University of Zagreb
Faculty of Mechanical Engineering and Naval Architecture
DEPARTMENT OF ENERGY, POWER ENGINEERING AND ENVIRONMENT

Inovacijski centar Nikola Tesla

MOGUĆNOSTI KORIŠTENJA ENERGIJE SUNCA U CENTRALIZIRANIM TOPLINSKIM SUSTAVIMA U REPUBLICI HRVATSKOJ

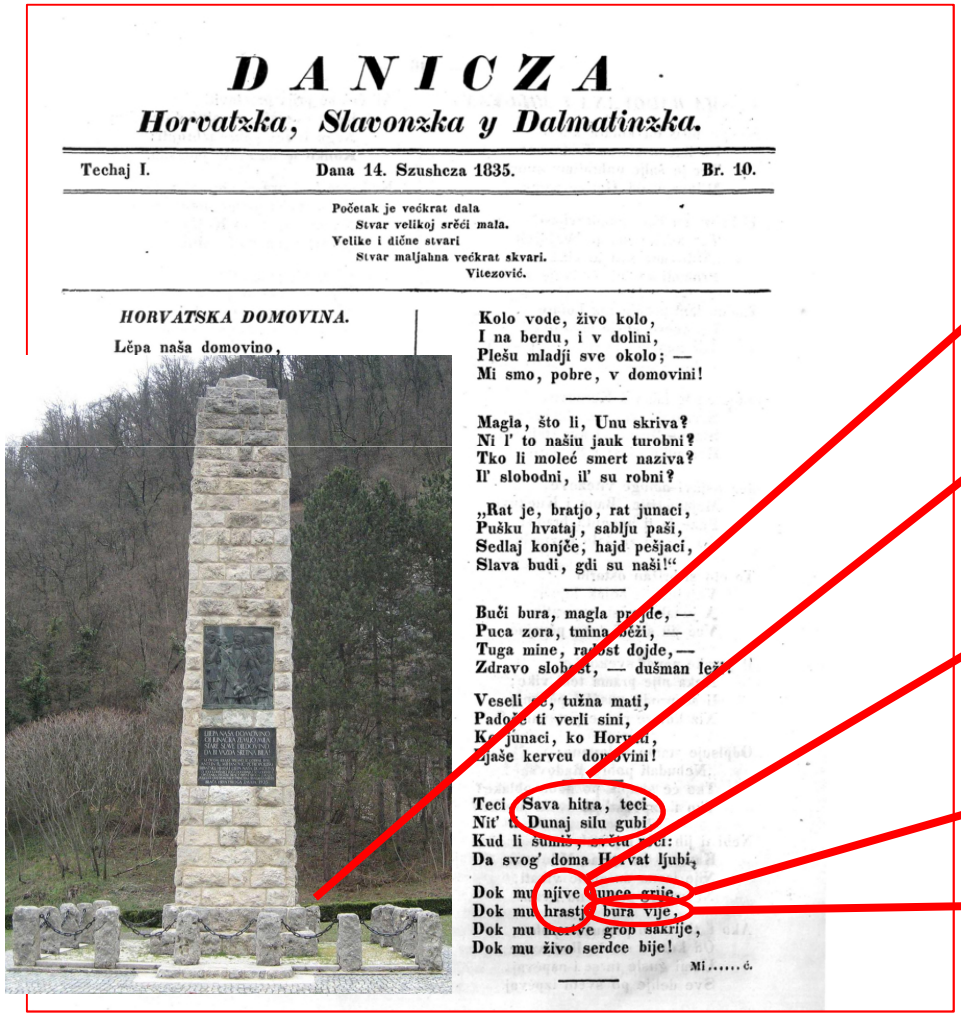
Doc.dr.sc. Goran Krajačić, FSB, Sveučilište u Zagrebu

OVOVREMENI IZAZOVI U ENERGETICI

Sveučilište u Zagrebu, Fakultet elektrotehnike i računarstva

Ponedjeljak, 24. travnja 2017., 14:00 sati

KAKO ODGOVORITI NA IZAZOVE U ENERGETICI?



DANICZA

Horvatzka, Slavonzka y Dalmatinzka.

Techaj I. Dana 14. Szushcza 1835. Br. 10.

Početak je većkrat dala
Stvar velikoj srčći mala.
Velike i dične stvari
Stvar maljahna većkrat skvari.
Vitezović.

HORVATSKA DOMOVINA.

Lěpa naša domovino,

Kolo vode, živo kolo,
I na berdu, i v dolini,
Plešu mladji sve okolo; —
Mi smo, pobre, v domovini!

Magla, što li, Unu skriva?
Ni l' to našiu jauk turobni?
Tko li moleć smert naziva?
Il' slobodni, il' su robni?

„Rat je, bratjo, rat junaci,
Pušku hvataj, sablju paši,
Sedlaj konjče, hajd pešjaci,
Slava budi, gdi su naši!"

Buči bura, magla prajde, —
Puca zora, tmina běži, —
Tuga mine, radost dojde, —
Zdravo slobošt, — dušman leži!

Veseli se, tužna mati,
Padoše ti verli sini,
Ko junaci, ko Horvati,
Ljaše kervcu domovini!

Teci, Sava hitra, teci
Nit' ti Dunaj silu gubi
Kud li sumiš, svěću reći:
Da svog' doma Hrvat ljubi,

Dok mu njive sunce grije,
Dok mu hrastje bura vije,
Dok mu mrtve grob sakrije,
Dok mu živo serdce bije!

Mi.....ć.

Geotermalna energija
125 MWt, 295 GWh, 2014

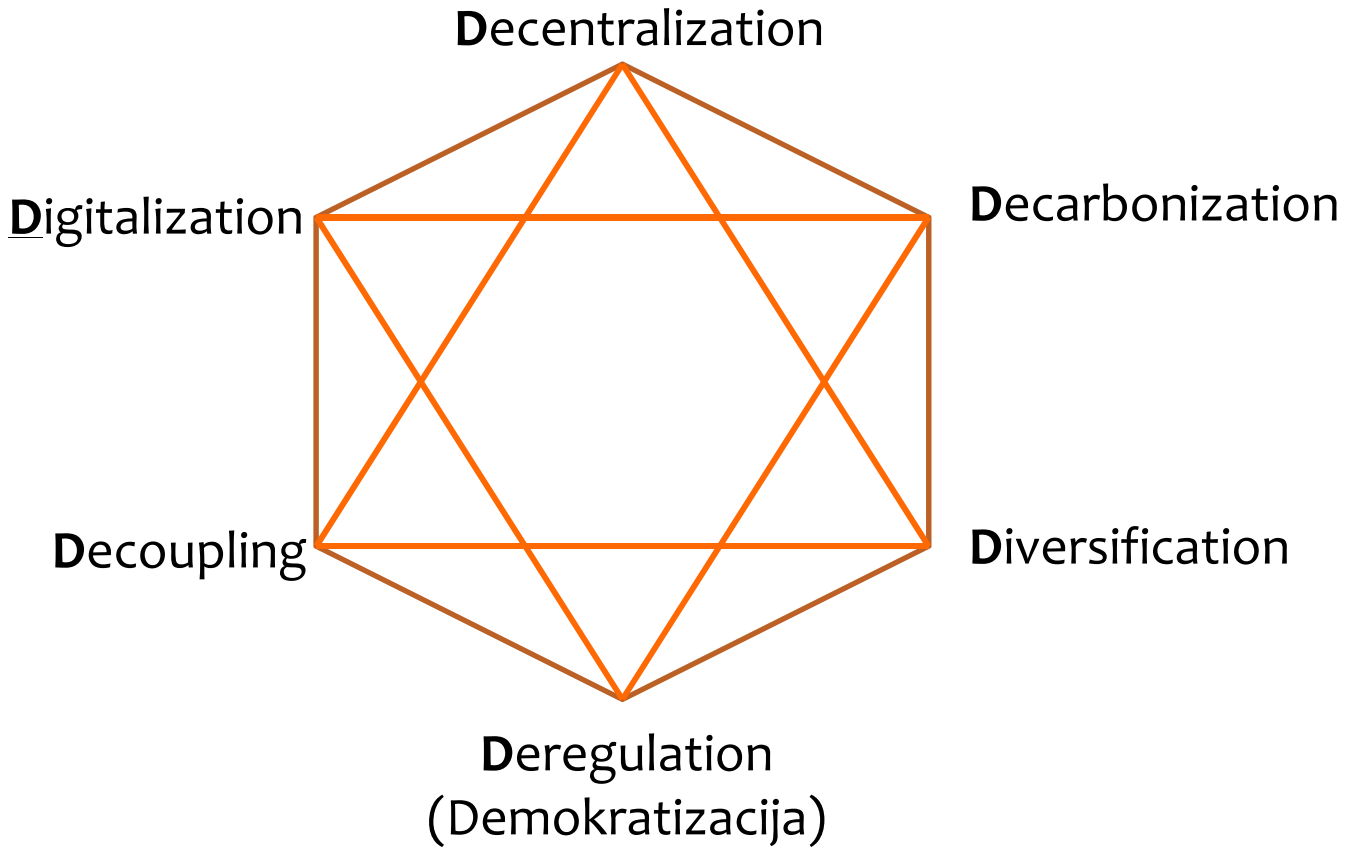
Hidroelektrane
2200 MW, 9000 GWh, 2014

Biomasa
(poljoprivreda i šume)
56 MWe, 388 GWh, 2016
515 MWt, 12600 GWh, 2014

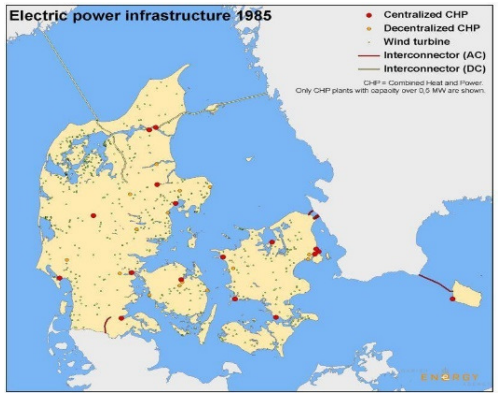
Energija Sunca
50 MWe, 61 GWh, 2016
113 MWt, 107 GWh, 2014

