Large district heating network development based on Waste Heat Recovery

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#SESAAU2021
• **A2A Calore e Servizi** is part of A2A, a “Life Company”. A2A is the biggest Italian multi-utility, serving over 2.3 million customers with one or more services, 12,000 employees and over 100 years of history

• We manage District Heating & Cooling networks and other Energy efficiency services in the cities of Milan, Brescia and Bergamo

• National leader in DHC industry

• «By 2030, we want to make a solid contribution to the attainment of 11 of the 17 United Nations 2030 Agenda Sustainable Development Goals» including #07 Affordable and clean energy and #13 climate action
The Opportunity

- Within the NextGenerationEU plan, the opportunity has materialised to study the recovery of waste heat from the Cassano’s thermal-electric plant.
- A preliminary design of a backbone to reach the East Milan area has been done, together with a storage system to increase peak capacity, with 3 feeding nodes.
- This may expand the East Milan system (area 1), bringing DH to a vast, highly populated area.

The Goal

- How to optimize the allocation of the available heat on the expansion areas (1, 2 e 3 in figure)?
- Which potential users should be connected first to increase sustainability?
- What is the optimal piping layout?

- 1TWh/y heat recovery
- ~34 km² of area

Optimize the DH network design and investment budget, taking into account technical and economical constrains.
Accredited Spin-off of the Alma Mater Università di Bologna (Operations Research and Management Science), based in Bologna and Cesena (Italy). We design, develop and provide state-of-art Solutions and Services in Advanced Analytics and Optimization.

Long-lasting experience in DHC modelling and Optimisation DSS. Significant role in key DHC communities (DHC+, Celsius Cities, UNEP’s District Energy in Cities Initiative, several EU Horizon 2020 projects, Italian and EU commercial projects ...)

Network Development Optimisation and Simulation

Energy Production Optimisation of Smart Energy Systems
Tool for Optimal Development of DH Networks

**BUSINESS OBJECTIVES**
Support development of District Heating/Cooling networks, achieving maximum ROI/NPV while respecting all thermo-hydraulic, economic and urbanistic constraints.

**THE SOLUTION**
Decision support system based on open-source GIS technology, to support generation of multiple optimal development scenarios with advanced modelling tools integrating all decision drivers (technical & economical)*

**KEY FEATURES**
- Large set of decision parameters to reproduce decision making process of large leading utilities
- Industry standard thermal-hydraulic modelling
- Quick generation of highly complex development scenarios

**APPLICATIONS**
- Support strategic investments (new networks or network expansion)
- Support commercial development (set of next best potential customers)
- Simulation to support advanced what-if analysis

* The tool is the evolution of a system presented at 4DH conference in 2016, used in other projects at EU level including
The Challenge

- «Blank Canvas» network development strategy over a very vast area (~34 km² in urban area)
- Huge dimension of problem: more than 20,000 arc roads and 8-10,000 potential customers
- Large uncertainty on several technical and economic decision variables
- Challenging delivery timeline to support engagement with local institutions

The project’s requirements:

- Pragmatic approach to the Feasibility Study to focus on key economic and technical issues
- Focus on the project’s goals leveraging on the tool’s functionalities (hydraulic model, economic optimisation)
- Flexible management of several scenarios
- Allow good User Experience to share results and analysis

Objectives:

- Support a complex decision making process involving multiple stakeholders
- Provide reliable KPIs and visualisation means to evaluate the most promising target scenarios
- Assess impacts and interdependencies of key decision variables
## The methodology

### AIM
- Handle problem dimension
- Bundle available geographic and economic data

### PROBLEM SETUP
- Scenario configuration starting from roads map

### NETWORK DESIGN
- Feasible optimal configuration of network

### WHAT-IF ANALYSIS
- Solution refinement and resiliency assessment

### PHASE

#### OUTPUT
- Data upload and integration
- Key simplifying assumptions to de-couple 3 zones

#### AIM
- Saturation of available power over most promising prospects
- Optimisation of CAPEX while respecting hydraulic constraints

#### WHAT-IF ANALYSIS
- Identification of most promising target scenario
- Basis for larger engagement of decision stakeholders

#### NETWORK DESIGN
- 2-step network design approach (see following slide)
- Baseline scenarios ready for sensitivity analysis

