SOLAR ACADEMY
ENERGY ECONOMY AND SOLAR HEAT – PERSPECTIVES AND BEST PRACTICE

SOLAR THERMAL ENERGY SYSTEM
BENCHMARK – METHODOLOGY – BEST PRACTICE EXAMPLES

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Motivation

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- High energy consumption in the urban area
- Huge potential to integrate solar thermal energy
- Inspiration for urban actors to consider solar thermal as reliable, efficient and eco-friendly technology that meets future low-carbon-economy requirements

  - **How ?**

Outline

- Classification and benchmark of solar energy system
- Methodology and tool to integrate solar energy
- Best practice examples

Outline

- **Classification and benchmark of solar energy system**
- Methodology and tool to integrate solar energy
- Best practice examples

Determination of representative techno-economic benchmark figures

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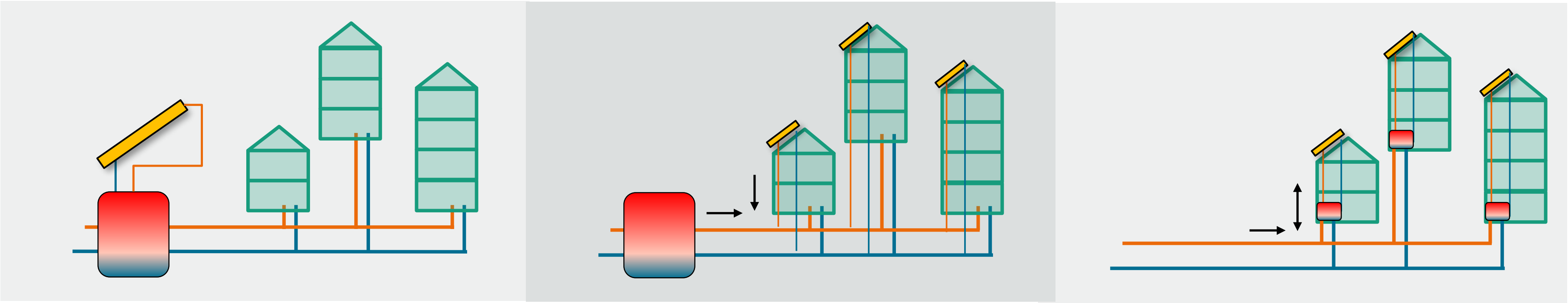
- Survey : solar thermal system in operation from countries participating in IEA-SHC Task 52 (AT, DE, and DK) : **in sum, 46 systems**

Classification and benchmarking

- Identification of solar thermal system configurations suitable for applications in urban environments

  a) Solar assisted heating of individual buildings

  b) Solar assisted heating of multiple buildings via thermal grid



Task 52
Solar Heat and Energy Economics in Urban Environments

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

a) Solar assisted heating of individual buildings

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Solar domestic hot water systems in single family homes

DHW-SFH

Solar-combi systems in single family homes

CS-SFH

Solar-combi systems in multi-family homes (terraced houses, apartment blocks)

CS-MFH

b) Solar assisted heating of multiple buildings via thermal grid – Diurnal or seasonal storage

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Solar block heating (SBH)
- roof/(ground) mounted collectors
- day/week/seasonal storage
- countries: AT, DE

*TTES: tank thermal energy storage

Location: Salzburg; AT
Commissioning: 2011/2013 (extended)
Collector field size: 2,050 m²
Storage: day/week (200 m³ TTES*)
Solar fraction: 25%
Picture source: Salzburg AG

Location: Munich, DE
Commissioning: 2007
Collector field size: 2,800 m²
Storage: seasonal (5,700 m³ TTES*)
Solar fraction: 46%
Picture source: ZAE Bayern

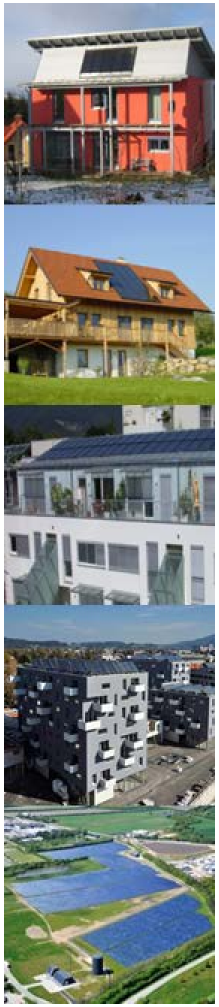
Solar district heating (SDH)
- central solar feed-in
- ground mounted collectors
- seasonal storage
- country: DK

*PTES: pit thermal energy storage

Location: Vojens, DK
Commissioning: 2012/2015 (extended)
Collector field size: 70,000 m²
Storage: seasonal (200,000m³ PTES*)
Solar fraction: 45-50%
Picture source: Vojens Fjernvarme

Location: Dronninglund, DK
Commissioning: 2014
Collector field size: 37,600 m²
Storage: seasonal (62,000m³ PTES*)
Solar fraction: 50%
Picture source: Dronninglund Fjernvarme

Classification of solar energy system

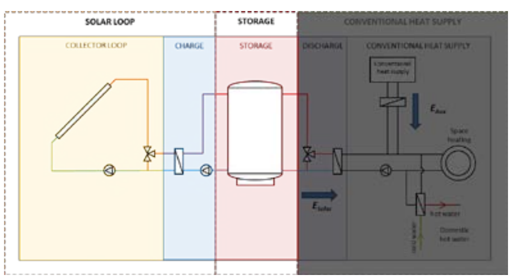


- Solar domestic hot water for individual houses
- Solar-combi system for individual houses
- Solar-combi system for multi-family houses
- Solar assisted heating of building blocks (diurnal or seasonal storage)
- Solar assisted heating of urban quarters (diurnal or seasonal storage)