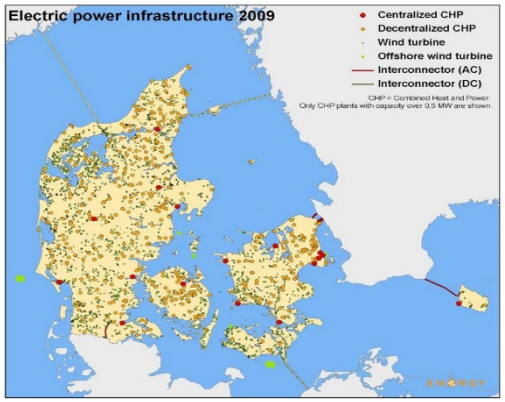
Vjetroelektrane
412 MW, 1018 GWh, 2016

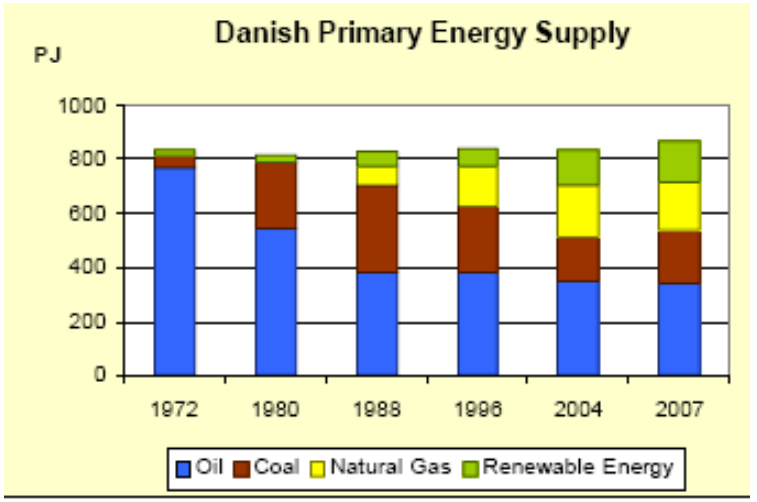
KAKO STRATEŠKI ODGOVORITI NA IZAZOVE U ENERGETICI?

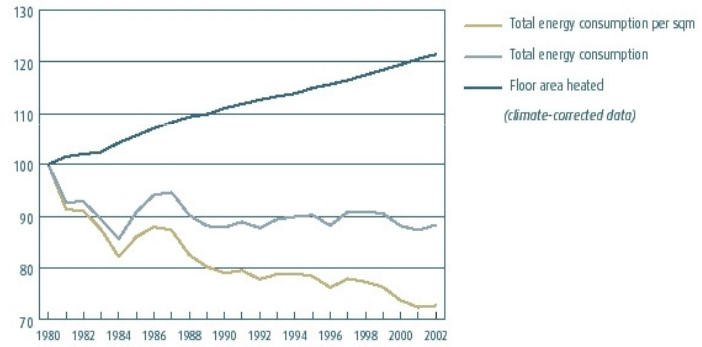


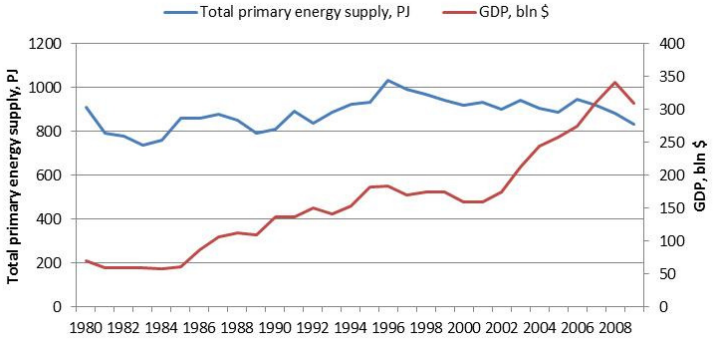
„6D” U DANSKOJ ENERGETSKOJ TRANZICIJI?

