Evaluating District Energy Options
Workshop Session 1

Henry Johnstone PE
District Energy Concept

- Central energy conversion plant(s) with underground network of heating and cooling lines, possibly electric power

- Aggregated thermal loads creates scale to apply fuels, technologies and strategies not feasible on single-building basis

- Provides Platform for Reliability, Resiliency, and Flexibility on a urban scale
District Energy Concept

- Economies of scale / load diversity
- Centralized operations
- Enables energy storage
- Adapts to smart grid
- High efficiency/ sustainability
- Alternative H&C Technologies
- Combined Heat and Power
District Energy Concept

Benefits

– Environmental
  • Improved energy efficiency
  • Reduced Greenhouse Gas

– Utility
  • Reduced energy utility costs
  • Consumption, Demand, Utilization

– Developer
  • Reduced initial capital cost
  • Reduced annual operating costs
  • Increased leasable SF

– Owner
  • Consolidated energy, O&M
  • Potential improved occupancy

Risk

– Cost of infrastructure
– Return on investment
– Certainty of load
District Energy Decision Making

Figure 6: This shows the project development process, or "flightpath", illustrating how risk reduces the farther along the project proceeds.
IDEA partners with US DOE CHP Technical Assistance Partnerships to provide first order screening

- For **Projects** with a proposed **Multi-Building/Mixed Use Development**.

- With identified **Champions/Stakeholders/Decision Makers**.

- To provide a **Green-Yellow-Red** first order assessment of options for phased district development & the value of **CHP and District Energy**.

- To assist **Champion/Stakeholders/Decision Makers** in moving the **Project** Forward.
High Density Planned Mixed Use Development

• Common Characteristics
  – Mixed Use: Live, Work, Play
  – Proximity to Mass Transit
  – High Efficiency, Low Carbon Footprint
  – Greenfield or major site redevelopment
  – Building Energy Efficiency Standards
  – Highly planned/documentated/rendered/costed/branded

  – Little or no thought toward district heating, cooling or power
High Density Planned Mixed Use Development

Relevant Planning Parameters

• Scale
  – 1 msf-10 msf

• Time to build out
  – 10-20 yrs

• Intended Occupancy
  – Hotel/Conference
  – Corporate Office/Office
  – Retail
  – Entertainment
  – Data Center
  – Residential*

• Developer Team -Building Ownership
  
Pittsburgh PA
Boulder CO
Westminster CO
Austin TX
Oakland CA
Mooretown CA
Tucson AZ
<table>
<thead>
<tr>
<th>Occupancy Type</th>
<th>input values here</th>
<th>input values here</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td># Bldg</td>
<td></td>
</tr>
<tr>
<td>Large Office</td>
<td>1,000,000</td>
<td>2</td>
</tr>
<tr>
<td>Medium Office</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Small Office</td>
<td>500,000</td>
<td>-</td>
</tr>
<tr>
<td>Warehouse</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stand Alone Retail</td>
<td>300,000</td>
<td>5</td>
</tr>
<tr>
<td>Strip Mall</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Primary School</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Secondary School</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Supermarket</td>
<td>100,000</td>
<td>-</td>
</tr>
<tr>
<td>Quick Service Restaurant</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Full Service Restaurant</td>
<td>100,000</td>
<td>5</td>
</tr>
<tr>
<td>Hospital</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Outpatient Health Clinic</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Small Hotel</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Large Hotel</td>
<td>1,000,000</td>
<td>-</td>
</tr>
<tr>
<td>Midrise Apt</td>
<td>1,000,000</td>
<td>5</td>
</tr>
<tr>
<td>User Building 1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>User Building 2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>User Building 3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>User Building 4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>User Building 5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>4,000,000</td>
<td>22</td>
</tr>
</tbody>
</table>

Illustrative Model
View looking east with Harlan Street in the foreground and city hall with its tower in the background.

Illustrative Model
View looking south along the new Eaton Street “green boulevard.” On the left-hand side of the image, US 36 leads towards Denver.
Developer built stand alone

Performance
A/C: 1.1kW/Ton (peak)
Gas Furnace Heat: 80% eff
Single Duct VAV

Capital Cost
Include increased building elec
5.00-6.00$/SF installed
Additional Leaseable Space (including rooftop real estate)
District Energy Alternatives

