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Lessons from Iowa: Development of a 270 Megawatt Compressed Air Energy Storage Project in Midwest Independent System Operator

A Study for the DOE Energy Storage Systems Program

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A Study for the DOE Energy Storage Systems Program

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Abstract

The Iowa Stored Energy Park was an innovative, 270 Megawatt, $400 million compressed air energy storage (CAES) project proposed for in-service near Des Moines, Iowa, in 2015. After eight years in development the project was terminated because of site geological limitations. However, much was learned in the development process regarding what it takes to do a utility-scale, bulk energy storage facility and coordinate it with regional renewable wind energy resources in an Independent System Operator (ISO) marketplace. Lessons include the costs and long-term economics of a CAES facility compared to conventional natural gas-fired generation alternatives; market, legislative, and contract issues related to enabling energy storage in an ISO market; the importance of due diligence in project management; and community relations and marketing for siting of large energy projects. Although many of the lessons relate to CAES applications in particular, most of the lessons learned are independent of site location or geology, or even the particular energy storage technology involved.

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ACRONYMS

AS	Ancillary Services
AWEA	American Wind Energy Association
CAES	Compressed Air Energy Storage
CAREBS	Coalition for the Advancement of Renewable Energy through Bulk Storage
CC	Combined Cycle
CEC	Clean Energy Credit
CES	Customized Energy Solutions
CO_2	Carbon Dioxide
CREB	Community Renewable Energy Bond
CT	Combustion Turbine
DIR	Dispatchable Intermittent Resources
DOE	Department of Energy
DR	Demand Response
D-R	Dresser-Rand
EASE	Electricity and Air Storage Enterprises, Inc.
EPA	Environmental Protection Agency
ERCOT	Electric Reliability Council of Texas
ESA	Energy Storage Association
FERC	Federal Energy Regulatory Commission
FTE	Full-Time Equivalent
GE	General Electric
HRSG	Heat Recovery Steam Generator
IAMU	Iowa Association of Municipal Utilities
IOU	Investor-Owned Utility
IPF	Iowa Power Fund
ISEP	Iowa Stored Energy Park
ISEPA	Iowa Stored Energy Plant Agency
ISO	Independent System Operator
ITC	Investment Tax Credit
IUB	Iowa Utilities Board
kV	kilovolt
kW	kilowatt (thousands of Watts)
kWh	kilowatt-hour (thousands of watt-hours)

LMP	Locational Marginal Price
LSE	Load-Serving Entity
MAPP	Midcontinent Area Power Pool
MISO	Midwest Independent System Operator
MRES	Missouri River Energy Services
MVP	Multi-Value Project
MW	Megawatt (millions of Watts)
MWe	Megawatt (millions of Watts) electrical
MWh	Megawatt-hour (millions of watt-hours)
NOPR	Notice of Proposed Rulemaking
NPV	Net Present Value
NYMEX	New York Mercantile Exchange
O&M	Operating and Maintenance
REC	Renewable Energy Credit
RES	Renewable Energy Standards
RT	Real Time
SA	Schulte Associates LLC
SCED	Security Constrained Economics Dispatch
SME	Subject Matter Expert
SNL	Sandia National Laboratories
SPA	System Planning Analysis
TO	Transmission Owner
WAPA	Western Area Power Administration

EXECUTIVE SUMMARY

This report summarizes the due diligence lessons learned in development of the Iowa Stored Energy Park (ISEP) project—the Lessons from Iowa. The purpose of the report and related documentation and marketing efforts is to enable these lessons to assist other storage projects in their development. The different areas of interest are broken into sections, and each section summarizes the lessons learned in bulleted form. Further details and resource references for each Lesson are provided in the individual sections.

Section 1: Introduction

Lessons from Iowa represent the due diligence lessons learned in development of the ISEP project. ISEP was a proposed 270 Megawatt (MW), $400 million compressed air energy storage (CAES) project to be located near Des Moines, Iowa, with in-service proposed for 2015. ISEP was owned by the Iowa Stored Energy Plant Agency (ISEPA), a public power agency organized under Iowa Statutes 28e, and representing 57 municipal utilities in four states (Iowa, Minnesota, North Dakota, and South Dakota).

The project planned to take advantage of the site's favorable geology and its location on the edge of a very favorable wind energy regime. Also, Iowa is a leading state in wind energy development. While ISEP was focused on CAES technology in the Midwest Independent System Operator (MISO) market, most of the lessons learned are independent of site-specific geology, and should be directly applicable to multiple storage technologies in multiple markets.

To provide context for the reader:

- ISEP was primarily intended to be a source of capacity as well as providing significant amounts of daily energy to the project owners. As such, it was intended as an "intermediate" supply resource available for operation up to 12 to 16 hours per day on weekdays, year-round.
- Providing ancillary services to the regional market was considered a secondary goal, rather than a primary goal of ISEP.
- ISEP was designed to be a large (270-MW) bulk storage facility located on the regional transmission grid. This contrasts to various other storage applications co-located with renewables facilities "behind the customer's meter," or located within a utility's distribution substation.
- The project was originally conceived by public power entities for use by public power entities. It was later revised to enable investor-owned participants as well.

The Lessons show that cost and economics considerations, while important, are only two of the challenges for implementing cost-effective bulk storage. Institutional, policy, legislative, and market forces also exist and need to be addressed.

Section 2: Project History

The benefit of hindsight shows that many of the Lessons from Iowa resulted from who the project owners were (and were not), and how the project was originally assembled and then evolved. The ISEP project was originally conceived as a public power project with public power (not-for-profit) owners. The public power-focused history of the ISEP project favorably affected the financials of the project, and negatively limited the market for project participation. The original participants in ISEP were municipal distribution utilities with extensive experience in distribution, but little experience in power plant project development. This negatively affected their ability to move the project forward until participants who had such experience joined ISEPA later in the project. The ISEPA members did not own wind energy or transmission facilities near the ISEP project site. They also did not own conventional intermediate or baseload generation facilities near the site. This negatively affected their ability to evaluate and capture all of the potential storage benefits of the ISEP facility.

Section 3: Economics

In evaluating costs, it is difficult to achieve comparable cost estimates for energy supply alternatives from different sources. Accordingly, the project spent much effort to develop costs for the proposed storage facility and conventional alternatives that were directly comparable. The owner’s in-service capital cost of a bulk storage CAES facility like ISEP is about 20% higher than a comparably sized, conventional natural gas-fired combined-cycle electric generation facility. The fixed and variable O&M costs and environmental emissions rates per kilowatt-hour (kWh) of a CAES facility are similar to comparably sized conventional generation alternatives.

A CAES facility is operationally more flexible than a conventional generation alternative. It can start up faster, ramp up and down faster and in a linear manner, accommodate multiple daily startups and shutdowns better, and has a lower minimum load level. In addition, it can store electricity. A CAES facility has a significantly better heat rate (better fuel efficiency) in generation mode than a conventional natural gas-fired generation facility. This means lower fuel use during the generation cycle, and lower emissions.[1]

A bulk storage CAES facility like ISEP can be cost-effective when operated in the MISO market. It can also be more cost-effective than conventional, natural gas-fired generation alternatives.

The ISEP studies outlined in this section describe how bulk storage has unique attributes that can reduce system-wide production costs, improve the operation and profitability of regional conventional generating plants, decrease cycling (and operating and maintenance [O&M] costs) of conventional plants, offer a 100% dispatchable off-peak load for use by system operators to optimize the regional system, and enable an electric options market to address hourly price volatility (both upward and downward).

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1 Exclusive of fuel used in the storage (compression) cycle.

In addition, a bulk storage facility like ISEP can be supportive of renewables development and positively affect the economics of a system. Dispatched against MISO market prices, it can store electricity during off-peak periods when the wind is blowing, and generate during on-peak periods when the wind is not blowing.

Section 4: Transmission

Much has been written about the potential benefits of storage in reducing or deferring transmission investment. As a result, the transmission benefits identified in the ISEP economics study (specifically, the lack thereof) was disappointing. However, the reasons for this outcome are illustrative of issues facing bulk storage.

Little or no such benefits were found because ISEP was a bulk storage unit to be located on the transmission system "outside the customer's meter," as compared to a distributed storage unit such as a battery collocated with renewable resources "behind the meter." This meant the ISEP storage could be subject to potential transmission constraints *between* the storage and the renewable resource.

The MISO system in and near Iowa currently needs very large amounts of additional new transmission. The magnitude of that need significantly exceeds the size of the ISEP storage facility. From a generation interconnection perspective, whether the ISEP facility happened or not would not materially change these transmission development plans.

The ISEP owners do not own transmission near the proposed ISEP storage site, so they would not directly benefit from any reduced investments from transmission deferral.

The MISO generator interconnection study process examines transmission requirements as driven by the generator side of the storage facility. It does not consider the potential transmission savings of the storage (dispatchable load) aspect of the storage facility.

The amount of analytical work involved in determining any potential transmission benefits of the ISEP storage in reducing the current curtailment of Iowa wind resources was beyond the scope and resources of the ISEP economics study, and would have required the cooperation of wind energy and transmission owners who were not participants in ISEP. As a result, no cost benefits for transmission were included in the ISEP economics analyses.

This outcome does not necessarily say that a storage facility like ISEP would not have transmission benefits. However, it represents "lessons learned" that location of the storage on the transmission system, particularly relative to generation facilities that could benefit from the storage, matters; ownership (of the storage) also matters, as discussed in Section 5, particularly with regard to transmission and integration with renewables; and the regional ISO has not yet developed sufficient planning processes (as further described in Section 4 with regard to transmission) and tariffs (as described in Section 5) necessary to accommodate and enable storage.

Section 5: Markets and Tariffs

An "ideal" storage owner would be able to internalize all the benefits of the various valuable storage attributes for themselves. However, in an ISO with centralized dispatch, most of these benefits are disseminated to entities other than the storage owner. The ISO needs to actively innovate and enact market and tariff improvements to "commoditize" the various beneficial attributes of storage, so the storage owner can "monetize" them as incentive for them to own and operate the storage. The authors offer multiple suggestions for the tariff improvements necessary for an ISO to enable storage in their market area.

Legacy computer resource planning models used by utilities do not do a good job of modeling storage. They simply do not capture all of the beneficial attributes of storage. As a result, ISO policy toward storage should not be based primarily on such models. Conversely, MISO policy toward storage and renewables should drive necessary improvements in the models.

MISO is in the process of performing a major study of storage. Without ISEP, MISO lacks a new large storage project to drive the particulars of needed policy and tariff development for storage and renewables.

Section 6: Renewables Policy and Legislation

There is a growing realization that renewables and cost-effective storage can be combined and coordinated into an effective combination electric supply resource for the future. Because it enables renewables development, bulk storage itself should be eligible for credit against state renewable energy standards (RES) or federal clean energy standards requirements. Legislation or other policy initiatives are necessary to enable the full benefits of storage in encouraging and supporting renewables development.

Some examples:

- Passing the investment tax credit (ITC) and Community Renewable Energy Bond (CREB) financing provisions of the federal STORAGE 2011 Act sponsored by Senators Bingaman, Wyden, and Shaheen into law. This would have a materially beneficial effect on storage economics. This bill was reintroduced in the U.S. Congress in November 2011 as the STORAGE 2011 Act (S. 1845) by Senators Wyden, Bingaman, and Collins.
- Assigning state Renewable Energy Credits (RECs) or federal Clean Energy Credits to the storage function itself, if the storage can demonstrate it supports renewables development and operations.
- Classifying bulk storage itself as a Clean Energy Technology in any federal Clean Energy legislation, if the storage can demonstrate it is supportive of renewable energy.
- Creating a market for "firm" renewable energy. This is where the combination of renewables and storage is used to create a renewable product with both energy *and* dependable capacity attributes that has value above and beyond a corresponding amount of conventional, fossil-fueled capacity and energy.

Section 7: Siting

Due diligence demands that a storage project engage in an active and collaborative public and government affairs initiative. When siting an underground storage project in a community, market research of the community in advance is useful. Once market research is gathered, it should be used in real and practical ways.

It is important for the project to appear credible and trustworthy early in the process. Community objections to a new project are often based on a lack of information. To the maximum extent possible, decision processes should be transparent and accessible to the community affected; and the local community should be involved in decisions about where the plant facilities will be located.

Section 8: Project Management

A storage project by definition involves multiple and diverse parties. These would include the storage facility owner(s), transmission owner(s), wind energy resource owner(s), power purchase agreement off-taker(s), the power market(s), and potentially others. In an open access environment, it is unlikely that all of these parties would be the same entity.

It is a common misconception that development of a power plant involves only physical construction and operations. Instead, the initial years of development involve organizational definition and relations, market development, geology research, cost estimates, economic studies, contracts, financing considerations, and regulatory permitting.

Development of a bulk storage project like ISEP takes years before a Notice to Proceed to purchase equipment and construction occurs. During the initial development phase, the project Board's and Project Manager's primary job is due diligence, as a storage project needs an articulated due diligence/development plan to be successful.

A storage project by its nature will involve multiple and diverse participants, and this needs to be built in from the start. All prospective project owners/participants should be qualified by the project before they join it. Unless the project capacity is fully subscribed from the start, its organizational structure, financing plan, and ownership contracts plan need to think broadly regarding the types of owners (i.e., public power or investor-owned) that would be eligible to participate in it. Project participation should be on a project MW output-share basis from the start, rather than only investment dollars-based. All owners' participation should be based on paying their pro-rata share of project costs, based on their respective planned shares of the plant output.

On important issues, second opinions should be sought when there is uncertainty because of lack of data or other factors. Politics internal to the project owners' group can have major consequences on a project; consideration of the needs of all the participants is important to provide the necessary cooperation for the project to proceed.

Because such projects will likely involve multiple and diverse project owners, and because the complexity of characterizing the aquifer-based reservoir will involve expert opinions rather than only facts, the due diligence team and project manager should report to the project as a whole, rather than an individual project owner.

Section 9: Geology

From a technical geology perspective, accomplishing the site selection and geologic analysis for a greenfield, aquifer-based CAES project where there is no existing data or prior use of the reservoir is time-consuming and challenging.

From the business perspective of the storage facility owner, developing a greenfield, aquifer-based CAES project is problematic. Although the project's long-term economics looked favorable, the geology was a negative factor.

Section 10: Observations and Recommendations for Follow-on Work

An entity or entities contemplating ownership of or participation in a bulk storage project need to consider who they are, and what kind of market they will be operating in. This affects whether they can achieve the full gamut of potential storage benefits described in Section 3 in such manner that they will be sufficiently incentivized to own and operate the storage facilities.

Off-peak to on-peak price spread arbitrage is often considered the primary potential economic benefit of a bulk storage unit, but the ISEP experience and studies show it is not the only one. Accomplishing bulk storage will require the tapping of the full range of storage's attributes, benefits, and value described in Section 3:

- Off-peak to on-peak price arbitrage (intrinsic value).
- Option value to address price and quantity variability (extrinsic value).
- Fast startup, multiple daily startups/shutdowns and fast ramping (ancillary services).
- 100% dispatchability of off-peak load (to improve capacity factors and reduce cycling of conventional plants, and reduce curtailment of renewable resources).
- Ability to enable more renewable resources than could be accomplished without storage.
- Transmission deferral.

A storage owner or participant must be ready and capable to innovate if they hope to achieve the full benefits of such a project. As described in Section 5, many of the market mechanisms necessary to enable new storage projects do not currently exist.

The ISEP project was focused on future operation in the MISO market. Although specific market operating rules vary among the various ISOs, the conceptual lessons learned about what it takes to make bulk storage happen in MISO would likely apply to other ISO markets as well. MISO is working on various storage studies and tariffs, and these efforts need to result in tariffs that can enable the full range of beneficial storage attributes and the full value of storage for the storage owners and the MISO region as described in Sections 3 and 5. This would include ancillary services tariffs, creation or participation in an electric options market as necessary to achieve the full extrinsic value if the storage owner cannot monetize such value themselves, and coordination with various legislative initiatives providing incentives for additional renewables (and related storage) development.

Another market concept that deserves consideration is the creation of a market product involving "firm" or "firmed" renewable energy, with both energy and capacity components. Historically, renewables have been thought of as primarily an energy resource because they are intermittent. Combinations of renewables and storage could provide renewable energy capacity value as well. This combination should be valued and priced as a premium product compared to conventional energy sources, similar to organic produce sold in supermarkets.

As described in Section 5, existing computer resource planning models do not do a good job calculating the potential benefits of storage. MISO is working on improved modeling techniques, but more improvements need to happen before the models. In the meantime, the authors suggest that MISO policy toward encouraging storage, particularly to address increasing levels of intermittent renewables on the regional system, should drive modeling improvements, rather than modeling shortcomings suggesting MISO storage policy.

Demonstration storage projects can also be useful. It is recognized that from a practical perspective, MISO and other markets probably need specific new proposed bulk storage projects of material scale that would help drive the need for proved tariffs, markets, and planning models. Doing such development in the abstract without an actual specific project to focus on is difficult, and would probably be (rightfully) assigned a low work priority.

The need for storage is growing, at least in part, as a result of legislatively driven incentives for renewable energy development. For the same reasons, storage should be similarly encouraged by legislation too. Simply, storage enables existing renewables (and other resources) to operate better, and enables more renewables to be built than could be accomplished otherwise.

Legislation at the federal level for storage should include passage of the STORAGE 2011 Act (as described in Section 3 and 6) or something similar, including ITCs for investor-owned bulk storage owners and CREB financing for public power entities. If a national RES or Clean Energy Standard is passed, then bulk storage that demonstrably enables renewables operation and development should itself be classified as a renewable or clean energy resource, and thereby eligible itself for RECs or clean energy credits.

Legislation at the state level for storage should include recognition of the role of bulk storage in enabling renewables development and achieving state RES. For those bulk storage facilities that demonstrably enable renewable operation and development their storage energy should be, in whole or in part depending on the project-specific circumstances, credited against the owners' state RES requirements and eligible for RECs of their own.

1. INTRODUCTION

1.1 Purpose

The Iowa Stored Energy Park (ISEP) project, a 270 Megawatt (MW), $400 million compressed air energy storage (CAES) project to be located near Des Moines, Iowa, was terminated on July 28, 2011 [1]. The Iowa Stored Energy Plant Agency (ISEPA), an Iowa Statutes Section 28e power agency representing 57 municipal utilities in four states who owned the project, ended the project after eight years of development because of project site geology limitations. About $8.6 million had been invested in ISEP by the ISEPA members, the U.S. Department of Energy's (DOE's) Storage Systems Program, and the Iowa Power Fund.

With the encouragement and support of the DOE's Energy Storage Program, "Lessons from Iowa" (referred to in this document as "Lessons") is the documented lessons learned of the ISEP project. The purpose of this report and related documentation and marketing efforts is to enable Lessons from Iowa to assist other storage projects in their development. By documenting Lessons, it is hoped that other storage projects, whether they use CAES or other technologies, can avoid confronting the issues and challenges addressed by ISEP. Most of the Lessons are independent of geology, or even of the storage technology used.

