**Size**	**SPP (yrs)**	**NPV ($)**	**Percent Total CO_2 Equivalent Saved**	**Initial Investment per Ton CO_2 Equivalent Saved ($/Ton)**
Cogeneration					
NG Gas Turbine	250 / 409	75.4	-$573,339	8%	$1,356
IC Engine	300 / 300	29.2	-$200,127	12%	$778
Fuel Cell	700 / 311	33.9	-$1,190,616	33%	$1,177
Trigeneration					
NG Gas Turbine	250 / 409	73.9	-$747,025	9%	$1,568
IC Engine	350 / 350	32.3	-$331,941	14%	$865
Fuel Cell	850 / 378	34.8	-$1,554,614	41%	$1,211
District GSHP					
GSHP	100% of Load	70.6	-$3,744,342	4%	$18,894
Biomass District Heat					
Wood Chip Boiler	40% of Heating Demand	99.7	-$1,351,146	21%	$1,106
Photovoltaics					
Solar Panels (19% efficient; Rooftops and Carports)	252,455 ft^2 (as multiple smaller systems)	45.2	$10,284,877	76%	$2,980
Solar Panels (15% efficient; Rooftops Only)	188,848 ft^2 (as multiple smaller systems)	38.9	$4,948,721	46%	$2,568
Solar Hot Water					
Flat Plate Panels	80% of DHW Load	88.8	$12,265,323	6%	$18,448

Although none of the district systems investigated for this analysis show favorable economics, some options may well make sense as integral parts of the final solution. However, it is highly recommended that other measures be maximized before implementing any district system. Specifically, it is vital that electrical loads, heating and DHW loads, and cooling loads in the community are reduced as much as possible. Electrical loads can be reduced by a combination of building system design (high efficiency pumps and fans, timers on bathroom vents, daylighting design), appliance efficiency standards, occupant education, and any number of occupant incentives. Heating loads can be reduced primarily by building design, including insulation levels and window specifications. DHW loads can be reduced by educating the occupants and using low-flow fixtures.

Perhaps the greatest improvements in the baseline energy use can be found in the reduction of cooling energy use. The Denver climate is ideal for natural ventilation, direct cooling with outdoor air, night-time pre-cooling, and evaporative cooling. It is conceivable that these technologies could virtually eliminate conventional cooling methods in the South Lincoln community and significantly reduce the electricity used for cooling.

In regards to district systems for this community, the most drastic reductions in GHG emissions will best be achieved using a combination of PV for electricity and biomass for heating and domestic hot water. If cooling and other electrical loads are reduced based on the recommendations above, it may be possible for the community to reach net zero GHG emissions by installing 19% efficient solar panels on rooftops and carports and installing a biomass heating system sized to 40% of peak heating and DHW demand. In this scenario, heating and DHW will require some natural gas input. However, with the reductions in cooling and other electrical energy, the PV system is projected to produce enough of a surplus of electrical power to offset the greenhouse gas emissions from the site's natural gas usage. Although the economics of buying and owning a PV system may be prohibitive, entering into a PPA could make such a system viable.

An alternative to the scenario above is to install PV to offset electricity, concentrate on reducing heating/DHW loads, and utilize high-efficiency natural gas systems at the building level in lieu of a central biomass plant. While the community is not expected to reach net zero GHG emissions in this scenario, emissions savings of about 80% or higher are achievable. Furthermore, upfront costs as well as operations and maintenance costs will be significantly lower. This approach would be much simpler and less costly to design and implement phase by phase, with a relatively small loss of environmental benefit. Considering both economics and environmental benefits, this may be the most reasonable option for South Lincoln.

A third possibility would be to use a cogeneration or tri-generation plant driven by an IC engine or a fuel cell to provide a portion of the community's heating and electricity needs. These systems show the most attractive economics of any of the systems analyzed. It would be possible to supplement a cogeneration plant with PV as a path to net zero emissions. However, implementation of a cogeneration or tri-generation strategy will require more planning and ongoing operations and maintenance effort by DHA than a PV strategy. Furthermore, while a PV system can be installed under a PPA, a cogeneration plant would require the consent of the utility for such an arrangement. Because the utility has little incentive to agree to this type of arrangement, a PPA for a cogeneration plant is very unlikely.

