

Energinet.dk  
Project no.  
2006-2-6750

## **Annex to**

# **Solar heat storages in district heating networks**

**Comprehensive list of Danish literature and R&D projects**

July 2007



ellehaug &  
kildemoes  
COWI

 intelligent energy  
**ieea**  
European Commission executive agency

# **PREHEAT**



Energinet.dk, project no. 2006-2-6750

## Solar heat storages in district heating networks

**July 2007**

Klaus Ellehauge

Ellehauge & Kildemoes  
Vestergade 48 H, 2s.tv.  
DK-8000 Århus C.  
Ph: + 45 86 13 20 16  
klaus.ellehauge@elle-kilde.dk  
www.elle-kilde.dk

Thomas Engberg Pedersen

COWI A/S  
Parallelvej 15  
DK-2800 Lyngby  
Ph: +45 45 97 22 11  
tep@cowi.dk  
www.cowi.com



## **Table of Contents**

<b>Preface</b>	<b>6</b>
<b>1 Literature</b>	<b>7</b>
<b>2 Projects carried out in Denmark</b>	<b>14</b>
<b>3 Danish companies</b>	<b>31</b>

## Preface

This annex relates to the report “Solar heat storages in district heating networks”, which has been elaborated to inform about the Danish experiences and findings on the use of central solar heating plants in district heating networks, especially with the focus on the development of the storage part of the systems.

The report has been funded as part of the IEE PREHEAT cooperation and by Energinet.dk, project no. 2006-2-6750.

The Danish experiences and findings have been documented in a large number of reports. However most of these are in Danish and it has therefore not been suitable to include the very long list in the main report.

Furthermore the findings are obtained in a large number of projects that have been carried out and for which information is given in the database:  
[www.energyprojects.dk](http://www.energyprojects.dk)

The projects are described by a title and an abstract, which sometimes is in English. A list of relevant projects for large storage is also given in this Annex

# 1 Literature

## Papers:

1.       ÆRØ – THE DANISH SOLAR ISLAND  
Engineer Flemming Ulbjerg, Ramboll, Toldbovej 13 A, DK- 5970 Svendborg.  
Phone +45 6320 5054, Fax: +45 6320 5090. E-mail: [fu@ramboll.dk](mailto:fu@ramboll.dk) ISES Solar  
World Congress 2003, Göteborg
2.       SUNSTORE 2. DESIGN AND CONSTRUCTION OF THE LARGEST  
SOLAR THERMAL SYSTEM IN THE WORLD  
Per Alex Sørensen, PlanEnergi, Jyllandsgade 1, DK-9520 Skørping, Denmark.  
Phone: +45 9682 0400. Fax: +45 9839 2498. Email: [pas@planenergi.dk](mailto:pas@planenergi.dk), ISES  
Solar World Congress 2003, Göteborg
3.       SOLAR HEATING PLANTS & LONG TERM HEAT STORAGE  
KEY-NOTE PAPER  
Per Alex Sørensen, PlanEnergi, Jyllandsgade 1, DK-9620 Skørping, Denmark,  
Phone: +45 9682 0400, Fax +45 9839 2498, E-mail: [nord@planenergi.dk](mailto:nord@planenergi.dk), Euro-  
sun 2000, Copenhagen
4.       Solar Production from the Marstal Plant 1997-1999  
Per Alex Sørensen and Leif Holm Tambjerg  
PlanEnergi, Jyllandsgade 1, DK-9520 Skørping, Denmark,  
Phone: +45 96 82 04 00, Fax: +45 98 39 24 00, E-mail: [nord@planenergi.dk](mailto:nord@planenergi.dk)  
Eurosun 2000, Copenhagen
5.       ADVANCES IN LARGE-SCALE SOLAR HEATING AND LONG-  
TERM STORAGE IN DENMARK  
Alfred Heller, Department of Buildings and Energy, Technical University of  
Denmark, Tel. 45 25 18 91, Fax 45 93 15 77, e-mail: [ajh@ibe.dtu.dk](mailto:ajh@ibe.dtu.dk)  
Eurosun 2000, Copenhagen
6.       RISE DISTRICT HEATING, 50% SOLAR FRACTION  
RAMBOLL, Sct Joergens Vej 15, DK -5700 Svendborg, Denmark, phone +45  
6320 5050, fax + 45 6320 5090, e-mail: [FU@RAMBOLL.DK](mailto:FU@RAMBOLL.DK), Eurosun 2000,  
Copenhagen

**Reports: (Most reports are in Danish)**

7. First Experience from the Worlds Largest Fully Commercial Solar Heating Plant  
Alfred Heller and Simon Furbo, Department of Buildings and Energy, Technical University of Denmark, Building 118, DK-2800 Lyngby, Denmark, [sf@byg.dtu.dk](mailto:sf@byg.dtu.dk), ISES Solar World Congress 1997 Taejon Corea
8. Kielsgaard Hansen, K.; Nordgaard Hansen, P.; Ussing, V. (1984). Temperaturlagdeling i forsoegsvarmelager. DTH-LV--84-34. 31 p. 1984
9. DTH . Danmarks Tekniske Hoejskole. Seasonal thermal energy storage in district heating systems. DTH-LET-RE-84-1. 221 p. 1984
10. Hanen, P.N., Dytczak, M., Mahalawy, N.E.: Teknisk og oekonomisk systemanalyse af solvarmecentraler med saesonvarmelagring. Laboratoriet for Varmeisolering, DTH, 1984. 40 s. 1984
11. Kielsgaard Hansen, K.; Nordgaard Hansen, P.; Ussing, V. (1984). Seasonal heating storage in underground warm water stores. Rapport 154. (Danmarks Tekniske Hoejskole. Laboratoriet for Varmeisolering, Lyngby); 1984
12. J. Hagelskjaer, J.A. Leth, J. Mortensen: Rapport - Varmelagring i grundvandsreservoir. Nordisk seminar kring vaermelagring av vaerme i jord, berg och vatten. Goeteborg, 5-6 oktober 198; 1985
13. Kielsgaard Hansen, K.; Nordgaard Hansen, P.; Ussing, V. (1985). Fortsatte maalinge paa 500 m<sup>3</sup> forsoegsvarmelager. DTH-LV--85-2. 113 p. 1985
14. METODER FÖR ACCELLERERAD PROVNING AV VÄRMERÖR AV PLAST. Mats Ifvarson. Studsvik Report 1985.1985
15. Nielsen og Rauschenberger (1985). Hoejtemperatur grundvandsvarmelagre. Redegoerelse for forundersoegelser, dimensionering og opbygning af hoejtemperatur grundvandsvarmelagre. 160 p. 1985
16. Qvale, B. et. al.: The economics, technology, and systems integration of aquifer thermal-energy storage. DTH-LET-RE-86-6. Sep 1986. 72 p.; 1986
17. Medierør af plast - muligheder og problemstillinger. EFP-Fjernvarme. Uffe Nielsen og Ole Pedersen. Plastconsult 1987. 1987
18. Oilconsult Raadgivende Ingenioerer A/S. (1987). Varmelager i halmfyret fjernvarmevaerk. vp. 1987
19. Oilconsult Raadgivende Ingenioerer A/S. (1987). Varmelager i halmfyret fjernvarmevaerk. vp. 1987



20. Schleisner Ibsen, L.; Kjaer Jensen, S. (1987). Lavtemperaturvarmelagring paa Risoe. 174 p. 1987
21. Andersen, S.; Ussing, V. (1988). Skitseprojekt til stort solvarmeanlaeg med saesonvarmelager. DTH-LV-88-18. 28 p. 1988
22. Berg, P. (1988). Simulering af termiske forhold i solvarmeanlaeg med saesonlagring. DTH-LV-MEDD-190. 192 p. 1988
23. Schleisner Ibsen, L.; Qvale, B. (1988). The Danish aquifer thermal energy storage project. Demonstration plant. RISO-M-2764. 144 p.; 1988
24. STORE LAGRE Slutrapport fra projekt udvikling af et optimalt 3.000-10.000 m<sup>2</sup> betonelementlager-damvarmelager og etablering af et 500 m<sup>2</sup> forsøgs-lager for verifikation af arbejdsmetoder 1989
25. Nielsen, J.E. (1990). Brugervejledning og dokumentation for: FJERN SOL - et PC-program til beregning af solvarmeanlaeg i fjernvarmenet. Version 0.3. 64 p. Nielsen, J.E. (1990). Verifikation af FJERN SOL med maaling-er fra Saltum Fjernvarmevaerk. 45 p. 1990
26. Wesenberg, C. (1990). Sol til sommerstop i eksisterende halmvarme-vaerk, forsoegsanlaeg. Skitseprojekt. 57 p. 1990
27. DESIGN AND INSTALLATION OF BURRIED PLASTICS PIPES Lars Erik Janson og Jan Molin. Wavin 1991. 1991
28. Informationssekretariatet for Vedvarende Energi (1991). Solar heating in Denmark: Large Plants. 20 p. 1991
29. Plan og Projekt A/S (1991). Måleprogram på akkumuleringstanke. 39 p.; + bilag. 73 p. 1991
30. Plast som konstruktionsmateriale i røggaskølere. EFP-Produktion og fordeling af el og varme. Uffe Nielsen og Johan Sørensen. Plastconsult 1991. 1991
31. Store Lagre 2: Slutrapport fra projekt lertætnet damvarmelager til solvarme-central, Carsten Wesenberg og Torsten Bliksted, Nellemann AIS. Ole Olesen, Laboratoriet for Varmeisolering, DTU. Per Alex Sørensen, PlanEnergi Nordjylland. 1991. 1991
32. Ussing, V. (1991). Forsoegsborehulslager og ombygning af damvarmelager til gruslager. DTH-LV-MEDD-219. 127 p. 1991
33. Forberedelse af varmeanlaeg med solfanger og lertætnet damvarmelager", PlanEnergi. Juni 1992. 1992