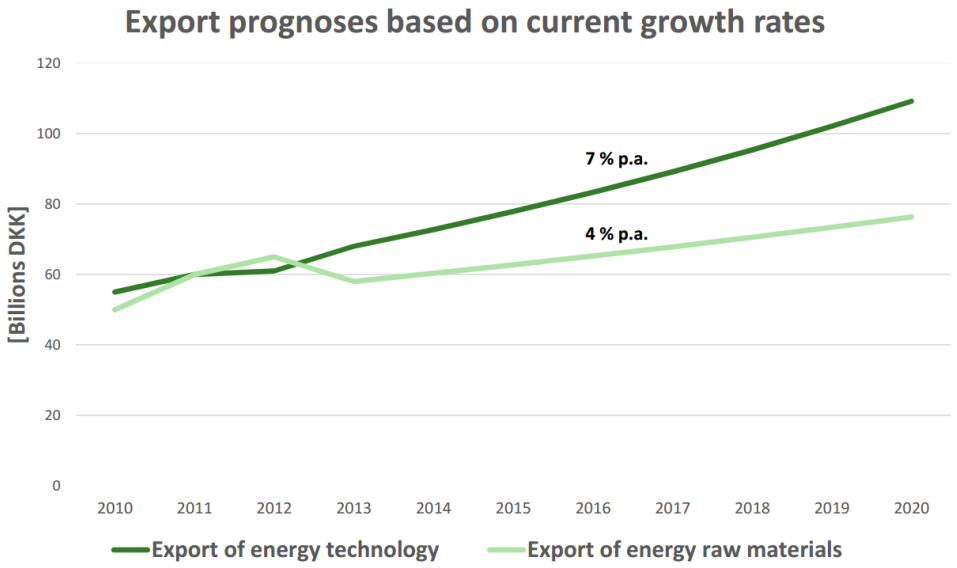




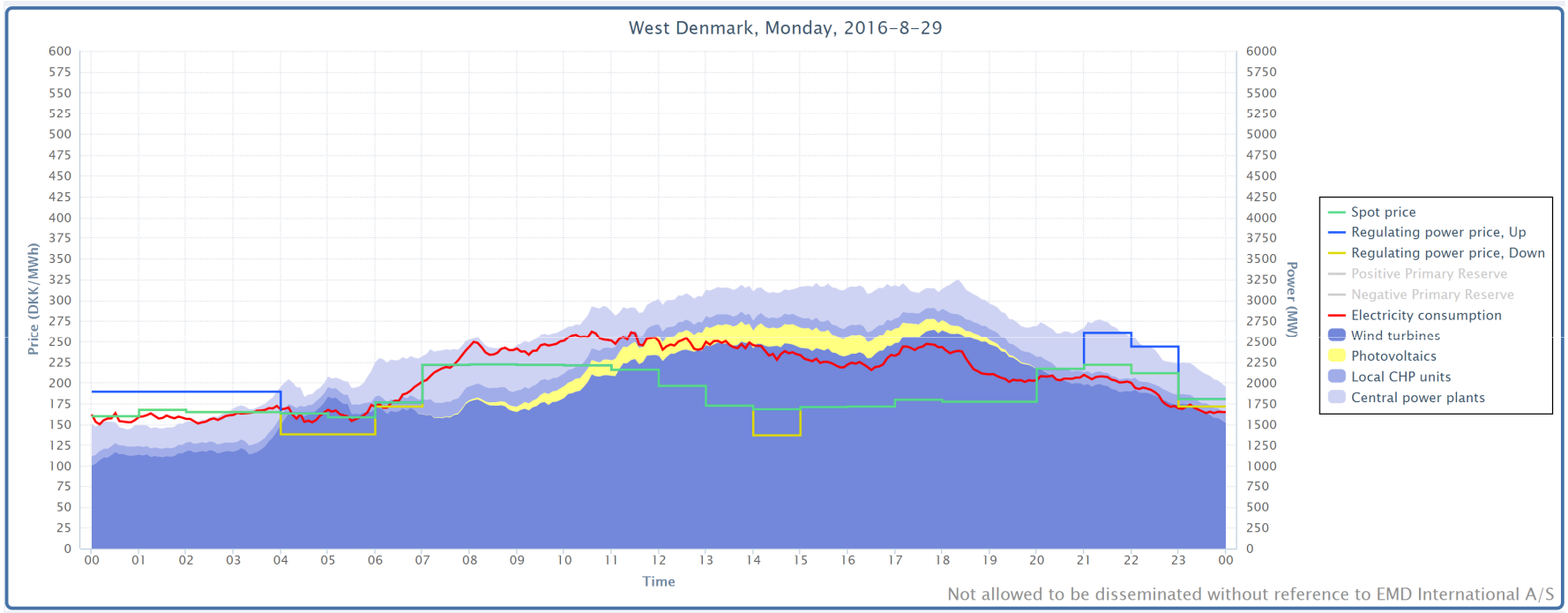


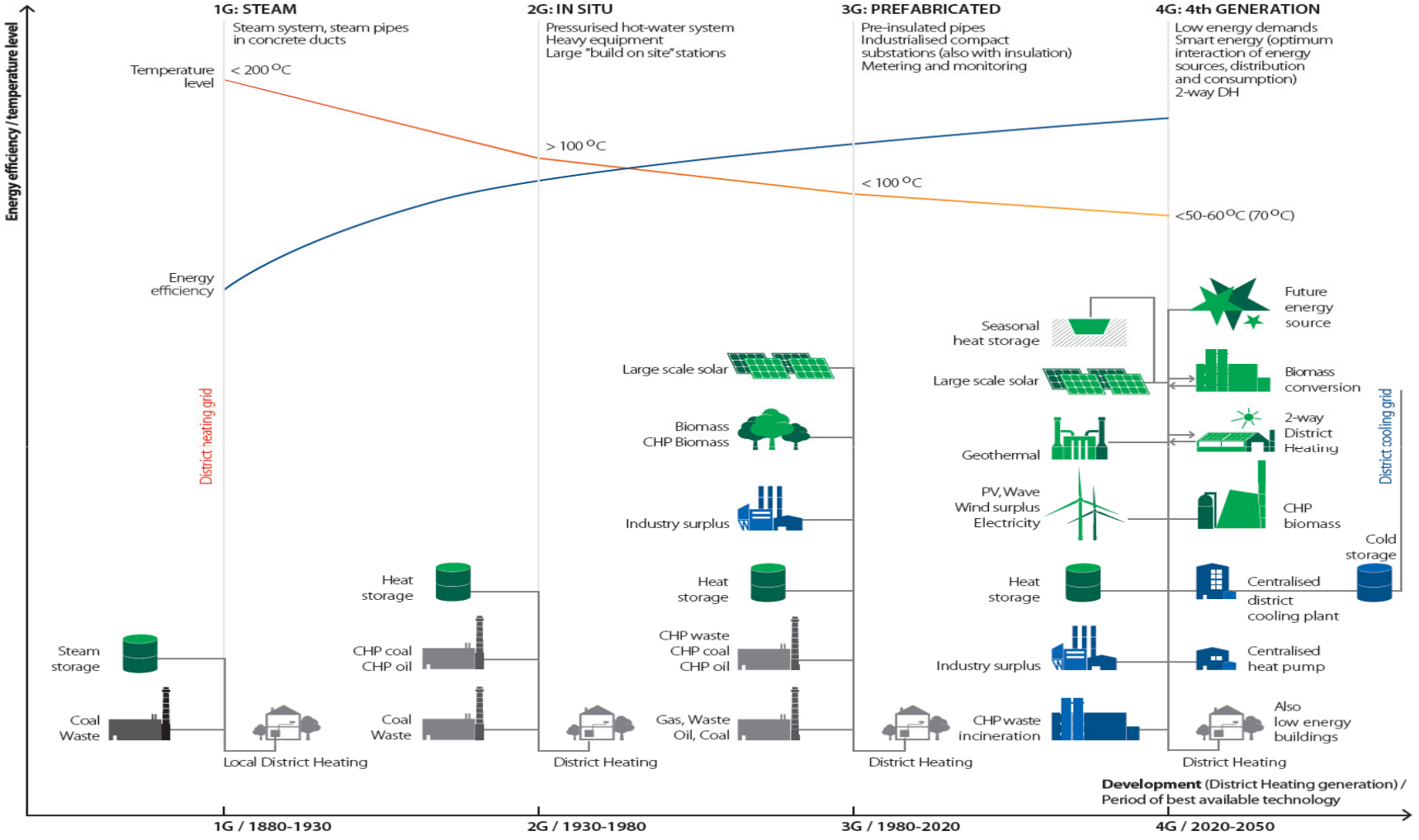






TRŽIŠTE I DOBAVA ELEKTRIČNE ENERGIJE ZAPADNA DANSKA

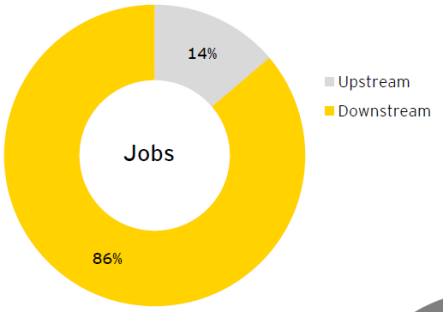


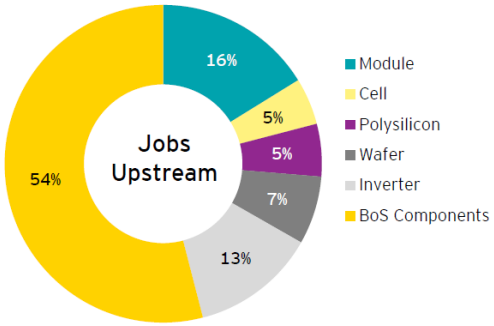

1G: STEAM
Steam system, steam pipes in concrete ducts
2G: IN SITU
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
3G: PREFABRICATED
Pre-insulated pipes
Industrialised compact substations (also with insulation)
Metering and monitoring
4G: 4th GENERATION
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
2-way DH
Energy efficiency / temperature level
Temperature level
< 200 °C
> 100 °C
< 100 °C
<50-60 °C (70 °C)
Energy efficiency
District heating grid
District cooling grid
Large scale solar
Biomass CHP Biomass
Industry surplus
Seasonal heat storage
Large scale solar
Geothermal
PV, Wave Wind surplus Electricity
Future energy source
Biomass conversion
2-way District Heating
CHP biomass
Cold storage
Heat storage
CHP coal CHP oil
Coal Waste
Steam storage
Coal Waste
Local District Heating
Heat storage
CHP waste CHP coal CHP oil
Gas, Waste Oil, Coal
District Heating
Heat storage
Industry surplus
CHP waste incineration
District Heating
Centralised district cooling plant
Centralised heat pump
Also low energy buildings
District Heating
Development (District Heating generation) / Period of best available technology
1G / 1880-1930
2G / 1930-1980
3G / 1980-2020
4G / 2020-2050

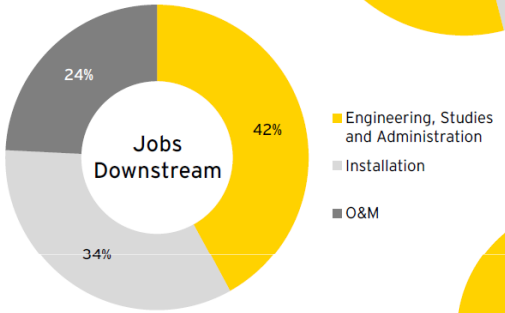
PV INDIKATORI PO ZEMLJAMA EU

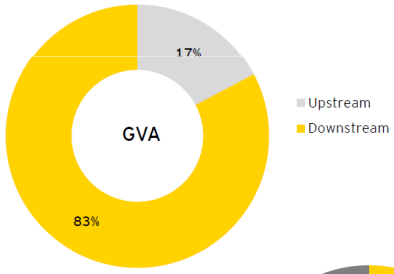
Zemlja	Instalirano 2015 [MW]	Kumulativno 2015 [MW]	kW/osobi	kW/GDP
Njemačka	1460	39640	0,4866	1068,46
Italija	300	18920	0,3104	700,74
Belgija	75	3200	0,2842	87,43
Grčka	10	2600	0,2414	160,49
Češka	n/a	2070	0,1965	131,01
Švicarska	280	1360	0,1645	18,63
Bugarska	n/a	1040	0,1447	165,08
Velika Britanija	3700	9080	0,1395	229,29
Danska	180	791	0,1394	16,55
Španjolska	49	5400	0,1163	232,76
Slovenija	1,4	240	0,1162	12,83
Austrija	170	940	0,1092	23,86
Slovačka	2	591	0,1089	40,76
Francuska	850	6550	0,0985	199,70
Nizozemska	400	1288	0,0757	32,20
Rumunjska	102	1301	0,0656	160,62
Portugal	28	460	0,0446	26,59
Hrvatska	10	44	0,0104	4,23