Classification and benchmarking

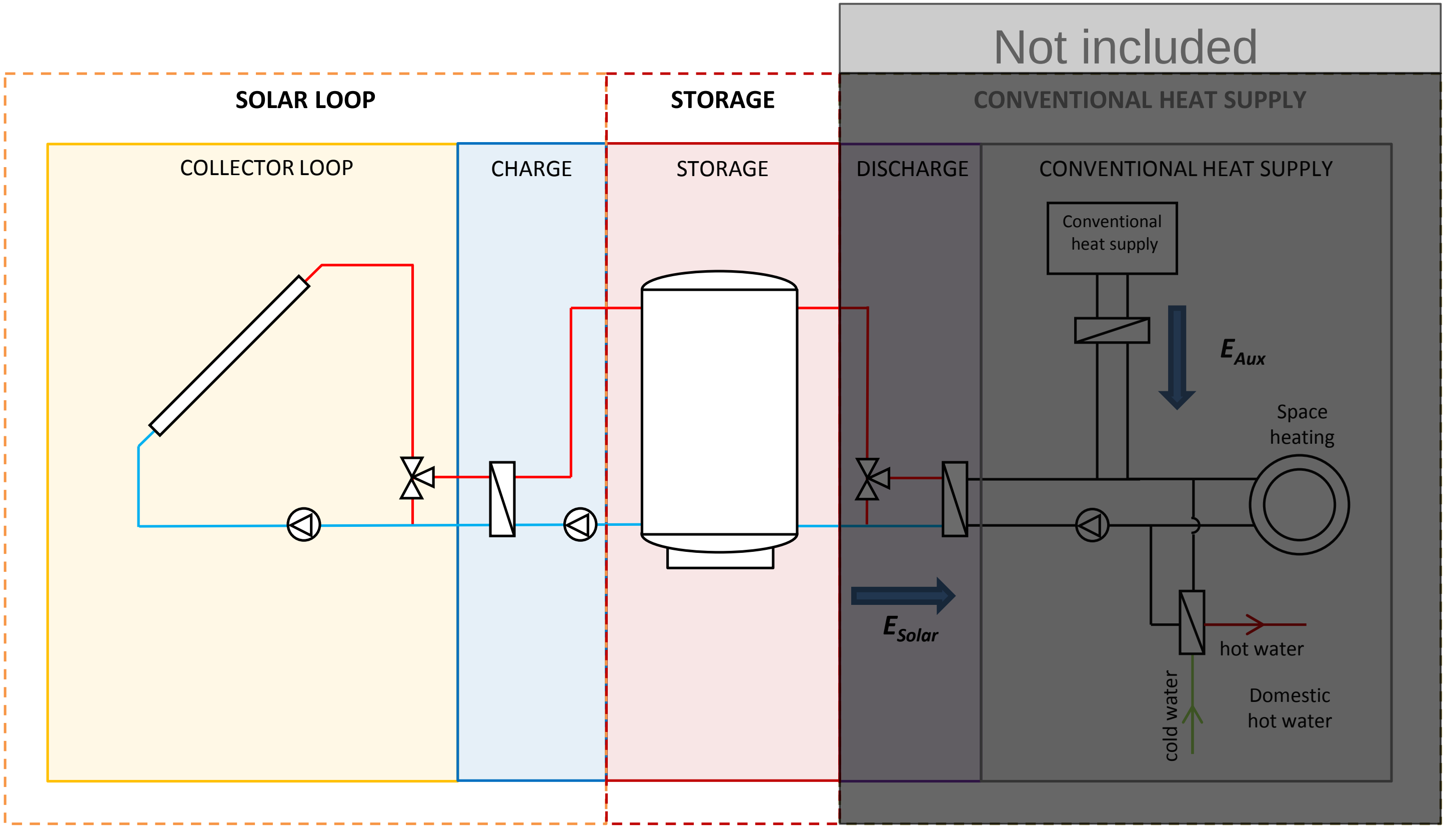
- Identification of solar thermal system configurations suitable for applications in urban environments

