Allocation of investment costs for large-scale heat pumps supplying district heating

Pieper, Henrik; Ommen, Torben; Bühler, Fabian; Lava Paaske, Bjarke ; Elmegaard, Brian; Markussen, Wiebke Brix

Published in:
Energy Procedia

Link to article, DOI:
10.1016/j.egypro.2018.07.104

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Supplementary material of: Allocation of investment costs for large-scale heat pumps supplying district heating

Henrik Pieper[a], Torben Ommen[a], Fabian Bühler[a], Bjarke Lava Paaske[b], Brian Elmegaard[a], Wiebke Brix Markussen[a]

[a]*Technical University of Denmark, Nils Koppels Allé Building 403, Kgs. Lyngby, 2800, Denmark;* [b]*PlanEnergi, A.C. Meyers Vænge 15, København SV, 2450, Denmark*

Table 1. Collected and correlated (italic) data (in million DKK) of large-scale heat pump projects supplying district heating in Denmark. Information about investment costs were collected for 26 built HP projects and three planned projects mainly from [1,2], personal communication with a consultant firm [3] and direct communication with DH companies that have large-scale HPs installed. Additional information about twelve offers for HP units using industrial excess heat as heat source was provided by Buhler et al. [4]. The considered investment costs included both purchase and installation of equipment and consulting services.

#	Location	Heat source	Status	Year	Capacity [MW_{th}]	COP	Refrigerant	Temp. Heat sink [°C]	Temp. Heat source [°C]	Total investment costs, not including others (Mio. EUR)	Heat pump costs (Mio. EUR)	Heat source costs (Mio. EUR)	Construction costs (Mio. EUR)	Electricity-related costs (Mio. EUR)	Consulting cost (Mio. EUR)	Others (Mio. EUR)
1	Sig	Air	built	2017	0.8	3.6	Ammonia	64	Ambient	0.86	0.37	0.06	0.23	0.17	0.03	
2	Tønder	Air	built	2017	4.4	3.5	Ammonia	70	Ambient	*3.30*	*1.50*	0.56	0.58	*0.58*	0.08	0.30
3	Ringkøbing	Air	built	2017	4.4	4.5	Ammonia	70	Ambient	*2.59*	*1.50*	0.56	0.27	0.24	0.01	0.05
4	Høje Taastrup	District cooling	built	2016	2.3	3.1	Ammonia	75	-1	3.31	1.60	0	0.20	1.26	0.24	0.05
5	Skejby	District cooling	built		10.0		Ammonia	90		*7.40*	4.37	0	*0.86*	2.02	*0.16*	
6	Industry	Excess heat	offer	2012	1.2	4.6	Ammonia/ water	85	45	*1.90*	1.14	*0.30*	*0.13*	*0.17*	*0.16*	
7	Skjern	Excess heat	built	2012	4.0	5.0	Ammonia	70	43	*2.78*	1.21	0.27	0.40	0.74	*0.16*	1.14
8	Bjerringbro	Excess heat	built	2013	3.7	4.6	Ammonia	67	18	*2.72*	1.06	*0.44*	0.40	0.60	0.22	1.72
9	Industry	Excess heat	offer	2014	3.0	5.0	Ammonia	85	44	*2.58*	1.34	*0.41*	*0.27*	*0.40*	*0.16*	
10	Industry	Excess heat	offer	2014	1.3	3.7	Ammonia	85	30	*1.37*	0.68	*0.22*	*0.13*	*0.18*	*0.16*	
11	Industry	Excess heat	offer	2014	3.7	5.3	Ammonia	85	45	*3.18*	1.69	*0.51*	*0.34*	*0.49*	*0.16*	
12	Industry	Excess heat	offer	2014	6.6	3.5	Ammonia	80	32	*3.82*	1.61	*0.61*	*0.58*	*0.87*	*0.16*	
13	Industry	Excess heat	offer	2014	6.8	4.5	Ammonia	70	32	*4.19*	1.88	*0.67*	*0.60*	*0.89*	*0.16*	
14	Industry	Excess heat	offer	2014	6.5	4.3	Ammonia	80	32	*4.47*	2.18	*0.72*	*0.57*	*0.85*	*0.16*	
15	Industry	Excess heat	offer	2014	6.7	4.7	Ammonia	80	32	*5.01*	2.59	*0.80*	*0.58*	*0.87*	*0.16*	
16	Industry	Excess heat	offer	2014	6.8	4.8	Ammonia	70	32	*6.53*	3.84	*1.04*	*0.60*	*0.89*	*0.16*	
17	Industry	Excess heat	offer	2014	8.2	4.8	Ammonia	85	39	*5.18*	2.42	*0.83*	*0.71*	*1.07*	*0.16*	

