Aalto University
School of Engineering

Design and comparison of two different optimized solar district heating typologies for Finnish Conditions

IBPSA-Nordic
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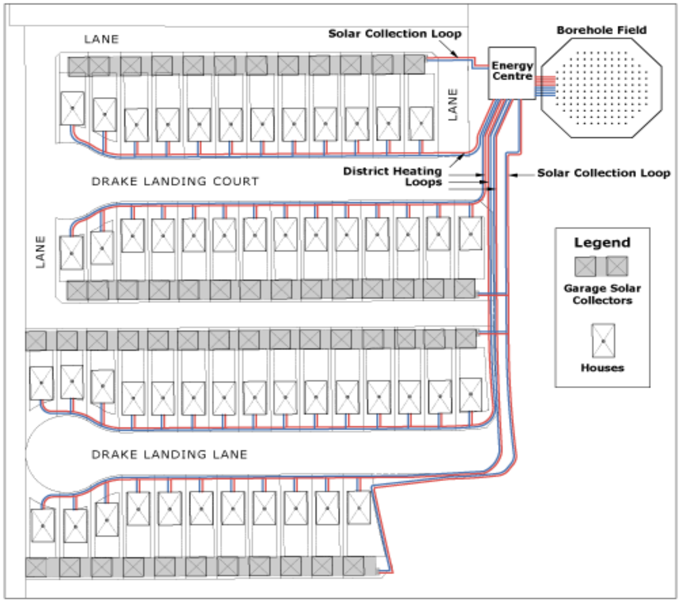
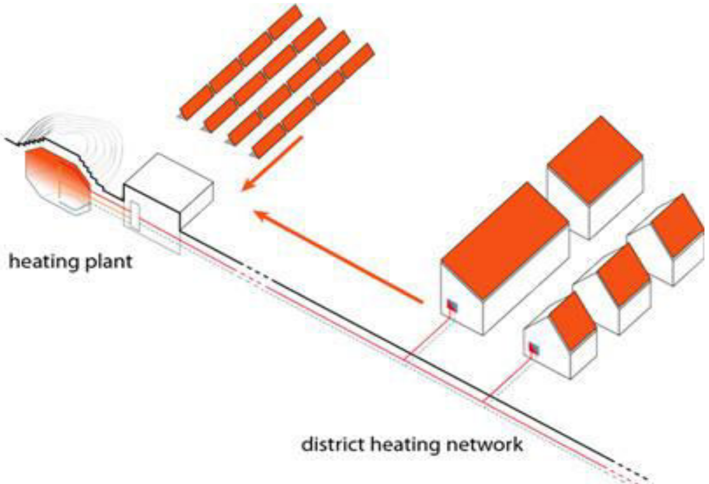
Background and challenges: Finland

- Building are largest consumers of energy in Finland
  - ➢ Two solar community concepts: Kerava (1980s) and Eko-Viikki (without seasonal storage).
- At high latitudes there are four major challenges:
  - ➢ The weather is extremely cold during winters
  - ➢ The annual mismatch between irradiation and demand
  - ➢ Losses from the seasonal storage are high-ground condition
  - ➢ The resulting energy costs are not yet competitive
- Seasonal storage is essential in Nordic conditions.
  - ➢ Borehole TES (BTES)
- We found that, solar district heating is influenced by
  - ➢ Climate of the location and controls





Research questions and motivation

Design of the centralized and de-centralized solar district heating network in Nordic conditions

- *Does De-centralized system configuration has any affect and influence on performance?*

Influence of the design variables on the system performance

- *Which important design variables in the system has an affect on the performance? And how much?*

Motivation:

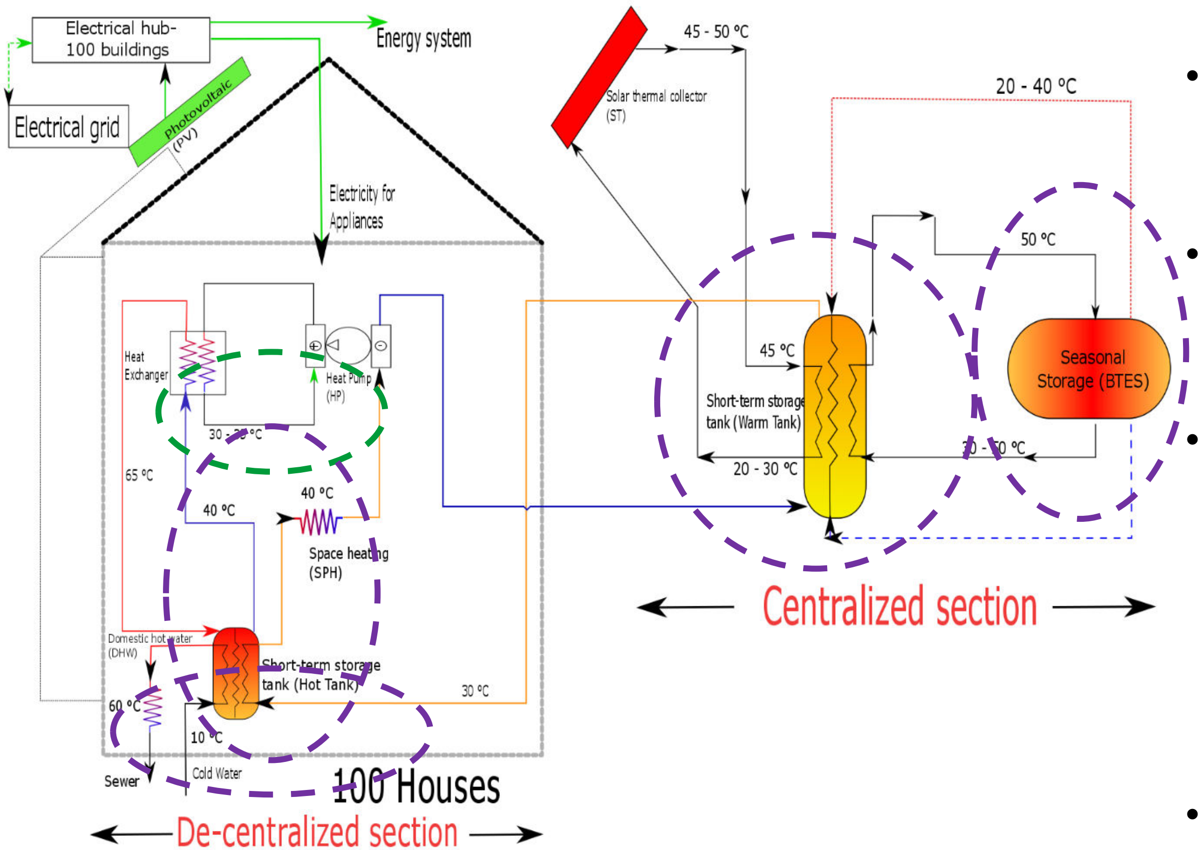
- **Develop economically competitive, locally optimized solar community concepts (SCC) with around 90% Renewable Energy Fraction (REF) in Finnish conditions.**

Methodology

- TRNSYS and TRNBuild Simulation
  - Solver (engine)
  - Component library, widely used in the simulation community
  - Solar district systems are designed and simulated on TRNSYS

- MOBO optimizer
  - Multi-objective optimization
  - Genetic algorithm
  - *Optimization objectives (minimize the life cycle costs and purchased electricity)*

Energy system design- Decentralized



- Solar thermal charge
  - Central large warm tank
- BTES charge & discharge via large central warm tank
- Individual house has small hot tank and heat pump
  - Individual house heat pump takes energy from SPH return line and charge hot tank
  - Provide SPH & DHW
- PV is used to provide electricity
  - Excess sold and shortfall imported via grid

- Hassam ur Rehman, Janne Hirvonen, Kai Siren, "Performance comparison between optimized design of a centralized and semi-decentralized community size solar district heating system," *Applied Energy*, vol. 229, pp. 1072-1094. 2018

Why De-centralized system?

Proposed/Desgined Case- Community with 100 buildings

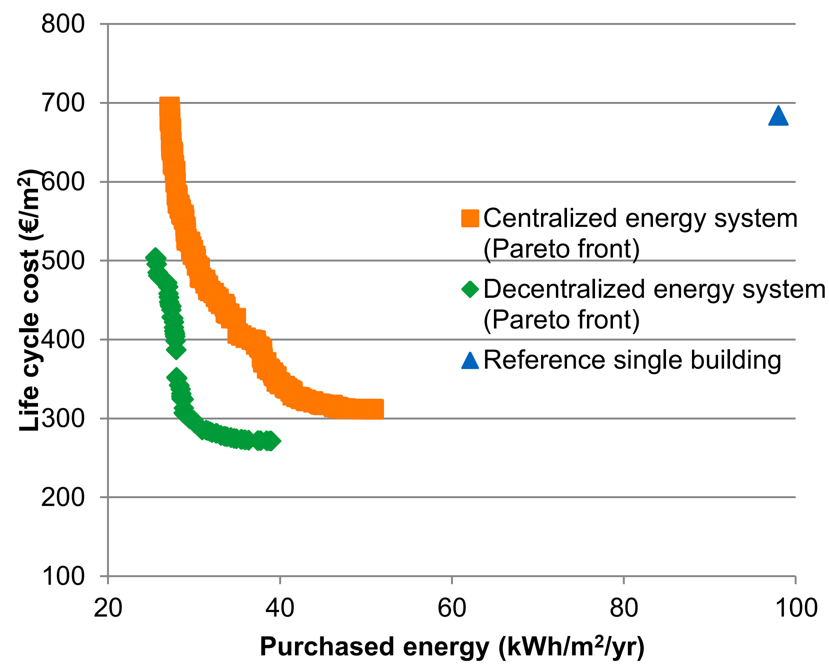
- De-centralized solar thermal system
  - ➢ Low temperature centralized operation (mainly space heating)
- Potentially less losses through network due to less lengths of domestic hot water piping
  - ➢ Hot water is produced inside the houses
- Lower cost

Reference Case- Single Building

- 50 kWh/m^2/yr space heating and 40 kWh/m^2/yr domestice hot water demands, with heat pump (3kW)
- No solar thermal or photovotialcs and seasonal storage (BTES)