- **Determination of representative techno-economic benchmark figures**



Determination of representative techno-economic benchmark figures

- Boundaries

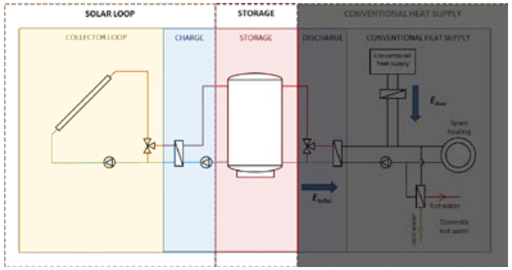


Determination of representative techno-economic benchmark figures

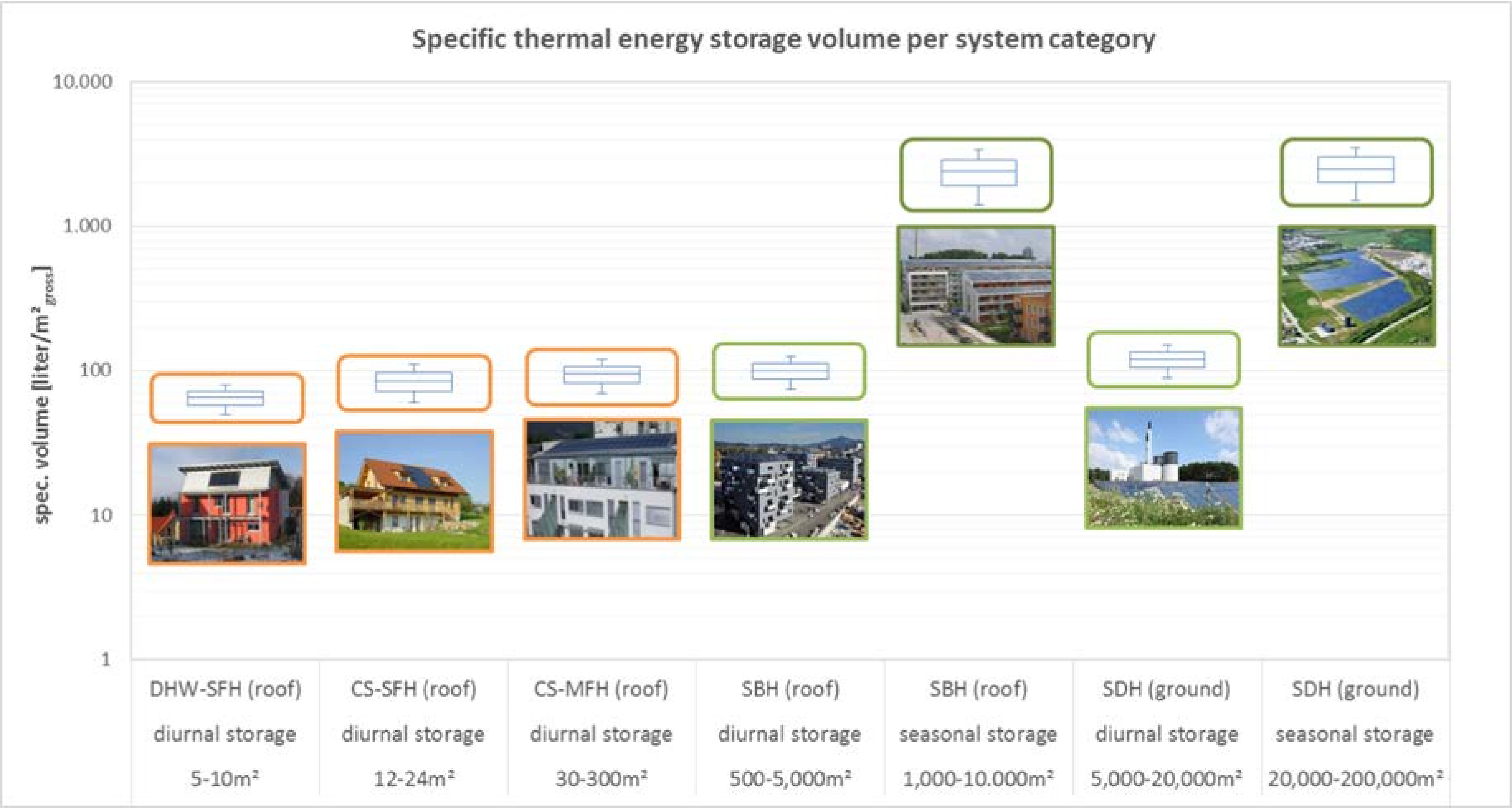
- Key figures

Energy/technical data
Kind of solar thermal collector used
Kind of solar energy storage used
Typical size per unit [m^2_{gross}]
Typical thermal peak capacity per unit [kW]
Typical storage volume per unit [ltr.]
Typical annual production per unit [kWh/a]
Specific storage volume per unit [ltr./m^2_{gross}]
Typical solar energy yield SE [kWh/m^2_{gross}/a]
Typical solar fraction sf [-]

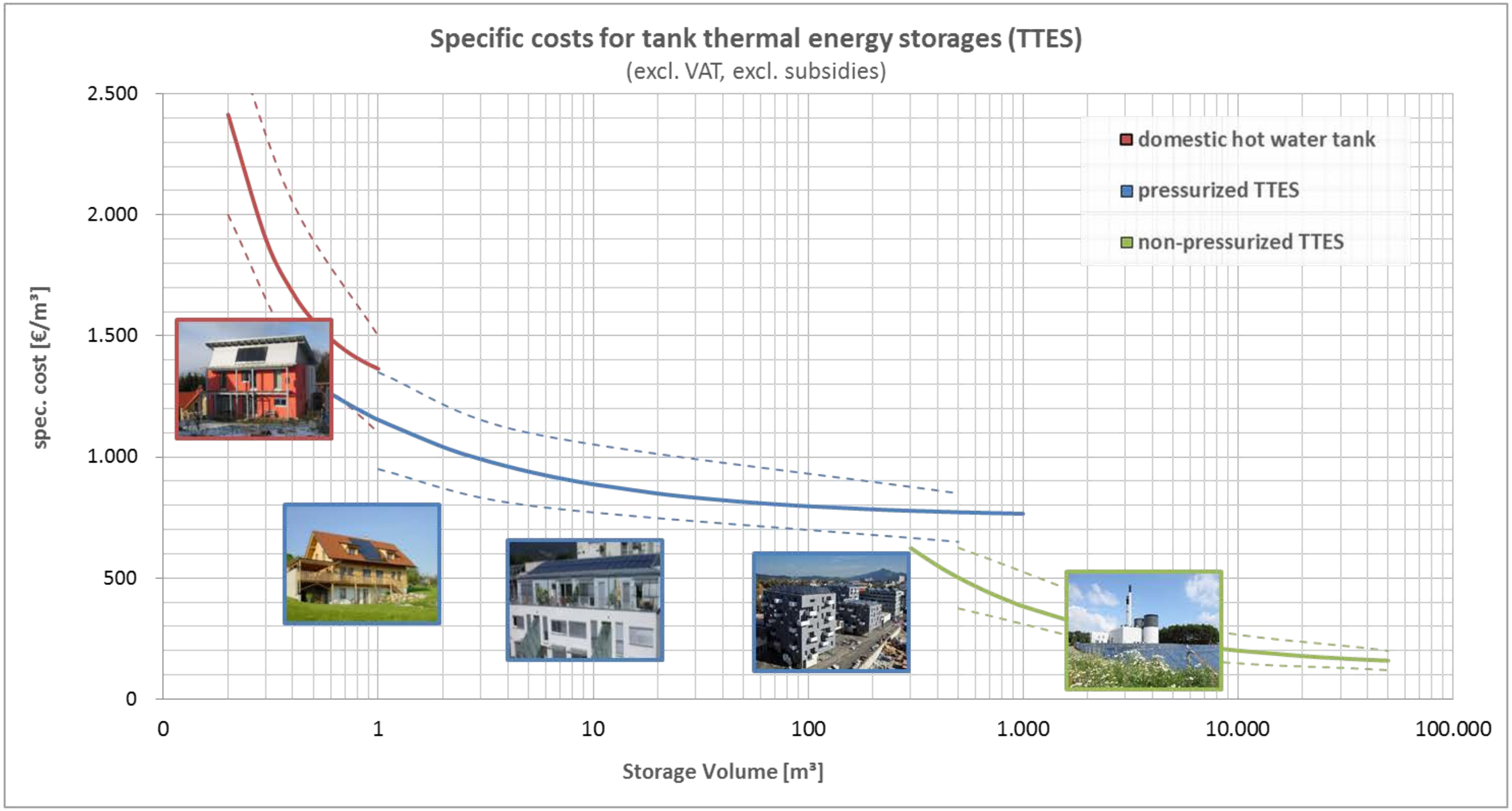
Financial data
Specific cost ready installed [1,000€/m^2_{gross}] (excl. VAT, excl. subsidies)
Specific cost (material only) [1,000€/m^2_{gross}] (excl. VAT, excl. subsidies)
Levelized cost of heat LCOH [€-ct/kWh]