Remote

Local
## Phase 2 Load Assumptions

<table>
<thead>
<tr>
<th>Occupancy Type</th>
<th>Input Values Here</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Office</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Medium Office</td>
<td>-</td>
</tr>
<tr>
<td>Small Office</td>
<td>300,000</td>
</tr>
<tr>
<td>Warehouse</td>
<td></td>
</tr>
<tr>
<td>Stand Alone Retail</td>
<td>100,000</td>
</tr>
<tr>
<td>Strip Mall</td>
<td>-</td>
</tr>
<tr>
<td>Primary School</td>
<td></td>
</tr>
<tr>
<td>Secondary School</td>
<td></td>
</tr>
<tr>
<td>Supermarket</td>
<td></td>
</tr>
<tr>
<td>Quick Service Restaurant</td>
<td></td>
</tr>
<tr>
<td>Full Service Restaurant</td>
<td>100,000</td>
</tr>
<tr>
<td>Hospital</td>
<td></td>
</tr>
<tr>
<td>Outpatient Health Clinic</td>
<td>-</td>
</tr>
<tr>
<td>Small Hotel</td>
<td>-</td>
</tr>
<tr>
<td>Large Hotel</td>
<td>500,000</td>
</tr>
<tr>
<td>Midrise Apt</td>
<td>-</td>
</tr>
<tr>
<td>User Building 1</td>
<td>-</td>
</tr>
<tr>
<td>User Building 2</td>
<td>-</td>
</tr>
<tr>
<td>User Building 3</td>
<td>-</td>
</tr>
<tr>
<td>User Building 4</td>
<td>-</td>
</tr>
<tr>
<td>User Building 5</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,000,000</strong></td>
</tr>
</tbody>
</table>

### Connected Load Schedule

![Connected Load Schedule Graph](graph.png)

**Legend**
- Connected Load SF: Green line
- Percent of Full Buildout: Red line

**Axes**
- GSF on the Y-axis
- Year 1 on the X-axis

**Year Breakdown**
- Year 1: 0%
- Year 2: 0%
- Year 3: 0%
- Year 4: 0%
- Year 5: 0%
- Year 6: 0%
- Year 7: 0%
- Year 8: 0%
- Year 9: 0%
- Year 10: 0%
- Year 11: 0%
- Year 12: 0%
- Year 13: 0%
- Year 14: 0%
- Year 15: 0%
- Year 16: 0%
- Year 17: 0%
- Year 18: 0%
- Year 19: 0%
- Year 20: 120%
District Energy For High Density Planned Development

[Map of the United States showing climate zones]

- Energy Use Characteristics
- Regional Impacts
- Climate Zones
- Individual Building Loads
- Composite Loads

[Table of building types and their characteristics]

- Building Type Name: Commercial reference building models are available for the following categories:
- New construction
- Existing buildings constructed in or after 1980 (pre-1980)
- Existing buildings constructed before 1980 (pre-1980)

- Building Type and Climate Zone
- DOE developed 16 reference building types that represent most commercial buildings across 16 locations, which represent all U.S. climate zones.

- Building Type Name: Large Office, Medium Office, Small Office, Warehouse, Stand-alone Retail, Strip Mall, Primary School, Secondary School, Supermarket, Quick Service Restaurant, Full Service Restaurant, Hospital, Outpatient Health Care, Small Hotel, Large Hotel, Midrise Apartment
- Floor Area (ft²): 490,580, 53,820, 5,500, 52,045, 24,982, 22,500, 73,960, 210,887, 45,000, 2,500, 5,500, 241,381, 40,486, 43,200, 2,122,120, 33,740
- Number of Floors: 12, 3, 1, 1, 1, 1, 2, 1, 1, 1, 1, 5, 3, 4, 6, 4
Sum of individual annual stand alone building heating system gas bills: $801,215 (current $)
Sum of individual annual stand alone building cooling system electric bills: $847,115 (current $)
District Energy For High Density Planned Development

• Energy Source Alternatives
  – Heating
    • Natural gas
    • Biomass
  – Cooling
    • Electric
    • Recovered Heat
    • Alternative
  – Electric Power
    • Utility purchase
    • CHP
    • On-site Renewable
District Energy For High Density Planned Development

• Utility Cost Factors
  – Minimum Demand
  – Variability
  – CHP Gas
  – Cooling energy sources
    • Electric
    • Recovered Heat
    • Thermal Energy Storage
  – Electric Power
    • Utility purchase
      – Demand, Time of Use
    • Distributed On-site Renewable
    • CHP
    • Trends
balance

Model inputs
screening tool

Inputs

- Location
- Building Types, Size, Age
- Utility Costs
- Finance Costs
- District Energy Alternative
- Conversion Efficiency
- Construction Costs
- Labor Costs
- Project Phasing