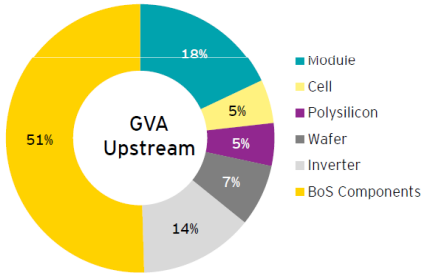
POSLOVI I DODANA VRIJEDNOST U PROIZVODNJI I INSTALACIJI PV SUSTAVA EU 28

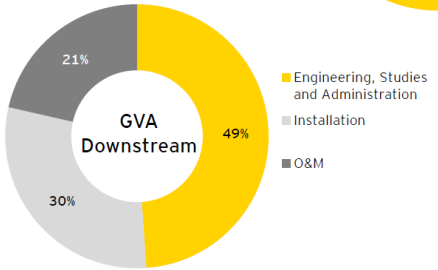












SolarPower Europe

Solar PV Jobs & Value Added in Europe
November 2015

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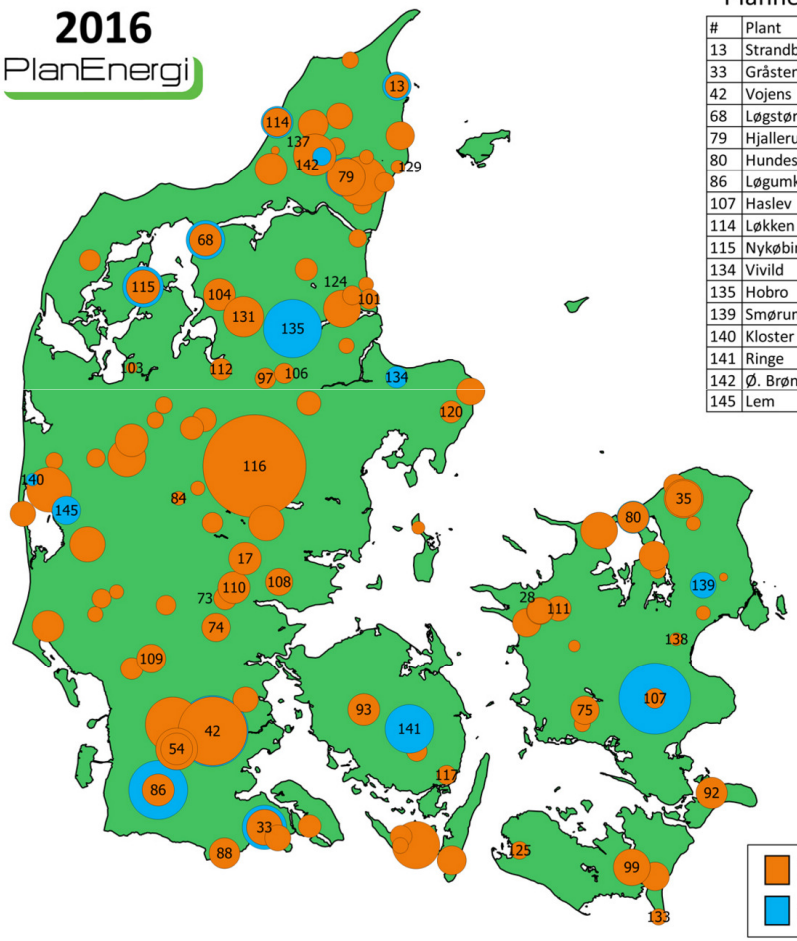
KORIŠTENJA ENERGIJE SUNCA U CENTRALIZIRANIM TOPLINSKIM SUSTAVIMA U DANSKOJ



Planned new & expansions

#	Plant	Collector area (m2)
13	Strandby	(8019)+4000
33	Gråsten	(19024)+11189
42	Vojens	(17500+52492)+5000
68	Løgstør	(15208)+7000
79	Hjallerup	(21546)+2500
80	Hundested	(14465)+1200
86	Løgumkloster	(9699+5576)+36000
107	Haslev	(6010)+70000
114	Løkken	(12096)+3000
115	Nykøbing Mors	(16708)+8000
134	Vivild	7000
135	Hobro	50000
139	Smørum	10000
140	Kloster	2300
141	Ringe	35000
142	Ø. Brønderslev	5000
145	Lem	12000

New plants & expansions in operation

#	Plant	Collector area (m2)
17	Tørring	(7284)+8467
28	Svebølle-Visking.	(7035+3000)+1000
35	Helsinge	(4733+14855)+3276
54	Toftlund	(11000)+15000
73	Bredsten - Balle	7800
74	Egtved	12000
75	Fuglebjerg	12000
84	Kølkær	2873
86	Løgumkloster	(9699)+5576
88	Padborg	13961
92	Stege	14515
93	Tommerup	15000
97	Ørum	6375
99	Øster Toreby	20000
101	Als (Mariagerfj.)	5947
103	Ejsing	1800
104	Farsø	15120
106	Hammershøj	6000
107	Haslev	6010
108	Hedensted	11000
109	Holsted	12500
110	Jelling	15290
111	Jyderup	9239
112	Løgstrup	7031
114	Løkken	12096
115	Nykøbing Mors	16708
116	Silkeborg	156694
117	Skårup (Sydfyn)	5418
120	Trustrup-Lyngby	7245
124	Veddum (VSV)	5500
125	Søllested	4701
129	Voerså	2873
131	Aalestrup	24129
133	Gedser	4000
137	Brønderslev	26929
138	Havdrup	2569

In operation	Total collector area (in operation): 1 302 331 m^2
Planned / planned expansion	Total collector area (planned): 269 189 m^2

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Solarna toplana u Dronninglundu, Danska instaliranog toplinskog kapaciteta 26 MW

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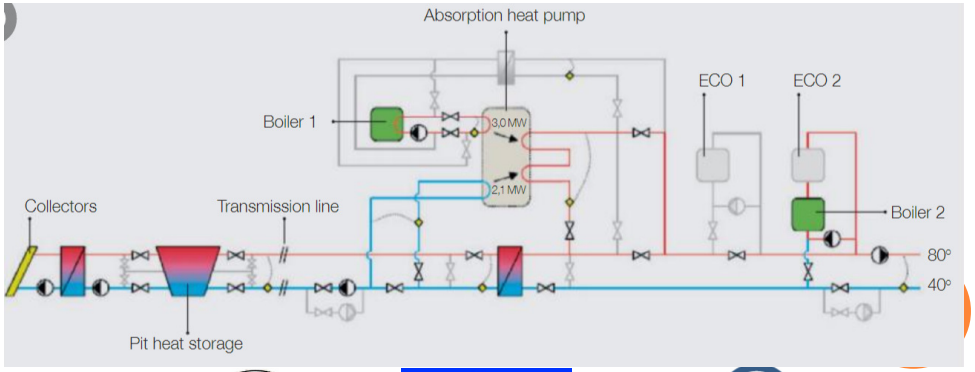
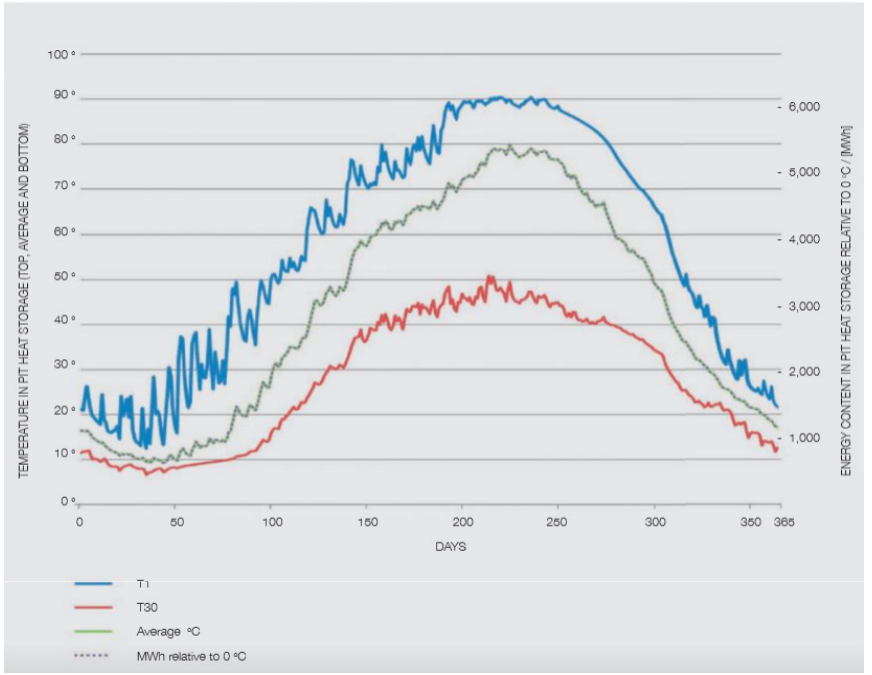
SOLARNA TOPLANA U DRONNINGLUNDU, DANSKA