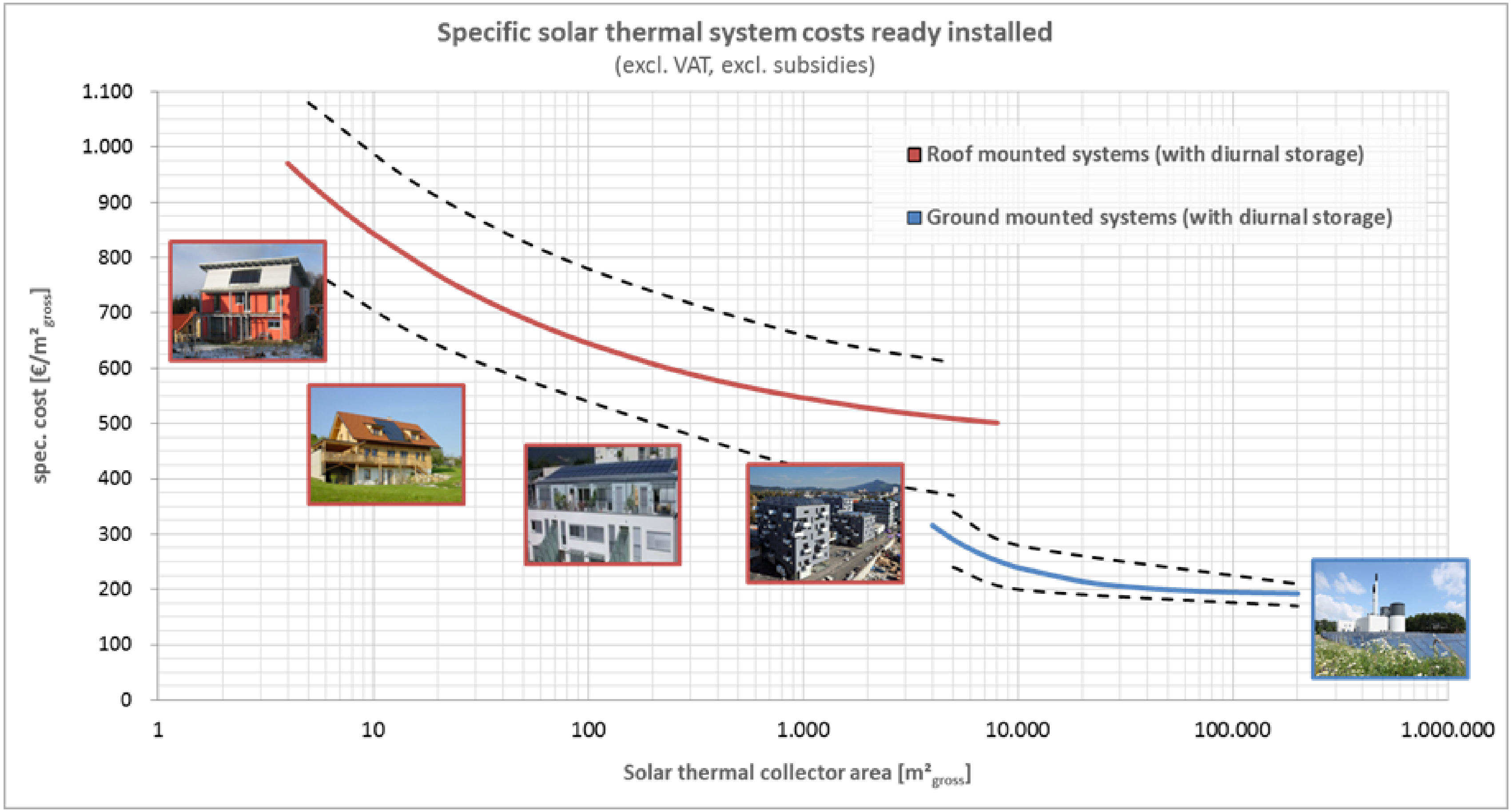
Classification and benchmark
Specific storage volume



