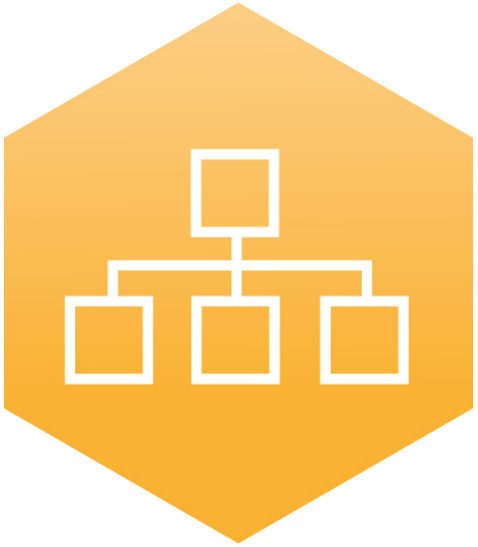
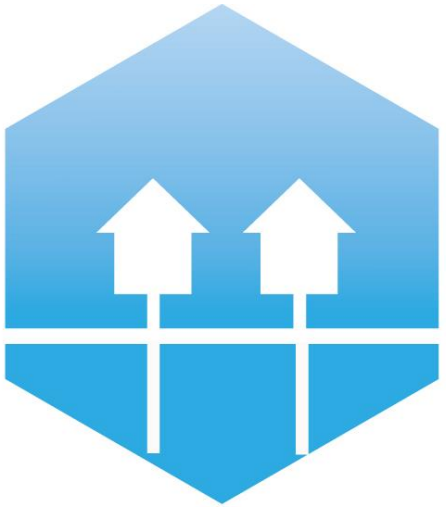
International Conference on Smart Energy Systems and 4th Generation District Heating
Copenhagen. 25-26 August 2015

Reducing CO_2 emissions and increasing the integration of renewables through the utilization of smart district heating system in the City of Velika Gorica





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4DH
4th Generation District Heating
Technologies and Systems

Index

- **Current situation**
- **Thermal demand and mapping**
- **Solar and biomass resources**
- **Solar technologies**
- **Solar energy**
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  - **Preheating district heating scale**
  - **Seasonal storage district heating scale**
- **Recommendations for future**

SMART ENERGY SYSTEMS

- Smart phones
- Smart appliances (e.g. smart TV)
- Smart buildings
- Smart grids, smart thermal grids, smart gas …
- Smart energy systems
- Smart cars
- Smart cities

WHAT ABOUT:

Smart governments? Smart politicians?
Smart companies?
Smart consumers? Smart people?
Smart society?

The long-term Objective of Danish Energy Policy

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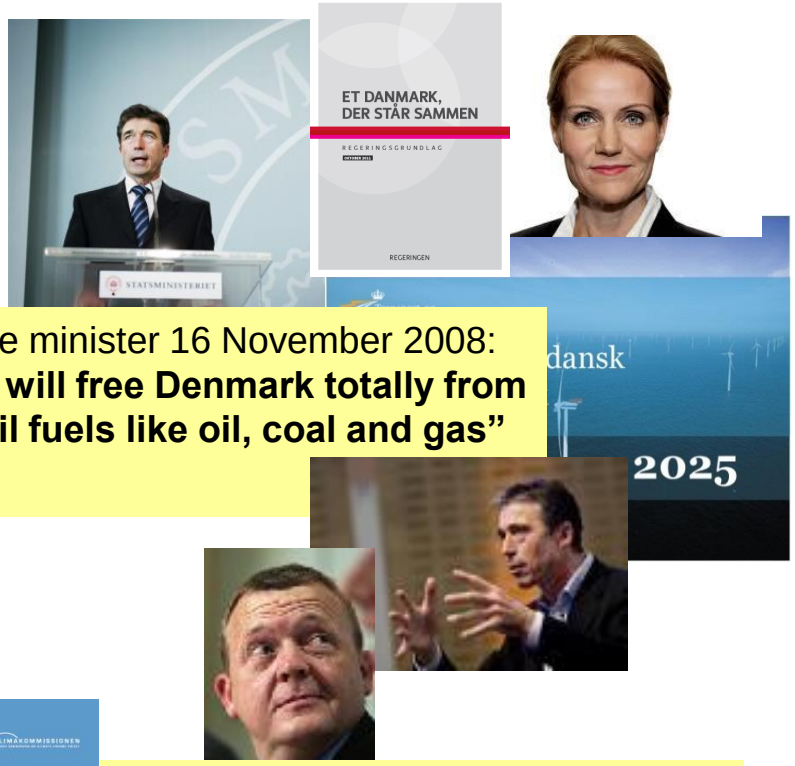
Expressed by former Prime Minister Anders Fogh Rasmussen in his opening speech to the Parliament in 2006 and in several political agreements since then:

To convert to 100% Renewable Energy

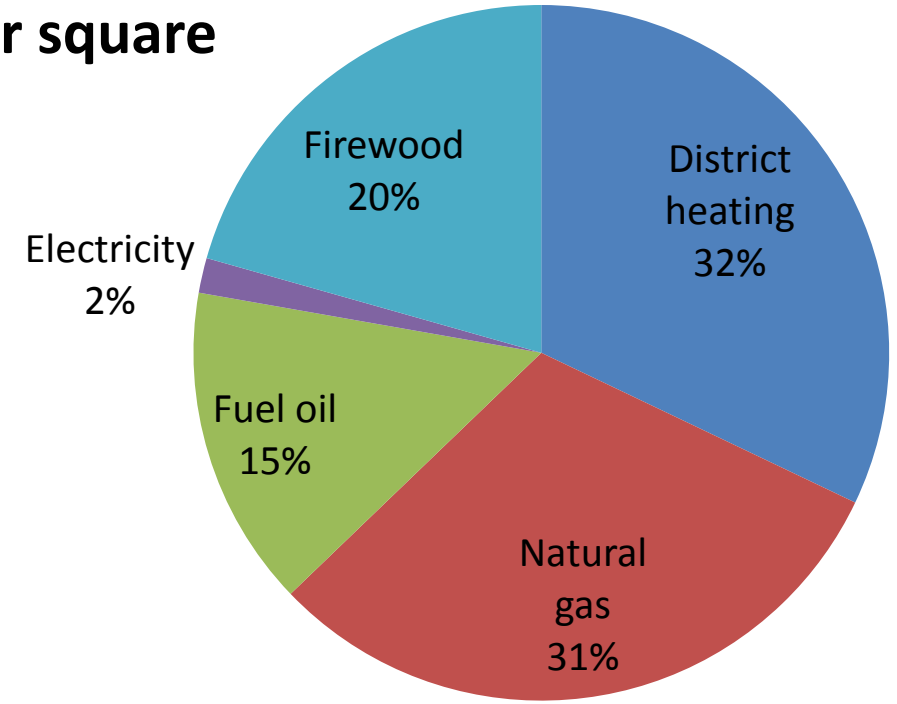


Prime minister 16 November 2008:
"We will free Denmark totally from fossil fuels like oil, coal and gas"