1.2 Content

Lessons represents the practical experience of public power utilities in developing a large, utility-scale, bulk storage project in an independent system operator (ISO) marketplace. The content of Lessons is designed to enable the reader to quickly identify the lessons learned in the project, and access the detailed project reports that document the individual lessons.

This report and associated documentation are organized in the following sections:

- An Executive Summary that overviews the Lessons in each section category.
- Section 1: Introduction (this section).
- Section 2: Project History.
- Section 3: Economics.
- Section 4: Transmission.
- Section 5: Markets and Tariffs.
- Section 6: Renewables Policy and Legislation.
- Section 7: Siting.
- Section 8: Project Management.
- Section 9: Geology.
- Section 10: Recommendations for Follow-on Work.

Each section includes references to the detailed project reports developed during the ISEPA project that provide additional background information on each section topic.

This report and the documentation library will be posted for public reference and use on the ISEPA website at www.isepa.com.

1.3 Context for the Reader

The Lessons from Iowa provide knowledge gained that can be used in the development of other storage projects.

The ISEP experience represents some of the most-current development work in bulk, grid-connected electricity storage in general, and CAES in particular. Also, in contrast to other, privately developed storage projects, the public nature of the ISEP project allows Lessons to be openly offered for public information and use.

While the ISEP project was focused on CAES technology, many of the lessons learned are independent of geology, and should be directly applicable to multiple storage technologies. Because ISEP was to be a bulk storage unit located on the transmission grid, some of the Lessons (particularly transmission system impacts) are unique to such a configuration. Some Lessons are not directly applicable to distributed storage applications where the storage is located behind the customer's meter, or within a utility's distribution substation. Because the ISEPA members intended ISEP to be a source of intermediate-duty capacity and energy, it was designed to be an energy machine, with ancillary services being only of secondary interest to the extent that could provide additional revenues for the project. This is in contrast to other storage technologies (i.e., flywheels and some applications of batteries) that have relatively short durations of output and thus see providing ancillary services as their primary source of revenue.

Because ISEPA is a public power entity, the primary focus of Lessons (particularly the economics studies) is from a public power perspective. However, because investor-owned participants/owners were also envisioned for the project, sensitivity analyses are included where financial and other economic results would vary from that of a public power owner.

Much of the ISEP work presented in Lessons from Iowa was performed as due diligence to help the ISEPA members and potential new project participants decide whether participating in the storage project was a good idea for them and for their customers. As such, Lessons represents a learning laboratory and process for anyone interested in considering storage, and whether storage will work for them. Lessons shows that costs and economics, while important, are only two of the challenges for implementing cost-effective bulk storage. Institutional, legislative, and market forces and market development issues also exist. Simply, storage is very different from the conventional generation and transmission resource technologies that have been applied in the electric grid to date. As described in Sections 3 and 7, in the process of the ISEP project the ISEPA members realized their strengths and weaknesses as candidates to own bulk storage. The corresponding costs and benefits for other storage ownership candidates will depend on their unique needs and characteristics, their customers, the electric market in which they operate, and certainly their level of innovation.

2. PROJECT HISTORY

2.1 Introduction

This section describes the history of the ISEP project and its owners, the ISEPA. The benefit of hindsight shows that many of the Lessons from Iowa resulted from who the project owners were (and were not), and how the project was originally assembled and then evolved.

2.2 Lessons

The ISEPA project was originally conceived as a public power project with public power (not-for-profit) owners. The project began as an effort by the Iowa Association of Municipal Utilities (IAMU, www.iamu.org) to develop an energy project for its members. The following time line outlines the chronology of project development.

In 2002, an IAMU study indicated a need for municipal utilities to secure intermediate[2] electricity supply resources. IAMU determined that CAES technology could meet that need. An ISEP Committee of IAMU members was formed to lead the effort. Iowa has an excellent wind energy regime. Figure 1 illustrates the wind potential in the United States, and highlights that most of the potential exists in the Midwest, including Iowa.

In 2003, the ISEP Committee raised $680,000 in project development funds from IAMU members. As an incentive, the members were offered multiples on their investments contingent upon the ISEP project reaching commercial operation. The ISEP Committee commissioned Burns & McDonnell to develop a conceptual design and cost estimate for the project [2].

In 2004, the project received a $150,000 Federal DOE grant. A study of a potential site near Ft. Dodge, Iowa, concluded the site would not meet the participants' needs [3]. Municipal funding of the project exceeds $1 million.

In 2005, multiple project studies were performed. Among them, a generic (non-site-specific) feasibility study by Black & Veatch Corporation found, "The project appears to be economically viable under a number of scenarios, and the project risks can be controlled." [4] A screening report by Hydrodynamics Group LLC identified possible geologic sites in Iowa [5]. The ISEPA was formed as a public power agency under State of Iowa Statutes 28e for purposes of administering the ISEP project. ISEPA took over the role of project governance from the ISEP Committee and IAMU. Eleven IAMU members became the original ISEPA members.

ISEPA received a $1.5 million DOE grant for the project.

In 2006, as described in Section 9, the Dallas Center site near Des Moines was chosen from other site alternatives, primarily because of its relatively favorable geology. As shown in Figure 2, the site was on the edge of a very favorable wind energy regime.

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2 The term "intermediate" refers to energy resources that are neither baseload (operating continuously) or peaking (operating only at peak load times). Instead, they operate on a daily basis (typically during daylight hours on weekdays) to meet the rise and fall of utility customers' typical electric usage.

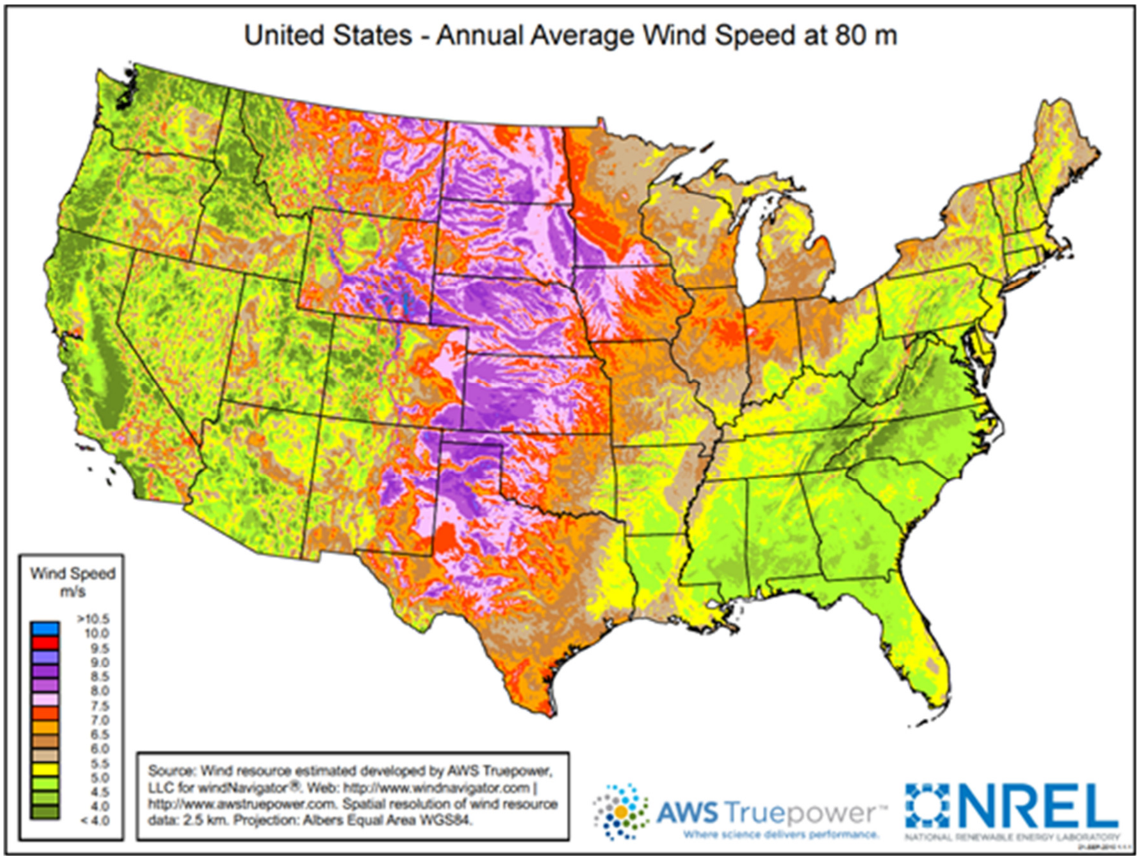

Figure 1. Annual average wind speed at 80 meters height [6].

Initial seismic studies of the Dallas Center Dome site were performed. Hydrodynamics interpreted the data and confirmed the presence of a geologic dome at the site [7].

ISEPA received another $1.5 million DOE grant for the project. The ISEPA Project Team determined that an overall public relations effort was necessary. Frank Magid Associates of Marion, Iowa, was retained to develop the plan. The resulting media strategy was executed with press and television coverage. See Section 7 for details.

In 2007, additional seismic studies were performed on the Dallas Center site to supplement and further extend initial studies done the previous year. Hydrodynamics used the collective seismic data to develop a computer reservoir simulation model, using the characteristics of the nearby Northern Natural gas storage site at Redfield as an analog [9].

A market feasibility study was performed, which concluded “the Project is estimated to yield positive net margin.” [10]

Congressional earmarks were eliminated in FY 2007. However, the DOE/OE Energy Storage Program provided $200K in funding to continue the project. The project governance structure was reorganized with ISEPA established as an Iowa Statutes 28e public power agency.

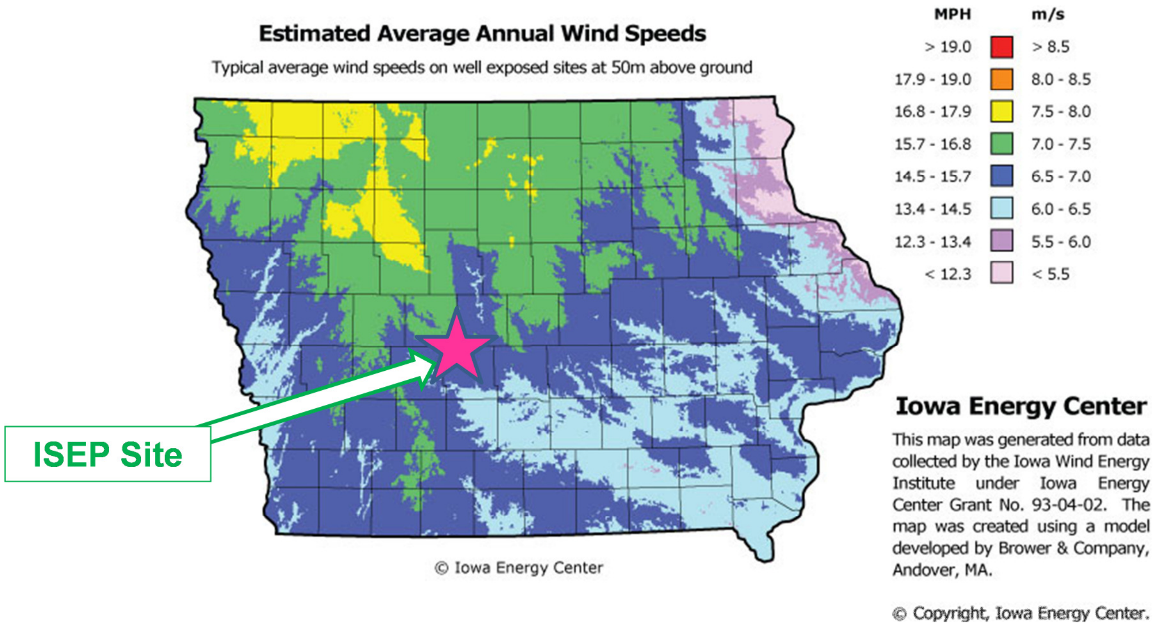

Figure 2. Annual average wind speed in Iowa and ISEP storage project site [8].

In 2008, ISEPA received an additional $1.5 million DOE grant for the project. ISEPA applied for and received a $3.2 million loan from the Iowa Power Fund to support test well drilling and pump testing at the Dallas Center site [11]. The loan was to be repaid, or converted to equity ownership in ISEP by the State of Iowa, contingent on the ISEP project successfully achieving commercial operation. The loan was forgivable if the project was not successful.

A study performed by Black & Veatch for Missouri River Energy Services (MRES) concluded "…that within a wide range of reasonable expected values for capacity and energy services, participation in the ISEP unit proposed by the Iowa Stored Energy Plant Agency (ISEPA) would be to MRES's economic benefit." [12]

In 2009, MRES and Utilities Plus, both municipal power agency's with experience and internal staffing for energy supply resource planning and power plant project development, joined ISEPA. A land acquisition strategy was developed, and land appraisals were acquired. The "Keith" property was purchased, as it represented the then-known center of the top of the storage reservoir structure. In November, the Mortimer property was acquired through a bidding process described in Section 7. Along with the Keith property, this was intended as the above-ground plant site. Discussions began within ISEPA regarding the need to retain an independent third-party to lead a due diligence effort as a basis for decisions on the project.

In 2010, the ISEPA Board of Directors retained Schulte Associates LLC (SA, www.schulteassociates.com), a management consulting firm with experience in power project development, management, and permitting, in April to develop and lead an independent, third-party, and objective due diligence effort on the project. Robert H. Schulte of SA became Executive Director and Project Manager to accomplish this. SA defined the due diligence process as having three components: economics studies, site geology, and project marketing. All three components needed to be successful for ISEP to be successful.

Two test wells (Keith Well #1 and Mortimer Well #1) were drilled and pump tested. Core samples were sent to Sandia National Laboratories (SNL) for testing (see Section 9 for details).

As the result of a competitive bid process, R.W. Beck was retained and performed the “Phase I” cost and economics studies. See Section 3for details. At SA’s recommendation, the ISEPA Board decided to consider other, non-public power entities as participants in the project (see Section 8 for details). Initial project marketing to potential new participants was performed (see Section 8 for details). Project transition agreements were developed between the ISEPA members to move the project from investment-based participation to Megawatt share-based participation, and to enable the addition of new, non-public power participants (see Section 8 for details). An additional $145,000 in project funding was invested by ISEPA members.

In 2011, the third test well (Mortimer #2) was completed. Core samples were sent to SNL for testing (see Section 9 for details). An additional $105,000 in project funding was invested by ISEPA members. R.W. Beck was retained and performed the “Phase II” economics studies (see Section 3 for details). Project marketing to potential new participants was continued and expanded early in the year, but later suspended when results of the geology studies indicated the outcome might be unfavorable.

Hydrodynamics performed computer reservoir modeling of the Dallas Center site including the results of the test wells. The results showed the geology of the site to be challenging because of low permeability of the sandstone storage structure. Instead of the contemplated 270 MW, the site could perhaps accommodate a smaller CAES Project of about 65 MW (see Section 9 for details). A third-party peer review of the site geology findings chartered by the ISEPA Board and performed by MHA Petroleum Consultants, based on the work by Hydrodynamics, found the Dallas Center site as unsuitable for a CAES project of any size (see Section 9 for details). The R.W. Beck Phase II report showed that a CAES project smaller than 270 MW would not be cost-effective. Based on the geology and economics results, the Project Management Team recommended to the ISEPA Board that the project at the Dallas Center site be terminated. The Board agreed and voted unanimously on July 28, 2011, to terminate the project. Project shutdown activities (capping of the test wells, restoration of the well sites, sale of project properties, etc.) were under way at the time this report was written.

The DOE’s Storage Systems Program and SNL provided support for documenting Lessons from Iowa, and providing Lessons to other storage projects under development.

The public power-focused history of the ISEP project favorably affected the financials of the project, and negatively affected (i.e., limited) the market for participation. As discussed in Section 3, having public power entities as owners of the project helped the cost-effectiveness of the ISEP storage project. This happened because the financing requirements of public power entities for large capital investments are lower than the corresponding requirements of for-profit entities like investor-owned utilities (IOUs). As a result, the annual capital investment-related revenue requirements on the ISEP investment (return of and on the debt service) for a public power storage owner are smaller relative to the potential annual operating benefits of the project than they are for a for-profit owner. This makes the project benefit/cost ratio for a public power entity tend to be higher than that for an investor-owned entity for the same project. In the absence of investment tax credits (ITCs), this is generally true for any large capital-intensive utility project, not just storage.

The project was originally conceived as an effort by public power, for public power. In the early stage of the due diligence effort in mid-2010, SA advised the ISEPA members that their total need for such resources could not justify the entire 270-MW project. In fact, the ISEPA members alone could potentially justify only about 50 MW to 100 MW of the project. Additional project participants would be needed to fully subscribe the project. That meant that the project would need to approach non-public power entities for their participation. After much discussion, the ISEPA members agreed to do that.

The original IAMU participants in ISEP were municipal distribution utilities with extensive experience in distribution, but little experience in power plant project development, and this affected their ability to move the project forward until participants who had such experience joined ISEPA later. The original participants typically procured their energy resources from wholesale power suppliers through contract arrangements, or as partners in multi-owner power plants. Those wholesale power suppliers and power plant partners had provided the expertise and management to actually develop the power plant facilities themselves. This background of the original ISEP participants limited their efforts to research and development studies until the MRES and Central Minnesota Municipal Power Company power agencies joined ISEPA as members in 2009.

The ISEPA members did not own significant quantities of wind energy or transmission facilities near the ISEP project site. They also did not own significant quantities of conventional generation facilities near the site. This negatively affected their ability to evaluate and capture all of the potential storage benefits of the ISEP facility. As a result, the due diligence process determined that the ISEPA members by themselves were probably not the most beneficial owners of storage. Either they needed to secure additional project participants with the desirable characteristics, or they needed further developments in MISO markets and tariffs to realize the full value, or both. See Section 5 for more details.

3. ECONOMICS

3.1 Introduction

The results of the economics analyses are described in this section. The cost assumptions developed for the CAES project and its alternatives are also included. The economics study was performed in two phases, and both phases are detailed here.

3.2 Costs

3.2.1 Introduction

In preparation for the economics study, the ISEPA Project Team and its consultants spent considerable effort to correctly estimate the input cost assumptions. The results of the cost estimate process are described here.

Experienced utility resource planners understand that it is very difficult to get truly comparable cost figures from different alternatives from different reference sources. This occurs because there is not a standard definition of what cost elements are included in a capital cost. Accordingly, the Project Team worked to develop cost assumptions for the various alternatives on a consistent and comparable basis.

