District Heating sustainability

Can economics beat physics?

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Agenda

1. Problem statement
2. Optimising network and production
3. Scenarios for future demand
4. Technologies
5. Business case
6. Way forward (TVW and RES)
7. Appendix
1. Problem statement

Reduce gas dependency and prepare for growth of the network

- Purmerend district heating is the 4th largest in the Netherlands, directly owned by the municipality.

- It supplies heat to 26 000 clients

- Its installed capacity is:
  - Biomass plant (BWC): 44 MW
  - Gas plant 1 (HWC1): 90 MW
  - Gas plant 2 (HWC2): 35 MW

The original gas fired CHP is now decommissioned.

- Yearly production: 1300 TJ / year = tapwater 200 TJ + heating 700TJ + losses 400 TJ,
  = biomass 900 TJ + gas 400 TJ

- Its maximum production was reached on February 28th, 2018
1. The heat demand is very volatile (seasonally and daily)

Daily and hourly average (GJ) 2017

3.6 GJ = 1 MWh
1. Daily profiles season dependent

BWC = Biomassa Warmte Centrale
HWC = Hulp Warmtecentrale

3.6 GJ = 1MWh
1. Volatility can be very high
2. Netwerk optimisation: temperature

2 challenges:
- Lower supply temperatures (primary and/or secondary)
- Lower return temperature (= increase dT) by improving heat exchange at client and reduce bypassing (for keeping on standby)

⇒ Objectives:
  ⇒ Lowering heat losses (now up to 35%)
  ⇒ Lower the flows (hence the operating pressures)
  ⇒ Enable lower temperature heat sources

⇒ Risks:
  ⇒ Cool down up to the “Legionella” limit
  ⇒ “Cold spots” where heat is not available within the specified time to client
  ⇒ Low dT, hence higher flows and pressures.

⇒ Requirements:
  ⇒ Increasing heat exchange surfaces in housing

Current observation:
The dT on secondary network is the sum of:
- “sold dT”: cooling at the clients delivery set
- “lost dT”: cooling in the networks

⇒ 4th Generation networks
2. Network optimisation: buffering network and user

How much can be stored:

- Network:
  References production: \( dT = 30K, 33\text{MW}, 1000\text{m}^3/\text{h} \)
  Network: 500km piping, 8000m\(^3\) (=260MWh, of 9MWh per degree)

- End users:
  Specific heat capacity of air: around 1 kJ/m\(^3\)/K
  Specific heat capacity of bricks: around 1 kJ/kg/K for a density of 2t/m\(^3\)
2. Network optimisation: buffering network and user

How fast is heat available?

- How fast does a temperature difference propagate in a network?
  Simplistic model: heat production at the end of linear pipe (length L) with an homogeneous heat consumption. The water velocity decreases linearly from the heat source to the end of the pipe (from Vo to 0m/s). \( V = Vo \times \frac{L-x}{L} \)
  A transient in source temperatuur reaches distance x after a time T calculated as follows:
  \( dt = dx/V \Rightarrow T = L/Vo \times \ln(L/(L-x)) \)
  The end of the network recieves the temperature change with huge delay.

*Installing bypasses prevents cold spots but consumes energy.*

- How does heat propagate throught a wall until a depth x?
  The damping and the phase delay is: \( x/\delta(w) = x/V \times 2\lambda/\rho c \omega \) (\( \omega = 2\pi/\text{dag}, \alpha = \lambda/\rho c \) heat diffusivity)

  The temperature stability is equally dependent conductivity (inverse proportional to isolation) as on specific heat capacity.

*This is illustrated by traditional stone habitat. Are current construction norms only focusing on conductivity, or also on specific heat capacity as factor of comfort?*
3. Factors influencing future demand

The future heat demand (average and peak) will be determined by:

- **Newbuild**: in Purmerend, ambitious newbuild programme and network expansion;
- **“Gasvrij”**: The city plans to replace gas heating by district heating, starting with a 100 connection pilot;
- **Client loss**: the current heating law allows individuals to refuse connection to DH and go for electrical solution;
- **Insulation improvement**: this applies to new built as well as existing housing;
- **Consumption habits ("Demand Side Response")**: with tarification and smart meters, peak will diminish, but average will increase.
- **Climate change**: There is a clear trend of “degree-days” decrease of 0.5% per year (KNMI stats). However, extreme events still remain possible.
- **Network losses**: decrease in supply and return temperature will decrease yearly average.
3. Climate change