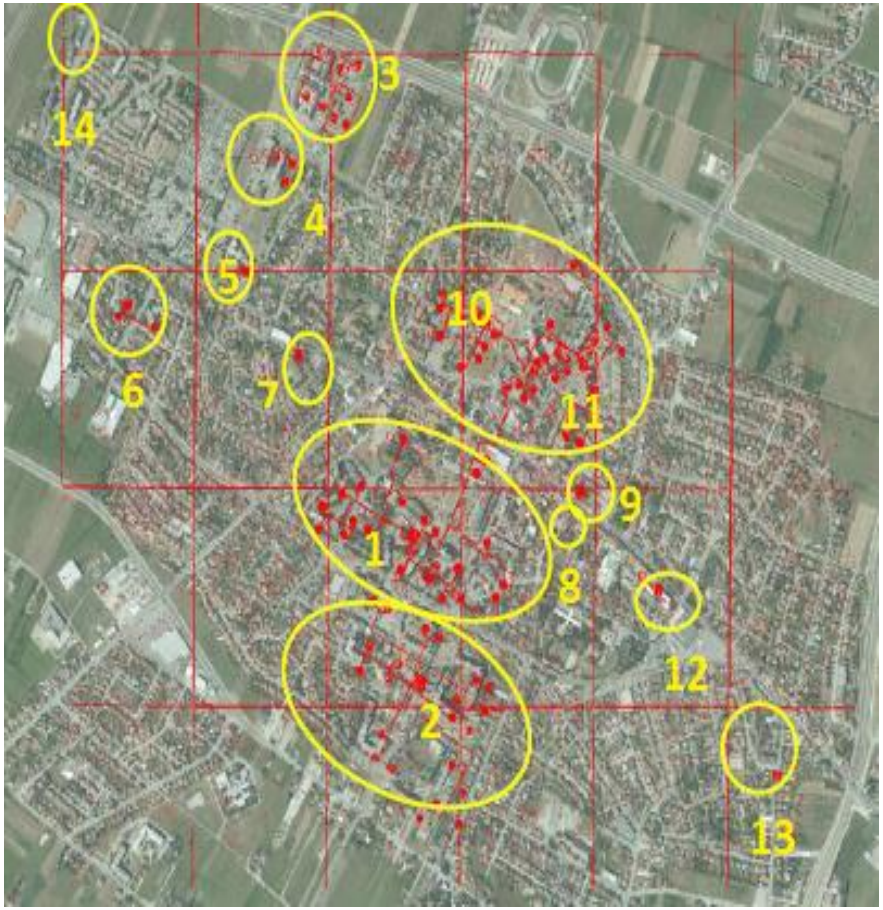
Prime minister 16 November 2008:
"… position Denmark in the heart of green growth"

City of Velika Gorica

- **Sixth largest city in Croatia**
- **Population: 63517. Area: 329 km²**
- **Urban area: 31.4 km². Population: 31553**
- **Density: 1004 inhabitants per square kilometre**
- **Total heat consumption in 2008 (SEAP): 197.34 GWh**



Current situation



- 14 heating plants and 34 boilers
- 63.3 GWh heat produced.
  60.76% gas operated.
  39.24% fuel oil operated

Number	Address	P installed (MW)	%
1	M.Magdalenica 3	0	0.00%
2	Vidriceva 1	35.61	60.76%
3	J.Dobrile 40a	3.52	6.01%
3	Domjaniceva 3	2.16	3.69%
4	J. Dobrile 8	1.89	3.22%
5	Zagrebacka 126	1.15	1.96%
7	Zagrebacka 71	0.45	0.77%
8	Zagrebacka 19	0.26	0.44%
9	Zagrebcka 12	0.11	0.19%
10	CV naselje 10	2.76	4.71%
11	Zvonimirova 9	6.93	11.82%
12	Trg k.tomislava 34	1.28	2.18%
13	E. laszowskos 35	0.49	0.84%
14	Sibenska	2	3.41%

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Velika Gorica vs Jelgava

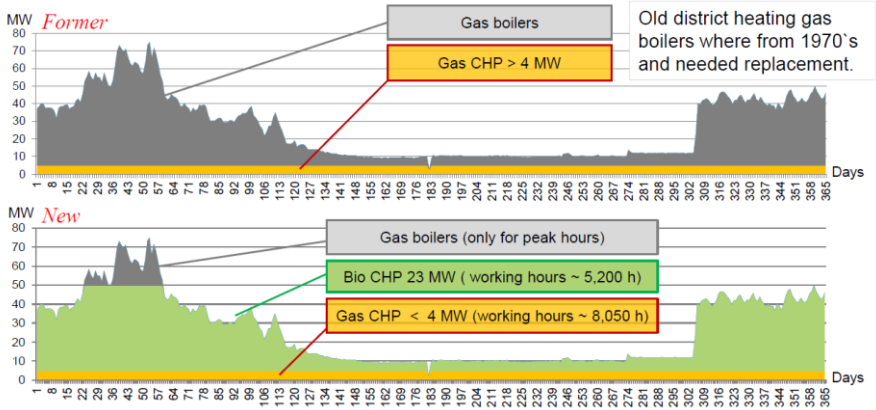
(63517 ppl. 64 279 ppl.)

Fortum's biomass CHP plant in Jelgava

Technical indicators:

- Fuel power – 77 MW_{fuel}
- District heat capacity – 45 MW_{heat}
- Electricity capacity – 23 MWe
- Estimated DH produced – 220 GWh
- Generated backpressure electricity – 110 GWh

- Boiler type – bubbling fluidized bed boiler – technology that allows to utilize lower quality wood chips
- Type of wood chips - wood residues and clearings of agricultural lands
- Fuel consumption per year – 400 000 MWh wood chips
- Fuel supply - around 6 thousand trucks per year
- **See video about Jelgava Bio CHP at:** http://youtu.be/J35wleC3dy0