34. Huulgaard, L.; Christensen, J.L., Lertætning af damvarmelager. Laboratorieundersøgelser ved høje temperaturer”, Rapport 1, Geoteknisk Institut. December 1992. 1992
35. Pilotprojekt for sæsonvarmelager. Erfarenheter Kronhjorten i Växjö”, Jan- Olof Dalenbäck, Byggeforskningsrådets rapport R40:1992. 1992
36. Skitseprojekt, Solvarmecentral med sæsonvarmelager til Skørping Varmeværk A.m.b.a.”, Carsten Wesenberg og Torsten Bliksted, NNR. December 1992. 1992
37. THERMIE 1994 - proposal SE 260/94-DK/DE “Solar District Heating Plant with Seasonal Heat Storage for the Distriet Heating Supply of approx. 660 houses”, NNR, AR-CON, DTU, ITW (D) og TNO (NL). December 1993. 1993
38. Nielsen, U. (1994). Linerløsninger til sæsonvarmelagre. 165 p. 1993
39. Solar Heating with Seasonal Storage”, Jan-Olof Dalenbäck, Chalmers Tekniska Högskola. Oktober 1993. 1993
40. Sæsonsol: Manual til version 3.0. EDB-program til simulering af det dynamiske samspil imellem solfangere, lager, fjernvarmenet og boligforbrug. Ole Olesen, Laboratoriet for Varmeisolering, DTU. Juni 1993. 1993
41. Sæsonvarmelagring i store ståltanke”, Henrik Lawaetz, Pr for Solenergi, DTI. Marts 1993. 1993
42. Solar Heating in Denmark, Large Plants, Energy Agency
43. Undersøgelse og udbedring af varmeakkumuleringstank udført i beton (HØRBY-TANKEN) 1990-1993.” Carsten Wesenberg, NNR. Juni 1993. 1993
44. LINERLØSNINGER TIL SÆSONVARMELAGRE”, Uffe Nielsen, Plast consult. Juli 1994. 1994
45. Vandpermeabilitetsmålinger på tætningsmembran til energiopsamlings-tank, Tubberup Vænge II” (Tubberupvængetanken) Brev af 18.04.1994 fra Søren Pedersen, DTI, til J. Pilegaard Kristensen, Værløse (syn- og skøn). 1994
46. Wesenberg, C.; Bliksted, T.; Frøsig Jensen, F.; Porsvig, M.; Sørensen, P.A. (1996). sol/sæsonvarmelagre, statusrapport. Store lagre 4. Lertætnet damvarmelager med flydende lågkonstruktion, status for udvikling. [70 p.] 1994
47. Europæisk samarbejde om udvikling af solfangerfelter med damvarmelagre”, Per Alex Sørensen, PlanEnergi, Carsten Wesenberg, MML Karsten Duer, DTU, Svend Andersen, AR-CON Solvarme A/S. December 1995. 1995

48. Frøsig Jensen, F. (1995). Sæsonsol. Manual til version 3.1. Tillæg til manual sæsonsol version 3.0. simulering af solvarmeanlæg med lagring i ståltanke samt variabelt flow i solfangerkredsen. DTU-LV-95-28. 57 p. DKK.100 1995
49. Rustfri stålliner til damvarmelagre”, Karsten Duer, DTU. September 1995. 1995
50. SLUTRAPPORT. Pilotprojekt 1.500 m lertætnet damvarmelager med flydende lågkonstruktion”, Ottrupgård Fjernvarme A.m.b.a., NNR og PlanEnergi. September 1995. 1995
51. STORE LAGRE 3”, Slutrapport fra projekt borehulslagre til solvarme-centraler, Karsten Duer og Frank Jensen, DTU. Per Kofoed og Peder Vejsig Pedersen, Cenergia, og Mogens Porsvig, Geoteknisk Institut December 1995. 1995
52. APAS “Large-Scale Solar Heating”, EU-projekt RENA CT 94-0057. Rapporter: “Evaluation of Existing Plants” (July 1995), “Feasibility and Predesign Studies” (February 1996) samt “The Market Potential for Solar Heating Plants in Some European Countries” (March 1996) 1996
53. Fisch, N., Gigas, M. & Kübler, R. Large-Scale Solar Heating, Executive Summary Report, Steinbeis 1996
54. STORE LAGRE 4, Lertætnet damvarmelager med flydende lågkonstruktion. Status for udvikling. Carsten Wesenberg mfl. 1996. 1996
55. Zinko, H., Bjärklev, J. & Margen, P. The market potential for solar heating plants in some European countries, Large-Scale Solar Heating Systems, ZW Energiteknik, Nyköping, Sweden. 1996
56. Leenaerts, C. (1997) Project Development Guide for Central Solar Heating Plants with Seasonal Storage, A Report of CSHPSS Working Group, A10:1997, Energie-Buro, Nederland, Swedish Council for Building Research, Stockholm, Sweden, ISBN 91-540-5797-3. 1997
57. Maureschat, G. & Heller, A. Modelforsøg: Varmetransport og effektafgivelse i grus (Danish), SR-9816, Department of Buildings and Energy, Technical University of Denmark, Building 118, DTU, 2800 Lyngby, ISSN 1396-402X. 1997
58. Nellemann, Nielsen og Rauschenberger A/S (1995). Otterupgård, 1.500 m<sup>3</sup> dampvarmelager - målerapport, 1996-1997 1997
59. Pedersen, V.P. Total Energy System with Solar and Low Energy Utilisation for 92 Houses in Tubberupvænge II, Denmark, Cenergia Energy Consultants, Ballerup, Denmark, SE-436-85-DK. 1997
60. Marstal Fjernvarme; PlanEnergi (1999). Biomassefyret kraftvarme i Marstal, forprojekt. vp. 1998

61. Maureschat, G.; Heller, A. (1998). Ottrupgård solvarmecentral. Validering af sæsonsol-beregninger. vp. 1998
62. Wesenberg, C. Rekonstruktion af Tubberupvaengetanken, Del 2: Bygning og driftssættelse, Reconstruction of Tubberupvaenge Storage: Part 2: Building and Operation Start (Danish), NNR Consultants, Odense, Denmark. 1998
63. Pedersen, S. & Nielsen, U. Fastlæggelse af levetider for plaslinier til sæsonvarmelagre, Estimation of live time for polymer liners for seasonal, thermal storage (Danish), Teknologisk Institut, Gregersvej, 2630 Taastrup, Denmark. 1999
64. Planenergi I/S, Nordjylland (1998). Beregning af langtidsvarmelager til Hjørring Kraftvarmeværk. vp. 1999
65. STORE LAGRE 5, Rapport fra etablering af jordslangelager ved Marstal. Per Alex Sørensen m.fl. 1999. 1999
66. Duer, K. Flydende låg for damvarmelager Statusrapport: Fase III, Floating lid designs for seasonal pit water storage - Status report: Phase III (Danish), R 040, Department of Buildings and Energy, Technical University of Denmark, Building 118, DTU, 2800 Lyngby, Denmark, ISSN1396-4011, ISBN 87-7877-042-4. 2000
67. Marstal Fjernvarme [2001]. Afrapportering af projekt 'varmepumpe til sæsonlager'. vp. 2000
68. Visbjerg, L.; Wesenberg, C.; Bliksted, T.; Porsvig, M.; Duer, K. (2000). Sydlangeland Fjernvarme A.m.b.a.: Forundersøgelse for 10-20.000 m<sup>3</sup> damvarmelager. 96 p. 2000
69. Marstal Fjernvarme; Planenergi I/S (2001). Langtidsvarmelager i Marstal. Forprojekt. vp. 2001
70. Rise Fjernvarme A.M.B.A, Etablering af 4000 m<sup>3</sup> sæsonvarmelager samt udvidet solafngerfelt, Rambøll 2001
71. Rise Fjernvarme A.M.B.A, Sæsonvarmelager og solvarme til fjernvarme, 50% dækning, Etape 2, Rambøll 2001
72. Marstal VVS (2002).Udvikling af svejseprocedure og kvalitetskontrol ved etablering af sæsonlager m.v. 2002
73. Nordby Mårup Varmeværk, Evalueringer af målinger, Solenergicentret, PlanEnergi 2004
74. Pedersen, S. (2004). Fastlæggelse af levetider for 2 HDPE plastlinere til sæsonvarmelagre. DKK 150,- 2004