Neither solar hot water systems nor a district ground source heat pump system is recommended for this project. Both of these systems show poor economics and minimal savings in GHG emissions. While some tri-generation systems show comparatively good economics and GHG reductions, these systems are not recommended because the initial recommendation to reduce cooling loads and cooling energy use would make district cooling unnecessary. Also, the same issues listed above for cogeneration systems apply equally to tri-generation systems.

Appendix 1: Analysis Assumptions and Sources

Economic Parameters:

Parameter	Value	Source
Project Lifetime	25 yrs	
Real Discount Rate	3%	FEMP discount rate (valid from April 1, 2010 to March 31, 2011)
Electricity Escalation Rate	0.50%	Energy Escalation Rate Calculator
Natural Gas Escalation Rate	0.40%	Energy Escalation Rate Calculator
Blended Residential Electricity Rate (Energy)	0.104 ($/kWh)	Sampling of South Lincoln Utility Bills (2010)
Residential Electric Demand Rate	0.00 ($/kW)	Sampling of South Lincoln Utility Bills (2010)
Commercial Electricity Rate	0.033 ($/kWh)	Xcel Energy
Commercial Summer Electric Demand Rate	20.24 ($/kW)	Xcel Energy
Commercial Winter Electric Demand Rate	17.24 ($/kW)	Xcel Energy
Natural Gas Rate	0.673 ($/therm)	Sampling of South Lincoln Utility Bills (2010)

Greenhouse Gas Emissions:

Energy Source	Emission Compound	Equivalent CO_2 Emissions	Source
Electricity (Generated in Colorado)	Carbon Dioxide	1,883 (lbs/MWh)	US Energy Information Administration (1)
	Methane	0.0228 (lbs/MWh)	US Energy Information Administration (1)
	Nitrogen Oxide	0.02875 (lbs/MWh)	US Energy Information Administration (1)
Natural Gas	Carbon Dioxide	53.06 (kg/MMbtu)	Environmental Protection Agency (2)
	Methane	0.005 (kg/MMbtu)	Environmental Protection Agency (2)
	Nitrogen Oxide	0.0001 (kg/MMbtu)	Environmental Protection Agency (2)

Sources:

1. *Electricity: US Energy Information Administration*, 2008 Colorado Electricity Profile Statistics, http://www.eia.doe.gov/cneaf/electricity/st_profiles/colorado.html
2. *Natural Gas: Natural Gas Emissions Data*, Environmental Protection Agency, http://www.epa.gov/climateleaders/documents/resources/comm_boiler_proto.pdf

Base Case:

Parameter	Value	Source
Overall Boiler Efficiency	85%	Based on ASHRAE Standard 90.1
Boiler Costs	20.7 ($/MBTUH)	R.S. Means
Overall A/C Efficiency	3.1 (COP)	Based on ASHRAE Standard 90.1
A/C Costs	3291 ($/ton)	R.S. Means

Distribution System (for all applicable district systems):

Parameter	Value	Source
Length of Piping Needed	5000 (ft)	Estimated based on site map
Installed Piping Costs	75 ($/ft) (based on 5" Pipe)	Based on a study at Oregon Institute of Technology (1)

Sources:

1. *Selected Cost Considerations for Geothermal District Heating in Existing Single-Family Residential Areas*, Kevin Rafferty, Jun-96 - http://geoheat.oit.edu/pdf/tp93.pdf

Cogeneration and Tri-generation Systems:

Parameter	Value	Source
	Gas Turbine	
Overall Efficiency	75%	Product Data, RETScreen Database
Electrical Efficiency	28.4%	Product Data, RETScreen Database
Thermal Efficiency	46.6%	Product Data, RETScreen Database
Altitude Derate	80% of rated capacity	EPA estimates (1)
Installed Cost (Cogen)	2500 ($/kWe)	EPA estimates, manufacturer quotes (2)
Installed Cost (Trigen)	3550 ($/kWe)	EPA estimates, manufacturer quotes (2)
O&M Cost	0.008 ($/kWh)	Manufacturer recommendation
Investment Tax Credit	10% of Initial Cost	DSIRE Database
	IC Engine	
Overall Efficiency	70%	Product Data, RETScreen Database
Electrical Efficiency	35%	Product Data, RETScreen Database
Thermal Efficiency	35%	Product Data, RETScreen Database
Altitude Derate	80% of rated capacity	EPA estimates (1)
Installed Cost (Cogen)	1500 ($/kWe)	EPA estimates, manufacturer quotes (2)
Installed Cost (Trigen)	2020 ($/kWe)	EPA estimates, manufacturer quotes (2)
O&M Cost	0.009 ($/kWh)	Manufacturer recommendation
Investment Tax Credit	10% of Initial Cost	DSIRE Database
	Fuel Cell	
Overall Efficiency	65%	Product Data, RETScreen Database
Electrical Efficiency	45%	Product Data, RETScreen Database
Thermal Efficiency	20%	Product Data, RETScreen Database
Altitude Derate	80%	EPA estimates (1)
Installed Cost (Cogen)	5000 ($/kWe)	EPA estimates, manufacturer quotes (2)
Installed Cost (Trigen)	5320 ($/kWe)	EPA estimates, manufacturer quotes (2)
O&M Cost	0.02 ($/kWh)	Manufacturer recommendation
Investment Tax Credit	30% of Initial Cost	DSIRE Database

Sources:

1. *EPA Catalog of CHP Technologies*, US Environmental Protection Agency, http://www.epa.gov/chp/basic/catalog.html
2. *Catalog of CHP Technologies,* Environmental Protection Agency Combined Heat and Power Partnership, December 2008, http://www.epa.gov/chp/

Biomass District Heating:

Parameter	Value	Source
Fuel Energy Content	8500 Btu/dry lb	
Fuel Moisture Content	20%	NREL biomass plant operator (Chris Gaul)
Fuel Density	12.6 (lb/ft^3)	NREL biomass plant operator (Chris Gaul)
Tractor Trailer Volume	130 (cubic yards)	NREL biomass plant operator (Chris Gaul)
Boiler Efficiency	75%	NREL biomass plant operator (Chris Gaul)
Distribution Losses	5%	NREL biomass plant operator (Chris Gaul)
Woodchip Fuel Cost	4.44 ($/MMbtu)	NREL biomass plant operator (Chris Gaul)
Installed Cost	248 ($/Mbtu/hr)	Manufacturer quotes, construction estimates (Randy Hunsberger, NREL)
O&M Cost	1.19 ($/Mbtu/hr)	Calculated labor and maintenance estimates (Randy Hunsberger, NREL)
Cost of Auxiliary Natural Gas Boiler	16 ($/MBTUH)	R.S. Means
Investment Tax Credit	10% of Initial Cost	DSIRE Database

District Ground Source Heat Pump:

Parameter	Value	Source
Installed Cost	568 ($/Mbtu/hr)	Final installed cost for 1099 Osage GSHP
Overall System Efficiencies	Calculated based on 1099 Osage Model	
Investment Tax Credit	30% of Initial Cost	DSIRE Database

Photovoltaics:

Parameter	Value	Source
Installed Cost (15% efficient)	5 ($/W)	Approximated based on real installation data
Installed Cost (19% efficient)	5.25 ($/W)	Approximated based on real installation data
Installed Cost (Carport Installation)	6.50 ($/W)	Approximated based on real installation data
O&M Cost	12.50 ($/kW)	
Xcel Energy Production Incentive (10kW to 500kW systems)	0.025 ($/kWh)	Xcel Energy Solar Rewards Program (1)
Xcel Energy Rebate	2 ($/W) ($200,000 cap)	Xcel Energy Solar Rewards Program (1)
Investment Tax Credit	30% of Initial Cost	DSIRE Database (2)
Panel Efficiencies	15% and 19%	Approximated based on product data

Sources:

1. *Xcel Energy Solar Rewards Program,* http://www.xcelenergy.com/Colorado/Residential/RenewableEnergy/Solar_Rewards/Pages/home.aspx
2. *Federal Investment Tax Credit,* http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1

Solar Hot Water:

Parameter	Value	Source
Installed Cost	90 ($\$/ft^2$)	Approximated based on real installation data
O&M Cost	1% of Installed Cost ($/yr)	
Investment Tax Credit	30% of Initial Cost	DSIRE Database