Smart Control and Digitalisation in District Heating Networks

Johan Van Bael, Application Area Leader DHC, EnergyVille/VITO

Content

- Why district heating networks?
  - Renewable sources for district heating networks
  - Residual heat
    - Industry
    - Cities

Solar Thermal Energy
Geothermal Energy
Aquathermal Energy
Biomass

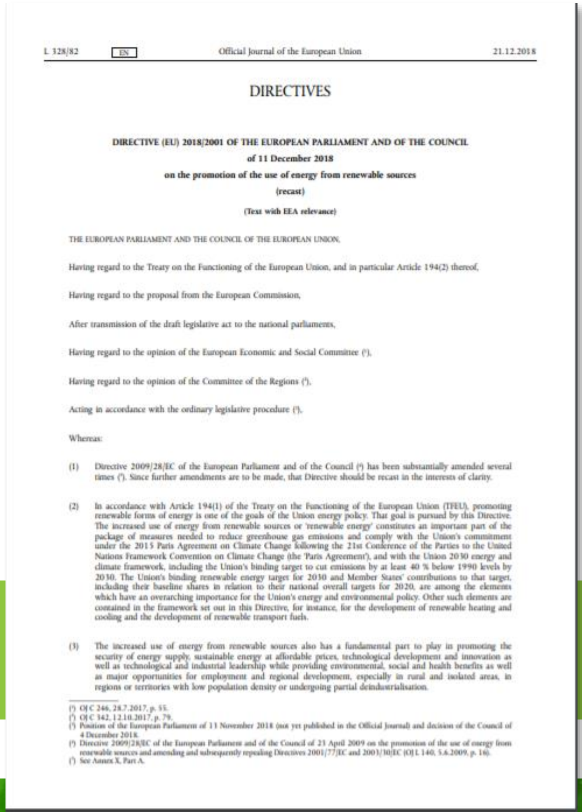
Residual heat

- Examples of digitalisation in district heating networks
  - STORM District Energy controller
  - Data Analytics in District Heating Networks
  - Pathopt : optimal layout of a thermal network

Energy Ville

Context and relevance

- European Green Deal
  - No net emissions of greenhouse gases by 2050
  - Reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.
- Renewable Energy Directive (Directive 2018/2001 - REDII)
  - Member states should **allow the use of efficient DHC**
  - Member states should **promote competitive and efficient DHC** to increase use of renewable energy and waste energy.
  - **Recognition of potential for decarbonization of DHC** through increased energy efficiency and renewable energy deployment



L 328/82 EN Official Journal of the European Union 21.12.2018

DIRECTIVES

DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 11 December 2018
on the promotion of the use of energy from renewable sources
(recast)
(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty on the Functioning of the European Union, and in particular Article 194(2) thereof,

Having regard to the proposal from the European Commission,

After transmission of the draft legislative act to the national parliaments,

Having regard to the opinion of the European Economic and Social Committee (¹),

Having regard to the opinion of the Committee of the Regions (²),

Acting in accordance with the ordinary legislative procedure (³),

Whereas:

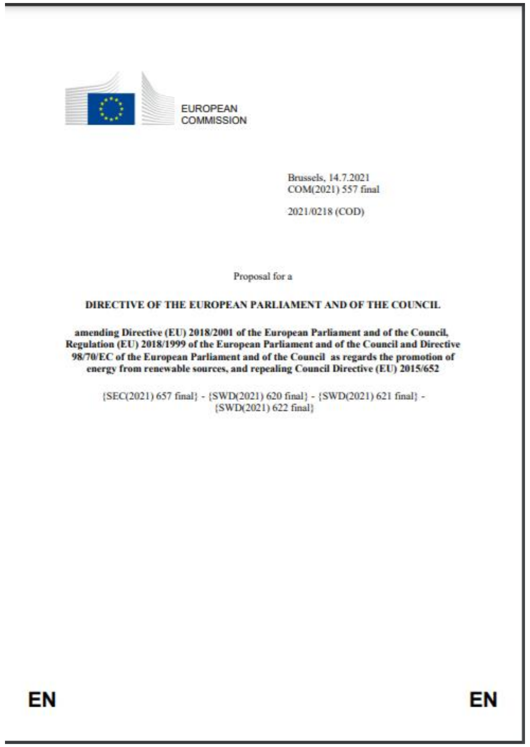
(1) Directive 2009/28/EC of the European Parliament and of the Council (⁴) has been substantially amended several times (⁵). Since further amendments are to be made, that Directive should be recast in the interests of clarity.

(2) In accordance with Article 194(1) of the Treaty on the Functioning of the European Union (TFEU), promoting renewable forms of energy is one of the goals of the Union energy policy. That goal is pursued by this Directive. ...

Energy Ville

Context and relevance

- Proposal for amendment Renewable Energy Directive (2021/0218-REDIII)
  - The **annual increase of renewable energy and/or waste heat** in district heating and cooling should be **raised from 1 percentage point to ~~2.1~~ 2.3**
  - Operators of district heating or cooling systems **above 25 MWth capacity are obliged to connect third party suppliers of energy from renewable sources and from waste heat and cold**
  - To ensure district heating and cooling participate fully in **energy sector integration**, it is necessary to extend the cooperation with electricity distribution system operators to electricity transmission system operators and widen the scope of cooperation to grid investment planning and markets to **better utilise the potential of district heating and cooling for providing flexibility services in electricity markets**.
  - Member States shall put in place a **coordination framework** between district heating and cooling system operators and the potential sources of waste heat and cold in the industrial and tertiary sectors to facilitate the use of waste heat and cold.


EUROPEAN COMMISSION

Brussels, 14.7.2021
COM(2021) 557 final

2021/0218 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652

{SEC(2021) 657 final} - {SWD(2021) 620 final} - {SWD(2021) 621 final} - {SWD(2021) 622 final}

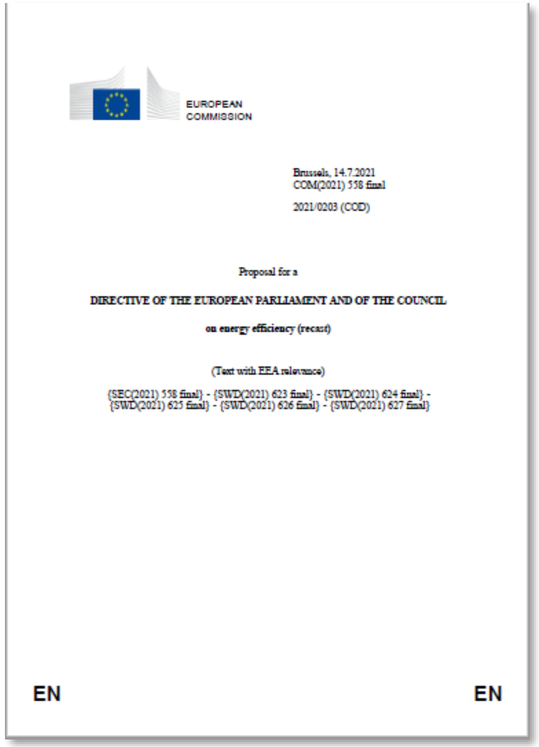
EN **EN**

Energy Ville

Context and relevance

- Proposal for amendment Energy Efficiency Directive (2021/0203-EEDII)
  - Art 24: In order to increase primary energy efficiency and the share of renewable energy in heating and cooling supply, an efficient district heating and cooling system is a system which meets the

Until 2025	From 2026	From 2035	From 2045	From 2050
>50 % RES,	>50 % RES,	>50% RES & waste heat,	>75 % RES & waste heat,	100% RES & waste heat,
50 % waste heat	50 % waste heat,	RES at least 20%;	RES at least 40%;	RES is at least 60%.
75 % CHP	80 % HE CHP	No role for CHP	No role for CHP	No role for CHP
or 50 % of a mix;	or at least a mix if RES >5%			


EUROPEAN COMMISSION

Brussels, 14.7.2021
COM(2021) 558 final

2021/0203 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on energy efficiency (recast)

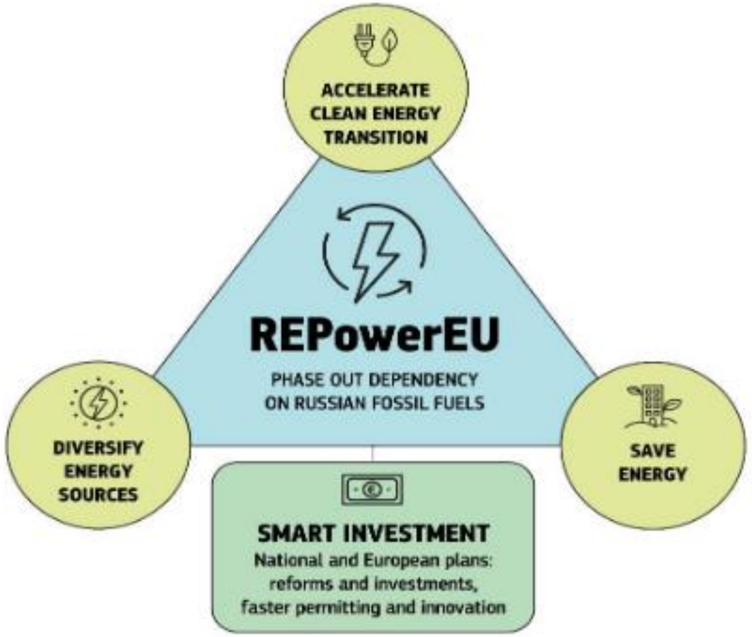
(Text with EEA relevance)

{SEC(2021) 558 final} - {SWD(2021) 623 final} - {SWD(2021) 624 final} - {SWD(2021) 625 final} - {SWD(2021) 626 final} - {SWD(2021) 627 final}