75. Public Final Technical Report. Sunstore 2. Per Alex Sørensen 2005.  
2005
76. Udvikling, produktion og demonstration af forbedret ARCON HT-SA solfanger (Ulsted), PlanEnergi 2006
77. Udredning vedrørende: Indpasning af solvarme i kraftvarme, Konklusioner fra arbejdsgruppens rapport, Dokument nr. 250786 v. Lise Nielson Energinet.dk + Bilagsrapport Marts 2006

## 2 Projects carried out in Denmark

### 1 Seasonal thermal energy storage in Denmark

1980 - 1982

*Boldt, J. (ing.); Qvale, B. (prof.); Nielsen, O.B. (civ.ing.)*

*Danmarks Tekniske Højskole. Laboratoriet for Energiteknik , Bygning 403 , DK-2800 Lyngby , Tel. 02-884622*

*DTH (1984). Danmarks Tekniske Højskole. Seasonal thermal energy storage in district heating systems. DTH-LET-RE-84-1. 221 p.*

Belysning af systemtekniske og økonomiske forhold ved udnyttelse af sæsonlagring af varme i Danmark. Udvikling af metoder til bedømmelse af disse forhold og anvendelse af metoderne til bedømmelse af forholdene omkring lagring af varme i en række konkrete situationer

### 2 Low temperature storage in groundwater reservoirs

1982 - 1983

*Leth, J.A. (civ.ing.); Hagelskjaer Christensen, J. (civ.ing.); Mortensen, J. (akad.ing.)*

*Forsoegsanlaeg Risoe. Konstruktionsafdelingen , P.O.Box 49 , DK-4000 Roskilde, Denmark , Tel. 42-371212*

Et væsentligt problem ved udnyttelsen af industriens lavtemperaturspildvarme er udgiften til etablering af egnede lagre. Efter lagring kan varmen eksempelvis nyttiggøres under anvendelse af varmepumper. Der har i nogle år været arbejdet med udnyttelse af grundvandsreservoirer til sæsonlagring af varme eksempelvis i forbindelse med kraftvarmeanlæg og affaldsforbrænding ved noget højere temperaturer. Demonstrationsanlæg er etableret ved Hoersholm. Ved lavere temperaturer er kravene til grundvandsreservoiret reducerede, ligesom der forventes færre problemer. Det skulle være muligt både at anvende åbne reservoirer og den øverste del af kalken når der er tale om lagring af lavtemperaturspildvarme. Projektet sigter mod at undersøge mulighederne for at etablere et lavtemperaturlager i et grundvandsreservoir. I fortsættelse af det indledende udredningsarbejde under EFP-82 etableres nogle undersøgelsesboringer med henblik på at afklare de hydrologiske forhold. Som lokalitet foreslås i første omgang Risoe, hvor der er en overskudsvarme fra reaktoren på ca. 8 MW og en varmepumpeinstallation, der kan nyttiggøre den lagrede varme under reaktordlukning. Derudover foretages projektering og budgettering af et demonstrationsanlæg i samarbejde med Ramboell og Hannemann, Raadgivende Ingeniører A/S

### 3 Measuring program concerning seasonal heat storage

1982 - 1984

Ussing, V. (proj.leder)

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2880 Lyngby , Tel. 02-883511*

*K. Kielsgaard Hansen, P. Nordgaard Hansen, V. Ussing: Seasonal Kielsgaard Hansen, K., Nordgaard Hansen, P., Ussing, V.: Seasonal heat storage in underground warm water stores. Dimensioning and planning of af full size store. Final report. DTH-LV-MEDD--154. 115 p.; heat storage in underground. Warm water stores. Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering, Meddelelser nr. 134, July 1983; Kielsgaard Hansen, K.; Nordgaard Hansen, P.; Ussing, V. (1985). Fortsatte maalinge paa 500 m<sup>3</sup> forsoegsvarmelager. DTH-LV--85-2. 113 p.*

Tidligere undersøgelser og beregninger har vist, at det tager lang tid at opnå stabile temperaturostilstande i jordlagene omkring et sæsonvarmelager. En afbrydelse af målearbejdet vedrørende forsøgsvarmelageret allerede i maj 1983 vil være meget u hensigtsmæssig, da tilstandene på det tidspunkt (ca. 8 måneder) efter forsøgets påbegyndelse endnu ikke vil være stabile. Projektet omfatter fortsat måling af temperaturer i forsøgsvarmelager og visse jordlag i forbindelse med et nøje planlagt varmetilgangs og -afgangsprogram indtil efteråret 1984. Målingerne vil muliggøre en sikrere vurdering af forsøgsresultaterne, ligesom de ved drift af lageret indvundne erfaringer vedrørende funktionen af lagerets tekniske detaljer vil få en rimelig baggrund

### 4 Technical and economical analysis of solar heating plants with seasonal storage

1983 - 1984

*Nordgaard Hansen, P. (lektor); Kielsgaard Hansen, K. (vid.med); Dytczak, M. (gaesteforsker); Mahalawy, N.E. (gaesteforsker)*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby , Tel. 02-883511*

*Hanen, P.N., Dytczak, M., Mahalawy, N.E.: Teknisk og økonomisk systemanalyse af solvarmecentraler med sæsonvarmelagring. Laboratoriet for Varmeisolering, DTH, 1984. 40 s.*

AIM: System optimization of a central solar heating plant with seasonal storage consisting of: A water pit uninsulated at the ground surface, solar panels, a heat pump, and a district heating system supplying 55 to 200 houses in a settlement with heat for house heating and domestic hot water. WORK CARRIED OUT: Theory has been developed which fit for handcalculations when dimensioning a solar heating plant for a given load. 2 different computer programmes have been used for verification. RESULTS: For Danish weather conditions it seems to be optimal to operate the water pit (uninsulated at the surface to the ground) between 0degC and 50degC. The price for energy supplied by the central solar heating plant in a 30 years period is comparable with the price of electricity in Denmark

### 5 Operational improvements for large storage pits

1984 - 1984

*Ussing, V. (civ.ing.); Kielsgaard Hansen, K. (akad.ing., lic.techn.)  
Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering, Bygning 118,  
DK-2800 Lyngby, Tel. 02-883511*

*Kielsgaard Hansen, K.; Nordgaard Hansen, P.; Ussing, V. (1984). Seasonal heating storage in underground warm water stores. Rapport 154. (Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering, Lyngby); Kielsgaard Hansen, K.; Nordgaard Hansen, P.; Ussing, V. (1984). Temperaturlagdeling i forsoegsvarmelager. DTH-LV--84-34. 31 p.*

The project aims to develop optimal details pertaining to operation of large storage pits. The project is expected to be finished within 1984. The results will be applied in construction work, hopefully executed in 1985. The project expects to deal with inlet- and outlet structures, stratification and thermal expansion of the water in district heating systems, including the storage content

## **6 Thermal energy storage in aquifers**

1978 - 1985

*Schleisner, L. (proj.leder); Mortensen, J.; Lindskou Christensen, P.  
Forskningscenter Risoe. Konstruktionsafdelingen, DK-4000 Roskilde, Denmark  
, Tel. 42-371212*

*Danmarks Tekniske Højskole. Laboratoriet for Energiteknik; Danmarks Geologiske Undersøgelse. Hydrologisk Afdeling*

*1) J. Hagelskjaer, J.A. Leth, J. Mortensen: Underground heat storage in Hoersholm, Denmark. International conference on subsurface heat storage in theory and practice. Proceedings. Appendix, part 1. Stockholm, June 6-8, 1983. Swedish Council for Building Research. 2) J. Hagelskjaer, J.A. Leth, J. Mortensen: Rapport - Varmelagring i grundvandsreservoir. Nordisk seminar kring vaermelagring av vaerme i jord, berg och vatten. Goeteborg, 5-6 oktober 198; Qvale, B. et. al.: The economics, technology, and systems integration of aquifer thermal-energy storage. DTH-LET-RE-86-6. Sep 1986. 72 p.; Schleisner Ibsen, L.; Qvale, B. (1988). The Danish aquifer thermal energy storage project. Demonstration plant. RISO-M-2764. 144 p.; Schleisner Ibsen, L.; Kjaer Jensen, S. (1987). Lavtemperaturvarmelagring paa Risoe. 174 p.*