Classification and benchmark
Storage cost



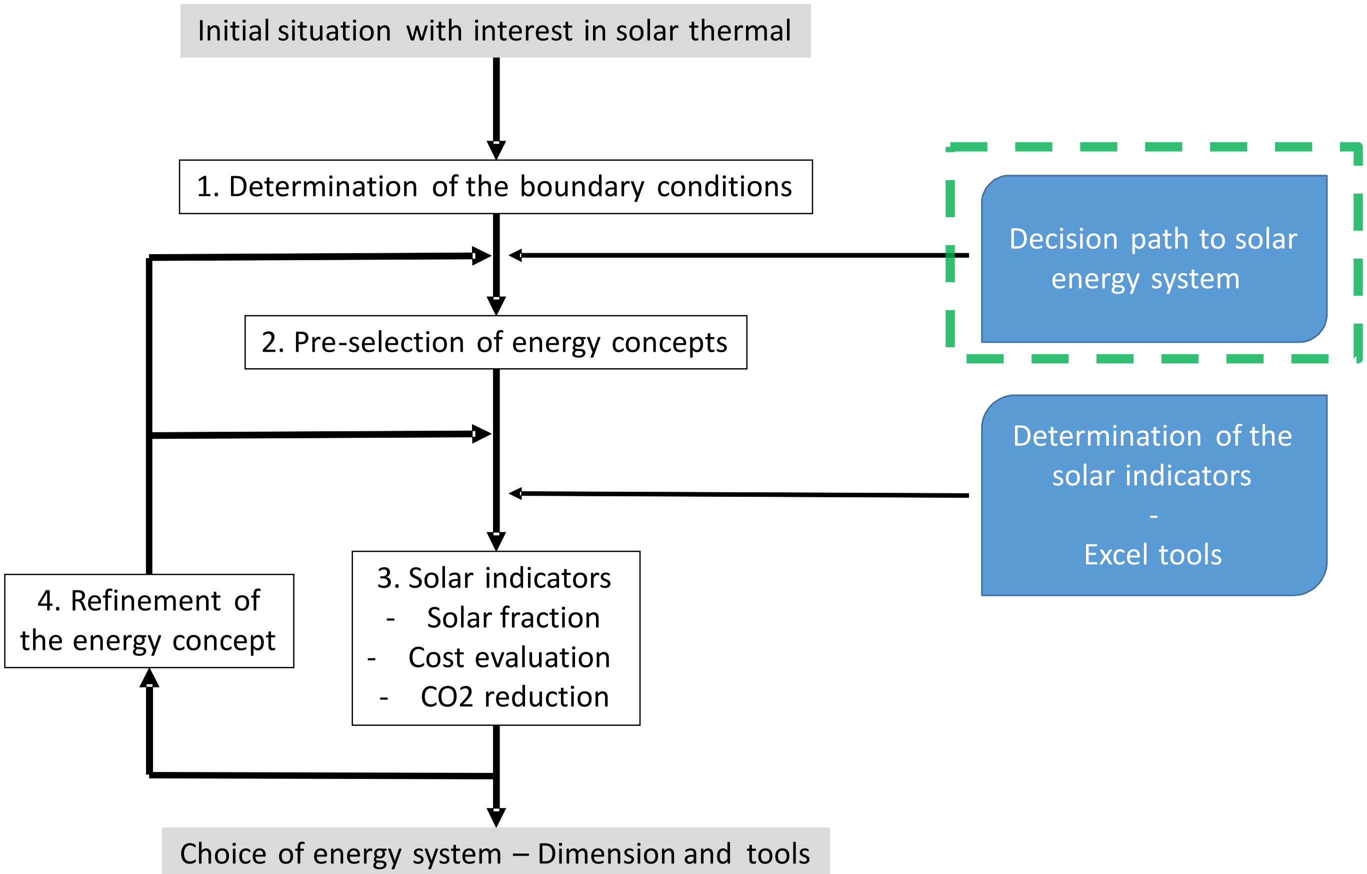
Classification and benchmark
Specific solar thermal costs



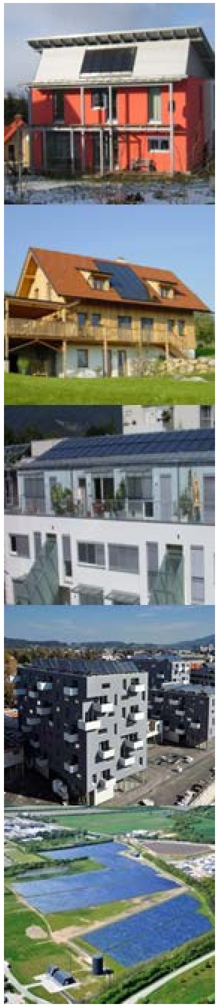
Outline

- Classification and benchmark of solar energy system
- **Methodology and tool to integrate solar energy**
- Best practice examples