Extreem demand decreases (Hellmann number)

Average demand decreases (graaddagen)
4. Technologies: on short list

**Biomass**
- Woodchips
  - Capex: 0.5M€/MW, Opex depending on biomass market
  - Limited availability in the Netherlands (1kW/ha)
- Biogas
  - Very limited amount (currently 100Mm³ out of 40Gm³)
  - Can be acquired through certificates or stake in a digestor

**Geothermal**
- Best case 1M€/MW, COP=10, 10MW doublets
- Technology and regulation still under development
- Political and social acceptance could deteriorate
- Industrial parties actively developing similar projects

**Heat Pumps**
- Add on heat source in the municipality
- Possibility to re-heat return water for low temperature application
4. Technologies: not on short list

**Solar energy**
- PV: not applicable
- Warm water/ seasonal storage: no BuCa on Purmerend scale. Physical constraint: population density in NL 4 times higher than Denmark

**Waste heat Alkmaar**
- Capex too high, no long term certainty

**Power to heat**
- Potential upside

**Hydrogen**
- Not readily available
5. The technologies have different positions in the merit order

Baseload solution:
- High capex, low opex
- Whole year
- Displaces biomass which already subsidized
- Peak consumption not addressed

Partial load solutions:
- Medium capex, medium opex
- Short operation time (max 3000 h)
- Peak consumption not addressed
- No displacement current biomass plant
5. The technologies have different positions in the merit order

Peak solution

- Low capex, high opex
- Short operation time (max 3000 h)
- Peak consumption almost addressed
- No displacement current biomasa plant
5. The technologies have different positions in the merit order

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<th>GT (MW)</th>
<th>BWC (MW)</th>
<th>BWC2 (MW)</th>
<th>buffers (MW)</th>
<th>gas (MW)</th>
<th>gas (MWh)</th>
<th>gas (m3)</th>
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5. BUSINESS CASE

Even without growth, it is worth asap to invest with current SDE subsidies.

Comparisons between technologies are based on the TCO of the different scenarios.

**With current SDE:**
Woodchips are most interesting
Geothermal just breaks even

**With lower SDE on de chips (for under 3000h/y)**
All options similar

**Without subsidies:**
Geothermal and woodchips are most interesting.

Heat pumps on the stack would have only a marginal contribution to the overall production, are therefore assessed on their own BuCa.

The optimal output for a new bioplant is around 20MW. However, the permitting process is significantly easier under 15MW.
5. Way forward Purmerend

- The existing buffer will be overhauled for intraday buffering (sizing based on statistics) for commissioning in 2020.

- Biomass: an additional 15MW plant is underdevelopment for operations in 2022.

- Geothermal: options are discussed with possible partners for start of works in 2025 (operations in 2027).

- Heatpumps: Subsidies regime is monitored for possible insertion in the system at the stack. Business development monitors opportunities for low temperature supply for newbuild.

- Biogas: partnerships with digestors under discussion for winterpeak consumption.

=> Gas still required for back-up, emergencies and winter peaks.
5. Way forward RES / TVW

Proposed strategies:

1) Individual electrical heating (heatpumps)
2) Collective network at medium or high temperature
3) Collective network at low temperature
4) Hybrid heatpump with renewable gas
5) Boiler with renewable gas

Many governmental bodies (EZK, RVO, ECW, CE Delft...) and consultants propose decision helping tools and algorithms (CEGOIA, VESTA-MAIS, WTM...). It should be observed that Purmerend had a top down approach whereas most models propose a bottom up methodology.

Main challenges for collective solutions:

- Availability of heat sources (waste heat, biomass, geothermal...). For argument sake, DH was originally (and is still in neighbouring countries) based on CHP’s (the metaphor for golden waste...).
- Justifying costs to customers: Warmtewet 2.0 (Heating low) as presented by Minister Wiebes to parliament suggest an open book type of costing. For heavy investments (pipelines @1M€/km), the amortisation period will stir heavy debates among customers.
- Summer losses will be difficult to explain.
5. Way forward Transitievisie Warmte Amsterdam
Way forward: H2 green (?)