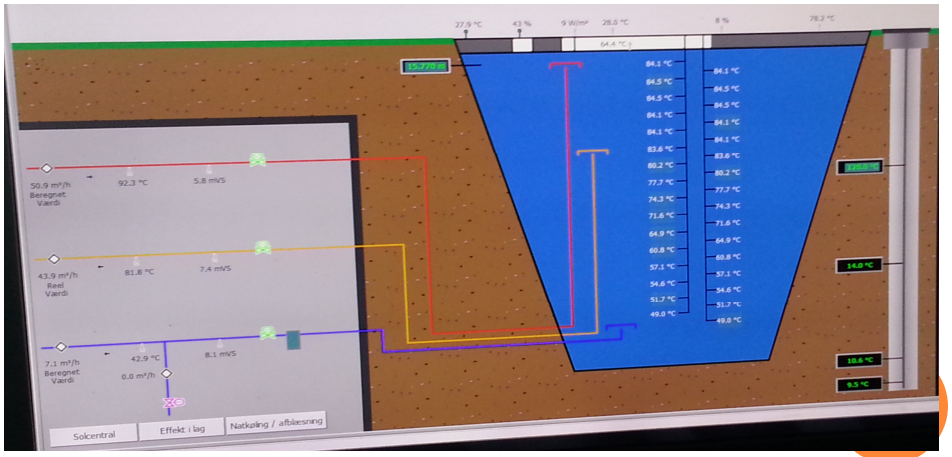
	Veličina	Jedinica	Jedinični trošak		Ukupni trošak [EUR]
Toplinski spremnik	62000	m^3	38,7	EUR/m^3	2.400.000
Zgrade					2.400.000
Solarni kolektori	37573	m^2	162,4	EUR/m^2	6.100.000
Cjevovodi CTS					1.340.000
Kotlovnica i dizalica topline					920.000
Troškovi financiranja (kamata), najam zemljišta					800.000
Ukupno troškovi opreme					13.960.000
Konzultanti/projektanti					673.000
EUDP subvencije					-2.953.000
Neto investicija					11.680.000



DRONNINGLUND, PROIZVODNJA

Mjesec	Proizvodnja topline u solarnoj toplani	Proizvodnja toplinske energije po m² solarnih kolektora	Dozračena sunčeva energija po m² površine
	(MWh)	(Wh/m²)	(Wh/m²)
Jan-16	144,57	3848	20503
Feb-16	886,36	23590	66777
Mar-16	1140,09	30343	82252
Apr-16	1908,12	50784	123807
May-16	2993,19	79663	166026
Jun-16	2485,28	66145	152909
Jul-16	1757,43	46774	132997
Aug-16	2014,00	53602	134509
Sep-16	1869,15	49747	130905
Oct-16	561,76	14951	52340
Nov-16	132,66	3531	28493
Dec-16	120,93	3219	21394





Stratego

STRATEŠKI PLANOVI ZA CENTRALIZIRANE TOPLINSKE SUSTAVE

Heat Roadmaps	Heat Savings	District Heating	Individual Heating Technology	District Heat Supply form Renewable Heat & Excess Heat*
	Reduction as a Percentage of the BAU 2050 Heat Demand	% of Total Heat Demand after Heat Savings (vs. % today)	Primary Technology	% of District Heat Production
Czech Republic	40%	40% (25%)	Heat pumps are recommended as the primary technology with small shares for biomass boilers, and solar thermal. The exact mix of each technology is not optimised.	60%
Croatia	40%	40% (15%)		45%
Italy	30%	60% (<5%)		35%
Romania	50%	40% (20%)		45%
United Kingdom	40%	70% (<5%)		40%

*Doesn't include excess heat from thermal power plants.

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Program korištenja potencijala za učinkovitost u grijanju i hlađenju za razdoblje 2016. – 2030.

Tablica 2 Podaci o energetskim subjektima u sektoru toplinarstva u Republici Hrvatskoj u 2013. godini.

Tvrtka	Grad	Broj potrošača	Grijana površina kućanstava	Grijana površina ostalih potrošača	Isporučena toplinska energija	Duljina distribuc. mreže	Gorivo **
		-	m^2	m^2	MWh	km	-
HEP Toplinarstvo d.o.o.*	Sisak	4.133	230.024	n/p	61.507	10	PP
	Osijek	11.692	602.063	n/p	180.702	56	PP, LU, LUEL
	Zagreb***	108.347	5.623.363	-	1.869.200	285	PP, LU, LUEL
Brod plin d.o.o.	Slavonski Brod	3.769	176.353	22.719	38.774	6	PP, LU
Plin VTC d.o.o.	Virovitica	483	23.517	6.613	3.430	1	PP
Hvidra d.o.o.	Split	908	62.864	1.711	2.204	1	LU, LUEL
Energo d.o.o.	Rijeka	10.010	537.776	42.908	73.639	16	PP, LU, LUEL
Grijanje Varaždin d.o.o.	Varaždin	1.860	99.791	4.102	16.180	2	PP
Tekija d.o.o.	Požega	417	19.839	-	2.378	1	PP
GTG Vinkovci d.o.o.	Vinkovci	1.698	86.352	2.845	8.919	2	PP, LU, LUEL
Tehnostan d.o.o.	Vukovar	3.712	186.271	19.236	19.128	7	PP, LUEL
Toplana d.o.o.	Karlovac	8.094	407.447	102.078	66.281	21	PP, LU, LUEL
Termalna voda d.o.o.	Topusko	191	8.980	14.837	-	2	GEO
Ivakop d.o.o.	Ivanić Grad	3	-	6.451	772	1	PP
SKG d.o.o.	Ogulin	192	7.503	4.187	8.545	1	LU, LUEL
UKUPNO		**155.509**	**8.072.143**	**227.687**	**2.351.659**	**412**	

** Uključuje i isporuku tehnološke pare*

*** PP-prirodni plin, LU-loživo ulje, LUEL-ekstralako loživo ulje, GEO-geotermalna*

**** HEP Toplinarstvo Zagreb uključuje Veliku Goricu, Zaprešić i Samobor*

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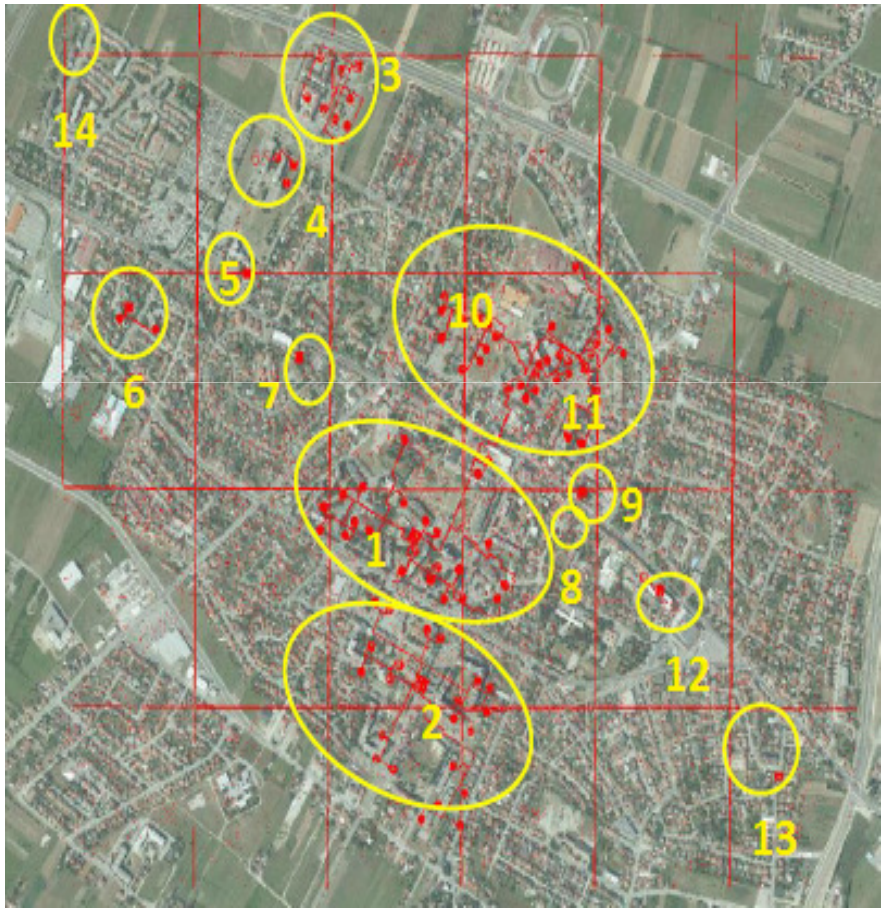
VELIKA GORICA