The project goals for the Danish aquifer thermal energy storage (ATES) are: 1) To develop mathematical models to simulate the heat transport in an aquifer storage. 2) To construct and operate a demonstration plant. 3) To demonstrate system efficiency and economy. 4) To investigate potential locations for ATES in Denmark. 2-dimensional finite element codes are developed and used for design of the demonstration plant and for evaluation of experimental results from the first short test cycles. The demonstration plant was ready for the first test at low temperature in the autumn of 1982. Due to leakage through the upper clay-layer in the summer of 1983 only a second short test at 100 deg C. was possible. The leak was repaired but reopened by injection in 1984. Due to this the storage in 1984 was drivers in reverse mode. In 1985 a new central well has been established and the first high temperature test cycle has succeeded

## **7 Technical guidance for preliminary investigation, design and construction of aquifer thermal energy storage**

1984 - 1985

*Andersen, J. (civ.ing.)*



*Nielsen og Rauschenberger A/S Raadgivende Ingenioerer , Teknikerbyen 19 , DK-2830 Virum, Denmark , Tel. 02-859222*

*Forsoegsanlaeg Risoe; Danmarks Geologiske Undersoegelse; Danmarks Tekniske Hoeskole. Laboratoriet for Energiteknik*

*Nielsen og Rauschenberger (1985). Hoesjtemperatur grundvandsvarmelagre. Redegoerelse for forundersoegelser, dimensionering og opbygning af hoesjtemperatur grundvandsvarmelagre. 160 p.*

The purpose is to collect and systematize experiences from existing plants for aquifer thermal energy storage. The experiences will form the basis for a technical concept for the planning and design of aquifer thermal energy projects. Experience from existing Danish thermal energy storage will be made available to the project. Furthermore experiences from selected foreign storage plants will be assessed in the project. The report will be structured as a guide to the evaluation of aquifer thermal energy storage projects, and will include suggestions for: preliminary investigations of the aquifer geology, parameters determining storage capacity, well design, surface equipment and control systems

## **8 Heat storage ponds**

1985 - 1985

*Nordgaard Hansen, P. (Lektor); Ussing, V. (civ.ing. projektleder)*

*Danmarks Tekniske Hoeskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby , Tel. 02-883511*

*Kielsgaard Hansen, K. et al (1985). Stratified operation of a 500 m<sup>3</sup> test pit. In: Proceedings Enerstock 85, Toronto Canada, p. 562-566*

It was the intention of the project by supplementary measurements during charge- and discharge operations of the 500 m<sup>3</sup> test pond at DTH to verify the design models for the change in temperature distributions in the storage water. Furthermore the investigations concerning the design of in- and outlet arrangements for the water of a storage pond with floating lid will be concluded. Economic advantageous application of the storage system is expected to be feasible

## **9 Steam-heat storage to be constructed in the central heating system of the Vestegnens Kraftvarmeselskab**

1985 - 1985

*Ussing, V. (civ.ing.)*

*Danmarks Tekniske Hoeskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby , Tel. 02-883511*

Forprojektering af et dampvarmelager paa ca. 50.000 m<sup>2</sup> til indbygning i Vestegnens Kraftvarmeselskabs fjernvarmesystem. Projektet har generelle perspektiver vedr. varmeenergilagring i forbindelse med energiforsyningssystemer

## **10 Solar heating system for district heating. Preliminary study**

1986 - 1987

*Andersen, I. (fmd.)*

*Saltum Fjernvarme , Tinghoejgade 11 , DK-9493 Saltum, Denmark , Tel. 08881013*

### **11 Heat storage in straw-fired district heating plants**

1987 - 1987

*Holmsgaard, P. (afd.leder, OC); Bruun, N.-O. (civ.ing., OC); Kjaergaard, C.-J. (civ.ing., OC); Ussing, V. (civ.ing., LfV); Nordgaard Hansen, P. (civ.ing., LfV) Oilconsult Raadgivende Ingenioerer A/S, Skt Peders Straede 4A, DK-4000 Roskilde, Denmark, Tel. 02357422*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering Oilconsult Raadgivende Ingenioerer A/S. (1987). Varmelager i halmfyret fjernvarmeværk. vp.*

A district heating plant and distribution system is to be installed in the town of Svinninge. This will be carried out in two phases. During the first phase, two oil-fired boilers and a straw-fired boiler are to be installed. During the second phase, a second straw-fired boiler is to be installed. It is possible to achieve savings in operating costs by combining this second straw-fired boiler with a short-term heat storage system. The storage system may also help to reduce peak loading requirements. As there is no simple method of determining the optimum size, it is necessary to develop detailed computer models which simulate the operation of the heat storage system. If it can be shown that the investment in a heat storage system would be offset by savings in operating costs, then a project to determine the optimum size could go ahead. The project would be completed within the current half year period. The project would principally be of interest to future district heating consumers in Svinninge, but could also be of interest to district heating consumers in towns which have, or would like to develop district heating systems based on local energy sources

### **12 Insulation of pool heat storage**

1987 - 1987

*Nordgaard Hansen, P. (projektleder) Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering, Bygning 118, DK-2800 Lyngby, Denmark, Tel. 02-883511 Berg, P. (1988). Simulering af termiske forhold i solvarmeanlæg med saesonlagring. DTH-LV-MEDD-190. 192 p.*

Formålet med dette projekt er en termisk optimering af damlagrene ved to centrale solvarmeanlæg i Roskilde og Herlev. De to anlæg analyseres med edb-modeller, der kan simulere et samlet anlæg bestående af damlager solfangerareal inkl. roersystem, fjernvarmenet og varmemeforbrugere i de enkelte husstande. Modellerne for fjernvarmenet og solfangerarealer er afprøvet og verificeret i andre sammenhænge. I analyserne undersøges først og fremmest effekten af forskellige isoleringsmetoder og -grader for lagrene.

### **13 Heat storage in straw-fired district heating plants**

1987 - 1987

*Holmsgaard, P. (afd.leder, OC); Bruun, N.-O. (civ.ing., OC); Kjaergaard, C.-J. (civ.ing., OC); Ussing, V. (civ.ing., LfV); Nordgaard Hansen, P. (civ.ing., LfV) Oilconsult Raadgivende Ingenioerer A/S, Skt Peders Straede 4A, DK-4000 Roskilde, Denmark, Tel. 02357422*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering Oilconsult Raadgivende Ingenioerer A/S. (1987). Varmelager i halmfyret fjernvarmeværk. vp.*

A district heating plant and distribution system is to be installed in the town of Svinninge. This will be carried out in two phases. During the first phase, two oil-fired boilers and a straw-fired boiler are to be installed. During the second phase, a second straw-fired boiler is to be installed. It is possible to achieve savings in operating costs by combining this second straw-fired boiler with a short-term heat storage system. The storage system may also help to reduce peak loading requirements. As there is no simple method of determining the optimum size, it is necessary to develop detailed computer models which simulate the operation of the heat storage system. If it can be shown that the investment in a heat storage system would be offset by savings in operating costs, then a project to determine the optimum size could go ahead. The project would be completed within the current half year period. The project would principally be of interest to future district heating consumers in Svinninge, but could also be of interest to district heating consumers in towns which have, or would like to develop district heating systems based on local energy sources

#### **14 Soil storage (test heat storage II)**

1987 - 1988

*Ussing, V. (raadg.ing.)*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby , Tel. 02883511*

The Thermal Insulation Laboratory of the Technical University of Denmark has in 1982 built and has since operated a 540 m<sup>3</sup> test pit studying heat losses from a partly insulated pit shaped as a truncated pyramid. As an initial step to build and operate a soil storage constructed with vertical pipe loops with a similar heat capacity (Test storage II) as Test storage I this project contains an overview over existing structures of similar type as well as a sketch proposal for the construction of the soil storage immediately adjacent to the existing storage pit operated by the same heating plant

#### **15 Solar heating plant for district heating . Preliminary study**

1987 - 1988

*Information missing*

*Ry Varmevaerk , Brunhoejvej 7 , DK-8680 Ry, Denmark , Tel. 06891365*

Forprojekt vedrørende undersøgelse af mulighederne for at udnytte solvarme til fjernvarmeforsyning i Ry by. Der indgaar flere store centrale solfangere samt lavtemperaturnet.