18	Skjern	Excess heat	built	2015	1.4	3.9	Ammonia	70	33	*1.18*	*0.50*	*0.19*	*0.14*	*0.19*	*0.16*	
19	Randers	Excess heat	built	2016	1.0	6.3	Ammonia	60	30	*0.92*	*0.37*	*0.15*	*0.11*	*0.14*	*0.16*	
20	Løgstør	Excess heat	planned		0.9					*0.85*	*0.33*	*0.14*	*0.10*	*0.13*	*0.16*	
21	Industry	Excess heat	offer		8.1	4.7	Ammonia	85	37	*6.09*	3.19	*0.97*	*0.71*	*1.06*	*0.16*	
22	Industry	Excess heat	offer		4.0		Ammonia			*4.57*	2.80	*0.73*	*0.36*	*0.53*	*0.16*	
23	Bjerringbro	Flue gas	built	2010	0.8	5.1	Ammonia	45	40	0.40	0.13	0.13	0	0.13	*0*	
24	Brande	Flue gas	built	2010	0.7	4.2	Ammonia	52	40	*0.37*	0.17	0.03	*0.08*	*0.09*	*0*	
25	Bjerringbro	Flue gas	built	2011	0.5	5.2	Ammonia	42	40	0.27	0.11	0.03	0	0.13	*0*	
26	Vinderup	Flue gas	built	2011	0.7	5.2	Ammonia	48	40	*0.41*	0.24	0.05	0.03	*0.10*	*0*	
27	Hundested	Flue gas	built	2012	0.8	4.8	Ammonia	48	40	*0.45*	0.16	0.04	0.13	*0.11*	*0*	
28	Vejen	Flue gas	built	2013	1.1	5.2	Ammonia	52	40	*0.61*	0.28	*0.06*	*0.11*	*0.15*	*0*	
29	Skårup	Flue gas	built	2014	0.3					*0.23*	*0.11*	*0.02*	*0.05*	*0.05*	*0*	
30	Frederikssund	Flue gas	built	2014	0.9					*0.47*	*0.20*	*0.05*	*0.09*	*0.12*	*0*	
31	Spjald	Flue gas	built	2015	0.4					*0.30*	0.16	*0.03*	*0.06*	*0.06*	*0*	
32	Rye	Groundwater	built	2015	2.0	4.0	Ammonia	75	9	1.40	0.67	0.38	0.13	0.12	0.09	
33	Broager	Groundwater	built	2017	4.0	4.2	Ammonia	75	11	4.26	1.20	2.15	0.30	0.44	0.17	
34	Farstrup-Kølby	Groundwater	planned		0.8	4.0		78		1.21	0.34	0.44	0.15	0.09	0.19	
35	Dronninglund	Groundwater	planned		3.0	4.0	Ammonia	75	9	2.53	1.24	0.65	0	0.54	0.11	
36	Rødkærsbro	Sewage water	built	2017	1.5	4.6	Ammonia	70	22	1.47	0.77	0.31	0.04	0.15	0.20	0.31
37	Kalundborg	Sewage water	built	2017	10.0	4.5	Ammonia	72	25	6.36	3.49	0.28	0.91	1.34	0.32	2.16
38	Brædstrup	Solar/storage	built	2012	1.2	3.2	Ammonia	80	10	0.99	0.10	0.31	0.14		0.45	
39	Marstal	Solar/storage	built	2012	1.5	3.1	CO_2	75	10		0.32					
40	Gram	Solar/storage	built	2015	0.9	4.5		70	15	0.47						
41	Løgumkloster	Solar/storage	built	2015	1.3	5.3	Ammonia/ water	60	23	0.95			0			0.20

Table 2: Collected and correlated (italic) data (in million DKK) of large-scale heat pump projects supplying district heating in Denmark.