Cost assumptions for the ISEP CAES facility were based on previous work by Burns & McDonnell and Black & Veatch for the project, updated by Brulin Associates working with R.W. Beck and Dresser-Rand (D-R). Cost estimates for comparably sized conventional natural gas-fired CC and simple-cycle CT generation facilities were developed by R.W. Beck. Beck then reviewed the information for all three alternatives, and revised them as necessary to place them on a consistent basis, with similar cost elements and development assumptions. Costs were expressed in 2010$, and escalated to represent costs for in-service in 2015.

3.2.2 Lessons

Although ISEP did not choose a specific CAES technology for its project, for planning purposes the facility was assumed to consist of two 135-MW (net generation) D-R trains of CAES equipment for a total generation output of 270 MW. This project size was based on a combination of factors including the estimated size of the ISEP reservoir, the nominal total need of the project participants as viewed at the time, and the size of the standard D-R equipment offerings. Larger sizes were viewed as desirable to achieve economies of scale.

Other suppliers and configurations of CAES equipment are available in the marketplace, and the ISEP project considered several. For purposes of the study, the ISEP Project Team used D-R equipment configurations because the D-R designs were more mature, and D-R offered more solid cost estimates and assurances that were considered to be more conservative than other, less mature designs. If the project had proceeded further, ISEPA would have considered all equipment vendors and designs for the final plant equipment order.

The assumed compression (storage) cycle load for the ISEP facility was 220 MW. The ISEP CAES facility was assumed to have a split-train configuration, with separate compression and generation trains. That is, the compressor motors and generators were separate machines [13].

Although it is unlikely that the facility would be storing and generating at the same time, this assumption was used to provide additional flexibility for ISEP operation during transition from storage mode to generation mode. The two operating CAES facilities in the world use “split shaft” configurations, with a single electrical machine doing both motor and generator duties. Shaft clutches on each side of the electrical machine separate the two modes of operation at these facilities. Small improvements in operating efficiency were also gained by eliminating the clutches in the ISEP design. Splitting the trains involved additional capital cost for the ISEP alternative.

Conventional generation alternatives to CAES included a comparably sized generic natural gas-fired CC facility, and a comparably sized generic natural gas-fired simple-cycle CT facility. The CC alternative was assumed to include one General Electric (GE) 7FA combustion turbine, one heat recovery steam generator (HRSG), and one steam turbine generator, nominally rated at 270 MW [14]. The simple-cycle CT alternative included three GE 7EA combustion turbines with a total nominal rating of 270 MW.

The estimated capital cost of a 270-MW CAES facility, including equipment costs, installation labor, owner’s costs and other factors described in Section 3 is about $1,374/kW (in 2010$), which is (see Table 1) about 22% higher than a comparably sized conventional natural gas-fired CC generating unit, at $1,122/kW (in 2010$); and about 83% higher than a comparably sized natural gas-fired simple cycle CT generating unit, at about $750/kW (in 2010$).

The inflation rate for costs from 2010 thereafter was assumed to be 2.4%/year [15].

The estimated employment staffing required for a 270-MW CAES unit is about 15 full-time equivalent (FTE) employees. This compares to (see Table 2) about 19 FTEs for a comparably sized CC, and about 10 FTEs for a comparably sized simple cycle CT unit.

The estimated fixed O&M cost of a 270-MW CAES unit (in 2010$) is $16.69/kW-year. This compares to (see Table 1) $19.81/kW-year (in 2010$) for a comparably sized CC, and $12.43/kW-year (in 2010$) for a comparably sized CT.

The estimated non-fuel variable O&M cost of a 270-MW CAES unit (in 2010$) is about $2.03/MWh. This compares to (see Table 1) $2.44/MWh (in 2010$) for the CC, and $2.63/MWh (in 2010$) for the CT.

The forced outage rate for the CAES facility was assumed to be 3%. This compares to (see Table 1) 2% for the CC unit, and 4% for the CT unit.

This assumption was based on Brulin Associates and R.W. Beck’s judgment that a CAES unit would likely have a forced outage rate somewhat higher than a CC unit, but somewhat lower than a CT.

The minimum load of the 270-MW CAES generating unit was assumed to be about 32 MW. This compares to (see Table 2) about 159 MW for the CC unit, and about 132 MW for the CT unit.

Table 1. Facilities Modeling Assumptions (2010$) [16].

	ISEP CAES	Generic CC	Generic CT
Total Capital Cost ($/kW)	1,374	1,122	750
Generation Cycle:			
Min Capacity (MW)	32.3	158.8	132.4
Max Capacity (MW)	264.7	264.7	264.7
Air Flow @min (lb/s)	149	-	-
Air Flow @max (lb/s)	800	-	-
Heat Rate @min (Btu/kWh HHV)	4,806	7,370	9,750
Heat Rate @max (Btu/kWh HHV)	4,395	7,000	9,750
Variable O&M ($/MWh)*	2.03	2.44	2.63
Fixed O&M ($/kW-yr)	16.59	19.81	12.43
Forced Outage Rate	3.0%	2.0%	4.0%
NO_x Rate (lb/MMBtu)	0.0100	0.0100	0.0300
SO_2 Rate (lb/MMBtu)	0.0006	0.0006	0.0006
CO_2 Rate (lb/MMBtu)	119	119	119
Compression Cycle:			
Load (MW)	219.82	-	-
Air Flow (lb/s)	830	-	-
Reservoir Capacity (lb)	100,000,000	-	-
Variable O&M ($/MWh)	0.00	-	-
Fixed O&M ($/kW-yr)	0.00	-	-
Forced Outage Rate	3.0%	-	-

*Calculated based on 50% capacity factor

Table 2. Facility Staffing Plan [17].

Description	CC 1x1 Facility	SC 3X0 Facility	CAES 2x0 Facility
Plant Manager	1	1	1
Office Manager	1		
Admin Assistant/Warehouse	1	1	1
Plant Engineer	1		1
O&M Manager	1	1	1
Control Room Operator	5	5	5
Power Block Operator	5		
Instrument, Controls and Electrical Technician	2	1	2
Mechanic	2	1	4*
Total Staff	**19**	**10**	**15**

*The mechanics at the CAES Facility would take on the role of Operation and Maintenance Technician. They would work a rotating schedule for two-shift to cover the startup, operation, and shutdown of the thermal expander and perform mechanical maintenance as needed.

The ratio of kWh of electricity input in the compression (storage) cycle to generation kWh output for a 270 MW CAES unit is about 80% [18].

In addition to energy contained in the compressed air, the CAES unit generation cycle uses natural gas firing. The heat rate for the CAES unit at full load of 270 MW is 4,395 Btu/kWh. This compares to (see Table 1) [19] 7,000 Btu/kWh for the CC unit, and 9,750 Btu/kWh for the CT unit.

The environmental emissions *rates* per MMBtu of fuel consumption for the three alternatives were assumed to be similar. However, *total* emissions of the three alternatives were different because of their differing heat rates. The CAES unit enjoyed a significant emissions advantage over the conventional alternatives because of its lower heat rate (fuel consumption rate) in generation mode. However, total CO_2 emissions of the CAES alternative were also affected by the fuels used to store air in the compression mode. This happened because the cost of CO_2 allowances was reflected in the price of the off-peak power that the CAES unit purchased to compress air. If compression power came from fossil units, that entailed an off-peak CO_2 cost penalty for the storage alternative. If compression power came from wind machines, that did not entail an off-peak CO_2 cost penalty for the storage alternative.

The ISEPA members intended the CAES unit to be an intermediate generation unit (not baseload or peaking) that is capable of daily operation on weekdays of 10 to 12 hours, and has a compression cycle occurring during low electric load periods on weeknights and weekends.

One 135-MW CAES generation unit of the type contemplated in the ISEP project requires about 400 pounds per second of air input at a minimum inlet pressure of 827 pounds per square inch (psi) [20]. A 270-MW generation facility consisting of two 135-MW units would require about 800 pounds per second (see Table 1). For a 270-MW facility, this represents a requirement for about 2.9 million pounds of air per hour.[3] The 220-MW compressions stage would produce about 800 pounds per second at maximum output (see Table 1).

For planning purposes, the ISEP CAES facility had a design assumption of being capable of continuous operation in generation mode of 36 hours at full load output of 270 MW. This would require a useful storage capability of about 100 million pounds of operational air (not counting "cushion" air) in the storage reservoir at the start of each weekly operations cycle (i.e., Monday mornings). Economic modeling of ISEP in the MISO marketplace over its lifetime did not challenge this reservoir size assumption [21].

3.3 Economics Studies

3.3.1 Phase I Economics Study

"Phase I" was performed by R.W. Beck from July to December 2010, with funding provided from the DOE Energy Storage Program. Beck was selected by the ISEPA Project Team as the result of a competitive bidding process. Two additional firms were selected as subject matter experts (SMEs) to assist R.W. Beck. Brulin Associates was retained as SME for CAES

3 (60 seconds/minute) * (60 minutes/hour) * (800 lb/second) = 2.9 million lb/hour.

equipment design and cost estimates. Customized Energy Solutions (CES) was retained to examine Midwest Independent System Operator (MISO) tariffs and business practices. The ISEP CAES facility and the conventional alternatives were assumed to operate as merchant plants dispatched against MISO locational marginal prices (LMPs), with public power ownership/financing. The LMPs were calculated based on zonal power market simulation of MISO to develop projections for Iowa Hub energy market prices, with adjustments for the nodal basis at the Grimes substation based on Security Constrained Economics Dispatch (SCED) simulation for selected years.

Other assumptions were made in this phase:

- The benefits and costs of all alternatives were examined over the 20-year time period 2015 through 2034.
- No coordination with regional wind resources was assumed.
- Compression energy was assumed to be provided from the resources operating in the MISO market when the compression stage was dispatched.
- Carbon regulation costs of $10.30 per ton in 2015 (in nominal dollars) increasing to $92.30 per ton in 2035 were included.
- A total wind energy build-out of about 23,000 MW (nameplate) was assumed in MISO over the planning period.
- Ancillary service revenues for spinning and non-spinning reserve were included. Revenues for regulation services were not included, primarily because of the difficulty in modeling this attribute with existing computer models.
- Three different planning scenarios for the future were examined Base Case, High Fuel Costs, and Lower Regional Wind Build-Out.

Both intrinsic benefits (i.e., based on average hourly LMPs) and extrinsic benefits (i.e., ability of alternatives to address future hourly price and quantity volatility around average hourly values) were calculated.

Present worth (in 2015$) $/kW values for CAES and alternatives were compared to estimated costs. Base analysis was performed using public power financial assumptions (i.e., 5%/year discount rate for present worth calculations); and sensitivity analysis performed using IOU financial assumptions (i.e., 8.7%/year weighted cost of capital discount rate), because potential additional participants in the Project may be IOUs.

3.3.2 Phase II Economics Study

"Phase II" extended the Phase I results further by examining coordination of ISEP storage with regional wind energy resources. It was performed by R.W. Beck from January to July 2011, with funding from the DOE Energy Storage Program. Potential additional benefits assessed in Phase II included the correlation of wind speed and LMPs in MISO; improving profitability of regional baseload plants; reducing cycling (and thus operating and maintenance [O&M] costs) at conventional facilities; reducing curtailment of regional wind facilities; transmission; MISO tariffs; and potential legislative incentives for storage.

Phase II determined that significant additional benefits were available to the storage option, resulting in net benefits higher than the conventional generation alternatives. But the additional benefits of storage would require innovation to achieve, as described below.

3.3.3 Lessons

3.3.3.1 Lessons from Phase I

Modeling using actual historical MISO loads and costs during the period 2007 to 2009 showed the ISEP CAES unit would have been dispatched at annual capacity factors of 32% in 2007, declining to 24% in 2009. However, the economic recession and lower natural gas prices resulted in lower capacity factors in 2010 and thereafter [22].

Modeling showed the annual capacity factor of the CAES unit in 2015 and thereafter would be in the range of 13% to 17% [23]. On average, this is equivalent to operation for five to six hours each weekday of the year. The dispatch of the CAES unit was simulated for each hour for 25 years. The modeling results showed that the operation of the CAES unit would be responsive to market prices during peak periods such as weekdays in winter and summer months when the off-peak and on-peak prices spreads were greater. The CAES unit operated less during the spring and fall months when price spreads were lower.

The intrinsic value of a resource alternative is the value typically calculated by utility resource planners for conventional electric generation facilities. The simulation used to calculate intrinsic value was based on deterministic forecast of hourly prices using average fuel prices and normal weather and load patterns. The intrinsic value of the ISEP CAES facility was found to be similar to that of the conventional alternatives.

Extrinsic value represents the option value of a resource to address future load quantity and price volatility, above and beyond the intrinsic value calculated using average hourly prices. See Figure 3. Intrinsic value represents the value of a resource calculated using average hourly prices. On Figure 3, these are shown as the solid lines representing the average off-peak and on-peak prices for a given time period. In reality, the CAES unit will respond to real-time MISO price signals, which have significant uncertainty and price volatility, as shown by the shaded "clouds" surrounding the average price.

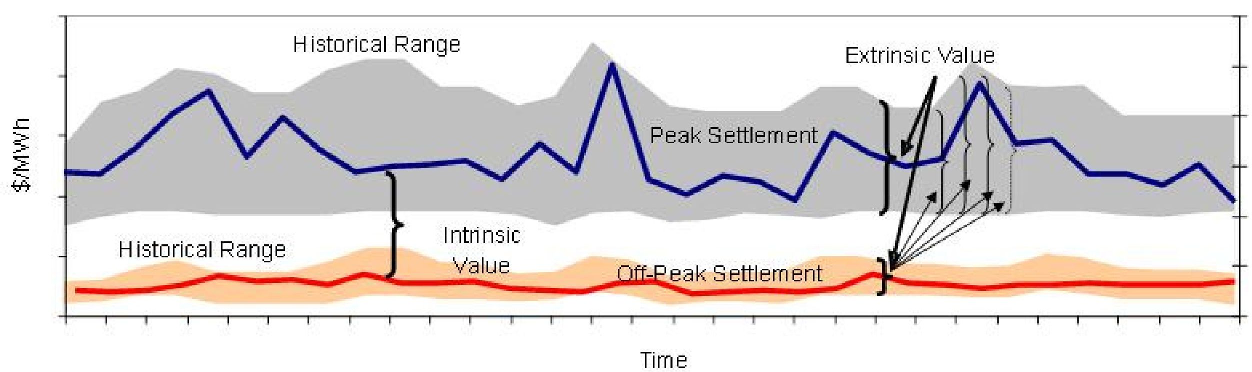

Figure 3. Illustration of the derivation of intrinsic and extrinsic values [24].

The extrinsic value was calculated based on historical volatility in MISO prices, using Black Scholes options valuation techniques, and using only hours when the unit was not otherwise dispatched for intrinsic value (to avoid double-counting) [25].

To estimate the "fair" value that the LSE may be willing to pay for such protection, it was decided to use a series of option valuations applied to the price uncertainty and label it extrinsic value. This method was used for it distinctly measures the value of volatility in excess of the intrinsic value economics of dispatch. [26]

In general the methodology suggested by Eydeland and Wolyniec (2002) [27] was used for the Forward Dynamic optimization and its approximation through a complex set of calendar spread options. The method essentially derives the value of the asset given prices of spread options with the strike prices adjusted so that the opportunities already included in the intrinsic value are not curtailed or double-counted by the implicit insurance protection;

Monetizing this extrinsic value will depend on the risk appetite by which the facility is operated. The methodology purposely does not incorporate a risk profile or operational characteristics in order to better understand the value of ISEP to an "average" investor. This therefore implies that the end-result may seem "low" for a relatively aggressive investor that is looking at a facility from a merchant perspective, but may be high for an investor that is simply not going to extract any volatility value. [28]

The extrinsic value of CAES was significantly higher than the conventional alternatives [29]. This resulted because the CAES unit could ramp fast (in both generation and storage modes), accommodate multiple starts and stops in a day, *and* store energy, and provided better insurance against future quantity and price volatility than the conventional alternatives, particularly in the storage mode that the conventional alternatives did not offer.

The magnitude of the extrinsic value of the CAES facility was found to be 59% to 119% of the gross intrinsic value of the CAES alternative in historical years 2007 to 2009 (for an average of 85% in those years) [30], and 30% to 40% of the CAES alternative's Phase I present worth net total value depending on the case studied [31].

Extrinsic value is thus a potentially large component of an electric storage unit's economic benefits, above and beyond the intrinsic value based on average hourly price off-peak to on-peak arbitrage, which is usually the primary focus of traditional storage economic studies.

There was internal debate among the Project Team during Phase I whether extrinsic value could actually be realized, because of the current absence of a liquid and transparent options market in MISO for such things. While the Phase I analysis valuation approach used Black Scholes options theory to define and price the extrinsic value,[4] the Project Team concluded that a storage owner did not actually need a formal options market to sell these advantages to others. They could extract most if not all of the extrinsic value for themselves.

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4 In the alternative to using Black Scholes options techniques, another way to calculate this value would have been to run hundreds or thousands of Monte Carlo simulations for various price paths, based on the expected volatility of hourly prices over the planning period. The options method was a more economical way to do this estimation.

The storage unit itself, dispatched against market prices, would see the price volatility and, through its operational flexibility, be able to generate into upward price spikes (if not already fully dispatched during such times). Similarly, the compression stage would be able to take advantage of downward price volatility by storing at those times (again, if not already fully dispatched to compress during those hours). As a result, the Black Scholes analysis did not represent a requirement that an options market actually be available in order to achieve extrinsic value. Instead, it was used as a proxy for the additional value that would have been calculated if available production cost models used in the intrinsic analysis could have captured hourly price volatility, rather than using only average hourly prices. Simply stated, the intrinsic analysis using only average hourly prices tended to understate the dispatch hours of the CAES unit. Considering price volatility in the extrinsic analysis means the CAES unit would actually see wider price spreads over more hours annually, thereby causing the CAES unit to be dispatched more frequently than the intrinsic analysis alone would suggest. The term "extrinsic" here really relates to the fact that price volatility calculations were external to the standard average hourly price methods and models used that are typical of traditional utility resource planning methods. The Black Scholes method was used in the analysis as an alternative to an infinite number of Monte Carlo production cost modeling runs that would otherwise be necessary to capture the probable production cost effects of hourly and sub-hourly price volatility.

Going beyond the capabilities of the storage unit itself to achieve extrinsic value, certain types of storage owners may have additional opportunities to extract extrinsic value, depending on their specific characteristics.

A storage owner who is a Load Serving Entity (LSE) (e.g., a distribution utility with an obligation to serve its retail customers — like the ISEPA members) may be able to extract additional extrinsic value from the ability to ramp up generation (or ramp down compression) quickly when hourly sales quantities and prices are volatile upward, thereby avoiding real-time market penalties for generation scheduling shortfalls, and the ability to ramp down generation (or ramp up compression) quickly when hourly sales quantities and prices are volatile downward, thereby avoiding inefficient generation scheduling oversupply during such time periods. Simply, this is an ability to avoid being long in supply resources in a low-price environment, or short on supply resources in a high-price environment.