Results-Centralized versus Decentralized system

Design variables	Types of variables	System type	Range/ Values (total for 100 houses)	Prices (€)
ST area (m^2)	Continuous	Decentralized	50-6000	1000—550 €/m^2
		Centralized	500-6000	600—550 €/m^2
PV area (m^2)	Continuous	Both systems	50-6000	450—200 €//m^2
Hot tank volume/house (m^3)	Continuous	Decentralized	0.5-5/house	900—810 €/m^3
		Centralized	1-5/house	850—810 €/m^3
Warm tank volume (m^3)	Continuous	Decentralized	300-500	900—810 €/m^3
		Centralized	150-500	
BTES aspect ratio	Continuous	Both systems	0.25-5	3€/m^3(excavation for insulation and piping) +33.5€/m(drill)+ 88€/m^3 (1.5 m thick insulation)
BTES borehole density			0.05-0.25	
BTES volume (m^3)			10,000-70,000	
Hot tank charge set points (°C)	Continuous	Decentralized	60-75 °C (for heat pump)	
		Centralized	68-83 °C (for collector)	
Warm tank charge set points (°C)	Continuous	Both systems	35-50 °C	
Building quality/configuration	Discrete	Both systems	Type 1: space heating demand= 25kWh/m^2/yr	15,628 €/building
			Type 2: space heating demand= 37kWh/m^2/yr	13,260 €/building
			Type 3: space heating demand= 50kWh/m^2/yr	12,655 €/building



Centralized system

- DHW in the centralized building

De-centralized system

- DHW heating in the buildings

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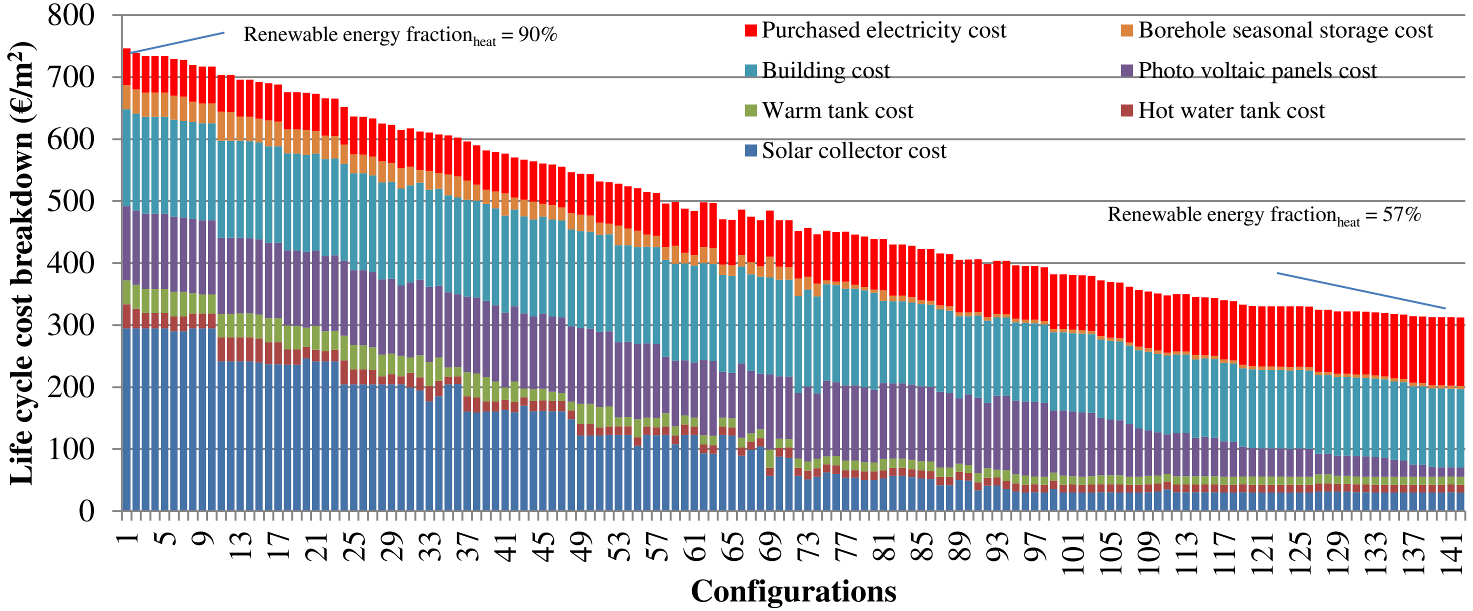
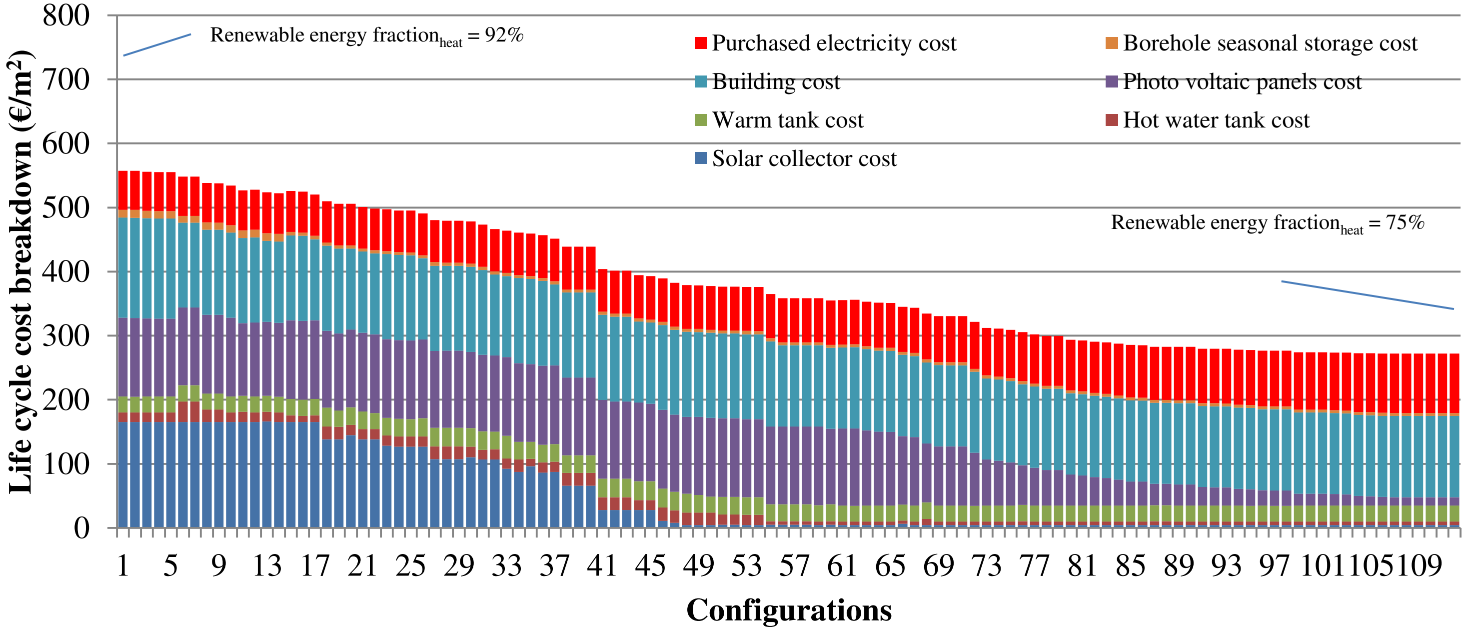
Results- Cost breakdown