Methodology – 4 steps



Pre-selection of solar energy system



- Solar domestic hot water for individual houses
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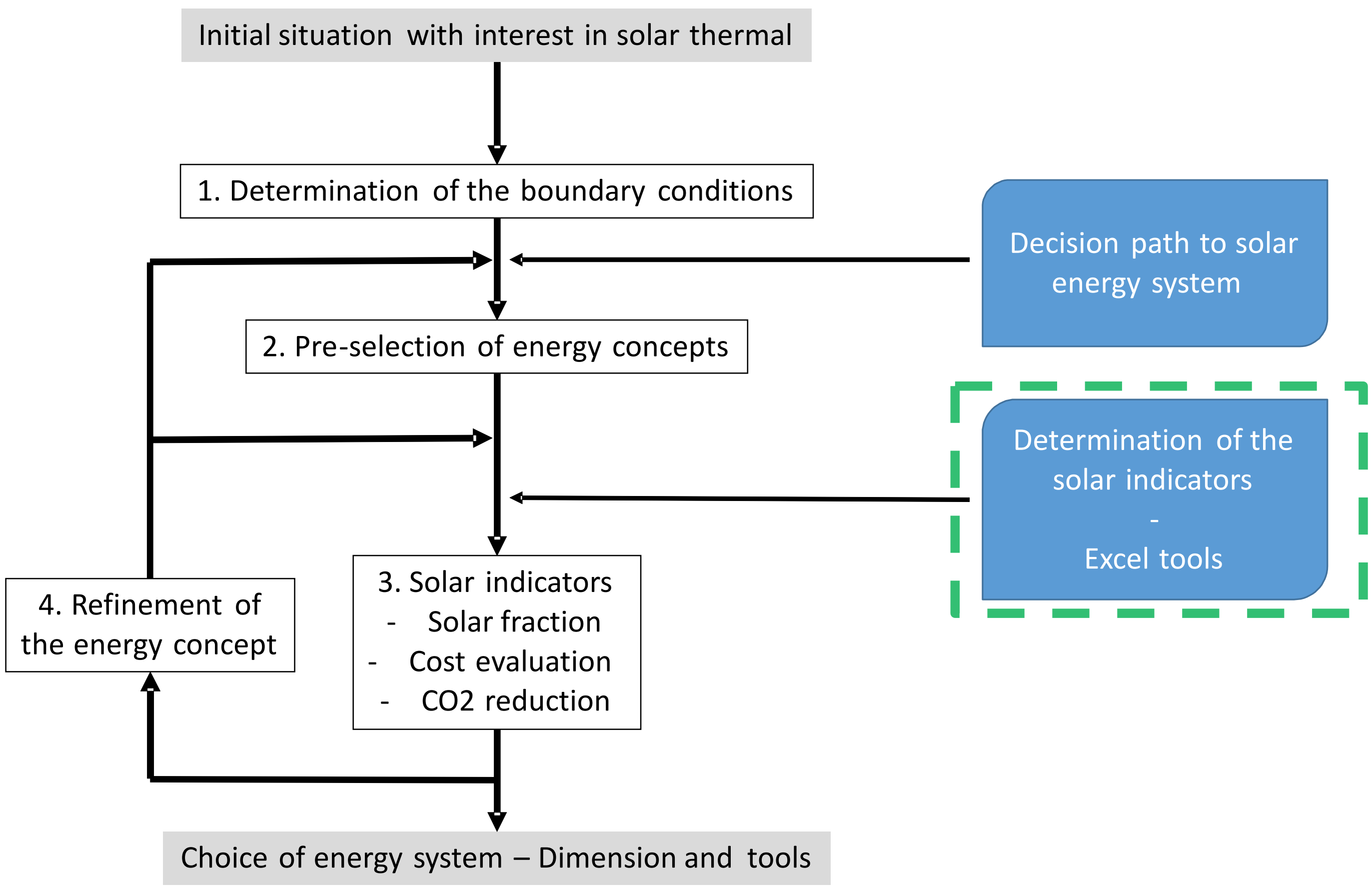
- Solar assisted heating of building blocks (diurnal or seasonal storage)
- Solar assisted heating of urban quarters (diurnal or seasonal storage)

Methodology – 4 steps



Solar indicators quantification

Input

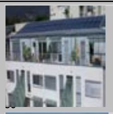
	Projet		
Country	**Island**		
Building type	**Single family house**	**Multi Family house**	**Apartment Block**
Heated floor area [m2]	**500**	**0**	**0**
Construction period	**1960-1970**	**1970-1980**	**1990-2000**
Refurbishment - Space heating gain [%]	**20**	**10**	**0**
Building need - Domestic hot water [kWh/year]	6944.444444	0	0
Building need - Space heating [kWh/year]	64320	0	0
Building total need per type [kWh/year]	71264.44444	0	0
Buildings total need [kWh/year]	71264.44444		
Max solar fraction - Diurnal storage [%]	37.6%		
Max solar production - Diurnal storage [kWh/year]	26805.7		
Max solar fraction - Seasonal storage [%]	-		
Max solar production - Seasonal storage [kWh/year]	-		

Collector total surface [m2]	**100**
Size index - 1 to 5	**3**
Pipe lentgh of the district heating derived from the nationnal mean heat density [m]	71

	Diurnal	Seasonal (PTES)
Storage	8.5 m3	0 m3
	898 €/m3	0 €/m3

Additionnal production source	Coke
Renewable fraction of the heat network [%]	50

Output

Type	**Picture**	**Diurnal storage volume**	**Diurnal storage cost**	**Heat district**	**Specific solar thermal system cost**	**Diurnal solar fraction**	**Energy cost - Diurnal**	**Saved CO2 emission**	**Tools**
Solar-combi systems in multi-family homes		**Diurnal storage volume 8.5 m3**	**Diurnal storage volume 898 €/m3**	**According to Island heat density statistic, mean national length of the district heatings with similar demand is 71m**	**645 €/m2**	**38%**	**The levelized cost for solar energy is 4479.9 €/year. The cost of energy is 16.7 €-ct/kWh +/- 20%**	**The avoided CO2 emission with the solar energy system is 4 ton-CO2/year**	-
-		-	-		-	-	-		
		-	-		-	-	-		

Output

Solar indicators - Inputs

M^2 -> Solar thermal area

M^2 -> Heated floor area

Solar indicators - Inputs

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M^2 -> Total solar thermal area