Outputs

- Energy Load Profile
- 20 year Cash Flow Projection
  - Capital Expense
  - Operating Expense
- Simple Payback of Alternatives
- Return on Investment of Alternatives

Input \( x_1, x_2, x_3, \ldots x_i \) \( \rightarrow \) Screening Tool \( \rightarrow \) Output (ROI)
Example
Piping Mains SIZED for full site build out
Cooling Mains- 5300 Ton peak – 7,000 GPM@ 18F dT – 18” D - $1,000/ft
Heating Mains– 33 MBH peak – 1,750 GPM@40 F dT – 10” D - $500/ft
Phase A-D branches (to building stubout) Cooling and Heating 1500 LF
Thermal Storage Tank sized for load level of 2 MSF (850,000 gal, 60’D, 40’H 9,300 Tonhr@16 FdT)
Lake water cooling - UTES Seasonal Energy Storage

UTES to Semper supply heat exchanger

Taken off-line at Max water to storage at 45 F
Annual potential cooling energy 4.8 M Ton hr

Fundamental Problem: Space

Examples:
- Alderney 5 Nova Scotia
- Ft. Benning GA
Local

Concept: Minimize upfront infrastructure costs by minimizing underground utility piping and installing heating and cooling capacity in discrete modules. Reduce energy cost with load leveling Thermal Ice Storage

Assumes: Adequate space is available in proximity of Phase 2 loads (parking deck?)

Pros:
- Piping size and extents limited to Phase 2 service only
- Invest in modular H/C plant only as load develops

Cons:
- Space for plant and TES: on site real estate value
  - Plant: 75 x 100 ft: 7,500 SF
  - Storage (at buildout) 5,000 SF (stacked)
- Cost reduction limited by ice production efficiency kW/Ton
- Cost of Components
Assumes
Third party purchase/install the piping distribution and thermal storage tank. These costs are not included in financial models.

Other assumptions:

Year beginning: 2019
Model duration (ROI horizon): 20 years
Energy cost escalation: 3%
Inflation: 5%
Cost of borrowing (private developers): 8%
Cost of Capital private sector: 15%
Growth of PH II development (after build out): 2%
## District Energy Screening Tool Results

### Life Cycle Cost: Net Present Value

<table>
<thead>
<tr>
<th></th>
<th>Stand Alone</th>
<th>District Energy</th>
<th>District Energy + CHP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Capital Distribution</strong> (Chilled Water/ Hot Water Pipe)</td>
<td>$0</td>
<td>-$3,761,427</td>
<td>-$3,761,427</td>
</tr>
<tr>
<td><strong>Project Capital Equipment</strong> (Chillers, Boilers, Pumps, etc...)</td>
<td>-$3,918,545</td>
<td>-$1,748,782</td>
<td>-$1,748,782</td>
</tr>
<tr>
<td><strong>Project Capital CHP</strong> (Combined Heat and Power Generator)</td>
<td>$0</td>
<td>$0</td>
<td>-$212,997</td>
</tr>
<tr>
<td><strong>Total Project Capital</strong> (Distribution + Equipment + CHP)</td>
<td>-$3,918,545</td>
<td>-$5,510,209</td>
<td>-$5,723,206</td>
</tr>
<tr>
<td><strong>Operation Cost</strong> (NG + Electricity + Building Operator)</td>
<td>-$33,043,128</td>
<td>-$25,358,799</td>
<td>-$24,752,621</td>
</tr>
<tr>
<td><strong>Project Capital + Operation Cost</strong></td>
<td>-$36,961,673</td>
<td>-$30,869,008</td>
<td>-$30,475,827</td>
</tr>
<tr>
<td><strong>Total Life Cycle Cost Net Present Value</strong> (Lower Number = More Attractive)</td>
<td>-$17,051,445</td>
<td>-$15,219,369</td>
<td>-$15,146,713</td>
</tr>
</tbody>
</table>

**Includes Debt Service**
Developer Benefits

Initial developer capital cost savings - $6.00/SF

Averaged annual operating cost savings- $0.45-$0.55/SF/YR

Potential increased leasable SF- %2
Potential increased leasable SF total 45,000 GSF

100,000 GSY Example (current $)

Developer initial capital cost savings - $600,000
Reduced Debt Service- $45,550/yr

Averaged annual operating cost savings- $55,000/yr

Potential increased leasable SF- 2,000 SF
Based on 4.5% Cap Rate (increased value) $3,560,000
District Energy Screening
Lessons Learned

• Examine district energy concepts early
• Every situation is unique - Test the edges
• Accelerate build out
• Explore split financing
  – Underground piping
  – Plant Construction
• Early screening is as much an education tool as a financial calculator