#### **16 IEA solar heating and cooling program Task 7 Phase 3. Analysis and evaluation of the existing and planned solar heating systems with seasonal storage**

1987 - 1989

*Ussing, V.*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby, Denmark , Tel. 42-883511*

The project comprised Danish participation in the 3. phase of Task VII of the IEA Solar Heating and Cooling Programme 1987-89 and Danish participation with the US Department of Energy in the study of the Danish EEC-demonstration project Tubberupvaenge II, Herlev. Technical feasibility of CSHPSS has been well established and the understanding of the design and

construction of plants and their major components has reached the level where selective introduction may be economically feasible. If the external costs of global pollution produced by burning fossil fuels were taken into account, CSHPSS would already be cost effective for many applications. Rational manufacturing techniques for large ground mounted, as well as roofintegrated solar collectors, do exist and it should be possible to bring the cost down to 130 US dollars/m<sup>2</sup> through larger scale production. The key issue for further development of CSHPSS, in order to be cost-effective in all countries, is further development of the storage technology. Specifically there is a need for internationally coordinated R and D on high temperature storages. Development of simple and general design tools, to be used by designers and consultants in feasibility studies, is also an important issue

### **17 Numerical model for a central solar heating system involving a seasonal heat storage**

1988 - 1989

*Berg, P. (lic.tech., civ.ing.); Olesen, O. (civ.ing.)*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby, Denmark , Tel. 42-883511*

A detailed numerical model for a central solar heating system, involving a water pit as a seasonal heat storage, has been developed in an earlier project at the Thermal insulation Laboratory. The model contains several new, and very effective approaches for simulation of the temperature conditions in hot water storages and in solar collectors. The aim of this project is to make the model applicable for a wider scale of users and to extend the model with an algorithm for ground storage. The project will be supplemented with a written users guide for the extended model

### **18 Storage module for district heating/solar heating PC program**

1989 - 1989

*Nielsen, J.E. (civ.ing.)*

*Teknologisk Institut. Afdelingen for Varme- og Installationsteknik , Postboks 141 , DK-2630 Taastrup, Denmark , Tel. 43504350*

*Nielsen, J.E. (1990). Brugervejledning og dokumentation for: FJERN SOL - et PC-program til beregning af solvarmeanlaeg i fjernvarmenet. Version 0.3. 64 p.*

*Nielsen, J.E. (1990). Verifikation af FJERN SOL med maalinger fra Saltum Fjernvarmevaerk. 45 p.*

Development of a storage module for the PC-programme fjernsol. Fjernsol is used for calculating solar heating in district heating systems. The storage module is a simple one layer (mixed) water storage

### **19 Solar heating system for a small demonstration district heating installation**

1989 - 1989

*Wesenberg, C. (akad.ing.)*

*Nellemann Raadgivende Ingenioerer og Planlaeggere A/S , Digtervejen 11 , DK-9200 Aalborg SV, Denmark , Tel. 98-181344*

*Wesenberg, C. (1990). Sol til sommerstop i eksisterende halmvarmevaerk, forsoegsanlaeg. Skitseprojekt. 57 p.*

In 1988 a 1,000 m<sup>2</sup> solar heating system was constructed for the heating supply of approx 270 houses in Saltum, North Jutland. The solar heating system in Saltum covers approx 4.5% of the annual heat production on the heating plant and the present review project will evaluate the installation of a similar solar heating system at the existing straw-fired heating plant equipped with a new heat accumulator in Hoerby close to Saeby may cover the total heat consumption during Summer in Hoerby (corresponds to an annual coverage with solar heating of approx 12.5%); and the advantages obtained by the straw-fired heating plant in terms of operation, maintenance and economy. The heat accumulator in Hoerby contains 500 m<sup>3</sup> and will be constructed as a test tank in connection with a new pit storage concept based on cheap 3,000-10,000 m<sup>3</sup> concrete panel tanks. The solar heating system in Saltum and the accumulator in Hoerby is supported financially by The Council of Technology

## **20 Soil storage . Test heat storage II**

1988 - 1990

*Ussing, V. (raadg.civ.ing.); Svendsen, S. (lektor); Andersen, S. (civ.ing.); Berg, P. (civ.ing.); Nordgaard Hansen, P. (lektor)*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby, Denmark , Tel. 02-883511/5352*

*Andersen, S.; Ussing, V. (1988). Skitseprojekt til stort solvarmeanlaeg med saesonvarmelager. DTH-LV-88-18. 28 p.*

The Thermal Insulation Laboratory at Denmark's Technical University has in 1982 built, and has since operated, a 540m<sup>3</sup> test pit in order to study heat losses from a partly insulated pit shaped as a truncated pyramid. The present project concerns subsurface storage utilizing vertical pipe loops. Two preliminary reports containing an overview of existing structures of this type and a sketched proposal, and another including documentation of the thermal efficiency and economy of this type of storage, were completed in 1988. The project concerns the construction and simulated solar operation of a 1800m<sup>3</sup> underground storage using vertical triple U-loop pipes in drilled holes. The project also allows the rebuilding of Test Pit I by filling it with gravel and horizontal pipe loops which can be operated under simulated solar conditions by using the heat stored in Test Pit II while the simulation process is also taking place

## **21 3.000m<sup>2</sup> solar heating system supplementing a district heating unit . Construction project**

1989 - 1990

*Rasholt, F.*

*Ry Varmevaerk , Baunehoejvej 7 , DK-8660 Ry, Denmark , Tel. 86-891555*

## **22 Examination of concrete heat storage tank**

1990 - 1990

*Baunwall, M. (civilingenioer) ; Wesenberg, C. (akademiingenioer)*

*Nellemann Raadgivende Ingenioerer og Planlaeggere. Energiafdelingen , Digtervejen 11 , DK-9200 Aalborg SV, Denmark , Tel. 98181344*

*Wesenberg, C. (1993). Undersoegelse og udbedring af varmeakkumuleringstank udfoert i beton (Hoerby-tanken), 1990-1993. 37 p. DKK.150*

The project comprises a description of materials testing and experiences gained in connection with the initial 12 month-running of a 500 m<sup>3</sup> high-temperature

concrete heat store tank, that was built as a testing tank for a new pit heat storage system based on 3,000 - 10,000 m<sup>3</sup> concrete tanks. The concrete heat store tank is situated in DK-Hoerby and from July 1989 to July 1990 it has functioned as a 24-hour heat store and spare heat storage tank in conjunction with a straw-fired district heating plant to which approx. 180 consumers are attached. The temperature at the top of the tank has constantly been between 90-95 deg. C

### **23 Soil storage . Test heat storage 2**

1990 - 1991

*Ussing, V. (Raadgivende civ.ing.); Svendsen, S.Aa. (Lektor)*

*Danmarks Tekniske Højskole. Laboratoriet for Varmeisolering , Bygning 118 , DK-2800 Lyngby, Denmark , Tel. 42-883511*

*Ussing, V. (1991). Forsoegsborehulslager og ombygning af damvarmelager til gruslager. DTH-LV-MEDD-219. 127 p.*

The Thermal Insulation Laboratory of the Technical University of Denmark has in 1982 built and has since operated a 540 m<sup>3</sup> test pit studying heat losses from a partly insulated pit shaped as a truncated pyramid. The present project concerns a soil storage with vertical pipe loops. Two preliminary reports containing an overview of existing structures of this type besides a sketch proposal and another containing a documentation of the thermal efficiency and economy of this type of storage was completed during 1988. The project concerns the construction and simulated solar operation of a 1260 m<sup>3</sup> soil storage with vertical triple U-loops of pipe in drilled holes. The project also allows the rebuilding of a test pit, filling the pit with gravel and horizontal pipe loops, which can be operated under simulated solar conditions by using the heat stored in test pit II during the simulations there. The project furthermore comprises laboratory measurements on the heat transfer from plastic tubes to borehole fill and soil storage

### **24 Information material, for international use, on larger Danish solar heating systems and heat storage**

1990 - 1991

*Information missing*

*Informationssekretariatet for Vedvarende Energi , Postbox 141 , DK-2630 Tåstrup, Denmark , Tel. 42996065*

*Informationssekretariatet for Vedvarende Energi (1991). Solar heating in Denmark: Large Plants. 20 p.*

Eksportmarkederne er så småt ved at åbne sig for solvarmeanlæg. Da der ikke fandtes et engelsksproget præsentationsmateriale for større danske solvarmeanlæg, var projektets formål at fremstille et sådant. I alt 8 principielt forskellige anlæg er omtalt og præsenteret med fotos i et 20-siders hæfte. For hvert anlæg er der 2 A4-sider, således at særtryk kan udarbejdes

### **25 Measuring programme in connection with operation of heat storage tanks at 4 existing straw fueled district heating plants**

1990 - 1991

*Sørensen, A.*

*Plan og Projekt A/S , Frichsparken, Søren Frichsvej 42 B , 8230 Åbyhøj , Tel. 86 15 68 66*

*Plan og Projekt A/S (1991). Måleprogram på akkumuleringstanke. 39 p.; + bilag. 73 p.*

## **26 Laboratory investigation of clay sealing of pond heat storage facility at high temperatures**

1991 - 1992

*Sørensen, P.A. ; Bliksted, T. (geoteknisk sagkynding); Porsvig, M. (Teknisk projektleder); Nielsen, U. (Plastsagkyndig)*

*Planenergi. Nordjylland , Jyllandsgade 44 , DK-9520 Skørping, Denmark , Tel. 98392400*

*Geoteknisk Institut; Nellemann Rådgivende Ingeniører og Planlæggere, A/S. Aalborg; PLASTconsult*

*Huulgaard, L.; Christensen, J.L. (1992). Lertætning af damvarmelager.*

*Laboratorieundersøgelser ved høje temperaturer. Rapport 1. vp. + Appendix til rapport lertætning af damvarmelager. 8 p. DKK.200*