EN EN

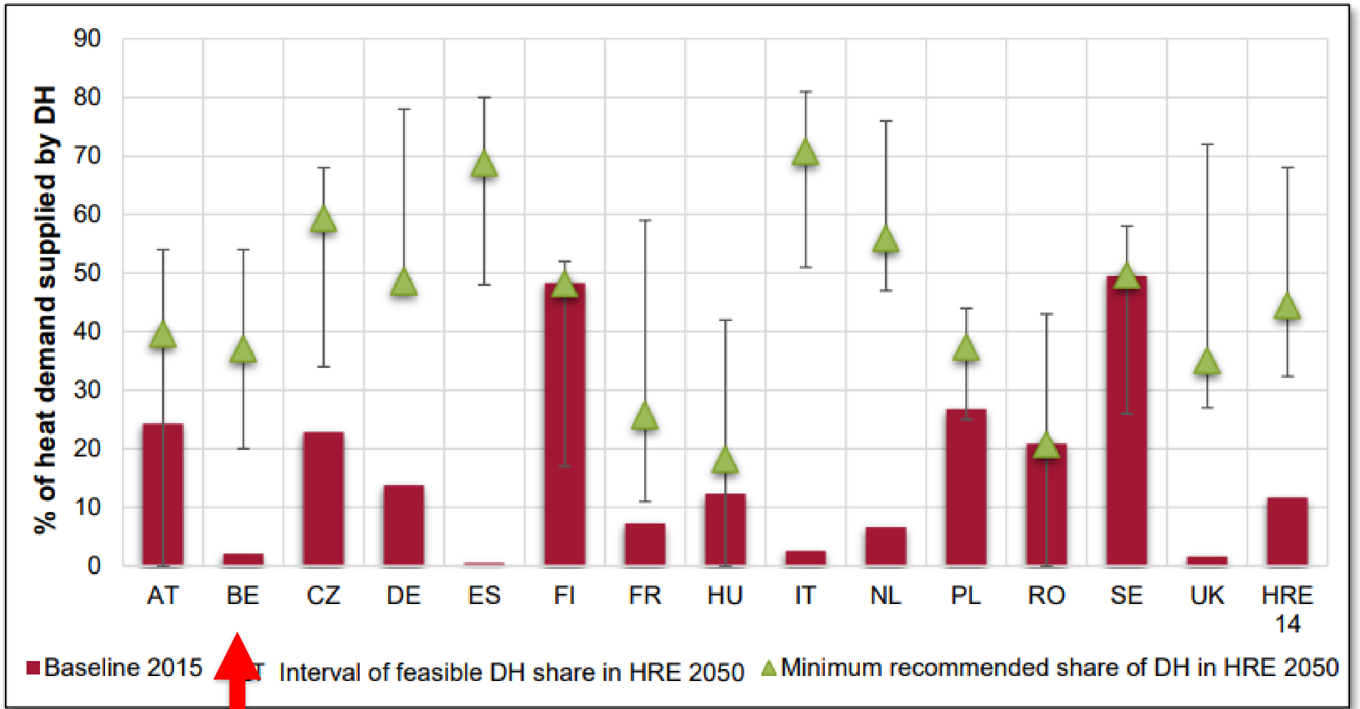
Context and relevance

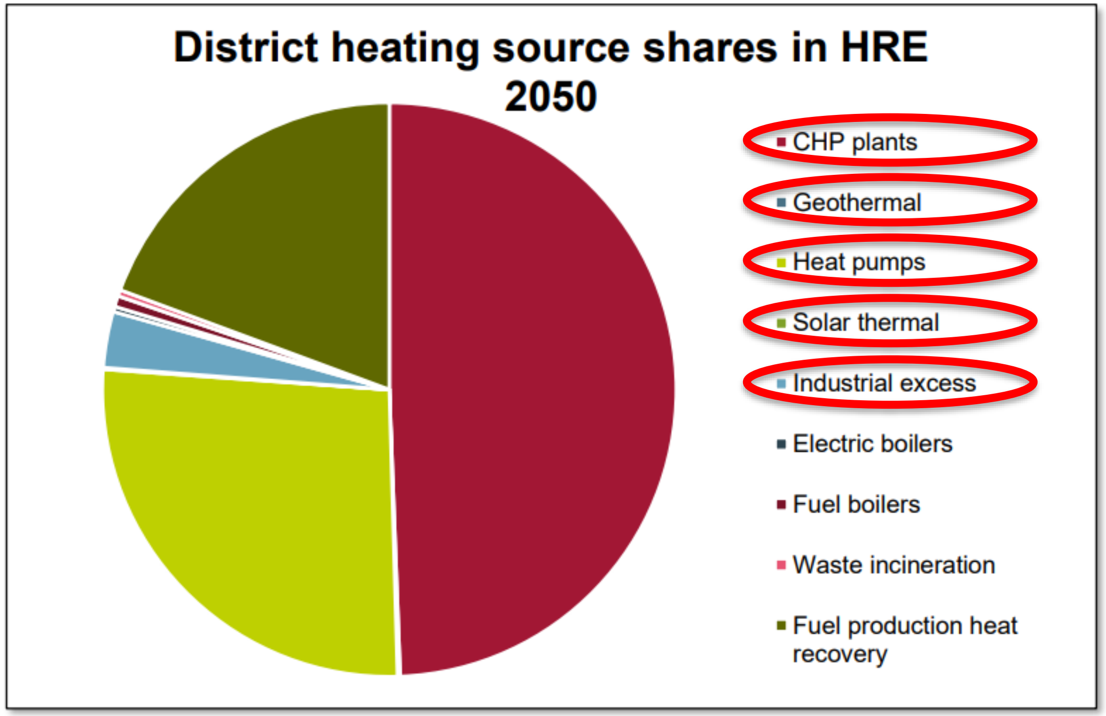
- RePowerEU
  - The European Union should aim at doubling the current deployment rate of individual heat pumps, resulting in a cumulative 10 million units over the next 5 years. Member States can accelerate the deployment and integration of large-scale heat pumps, geothermal and solar thermal energy in a cost-effective way by:
    - **developing and modernising district heating systems** which can replace fossil fuels in individual heating;
    - **clean communal heating, especially in densely populated areas and cities;**
    - **exploiting industrial heat whenever available.**



Why district heating networks?

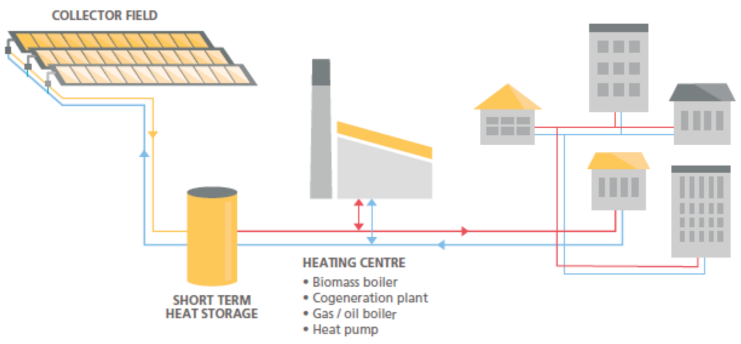
- Options for district heating in Belgium



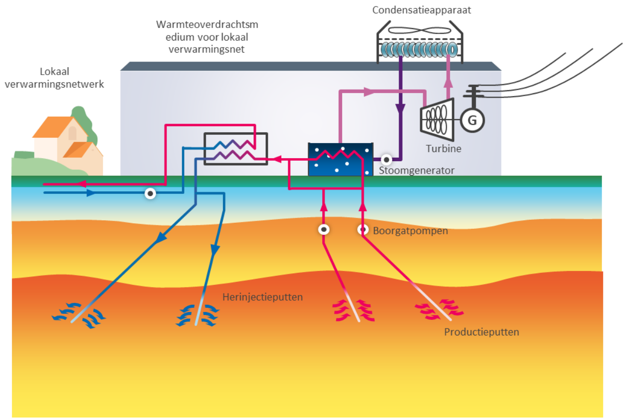


REF: Heat Roadmap Europe: Heat Roadmap Belgium, quantifying the Impact of Low-carbon Heating and Cooling Roadmaps

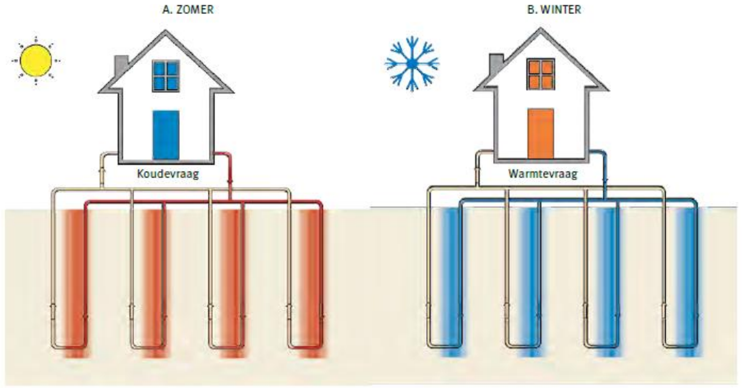
Why district heating networks?