A storage owner who owns wind resources has the ability to ramp up compression load when LMP prices are low and wind output is high; the ability to ramp-down compression load when LMP prices are high and wind output drops; the potential ability to avoid curtailment of their wind resources; the overall improved ability to match load with wind output from their own resources, and the ability to provide regulation or ramping ancillary services (when such tariff products are available in the market).

The ideal is a storage owner who is *both* an LSE *and* owns significant quantities of wind resources.

A storage owner who was an LSE and/or a wind owner could extract the additional extrinsic value. By changing the way their resource planners plan their generation mix, relying more on the new, faster-ramping, higher-flexibility CAES to replace less flexible, slower-ramping resources. This allows them to avoid oversupplying needs with fixed generation blocks or purchases just to meet future quantity/price volatility. A storage owner could also get additional value by adjusting the way their load schedulers scheduled their daily load and generation, again taking advantage of the faster resource that also includes storage. The fast-ramping capabilities would be a new tool to help them avoid real-time price penalties that they may currently accept as a matter of "business as usual."

To the extent the storage owner could not extract the full extrinsic value by operating the storage facility to maximize their own operations, the owner could use bilateral agreements with third-party LSEs and wind owners to sell whatever surplus of extrinsic value they themselves did not need or could not realize.

Finally, an open and transparency electric options market, if available, would be useful if necessary to monetize any remaining extrinsic value not otherwise captured by the storage owners. It was recognized that the ongoing future evolution of ancillary services markets in MISO for such things as fast ramping, or a Demand Response (DR) tariff for off-peak dispatchable loads, could also realize a portion of the extrinsic value calculated in the Phase I analysis (see Section 5 for details).

Including both intrinsic and extrinsic value, the CAES unit offered higher total $/kW value than the conventional generation alternatives in all scenarios studied (see Table 3). The CAES option also has a higher capital cost, as described later in this section. As shown on Table 3, the result of the Phase I analysis was that the lifetime net $/kW present worth benefit of the CAES facility (benefits minus costs) was positive (i.e., benefits exceeded costs), and comparable to that of the conventional alternatives.

Table 3. Base Case Intrinsic and Extrinsic Value Summary for Public Power Entities [32]. (Present Worth $/kW in 2015$)

	ISEP	CC	CT
Intrinsic	1,713	1,696	1,281
Extrinsic	473	264	190
Total	2,186	1,960	1,471
Cost	1,547	1,205	805
Net Benefit	**639**	**755**	**666**

A sensitivity case (high fuel prices) was examined to evaluate the effects of higher natural gas and coal prices (see Table 4). The results of this case showed:

- The net benefits of all three alternatives increased compared to the Base Case.

Table 4. High Fuel Prices Sensitivity Case Intrinsic and Extrinsic Value Summary For Public Power Entities [33]. (Present Worth $/kW in 2015$)

	ISEP	CC	CT
Intrinsic	1,703	1,740	1,191
Extrinsic	703	373	334
Total	2,406	2,113	1,525
Cost	1,547	1,205	805
Net Benefit	**859**	**908**	**720**

- The net benefit of the CAES alternative moved closer to that of the combined cycle (CC) unit, and surpassed that of the combustion turbine (CT). This occurred because the CAES unit has a better heat rate (fuel efficiency) in generation mode than the conventional alternatives. Also, its extrinsic value becomes larger faster than the conventional alternatives as fuel prices increase.

- A CAES unit like ISEP represents a hedge against increasing future fuel prices.

To test the relationship between the assumed regional wind build-out and the economics of storage, a sensitivity case (reduced wind build-out) was performed assuming the wind build-out in MISO would be half that of the Base Case. This was not an expression of lack of faith in the assumed level of wind build-out over time. Instead, it was performed to assess how the level of wind affected storage economics.

The results of this analysis showed that a deceased level of wind build-out make storage *more* cost-effective (see Table 5). This was initially a counterintuitive result, as it was expected that less wind would make storage less valuable. Upon further review, two things effected this result:

1. Delaying/reducing the wind build-out moved the capacity value for the CAES facility earlier in time. Although wind was not provided much firm capacity value, its deferral gave the CAES unit (as well as its alternatives) more capacity value earlier.

2. Potentially more important, it was realized that the analysis probably did not capture the potential benefits of storage to the profitability of the wind machines. Any benefits of storage to the wind machines (e.g., in reducing curtailments to them) would have occurred outside the analysis, and thus were not internalized to the storage facility's benefit. This was an initial signpost that potential benefits associated with certain storage attributes were not being captured in the analysis. Although the Phase I analysis used a merchant plant perspective, conventional utility planning analyses typically have the same shortcoming. See Section 5 for more examples of this phenomenon.

Table 5. Low Wind Build-Out Case Intrinsic and Extrinsic Value Summary For Public Power Entities [34]. (Present Worth $/kW in 2015$)

	ISEP	CC	CT
Intrinsic	1,812	1,906	1,397
Extrinsic	540	330	264
Total	2,352	2,237	1,661
Cost	1,547	1,205	805
Net Benefit	**805**	**1,032**	**856**

Similar sensitivity analyses in storage planning studies to date by the MISO planning staff have yielded similarly counter intuitive results on this topic [35]. The authors believe the same factors affecting the ISEP work are at play here.

The Phase I study concluded that all three generation alternatives were economically viable in the Base Case and the two sensitivity cases [36]. These Phase I results were encouraging to the ISEPA members because the net benefit of a new generation resource is not always positive. In fact, in utility applications it is often negative, requiring the utility LSE to raise its rates (prices) to customers to accommodate the resource addition. This happens because an LSE does not have the option to do nothing (i.e., not supply the retail customer's electric needs). This utility-based perspective is different from that of an independent power producer or investor, who does not have an obligation to serve, when they look at a potential project investment. As an investment, they require the net benefits to them to be positive, or they will not do the project at all.

Although the CAES option's capital cost was higher than the conventional alternatives, there was potential that the operating benefits would be sufficient to offset that disadvantage. The ISEP members knew that Phase I did not include all of the potential benefits of the CAES unit. Thus, the Phase I results taken alone were conservative (i.e., biased against the CAES unit) [37]. The ISEPA members also knew that the innovative technology of the CAES facility (particularly the geology) represented a higher risk factor than the conventional alternatives (see Section 9 for details).

Because the basic Phase I analysis was performed from the perspective of a public power owner of the facility, a sensitivity analysis was also performed to assess the corresponding results for an IOU. An IOU has higher financing costs than a public power entity due to shareholder return requirements and taxes. For example, an 8.7% weighted cost of capital was used as the discount rate for IOUs in the sensitivity analysis. As a result, future benefits of a project look smaller in present value to an IOU than a public power entity.

Results for the high fuel cost and low wind build-out sensitivity cases were also calculated for IOUs [38]. The conclusions were similar to those for public power entities described above.

To assist the ISEPA members and new participants in evaluating storage for their own systems, Phase I included preparation of a Resource Planner's Toolkit. The Toolkit included modeling assumptions, price forecasts, capital costs, extrinsic value adders, and ISEP dispatch results in detailed form [39]. A Resource Planners Toolkit Supplement provided additional assumptions and details of the analysis in spreadsheet form [40].

3.3.3.2 Lessons from Phase II

Following Phase I, a Phase II effort was enacted to investigate additional benefits of CAES that were not considered in Phase I. Such benefits included [41]:

- Coordination of the bulk storage facility with regional wind energy resources (Phase II, Task 1) [42], including usefulness of bilateral supply contracts with wind resources to supply off-peak compression energy (and thereby create a new market for wind during time periods when it is least valuable); correlating MISO LMP prices with wind speed; reducing wind energy curtailment; enabling more wind installations than would be possible without storage; and enabling credit for storage toward state Renewable Energy Standards (RES) or federal Clean Energy Standards.
- Improved operation of other generating units (Phase II, Task 2) [43], including reduced cycling and improved capacity factors and profitability.
- Ancillary services revenues (Phase II, Task 3) [44], including regulation; fast ramping; off-peak dispatchable load (or demand response, DR) during off-peak periods to add/build load); transmission benefits of storage (Phase II, Task 4) [45], and summary of total Phase I and Phase II benefits of CAES compared to alternatives.

Phase II also examined existing MISO tariffs as they would be applied to storage, and changes that may be needed to enable storage [46]. See Section 5 for details.

Overall, Phase II determined that additional $/kW value was possible using the unique storage capabilities. But achieving these benefits would often require innovation, changes in current utility practices and MISO tariffs, legislative changes, or bilateral contracts.

Phase II, Task 1 examined the correlation with wind. At face value, some form of coordination between intermittent wind resources and a fully dispatchable load like a CAES or other storage unit implicitly makes sense. From the total market's perspective, such coordination benefits the market as a whole. However, ways of practically achieving such benefits *for the economic benefit of the storage facility owner or an individual wind owner* (and thereby motivating them to build storage, or to benefit their wind resource), particularly in an LMP market like MISO as it is currently defined, are not so obvious. For example, ignoring transmission congestion effects, a wind machine and a storage unit located near each other would see the same LMP in any particular hour. The wind machine has no economic incentive to sell its output to the storage unit instead of to the market. Conversely, the storage unit would have no incentive to buy compression energy from the wind machine instead of buying it from the market at the LMP. MISO is set up to maximize the benefits of dispatch for the market as a whole. So any unique advantages of a fully dispatchable storage load accrue to the market as a whole, not to individual wind machines or other generators. While the benefits of wind/storage coordination are seen by the market as a whole, MISO itself does not own facilities; therefore, it is not a candidate to own the storage capabilities. However, it can encourage storage by appropriate tariffs and pricing that appropriately reflect the benefit of storage to the market participants.

As a result, whether a bilateral contract between bulk storage and wind resources for compression power would be a good idea in an LMP market was a subject of internal debate among the Project Team. Two ideas where such a bilateral contract may make sense are:

1. To create a hedge option so the wind machines would not see the lowest prices during low load periods, because the storage unit would ramp up its compression load during such times. This would serve to focus the benefits of the dispatchable load of the storage on particular wind machines; rather than allow the same benefit to be dispersed to the market as a whole.
2. To demonstrate that the storage and renewables are directly contractually linked, as may be necessary to qualify the storage for credit toward state renewable energy standards or federal Clean Energy Standards. Such credit for storage itself (in addition to Renewable Energy Credits [RECs] earned by the wind machines), should be considered because storage enables more renewables to be installed.

In lieu of a bilateral contract arrangement between the storage and wind, Phase II examined the probability that the storage would be compressing when the wind is blowing.

Many things affect LMP prices in an ISO market. However, based on historical data for MISO LMP prices and wind speed/output, Phase II found that on average the wind blows more during off-peak hours (see Figure 4). Also, there is a negative correlation between MISO LMP prices and wind output in MISO. "Negative correlation" means when wind output goes up, MISO prices go down (see Figure 5). This was true for all five price hubs of MISO examined (Figure 4), and it was true for Iowa as well [47].

For comparison, a similar wind speed/price correlation was done for four Electric Reliability Council of Texas (ERCOT) zones in Texas. ERCOT currently has a higher installed wind capacity-to-load ratio than MISO does. The results showed an even stronger negative correlation between wind speed and market prices there [50]. Phase II concluded that ERCOT is probably a precursor to future effects in MISO as the wind build-out in MISO increases [51]. That is, market prices will become even more dependent on wind speed and output.

These findings suggest that there need not be a bilateral contract between wind machines and storage to demonstrate cooperative operation between them. Dispatched against MISO LMP prices, the storage will be compressing during the low-load periods when the wind is blowing. Also, wind affects MISO LMP prices, and MISO LMP prices drive CAES dispatch; therefore, wind affects CAES dispatch.

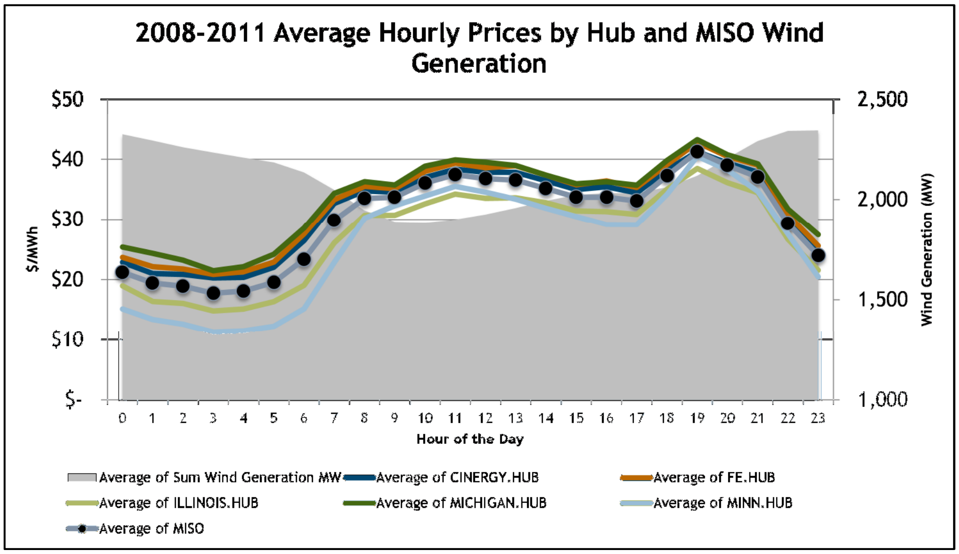

Figure 4. Average wind speed and MISO LMP prices for five price hubs in MISO [48].

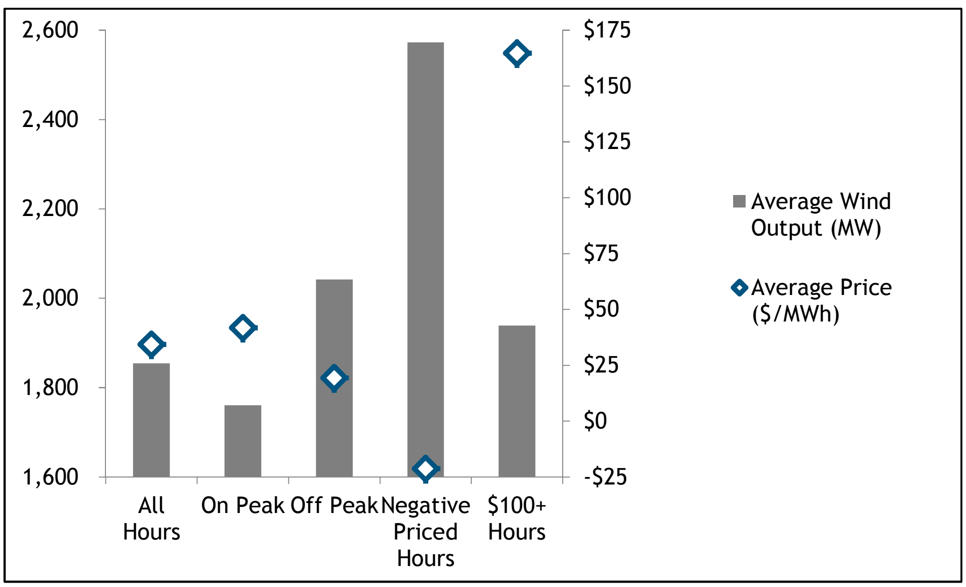

Figure 5. MISO wind output higher during off-peak and low-priced hours [49].

In theory, correlating the operation of the bulk storage facility should enable reduced curtailment of wind resources. There are two opportunities to do this:

1. If the curtailment is because of generation oversupply during low-load periods, the storage can provide additional dispatchable load to absorb the excess generation output. Phase II calculated that reducing wind curtailment in Iowa would result in a benefit of $5 million per year for each 1 percentage point reduction in such curtailment. If the storage could capture 50% of this benefit (a reasonable assumption considering the size of the ISEP storage capability), the resulting additional present

worth (2015$) benefit for the CAES unit over its lifetime would be $40/kW [52]. However, it would require a mechanism to recapture this benefit directly by the storage owner, not dispersed to the market as a whole. Either a bilateral contract with wind machines (perhaps also owned by the storage owner), or a MISO tariff that rewarded dispatchable off-peak load (i.e., a DR-type tariff, but aimed at off-peak rather than on-peak time periods), would be necessary.

2. If the curtailment was because of transmission constraints, the storage could theoretically be used to absorb the output of the wind machine during the constrained time periods. This would keep the wind machine(s) operating while keeping the output off the transmission system until the constraint was resolved, and the storage could then release the energy to the system. See Section 4 for more details.

Phase II considered the ability of a bulk storage facility like ISEP to enable additional wind resources to be installed. As such, ISEP could potentially qualify for REC values. Some precedent exists for energy storage projects to qualify for RECs, but would require state or federal legislation to implement it. ISEP may need to show its compression energy is actually provided by wind energy to qualify for RECs (e.g., a contract path back to a wind farm or other support for linkage). Assuming 25% of ISEPA's generation Megawatt-hours (MWhs) would qualify and REC value is $25/MWh (which is significantly above the current market in MISO, but representative of a robust future renewables market), the average annual revenue would be approximately $2 million. This represents a net present value (NPV) (2015$) of $37/kW for a 270-MW ISEP project [53].

Phase II, Task 2 examined the improved operation of other generating units. Phase I modeling determined that the ISEP storage unit reduced MISO system production costs by about $11 million per year by 2025, compared to no storage unit. If ISEP could capture 50% of this benefit for its owners, this is equivalent to a present value benefit (2015$) of $65/kW for a 270-MW ISEP project [54]. A mechanism necessary to capture this system benefit and focus it on the ISEP owners to help them pay for the project is not currently available. The benefit is MISO-wide, and MISO does not own facilities; therefore MISO owning the storage is not in MISO's business model. In the pre-MISO past, an individual utility would dispatch its own generation, and could thereby internalize the benefits of its own storage facilities through improved operation of its own generation system.

A literature search in Phase II identified national and regional work and concern regarding increased cycling of conventional coal generating units because of increasing penetrations of intermittent wind energy resources. This increased cycling was increasing wear and tear on such units, and the resulting O&M costs.

The Phase I modeling had determined that ISEP would reduce cycling of certain nearby coal units in Iowa. Phase II estimated that this increase in cycling represented an increase in O&M costs of $24 million per year. If ISEP could reduce the cycling by 30% (represented by ISEP's MW output compared to the total MW of coal units affected), that would be a $7 million per year savings. If ISEP could capture 50% of this savings, that would be a present value benefit of $42/kilowatts (kW) for a 270-MW ISEP project [55]. Unless the affected coal units' owner(s) also owned the storage, there is no current method for transferring these benefits to the owners of ISEP.