Lertaetnede damvarmelagre i størrelsesordenen 100.000 m<sup>3</sup> ser til under danske forhold at kunne etableres for under 200 kr/m<sup>3</sup>. Derved er lagrene økonomisk interessante til sæsonvarmelagring. Lagrene kan forventes opvarmet til 95 grader C, hvorfor Geoteknisk Institut har foretaget en række laboratorieundersøgelser af egenskaberne hos smeltevandsler og moræneler under høje temperaturforhold. Desuden er foretaget modelforsøg for om muligt at konstatere ændret permeabilitet ved ændrede temperaturer. Forsøgene viste bl.a., at moræneler er egnet til lertætningen, at der kan anvendes anlæg 1:2 på damvarmelagerets sider, såfremt der anvendes en EPDM-gummiliner på lertætningens bagside, og at lerens permeabilitet tilsyneladende ikke forøges over 10<sup>-9</sup> m/s som følge af opvarmningen, hvilket er tilfredsstillende

## **27 Solar heating plant with seasonal heat storage for the district heating supply of approx. 660 houses**

1992 - 1992

*Wesenberg, C. (akad.ing.) ; Røggild Knudsen, P. (civ.ing., afd.leder)*

*Nellemann Rådgivende Ingeniører og Planlæggere A/S. Aalborg , Digtervejen 11 , DK-9200 Aalborg SV, Denmark , Tel. 98181344 , Fax 98183328*

*Wesenberg, C.; Bliksted, T. (1992). Solvarmecentral med sæsonvarmelager til Skørping varmeværk A.m.b.a. Skitseprojekt. 43 p. DKK.200*

The project includes draft project and pilot studies etc. in connection with the establishment of a large-scale (30,000 m<sup>2</sup>) solar heating system and a large-scale (95,000 m<sup>3</sup>) seasonal heat store for the Skørping Varmeværk A.m.b.a. The heating plant is about to extend the district heating supply from approx. 320 to approx. 660 households, which is why the existing chip heating plant has to be extended and moved outside the town. Instead the heating plant contemplates the establishment of a solar heating system/seasonal heat storage and exploitation of the existing chip boiler as a back-up via the seasonal heat storage. The town of Skørping is situated outside the natural gas area and furthermore it is the domicile of the only Danish producer of large-scale solar heating systems for district heating. Therefore, Skørping will be an obvious choice when it comes to siting the very first Danish full-scale demonstration project for solar heating including a seasonal heat storage made as a pit heat store in accordance with a brand new concept, developed by a working group for seasonal heat storage, set up by the Danish Energy Agency. If the solar heating system is made in

accordance to the draft project, it is assumed that well over 50% of the annual heat consumption in the town of Skørping can be covered by the solar heating system/the seasonal heat storage

### **28 Low price liner-solution for seasonal heat storage facilities**

1992 - 1993

*Nielsen, U.D. (udviklingsing.) ; Randa, J. (akad.ing.)*

*PLASTconsult. Energi , Messingvej 30 , DK-8900 Randers, Denmark , Tel. 86447577 , Fax 86447310*

*Nielsen, U. (1994). Linerløsninger til sæsonvarmelagre. 165 p.*

The purpose of the project is to give a basis for procuring low price liners with a sufficient durability to be used for pit-heat-storage and bore-hole-storage for storing heat produced in the summer for using in the winter in relation to solar energy. Working plan: a: Performance-specification. b: Possibilities for a solution with already known materials and equipment for producing. c: General examination of the possible suppliers. d: Systematical search for solutions. e: Statusreport. f: Procuring solutions for the first test plant. g: End report. Status: Performance-specification is worked out. Communication with 40-50 suppliers, contractors and producers in Europe has started. The solutions are expected to be used for a test plant in Ottrupgård (building-start april 1993) - and for other big storage facilities to be built in the future. The first big storage facility is going to be about 78,000 m<sup>3</sup> and is expected to be built in Skørping in 1994

### **29 European cooperation on the development of solar collector arrays with pond heat storage**

1993 - 1993

*Planenergi, Nordjylland , Jyllandsgade 44 , DK-9520 Skørping, Denmark , Tel. 98392400*

Udvikling af store solfangerfelter med damvarmelagre havde i 1993 i Danmark nået et stade, hvor europæisk støtte til demonstrationsprojekter var nødvendig. Desuden ville erfaringer fra andre landes undersøgelser (f.eks. af linere) og projekter formentligt kunne bruges. Derfor toges i regi af projektet kontakt til europæiske nøglepersoner, som sammen med projektgruppen udarbejdede og forelagde et europæisk udviklingsprogram for store solvarmeanlæg for EU (DG 12). Desuden er gennem workshops udvekslet erfaringer fra projekter og laboratorieforsøg. Takket være projektet er nu dannet et europæisk netværk af forskere, rådgivere mv. som med EU-støtte formulerer et forslag om store solfangerfelter som prioriterer område i EU's 4. rammeprogram for energi

### **30 Status report on developing large scale heat storage . Large heat store 3**

1994 - 1994

*Wesenberg, C. (akad.ing.) ; Duer, K. (civ.ing, DTU. Inst. for Bygninger og Energi); Sørensen, P.A. (akad.ing., Planenergi. Nordjylland)*

*Nellemann Rådgivende Ingeniører og Planlæggere A/S. Energiafdelingen , Digtervejen 11 , DK-9200 Aalborg SV, Denmark , Tel. 98181344 , Fax 98183328 Danmarks Tekniske Universitet. Institut for Bygninger og Energi; Planenergi. Nordjylland*

*Wesenberg, C.; Bliksted, T.; Frøsig Jensen, F.; Porsvig, M.; Sørensen, P.A. (1996). sol/sæsonvarmelagre, statusrapport. Store lagre 4. Lertætnet damvarmelager med flydende lågkonstruktion, status for udvikling. [70 p.]*



The aim of the project is to make an appraisal of development of clay sealed pit heat storages in Denmark and to accumulate the results of the gathered experience from investigations, construction of a pilot plant etc. in a status report (written in Danish and English respectively). In the report the consequences of the alterations regarding a full-scale demonstration plant (DK-Skørping) will be described. Further alternative Danish seasonal heat storages (large steel tanks, bore hole storages, and gravel storages) will be elucidated and compared to the pit heat storage concept

### **31 Optimally designed heat storages for large solar heating systems**

1995 - 1995

*Carlsson, Peter (civ.ing., ph.d.)*

*Danmarks Tekniske Universitet. Institut for Bygninger og Energi , Bygning 118 , DK-2800 Lyngby, Denmark , Tel. 45934477 , Fax 45934430*

*Københavns Kommunes Ingeniørkontor*

The purpose of the project is to describe the improvement possibilities for heat storage tanks in medium-sized solar heating systems. It is important that the temperature stratification in the tank is maintained so that the largest possible solar performance is obtained. Tests have shown that especially the design of the inlets to the tank are of great importance with regard to the temperature stratification. Therefore it will mainly be described how these inlet designs should be designed so that the temperature stratification is maintained to the greatest possible extent. Measurements from a medium-sized solar heating system in Glostrup are to illustrate how much Circon valves in the domestic water system increase the performance of the solar collector and to what extent the volume flow rate and the heat loss in the circulation pipe are reduced. From tests with the system in Glostrup and experience within the storage field a report will be worked out, describing the results of the project

### **32 New storage module for SæsonSol and extension with variable flow**

1995 - 1995

*Danmarks Tekniske Universitet. Institut for Bygninger og Energi , Bygning 118 , DK-2800 Lyngby, Denmark , Tel. 45934477 , Fax 45934430*

*Frøsig Jensen, F. (1995). Sæsonsol. Manual til version 3.1. Tillæg til manual sæsonsol version 3.0. simulering af solvarmeanlæg med lagring i ståltanke samt variabelt flow i solfangerkredsen. DTU-LV-95-28. 57 p. DKK.100*

The simulation program SæsonSol can simulate large solar heating systems with seasonal heat storage in hot water pits and bore hole storages. In this project the program is extended in order to be able to calculate on large steel tanks for seasonal storage and to operate with variable flow in the solar collector loop

### **33 Installation of heating system with a solar collector and clay-sealed pond heat storage**

0 - 1998

*Planenergi, Nordjylland , Jyllandsgade 44 , DK-9520 Skørping, Denmark , Tel. 98392400*

*Maureschat, G.; Heller, A. (1998). Ottrupgård solvarmecentral. Validering af sæsonsol-beregninger. vp.*