#### PROBLEM SETUP
- Identification of most promising target scenario
- Basis for larger engagement of decision stakeholders
The 2-step Network Design approach

**NETWORK LAYOUT**

**Objective function:**
Topology optimization

(minimization of network length considering piping flow)

Output:
Backbones graph

**CAPEX OPTIMIZATION**

**Objective function:**
Diameters optimization

(target power saturation respecting hydraulic constraints)

Output:
Optimally sized network

**LAYOUT MODEL**

**TECHNO-ECONOMIC MODEL**
Main decision drivers explored

- Capacity Allocation to different zones linked to given constraints, leading to different expansion patterns
- User Acquisition variability ranging from 100% to 70% of the total users
- Piping Costs variation evaluation, associated to expected infrastructural issues
- Different Peak Power availability

What-if & Sensitivity analysis

<table>
<thead>
<tr>
<th>Baseline</th>
<th>What-if 1</th>
<th>What-if 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV (€)</td>
<td>-</td>
<td>6,5%</td>
</tr>
<tr>
<td>TOTAL COST (€)</td>
<td>-</td>
<td>-2,4%</td>
</tr>
<tr>
<td>BACKBONES COST (€)</td>
<td>-</td>
<td>0,5%</td>
</tr>
<tr>
<td>CONNECTIONS COST (€)</td>
<td>-</td>
<td>-2,2%</td>
</tr>
<tr>
<td>EXTRA COSTS (€)</td>
<td>-</td>
<td>-17,4%</td>
</tr>
<tr>
<td>SST COSTS (€)</td>
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<td>-1,9%</td>
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<tr>
<td>TOTAL LENGTH (km)</td>
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<td>-0,4%</td>
</tr>
<tr>
<td>BACKBONES LENGTH (km)</td>
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<td>0,0%</td>
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<tr>
<td>CONNECTIONS LENGTH (km)</td>
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<tr>
<td>€/m COST (TOT)</td>
<td>-</td>
<td>-2,1%</td>
</tr>
<tr>
<td>€/m COST (pipes only)</td>
<td>-</td>
<td>-2,9%</td>
</tr>
<tr>
<td>€/m COST (backbones only)</td>
<td>-</td>
<td>0,1%</td>
</tr>
<tr>
<td>CONSUMERS DENSITY (MWh/km)</td>
<td>XXX</td>
<td>0,2%</td>
</tr>
<tr>
<td>CONSUMERS DENSITY (€/MWh)</td>
<td>-</td>
<td>-2,7%</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Baseline</th>
<th>What-if 1</th>
<th>What-if 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>INSTALLED PIPE DN (km)</td>
<td>-</td>
<td>261,1</td>
</tr>
<tr>
<td>Distribution Network (DN &lt; 300)</td>
<td>-</td>
<td>25,1</td>
</tr>
<tr>
<td>Transmission Network (DN ≥ 300)</td>
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<td>25,1</td>
</tr>
</tbody>
</table>
Advanced analysis tools & deliverables

- BI support
- Scenario shapefiles
- Cash flow sheets
- High impact analysis
- Usability
- Stakeholder engagement
Conclusions

• Proven approach for very large DH Networks design
  ❑ Starting from the project scope definition, a step-by-step approach based on Optit’s advanced Decision Support System enabled the joint team qualify the most significant scenarios, out of a virtually limitless number of possible expansion patterns, within challenging time constraints

• Backbone Topology and Optimal Sizing Definition
  ❑ The optimal network topology was designed for each target area, taking into account specific technical and economic constraints
  ❑ CAPEX and NPV Optimization for each scenario was achieved, yielding the perspective network outlook for each scenario, while ensuring thermal-hydraulic feasibility
  ❑ The most promising scenario of network configuration was eventually identified, with corresponding technical and economic KPIs (expected investment costs)

• Comprehensive Deliverables
  ❑ Cash-flow sheets, target KPIs and cartographic representation of each scenario was provided, leading to further deep-dive analysis and supporting decision making process across various stakeholders

• Future Steps
  ❑ Consolidate the technical and economic conditions, in a dynamic multi-stakeholder context
  ❑ Refine the NPV assessment, taking into account further operational and economic conditions
  ❑ Locally adjust the network topology in order to assess more detailed geographic constraints
Thank you for your attention

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