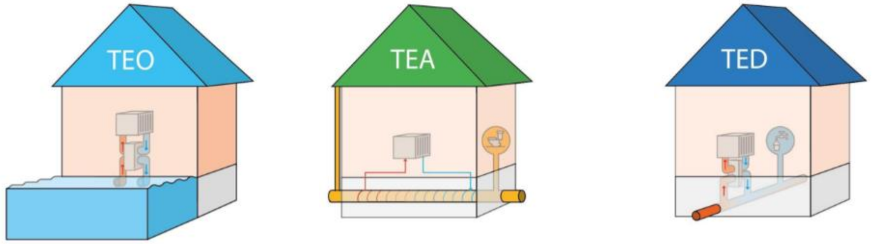
Solar Thermal Energy



Geotheraml Energy



Geotheraml Energy

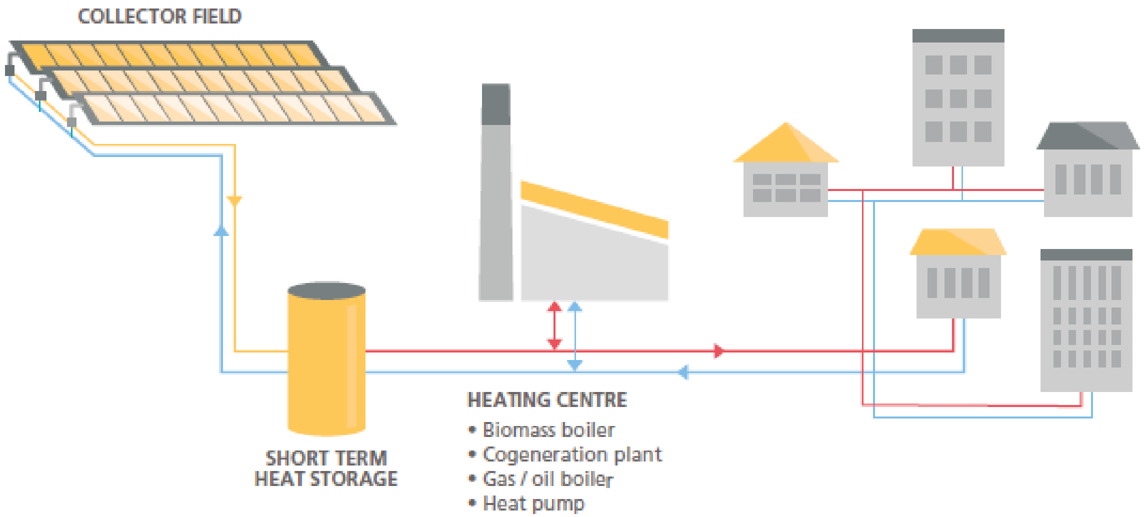


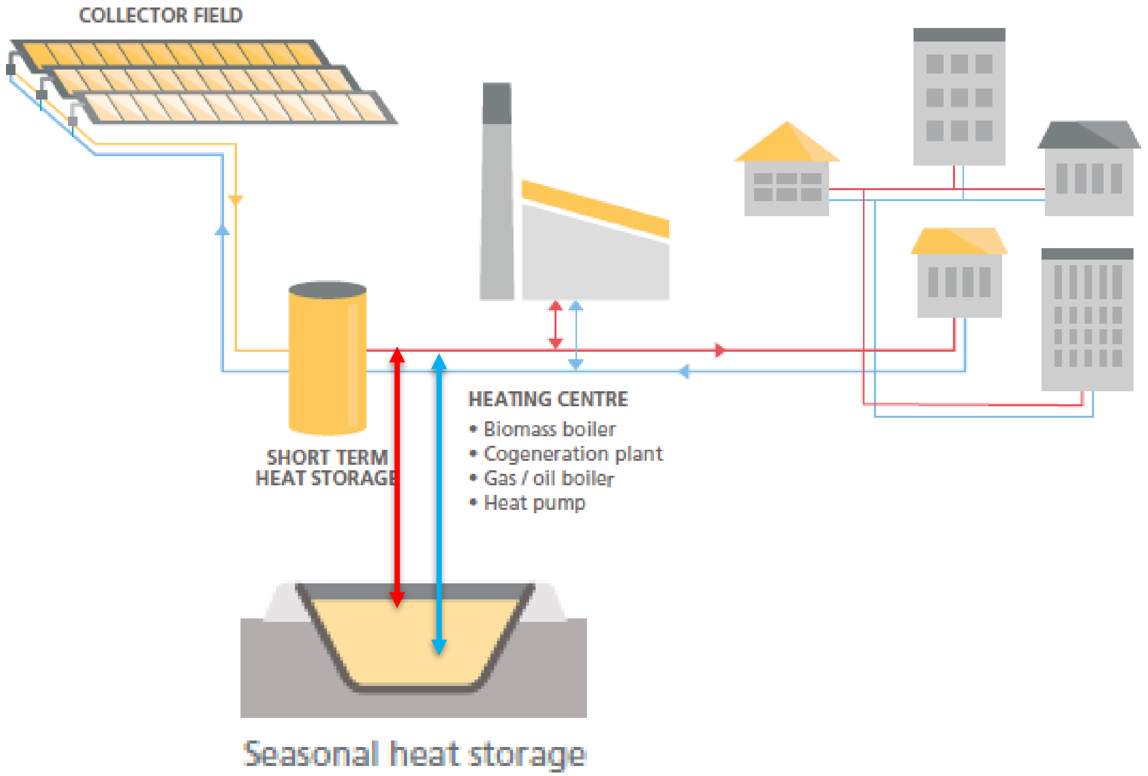
Aquathermal Energy

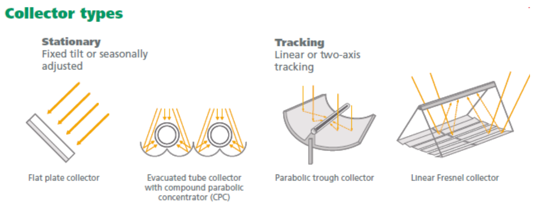
Biomass

Solar thermal energy
Geothermal energy
Aqua thermal energy
Biomass
Residual heat

Sustainable heat sources – solar thermal energy







REF: IEA SHC – TASK 55 Integrating Large SHC Systems into District Heating and Cooling Networks

Solar thermal energy
Geothermal energy
Aqua thermal energy
Biomass
Residual heat

Sustainable heat sources – solar thermal energy

- Denmark as example

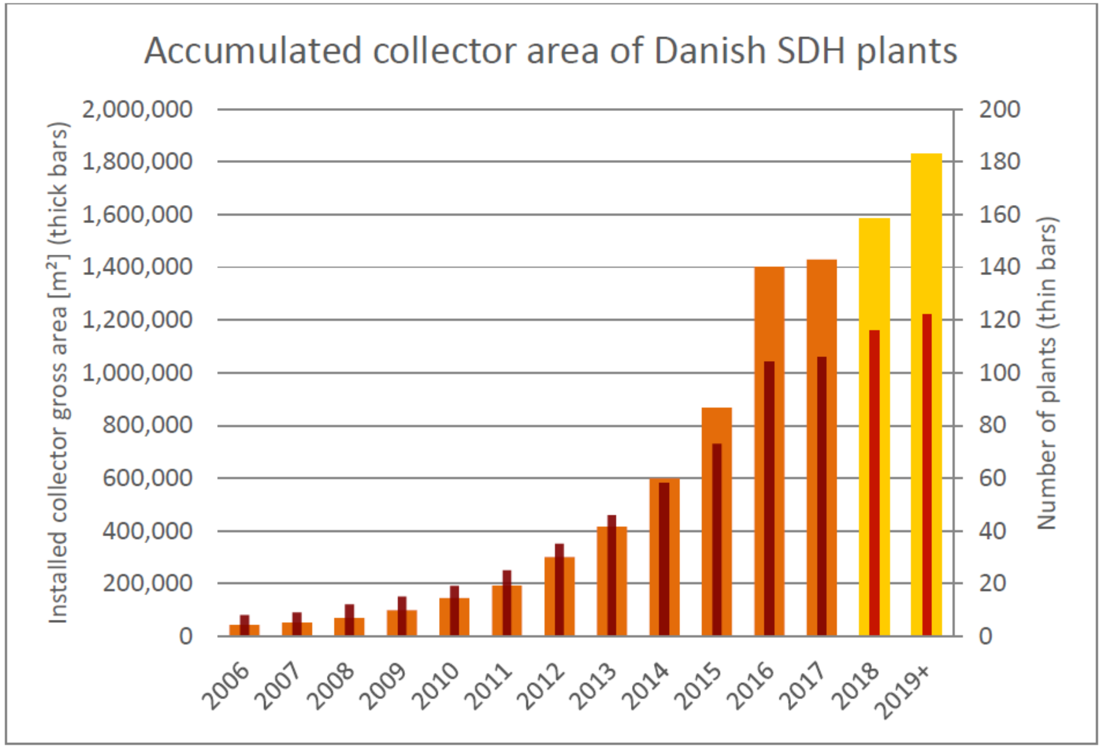


Figure 1. Development in the installation of large-scale solar thermal plants in Denmark since 2006. The number of total installed plants exceeded 100 during 2016 (thin bars) and the total installed collector (gross) area is above 1.4 million m² as of 2017. (Planned systems are indicated with lighter colours.)

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REF: IEA SHC Task 52 – trends and possibilities – characteristics of ground-mounted systems for screening of land use requirements and feasibility

Sustainable heat sources – solar thermal energy

- Denmark as example

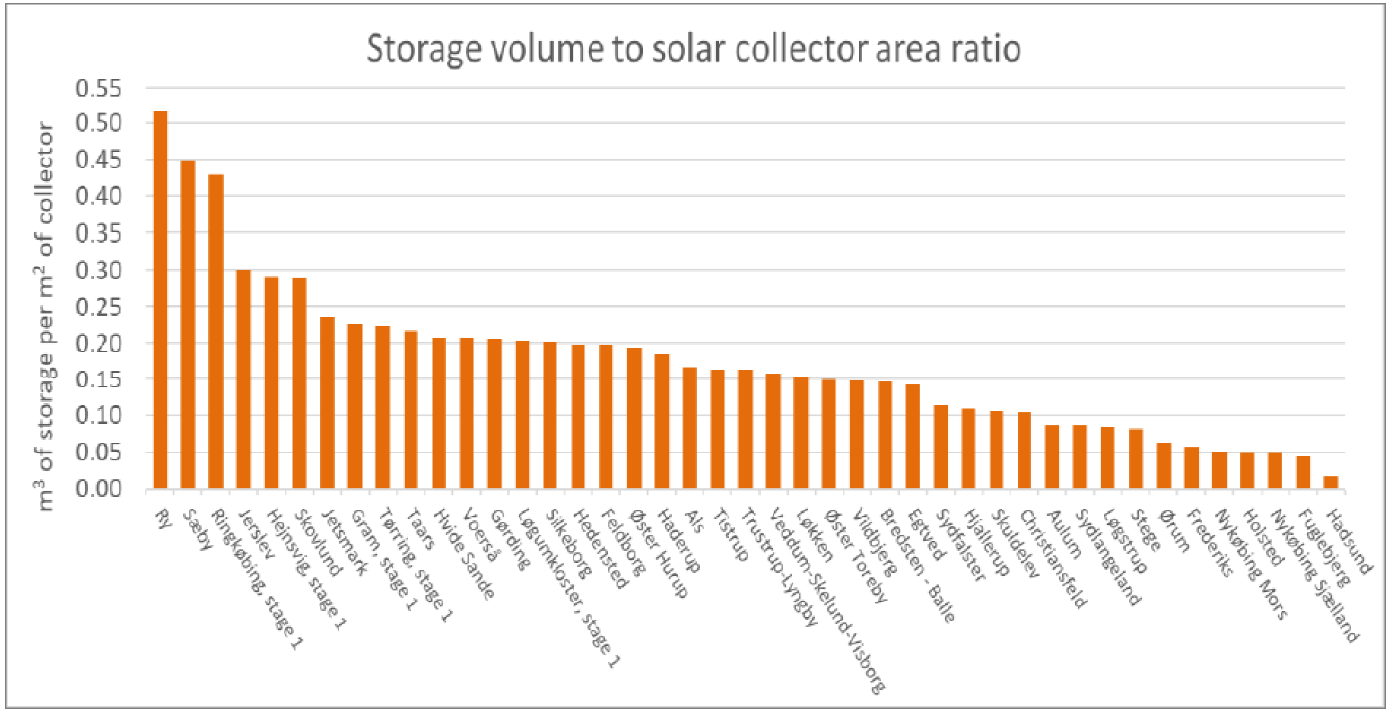


Figure 27. Ratio between storage volume and collector area for 43 SDH plant examples.