Udredningsprojektet 'Store lagre 2' og projektet 'Lertætning af damvarmelager, laboratorieundersøgelser ved høje temperaturer' viste at der er god grund til at tro at lertætnede damvarmelagre vil kunne fungere teknisk samtidigt med at prisen kan holdes under 250 kr/m<sup>3</sup>. Et forsøgslager på 1.500 m<sup>3</sup> i Otterupgård ved Skørping skulle eftervise dette i en skala, som er stor nok til at entreprenørfaringerne har relevans for lagre i størrelsesorden 50.000-100.000 m<sup>3</sup>. Disse erfaringer er blevet opnået i løbet af byggeprocessen. Det har også vist sig, at prisen på trods af en del projektændringer og fordyrelser undervejs fortsat ser ud til at kunne holdes under 250 kr/m<sup>3</sup> for lagre større end 50.000 m<sup>3</sup>. Problemer med den flydende lågkonstruktion har medført, at der er bevilget midler fra Energistyrelsen til mere intensiv kontrol af vandindtrængning og til laboratorieforsøg med en model af låget

### **34 Measurement program - Establishment of a heating systems with solar collector and clay-lined heat storage pool**

1992 - 1998

*Information missing*

*Planenergi Midtjylland A.m.b.A. , Jyllandsgade 1 , DK-9520 Skørping, Denmark , Tel. 96920400*

*Nellemann, Nielsen og Rauschenberger A/S (1995). Otterupgård, 1.500 m<sup>3</sup> dampvarmelager - målerapport, 1996-1997*

Målerapport for projektet; 'Etablering af varmeanlæg med solfanger og lertætnet dampvarmelager'. Måle- og styresystem for 1.500 m<sup>3</sup> dampvarmelager ved Otterupgård dokumenteres. Resultater af de to første års drift gengives. Anlægget yder stort set som forventet på trods af et betydeligt vandtab. Dette skyldes bl.a. at bebyggelsens varmekonsum er større end antaget

### **35 Cogeneration plant in Marstal fuelled with biomass, pre-project**

1998 - 1998

*Holm, Leo (Driftleder) ; Sørensen, Per Alex (PlanEnergi) ; Tambjerg, Leif (PlanEnergi); Münster, Ebbe (PlanEnergi); Lonnebjerg Carlsen, Jan; Sørensen, Keld; Bach, Inger; Jensen, Niels Aage*

*Marstal Fjernvarme , Jagtvej 2 , DK-5960 Marstal, Denmark , Tel. 62531564 , Fax 62532564 , info@solarmarstak.dk*

*PlanEnergi*

*Marstal Fjernvarme; PlanEnergi (1999). Biomassefyret kraftvarme i Marstal, forprojekt. vp.*

Marstal Fjernvarme received a permission, from the Danish department of Energy and Environment (Energi- og miljøstyrelsen), to use waste oil as fuel until 2001. Before the permission expires, it has to be investigated whether the resources have changed in a way, which could make it possible to change to biomass. It is to be investigated, through research, how the economic consequences by establishing a biomass fired combined heat and power station with long period heat storage, and various system configurations, would influence Marstal Fjernvarme. The user price will be calculated for the configurations: 1. Chip fired combined heat and power station 4 MW heat 1,5 MW electricity (electrical efficiency at 23-25%), and long period heat storage for storage of peak load production in the summer period. 2. As 1., but added a straw fired steam producing boiler for winter operation. 3. As 1., but added a biogas fired over heater. 4. As 1., but added a larger solar collector unit and a larger long

period heat storage. 5. An established larger chip fired combined heat and power station, but without the long period heat storage. The project results could have the interest of about 100 biomass fired heat stations, which do not have established electrical production. The project will help to illustrate the use of boiler systems with high electrical efficiency, and help to a faster change-over to biomass fired combined heat and power stations. Parts of the project results will be published at homepage: [www.solarmarstal.dk](http://www.solarmarstal.dk)

### **36 Calculation of heat storage for long periods for Hjørring heat supply 0 - 1999**

*PlanEnergi I/S , Jyllandsgade 1 , DK-9520 Skørping, Denmark , Tel. 96820400  
Planenergi I/S, Nordjylland (1998). Beregning af langtidsvarmelager til Hjørring Kraftvarmeværk. vp.*

Det var projektets formål at undersøge økonomien i etablering af sæsonvarmelagring i et kraftvarmesystem. Hjørring Varmeforsyning var valgt, fordi man der er dækket af varme fra affaldsforbrænding i 2 sommermåneder, hvorfor et naturgasfyret combined cycle anlæg står stille. Ideen med sæsonvarmelageret var at opbevare varme produceret med CC-anlægget i elspidslastperioder om sommeren og anvende den i lavlastperioder om vinteren. I projektet beregnedes økonomien ved anvendelse af en 100.000 m<sup>3</sup> ståltank henholdsvis med og uden varmepumpe og et damvarmelager med og uden varmepumpe. Økonomiberegningerne viste, at ingen af de foreslåede løsninger var rentable for Hjørring Varmeforsyning. Nærmest var et damvarmelager uden varmepumpe med en simpel tilbagebetalingstid på 18,9 år uden tilskud

### **37 Predesign study seasonal heat storage, St. Rise**

1999 - 1999

*Ulbjerg, Flemming (ing.) ; Knudsen, Henrik  
Ærø Energi- og Miljøkontor. Arbejdsgruppen for Fjernvarme i St. Rise , Vestergade 64 , DK-5970 Ærøskøbing, Denmark , Tel. 62521537 , Fax 62522731  
RAMBØLL*

To establish the necessary background for a decision to start a cooperation for a new district heating project in St. Rise at Aero (DK). Special focus: 1) Visualising the plant with 4000 m<sup>2</sup> solar panels and 4000 m<sup>3</sup> steeltank for heat store. 2) Visits to other biomass district heating companies. 3) Calculations of performance of the solar heating plant and the heat store. 4) Economic calculations for the entire plant ending up in the heat price for the consumers. The goal is with wellknown technology to gain a 50% solar fraction of the total demand for heat. A special attention is set on the temperature levels in the district-heating network. A return flow temperature under 35 degrees C in summer is another goal. The rest of the demand is planned being covered by wood pellets

### **38 Heat pump for heat storage tank**

1998 - 2000

*Marstal Fjernvarme A.m.b.A. , Jagtvej 2 , DK-5960 Marstal, Denmark , Tel. 62531564 , Fax 62532564 , [info@solarmarstal.dk](mailto:info@solarmarstal.dk)  
Marstal Fjernvarme [2001]. Afrapportering af projekt 'varmepumpe til sæsonlager'. vp.*

The purpose with this project is to investigate the interaction between solar heat unit, heat storage, buffer storage and the heat pump. The heat pump would be able to utilize the storage temperature from 35 deg. C to about 5 deg. C, at which the production of the solar collector, especially in the winter period, would be able to be increased and the storage capacity in the earth pipe storage tank will be doubled. The heat production could take place at any time of the day. At last the project will demonstrate the use of a heat pump with high COP and propane as a refrigerant

### **39 Feasibility study on establishment of 10-20,000 m<sup>3</sup> pit heat storage at Sydlangeland straw-fired district heating plant**

2000 - 2000

*Wesenberg, Carsten (akad.ing.) ; Bliksted, Torsten (geolog); Porsvig, Mogens (geotekniker, Geoteknisk Inst.); Duer, Karsten (civ.ing., DTU, IBE)*

*NIRAS Rådgivende Ingeniører og Planlæggere A/S. Energi- og Ressourceafdelingen , P.O. Box 119 , DK-9100 Aalborg, Denmark , Tel. 96306400 , Fax 96306474*

*Danmarks Tekniske Universitet. Institut for Byninger og Energi; Geoteknisk Institut*

*Visbjerg, L.; Wesenberg, C.; Bliksted, T.; Porsvig, M.; Duer, K. (2000).*

*Sydlangeland Fjernvarme A.m.b.a.: Forundersøgelse for 10-20.000 m<sup>3</sup> damvarmelager. 96 p.*

DA

### **40 Long-term heat storage in Marstal - Pilot project**

0 - 2001

*Holm, Leo*

*Marstal Fjernvarme , Jagtvej 2 , DK-5960 Marstal, Denmark , Tel. 62531564*

*Marstal Fjernvarme; Planenergi I/S (2001). Langtidsvarmelager i Marstal.*

Forprojekt. vp.

### **41 Lid constructions for warm water pit storages, phase 4**

1999 - 2001

*Duer, Karsten (forskningsadjunkt)*

*Danmarks Tekniske Universitet. Institut for Bygninger og Energi , Bygning 118 , DK-2800 Lyngby, Denmark , Tel. 45251867 , Fax 45934430 , kd@ibe.dtu.dk*

*Plastconsult; NIRAS; RAMBØLL*

Creating inexpensive and reliable lid constructions for large scale warm water pit storages is an important step in the development of non-polluting central solar heating plants with seasonal heat storage. The purpose of the project is to carry out large scale experimental tests on prototypical lid constructions (ca 5x20 m). The lid constructions developed and projected in the the previous phases of the lid constuction project are investigated over a period of about one year under realistic conditions and accelerated cycling of heating and cooling periods. Two different constructions will be investigated: a lid based on a polymer-liner and a lid based on a thin plate stainless steel liner. The water/vapour tightness, material corrosion/degradation, movements of the lid and the quality of the joints will be monitored. The test will also give valuable experience in the mounting and handling of the large floating lids

**42 Seasonal heat storage and solar heating for district heating. Phase 2**

2001 - 2001

*Ulbjerg, Flemming (ing.)**Rise Fjernvarme A.m.b.A. , Lykkevej 11 , DK-5970 Ærøskøbing, Denmark , Tel. 62522424 , Fax 62522430*

Projektet skal vise at det er teknisk muligt at dække 50% af et varmebehov ved fjernvarme med solvarme. Give driftserfaringer. Rimelig økonomi. Et led i Ærø som 100% VE-Ø. Målgruppen er forbrugere i Rise samt andre nye værker.