Phase I modeling calculated that ISEP operation in compression mode during off-peak time periods would improve the capacity factor of certain baseload generating units in Iowa by 11% to 12%. This represents an estimated potential gross margin improvement of $5 million for these units. If ISEP could capture 50% of these benefits, that would amount to an NPV benefit of $37/kW for a 270-MW ISEP unit [56]. Unless the affected baseload units' owner(s) also owned the storage, there is no current method for transferring these benefits to the owners of ISEP.

Phase II, Task 3 examined existing MISO tariffs as they would be applied to storage, and changes that may be needed to enable storage [57]. The results include:

- Current MISO tariffs do not fully recognize the value of fast-ramping resources and generally tend to undervalue Ancillary Services (AS).
- MISO is working to improve AS markets and the pricing of AS.
- Improvements could lead to additional revenue for ISEP from higher Spin and Regulation prices in particular and potential incremental value from a ramping AS product that could be introduced in the future.
- Some of the improvements in AS markets combined with other changes MISO is working on related to dispatching units in the Real Time (RT) market could reduce price volatility in the RT market.
- Since historic price volatility was incorporated in the valuation of ISEP under the Phase I estimation of Extrinsic Value, the changes under way at MISO could present at least a partial trade-off for ISEP's valuation (i.e., higher AS revenues but lower energy revenues).

This is a dynamic issue and will continue to evolve. MISO is actively investigating energy storage and existing barriers. MISO storage studies should highlight and quantify the benefits of energy storage and the existing barriers that need to be addressed. Beyond the studies, the specific rules will be critical but this will be a long process that will continue to evolve through 2012 and 2013.

Some form of off-peak dispatchable load (DR) tariff (during off-peak periods to add/build load) would be beneficial to help enable storage development. To date, most tariff and DR efforts have been focused on on-peak time periods. Little or no focus has been placed on off-peak time periods, largely because historically there has not been significant storage project opportunities that would drive the need for and discussion about such tariff developments. See Section 5 for further discussion of MISO tariffs.

Phase II, Task 4 considered the potential transmission benefits of storage [58]. As a result of this analysis, no benefits for transmission were included in the projected benefits of the ISEP CAES facility (see Section 5 for details).

The effects of greenhouse gas (CO_2) regulation were examined. It is often claimed that storage helps reduce CO_2 emissions. The statement is true if the storage enables more renewables to be built than would otherwise be built without the storage. However, the veracity of the statement depends upon the resources used for the CAES unit's compression cycle, and the resources displaced by the CAES unit's output in generation mode. In MISO, the off-peak compression energy would likely come from coal resources and wind. The on-peak resources that would be displaced would likely be coal or natural gas.

The Phase I study assumed CO_2 regulatory costs of $10.30 per ton (in 2015) to $92.30 per ton (in 2035) over the analysis period [59] (nominal $). While in an absolute sense the CAES unit was penalized for this assumption because its generation mode uses natural gas (resulting in CO_2 emissions), in a relative sense it was benefitted by it compared to the conventional generation alternatives that have higher heat rates (i.e., lower fuel efficiency). However, Phase I assumed the CAES unit would get its compression energy from whatever resources were available in the MISO market at the time. This entailed fossil-fired resources including coal. The CAES unit was further disadvantaged by the CO_2 assumption because the purchased electricity to operate the compression was assumed to be purchased at the MISO LMP, which included the pass-through of CO_2 allowance costs by the units (mainly coal) setting the marginal price in off-peak hours. When the ISEP unit was generating, the sale price of electricity at the MISO LMP also included the pass-through of CO_2 allowance costs, but on-peak the marginal unit was typically a natural gas CC plant, which has less than half the CO_2 emissions rate compared to a coal unit. Therefore, the ISEP unit's costs increase more relative to power sales due to the assumptions about CO_2 regulation. In the Phase I analysis, the off-peak CO_2 penalty to the CAES alternative was larger than its on-peak CO_2 benefit. The result in was a net CO_2 penalty overall for the CAES unit compared to conventional generation alternatives. Again, this was a Phase I result where compression energy was assumed to come primarily from coal resources. This result reverses if compression energy would come from renewable resources, as discussed below.

Given the passage of time since Phase I was performed, it is less certain that CO_2 regulation will occur, and in the magnitudes assumed in Phase I. If CO_2 regulation involving CO_2 allowances or similar taxes did not occur, removal of the off-peak to on-peak compression penalty would increase the present value lifetime benefits of the CAES unit compared to the conventional alternatives by $140/kW [60]. The off-peak compression energy penalty of CO_2 against the CAES unit, if it occurred, was bigger than the on-peak advantage of the CAES unit because of its higher generation efficiency. Whether ISEP would achieve this increase in benefits compared to conventional alternatives depends upon whether CO_2 regulation is passed, and at what $/ton cost, or whether CO_2 regulation, if any, is implemented as a direct mitigation through controls (e.g., through the Environmental Protection Agency's (EPA's) Title V and prevention of significant deterioration programs) without an allowance trading program. If that occurs, then the outcome would be the retirement of coal units and no accompanying allowance trading as was modeled in Phase I [61].

Phase II did not attempt to calculate the potential CO_2 benefit that would occur if ISEP used a bilateral contract with wind machines to supply compression energy, thereby increasing the percentage of energy that renewables contributed to its total compression energy. Instead, it was assumed that any CO_2 benefit of doing this would probably be reflected in the price for compression energy offered by the wind producer, so there would be no actual savings for the storage owner.

Table 6 summarizes the various additional benefits for the ISEP CAES facility determined in Phase II.

Table 6. Summary of Phase II Benefits of ISEP CAES Facility [62]. (Present Worth $/kW in 2015$)

Phase II Results	$/KW
MISO System Savings	$66
Baseload Unit Profit	$37
Baseload Unit O&M Savings	$42
Avoided Wind Curtailment	$40
REC Value	$37
Total	**$222**

As summarized above, the Phase II study identified potential additional benefits for the CAES option that did not apply to the conventional generation alternatives. Table 7 illustrates the total lifetime present worth benefit/cost analysis for the CAES unit and alternatives including results from both Phase I and Phase II.

Table 7. Adjusted Phase I Value and Phase II Values for Public Power Entities 270-MW Alternatives [63]. (Present Worth $/kW in 2015$)

	ISEP	CC	CT
Intrinsic	1,713	1,696	1,281
Extrinsic	473	264	190
Original Phase I Total	**2,186**	**1,960**	**1,471**
CO_2 Penalty Removal	140		
CREB Benefit	199		
Revised Phase I Total	**2,525**		
Phase II Benefits	222		
Total Phases I and II	**2,747**		
Capital Cost	1,547	1,205	805
Net Benefit	**1,200**	**755**	**666**

3.3.3.3 Results of Phase II Analysis

The results of the Phase II analysis show that a 270-MW bulk storage unit like ISEP operating in MISO potentially offers significant benefits compared to the conventional generation alternatives, but it will take innovation, contract arrangements, and changes in MISO tariffs and legislation to accomplish it.

3.3.3.4 Potential Value of Storage

The results of Phases I and II also demonstrate that traditional utility resource planning analyses that typically examine only those benefits that were considered intrinsic value in the ISEP analysis *significantly understate the potential value of storage*. See Figure 6.

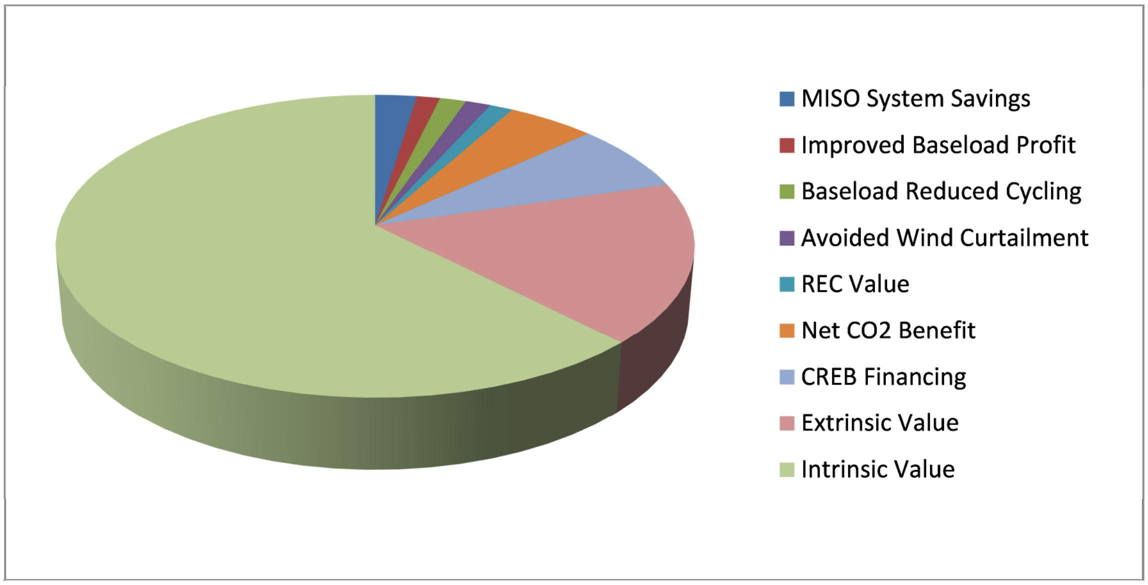

Figure 6. Estimated ISEP storage lifetime total value by component[5] (Present Worth $/kW).

3.3.3.5 Sensitivity Analyses

The results described above were for the Base Case Phase II analysis. One Phase II sensitivity analysis was also performed. Instead of a 270-MW CAES facility, Table 8 provides comparable economic results for smaller (70-MW and 135-MW) CAES facilities. These results were prepared in mid-2011 when it appeared the site geology may limit the size of the facility. As shown on Table 8, and considering the uncertainties involved in achieving the Phase II benefits, a 135-MW CAES facility would be roughly comparable in economic benefit compared to a conventional 270-MW combined cycle unit,[6] and a 70-MW CAES facility would not be cost-effective compared to the 270-MW combined cycle alternative. This happens due to lost

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5 Values shown from Table 7.

6 Although capital costs for smaller CC and CT alternative units were developed, the ISEPA members considered a 270-MW CC unit to be their alternative, not a smaller one.

economics of scale for the smaller CAES unit. That is, if the entity contemplating using a storage option considers a 270 MW CC or CT unit as their practical alternative to storage, the higher $/kW costs of a smaller CAES unit would tend to make it less cost-competitive compared to the larger conventional generation alternative.

Table 8. Adjusted Phase I Value and Phase II Values for Public Power Entities CAES Units Smaller than 270 MW [64]. (Present Worth $/kW in 2015$)

$/KW	ISEP 70 MW	ISEP 135 MW	CC 270 MW	CT 270 MW	CT 53.5 MW
Intrinsic	1,713	1,713	1,696	1,281	1,281
Extrinsic	473	473	264	190	190
Original Phase I Total	**2,186**	**2,186**	**1,960**	**1,471**	**1,471**
CO_2 Penalty Removal	140	140			
CREB Benefit	199	199			
Revised Phase I Total	**2,525**	**2,525**			
Phase II Benefits	222	222			
Total I & II	**2,747**	**2,747**			
Capital Cost	2,187	1,714	1,205	805	1,451
Difference	**560**	**1,033**	**755**	**666**	**20**

4. TRANSMISSION

4.1 Introduction

The potential transmission impacts and benefits of the storage project, as determined in Task 4 of the Phase II study [65], are described in this section.

4.2 Lessons

Much has been written about the potential benefits of storage in reducing or deferring transmission investment. Although this can take many forms, it is frequently represented as a way where storage can absorb intermittent renewable energy when it is available and the transmission is constrained. This avoids placing the energy on the transmission system until a later time when the constraint is no longer present. This scenario assumes there is not a transmission constraint between the renewable energy source and the storage.

A simple example of such a transmission opportunity is a distributed storage unit (such as a battery) collocated with a wind machine "behind the (customer's or wind producer's) meter." In such a scenario, the transmission system sees the wind resource and storage as one combined resource, with no transmission constraints between them. In the ISEP example, the ISEP bulk storage facility would be located on the transmission system, with transmission facilities (and potential constraints) between the storage and the renewable energy facilities. Wind facilities in Iowa currently experience significant curtailments/interruptions because of transmission constraints in the region. By itself, this would appear to be an opportunity for storage.

ISEPA filed a generator transmission interconnection request with MISO in September 2009. In accordance with the MISO study process, ISEP was included with other proposed Iowa generation resources in the "System Planning Analysis (SPA) 2010 Iowa" group. This group included about 800 MW of wind machines, and the ISEP storage facility [66]. The SPA Iowa groups for the past three years (2008 to 2010) included more than 5,000 MW of wind machines, and the ISEP storage facility. Again, this would appear to be a storage opportunity in Iowa.

MISO issued a SPA report in May 2011 with regard to the SPA 2010 Iowa group [67]. The report concluded

- Interconnection of the SPA 2010 Iowa group of generators as MISO network resources would require high-voltage transmission improvements—primarily 345-kilovolt (kV) facilities located near the Iowa/Illinois border for exports to the East.
- The total cost of the necessary transmission improvements would be approximately $130 million, of which $20.6 million (or $76/kW based on 270 MW of ISEP output) was allocated to ISEP [68]. This figure may change in accordance with additional studies [69].[7]

[7] This network interconnection cost for ISEP was assumed to apply to any of the generation alternatives in the ISEP economics study whether ISEP, combined cycle or simple cycle. As such, these network transmission costs were assumed to offset each other between the various generation alternatives considered in the study.

- Notably for ISEP, the MISO study considered ISEP as only a generation facility that needed interconnection service. The study process did not include consideration of potential transmission benefits of matching the storage up with regional wind and other generation resources to delay or eliminate transmission.

Phase II, Task 4 of the ISEP economic study as described in Section 3 considered the potential transmission benefits of storage. In terms of network interconnection costs, R.W. Beck determined that whether ISEP were built or not, it was unlikely to affect the amount of new transmission needed for interconnection of the other SPA 2010 Iowa generation projects [70]. If ISEP were built, it would benefit the other generation projects in the SPA 2010 Iowa group because ISEP would be allocated a portion of the transmission costs that would otherwise be allocated to the other generation projects without ISEP [71].

The MISO process also identified other local transmission developments, the need for which was not affected by the presence of the ISEP generator [72]. Also, it was unclear whether ISEP could defer or eliminate the need for these transmission projects [73]. The MISO SPA study did not consider the potential benefits of the ISEP generator generating into a known load substation (MidAmerican Energy's Grimes substation near Des Moines) during on-peak load times, thereby theoretically delaying or deferring transmission investment. The MISO process is focused on generation interconnection costs, not potential savings from generator interconnections. As a result, no transmission benefits were assigned to ISEP for this cost element in the economics study.

Considering reducing wind curtailments because of transmission constraints, while this is a theoretical benefit of storage, during Phase II it was acknowledged that the transmission constraint could not be between the storage and the wind machine(s). Instead, such a benefit would be more likely if the storage and wind were both located "behind the same meter"—such as battery co-located with the wind machine. A bulk storage facility like ISEP located some distance from the wind machines may not be able to realize such transmission benefits. Also, transmission constraints can be relieved with time and money through improvements to the transmission system. Phase II realized that it would not be prudent to justify a long-term storage resource using short-term transmission benefits that may be fleeting as the transmission system continues to evolve. However, the use of storage to delay or defer transmission investments may have potential value.

Detailed assessment of the potential benefits, if any, of reducing wind curtailments because of transmission constraints in the specific case of ISEP and nearby wind machines was beyond the scope of the Phase II effort and funding. It also would require study participation by the wind project owner being affected by the curtailments and owners of the transmission facilities involved. The ISEP owners represented neither of these interest groups. As a result, no transmission benefits were assigned to ISEP in the economics study.

It is clear that the current MISO transmission interconnection study process is traditionally geared to examine costs of connecting generators on-peak. This captured the cost required in connecting the generation side of the CAES facility to the network, like any other similarly sized generating unit. There currently are no apparent provisions in the MISO process to examine the potential transmission benefits of storage limiting wind curtailment off-peak; in the past there have not been significant storage projects that drove the need for such analysis. This shortcoming needs to be addressed if significant storage development is to be accomplished in MISO.

5. MARKETS AND TARIFFS

5.1 Introduction

This section discusses actions that need to happen at the ISO level in order for a storage owner to achieve the estimated benefits.

5.2 Lessons

One lesson learned is that ownership (of the storage) matters. As described in Section 2, the ISEPA members consisted of three municipal power agencies and ten individual municipal utilities. While the ISEPA members represented LSEs, they did not own significant quantities of wind energy resources near the ISEP site. They did not own significant amounts of transmission or conventional baseload generation in the area, either. Two of the municipal agencies who were ISEPA members were MISO participants and transmission owners (TOs). The other ISEPA members were neither.

These characteristics of the ISEPA members (or the absence of them) became important during the ISEP project. The ISEP Project Team came to realize that the ISEPA members were not necessarily the ideal bulk storage owner for the reasons described in this section. When ISEPA embarked on efforts to market a portion of ISEP to new participants, in addition to looking for capacity and energy off-takers the marketing effort was focused primarily on entities who were potentially better suited to be storage owners.

A significant portion of the potential benefits of a storage facility operating in MISO are storage attributes (and potential market products) above and beyond the basic off-peak/on-peak price arbitrage available from corresponding LMPs.

In theory, a "perfect" or ideal bulk storage owner would be an entity that can internalize all the potential economic benefits of storage. In simple terms, before the MISO market such a perfect owner might be a vertically integrated utility that:

- Directly dispatches its own energy resources for the benefit of its own customers.
- Owns or otherwise has access to energy supply resources whereby the storage can experience adequate off-peak to on-peak price spreads.
- Is an LSE with an obligation to serve its customers. This means the entity's customers may be exposed to upward hourly price volatility that would benefit from the extrinsic value of storage described in Section 3.
- Owns significant wind energy resources near (within an unconstrained transmission distance of) the storage. This means the entity's wind resources may be exposed to downward hourly price volatility (or even negative LMPs) during off-peak hours that would benefit from the extrinsic value of storage described in Section 3.
- Owns conventional baseload generation resources that would benefit from increased load factors (and improved profitability) from the storage operation in off-peak hours.

- Owns conventional generation resources that are subject to increased cycling and startups/shutdowns (and increased O&M costs) because of intermittent renewables and other causes. The storage could take on this cycling burden instead.
- Is experiencing transmission constraints that may be alleviated by appropriately located and operated storage.
- Is experiencing wind energy curtailments (and thereby lost revenues) because of transmission constraints, or because of excessive generation in the area during off-peak periods when the wind is blowing.
- Wants to maximize the depth and effectiveness of its renewables portfolio.

This definition of the perfect storage owner is provided for purposes of illustration. The characteristics are all aimed at achieving the various benefits of storage described in Section 3. Few individual utilities can fulfill all of the characteristics in this simplified definition, but some utilities may have many of them. If an entity is not a perfect storage owner, then they need market mechanisms or tariffs to enable them to sell certain storage attributes to others and thereby monetize them.