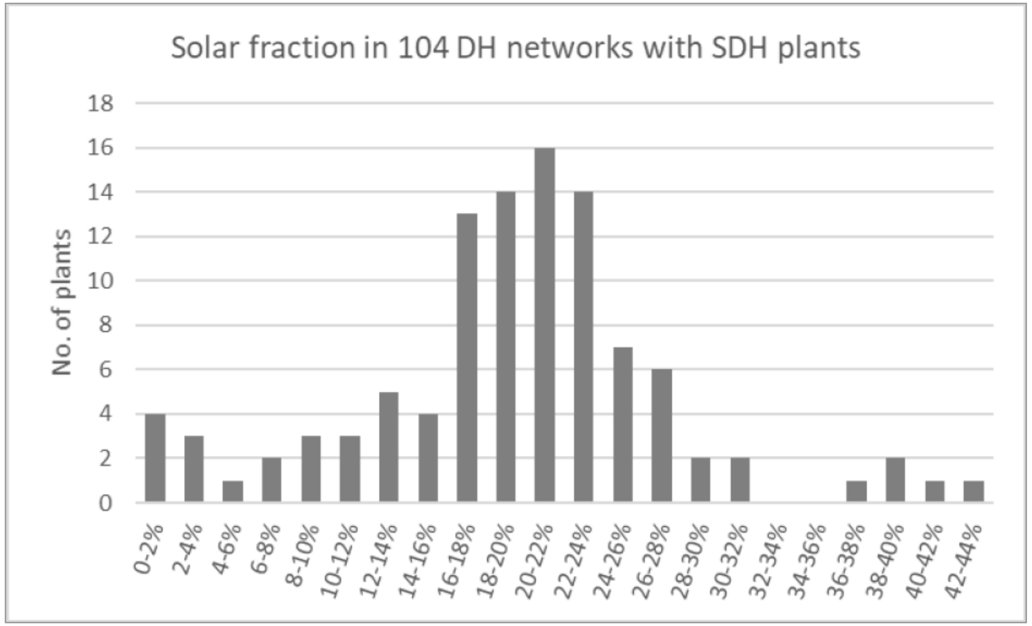
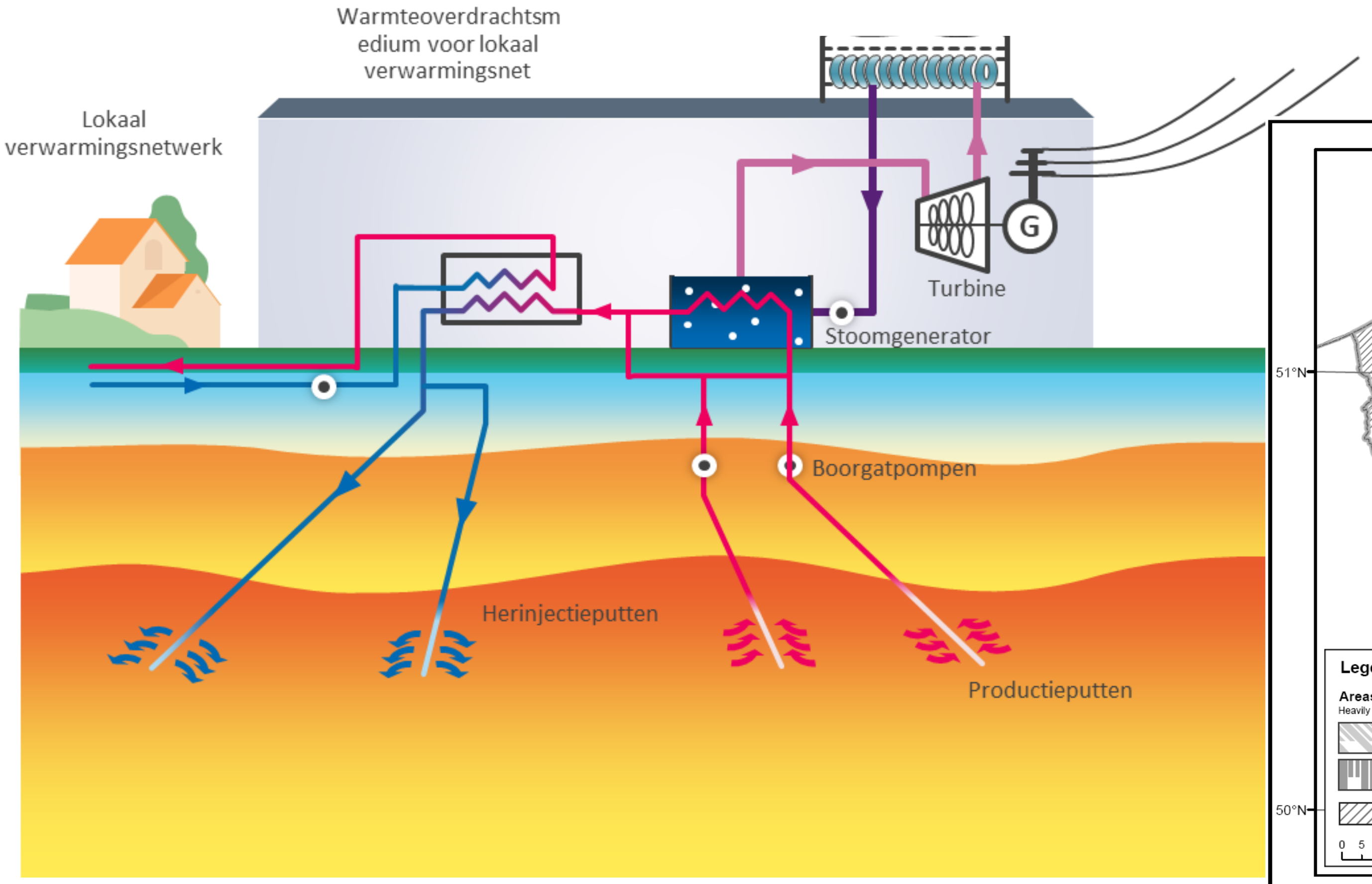


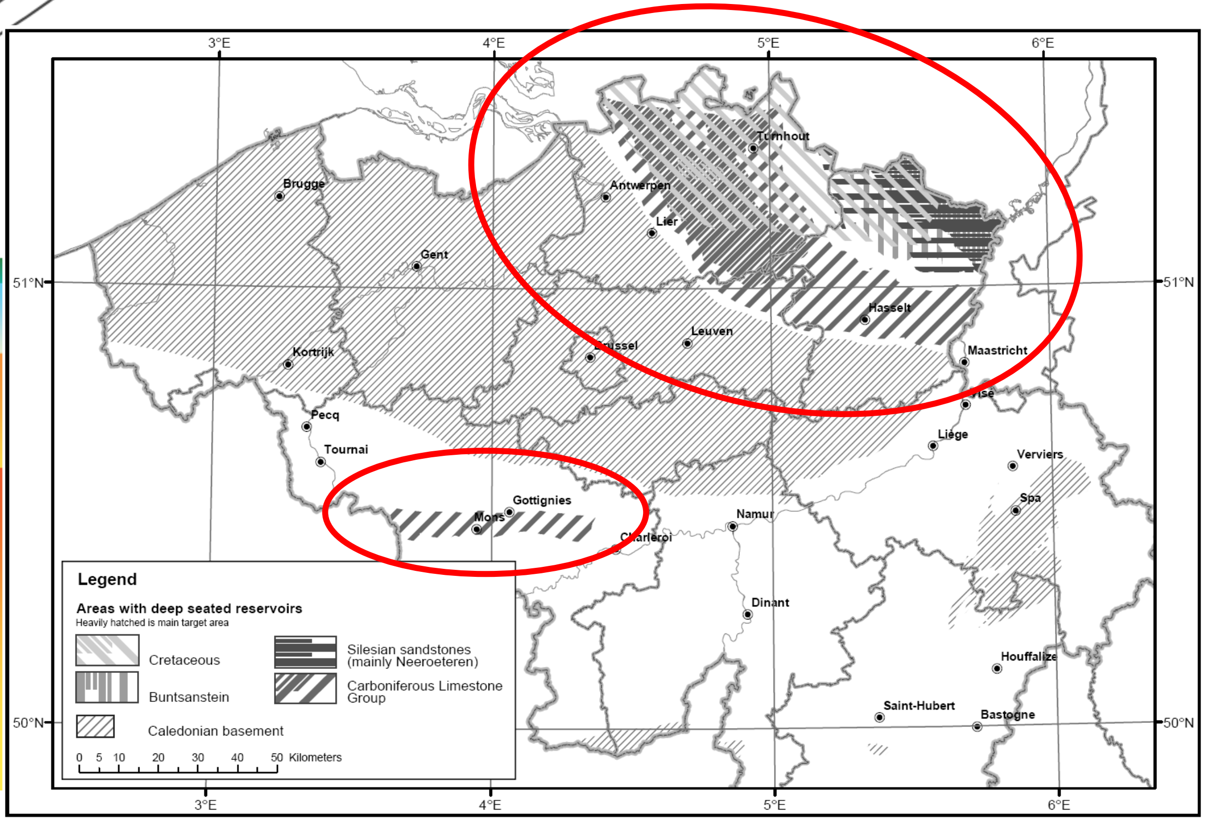
Figure 19. Categorised span of the solar fraction in the 104 Danish DH grids with large-scale solar thermal plants.

