Results from a Workshop on Research Needs for Modeling Aquifer Thermal Energy Storage Systems

August 1990

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RESULTS FROM A WORKSHOP ON RESEARCH
NEEDS FOR MODELING AQUIFER THERMAL
ENERGY STORAGE SYSTEMS

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SUMMARY

A workshop on aquifer thermal energy storage (ATES) system modeling was conducted in Seattle, Washington, on November 30 and December 1, 1989 by Pacific Northwest Laboratory (PNL).^(a) The goal of the workshop was to develop a list of high-priority research activities that would facilitate the commercial success of ATES. During the workshop, participants reviewed currently available modeling tools for ATES systems and produced a list of significant issues related to modeling ATES systems. Participants assigned a priority to each issue on the list by voting and developed a list of research needs for each of four high-priority research areas: the need for a feasibility study model, the need for engineering design models, the need for aquifer characterization, and the need for an economic model. The workshop participants concluded that ATES commercialization can be accelerated by aggressive development of ATES modeling tools and made specific recommendations for that development.

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RESULTS FROM A WORKSHOP ON RESEARCH NEEDS FOR MODELING AQUIFER THERMAL ENERGY STORAGE SYSTEMS

1.0 INTRODUCTION

As aquifer thermal energy storage (ATES) progresses towards commercialization, it is becoming increasingly important to move from basic research to applications of the technology. This trend will require the availability of modeling tools to support research, application feasibility studies, and engineering design studies. While there are active ATES research programs in both the United States and Europe, a focused and efficient research effort requires coordination of research activities. To encourage such coordination, a workshop on ATES system modeling was conducted in Seattle, Washington, on November 30 and December 1, 1989. The workshop was conducted by Pacific Northwest Laboratory (PNL), and it included internationally recognized experts in ATES modeling from Europe and North America. The goal of the workshop was to develop a list of high-priority research activities that would facilitate the commercial success of ATES heat and chill storage.

2.0 CURRENT SIMULATION MODELS

The first day of the workshop was spent in reviewing currently available modeling tools for ATEs systems. Table 1 summarizes the available models (computer codes) and indicates the types of research that can use each code. Applications are divided into research and development (R&D) applications and project applications. R&D applications tend to be generic investigations with the objective of understanding the factors influencing a system's cost and performance. The project applications are site-specific and focus on developing a workable, cost-effective design. A number of ATEs system models are available, but there are significant shortcomings in ATEs modeling, particularly the lack of models for system selection and feasibility studies, optimization studies, and detailed design studies. Component models do exist for some major components (particularly for the aquifer), but additional component model development is required.

TABLE 1. Review of Aquifer Thermal Energy Storage Modeling Tools

R&D	Modeling Tools (Computer Codes)												
	TEBKO	HST 2D	ZWALW PENGWIN	MINSUN	ATESSS	WFD	TRNSYS	DOE2	ASEAM	ATES EXP.	AQUA- STOR	DST SST	AST SBM
Systems			X	X			XX						
Components		XX				X	X	X				X	X
Optimization													
Project													
Prefeasibility (a.a. system selection)	XX								XX	XX			
Feasibility													
- technical	X	X	X	X	X	X			X			X	X
- economic	X		X	X					X				
Predesign													
- system opti- mization			X	X	X		X						
- control			XX		X		XX						
- costs			X	X		X		X			XX		
- components		XX			X	XX	X	XX			XX	XX	XX
Design													
- components											X		
Documentation	N	Y	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y

Legend

- X Indicates that the modeling tool (computer code) is useful for this type of research.
- XX Indicates that the modeling tool (computer code) is very useful for this type of research.
- N Documentation is not available for the computer code.
- Y Documentation is available for the computer code.

3.0 RANKING OF RESEARCH ISSUES

Following the review of current simulation models, the committee produced a list of 11 groups of significant research issues related to modeling ATES systems. They identified the following needs and issues:

- need for improved feasibility models - We need a simple model for conducting feasibility studies for a range of applications. The feasibility study model should include a simple aquifer model, but the required level of detail has not been resolved. It would be useful to have a model which could track uncertainties throughout the cost and performance calculations.
- need for improved design tools - It is important to develop a model suitable for conducting engineering evaluation studies. The model should be flexible to allow the simulation of a range of systems designs. The level of detail required in the aquifer model needs to be determined. Questions that need to be answered include the usefulness of the model for evaluating retrofit applications and the issue of developing a few general models or a larger number of models directed towards specific systems. It is important that the design tool be able to simulate the integration of the ATES system with the application.
- need for improved models of ATES/heating, ventilating, and air conditioning (HVAC) system integration - We need to develop a comprehensive list of the generic options for integrating ATES with typical HVAC and industrial process heat applications. The impact of aquifer characteristics on the selection of generic options needs to be understood.
- impact of site-specific aquifer characterization - There is general agreement that the site-specific features of the aquifer in an ATES system can be critical in determining the feasibility of an ATES application. Specifically, we need
 - improved methods of characterizing an aquifer during the feasibility study phase of a project
 - improved and more cost-effective methods for acquiring good input data for the more detailed aquifer models used during the design phase
 - alternatives to expensive testing for evaluating the geohydraulic parameters of a specific site.

- need for improved optimization models - The successful commercialization of ATEs will require the development of tools which are capable of evaluating a number of designs and selecting the optimum combination of design parameters. The major issue is the appropriate application of optimization tools: Should they be used in the feasibility study phase or in the detailed design phase?
- need for improved economic modeling - The accuracy of the economic model used in design and feasibility studies is as important as the performance model in determining the feasibility of a specific application. Economic models can be improved by information transfer between modelers on subjects such as the design basis for capital costs, economic methodologies, and economic assumptions.
- need for additional field testing - Additional field tests are required to verify models and theory.
- impact of improved software development techniques - Improvements in hardware and new software development tools will impact the development of ATEs modeling tools by allowing more rapid development and allowing the use of more computationally intensive models. New model development should be influenced by developments in this area.
- technology transfer - There is a danger in letting users simply operate the current generation of ATEs applications models because those models require that the user have substantial experience to develop inputs and to evaluate results. It is important to keep the needs of the user community in mind as new models are developed.
- impact of time scales - Design tools that can simulate short time scale events such as transient effects and control issues need to be developed. The coupling of short time scale effects with long time scale phenomena such as aquifer charging will require innovative techniques.
- need for generic aquifer models - One approach to handling site-specific aquifer characteristics is to develop generic aquifer models that can be used for site-specific studies.

The committee assigned priority to these issues by voting. Each member could cast eight votes, but no more than three votes could be cast for any one issue. The results of the voting are reported in Table 2. Because they are similar, the issues related to aquifer/application integration and design tool development (need for improved design tools and need for improved models for

ATES/HVAC system integration) were combined into one issue related to design tool development. The five highest priority issues were

- the development of a model for feasibility studies
- the development of a model for engineering design evaluations
- the development of procedures for evaluating and incorporating site-specific features of an aquifer into system models
- the development of optimization models
- the development of improved economic models.

TABLE 2. ATES Modeling Research Issue Priority

<u>Issues</u>	<u>No. of Votes</u>	<u>Priority</u>
Need for improved feasibility models	21	1
Need for improved design tools	13	2a
Need for improved models for ATES/HVAC system integration	9	2b
Impact of site-specific aquifer characterization	14	3
Need for improved optimization models	12	4
Need for improved economic modeling	10	5
Need for additional field testing	9	6
Impact of improved software development techniques	7	7
Need for technology transfer	2	8
Impact of time scales	5	9
Need for generic aquifer models	2	10

4.0 RESEARCH NEEDS

Following the identification of the high-priority research issues, the committee was divided into three groups. Each group developed a list of research needs for one of the high-priority research issues. The first group reviewed research needs associated with the development of a model for feasibility studies. The second group evaluated research needs for engineering design modeling. The third group assessed the research required for incorporating site-specific characteristics of aquifers into systems models. Recommendations on research needs for economic modeling were generated in a brief meeting of the whole committee. The development of an optimization model was not specifically addressed by the committee, but plans for the development of an optimization model for building cooling were discussed.

4.1 FEASIBILITY MODEL RESEARCH NEEDS

The group envisions the users of the feasibility study model to be engineering firms and government agencies involved in promoting seasonal ATES. With those users in mind, the group developed the following objectives for the feasibility study model:

- Determine the preliminary technical and economic feasibility of an application of ATES.
- Allow the selection of preferred or optimum ATES/HVAC system configurations or arrangements.
- Use relatively simple modeling techniques.
- Be easy to use (user friendly).
- Incorporate measures of risk or uncertainty.

The TEBKO code has been developed in The Netherlands for industrial applications. A new feasibility study model should be developed for space heating and cooling. A list of desirable characteristics for the HVAC feasibility study was developed:

- The model should be able to address all of the major elements of the system including the ATES system and the HVAC system.