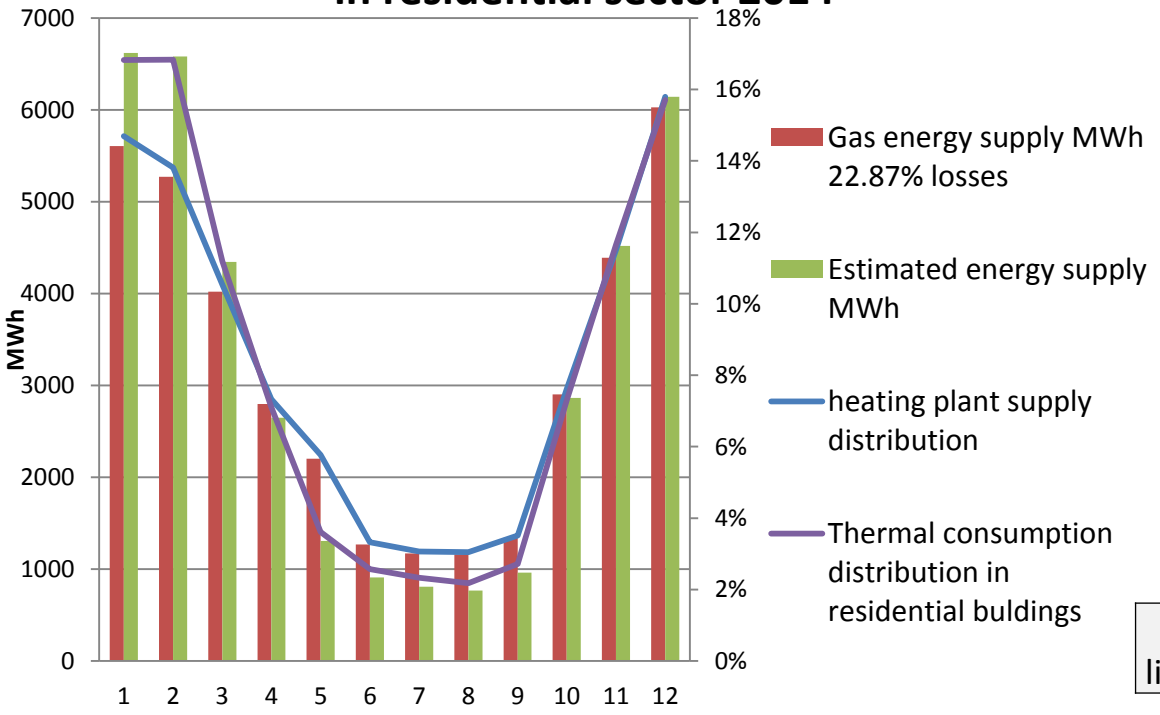


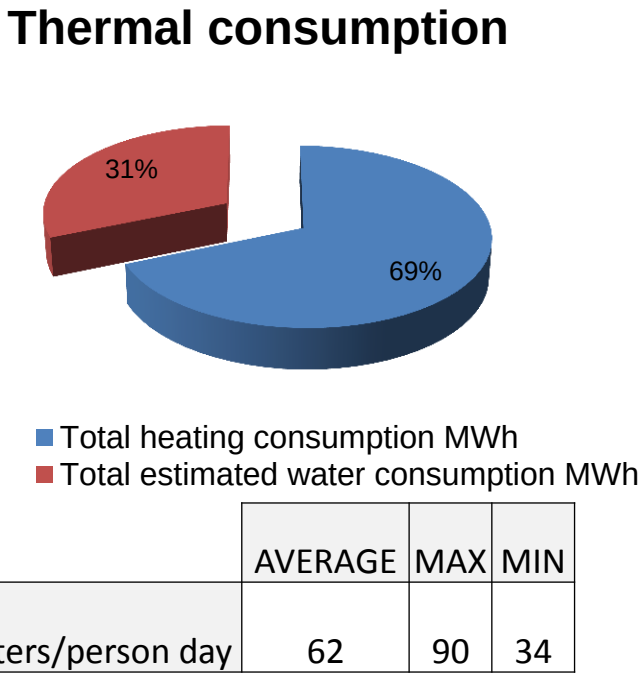
Next generation energy company | Fortum

Beyond Energy Action Strategies BEAST

www.beastproject.eu

Thermal demand





	AVERAGE	MAX	MIN
liters/person day	62	90	34

- **Estimated with data from Vidriceva 1 gas operated power plant**
- **Distribution loses and a high specific heating consumption of roughly 200 kWh/m²**

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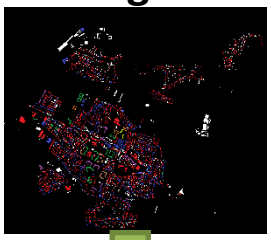
Heat mapping

- **Geoportal – locations and surface areas of structures**
- **Height (number of floors)**
- **Type of building**

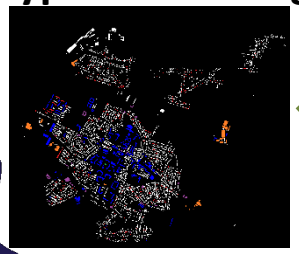
Heat mapping

Matrix (1.36X1.36m)

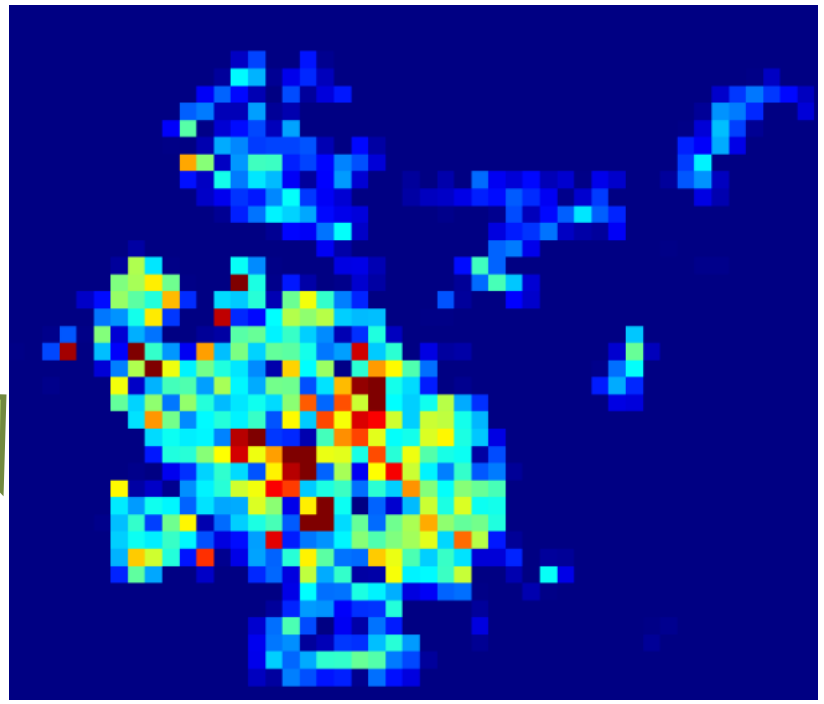
Height



Type of building



Heat map of Velike Gorice. resolution 100X100m



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Stratego | ENHANCED HEATING & COOLING PLANS

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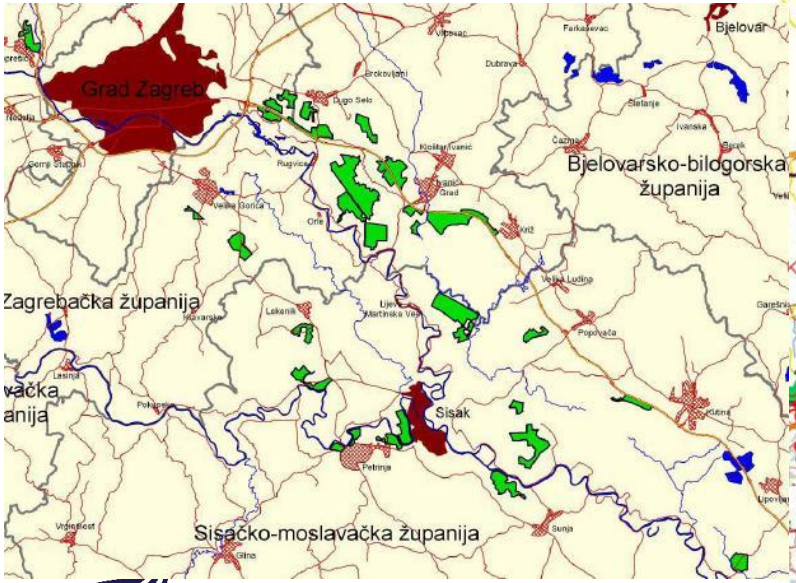
Solar resources