REF: IEA SHC Task 52 – trends and possibilities – characteristics of ground-mounted systems for screening of land use requirements and feasibility

Sustainable heat sources – deep geothermal energy

- Solar thermal energy
- Geothermal energy
- Aqua thermal energy
- Biomass
- Residual heat

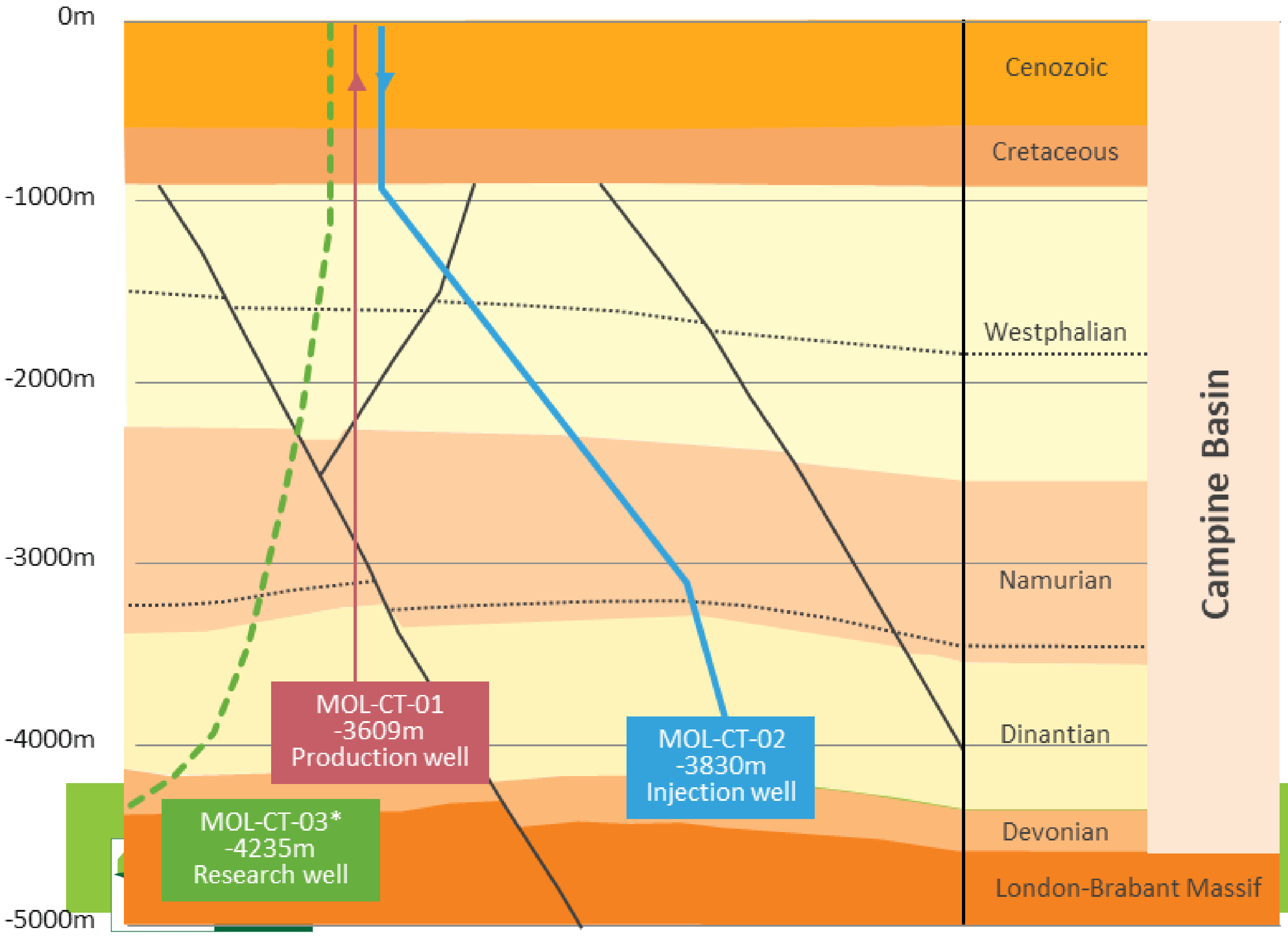




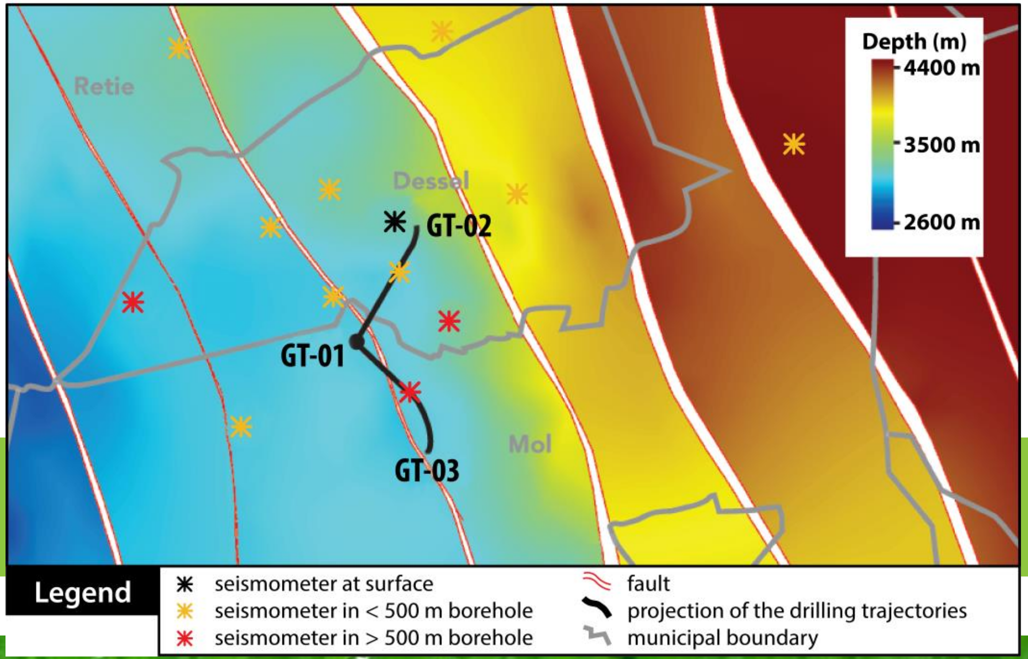
Sustainable heat sources – deep geothermal energy

- Solar thermal energy
- Geothermal energy
- Aqua thermal energy
- Biomass
- Residual heat

- Case: VITO, Mol



Depth and fault map at top reservoir
Projection of drilling trajectories and seismometer network (*)



Residual heat - industry

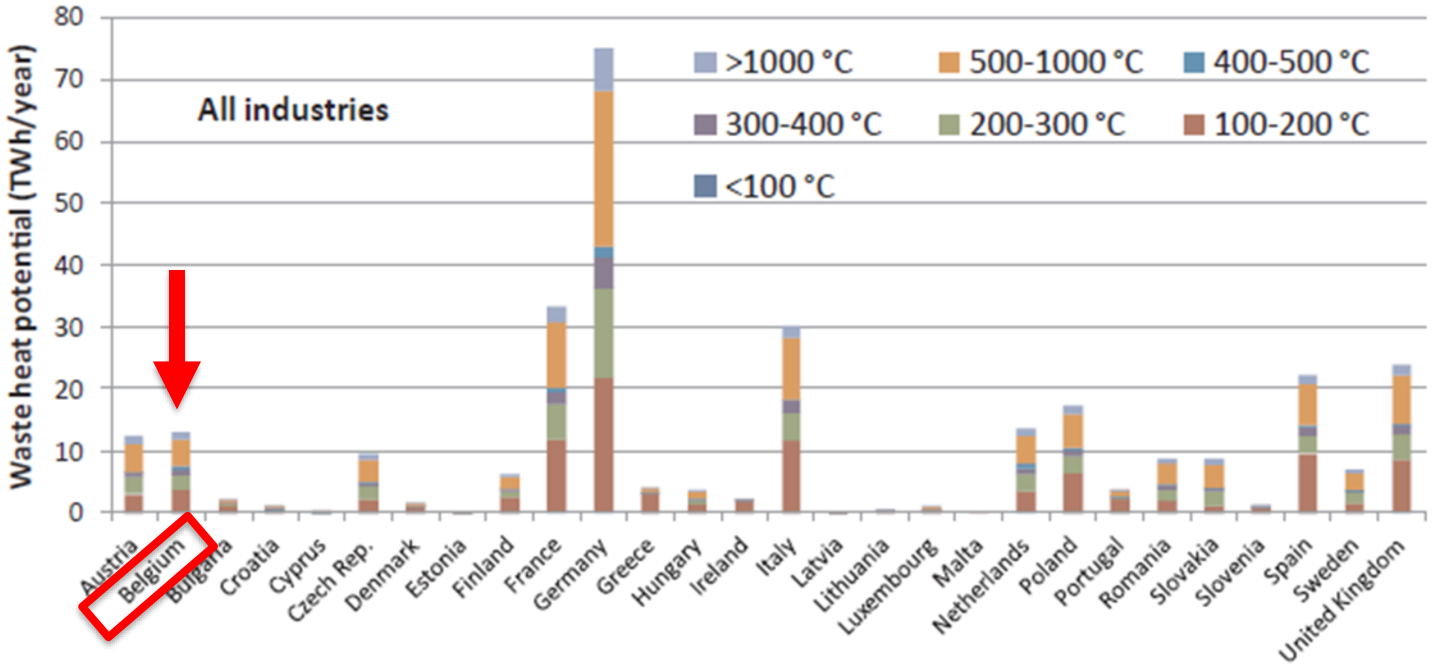


Fig. 12. Waste heat potential in each EU country per temperature level in all industries.