- 14 kotlovnica s 34 kotla
- 63.3 GWh proizvodnja
  60.76% prirodni plin
  39.24% loživo ulje

4DH
4th Generation District Heating Technologies and Systems

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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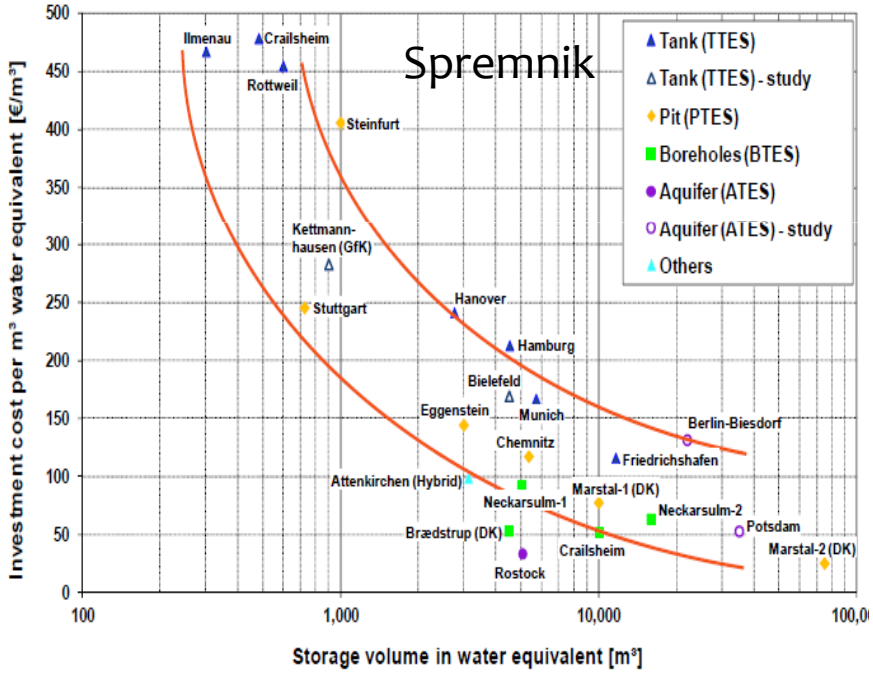
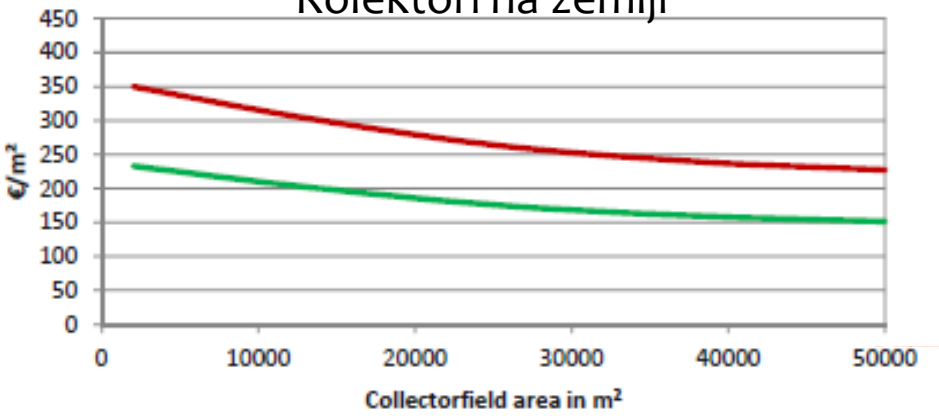
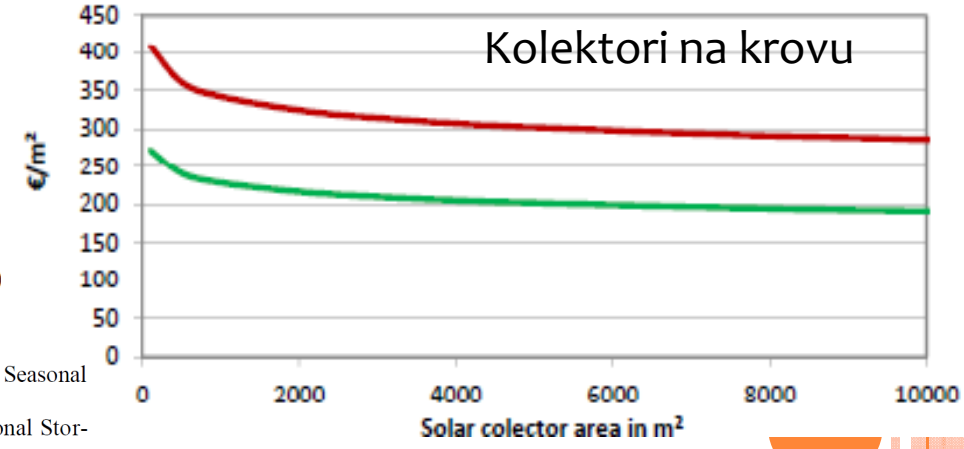
TROŠKOVI ZA SUSTAV U V. GORICI

Felipe Andreu Javier, Schneider Daniel Rolph, Krajačić Goran: ***Evaluation of integration of solar energy into the district heating system of the city of Velika Gorica***, Thermal Science 2016 Volume 20, Issue 4, Pages: 1049-1060 https://doi.org/10.2298/TSCI151106106A





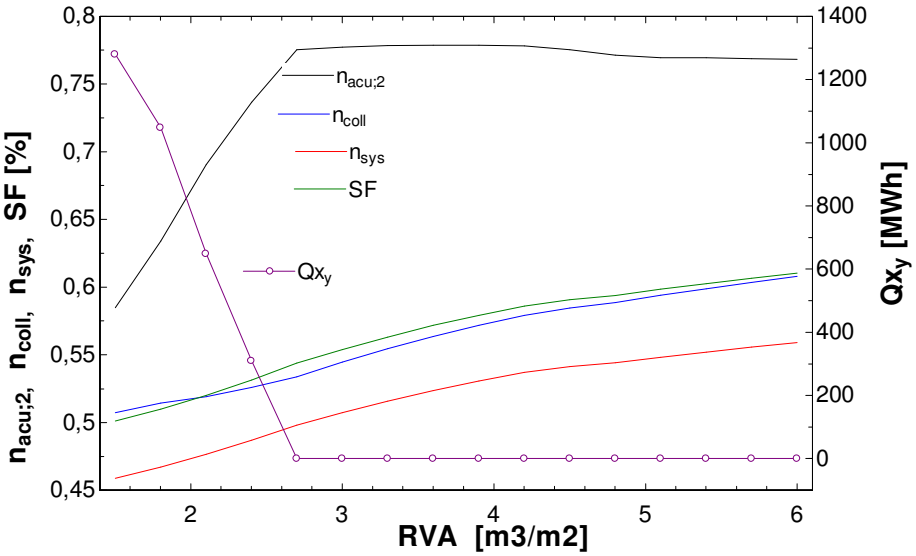


Guadalfajara, M., *et al.*, A Simple Method to Calculate Central Solar Heating Plants with Seasonal Storage, *Energy Procedia*, *48* (2014), Apr., pp. 1096-1109
Guadalfajara, M., *et al.*, Simple Calculation Tool for Central Solar Heating Plants with Seasonal Storage, *Solar Energy*, *120* (2015), Oct., pp. 72-86

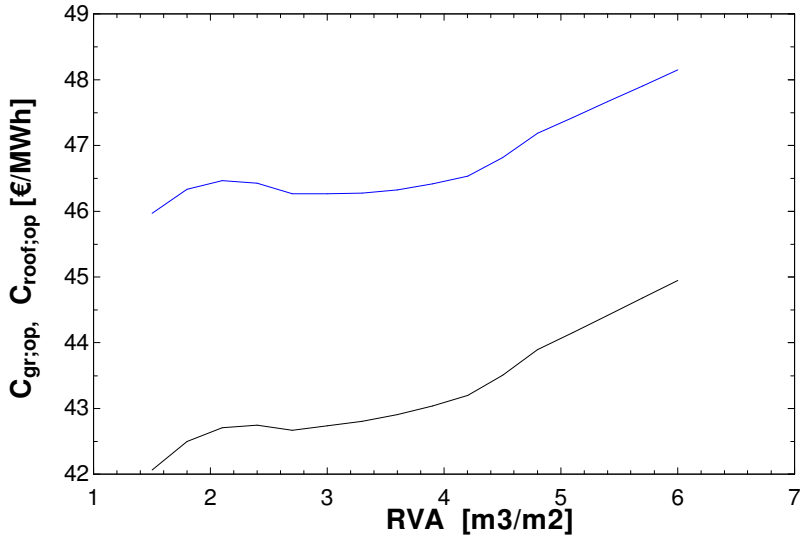
Felipe Andreu Javier, Schneider Daniel Rolph, Krajačić Goran: ***Evaluation of integration of solar energy into the district heating system of the city of Velika Gorica***, Thermal Science 2016 Volume 20, Issue 4, Pages: 1049-1060; https://doi.org/10.2298/TSCI151106106A