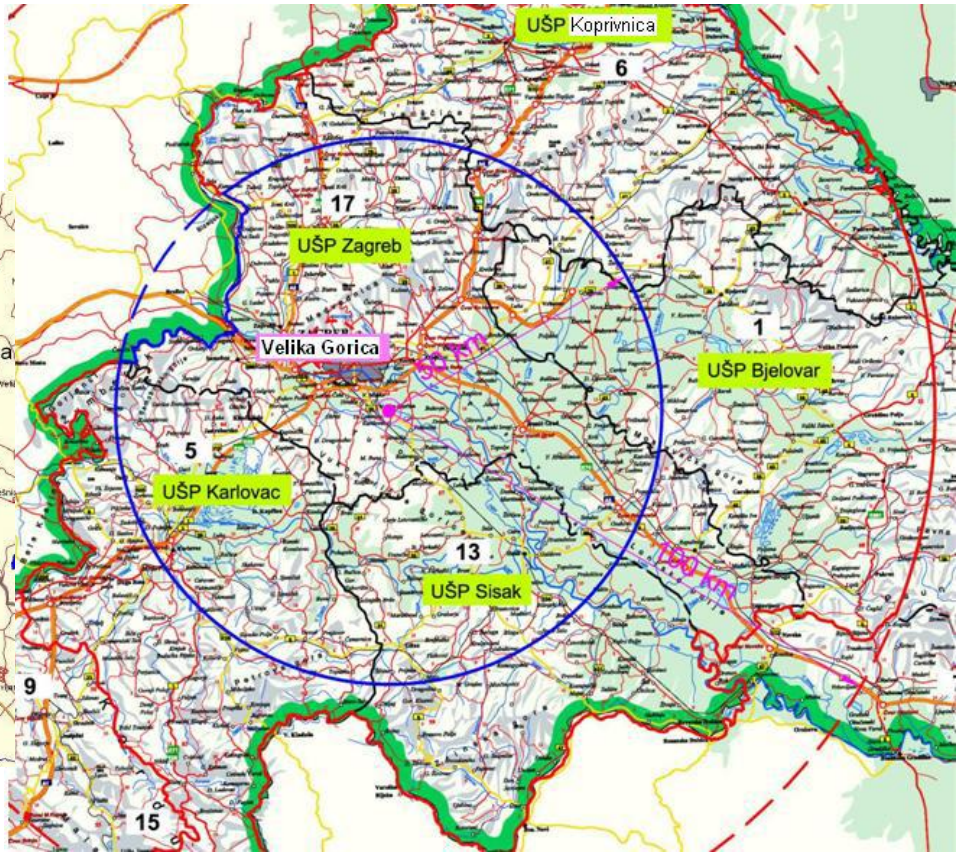
- **Irradiance in W/m² in a tilted surface of 34°**
- **Global radiation of 1364 kWh/m² in a tilted surface of 34°**

Hour	January	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6	0.00	0.00	0.03	9.67	43.84	54.33	46.94	19.87	1.43	0.00	0.00	0.00
7	0.00	0.04	19.45	90.23	171.77	160.97	154.35	127.94	66.47	10.48	0.03	0.00
8	0.65	26.43	143.81	221.43	323.45	296.47	318.94	297.29	184.63	119.29	25.80	0.52
9	107.94	144.18	292.00	355.60	457.52	436.20	475.23	469.35	316.33	237.13	105.33	62.84
10	188.68	277.21	390.61	462.10	586.74	567.63	609.97	610.26	413.53	330.81	158.63	138.35
11	256.90	386.29	464.23	563.47	682.45	661.93	733.35	715.71	471.20	400.39	214.50	173.97
12	294.48	413.14	505.58	606.17	655.23	689.10	651.32	679.19	511.23	442.71	258.97	201.84
13	262.03	392.82	520.81	556.27	679.68	694.03	682.87	645.03	513.97	430.77	263.53	186.77
14	293.52	456.32	505.00	521.30	601.84	626.20	627.29	584.84	488.67	433.26	300.40	226.03
15	239.19	397.96	394.65	446.47	509.45	531.43	557.52	494.32	407.87	345.29	235.37	168.52
16	129.58	255.32	273.42	324.33	393.84	406.17	415.65	383.65	261.73	194.68	115.47	78.13
17	2.48	113.79	154.29	204.63	254.23	272.50	284.68	239.03	142.53	61.13	0.80	0.00
18	0.00	1.36	28.26	80.67	119.19	142.23	143.23	106.29	34.50	0.45	0.00	0.00
19	0.00	0.00	0.10	6.67	29.00	49.97	46.29	17.03	0.47	0.00	0.00	0.00

Biomass resources

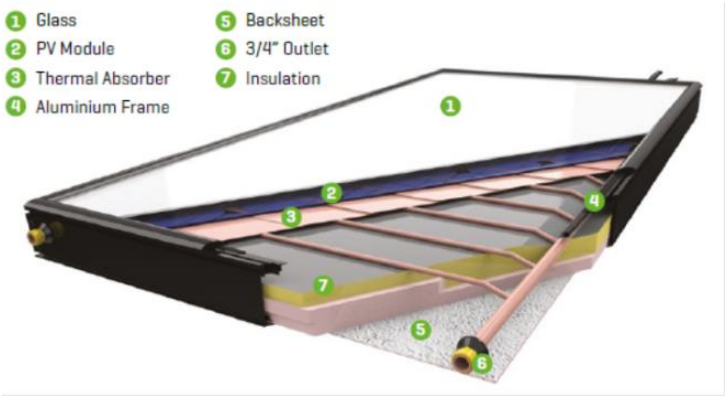
- 50 km -200.000 t
- 100 km-520.000t (w=35%)





Solar technologies

- **Solar thermal collectors**
  - **+ Developed technology. roof mounted. widely use**
  - **- Requires big portion of land**
- **Photovoltaic thermal system (PVT)**
  - **+ Co-generation of thermal and electrical energy. saves space. feasible depends on electricity price. combined advantages from solar thermal and PV**
  - **- Lower performance than thermal collectors**



Storage technology

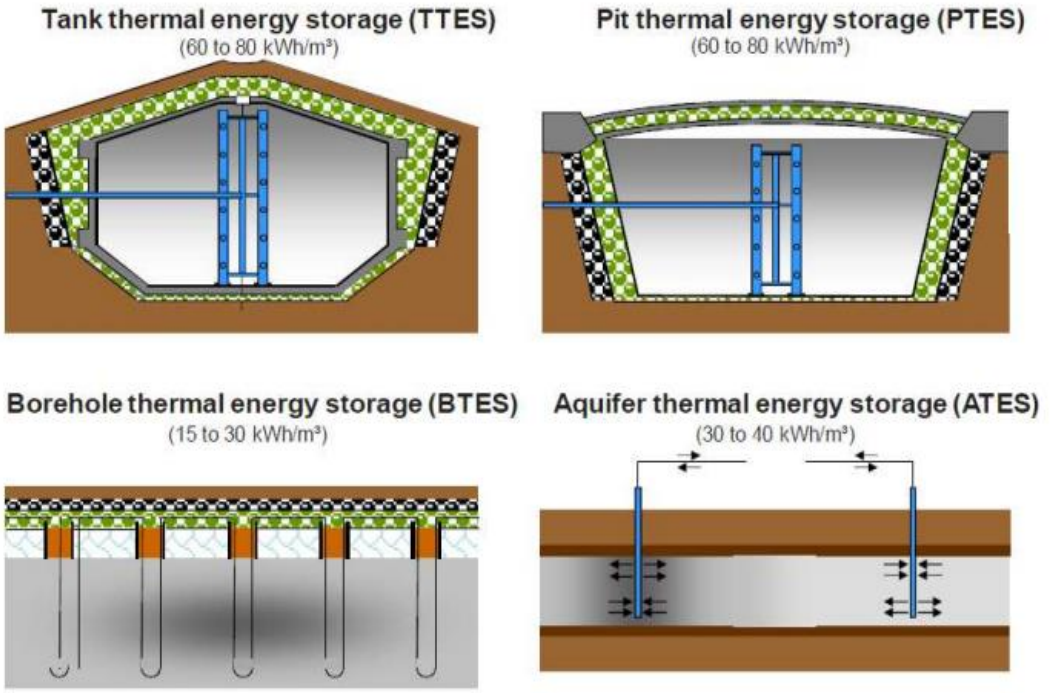
- **Seasonal storage**
  - **+ improve control for some technologies. reduces mismatch between supply and demand. storage materials low cost**
  - **- Heat losses.**

some technologies still in developing.

needed big surfaces.