#	Location	Heat source	Status	Year	Capacity [MW_{th}]	COP	Refrigerant	Temp. Heat sink [°C]	Temp. Heat source [°C]	Total investment costs, not including others (Mio. DKK)	Heat pump costs (Mio. DKK)	Heat source costs (Mio. DKK)	Construction costs (Mio. DKK)	Electricity-related costs (Mio. DKK)	Consulting cost (Mio. DKK)	Others (Mio. DKK)
1	Sig	Air	built	2017	0.8	3.6	Ammonia	64	Ambient	6.40	2.72	0.48	1.70	1.30	0.20	
2	Tønder	Air	built	2017	4.4	3.5	Ammonia	70	Ambient	*24.58*	*11.18*	4.20	4.30	*4.31*	0.60	2.20
3	Ringkøbing	Air	built	2017	4.4	4.5	Ammonia	70	Ambient	*19.28*	*11.18*	4.20	2.00	1.80	0.10	0.40
4	Høje Taastrup	District cooling	built	2016	2.3	3.1	Ammonia	75	-1	24.60	11.90	0	1.50	9.40	1.80	0.40
5	Skejby	District cooling	built		10.0		Ammonia	90		*55.09*	32.50	0	*6.43*	15.00	*1.16*	
6	Industry	Excess heat	offer	2012	1.2	4.6	Ammonia/ water	85	45	*14.13*	8.50	*2.26*	*0.94*	*1.27*	*1.16*	
7	Skjern	Excess heat	built	2012	4.0	5.0	Ammonia	70	43	*20.66*	9.00	2.00	3.00	5.50	*1.16*	8.50
8	Bjerringbro	Excess heat	built	2013	3.7	4.6	Ammonia	67	18	*20.24*	7.90	*3.24*	3.00	4.50	1.60	12.80
9	Industry	Excess heat	offer	2014	3.0	5.0	Ammonia	85	44	*19.18*	9.95	*3.07*	*2.04*	*2.96*	*1.16*	
10	Industry	Excess heat	offer	2014	1.3	3.7	Ammonia	85	30	*10.20*	5.06	*1.63*	*1.00*	*1.36*	*1.16*	
11	Industry	Excess heat	offer	2014	3.7	5.3	Ammonia	85	45	*23.66*	12.54	*3.78*	*2.50*	*3.67*	*1.16*	
12	Industry	Excess heat	offer	2014	6.6	3.5	Ammonia	80	32	*28.43*	11.95	*4.55*	*4.32*	*6.45*	*1.16*	
13	Industry	Excess heat	offer	2014	6.8	4.5	Ammonia	70	32	*31.15*	13.95	*4.98*	*4.43*	*6.62*	*1.16*	
14	Industry	Excess heat	offer	2014	6.5	4.3	Ammonia	80	32	*33.25*	16.20	*5.32*	*4.24*	*6.33*	*1.16*	
15	Industry	Excess heat	offer	2014	6.7	4.7	Ammonia	80	32	*37.25*	19.30	*5.96*	*4.35*	*6.49*	*1.16*	
16	Industry	Excess heat	offer	2014	6.8	4.8	Ammonia	70	32	*48.59*	28.60	*7.77*	*4.43*	*6.62*	*1.16*	
17	Industry	Excess heat	offer	2014	8.2	4.8	Ammonia	85	39	*38.58*	18.00	*6.17*	*5.30*	*7.95*	*1.16*	
18	Skjern	Excess heat	built	2015	1.4	3.9	Ammonia	70	33	*8.75*	*3.73*	*1.40*	*1.04*	*1.43*	*1.16*	
19	Randers	Excess heat	built	2016	1.0	6.3	Ammonia	60	30	*6.82*	*2.74*	*1.09*	*0.79*	*1.04*	*1.16*	
20	Løgstør	Excess heat	planned		0.9					*6.33*	*2.49*	*1.01*	*0.73*	*0.94*	*1.16*	
21	Industry	Excess heat	offer		8.1	4.7	Ammonia	85	37	*45.33*	23.77	*7.25*	*5.26*	*7.89*	*1.16*	
22	Industry	Excess heat	offer		4.0		Ammonia			*34.03*	20.83	*5.44*	*2.67*	*3.92*	*1.16*	
23	Bjerringbro	Flue gas	built	2010	0.8	5.1	Ammonia	45	40	3.00	1.00	1.00	0	1.00	*0*	