M^2 -> Total heated floor area

Consumption : TABULA WebTool
http://webtool.building-typology.eu

- Single family house
- Multifamily house
- Apartment block

Solar indicators - Outputs

- Storage volume [m3]
- Solar fraction [%]
- Cost : Storage [€/m3] and Solar thermal system [€/m2]
- Energy cost [ct./kWh]
- Saved CO_2 emission [ton/year]
- Pipe length as function of the national mean heat density [m]

Outline

- Classification and benchmark of solar energy system
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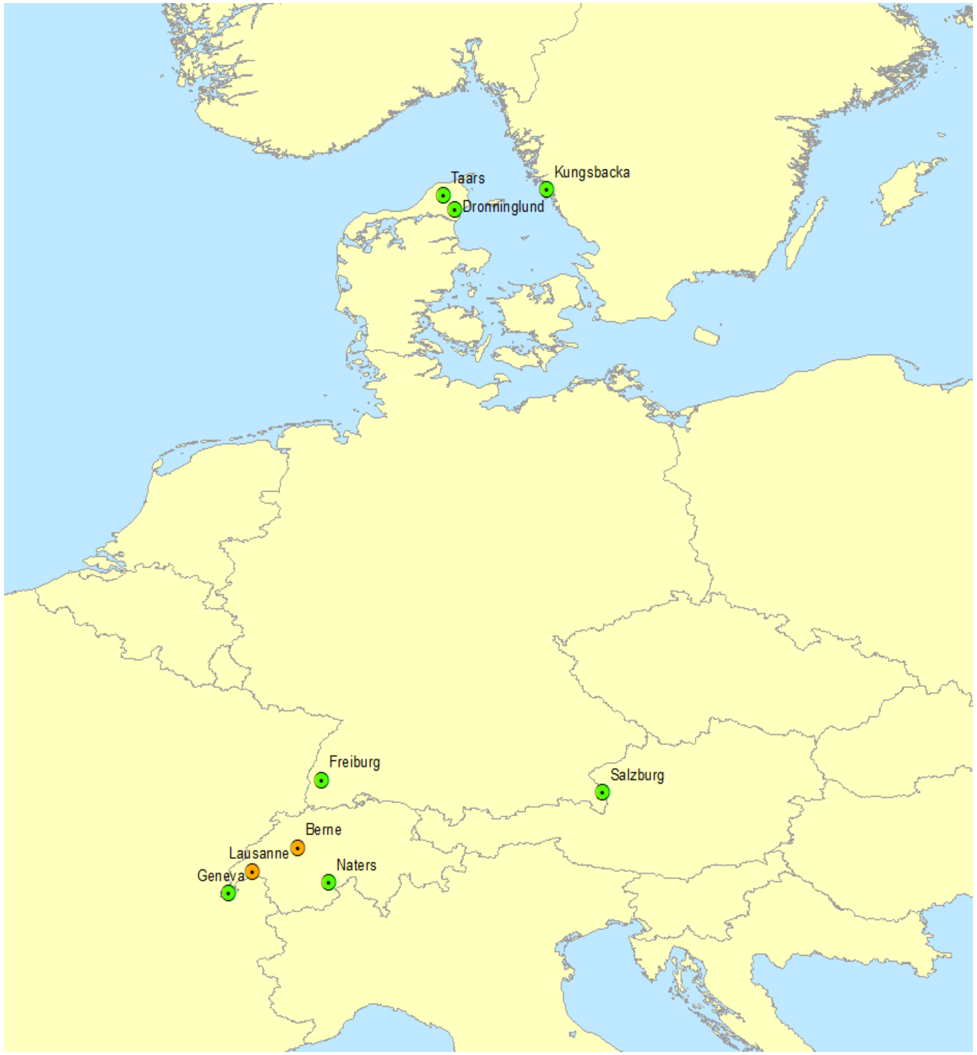
- **Best practice examples**

Best practice examples

- Technico-economic description of the concept
- Decision and design process
- Lessons learned

  (barriers and success factors)



http://task52.iea-shc.org/publications

Solar district heating with seasonal storage in the city of Dronninglund, DK

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(Source: Dronninglund Fjernvarme A.m.b.A)

Hybrid solar district heating in the city of Taars, DK

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DTU

(Source: Aalborg CSP)

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Solar Heat and Energy Economics in Urban Environments

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Solar-assisted urban quarter “Salzburg-Lehen”, AT

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(Source: AEE INTEC)

Solar-assisted urban quarter “Freiburg-Gutleutmatten”, DE

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Fraunhofer ISE, DE
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(Source: Fraunhofer ISE)

Solar-assisted residential area
"Vallda Heberg" in Kungsbacka, SE

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CHALMERS UNIVERSITY OF TECHNOLOGY
DALARNA UNIVERSITY

(Source: Eksta Bostads AB)

Solar-assisted mountain holiday resort "Reka Feriendorf" in Naters, CH

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CREM
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(Source: Lauber IWISA AG)

Solar assisted apartment blocks
“La Cigale” in Geneva, CH

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Discussion and conclusion

- Benchmark and methodology :
- Pre-project phase
- From basic inputs to main solar indicators
- Includes diurnal and seasonal storage benchmark
- Adapted to European countries

➢ Documents :

- Classification and benchmarking of solar thermal systems in urban environments – Report C1
- Methodology and tools – Report B
- http://task52.iea-shc.org/publications

Discussion and conclusion

- Best practice examples :
- Economically viable solar thermal system
- Diverse technical solution to integrate solar thermal energy
- Strong willingness

- Documents :
  - Technical Report B&C - Analysis of built best practice examples and conceptual feasibility studies - Report
  - Solar thermal application in urban environments - Leaflet
  - http://task52.iea-shc.org/publications

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- Colleges and institutions who contributed to this work