- **Lake storage**

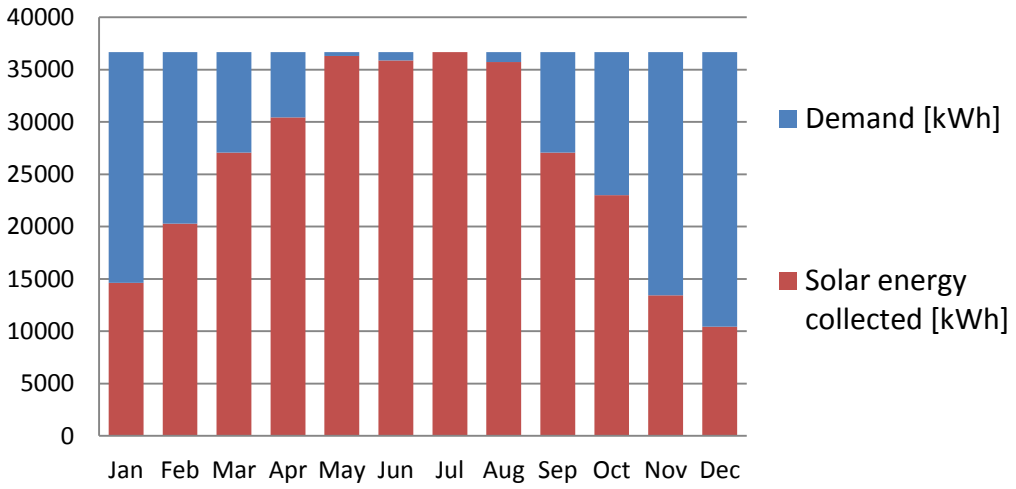
discarded



Residential scale solar energy

- **Model for residential buildings not conected to DH**
- ***f*-chart method of Klein and Beckman. results of many numerical experiments are correlated**
- **Provides a means for estimating the fraction of a total thermal load (Domestic Hot Water) that will be supplied by solar energy**
- **Example building J. Dobrile 18-24. 36667 kWh → 346 people**
- **Hybrid collector (Ecomesh) and thermal collector (Eborx Eco Classic 2.0) have been compared**

456 m² hybrid collectors 70% annual solar fraction



Residential scale solar energy

- **Compared with gas.**
- **With electricity and fuel oil Payback lower than 5 year in both technologies.**

											Grant 40%	
	Surface	SF	Payback	PV [25]	n_coll	Q_col	P_e	Investment	Investment / person	Solar cost	Payback	PV [25]
	[m2]	[%]	[years]	[€]	[%]	[KWh/m2]	[kWhe/m2]	[€]	[€/p]	[€/kWh]	[years]	[€]
hybrid	296.66	0.5034	15.78	167661	0.6615	746.64	153.6	268441	775.84	0.05759	9.47	274800
	374.9	0.6088	16.84	197046	0.6379	714.52	153.6	339239	980.46	0.06018	10.10	332442
	456.4	0.7065	18.8	221131	0.6134	681.12	153.6	412986	1193.60	0.06313	11.28	385960
	n	Surface	SF	Payback	PV [25]	n_coll	Q_col	Investment	Investment /person	Solar cost	Payback	PV [25]
		[m2]	[%]	[years]	[€]	[%]	[KWh/m2]	[€]	[€/p]	[€/kWh]	[years]	[€]
Thermal	145	263.61	50.98%	11.57	146721	62.52%	850.9	129229	373	0.0419	6.94	198413
	180	327.24	60.75%	12.05	168414	60.02%	816.8	160422	464	0.04365	7.23	232583
	220	399.96	70.71%	12.65	186693	57.16%	777.9	196071	567	0.04583	7.59	265122

Solar cost lower than 0.046 €/KWh (Current natural gas price in 2014, Eurostat)

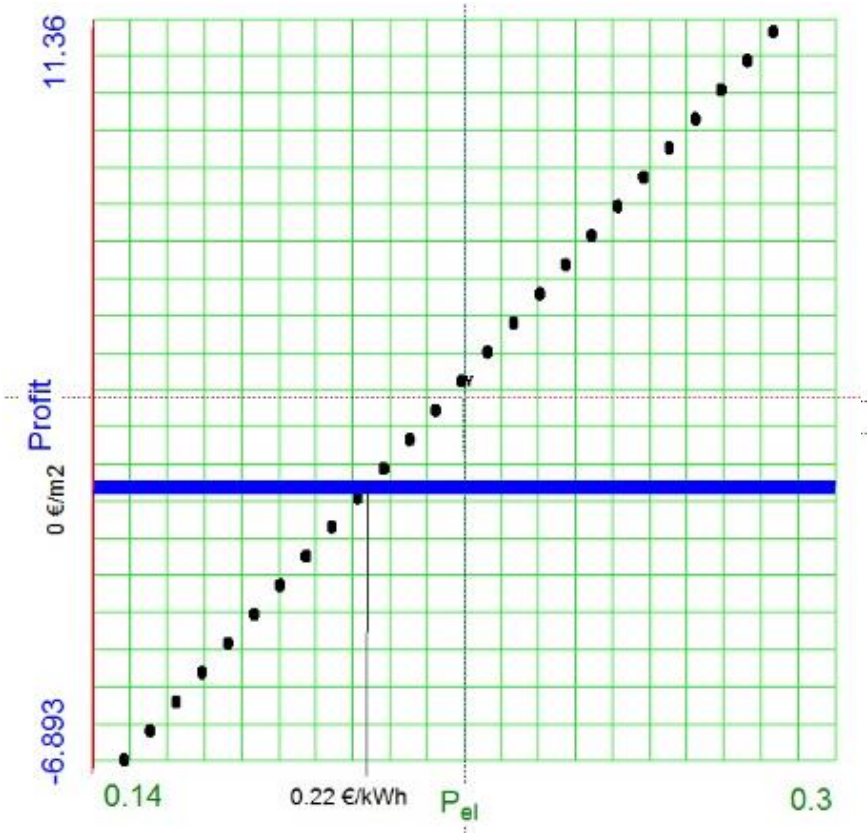
Solar energy for DH - Preheating

- **Model with hourly values for a typical day.**
- **Different collectors have been compared**