Formidle ved artikler, møder m.m.

**43 Establishment of 4000 m3 seasonal heat storage and exterior solar heating for district heating**

2001 - 2001

*Ulbjerg, Flemming (ing.)**Rise Fjernvarme A.m.b.A. , Lykkevej 11 , DK-5970 Ærøskøbing, Denmark , Tel. 62522424 , Fax 62522430*

Projektet skal vise at det er teknisk muligt at dække 50% af et varmebehov ved fjernvarme med solvarme. Give driftserfaringer. Rimelig økonomi. Et led i Ærø som 100% VE-Ø. Målgruppen er forbrugere i Rise samt andre nye værker.

Formidle ved artikler, møder m.m.

**44 Development of welding procedure and quality control for building of seasonal storage**

2001 - 2002

*Grydehøj, Hans (dir.) ; Hurup, Kim (FORCE Institutterne)**Marstal VVS A/S. Solvarme , Industrivej 5 , DK-5960 Marstal, Denmark , Tel. 62532346 , Fax 62531929 , mar\_vvs@post10.tele.dk**FORCE Institutterne**Marstal VVS (2002).Udvikling af svejseprocedure og kvalitetskontrol ved etablering af sæsonlager m.v.*

Formål: Projektets formål er, at udvikle svejseprocedurer for automatisk modstandssvejsning af rustfastplade AISI 2343 til brug ved bygning af flydende låg og yderliner i forbindelse med sæsonlagring af solvarme. Projektet skal endvidere udvikle et kvalitetsikringssystem, som dokumentere at den udførte svejsning ligger indenfor weldability lobe. Formålet i forhold til målgruppen er at dokumentere, at det er teknisk muligt at modstandssvejse rustfast tyndplade AISI 2343 in situ og kvalitetssikre det udførte svejse arbejde. Mål opfyldelse: Der er etableret svejseprocedure for modstandssvejsning af rustfast tyndplade, AISI 2343. Proceduren er dokumenteret i form af 2 WPS'er, der er vedlagt rapporten i bilag. Der er udarbejdet kvalitetssikringsmanual for svejse metoden og denne er afprøvet in situ. Destruktiv test på udvalgte steder har dokumenteret, at kvaliteten er ensartet og opfylder accept kriterierne fastlagt i WPS II. Der er udarbejdet en rapport der samler informationerne og de høstede erfaringer

**45 Solar thermal and long term heat storage in Marstal**

2002 - 2003

*Holm, Leo ; Sørensen, Per Alex; Münster, Ebbe; Tambjerg, Leif (Planenergi);**Ulbjerg, Flemming (RAMBØLL); Andersen, Svend (Arcon); Dalenbäck, Jan Olof (CIT Energy Management (SE)); Mangold, Dirk (Univ. Stuttgart (DE)); Schmidt, Thomas (Univ. Stuttgart (DE))*

*Marstal Fjernvarme , Jagtvej 2 , DK-5960 Marstal, Denmark , Tel. 62531564 ,  
Fax 62532564 , info@solarmarstal.dk*

*Planenergi; RAMBØLL; Arcon; CIT Energy (SE); Universität Stuttgart (DE)*

The scientific and technical objectives in this project are: The design of a ground mounted flat-plate collector with an efficiency improvement of at least 10% without corresponding increase of the price. Demonstrate a 10.000-m<sup>2</sup> solar collector field, divided in parts adapted for different levels of temperatures. Hereby both different types of ground-mounted flat-plate collectors will be demonstrated as well as focusing solar collectors. Thus district heating companies, for example, will be able to receive information about performance and experiences concerning maintenance under identical conditions for different types of solar collector fields. Heat storage and solar collector field will be demonstrated in the town Marstal, Denmark

#### **46 Activities concerning development of plastic liners for seasonal heat storage**

2001 - 2004

*Pedersen, Søren*

*Teknologisk Inst. Plastteknologi , P.O. Box 141 , DK-2630 Taastrup, Denmark ,  
Tel. 72203115*

*Pedersen, S. (2004). Fastlæggelse af levetider for 2 HDPE plastlinere til sæsonvarmelagre. DKK 150,-*

Projektets formål var at fastlægge levetider for plastlinere -til sæsonvarmelagre. Plastlinerne havde følgende mærkning. 'GSE HDPE geomembran' og HDPE type 507 - Fastlæggelse af levetiderne for disse plastlinere var en fortsættelse/udvidelse af projektet 'Fastlæggelse af levetider for plastlinere til sæsonvarmelagre, Energistyrelsens Udviklingsprogram for vedvarende energi j.nr. 151181/97-0074'. De testede plastlinere havde klart længere levetider end plastlineren testet i første projekt, idet levetiderne med samme ældningsprofil var forøget fra ca. 6 år til 24 år. Der var meget lidt forskel på de testede plastlinere, der var dog en tendens til at plastlineren mærket 'HDPE type 507' havde den længste levetid. I forbindelse med fastlæggelse af levetiderne, blev der også gjort forsøg med reduceret ilttilgang til plastlinerne. Dette forsøg var ikke vellykket, idet forsøget blev udført så der kom en utilsigtet påvirkning af ' metalioner, og disse medførte en additiv nedbrydningsmekanisme. Testene viste dermed ikke en forøget levetid, som følge af reduceret ilttilgang. Plastlinerne blev leveret af firmaet John Hunderup Import og Eksport, Syrenvænget 4, Kirke Stillinge, 4200 Slagelse

**47 Sunstore 2.** Per Alex Sørensen 2005. 2005 (see literature reference [75])

### 3 Danish companies

Danish companies involved in development, design and construction of storages for district heating purposes.

#### Consultants and knowledge centres:

PlanEnergi consultant engineers

[www.planenergi.dk](http://www.planenergi.dk)

Jyllandsgade 1

9520 Skørping

Contact person: Per Alex Sørensen

+45 96 82 04 00

Rambøll consultant engineers

[www.ramboll.dk](http://www.ramboll.dk)

Englandsgade 25

5100 Odense C

Contact person: Flemming Ulbjerg

+45 65 42 58 87

Niras consultant engineers

[www.niras.dk](http://www.niras.dk)

Vestre Havnepromenade 9, Postboks 119

9100 Ålborg

Contact person: Carsten Wesenberg

+45 96 30 64 00

COWI A/S consultant engineers

[www.cowi.com](http://www.cowi.com)

Parallelvej 15

2800 Lyngby

Contact person: Thomas Engberg Pedersen

+45 45 97 22 11

Marstal Fjernvarme district heating utility

[www.solarmarstal.dk](http://www.solarmarstal.dk)

Jagtvej 2

5960 Marstal

Contact person: Leo Holm  
+45 62 53 15 64

Brødstrup district heating utility  
[www.braedstrup-fjernvarme.dk](http://www.braedstrup-fjernvarme.dk)  
Fjernvarmevej 2  
8748 Brødstrup  
Contact person: Per Kristensen  
+45 75 75 33 00

GEO geotechnical Institute  
[www.geoteknisk.dk](http://www.geoteknisk.dk)  
Maglebjergvej 1  
DK-2800 Lyngby DK  
+ 45 45 88 44 44

BYG\* DTU Technical University of Denmark  
[www.byg.dtu.dk](http://www.byg.dtu.dk)  
Bygning 118  
2800 Lyngby  
Contact person: Simon Furbo  
+45 45 25 1857

Energinet.dk electricity and gas utility  
[www.energinet.dk](http://www.energinet.dk)  
Fjordvejen 1-11  
7000 Fredericia  
Contact person: Lise Nielson  
+45 70 10 22 44

### **Industries:**

ARCON Solvarme A/S Solar collectors for district heating  
[www.Arcon.dk](http://www.Arcon.dk)  
Jyttevej 18  
9520 Skørping  
Contact person: Jan Runager  
+45 98 39 14 77

GJ Vietnam Company Ltd. Solar collectors for district heating  
DK company situated in Vietnam  
[www.gjvietnam.com](http://www.gjvietnam.com)

Bladt Industries A/S manufacturer of steel tanks  
[www.bladt.dk](http://www.bladt.dk)  
Nørredybet 1  
9220 Aalborg Ø  
Contact person: Troels Jensen  
+45 96 35 37 28

Ellehauge & Kildemoes, COWI A/S