Many storage benefits would occur at the ISO level. Going beyond the simplified definition of a perfect storage owner, operation in the MISO marketplace makes the search for the appropriate (if not perfect) storage owner more complicated. Unlike the simplified vertical utility example, operation in an LMP market like MISO means many of the benefits of storage are dispersed (or even dissipated) among many market participants, rather than directed specifically to the storage owner alone.

For example, the operation of storage to absorb energy during off-peak load periods would increase the load factor (and likely the profitability) of multiple baseload generation units in the region. Those profits would accrue to the owner of the baseload units, who would not necessarily be the storage owner. Similarly, the operation of storage to absorb energy during off-peak load periods would reduce the possibility of curtailment of regional wind resources during those time periods. It would also be supportive of additional wind development because it represents a new market during off-peak periods that would not otherwise exist. These benefits would accrue to the owners of multiple wind machines in the region, who would not necessarily be the storage owner. The fast-ramping capabilities of certain kinds of storage like ISEP would be useful to handle the ramping burdens currently carried by conventional generation units. If the storage took this duty, the owners of conventional generation units would experience O&M savings from the reduced cycling. But the storage owners would not necessarily see these cost benefits.

Much of the rationale for dispatching resources at the ISO level (rather than the individual utility) is to minimize energy production costs ISO system wide. As a result, operation in an ISO market means many of the potential benefits of storage are observed at the system level. However, they are dispersed among various ISO market participants who are not necessarily directly involved in providing or operating the storage.

Because much of the potential benefits of storage are observed at the MISO system level, it would seem that MISO would be the perfect storage owner. But MISO does not own facilities.

Given that, the issue is how to give an entity other than MISO incentive to own and operate bulk storage.

Short of MISO owning facilities, development of bulk storage in MISO depends upon innovation in the development of appropriate market products, mechanisms, and tariffs that recognize the potential benefits of storage and places value on them.

Just as current LMP market prices place a value on the marginal costs of energy production, transmission losses and constraints, the enactment of storage awaits development of similar market mechanisms that recognize the other dispatchability, flexibility, ramping, and option attributes (values) of that resource.

Task 3 of the ISEP Economics Study Phase II examined current and planned MISO tariffs as they may be applied to storage [74], and found that the existing MISO tariffs currently undervalue storage. In fairness to MISO, there have not been many new, large storage project opportunities to drive necessary tariff developments, so the absence of such tariffs has been largely moot.

But examination of the current MISO tariffs as they would be applied to projects like ISEP indicates that the tariffs undervalue the potential benefits of storage. Some examples include:

- MISO currently relaxes spinning reserve requirements during time periods of capacity shortages [75]. This policy undervalues all potential sources of spinning reserves, including storage.
- MISO lacks a "look ahead" capability when it develops dispatch orders [76].
- MISO procurement of regulation as a share of load is significantly low compared to most other ISOs. One possible explanation for this is the five-minute dispatch horizon discussed above [77].

The current MISO market does not feature tariffs that address all the potential attributes of and benefits that storage can provide. These benefits include fast ramping, fast cycling, and fully dispatchable off-peak loads. MISO simply has not had sufficient storage project opportunities where such products were necessary until now.

The ISEP Phase II economics study examined current MISO efforts in tariff development that may be useful for storage applications [78], [79]. These developments include:

- Development of a fast-ramping tariff [80]. This effort would be designed to help place value on fast-ramping storage resources like ISEP. The Federal Energy Regulatory Commission (FERC) has also issued a Notice of Proposed Rulemaking (NOPR) on fast-ramping resources [81]. ISEP provided comments to this FERC NOPR process [82].
- Development of improved dispatch "look ahead" capabilities [83]. This work would be designed to improve the dispatch of storage resources.
- Recent implementation of a Dispatchable Intermittent Resources (DIR) tariff. This too would be designed to further improve the dispatch of all system resources, including storage, in concert with intermittent wind [84].

- In addition to tariff efforts, MISO has begun a major storage study to be completed in 2012 [85].

ISEP believes these efforts are valuable, and suggestions for additional work follow.

Based on the ISEP experience, further development of new tariffs and mechanisms such as the following "shopping list" of potential actions is recommended:

- An ancillary services tariff that rewards fast-ramping resources (both ramp-up and ramp-down, in both storage and generation modes). One of the key beneficial attributes of CAES units (and other storage technologies as well) is their ability to ramp their output up and down, both in generation and storage modes. This is an important attribute to address and offset the variability of renewable energy resources. As noted in the previous section, MISO is already examining this topic.
- An ancillary services tariff that rewards fully dispatchable off-peak loads. In essence, this would be a DR tariff that addresses off-peak load dispatching, the converse of the traditional on-peak interruptible loads. This is a major "missing link" in ancillary service developments to date with regard to storage. Most ancillary services address dispatchable generation topics, not dispatchable load because there have not been significant new dispatchable load options proposed in MISO since the start of MISO operations.
- An ancillary services tariff that recognizes and compensates resources that can help avoid cycling wear and tear on conventional generation units. The ISEP economics study included a literature search on studies correlating increased cycling of conventional generating plants with increased O&M costs [86]. This search revealed there is significant concern in the industry about the effect of increasing levels of renewables on the cycling of conventional units. An expanded and enhanced ancillary services tariff should be considered to reimburse facilities like storage that are designed for cycling and can take the cycling burden off of conventional facilities.
- As a global solution to the issues unique to storage, MISO (perhaps with guidance from the FERC) should consider establishing storage as a class of facilities of its own (similar to generation or transmission), and then allocating cost recovery of such facilities across the entire MISO footprint, similar to the Multi-Value Project (MVP) classification recently adopted to classify transmission lines with region-wide benefits.[87]Elimination of the current MISO practice of relaxing spinning reserve requirements when resources are short, which undervalues spinning reserves when they are most needed. Review of current MISO practices showed that MISO relaxes its spinning reserve requirements when resources are short [88]. This practice reduces the value of spinning reserve, and the resources like storage that are well placed to provide it.
- To the extent the storage owner cannot harvest the full extrinsic value of the facility in other ways as described in Section 3, a fully transparent electric options market may also be necessary that enables LSEs to contract for fast-ramping generation services from storage when hourly LMPs are volatile upward, enables wind resource owners to contract for storage (load) services when hourly LMPs are volatile downward (and perhaps

negative), and enables storage to achieve its full extrinsic value, as discussed in Section 3.

As discussed in Section 3, extrinsic value was found to offer 30% to 40% of the total potential benefit for storage in the ISEP economics studies. While the storage owner may be able to internalize most of this extrinsic value without an options market if it had the right characteristics,[8] an options market, if available, would be useful to sell any residual extrinsic value the storage owner cannot absorb themselves to others. MISO itself would not necessarily need to establish such an options market. Perhaps the market could be supplied by the New York Mercantile Exchange (NYMEX) or similar entities, with authorization by MISO for operation in the MISO region and coordinated with MISO markets. In the alternative, if a "perfect" array of appropriate ancillary services tariffs was put in place that would potentially obviate the need for an options market to achieve similar levels of extrinsic value.

- A transmission interconnection study process that examines the benefits of off-peak storage to the transmission system, rather than only the interconnection requirements of the generation side of the storage resource as is done now. As discussed in Section 4, in the ISEP experience the MISO process for evaluating transmission requirements associated with interconnection of new generation developments has traditionally looked only at the new generation facility as just a generation process, with no evaluation of the potential *benefit* to the transmission system of the storage (load) phase of a generation project that also happens to include storage. This represents a missed opportunity for MISO, where appropriately located storage may provide transmission benefits and reduced or deferred transmission costs.
- A market mechanism to recognize, in monetary terms, benefits that storage may have in deferring transmission investments and making a fair portion of that benefit available to the storage owner. It is not difficult to conceptualize opportunities where storage could help reduce or defer transmission investment. For example, what if storage could be used to absorb the output of wind machines when the existing transmission system was constrained?[9] The wind output could then be released to the transmission system when the constraint was no longer present. In another example, what if the generation side of the storage facility (as in the ISEP example) would generate into a known load substation during peak load times, thereby potentially deferring the need for additional transmission into the substation?

  Some form of MISO-level monetary mechanism is necessary to enable storage to capture some of these types of storage benefit to the transmission system. Similar to other storage benefits, because the storage facility owner may not be the affected transmission owner, a way to transfer some of these benefits to the storage owner is not immediately obvious.

8 As discussed on Section 4, the storage owner would need to be a Load Serving Entity (LSE) and a wind resource owner to internalize the extrinsic value for themselves. But they would still need an options market to monetize extrinsic value they could not use.

9 Of course, in this example the transmission constraint could not be between the storage and the wind machines.

- A mechanism where storage investment can, at least in part, be considered as a transmission investment where storage assists the transmission system, either by deferring or obviating the need for specific transmission investments. To address the challenges described in the previous paragraph, perhaps MISO should allow a certain portion of the storage investment to be considered as transmission rate base,[10] rather than generation rate base. By doing that, the storage owner would be enabled to earn a return on its storage investment as an alternative to transmission investment.

Because traditional resource planning models used by utility planners were built to consider generation options, they do not do a good job evaluating storage. This happens because the current models:

- Do not do a good job of representing the daily, hourly, or sub-hourly dispatch of storage. Most models use an hourly dispatch algorithm, or even further simplified dispatch algorithms, in the interest of computation speed. This approach does not optimize the operation of a storage unit against off-peak and on-peak market prices.[11]
- Do not examine storage operations on a sub-hourly basis (and thus do not capture all the potential benefits of providing ancillary services). As discussed in Section 3, one of the primary attributes of a CAES storage facility is its ability to ramp its output up and down quickly—within minutes. Planning models that use only hourly dispatch cannot capture the benefits of such sub-hourly attributes.
- Do not examine the full array of potential benefits of storage to the system. As described in Section 3, storage offers benefits in terms of improved profitability of and reduced cycling wear and tear on other regional generation resources.[12] Such benefits are not captured in traditional planning analyses.
- Do not internalize the benefits of storage that accrue to individual market participants (and thus undervalue storage benefits to the system participants). Traditional planning analyses at the MISO level examine the net market cost of various alternatives. They do not examine the relative profitability to the owners of individual regional resources under various scenarios. The ISEP economics analyses show that storage not only reduces system-wide costs, it also (positively) affects the profitability of nearby resource owners whose facilities are benefited from operations of the storage.

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[10] For example, a portion of the storage investment would be included in the owner's MISO "Attachment O" as transmission investment. This would imply the storage owner would be a "transmission owner" in MISO—even though the storage owner may not own traditional transmission facilities in MISO.

[11] For this reason, in the ISEP Project Team's search for a contractor to perform the ISEP economics studies, if a contractor in its bid proposal offered to use PROMOD, a leading resource planning model, without acknowledging that PROMOD has shortcomings in modeling storage, it was grounds for immediate disqualification for the work.

[12] Increased capacity factors on and reduced cycling of regional intermediate and baseload generation resources, and reduced curtailment of regional wind resources.

Because resource planning computer models are complex, there is a risk that their results could be perceived as the ultimate answer to planning questions. Good planners know better. Models only provide additional insight into planning issues and sensitivities to various planning assumptions. When the model itself does not completely capture all the costs and benefits of an alternative, the planner needs to apply additional caution and judgment.

Bulk storage is a prime example of the need for such judgment. As noted above, traditional hourly planning models cannot capture the sub-hourly activities of a storage facility's operation. The MISO planning staff is pursuing a newer, PLEXOS™ planning model that offers sub-hourly analyses. That is a positive step. But even PLEXOS™ is not built to include consideration of all the benefits that storage can provide. One need only look at the various benefits of storage calculated in Phases I and II of the ISEP work (Section 3) to identify the things the modeling approach needs to consider when analyzing storage.

Accordingly, it is suggested that the ISO's interest in considering storage at a policy level[13] should continue to drive and demand additional improvements in the associated planning models and planning approaches. The output of traditional planning models and analyses without needed improvements should not suggest what the ISO's storage policy should be.

New or revised MISO tariffs or market mechanisms may be necessary to implement legislative initiatives promoting the integration of storage and renewables. Such initiatives are described in Section 6.

[13] It is observed that an ISO forecasting 23,000 MW or more of intermittent wind resources, as MISO is doing, should be interested in cost-effective storage of all types.

6. RENEWABLES POLICY AND LEGISLATION

6.1 Introduction

This section discusses the types of legislative actions that need to happen at the state and federal levels in order for a storage owner and the region to achieve the estimated benefits.

6.2 Lessons

There is a growing realization that renewables and cost-effective storage can be combined and coordinated into an effective combination electric supply resource for the future.

Though the storage and renewables industries in many instances have worked together in recent years, the wind industry as a whole (as represented by wind equipment manufacturers) has been reluctant to acknowledge any need for storage. This is in part because of sensitivity to the costs of renewables, which would only be increased by the cost of storage, combined with the practicality that the electric grid could accommodate initial amounts of intermittent renewables without significant impacts, and relatively few cost-effective storage alternatives existed. However, the growing contribution of intermittent renewables to the nation's energy portfolio now makes combinations of renewables and cost-effective storage increasingly important.

More recently, the American Wind Energy Association (AWEA) and the Energy Storage Association (ESA) issued a joint statement regarding the combination of renewables and storage [89]. The statement, in part, said:

> *"Energy storage provides many benefits to the power system, and the benefits associated with facilitating the integration of renewable energy are just one benefit of many."*

- Legislation or other policy initiatives are necessary to enable the full benefits of storage in encouraging renewables development. Some examples of potential legislative incentives include: Passage of the ITC and Community Renewable Energy Bond (CREB) financing provisions of the federal STORAGE 2011 Act bill sponsored by Senators Bingaman, Wyden, and Collins. This bill was a reintroduction of the STORAGE 2010 Act sponsored by Senators Bingaman, Wyden, and Shaheen [90], with provisions similar to the 2010 version. The STORAGE 2011 Act bill includes [91] a 20% ITC for investments up to $40 million per qualified storage project. Passage of this bill would have a material positive effect on the economics of storage ownership for IOU and other taxable entities interested in owning storage facilities. The analysis (Table 9) showed that passage of the ITC would have a positive and material effect on the net benefits of the CAES project for IOU owners. Similar to the results for public power entities, the results for the three alternatives were close, pending the results of Phase II.

Table 9. Base Case, Phase I Intrinsic and Extrinsic Value Summary For an Investor-Owned Utilities [92]. (Present Worth $/kW in 2015$)

	ISEP	CC	CT
Intrinsic NBITDA[14]	1,171	1,141	869
Extrinsic	335	183	136
Total Value	1,506	1,324	1,005
Capital Cost	1,547	1,205	805
Investment Tax Credit	(111)	0	0
Net Benefit	**70**	**119**	**200**

- CREB financing for public power entities interested in owning storage. CREB financing could mean a benefit to public power owners of about $199/kW [93].

Another potential legislative incentive is assigning state RECs or federal Clean Energy Credits (CECs) to the storage function itself, if the storage can demonstrate it supports renewables development and operations. As described in Sections 3 and 4, the ISEP project experience demonstrates that bulk storage like ISEP would be supportive of wind energy development in the region. This raises the possibility that the role of storage in encouraging and enabling additional renewables should be recognized in state or federal renewable energy goals and/or credits.

Using innovative ways to provide renewables credit to technologies is not without precedent. In Minnesota, for example, a number of public power entities have received allocations of hydro energy from the Western Area Power Administration (WAPA) for decades. Although the energy from this renewable resource is not eligible for application against the utilities' RES requirements, it is nevertheless deducted from the total retail energy used to calculate the utilities' RES requirements. This way, the WAPA allocations are not counted 100% against the RES requirements, but they do reduce the total RES requirements that would otherwise be necessary.

The amount of wind that would be enabled by storage was subject to considerable discussion and debate among the ISEPA Project Team and its consultants. From a simple perspective, if a 270-MW storage facility like ISEP featured 220 MW of compression, that compression load would represent a new market for regional wind machines that would not exist otherwise. Also, the market would exist during off-peak hours, when non-dispatchable wind energy was worth the least. This is a capacity-based perspective.

[14] Net earnings before interest, taxes, depreciation, and amortization.

As an alternative view, from an energy perspective 220 MW of compression load could serve a wind farm larger than 220 MW. This is possible because a wind farm does not always operate at its maximum output because of wind variation; a 220-MW storage facility could serve a larger (say, 350-MW) wind farm during hours when the farm was operating at less than maximum wind speeds. Simply, the capacity factor of the bottom 220 MW of a 350-MW wind farm is higher than the capacity factor of the 350-MW wind farm overall. This perspective, while theoretical and more complex than the capacity perspective, is nonetheless valid.

Section 3 used the more conservative (capacity) approach to assigning REC credits to storage, and assumed that only 25% of the energy stored would qualify for REC treatment. This yielded an additional present value (2010$) benefit of storage of $37/kW [94].

Proposed state legislation regarding storage and renewables include:

- California AB 2514, which directs the California Public Utilities Commission by March 1, 2012, to open a proceeding to determine appropriate targets, if any, for each load-serving entity to procure viable and cost-effective energy storage systems and, by October 1, 2013, to adopt an energy storage system procurement target, if determined to be appropriate, to be achieved by each load-serving entity by December 31, 2015, and a second target to be achieved by December 31, 2020 [95].
- Ohio Senate Bill 221, which would categorize storage that improves utilization of renewable resources during off-peak hours as a "Renewable Energy Resource" [96].
- Proposed legislation in Utah, which would categorize CAES projects like ISEP as a renewable energy source [97].

Another potential legislative incentive is classifying bulk storage itself as a Clean Energy Technology in any federal Clean Energy legislation, if the storage can demonstrate it is supportive of renewable energy. Another way of legislatively encouraging the function of storage in enabling renewables would be to classify qualified storage facilities as a Clean Energy Technology in any federal Clean Energy legislation. Doing this would enable qualified storage facilities to be eligible for certain incentives offered renewables.

In April 2011, ISEP participated with the Coalition for the Advancement of Renewable Energy through Bulk Storage (CAREBS, www.carebs.org), a bulk storage industry association, in submitting comments in response to a request by the Senate Energy and Environmental Committee regarding potential components of a congressional Clean Energy bill [98]. Among other things, the comments proposed that bulk storage that can demonstrate it is supportive of clean energy resources like renewable wind energy should itself be classified as a Clean Energy Technology—and thereby entitled to similar incentives [99].

Creating a market for "firm" renewable energy would be another incentive. This is where the combination of renewables and storage is used to create a renewable product with both energy *and* dependable capacity attributes. Such a combination resource could theoretically have market value above and beyond a corresponding amount of conventional, fossil-fueled capacity and energy offering similar amount of dependable capacity.

Historically, renewable energy goals and market transactions have typically been expressed in energy terms, not capacity. This happened because wind energy in particular is considered an energy resource, with little dependable capacity value, so it has been priced accordingly.