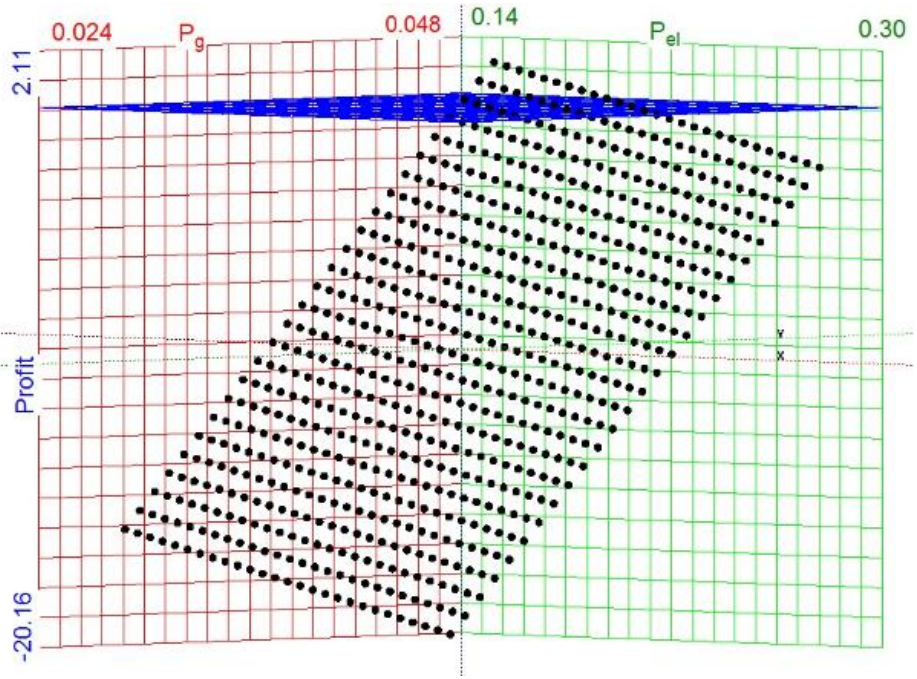
	Z	Csolar	PV 25 years
Collector	€/m^2 year	€/kWh	[€/m^2]
Ecomesh	61.41	0.06135	310.1
Powetherm	43.51	0.07688	29.05
M-240 PVT	91.48	0.09288	-333
SOLARUS	44.1	0.05967	206.6
Eborx eco classic 2.0	30.09	0.04168	211
Arcon solar HEATstore	25.3	0.02724	486.6

Solar energy for DH - Preheating

- **Small solar field**
- **Hybrid profitable at high electricity price**

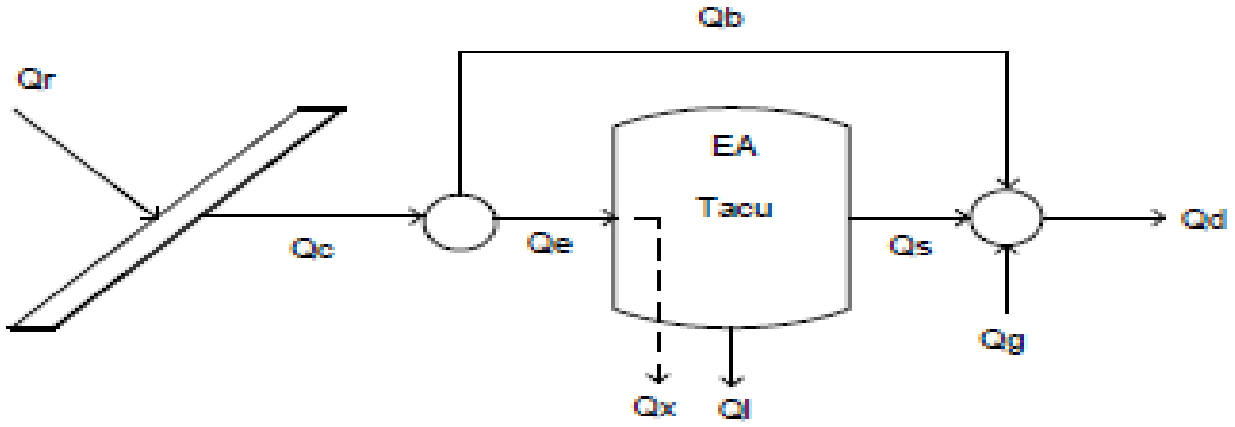


- **Large scale solar field**
- **Hybrid profitable at high electricity price. and low gas price**



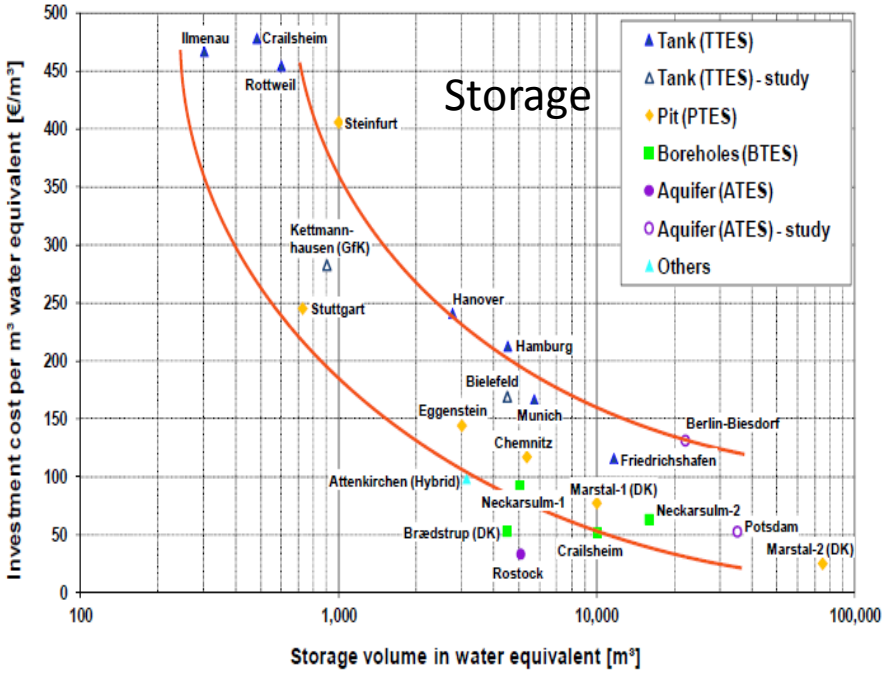
Solar energy for DH – Seasonal storage

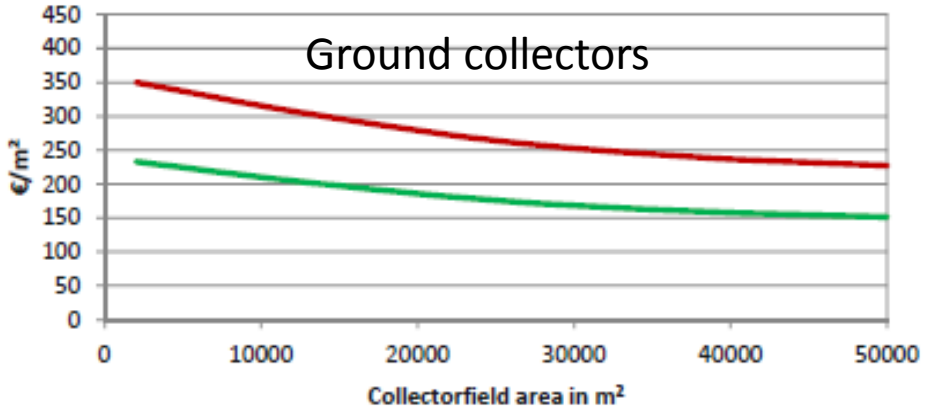
- **Model - Simple Method developed by Mateo de Guadalfajara. proposed by Solar heating and cooling SHC in the task 45 as an evaluation tool for Central Solar Heating Plants with Seasonal Storage**

