International Conference on Smart Energy Systems and 4th Generation District Heating
Copenhagen, 25-26 August 2015

INTEGRATION OF DECENTRALIZED SOLAR HEAT GENERATION TO A LOW-TEMPERATURE DISTRICT HEATING NETWORK VIA SUBSTATION NET-METERING

José F. CASTRO FLORES[1,2] (presenter)
Viktoria MARTIN[1], Justin NW. CHIU[1]
Olivier LE CORRE[2], Bruno LACARRIÈRE[2]

[1] **KTH** – Royal Institute of Technology, Department of Energy Technology, *Stockholm, Sweden*
[2] **EMN** – École des Mines de Nantes, Department of Energy Systems and Environmental Engineering, *Nantes, France*

AALBORG UNIVERSITY
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4DH
4th Generation District Heating Technologies and Systems

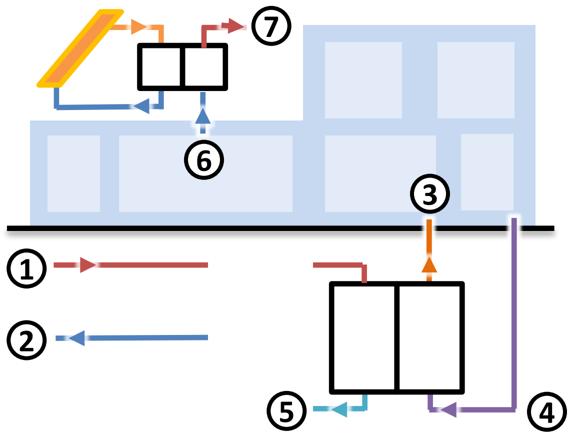
Overview

- District Heating/Cooling,
  - Key technology to (1) achieve a higher overall energy system **efficiency**,
  - and (2) integrate **non-conventional** heat resources,
- Low Temperature District Heating (55/25 °C)
  - Response to challenges: low-energy buildings (losses > consumption, in summer)
  - Enhance heat recovery from low-grade heat sources: Solar DH
- Integration of **LT Substation** using a mix of low-exergy resources
  - **Solar heat**, DH return flow, (DH supply/forward flow used when necessary)
- Performance comparison (Energy, Collector efficiency)
  - Different possibilities for connection/feeding load
- Effects on the substation's load curve (aggregated demand pattern)

Thermodynamic modelling & simulation

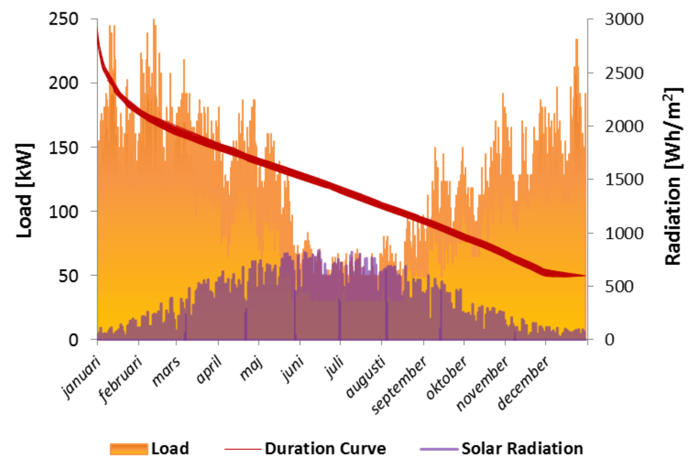
System Description

Low-Temperature Substation + Solar Collector



1.	**DH Supply**
2.	**DH Return**
3.	**LT Supply**
4.	**LT Return**
5.	**Subs. Return**
6.	**Collector In**
7.	**Collector Out**

- **Low-Temperature Network** (Load)
  - Multi-dwelling building (50 - 75 apartments)
  - LT Supply/Return temp.: 55/25°C
  - Location: Stockholm
  - Maximum Load = 250 kW_{th}
  - Heat Demand: 1,01 GWh_{th}/yr
- **Weather Data**
  - Typical meteorological year (hourly)



