FLEXYNETS

Fifth generation, Low temperature, high EXergY district heating and cooling NETworkS
Strategic Objectives

TO REDUCE TRANSPORATION HEAT LOSSES
∞ By using a carrier fluid working at “neutral” temperature levels – between 10 and 25°C

TO DISTRIBUTE HEATING AND COOLING CONTEMPORARILY ON THE SAME PIPELINE

TO INTEGRATE EFFECTIVELY MULTIPLE ENERGY GENERATION SOURCES

TO DEVELOP CONTROL STRATEGIES AND POLICIES
Definition of substations for connection to DHC network through reversible heat pumps

Approach

From the water-loop concept to a decentralised low-temperature DHC network

Assessment of energy sources for DHC networks
Substations integration into networks
Substations integration into networks

Prosumers substations

Production substations
Networks control strategies

Management Level
Strategic control

Data Management  Optimization  Simulation / Load forecast

High Level Control  enisyst
Energy flow control

Supply System Control
LC1  LC2  LC3  LC4  LC5

Load Control
LC6  LC7

Storage Control
Energy trading strategies

What energy sources are worth to be integrated from the economic perspective?

(What price shall be given to each energy source?)

What business models are reasonable from the energy utility and the customer perspectives?

(based on the who bears the investment cost)

How can decision makers promote fifth generation district heating and cooling networks?

(with incentives on investment or waste/renewable energy integrated in the network)
Energy TRADING strategies

Assessment of incomes for the utility company, based on running costs

Assessment of maximum heat price to the customer, based on electricity price

Cost of electricity = 150 €/MWh

SCOP = 5

Price of electricity to customer [€/MWh]

- 100
- 150
- 200
- 250

Annualised cost of heat for utility company [€/MWh]

- 30
- 50
- 70
- 90
- 110
- 130

Income on heat delivered, $I_{H,\text{net}}$ [€/MWh]

Reference heating price, $c_{H,\text{ref}}$ [€/MWh]
Energy TRADING strategies

A number of business cases can be addressed:

- **Energy Producer**
  - Investment on Producer
  - Th. energy is paid by utility
  - Th. energy is provided for free

- **Energy Prosumer**
  - Investment on Prosumer
  - Th. energy is paid by utility
  - Th. energy is provided for free

- **Energy Consumer**
  - Investment on Consumer
  - Electricity is paid by utility
  - Electricity is paid by customer

  - Investment on Utility
  - Electricity is paid by utility
  - Electricity is paid by customer
Energy TRADING strategies

Business case 1a: Producer – Investment on Utility Company

- Waste heat recovery from medium size supermarket dry cooler (150 kW)
- W/W Heat Pump increases waste heat temperature from 25 °C to 40 °C

<table>
<thead>
<tr>
<th>Utility investment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment per kW</td>
<td>1500 €/kW</td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>150 kW</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>1% -/year</td>
<td></td>
</tr>
<tr>
<td>Investment Cost</td>
<td>€ 225,000.00</td>
<td></td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>€ 2,250.00</td>
<td></td>
</tr>
<tr>
<td>interest rate</td>
<td>2% -</td>
<td></td>
</tr>
<tr>
<td>Investment Horizon</td>
<td>20 years</td>
<td></td>
</tr>
<tr>
<td>Annualised Investment</td>
<td>€ 320,205.23</td>
<td></td>
</tr>
<tr>
<td>Annuity</td>
<td>7.1% -</td>
<td></td>
</tr>
<tr>
<td>Operation hours 1</td>
<td>3000 hours/year</td>
<td></td>
</tr>
<tr>
<td>Operation hours 2</td>
<td>6000 hours/year</td>
<td></td>
</tr>
<tr>
<td>SCOP</td>
<td>5 -</td>
<td></td>
</tr>
<tr>
<td>Cost of electricity</td>
<td>100 €/MWh</td>
<td></td>
</tr>
</tbody>
</table>
Energy TRADING strategies

Business case 1a: Producer – Investment on Utility Company

- Waste heat recovery from medium size supermarket dry cooler (150 kW)
- W/W Heat Pump increases waste heat temperature from 25 °C to 40 °C

Costs and SCOP:

- Investment = 1500 €/kW, SCOP = 5

<table>
<thead>
<tr>
<th>Cost of heat (investment)</th>
<th>Cost of heat 1 (Investment)</th>
<th>€ 35.58</th>
<th>€/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost of heat 2 (Investment)</td>
<td>€ 17.79</td>
<td>€/MWh</td>
</tr>
<tr>
<td>Cost of heat (electricity)</td>
<td>Cost of heat 1 (electricity)</td>
<td>€ 20.00</td>
<td>€/MWh</td>
</tr>
<tr>
<td></td>
<td>Cost of heat 2 (prosumer)</td>
<td>€ -</td>
<td>€/MWh</td>
</tr>
<tr>
<td>Cost of heat (total)</td>
<td>Cost of heat 1 (prosumer)</td>
<td>€ -</td>
<td>€/MWh</td>
</tr>
<tr>
<td></td>
<td>Cost of heat 1 (total)</td>
<td>€ 55.58</td>
<td>€/MWh</td>
</tr>
<tr>
<td></td>
<td>Cost of heat 2 (total)</td>
<td>€ 37.79</td>
<td>€/MWh</td>
</tr>
</tbody>
</table>