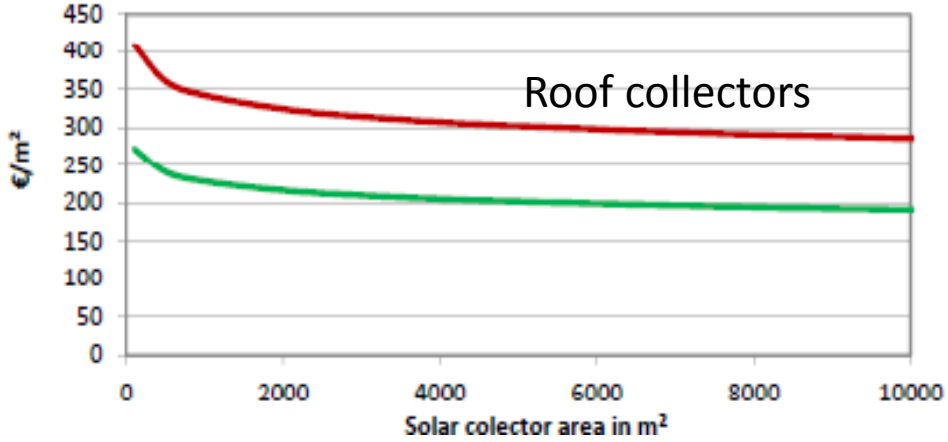


Solar energy for DH – Seasonal storage

- **Costs**







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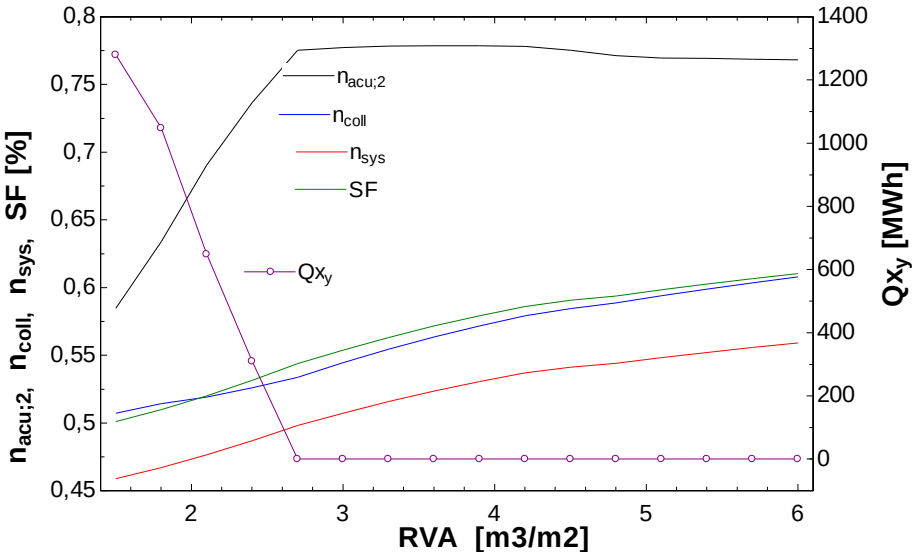
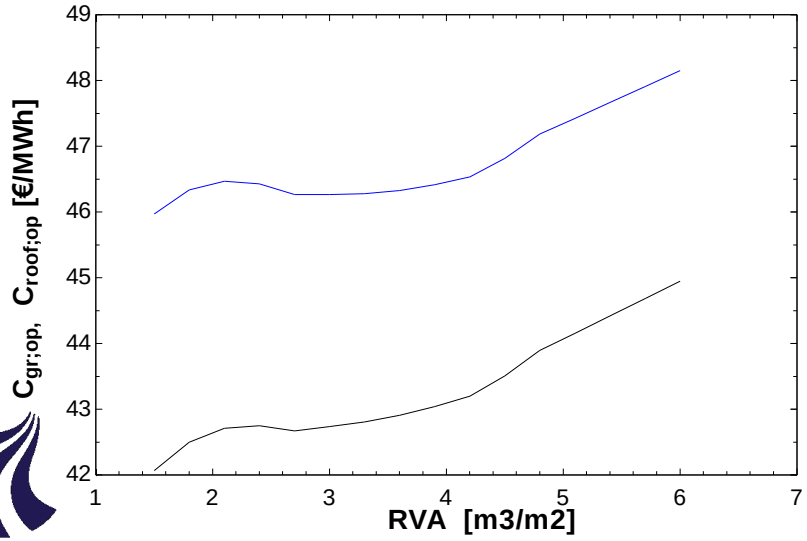
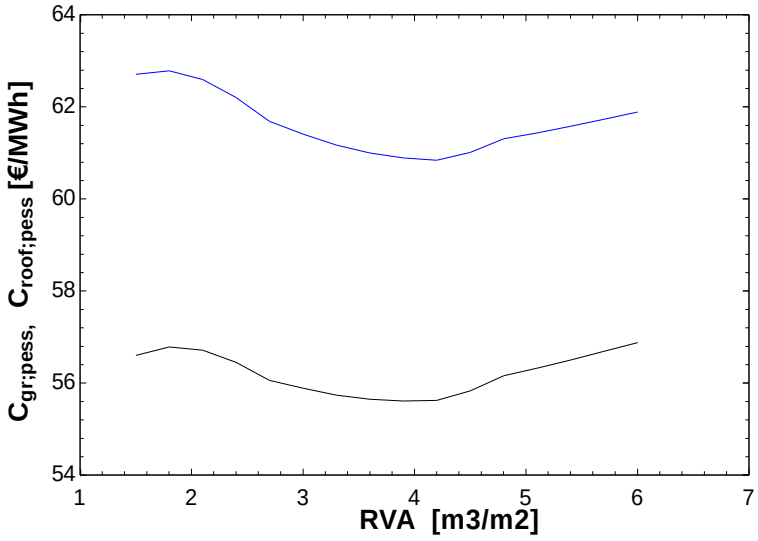
Seasonal storage – results



- **Fixed RAD (ratio of the area of the solar field in m². divided by the annual demand in MWh/year)**