Levelized cost of energy

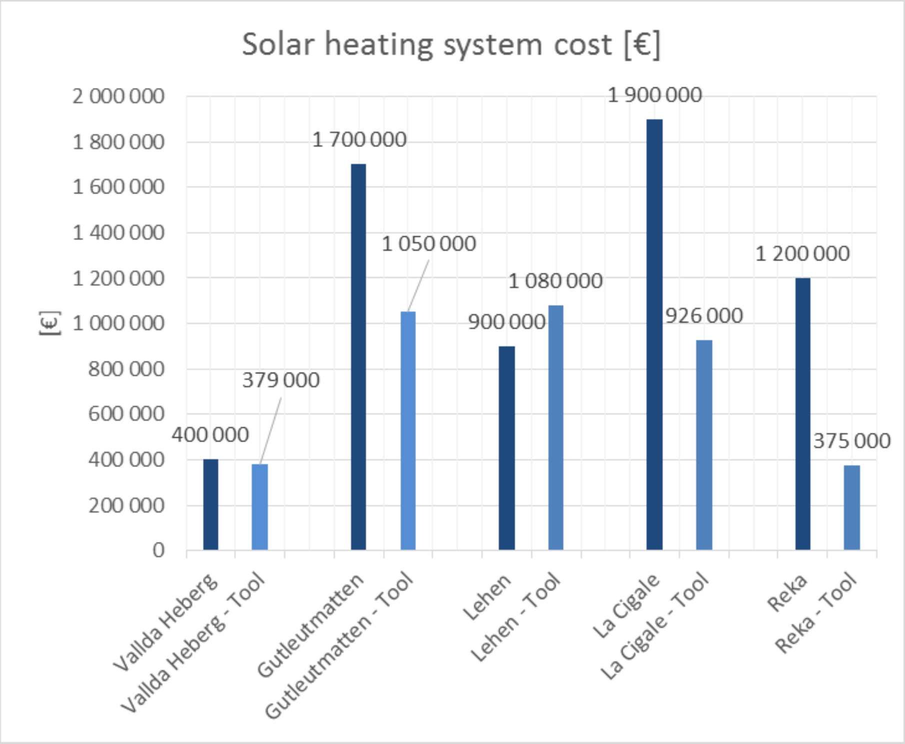
$$LCOE = \frac{\sum_{t=1}^{t_{ges}} C_t \cdot (1+r)^{-t}}{\sum_{t=1}^{t_{ges}} E_t \cdot (1+r)^{-t}} \qquad \text{Eq. 2}$$

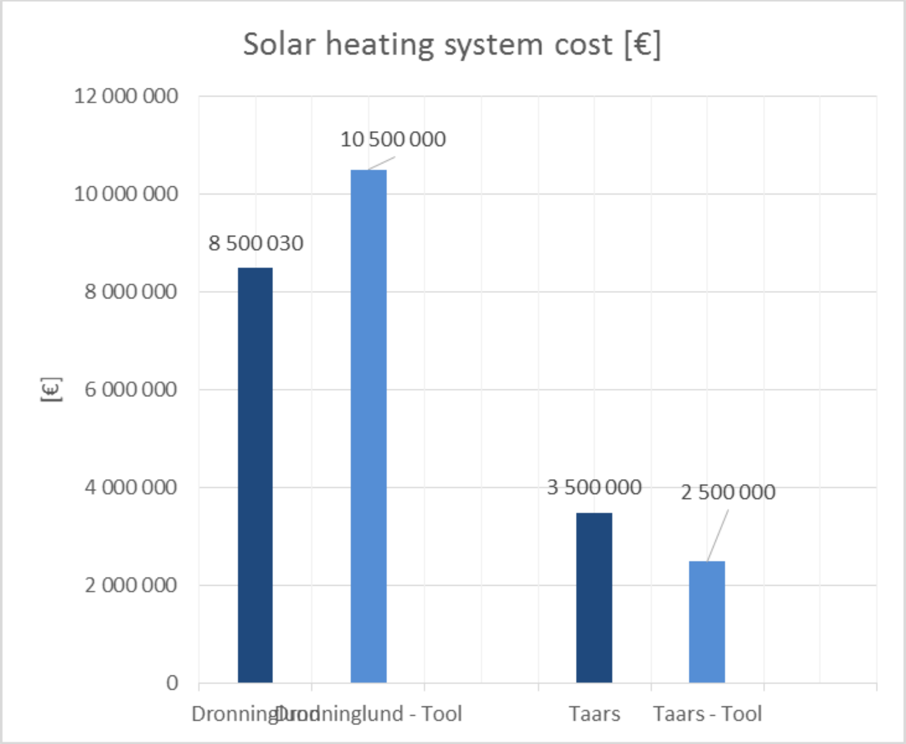
The calculation of levelized cost of solar thermal generated heat $LCOE_{ST}$ in this report is derived from Eq. 2 and may be expressed as following:

$$LCOE_{ST} = \frac{I_0 + \sum_{t=1}^{t_{ges}} A_t \cdot (1+r)^{-t}}{\sum_{t=1}^{t_{ges}} SE \cdot (1+r)^{-t}} \qquad \text{Eq. 3}$$

$LCOE_{ST}$	levelized cost of solar thermal generated heat [€/kWh]
I_0	specific solar thermal system costs incl. installation (excl. VAT and subsidies) [€/m$^2_{gross}$]
A_t	fixed and variable O&M expenditures in the year t [€/m$^2_{gross}$]
SE	solar energy yield in the year t [kWh/m$^2_{gross}$]
r	discount (interest) rate [%]
t_{ges}	period of use (solar thermal system life time in years) [a]
t	year within the period of use (1,2,… t_{ges})

Best example VS benchmark





Measured value

Calculated value

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