- **Solar Collector** (Flat plate type)
  - Collector area: 200m²
  - 150 kW_{th} peak (@ 1000 W/m²)
  - Output temp. range: 65 – 90 °C
  - No storage tank
  - Network short-term storage: 90% eff.
  - Collector output estimation according to European standard **EN12975**

Substation-Collector System

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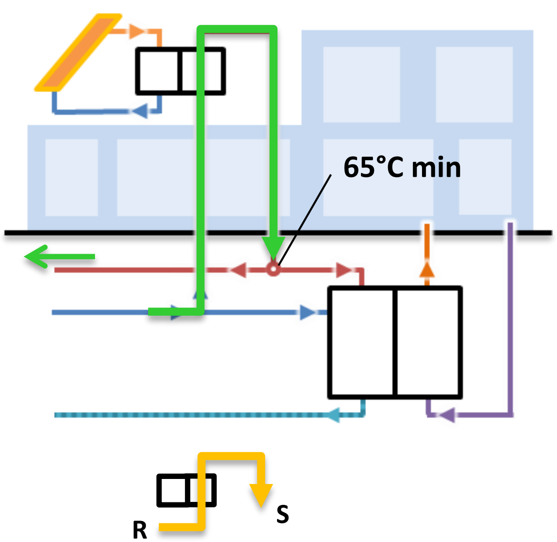
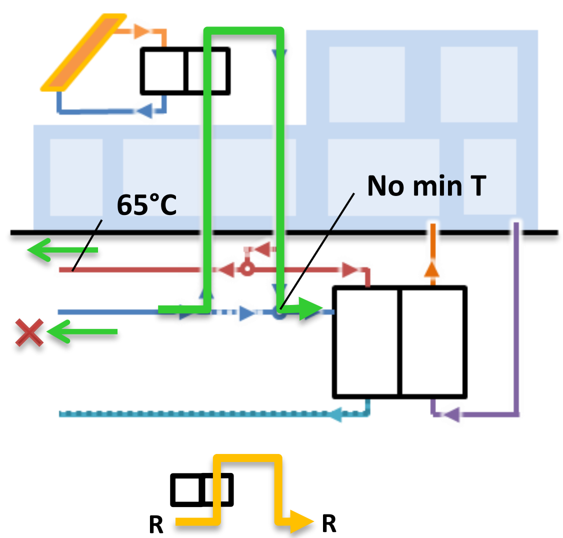
- Solar collector coupled to the **primary** DH network
  - Allow short-term network storage
- Use of two low-exergy resources: (1) Solar thermal (2) DH return flow
  - DH supply flow used to boost temperature level

- <u>Solar collector, connection configurations</u>:

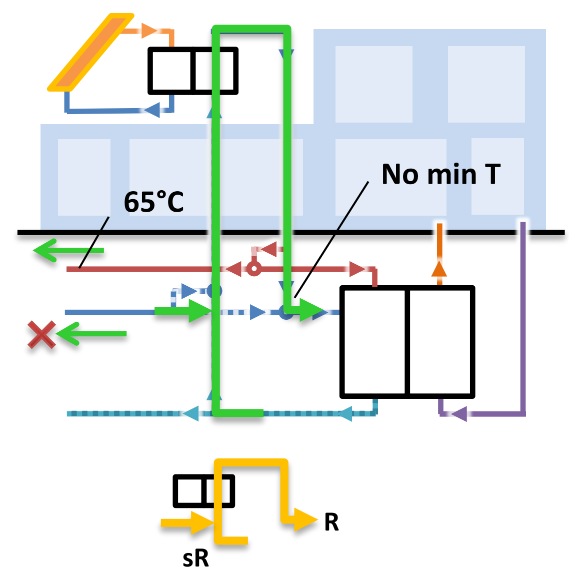
LT Substation + R-S collector



LT Substation + R-R collector



LT Substation + sR-R collector



Methodology

Case Definition
- Configuration
- Weather Data
- Temp. & Loads

Thermodynamic Simulation
- Output
  - Mass flows
  - Temperatures

Data Analysis
- Yearly/Seasonal
- Energy analysis
- Volume Flows

Results
- LD Curves
- Performance Indicators

Modelling Assumptions:

- Aggregated demand patterns (SH + DHW)
- Use of average values over the year (loads, solar radiation, …)
- Full and partial load (steady-state)
- Pumping energy neglected (~2% of energy delivered)

Operation Targets:

- Use the least DH supply/forward flow
- Aim for low substation return temperatures
- Enhance solar heat generation
- Use most solar heat at the substation (reduced use of short-term storage)

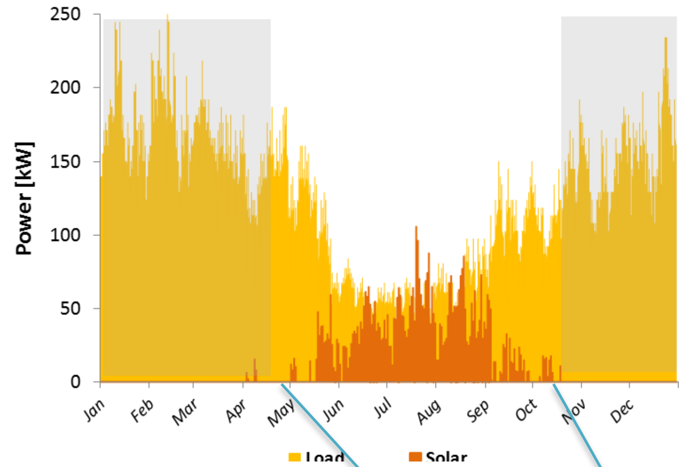
Results - Annual

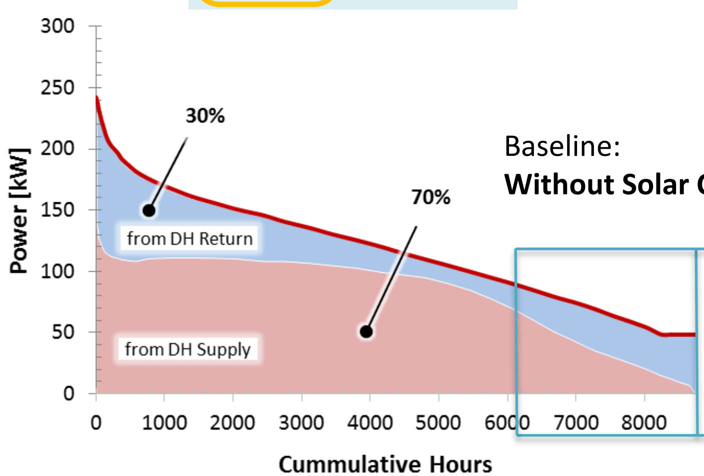
Collector Performance:

	Operating Hours	Collector Efficiency	MWh/yr	% of yr Demand	kWh/m² yr of coll. area
No Sol	0	n/a	0	0	0
R-S	1468	29%	43,4	**4,3%**	**217**
R-R	2071	27%	52,0	**5,2%**	**260**
sR-R	2266	30%	60,9	**6,1%**	**305**