24	Brande	Flue gas	built	2010	0.7	4.2	Ammonia	52	40	*2.77*	1.25	0.25	*0.57*	*0.70*	*0*	
25	Bjerringbro	Flue gas	built	2011	0.5	5.2	Ammonia	42	40	2.00	0.80	0.20	0	1.00	*0*	
26	Vinderup	Flue gas	built	2011	0.7	5.2	Ammonia	48	40	*3.08*	1.80	0.36	0.20	*0.72*	*0*	
27	Hundested	Flue gas	built	2012	0.8	4.8	Ammonia	48	40	*3.35*	1.20	0.30	1.00	*0.85*	*0*	
28	Vejen	Flue gas	built	2013	1.1	5.2	Ammonia	52	40	*4.52*	2.10	*0.43*	*0.85*	*1.14*	*0*	
29	Skårup	Flue gas	built	2014	0.3					*1.70*	*0.83*	*0.15*	*0.35*	*0.37*	*0*	
30	Frederikssund	Flue gas	built	2014	0.9					*3.46*	*1.52*	*0.35*	*0.70*	*0.90*	*0*	
31	Spjald	Flue gas	built	2015	0.4					*2.27*	1.20	*0.19*	*0.41*	*0.46*	*0*	
32	Rye	Groundwater	built	2015	2.0	4.0	Ammonia	75	9	10.40	5.00	2.80	1.00	0.90	0.70	
33	Broager	Groundwater	built	2017	4.0	4.2	Ammonia	75	11	31.70	8.90	16.00	2.20	3.30	1.30	
34	Farstrup-Kølby	Groundwater	planned		0.8	4.0		78		9.00	2.50	3.30	1.10	0.70	1.40	
35	Dronninglund	Groundwater	planned		3.0	4.0	Ammonia	75	9	18.85	9.20	4.85	0	4.00	0.80	
36	Rødkærsbro	Sewage water	built	2017	1.5	4.6	Ammonia	70	22	10.90	5.70	2.30	0.30	1.10	1.50	2.30
37	Kalundborg	Sewage water	built	2017	10.0	4.5	Ammonia	72	25	47.30	26.00	2.10	6.80	10.00	2.40	16.10
38	Brædstrup	Solar/storage	built	2012	1.2	3.2	Ammonia	80	10	7.39	0.75	2.30	1.02		3.32	
39	Marstal	Solar/storage	built	2012	1.5	3.1	CO_2	75	10		2.39					
40	Gram	Solar/storage	built	2015	0.9	4.5		70	15	3.50						
41	Løgumkloster	Solar/storage	built	2015	1.3	5.3	Ammonia/ water	60	23	7.09			0			1.50

References:

[1] Danish Energy Agency. Inspirationskatalog for store varmepumpeprojekter i fjernvarmesystemet (English: Inspiration catalogue for large-scale heat pump projects in district heating. 2017

[2] Danish Energy Agency. Large heat pumps in district heating systems (in Danish: Store varmepumper i fjernvarmeforsyningen) 2016

[3] PlanEnergi. Large-Scale Heat Pumps 2018. http://planenergi.eu/activities/district-heating/heat-pumps/ (accessed January 31, 2018)

[4] Bühler F, Petrović S, Holm FM, Karlsson K, Elmegaard B. Spatiotemporal and economic analysis of industrial excess heat as a resource for district heating. Energy 2018. doi:10.1016/j.energy.2018.03.059