<table>
<thead>
<tr>
<th>TO PRODUCE 1 MWh OF HYDROGEN</th>
<th>Primary source</th>
<th>Emissions (tCO2/MWh of H2)</th>
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</thead>
<tbody>
<tr>
<td>Steam Methane Reforming (grey H2)</td>
<td>1,5 MWh of natural gas</td>
<td>0,3</td>
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<tr>
<td>Electrolysis (&quot;green&quot; H2)</td>
<td>3 MWh of natural gas</td>
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<tr>
<td>marginal power production on gas</td>
<td>4 MWh of coal</td>
<td>1,2</td>
</tr>
</tbody>
</table>

Heating efficiency to primary energy source (methane, wind, solar):
- Gas heating: almost 100%
- Electrical:
  - From G to P to Heat Pumps: 55% x 300% = 165%
  - From wind to Heat Pumps: 300%
  - From stored wind (PtoG - GtoP) 70% x 70% x 300% = 150%
- Gas heating H2: 70%
Food for thoughts...

Summer usage of network:
Considering the low tapwater consumption, could networks be shut down in the summer, and heat tapwater electrically?

Cold spots on the network:
Is it acceptable to reduce bypassing to decrease temperature in the supply line? The user would experience a delay in getting hot water for the period required to circulate the cold spot.

Demand Side Response:
By using the specific heat in the system, in particular in houses, can we smoothen the heat production without affecting comfort?

Remove natural gas only when all alternatives are fully renewable.
Combustion of NG at home is the lowest carbon emitting energy usage our system to the exception of wind and solar. It should be the last fossile application to be removed, as its alternatives (even H2…) will emit more CO2 before being fully sustainable.

What is our time frame and expected return?
Comparing individual electrical heating to collective networks requires a timeline and WACC to calculate respective BuCas and EROEI (Energy Returned on Energy Invested). Considering 30 years instead of 15 might give different results.
Back up: Technologies, geothermie

- Base load, displaces biomass
- Long term option, dependent on development of regulation and market
- Expected power per well-doublet: approx 10MW thermal
- Social acceptancy and political support now positive
- Positive discussions to create an OpCo to run the wells and sell the heat to SVP between:
  - gas concessionholders (NAM)
  - Experienced industrial parties.
- Technology and regulation still under development
- Well-doublets probably outside the municipality, requiring additional transportation pipes.
Back up: Technologies, Heat pumps

Several options:

a. Heat recovery from stack biomass plant
   Its the highest heat source in the municipality. It could increase the output by 7%. It requires adequate subsidies (as in Denmark) to be viable.

b. Add-on (heat from own network)
   Reheating return water for low temperature applications (newbuild).
   => discussion with housing corporations on newbuild

c. Add-on (heat from environment / buffering)
   No interesting heat sources in the municipality

Benchmark:
Utrecht (Eneco) developed an aquathermie project to pump heat out the sewage, to be followed up.
Back up: Technologies, biomass (solid)

Woodchips
- Know technology
- Available without conversion and excessive transportation (Staatsbosbeheer), SDE subsidies will probably go down
- Woodchips have a high moisture content, hence unflexible combustion
- Bad social & political perception
- Physical constraints: 4t of wood per ha/y => 1 kW/ha.

Pellets:
- High flexibility
- Sourcing outside Europe and subject to environmental criticism

General comment:
There is no consensus on carbon footprint of biomass, in particular the carbon debt. We could imagine a footprint proportional to the time required to re-grow the biomass on a 30 year time horizon.

\[ \text{CO2 eq} = \frac{\text{years to grow biomass}}{30} \times \text{CO2 content of biomass}. \]
Back up: Technologies, biomass (fluid: pyrolyse olie)

- High flexibility (referentie Friesland Campina)
- High SDE subsidies
- Transportation and storage difficult (acidity, clogging)
- Social perception unclear, imported from Scandinavia and Canada
- 2 suppliers (BTG, Honeywell)
- Capex pyrolyse olie 25ME, output 15MW olie, 7MW stoom en electra, 3MW verlies, 7fte bedrijfsvoering, capex ketel 4ME excl civiel, olie prijs gelijk aan SDE. Dichtheid: 1150-1250 kg, 17-20GJ/m3, op basis van chips of zaagsel.

⇒ Converting biomass into oil instead of direct combustion is energetically unefficient.

=> Pyrolysis of wastestream such as berm grass could be an option.
Optie 1: Buy green gas certificates (very volatile)

Optie 2: Take a share in a fermentation/ digestor plant (no certificate risk)
Physical constraint: little availability, waste stream only, energy crops excluded by climate requirements. Current Dutch yearly production 100Mm3 out of 40Gm3.

Optie 3: Take a share in gasification
Current pilots would cost 25ME for 4 MW, which is out of reach.