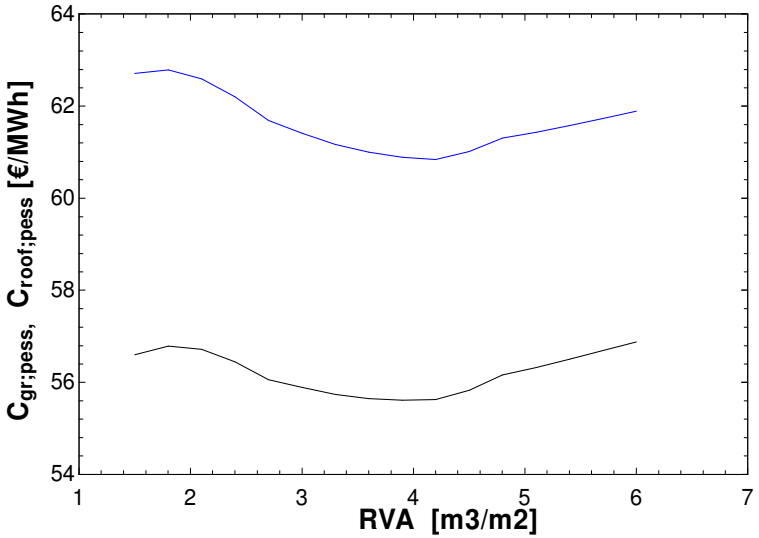
V.GORICA

4DH
4th Generation District Heating Technologies and Systems



fiksni RAD (omjer polja solarnog kolektora m² i potrošnje MWh/godišnje)





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sdewes

V. GORICA - REZULTATI

Felipe Andreu Javier, Schneider Daniel Rolph, Krajačić Goran: ***Evaluation of integration of solar energy into the district heating system of the city of Velika Gorica***, Thermal Science 2016 Volume 20, Issue 4, Pages: 1049-1060
https://doi.org/10.2298/TSCI151106106A

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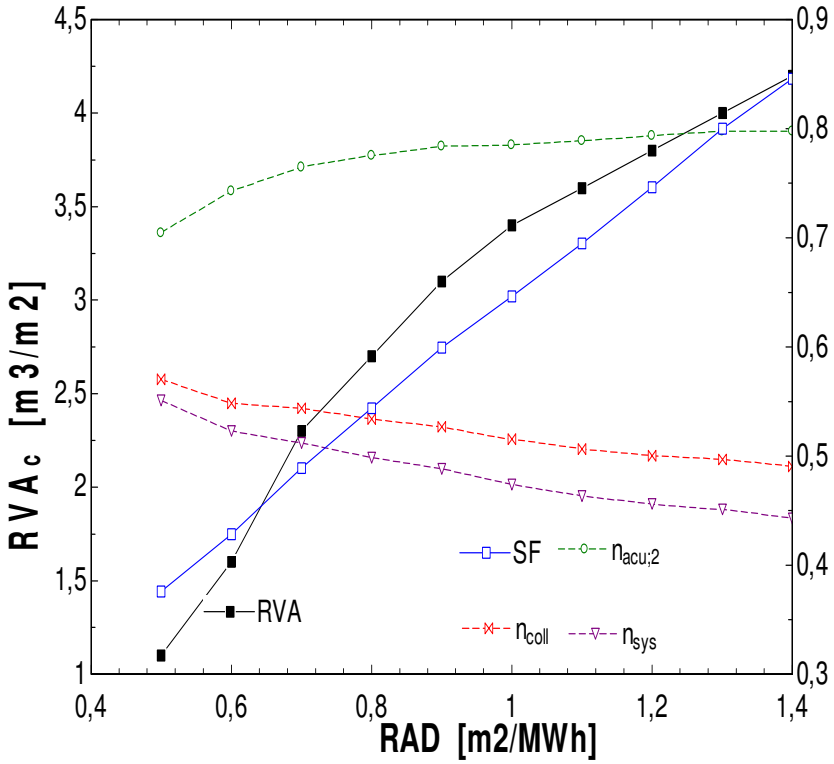
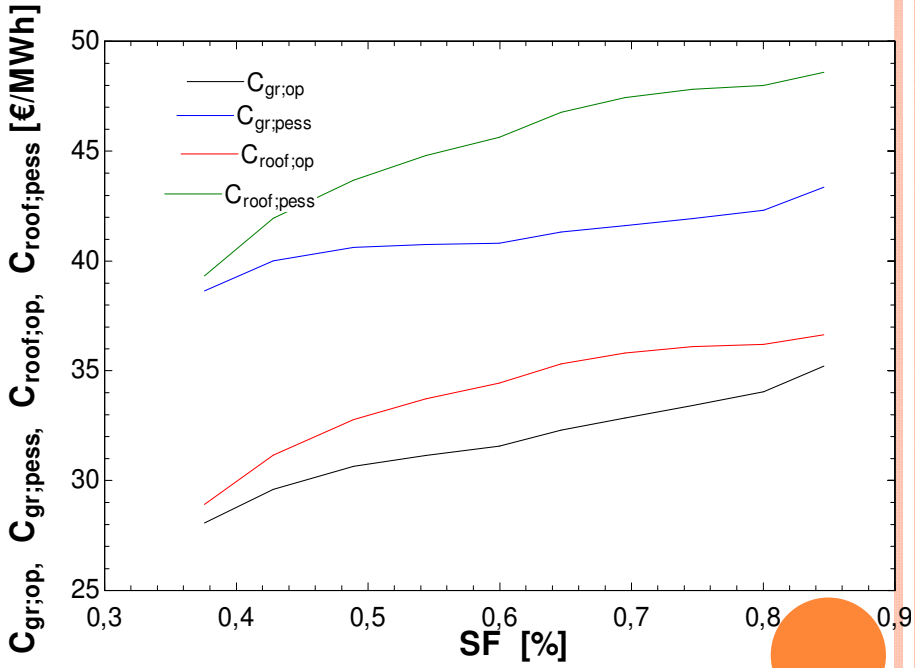


Kriteriji za spremnika

- Nema odbacivanja proizvodnje
- Maksimalno korištenje akumulirane topline



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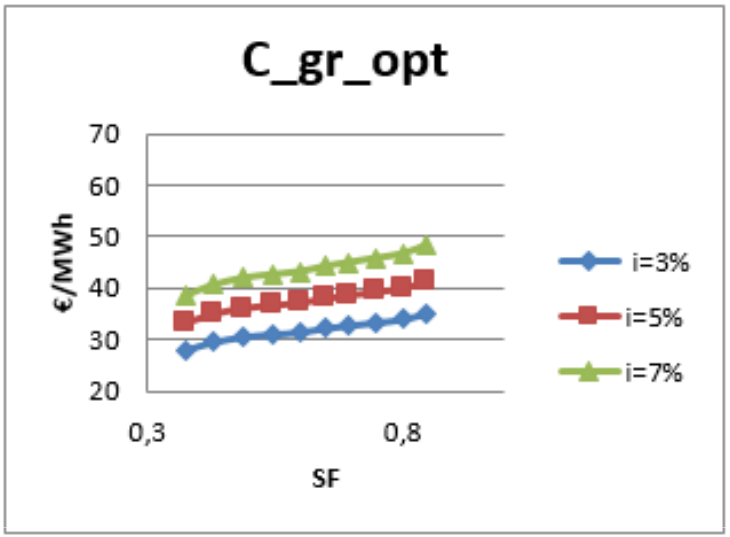
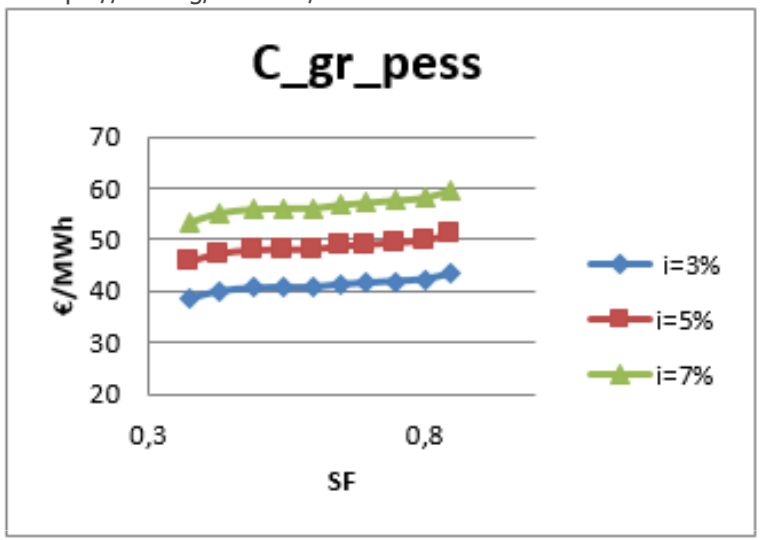
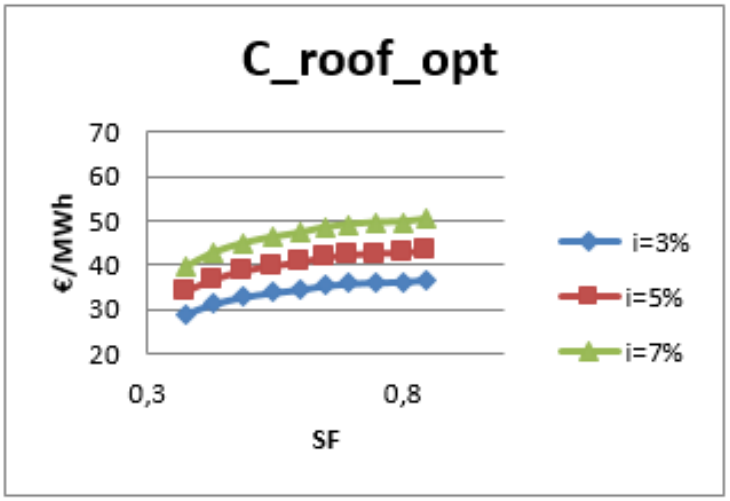
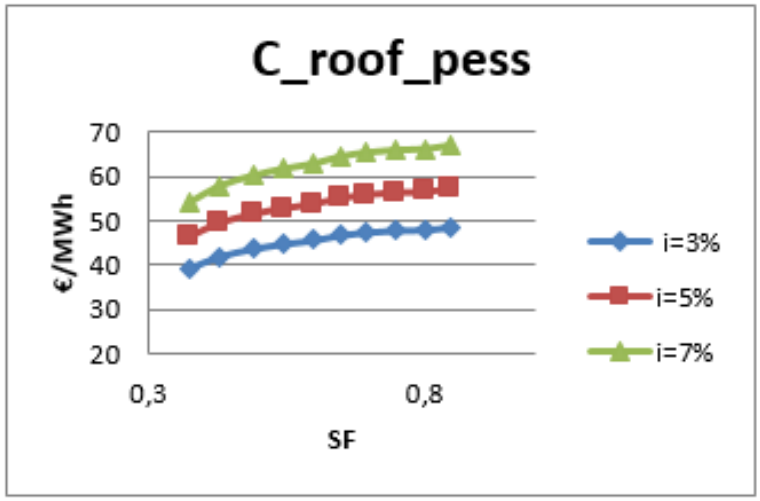