- Europe - Industry
  - 304.13 TWh/year (or about 34 700 MWt)
  - Potentieel op 100° - 200° : 100 TWh/year
- Belgium - Industry:
  - 12 TWh/year
  - 1 350 MWt (average)
- Amount of waste heat can change in case of further EE and integration of RES
- Residual heat from electrolyses!

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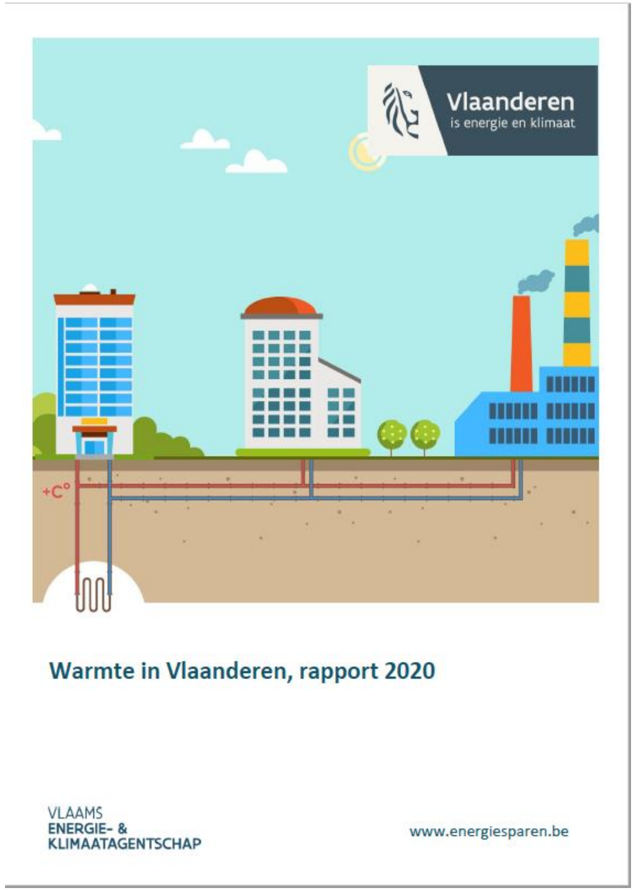
REF: Papapetrou 2018: Papapetrou, M., Kosmadakis, G., Cipollina, A., La Commare, U., MIcale, G., 2018, Industrial waste heat: Estimation of the technically available resources in the EU per industrial sector, temperature level and country, Applied Thermal Engineering 138 (2018) 207-216

Solar thermal energy
Geothermal energy
Aqua thermal energy
Biomass
Residual heat

Residual heat – Industry - Flanders

Sector	Warmtevraag grote bedrijven [GWh]	Theoretische restwarmte berekend volgens PDC methode [GWh]	Ingeschatte theoretische restwarmte na herschaling [GWh]	Aantal bedrijven in analyse
Chemie Farma	19.686	16.499	6.973	128
Hout	466	0	1	17
Ijzer & staal	4.912	3.179	3.106	41
Kunststof	5.999	3.516	2.951	63
Mineraal niet-metaal	3.044	3.023	2.998	59
Non-ferro	2.060	2.060	1.474	22
Overig	3.065	1.447	2.050	63
Papier Karton Druk	3.173	589	2.153	25
Raffinaderijen	13.937	13.937	1.514	5
Technologie	5.928	6	51	120
Textiel	835	0	0	45
Voeding	18.523	2.004	2.007	165
Totaal	81.627	46.266	25.277	753

Tabel 12: Warmtevraag en ingeschatte restwarmte per sector. De IMJV databron werd geanalyseerd volgens de PDC methode en per sector herschaald met bijschattingen uit de MIP2HEAT studie



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Residual heat - cities

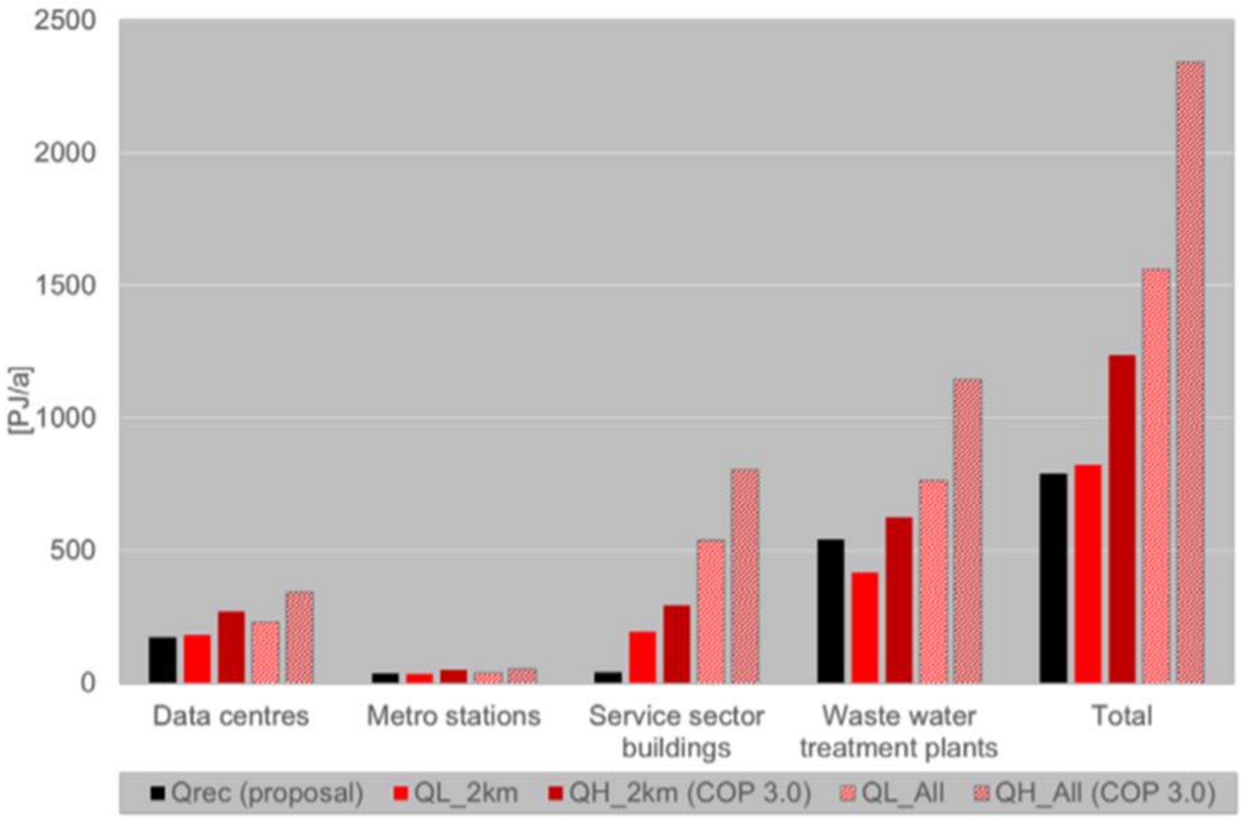

Figure 26. Summary overview of modelled available and accessible excess heat total volumes inside or within 2 kilometres of urban district heating areas (2km) vs. volumes unrestricted by local conditions (all), by source category and with comparison to recoverable excess heat volumes (Q_{rec}), as anticipated in the project proposal.

- Europe - cities
  - Residual heat sources
    - Data centers
    - Waste water treatment
    - Tertiary buildings
    - Metro stations
  - 391 TWh/year
  - About 44 600 MWt
- Belgium - cities:
  - 10.4 TWh/jaar (average 1 185 MWt)

REF: H2020 project ReUseHeat – Accessible Urban Waste heat

Content

- Why district heating networks?
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  - Residual heat
    - Industry
    - Cities
- **Examples of digitalisation in district heating networks**
  - STORM District Energy controller
  - Data Analytics in District Heating Networks
  - Pathopt : optimal layout of a thermal network

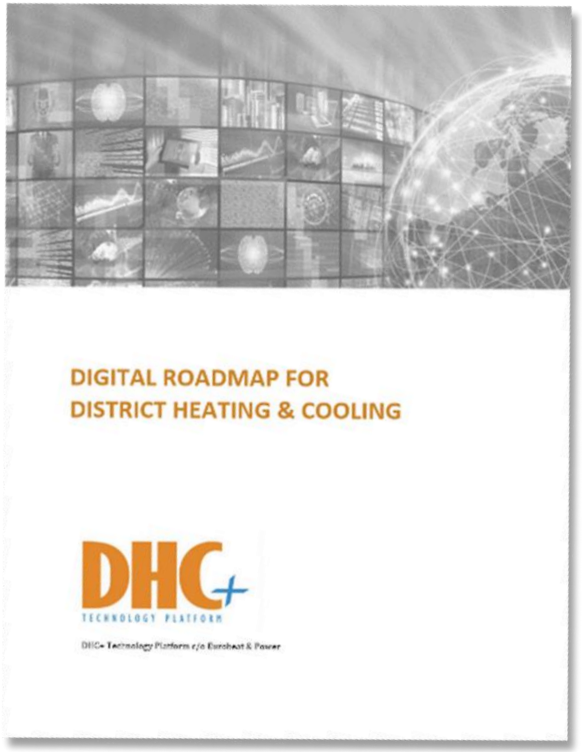
Solar Thermal Energy
Geothermal Energy
Aquathermal Energy
Biomass