- The model should include simple subroutines, submodels, or modules.
- A similar level of detail and accuracy should be used in all of the subcomponent models.
- The user should be able to select from several (four to six) alternative ATEs/HVAC systems.
- The model should include several/many subroutines modeling individual elements of the system.
- The model should address technical and economic risks.

The suggested model development activities include modifications to the TEBKO code for industrial process feasibility studies and the joint development of a feasibility study model for use in HVAC applications. The suggested modifications to TEBKO will be conducted by The Netherlands and will include

- improving the aquifer model in the TEBKO computer code
- improving some system sizing routines in TEBKO
- documenting cost and economic models
- including options for the user to adjust component cost relations.

The development of an HVAC feasibility study model will be conducted jointly by the United States and The Netherlands and will consist of the following activities:

- developing a simple aquifer model for feasibility studies
- developing equipment models for air coolers, duct coolers, and cooling towers
- developing new HVAC equipment models
- developing all new cost models
- developing optimization/selection methods for determining the best ATEs/HVAC configurations from sets of ATEs/HVAC options
- developing calculation schemes for the various HVAC system configurations
- developing a data base with component data that can be adjusted by the user.

4.2 ENGINEERING DESIGN MODEL RESEARCH NEEDS

Two engineering design models are required. The first class of model will be a complex and detailed system simulator with the capability to model complete systems, control strategies, and transient effects. It will be used by researchers to identify and develop attractive design configurations. The second class of model will be used to conduct engineering design evaluations. These models will simulate specific system configurations (rather than having the extensive flexibility of the first model) and will be used by engineering firms to select design parameters during a design study.

The goals for the detailed system simulator and the engineering design model include

- enabling evaluation of major design parameters and parameter sensitivity studies
- allowing the evaluation of control strategies
- facilitating the sizing of major components
- allowing the evaluation of risks and uncertainties.

The model should also be linked to economic models to allow parametric trade-off studies.

A general program for developing ATEs applications could consist of several steps. The first stage would consist of identifying possible applications and concept arrangements through workshops and literature reviews. An initial screening would identify the clearly attractive concepts, which would then be investigated in more detail. This review would use the detailed system simulator to identify attractive control strategies and design parameters and to investigate transient operation. This information would then be used to select the best concept configurations. It is anticipated that for each class of application concepts, a discrete engineering design tool will be developed. Although the engineering design tool will lack the flexibility and complexity of the detailed system simulator, it will be sufficient for sizing major components, selecting operating conditions, and evaluating uncertainties. While it is anticipated that a separate engineering design tool will be developed for each major concept, these tools should use common models, subsystems, and elements wherever possible.

4.3 AQUIFER CHARACTERIZATION RESEARCH NEEDS

During the feasibility stage of a project, the existing data bases are sufficiently developed to provide the necessary information; therefore, no extra effort is required in this area. If the project enters the design phase, then aquifer characterization must be an integral part of the design. In principle, the techniques for aquifer characterization are well understood and advanced. These techniques include 1) well pumping tests, 2) core evaluations, 3) geological aquifer studies, 4) outcrop studies, 5) tracer tests, and 6) shallow seismic surveys. Possible topics for research include

- a study of each aquifer characterization technique to determine its relative merits and costs
- a study of the ways that these techniques can be made more economical and efficient.

4.4 ECONOMIC MODELING

It was felt that the establishment of a consistent economic model or model inputs would not be fruitful given the differences between national economies. The emphasis was on clearly documenting and exchanging information on economic models and assumptions. Specific recommendations included the following:

- Each country should establish and document standard economic assumptions and criteria to be used by that country for conducting feasibility studies.
- The generic financial model developed by PNL should be documented and distributed internationally.
- Each country should document the designs and design assumptions used in developing capital costs.
- Each country should document the design and cost characteristics of the reference systems used for feasibility studies.
- Countries should share information on noneconomic factors that affect the selection of ATEs systems.
- An international economic and cost data base should be established and maintained.
- A procedure for verifying economic models should be developed.

5.0 CONCLUSIONS

The workshop participants agreed that ATES commercialization can be accelerated by aggressive development of ATES modeling tools. The participants made the following specific recommendations:

- Simple and flexible ATES systems models for feasibility studies should be developed.
- A detailed design tool for ATES systems research should be developed if existing design tools such as the TRNSYS and HVACSIM computer codes are not suitable.
- Engineering design tools should be developed for attractive ATES systems concepts.
- Improved methods for ATES field characterization should be developed.
- Economic data and assumptions should be shared between the countries involved in ATES research.

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