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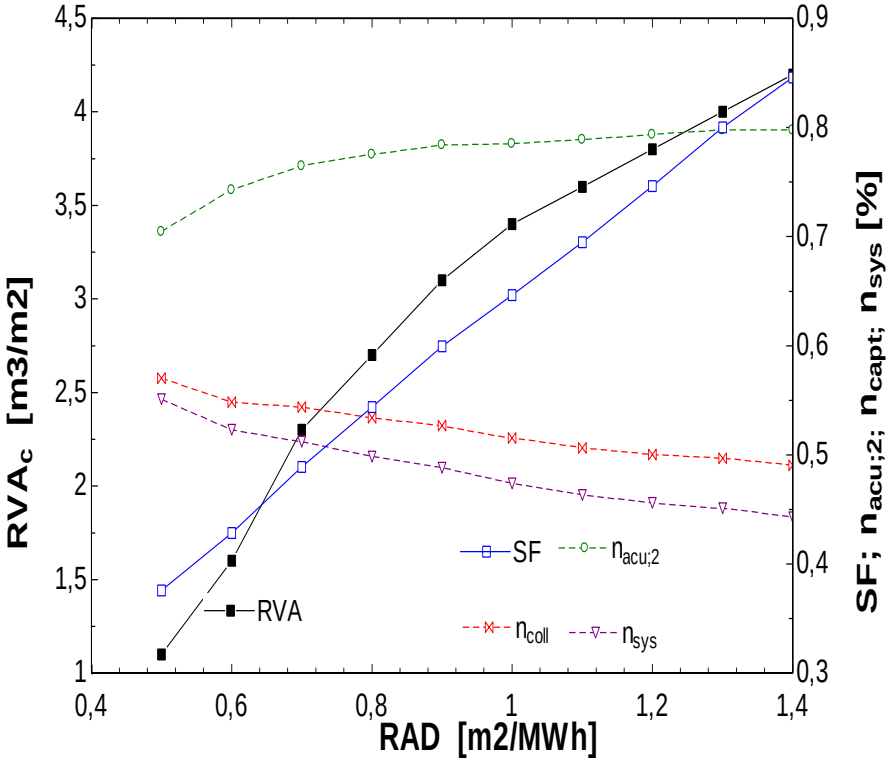
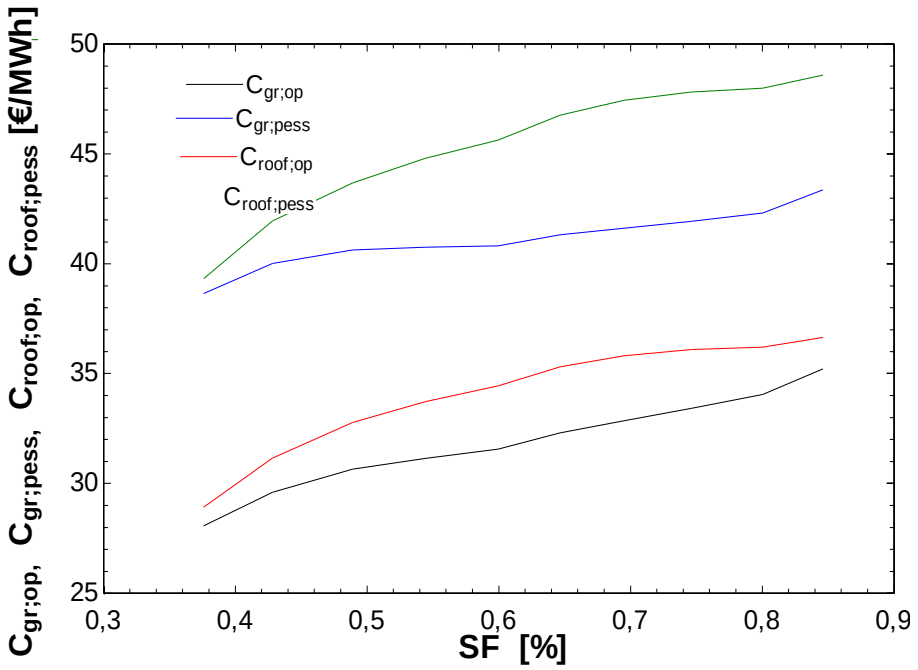
Seasonal storage – results



Critical volume criteria

- do not reject any heat produced
- reach the maximum usage of the accumulation



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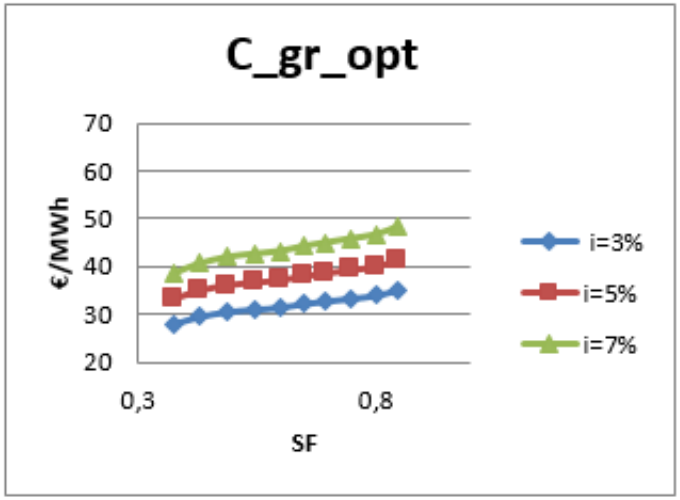
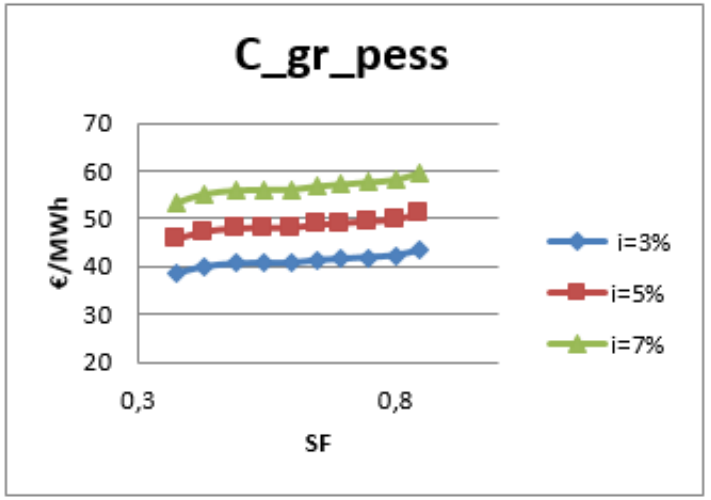
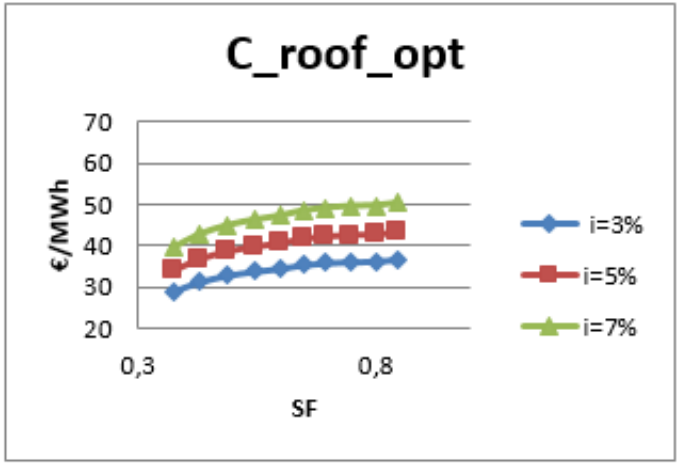
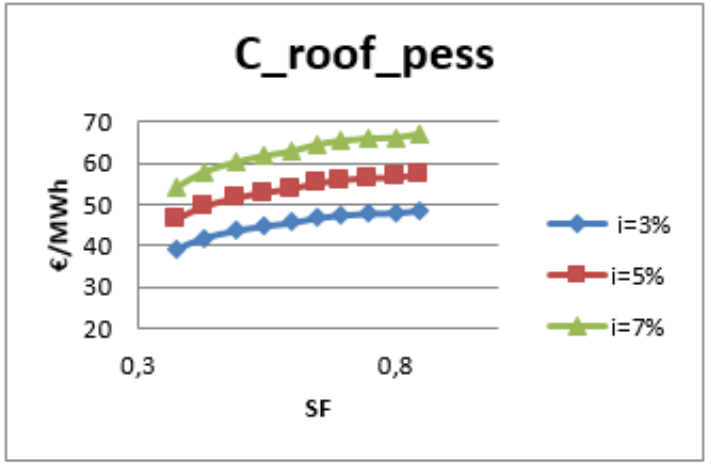
Seasonal storage – sensitivity analysis









Sensitivity analysis for different interest rates

Similar cost to solar district heating in Denmark, Nielsen

Utility company plans

- **Construction of DH system with two plants and expansion of distribution network**
- **Decommissioning of other boiler rooms**
- **Increase in energy efficiency**
- **Introduction of RES into the system**
- **Construction of optimization and remote control system**

Recommendations for future

- **Integration of all the plants → 2 plants. one solar plant and the other one gas operated or biomas power plant**
- **Decrease the working temperatures from 105°C/70°C to 50°C/30°C**
- **System with low losses**
- **40.4 potential GWh for domestic hot water demand 44 GWh for district heating**
- **Recommendations are in correlation with utility company plans**

Thank you for your attention!

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4th Generation District Heating Technologies and Systems

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