Residual heat

EnergyVille

Digitalization in district heating networks

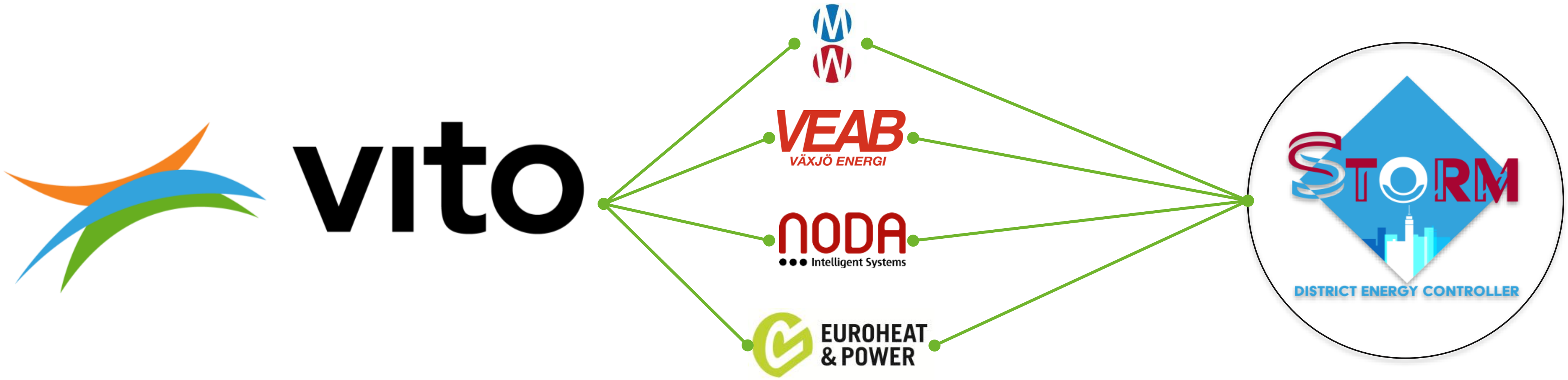
- Digital heat roadmap



- To offer insights on how digitalization impacts the DHC industry
- State-of-art in digitalisation
- Objectives, targets and recommendations
- Chapters:
  - Production level
  - Distribution level
  - Buildings level
  - Consumption level
  - Design & planning
  - Sector Coupling & integration of multiple sources
- https://www.euroheat.org/publications/digital-roadmap-district-heating-cooling/

Storm District Energy Controller

- The Storm District Energy Controller has been developed by VITO/EnergyVille as a part of a H2020-project.

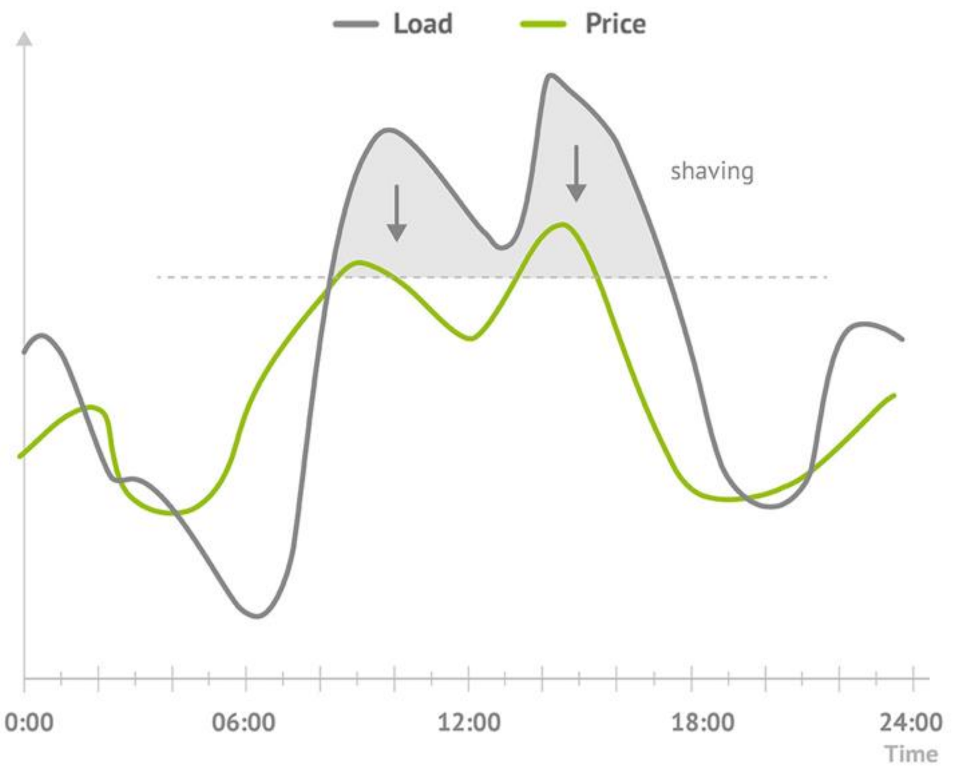


What is Storm District Energy Controller?

- An artificial intelligence based smart controller for district heating network operators to optimize operations through active demand side management.

Operational Optimization Potential

- Base load (Cheap): Residual heat, Biomass, Renewables, CHP
- Peak load (Expensive): Oil, Gas



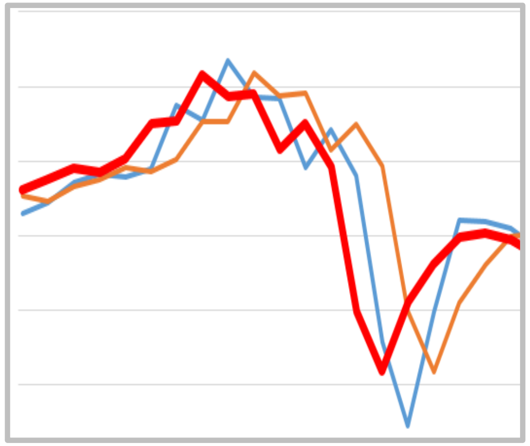
Basic operational principle

- Active demand side management utilizing flexibility offered by the buildings' thermal mass without loss in quality of service.

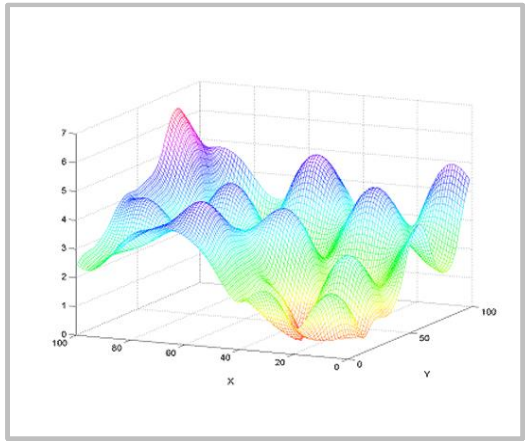
Duration	Potential reduction in heat demand (%)
Short-term [1-3h]	40-50%
Medium-term [3-5h]	20-30%
Long-term [>5h]	10-12%

1. **Without loss in thermal comfort ($\Delta T_{indoor} \approx 0.1^{o}C$ Order of magnitude)**
2. **Regardless of outdoor temperature (ODT)**

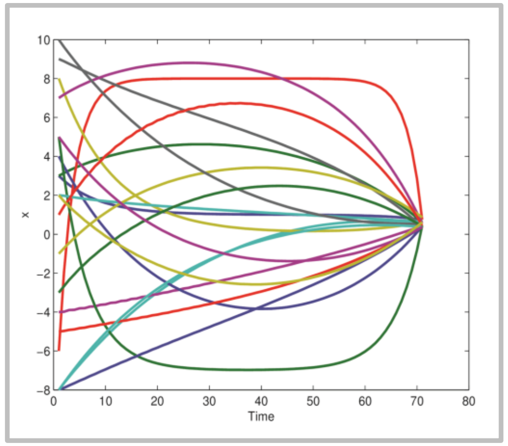
Technical details



FORCASTING (AI)



DAY-AHEAD SCHEDULING & OPTIMIZATION



REAL TIME TRACKING & OPTIMIZATION

WIRELESS COMMUNICATION OF CONTROL SIGNALS

Demonstrated technology

3GDH in Rottne, SE

5GDH in Heerlen, NL

3GDH in Eindhoven, NL

3GDH in Mol, BE

5GDH in Paris, Fr

Past projects

Current projects

Benefits in numbers

Reduction in peak heat demand
17.3%

Reduction in CO_2 emissions
11.2 kilo Tonnes/year

Potential increase in capacity of
42.1% enabling **48.000** additional homes

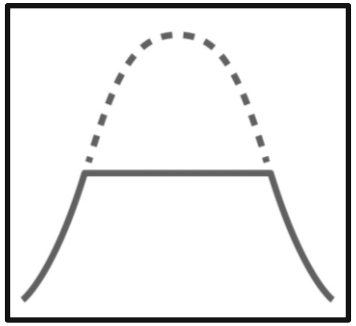
VEAB
VÄXJÖ ENERGI

Reduction in peak heat demand
12.7%

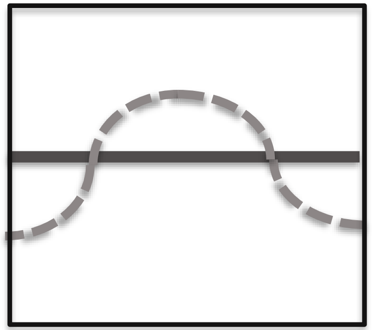
Reduction in CO_2 emissions
10.8 kilo Tonnes/year