With the potential for wind/storage combinations, renewable energy can have additional capacity value made possible by the storage. As this occurs, a potential arises for a new category of market product: "firm" (or "firmed")[15] renewable energy, with its own energy *and capacity* price components. This would be analogous to "organic" vegetables being sold for a premium price at the supermarket, compared to non-organic ones.

These legislative concepts are only examples of ways storage could be encouraged in combination with renewable energy. Other concepts are certainly possible.

[15] Depending on the dependability of the contract arrangement between the wind and the storage, the resulting combination might be "firm" like a conventional generation unit, or something less than that but more firm than the renewable resource by itself.

7. SITING

7.1 Introduction

Candidate site identification and selection for the ISEP facility represent a significant portion of the project's eight-year history (see Section 2 for details). The process of geologic work related to site selection is discussed in Section 9. This section discusses the communication and community outreach efforts related to the selected Dallas Center site.

7.2 Lessons

Due diligence demands that a storage project engage in an active and collaborative public and government affairs initiative.

In Spring 2006, it became apparent that the CAES site would be located somewhere in central Dallas County, Iowa. The probable site was located in one of the most desirable, transitional rural/suburban areas in the northwest part of metropolitan Des Moines, and gaining the public's acceptance would be difficult. Furthermore, public acceptance was made more complex by the fact that previously Northern Natural Gas had alienated many of the local residents when it purchased storage rights for its underground natural gas storage operation six miles to the west. Performing the required non-invasive seismic testing for ISEP would require the purchase of access rights from landowners and permits from Dallas County.

Members of the ISEPA Project Team realized that a strategic plan was necessary to measure and obtain the public's acceptance of the CAES project. In the teams' view, this was critical given the fact that the public had a very negative impression of storage projects as a result of its adverse experience with Northern Natural. Furthermore, obtaining approval and permits from county and municipal governments would be difficult given that history. Due diligence demanded that ISEPA have a robust public affairs and government affairs strategy.

Regarding public affairs, ISEPA engaged the services of Frank Magid and Associates of Marion, Iowa. The Magid group was a consultant to the ABC, NBC, and CBS networks, as well as several Fortune 500 companies. Working with Magid, the Project Team engaged in goal-setting and strategic planning. The public relations goal was three-fold:

1. Counter the adverse perception of the project left from the Northern Natural experience;
2. Enhance ISEPA's credibility in the community; and
3. Gain the public's acceptance and endorsement of the project.

Strategically, the goal was accomplished by identifying and measuring the public's specific concerns concerning energy supply, costs, and delivery.

When siting an underground storage project in a community, market research of the community in advance is useful. The Magid group performed a survey of the Dallas Center community to learn the residents' attitudes about energy in general and the project in particular. With regard to general attitudes about energy, the survey found [100]:

- A significantly high number of respondents (41%) felt that current household energy costs were higher than they should be.
- There was overwhelming support about the need to develop alternative energy sources.
- Only 10% of respondents were aware of the ISEP project. When asked for details about the project, most of the 10% did not know.
- After being read a description of the project, almost 60% thought it was a good idea.
- About 45% of respondents strongly supported the project idea, and 10% were strongly non-supportive. Importantly, 42% did not have an opinion.
- Of the 10% who were strongly non-supportive, the primary issue was safety of the project. Their primary issues, in descending order or importance, were:
    1. Safety/issues/dangerous for the area.
    2. I don't know enough about it/I don't know/don't understand it.
    3. Don't want it under my house/don't want it in my community.
    4. I would want more research done/sounds too good to be true.
    5. It wouldn't work/not feasible/doesn't make sense.
    6. Already have natural gas stored and I'm not comfortable with that.
    7. Cost to the county/expense.

The findings of the survey included the following recommendations to the project [101]:

- ISEPA needed to work to retain the 45% who supported the project, while convincing the 42% in the middle to support the project as well.
- Key messages of interest to the community were developed based on the Magid work. The resulting eight key talking points addressed why ISEP was a good idea:
    1. Help reduce costs/cheaper/wind is free/help control energy prices.
    2. There's lots of wind/it's something we already have/uses the wind/uses something we're not using.
    3. Decrease dependence on foreign oil/decrease dependence on foreign countries.
    4. Alternative resource/alternative source is a good idea/need to find different kinds of energy services.
    5. Healthier for the environment/clean energy.
    6. Decrease fossil fuel use, dependence/reduce our dependency on gasoline, natural gas, and other forms of energy.
    7. It's a natural source/should use the natural resources, like wind.
    8. Save energy/save resources/conserves fossil fuel/can't depend on fossil fuels forever/more efficient.

The market research firm also reviewed all project communications materials and the project website. Among other findings, it was recommended that the project reduce emphasis on building an industrial-like "plant" in the community, and choose the term "park" instead. As it turned out, the Lesson was that sometimes the simplest suggestions are the most elegant and effective. Here, Magid suggested that the public would likely view a "plant" as a purely industrial facility with all the potentially unfavorable visual and environmental aspects of such a development. Instead, following Magid's advice, the agency changed the project name from "Iowa Store Energy *Plant*" to "Iowa Stored Energy *Park*." The project logo became an image of stately wind machines in a bucolic scene of corn fields typical of the Dallas Center area.

Based upon the Magid study, the ISEPA due diligence team was able to formulate a successful Public Affairs program that emphasized the positive and sought to educate regarding the negative. ISEPA encountered no obstacles in obtaining access rights and local government permits for geophysical testing. When it came time to purchase property for test wells, the public support encouraged landowners to engage in a bidding process to determine who would sell or lease their property to ISEPA for testing. Government Affairs was impacted positively by the fact that city and county government and the local school district actively promoted the ISEP project.

Once market research is gathered, it should be used in real and practical ways. Based on the market research of the community, the project applied its recommendations to its operations in several ways.

- The project name was changed from "Iowa Stored Energy *Plant*" to "Iowa Stored Energy *Park*."
- The project website look and text was revised from an engineering, power-plant orientation to conform with the various important environmental reliability and energy security messages identified in the research as important to community members.
- The primary community messages were incorporated into project communication and marketing collateral materials and presentations going forward.

It is important for the project to appear credible and trustworthy in the process. The ISEP project Technical Director and Development Director spent a lot of time in the field interacting and communicating with people in the community. Although these contacts were not specifically part of the overall communications plan, they became an important asset to the project's community relationship.

Objections to a new project are often based on a lack of information. The project needs to ensure that basis for objection is minimized by substantial communication. Also, the project needs to establish a recognized and sanctioned community forum for regular communications about the project. In addition to monthly board meetings, the project established a Dallas Center community forum, chaired by the mayor. This was used to communicate and collect community input to the project.

It is useful to establish a community mailing list and use it for project updates. The Project Team established and maintained such a mailing list, and used it for project announcements and notifications of upcoming events. A project starting today would likely have a presence on Facebook or similar social networking media.

To the maximum extent possible, the decision processes should be transparent and accessible to the community affected. Project board meetings were held in the community to facilitate attendance by community members; most board meetings were held in the city of Dallas Center. The ISEPA board meeting agendas were posted on the isepa.com web site in advance of the meetings, and community members were encouraged to attend the meetings. Conference call dial-in and webinar connections to board meetings were provided so community members who could not attend in person could listen in. Community members also dialed in to board conference calls.

If possible, it is also important involve the local community in decisions about where the plant facilities will be located. Once the project's underground reservoir "footprint" had been identified by geology studies, the ISEP Project Team researched the property titles of the affected properties represented by the footprint. It was anticipated that this information would be useful later for permitting of underground storage rights with all affected property owners. More immediately, it was useful for the siting of the above-ground plant equipment and facilities.

Based on the property records, the ISEPA Project Team issued a Notice of Intent to Purchase the plant site land for the above-ground facilities. It was sent to every landowner in the project footprint. Each landowner was invited to bid on selling the land to the project. The Notice included a statement that the project had the right of condemnation for the property, but this was never necessary.

Multiple landowners submitted bids to sell their property to the project. Some bids were subsequently revised downward by the property owner when the original bid amounts were announced to the public. Although not all community members were enthusiastic about the prospect of having a power plant in their neighborhood, the bidding process resulted in some generally friendly competition among property owners for selling the plant site. The positive tone established in this process was supportive of good relations with the community throughout the balance of the project.

In the end, although it took some additional time and effort, maintaining a transparent and open decision process with ongoing accessibility to the public turned out to be the right thing to do. Although they did not necessarily agree with every project decision, the public came to know what to expect and came to respect that everything that was happening was being communicated. In fact, the Team observed that for the most part the local community was, in the end, just as disappointed in the project's termination as the owners and the Team were, and expressed that to the Team. The Lesson is simple: Projects of this nature are not by industry; industry needs to be a partner with the community.

8. PROJECT MANAGEMENT

8.1 Introduction

This section describes project management lessons learned in the ISEP project. The context is initial development from technology development to ownership development to marketing the project to potential project participants and the local community.

Project management of a multi-owner power plant project encompasses many topics. The focus of this section is on topics that relate specifically to a storage project like ISEP.

8.2 Lessons

It is a common misconception that development of a power plant involves only physical construction and operations. Instead, the initial years of development involve organizational definition and relations, market development, geology research, cost estimates, economic studies, contracts, financing considerations, and regulatory permitting. Development of a bulk storage project like ISEP takes years before a Notice to Proceed to purchase equipment and construction occurs. During the initial development phase, the project board's and Project Manager's primary job is due diligence. Before a Notice to Proceed to purchase equipment and construct the facility, these points are made regarding the Project Manager role:

- His/her primary responsibility is due diligence – enabling the project owners to make correct decisions regarding the project, including the decision to *not* construct the project.
- The Project Manager should be a qualified, independent, and objective third-party. He or she cannot have a personal vested interest in ownership or construction of the project.
- At this phase of development, the Project manager should *not* be:
    - The eventual planned construction or operations manager of the project (although such skills would be useful). The skill sets for developing and permitting a project are not always the same as constructing and operating it.
    - An employee of one of the project owners/participants. Instead, he/she should report to the project owners *as a group*. This is necessary so the Project Manager is not pressured by the interests of only one owner.
    - A developer with a personal financial interest in the project proceeding to construction. During the initial years of ISEP development, project management consisted of an ad hoc group of project team members and consultants. For lack of a designated project leader, at times the consultants seemed to be in charge of the project. In 2009, the ISEPA Board realized that they needed to designate someone to be in charge, and determined that an independent and objective Project Manager was necessary.
- The Project Manager needs to ask the right (and sometimes impertinent) questions of project staff, consultants, and geologists.
- The Project Manager should be responsible for every aspect of the project's development, and to the project's governing body for results.

A storage project needs an articulated due diligence/development plan to be successful. In the ISEP project, this plan consisted of three components:

- Economics (see Section 3 for details).
- Geology (see Section 9 for details).
- Marketing. The marketing effort consisted of contacts to and meetings with various regional public power and investor-owned entities potentially interested in becoming a participant in the project. Non-disclosure and confidentiality agreements were established with these entities to facilitate the discussions.

For a CAES project, "Geology" and "Utility" are two different languages. During the ISEP project, it became clear that geologists and utility personnel (i.e., board members) did not speak the same language. Often, the geology had to be interpreted into utility engineering and business language to facilitate communication with the board.

All prospective project owners/participants should be qualified by the project before they join it. Such qualifications include but are not limited to:

- Knowledge of what kind of resource (baseload, intermediate, peaking, renewables, etc.) they want/need.
- Ability to determine the range of MW of the project they need for their own customers.
- Ability to accommodate the project in their resource portfolio. This particularly applies to distribution utility entities with long-term wholesale contracts with other suppliers and the specific provisions of those contracts.
- Ability to economically participate in the market in which the storage will be operated.
- Ability to finance their share of the project.

The ISEPA members were not prequalified on such characteristics before they joined the project. As a result, these qualifications for some of the members had to be backfilled later as the project progressed – requiring additional ownership agreements to be negotiated among the ISEPA members while the project was in development.[16] These qualifications, or lack thereof, caused some members to withdraw.

A storage project by its nature will involve multiple and diverse participants, and this needs to be built in from the start. These would include the storage facility owner(s), transmission owner(s), wind energy resource owner(s), power purchase agreement off-taker(s), owners of conventional facilities nearby that would benefit from the off-peak load, the power market(s), and potentially others. In an open access environment, it is unlikely that all of these parties would be the same entity.

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[16] The ownership agreements included a Transition Plan, which defined the needed changes from investment-based participation to MW capacity-based participation and enabled entities other than public power to participate in the project; an Asset Sale Agreement, which sold the project from the ISEPA members to a new entity called "Iowa CAES Project"; and an Iowa CAES Project Organization Agreement, which defined the new project entity that would proceed with ISEPA members and new participants, both public power and investor-owned. These agreements were approved by the ISEPA Board in Summer 2011.

In the ISEP experience, the original ISEPA storage facility owners did not own the transmission or wind energy resources or significant amounts of conventional generation resources in the vicinity of the storage site. As described in Section 3, this represented a handicap to them achieving the various benefits of storage. The importance of these factors came to light later in the effort. In retrospect the Project Team members realized that involving a diversity of project participants earlier in the effort, rather than focusing primarily on geology alone, would have been beneficial, even though it would add complexity to the effort.

Unless the project capacity is fully subscribed from the start, its organizational structure, financing plan, and ownership contracts plan need to think broadly regarding the types of owners (i.e., public power or investor-owned) that would be eligible to participate in it. As described in Section 1, the project was originated by public power entities, for the use and benefit of public power only. Later, when it was realized that public power alone could not fully subscribe the project and investor-owned utilities would be needed as participants too, the project organization (e.g., organized as a public power agency) needed to be changed. This required the development of several organizational transmission contractual agreements among the ISEPA members to address.[17] In retrospect, it would have been better if an broad-based project organization structure had been set up from the start.

Project participation should be on a project MW output-share basis from the start, rather than only investment dollars-based. All owners' participation should be based on paying their pro-rata share of project costs, based on their respective planned shares of the plant output. In ISEPA, project participants originally joined the project on an investment basis. This investment turned out to have little relationship to each participant's actual MW need for the project. This had to be reconciled late in the project in order to determine investment responsibilities among the ISEP members for the project going forward, and to prepare to add outside parties as new participants under consistent investment rules. In retrospect, this needed to have been done at the beginning of the project.

On important issues, second opinions should be sought when there is uncertainty because of lack of data or other factors. In the ISEPA experience the uncertainty created by limited geology data (as discussed in Section 9) made the geology recommendations to proceed or not an opinion, as viewed by the ISEPA staff. Because the geology was so important and would potentially require a high level of investment in subsequent project steps, the staff was not comfortable with depending solely on the opinion of only one expert. As a result, ISEPA sought and secured a second opinion on the site geology.

Politics internal to the project owners' group or department within a single significant owner can have major consequences for a project. Consideration of the needs of all the participants is important to provide the necessary cooperation for the project to proceed.

Finally, with the benefit of hindsight, the Project Team offers the following guidance to those who may be contemplating an aquifer-based CAES project:

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[17] Ibid.

- *Project Team independence.* Future project owners would be well advised to employ as ISEPA did a due diligence project management team whose members are totally independent from individual project owners. The due diligence team should report to a committee or board representing the project owners as a group. Having multiple project owners naturally entails the potential for differing and potentially hidden agendas and philosophy that can easily result in a conflict of interest, the ramifications of which can be very detrimental. The independence of the project management team acts as a bulwark against conflicts to protect the integrity of the project's decision-making process on behalf of the project as a whole.
- *Risk assessment.* Determine, at an early stage, the owners' tolerance for risk and how that risk will be determined. It is much easier to benchmark a project against a predetermined risk standard than one which is fluid or, worse yet, non-existing.
- *Fact and opinion.* Because the critically important aquifer-based storage reservoir cannot be easily or precisely defined, project decision-making in such a CAES project will, in large measure, be based upon a combination of fact and the opinions of experts. Facts are those findings about which there is absolutely no dispute. Facts are static, and capable of being proved; opinions can differ, even when they are based on the same facts. To ensure quality decision-making we suggest that whenever reasonable, opinions be corroborated. Access to the geological expertise of SNL and the Iowa Geologic Survey as well as its contracted experts Hydrodynamics and MHA Petroleum Consultants was instrumental to the Project Team.
- *Public domain data.* Certain facts regarding the nature and size of the candidate site may exist in the public domain. It is advised to corroborate the accuracy of the data, particularly if is more historical than recent in nature.
- *Seismic data.* Non-invasive or seismic data are extremely important. However, geologists can often differ regarding seismic interpretation. One can rarely over-seismic a project. Had the ISEP had proceeded further, it is likely the project would have accomplished advanced, three-dimensional seismic to further define the reservoir and optimize locations for the production wells.
- *Core sampling.* Determining the appropriateness of an underground aquifer geological structure is always challenging. It is difficult to determine, with precision, the exact characteristics of what actually exists underground without core sampling (i.e., test wells). A CAES aquifer candidate will soon learn that "when you see one core sample, you've seen just one core sample." The characteristics of a core sample provides accurate data only as to the particular 5-inch diameter (i.e., the diameter of the test well) sample. What exists beyond the 5-inch sample is a matter of extrapolation. The further one extrapolates from the 5-inch sample without additional data, the greater the risk of missing an important geologic anomaly. Consequently, the number of and spacing between the core samples becomes very important and will form the basis for "go/no-go" decisions involving future investment of many millions of dollars. Each sample (test well) in the ISEP experience cost $500k to $700k to collect. These decisions are more easily made if the concepts of team independence, risk tolerance assessment, and opinion corroboration have already been embraced.

9. GEOLOGY

9.1 Introduction

While the site-specific geology details for ISEP may not be particularly instructive to other CAES projects in other locations, the process of securing the information should be. The Lessons for this section include a chronological list of the various geology studies performed by the project, and also includes lessons learned from the business perspective.

9.2 Lessons

9.2.1 Technical Geology Perspective

From a technical geology perspective, accomplishing the site selection and geologic analysis for a greenfield aquifer-based CAES project where there is no existing data or prior use of the reservoir time-consuming and is challenging. As an illustration, the following is a chronology of the geology studies performed for ISEP:

In 2004, Fairchild & Wells, Inc. produced a report to the Iowa Stored Energy Plant Committee, providing a review of SP27 site geology for use as natural gas and/or compressed air storage site [102].

In 2005, The Hydrodynamics Group, LLC, the primary geology consultant to ISEPA, conducted a reservoir selection study of potential CAES geological storage structures in Iowa for Electricity and Air Storage Enterprises, LLC [103]. The goals of this initial reservoir selection study were acquisition of geological data; development of high-level reservoir screening criteria; and high-level reservoir screening of geological structures. The report included comparative data for input requirements of various CAES equipment types and suppliers. The report recommended further investigation of the Stanhope Anticline and Dallas Center structures.