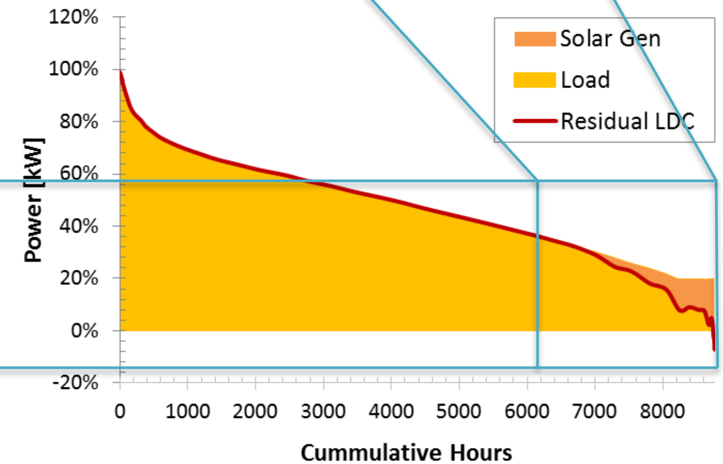
4340 hr/yr with sunlight
8760 hr/yr total

~80% in summertime

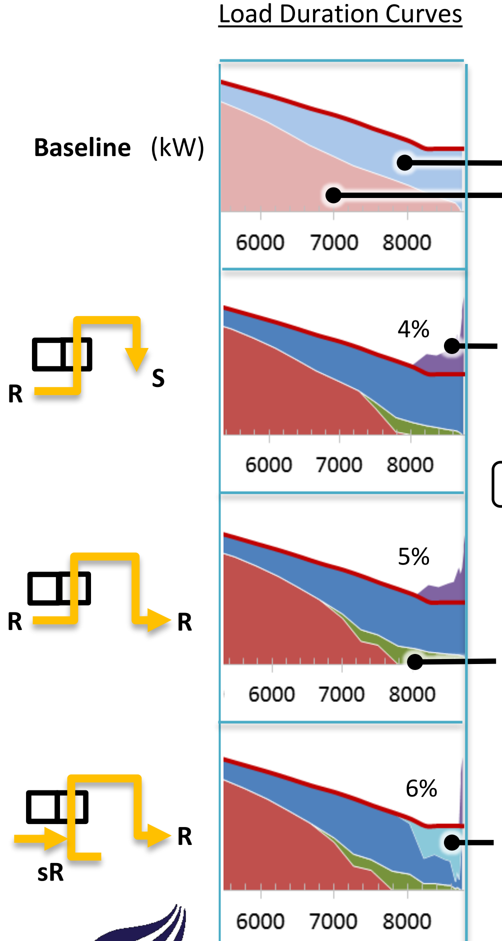


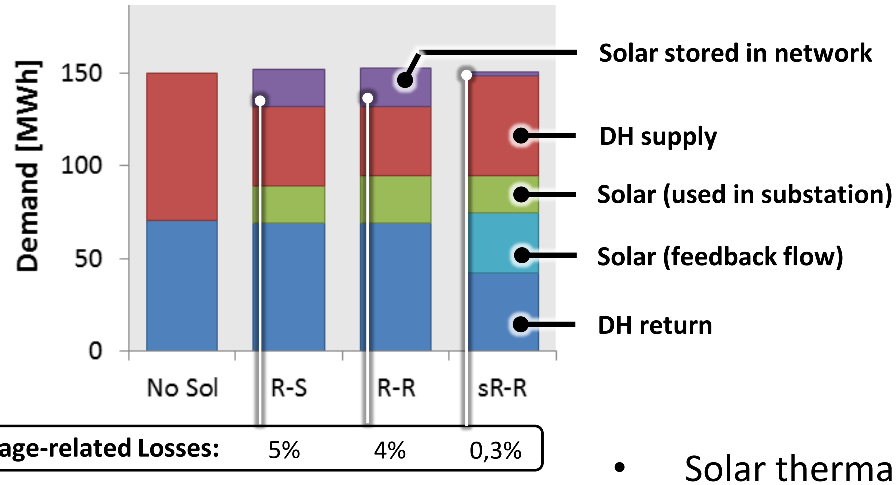


Baseline:
Without Solar Collector

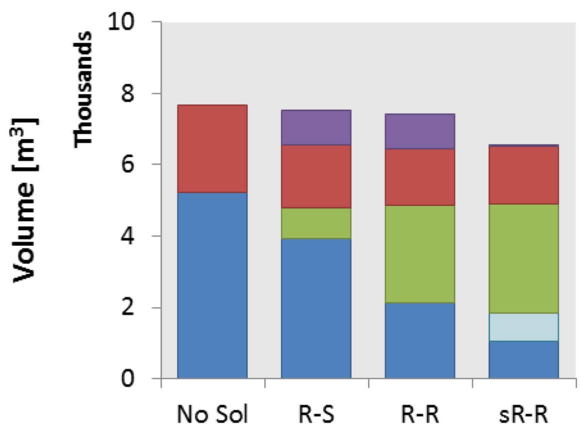


Results - Summer





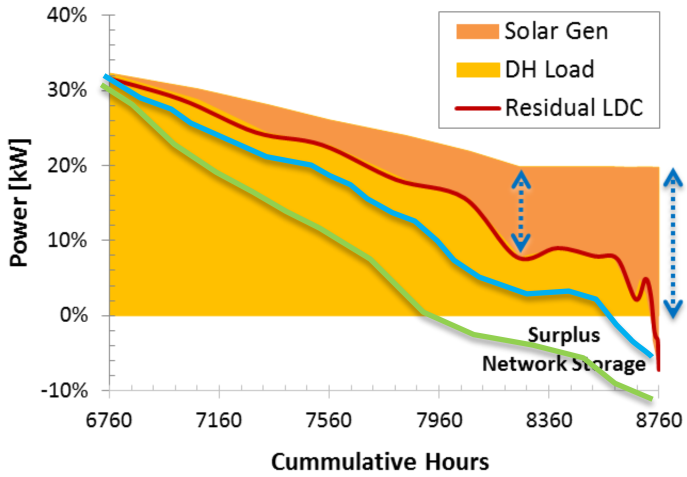
Solar Fraction Summer	
R-S	27%
R-R	31%
sR-R	36%



- Solar thermal displaces both DHs and DHr flows
- Using the LT substation return allows for:
  - Further solar heat recovered
  - Higher collector efficiency
  - Less energy stored in the DH network
  - Increased auto-sufficiency

Discussion

Residual LDC



- Dependent on penetration level of solar heat generation
- Ramping (morning/evening)
- Role of TES (potential)
- **Phase-out conventional sources (during summer)**

Metering & Charges

Demand	1002 MWh/yr
Heat Price	0,09 EUR/kWh
Solar Heat	0,07 EUR/kWh
Consumption	**90,2 k EUR/yr**

- Individually
  - Total Consumption & Total Generation

Savings	(per year)		
R-S	3,4%	3,0	k EUR/yr
R-R	4,0%	3,6	k EUR/yr
sR-R	4,7%	4,3	k EUR/yr

- Alternative Models
  - Net Consumption & Network Input (DHs pipe)

Savings	(per year)		
R-S	3,4%	3,0	k EUR/yr
R-R	4,7%	4,3	k EUR/yr
sR-R	6,1%	5,5	k EUR/yr

Concluding Remarks

- Combination of **low-exergy heat resources**
  - Solar heat, DH return flow
- Solar collector connection: S-R / R-R / sR-R
  - **sR-R:** better performance, more solar heat recovered, less use of network storage
- Applications (advantages) of system integration
  - Small-scale (local) -> large scale
  - Heat recovery from intermittent sources (surplus heat, electricity, TES)
- Potential to supply a larger fraction of solar heat during summer
  - High solar heat capacity + short-term thermal energy storage (TES)
- Techno-economics
  - Pricing, connection fees, storage fees …

Thank you!

José F CASTRO FLORES *(PhD Fellow)*
KTH – Royal Institute of Technology
jfcf@kth.se

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Supporting Slides

José F Castro Flores

Input Curves