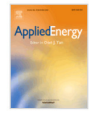




Sensitivity analysis for different interest rates

DEKARBONIZACIJA JI EUROPA

Applied Energy
Available online 19 March 2016
In Press, Corrected Proof — Note to users



Zero carbon energy system of South East Europe in 2050

D.F. Dominković[a], I. Bačeković[b], B. Ćosić[c], G. Krajačić[c], T. Pukšec[c], N. Duić[c], N. Markovska[d]

[a] Technical University of Denmark, Department of Energy Conversion and Storage, Frederiksborgvej 399, Roskilde, Denmark
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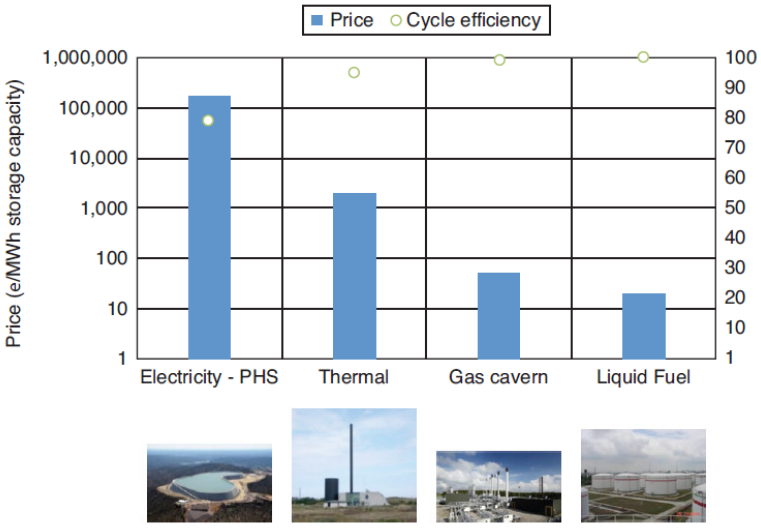
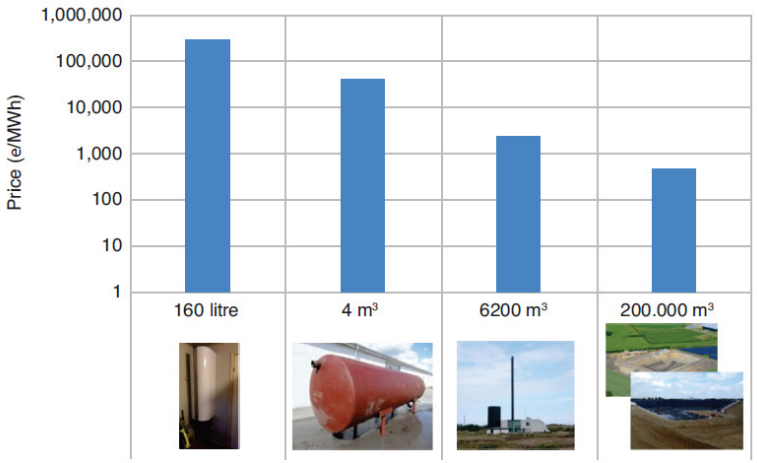
[d] Macedonian Academy of Sciences and Arts, Skopje, Macedonia

Received 23 November 2015, Revised 26 February 2016, Accepted 14 March 2016, Available online 19 March 2016

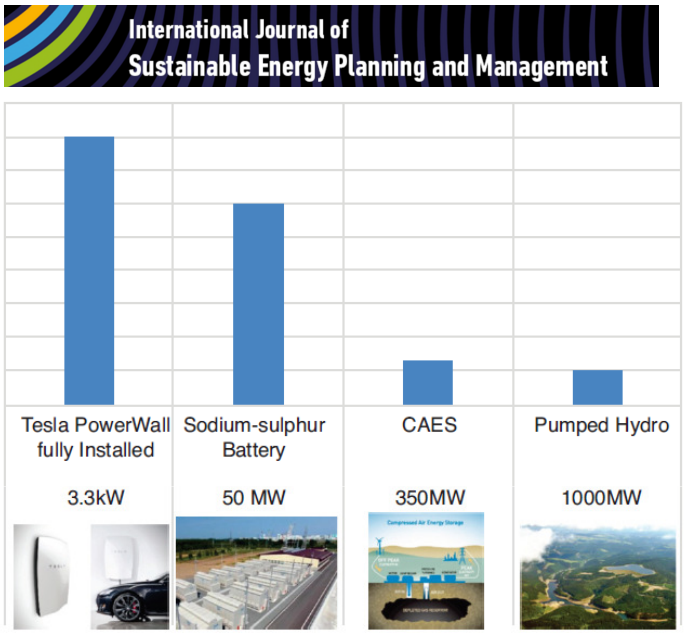
- PV: 65 GW
- Wind: 50 GW
- CSP: 11 GW
- Dammed hydro: from 18.8 to 23.5 GW
- Large-scale HPs: 1.5 GW
- Solar thermal with energy storage in DH: 13.3 %
- Seasonal thermal energy storage: 230 GWh
- Waste incineration plants: 0.96 GWe
- Geothermal plants: 1.25 GWe
- Geothermal heating plants: 7.5 GW
- River hydro, pumped-hydro 2 GW, 1000 GWh
- Decomission of nuclear PPs
- Reduction in thermal power plants capacity to 24.7 GW

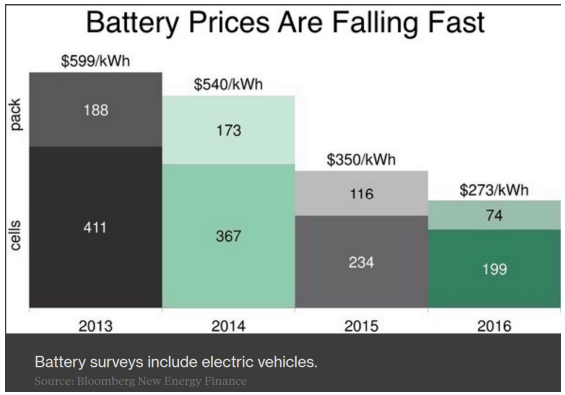
SKALDIŠTENJE ENERGIJE?





Source: Energy Storage and Smart Energy Systems
Henrik Lund, Poul Alberg Østergaard, David Connolly, Iva Ridjan, Brian Vad Mathiesen, Frede Hvelplund, Jakob Zinck Thellufsen, Peter Sorknæs





HRVATSKA ENERGETSKA TRANZICIJA

4dh

STRATEGO

CoolHeating

BEAST

HRE

Bin2Grid

AGROCYCLE

fosterREG

PlanHeat

goran.krajacic@fsb.hr