Centralized system

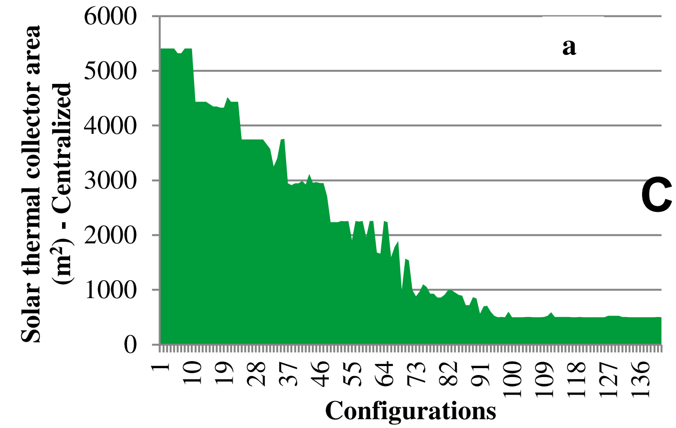


Decentralized system

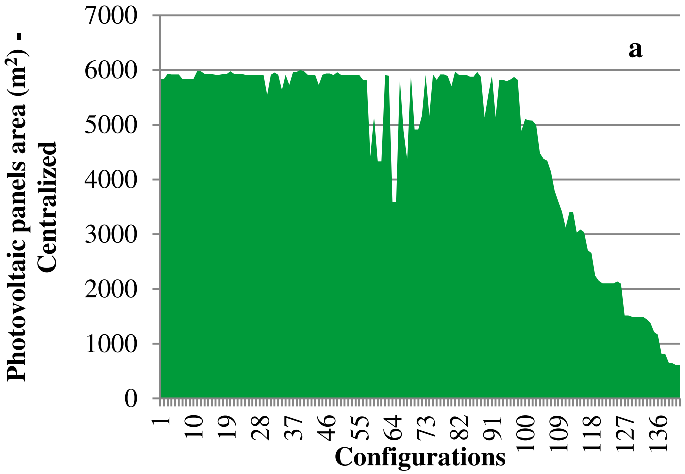


Results- Design variable (Collectors and PV)