Reduction in power procurement costs of **6%**

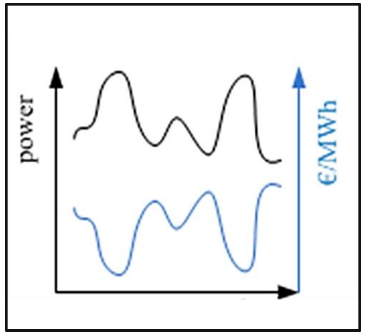
Storm Technology Roadmap



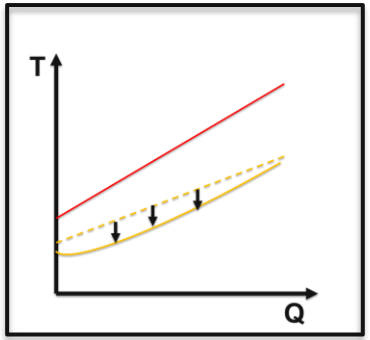
Peak shaving



Load curve flattening



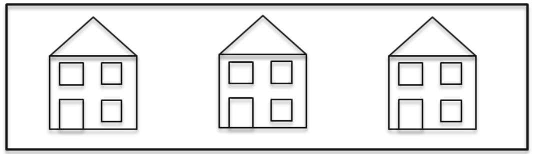
Electricity Market Interaction



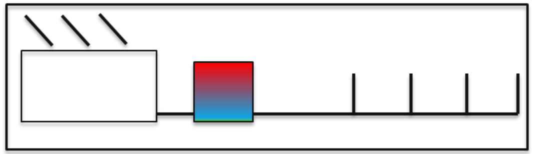
Return temperature reduction

Demonstrated

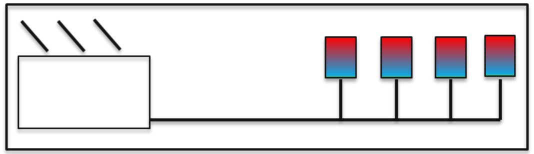
roadmap



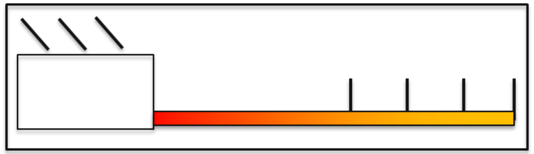
Building mass



Centralised storage



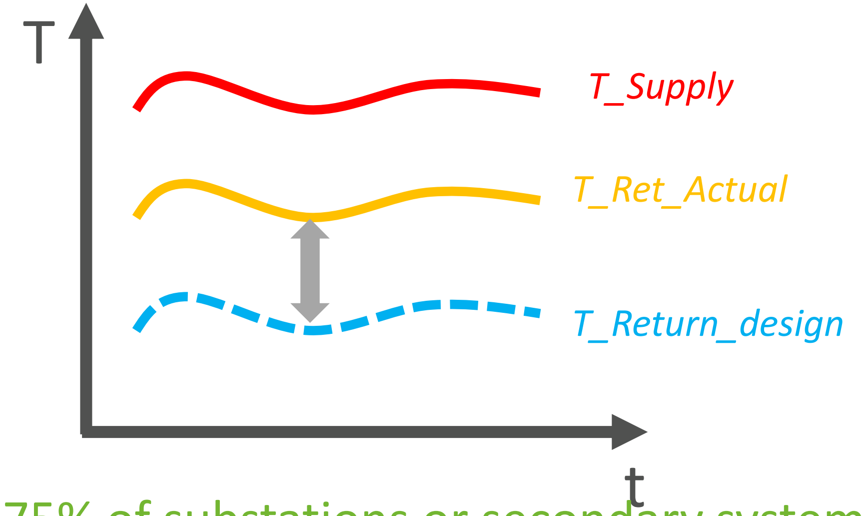
Decentralised storage



Storage in the network piping

Example of Data Analytics – Fault detection

Anomalies in DH substations usually lead to high return temperature



43-75% of substations or secondary systems are performing sub-optimal[1,2]

Decrease in efficiency

- ❑ On production side (heat pumps, flue gas condensation)
- ❑ Inefficient integration of renewable energy sources
- ❑ Increased heat losses in the distribution grid

Increased Costs

- ❑ Pumping costs due to higher flows
- ❑ Costly technical interventions
- ❑ Increased heat production costs
- ❑ Increased energy costs for costumers

- Especially with the lower DH temperature, there are lower margins for low temperature district heating systems

(1) Henrik Gadd. "To analyse measurements is to know!" PhD thesis. Lund University, 2014.
(2) Sara Mansson et al. "Automated statistical methods for fault detection in district heating customer installations". In: Energies 12.1 (2019), p. 113.

Faults categories

Survey of 56 DH utilities in Sweden

Controller and control system

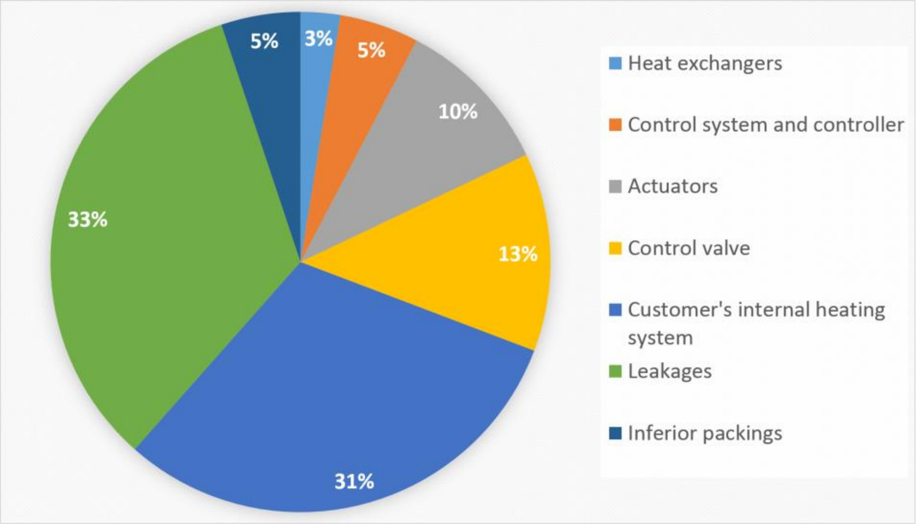
Heat exchangers

Actuators

Leakages (can be a consequence)

Control valves

Internal heating system



Distribution of most frequently occurring fault categories

The Fault Detection and Diagnosis technology

Fault detection

- Detect a deviation from expected performance of a customer's installation

Fault diagnosis

- Identify the cause(s) of the poor performance

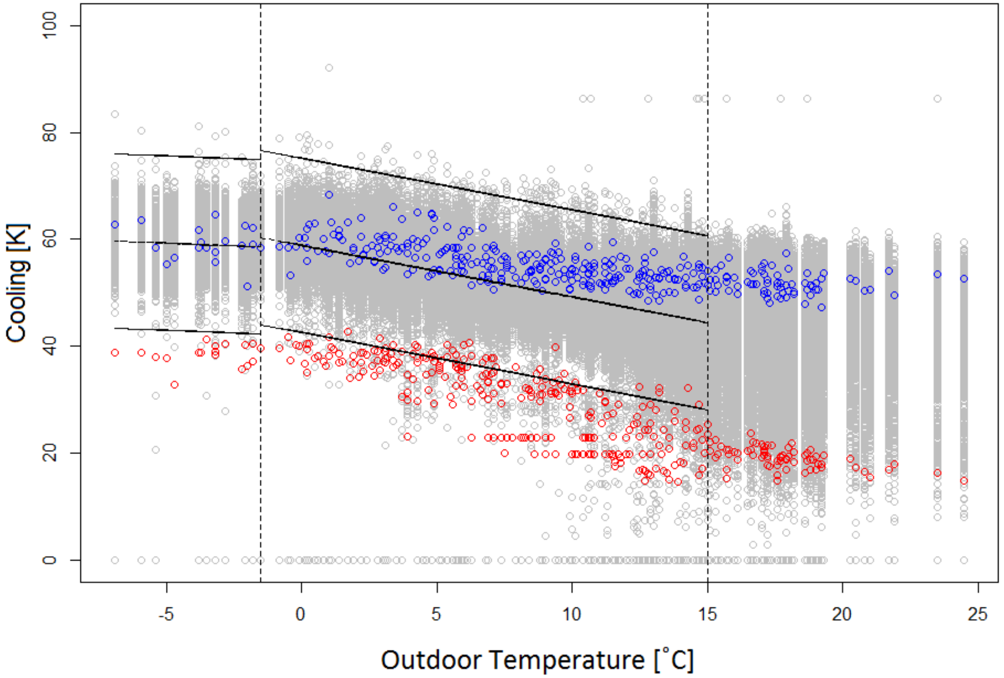
Fault correction

- Fix the fault(s)

Fault detection approaches

Cluster/Group-based

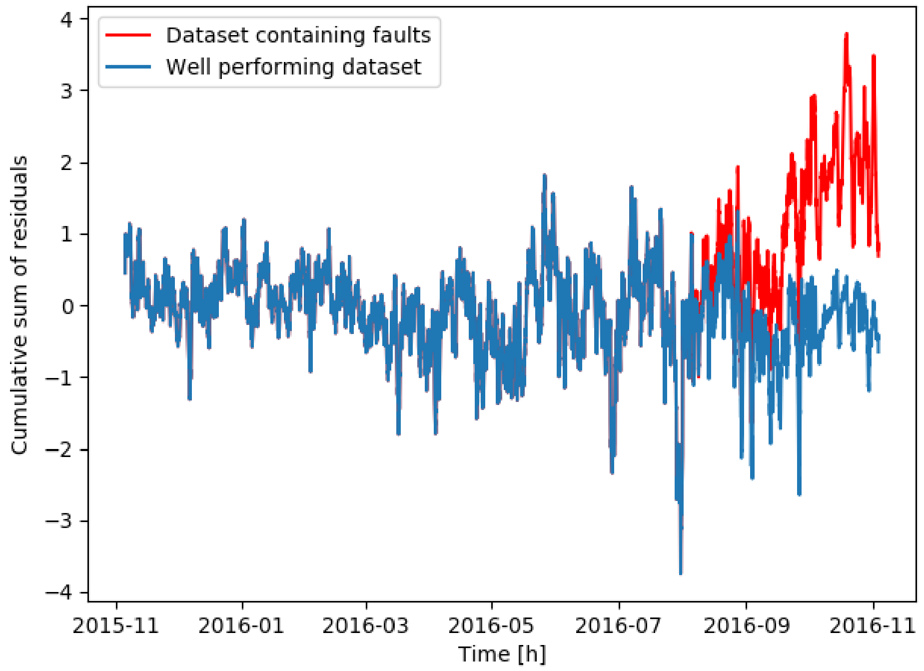
- Fault detection by clustering substations according to a certain criteria
- Automated limit checking
- Statistical analysis
- Ranking



Fault detection approaches

Instance-based

- Prediction of district heating substation behavior using a grey-box model
- Compare the outcome of model to the measurements



Pathopt

- Determine the optimal layout of a thermal network:
  - Automatic, fast and accurate
  - Based on geographical input
  - Up to city level
  - Economic and energetic output targets
  - Multiple production sources

Further Information @ energyville.be/en/storm-controller

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