Annualised Investment = Capacity * Operation Hours * Horizon

Cost of electricity = SCOP
Energy TRADING strategies

Business case 1b: Producer – Investment on Utility Company

- Waste heat recovery from medium size supermarket dry cooler (150 kW)
- Direct waste heat recovery without heat pump from 30 °C to 20 °C

Cost of heat (investment)

| Annualised Investment | Capacity * Operation Hours * Horizon |

Cost of heat (electricity)

| Cost of electricity | SCOP |

Investment = 750 €/kW, SCOP = 20

| Cost of heat 1 (investment) | € | 17.79 | €/MWh |
| Cost of heat 2 (investment) | € | 8.89 | €/MWh |
| Cost of heat 1 (electricity) | € | 5.00 | €/MWh |
| Cost of heat 1 (prosumer) | € | - | €/MWh |
| Cost of heat 2 (prosumer) | € | - | €/MWh |
| Cost of heat 1 (total) | € | 22.79 | €/MWh |
| Cost of heat 2 (total) | € | 13.89 | €/MWh |
Energy TRADING strategies

This calculation does not consider the investment for the installation of the substations at the single consumer buildings

COP = 5
Energy TRADING strategies

Business case 3a: Consumer – **Investment on Utility Company**

- Small multifamily house (10 apartments – 7.000 kWh/y)
- W/W Heat Pump increases carrier temperature from 20 °C to 50 °C

<table>
<thead>
<tr>
<th>Investment per kW</th>
<th>2500 €/kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>20 kW</td>
</tr>
<tr>
<td>Maintenance</td>
<td>2% /year</td>
</tr>
<tr>
<td>Investment Cost</td>
<td>€ 50,000.00 €</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>€ 1,000.00 €/year</td>
</tr>
<tr>
<td>interest rate</td>
<td>2%</td>
</tr>
<tr>
<td>Investment Horizon</td>
<td>20 years</td>
</tr>
<tr>
<td>Annualised Investment</td>
<td>€ 81,156.72 €</td>
</tr>
<tr>
<td>Annuity</td>
<td>8.1%</td>
</tr>
<tr>
<td>Operation hours</td>
<td>3500 hours/year</td>
</tr>
<tr>
<td>SCOP</td>
<td>5</td>
</tr>
<tr>
<td>Cost of electricity</td>
<td>100 €/MWh</td>
</tr>
</tbody>
</table>

- **Investment = 2500 €/kW, SCOP = 5**
- **Cost of heat = 72 €/MWh**
- **Cost of heat (electricity) = 25 €/MWh**
- **Total cost = 97 €/MWh**
Energy TRADING strategies

- Including the investment costs related to installing substations at customers buildings the annualised costs of thermal energy delivered increase to 100 – 120 €/MWh

- In this business case, the electricity is paid by the utility company

COP = 5
FLEXYNETS vs DH vs individual
1 million sqm living surface

<table>
<thead>
<tr>
<th>Equivalent annual cost [M€/year]</th>
<th>FLEXYNETS no WH</th>
<th>DH + Split Units</th>
<th>FLEXYNETS 40 % WH</th>
<th>FLEXYNETS 66 % WH</th>
<th>Individual boilers + Split Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-DH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26-FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-indiv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Cap. cost of DH network**
- **Cap. cost + fixed O&M of heaters**
- **Cost of excess heat**
- **Cap. cost + fixed O&M of split units**
- **Cap. cost + fixed O&M of reversible HP**
- **Operation of HP (cooling)**
- **Operation cost of central chiller**
- **Pumping cost**
- **Operation cost of heaters**
- **Cap. cost + fixed O&M of substations**
- **Operation cost of split units**
- **Operation of HP (heating)**
- **Cap. cost + operation of central chiller**
FLEXYNETS vs DH vs individual
1 million sqm living surface

<table>
<thead>
<tr>
<th></th>
<th>FLEXYNETS no WH</th>
<th>DH + Split Units</th>
<th>FLEXYNETS 40 % WH</th>
<th>FLEXYNETS 66 % WH</th>
<th>Individual boilers + Split Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent annual cost [M€/year]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-DH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26-FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-indiv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Cap. cost of DH network
- Cap. cost + fixed O&M of heaters
- Cost of excess heat
- Cap. cost + fixed O&M of split units
- Cap. cost + fixed O&M of reversible HP
- Operation of HP (cooling)
- Operation cost of central chiller
- Pumping cost
- Operation cost of heaters
- Cap. cost + fixed O&M of substations
- Operation cost of split units
- Operation of HP (heating)
- Cap. cost + operation of central chiller
Take home considerations

- Gathering waste heat and renewable energy can be economically viable, and allows significant savings on CO2 emissions. Incentives are disregarded on purpose in these calculations. **What if carbon trade exchange is considered?**

- Work still to be done **to optimise pipes costs and to standardise heat pump substations.**

- Depending on temperature levels of energy source and network, the cost of energy made available can vary largely (factor 2). Better overall performance if utility company sales also electricity, however coupling heating and electricity grids unleashes a number of service scenarios.

- As limited investments are involved in connecting substations to the network, **urban waste heat recovery can grow with the time and as far as the network grows.**
VISIT FLEXYNETS WEBSITE

WWW.FLEXYNETS.EU

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 649820