Centralized



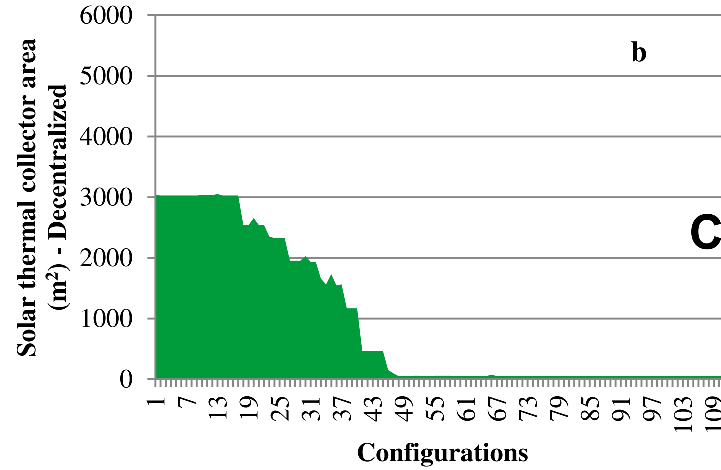
Collectors



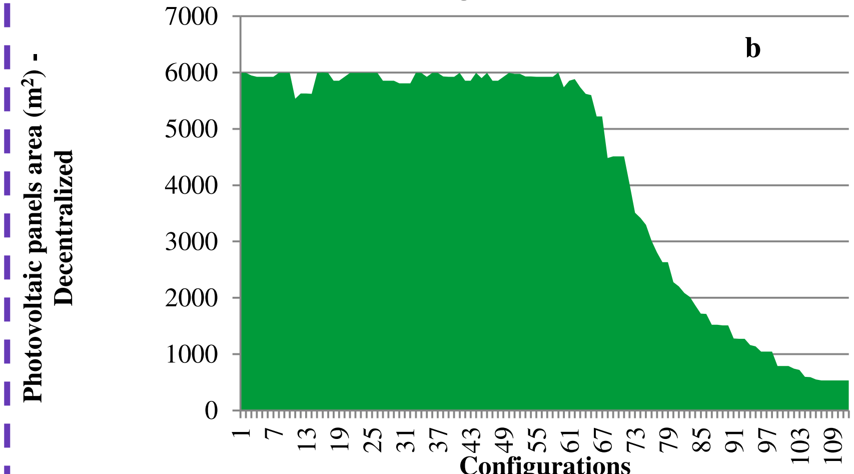
PV

- Larger area of collectors

Decentralized



Collectors



PV

- Less area of collectors

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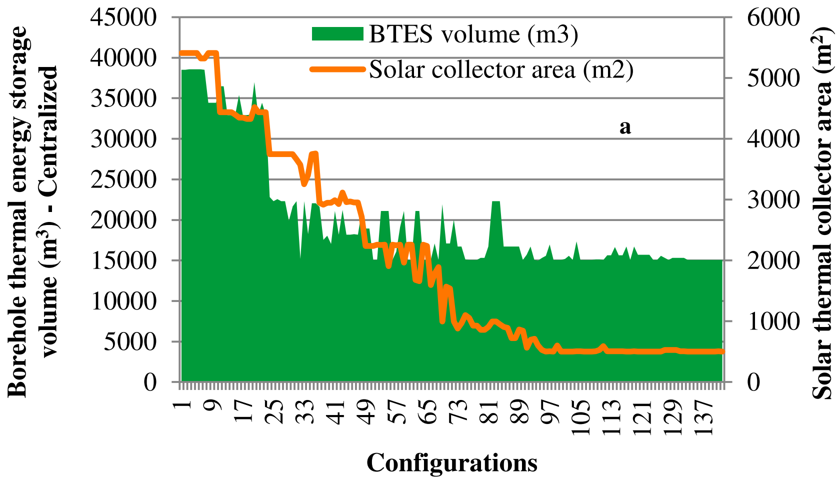
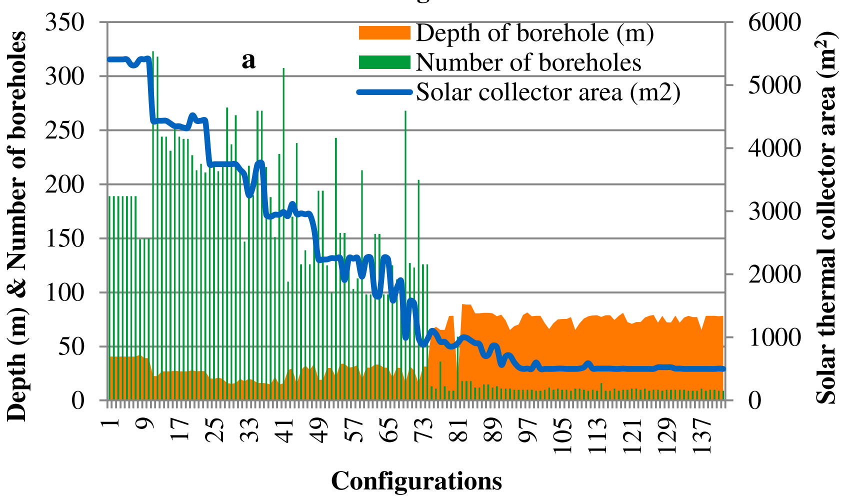
Results- Design variable (BTES)

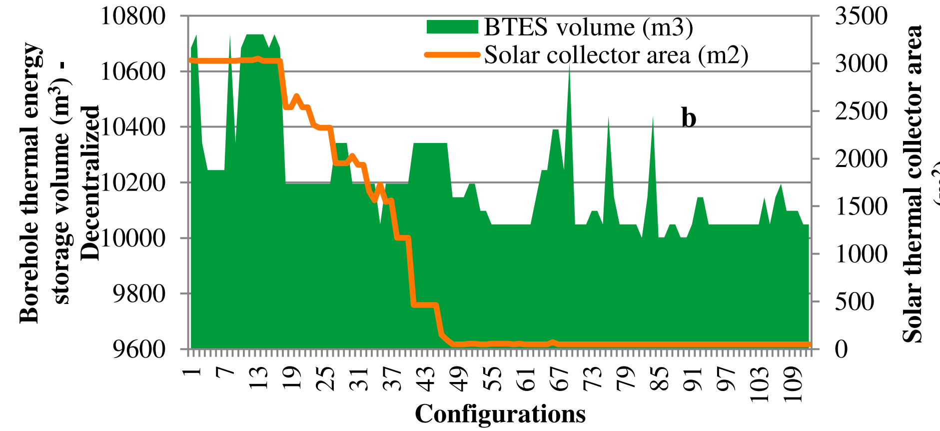
Centralized

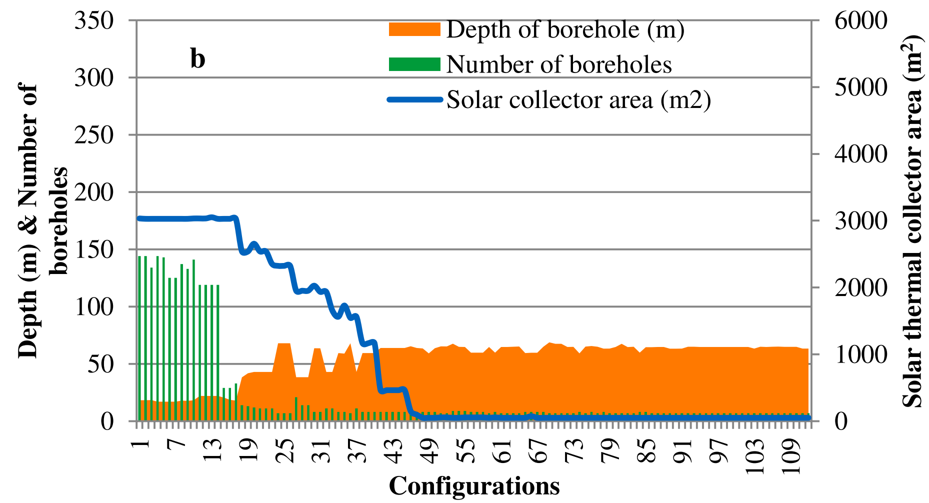




Large BTES volume, less depths and more boreholes

Decentralized





Large BTES volume, less depths and more boreholes

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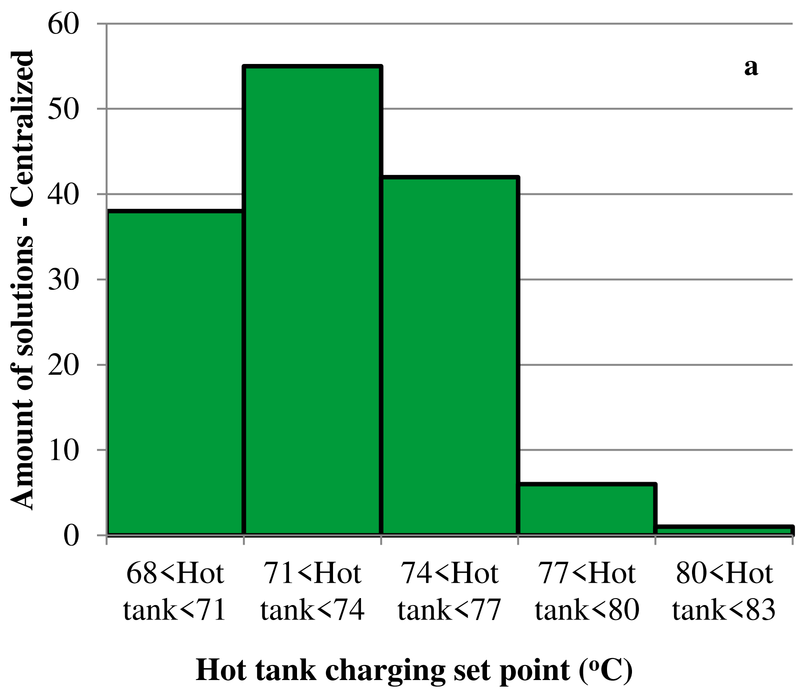
Results- Design variable (Hot tank set point)

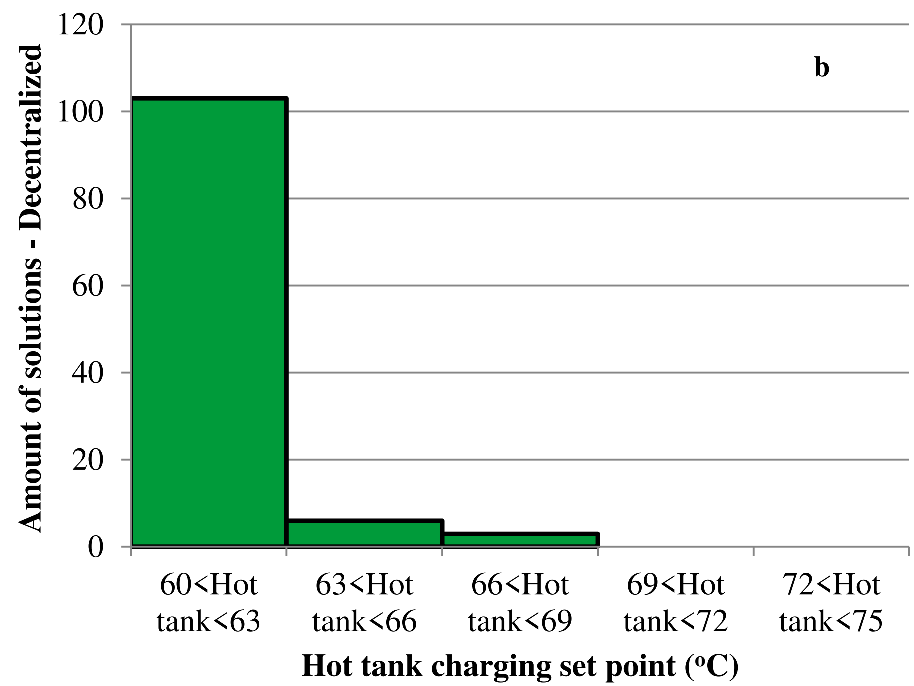
Parameter	Reference value	Proposed value- Frequency
Hot tank set point – Centralized (Collector)	70 ^{o}C	71-74 ^{o}C
Hot tank set point – Decentralized (Heat pump)	65 ^{o}C	60-63 ^{o}C

Centralized



- Higher setpoint- Collector

Decentralized



- Lower setpoint- Heat pump

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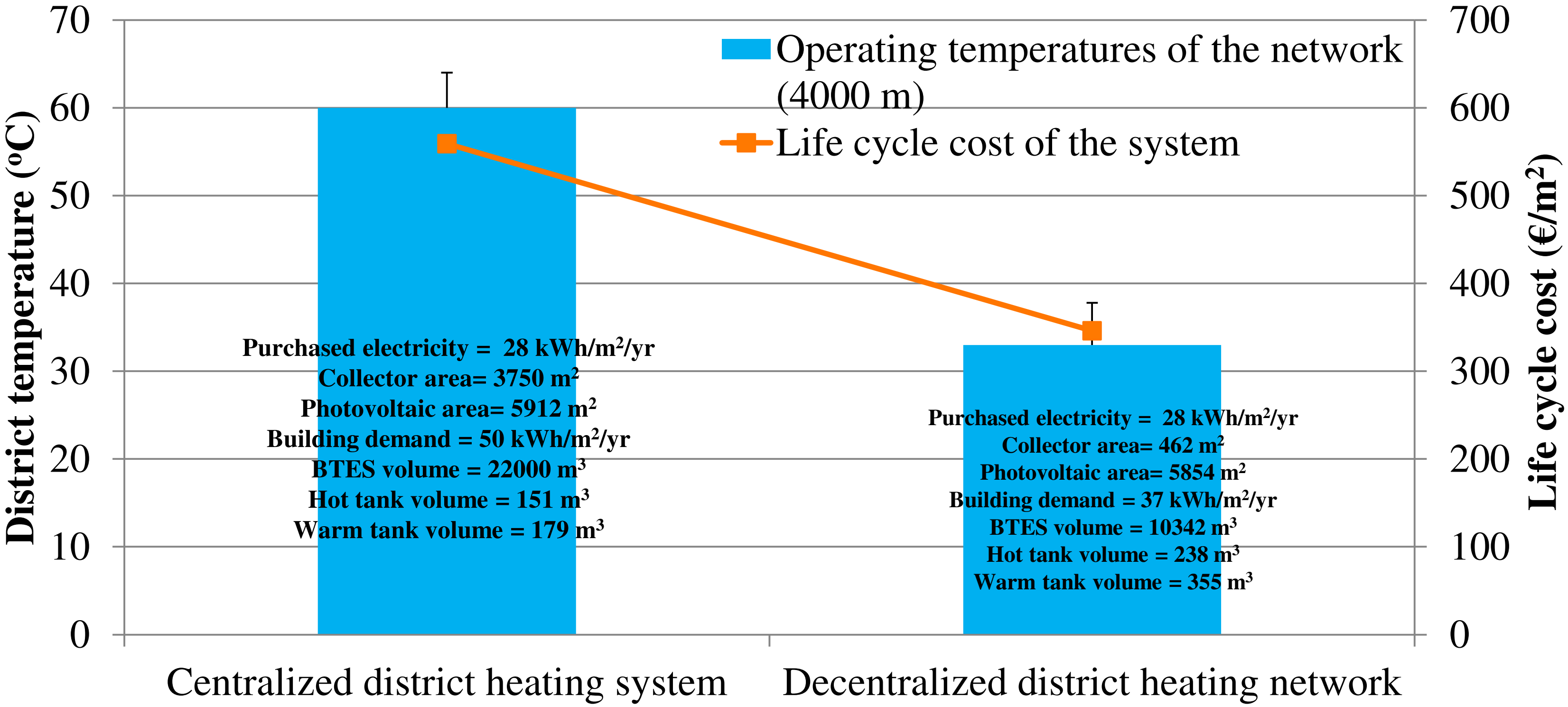
Results- Distribution operating temperature



Centralized network has 40 % higher losses compared to decentralized network

- Decentralized system has 400 m length of heating network, where as centralized system has 4000 m length for 100 buildings

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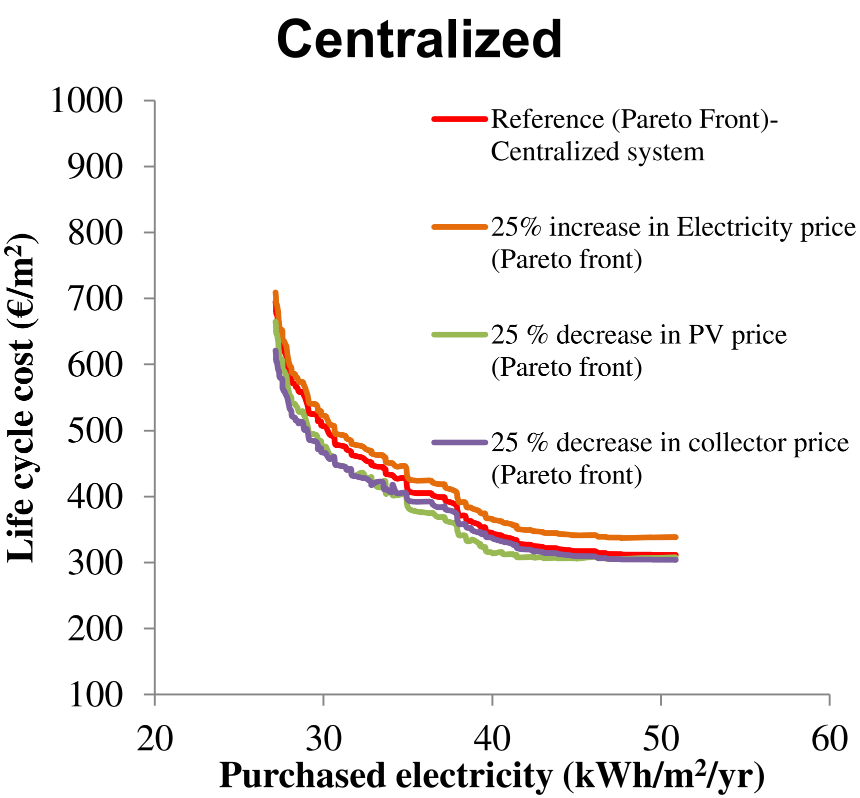
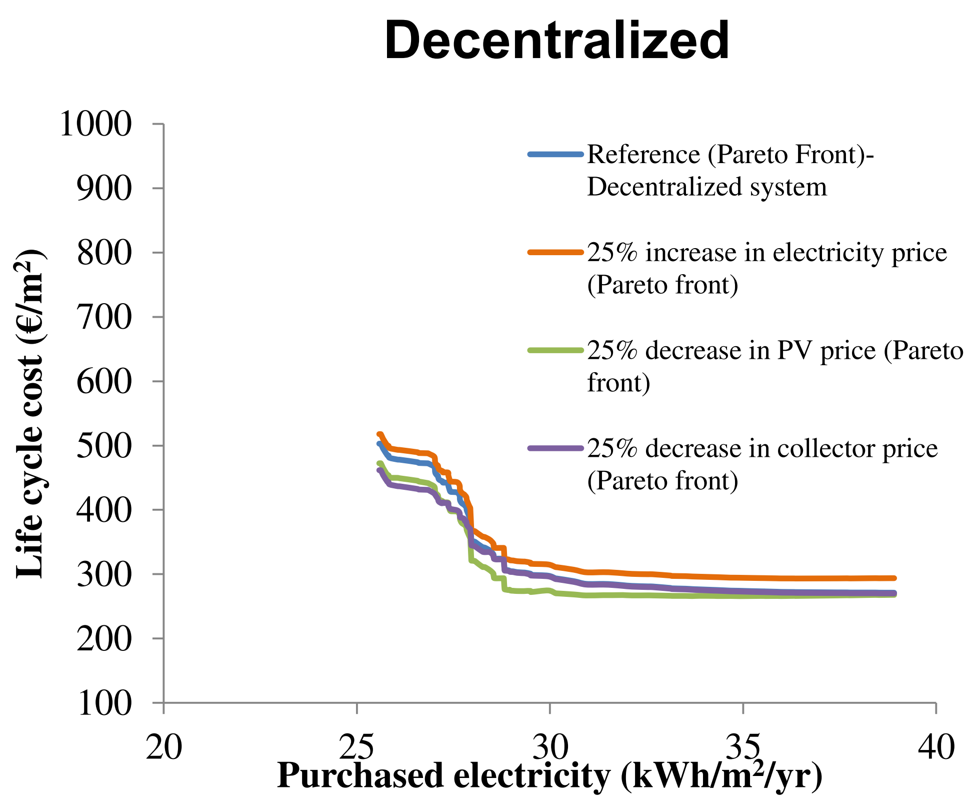
Results-Economic sensitivity

Parameter	Value	Trend	Reference
Electricity price	25 %	Increase	Peak oil news, "Trends In The Cost Of Energy," 2013. [Online]. Available: http://peakoil.com/alternative-energy/trends-in-the-cost-of-energy. [Accessed 2018].
Collector and photovoltaic	25 %	Decrease	J. Sanchez, "PV Market Trends," 2012. [Online]. Available: https://www.homepower.com/articles/solar-electricity/equipment-products/pv-market-trends. [Accessed 2018].

Centralized



Decentralized



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Summary

- **Community energy system is better** both technically and economically compared to **single building heat pump system.**

- **Community sized solar district heating systems** for higher latitudes can achieve **renewable energy fraction of 57-90%.**

- **Decentralization can reduce** the **life cycle cost by 35% and losses in the network by 40%** compared to centralized system.

- **Number of boreholes and volume of storage increased** when the performance improved, on the other hand **the depth of the boreholes decreased**.

- The **set points are sensitive** to the system typology and the hydraulic connections.

- The **Pareto fronts are more sensitive to the electricity price** in **worst performance cases**, and more sensitive to **the component prices in best performing cases**.

Thank you

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Reference

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