A study by Electricity and Air Storage Enterprises, LLC (EASE), a consultant to ISEPA, compared the infrastructure needs of three potential sites: "Alpha" (Dallas Center Dome), "Bravo" (Bagley-Herndon Anticline), and "Charlie" (Stanhope Anticline) [104].

EASE produced a report on efforts to conduct a review of potential reservoirs and locations for the ISEPA CAES facility. Based on work performed by Hydrodynamics, the report recommended further investigation of the Stanhope Anticline and Dallas Center structures [105].

EASE reported on transmission screening using load flow analyses performed by Wind Utility Consulting to examine transmission interconnection requirements for the Stanhope Anticline, Bagley-Herndon Structure, and Dallas Center Dome sites. They assumed 400 MW of peak demand impact including both wind and the storage facility's output at the same time. The study focused only in interconnection requirements, and did not attempt to replace detailed transmission network interconnection studies that will be necessary in the Midcontinent Area Power Pool (MAPP)/MISO [106].

EASE issued a report listing legal issues remaining to be addressed by ISEPA. The report addressed the structure of the project entity, project financing, joint action agency, storage rights ownership, Iowa Utilities Board (IUB) certification required, property taxes, income taxes, renewable energy tax credits, compression energy (wholesale or retail selection), and other considerations [107].

EASE developed a report on infrastructure assessment (water, highways, rail, land rights ownership, gas supply, etc.) comparing the Stanhope Anticline, Bagley-Herndon Structure, and Dallas Center Dome sites. The report recommended the Stanhope Anticline site for further assessment as most likely to support a CAES operation [108].

EASE produced a report that advanced the analysis of the previous four reports further by recommending the next steps to be taken to confirm the technical viability of the location and reservoir with the most promise for technical and commercial success based on reports and investigations to date. The report affirmed the Stanhope Anticline should be the target for seismic studies, with the Dallas Center site as a backup.

In 2006, Hydrodynamics produced a reservoir selection study examining the Stanhope and Dallas Center sites. The report was on results of seismic survey performed at the Stanhope site in November 2005. The target was the support of two 134-MWe D-R trains of CAES equipment. The Dallas Center site was chosen as the primary site, and Stanhope the secondary site [109].

EASE reported on the conclusions of seismic studies at the Stanhope Anticline. Results showed Stanhope is unsuitable for a CAES Project because it is too small and the caprock appears to be fractured. Attention turned to the Dallas Center site [110]. Hydrodynamics issued a report on the results of a high-resolution seismic survey performed at the Dallas Center site in August 2006 [111].

EASE issued a report referring to the Hydrodynamics report dated September 26, and provided a recommended technical plan for next steps in project development. EASE recommended that site modeling and the initial preparations for test wells begin, a communications plan be developed, and initial steps be taken to fulfill IUB requirements [112].

Hydrodynamics issued a report summarizing analyses of the Dallas Center site for two 134-MWe CAES units. Site modeling was performed using Northern Natural Gas' Redfield site characteristics as an analog. The report outlined multiple phases of work that needed to be done, including test wells, air injection testing, and CAES design [113].

In 2007, Hydrodynamics issued a revised edition of the September 2006 report that was the culmination of the Iowa site candidate screening analysis and selection process, a seismic reflection survey of the Dallas Center geological structure, and a CAES reservoir simulation model using the characteristics of the Redfield storage field as an analogue. The report recommended a multi-phase approach including test wells, air injection testing, and a CAES design effort [114]. The report also highlighted the key issues in doing an aquifer-based reservoir [115]:

- Water encroachment,
- Matching reservoir air pressure cycles to turbo-machinery requirements,

- Air bubble deliverability,
- Oxygen depletion,
- Oxidation issues,
- Caprock integrity, and Structure integrity with faulting.

EASE issued a report referring to and based on the findings in December 2006 and March 2007 Hydrodynamics reports. EASE recommended that ISEPA proceed with the recommendations of Hydrodynamics, and begin work securing storage leases [116].

EASE issued a report on the results of a supplemental seismic survey performed at Dallas Center in January 2007. The results modified the previous results slightly, and confirmed a dome structure at Dallas Center. EASE recommended that modeling of the site proceed using the seismic data, as supplemented, to take initial steps to drill test wells, and articulated steps for obtaining necessary IUB certificates [117].

In 2008, ISEPA requested and received from the Iowa Power Fund (IPF) a $3.2 million loan for funding the test well drilling program [118]. The Princeton Environmental Institute issued a study drawing on the results of various field tests and feasibility studies as well as the existing literature on energy storage and CAES. The report outlined the issues and framed the need for further studies to provide the basis for estimating the true potential of wind/CAES. Geologic storage in aquifers and aquifer distribution around the United States were highlighted. Several CAES projects including ISEP were discussed [119].

A review by the Iowa Geological Survey of various project reports stated the planned Dallas Center site is an “environmentally safe project,” that is “well researched and planned,” and the site is “a totally appropriate container for compressed air energy storage [120].”

In 2010, the first test well, “Keith #1,” was accomplished at the site during April to May. Hydrodynamics issued a report on the effort on May 18 [121]. Among other findings, the report concluded:

- The top of the Mt. Simon is approximately 100 feet deeper than originally projected [122].
- The structure is more of a saucer-shaped dome, rather than a bowl.
- The structure has about 50 feet of closure, rather than 150 feet as originally envisioned. This represents an approximately 50% reduction in the air storage capacity of the vessel, compared to previous estimated performed in 2007 [123].
- Pump test results indicated a relatively low permeability of 3 milli-Darcys, but at the time this was attributed to be more representative of the cap rock materials.
- “The results of the drilling indicate additional exploratory wells will be necessary to determine the configuration of the target geologic structure [124].”

SNL completed water chemistry analysis [125], and core sample testing [126] for the Keith #1 well. These measurements indicated low permeability in the reservoir formation. The second test well, "Mortimer #1," was accomplished on the site during July to October. Hydrodynamics issued a report on the effort in November [127]. Among other things, the report concluded:

- The revised structure map indicates a saucer-shaped structure with approximately 65 to 70 feet of closure over a 1-1/2 mile area [128].
- The relatively low pump test-calculated permeability may suggest a concern.
- The known aquifer CAES reservoir properties measured at the first two test wells are "PARTIALLY" consistent with assumed properties used of the original reservoir performance analysis.
- Although the Keith and Mortimer #1 wells provided important structural control data, additional Mt. Simon exploratory monitoring wells would be necessary to confirm the structure to the confidence level required to recommend further development of this structure for CAES service [129].

Figure 7 illustrates the seismic results for the underground structure, after they were revised with results of the Mortimer #1 test well.

SNL issued a report on the Mortimer #1 core analysis on October 7, which was included at Appendix H in the Hydrodynamics November report [130]. Based on the results of the first two test wells as outlined above, there was much discussion within ISEPA whether doing a third test well was a good idea. The ISEPA Board subsequently approved a Test Well #3 effort on November 11 [131]. The third test well, "Mortimer Well #2," was accomplished on the site during the time period from November 2010 to March 2011. Figure 8 depicts the location of the three test wells, and the underground reservoir footprint relative to the town of Dallas Center, Iowa.

In 2011, because of the importance of the geology results to the overall project, the ISEPA Board in January authorized a third-party objective peer review and second opinion on the geology results and forthcoming recommendations. MHA Petroleum Consultants was retained as a result of a competitive bidding process to perform the second opinion.

In April, SNL issued a report on the Mortimer Well #2 core sample results [133]. On April 28, Hydrodynamics issued a report on the Mortimer Well #2 results [135]. Among other things, the report concluded:

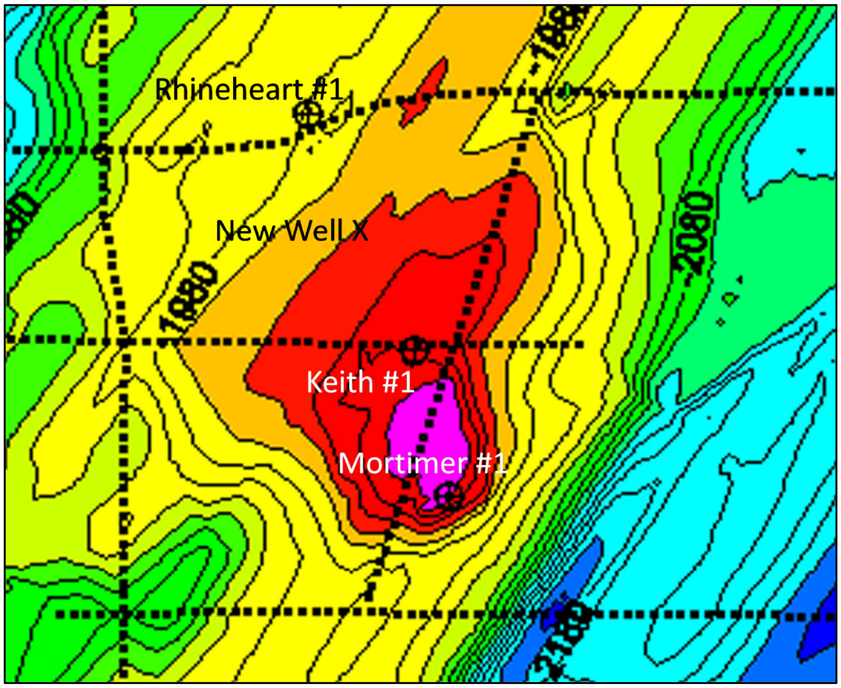

Figure 7. Illustration of ISEP reservoir structure following completion of Mortimer #1 test well [132].

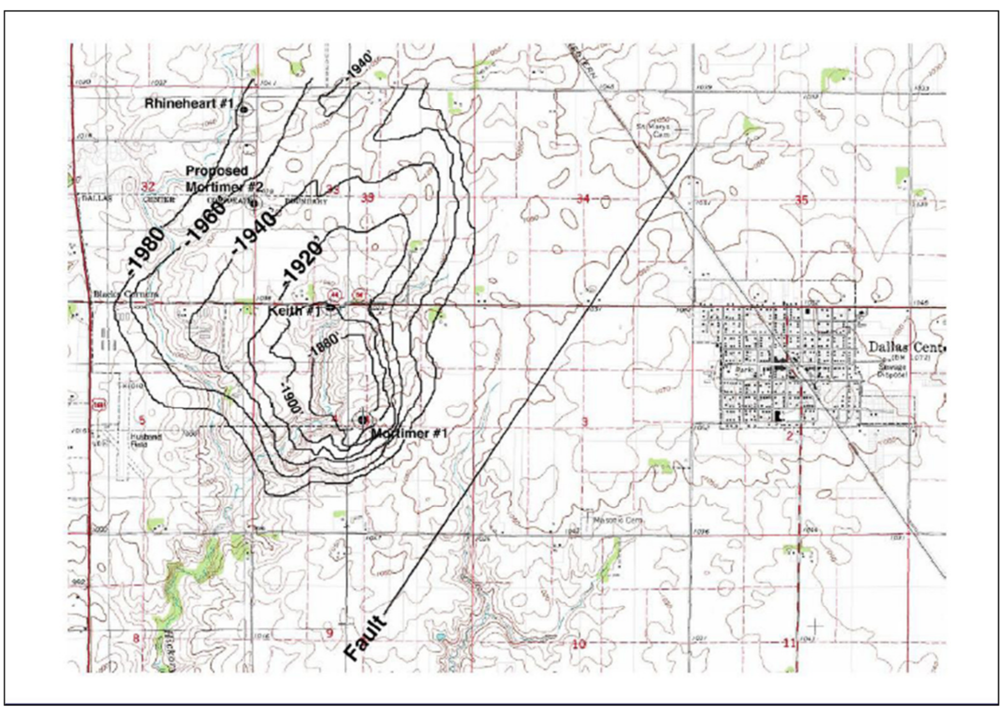

Figure 8. Location of the three test wells, the footprint of the underground structure and the town of Dallas Center, Iowa [134].

- The revised interpretation based on all three test wells is that the saucer-shaped dome has approximately 65 to 70 feet of closure over about a 1-1/2 mile square area. This represents approximately 25% reduction in the air storage capacity of the Mt. Simon air storage vessel, compared to estimates made in 2007 [136].
- The structure's porosity is 16% to 17%, consistent with original estimates.
- Low pump test results again indicate that the permeability of the sandstone was a primary concern [137].
- The water chemistry indicates a relative high concentration of sulfate that will need to be evaluated for impact on air oxygen content.

On July 22, after completing revised reservoir computer modeling, Hydrodynamics issued a final report and recommendation for the Dallas Center site, based on all work performed there and the results of the test wells. The report concluded [138]:

- The Dallas Center site geology is "dramatically different" from that found at Northern Natural Gas's Redfield site (the one originally used as an analog for Dallas Center).
- The porosity and permeability of the multiple lenses within the Mt. Simon are not conducive to simple air bubble development in a vertical direction, and represent the lower limit of reservoir permeability values for economic air production from vertical and/or horizontal wells.
- Numerical simulation studies show that a horizontal well is unable to support a 135-MW power plant because of pressure drops below the minimum operating pressure, but a 65-MW plant may be possible.
- An air injection test will be necessary to further determine the technical feasibility of developing the Dallas Center Mt. Simon for CAES:

  "5. It appears that bubble creation in this particular dual dome structure poses significant challenges that make the process ***difficult, impractical and potentially impossible*** *within the limitations of such a project." [139] (Emphasis added)*

Although not stated in the Hydrodynamics report, the cost of the additional air injection testing suggested by the report that would be required to further explore the viability of the site would entail an additional investment of $12 million to $20 million or more [140].

In July, MHA Petroleum Consultants issued their peer review second opinion on the geology results and recommendations [141]. Their report concluded:

- The Dallas Center dome location is not a suitable candidate for a CAES Project.
- The Dallas Center site has been adequately tested. Additional data (i.e., an air injection test) would not lead to a different conclusion.
- MHA recommended that project activities be ceased, and the Dallas Center site abandoned.

Project Manager SA issued its due diligence report and recommendations for the project as described in Section 8 [142]. Based on the geology findings of site limitations, the fact that a smaller CAES unit would not be cost-effective compared to conventional alternatives, and that if the project continued the next step would be a $12 to $20 million air testing effort with no guarantee of success, SA recommended with the other Project Team members' concurrence that the ISEP project be terminated. On July 28 the ISEPA Board agreed with this recommendation.

9.2.2 Business Perspective

From the business perspective of the storage facility owner, developing a greenfield, aquifer-based CAES project is challenging. The project's long-term economics (Section 3) looked favorable (assuming the geology worked). Although the geology was a negative factor, there are still some lessons to be learned from the owners' perspective.

The site identification and geology testing due-diligence process described in this section probably included the correct steps. However, extending as it did over seven calendar years, the process probably could have been done in a significantly shorter amount of time. In retrospect, the long development period was primarily driven by:

- Funding limitations, where the ISEPA members worked to leverage their own investments with funding provided by government earmarks and agencies.
- The relative complexity of developing a greenfield, aquifer-based reservoir.
- The ISEPA members' own natural conservatism when dealing with an innovative technology based on geology, a science that was unfamiliar to the ISEPA members' traditional utility business.

An aquifer reservoir is difficult to do, particularly when compared to other potential underground storage opportunities that may entail existing empty caverns, defined salt formations that can be mined, or depleted natural gas reservoirs for which some production or reservoir data are already available [143]. In the ISEPA experience, in an aquifer approach:

- The potential reservoir is unfamiliar to the non-geologist decision makers involved in pursuing a CAES project. The reservoir is a solid but porous structure thousands of feet underground that is inaccessible. It can only be conceptualized and remotely measured by seismic studies, and drilling/core sampling of test wells that cost $500,000 to $1 million each.
- The number of test wells that can be done are limited by cost, and each well, while critically useful, provides only a 5-inch-diameter vertical sample of a reservoir that in the ISEP example was more than a mile across. Cost precludes doing enough test wells to grant complete confidence of success, but perhaps only enough to test the reservoir by actually putting air in it. ISEP never got that far.
- The presence of water in the aquifer raises additional issues with regard to possible interaction of it with the air stream (e.g., oxidation of the iron in the water) and project equipment (e.g., corrosion). Because there is some water in almost all rocks underground, this issue is ever-present and may be mitigated.

While all of these issues could be addressed with the proper geology test data and project design, there is good reason why the following words appear in the "Statement of the Problem" in all three of the Hydrodynamics test well reports on the project [144]: "The use of an aquifer air storage system, like the Dallas Center structure, is problematic," and "We currently do not have adequate geological and reservoir data to determine the CAES potential of the Dallas Center Mt. Simon structure." In the ISEP experience, balancing costs and achievement of sufficient geology data to justify further project investment with a reasonable probability was an ongoing effort. Other aquifer projects would likely be similar.

Success of the project would have eventually had to rely on achievement of a reasonable comfort level with the underground geology among the utility off-takers of the plant's output. The ISEPA members, while enthusiastic during the project's development, were appropriately cautious about the geology and its critical importance to the project. In addition, multiple utilities that were involved in the ISEPA outreach effort to market the project were familiar with the above-ground CAES equipment but not with the underground geology . In the authors' view, if the project had gone forward, a communications effort would have been necessary to grant the off-takers/owners/investors enough confidence in the geology to proceed with the project. Positive geology testing results would certainly be helpful in this regard.

An innovative storage project for utility applications must contend with other, conventional generation options available to the utility off-takers that represent less technical risk and could be cheaper.

10. RECOMMENDATIONS FOR FOLLOW-ON WORK

10.1 Introduction

From the ISEP project experience and Lessons from Iowa as a whole, the authors offer the following observations and recommendations for follow-on work in bulk storage in general, and in MISO in particular.

10.2 Observations and Recommendations

10.2.1 Ownership

An entity contemplating ownership of or participation in a bulk storage project needs to consider who they are, and what kind of market they will be operating in. This affects whether they can achieve the full gamut of potential storage benefits described in Section 3 in such manner that they will be sufficiently incentivized to own and operate the storage facilities.

If the entity dispatches its own resources (as opposed to operating in a centrally dispatched market like MISO), to achieve the full value of storage the entity ideally either needs to be an LSE that owns renewable resources, or have contractual relationships with other entities with those characteristics. Also, they would have to consciously adjust their system resource procurement and day-to-day resource scheduling activities to take full advantage of the unique things the storage facility can do.

If the entity is in a centrally dispatched market like MISO, the ISO needs to have sufficient tariffs and other market mechanisms in place to enable the storage owner to achieve the full value of the benefits available from all of the storage facility's attributes. In the absence of such tariffs and market mechanisms, many of the potential benefits of the storage facility will go un-monetized, or will accrue to the benefit of market participants other than the storage owners.

10.2.2 Economics

Off-peak to on-peak price spread arbitrage is often considered the primary potential economic benefit of a bulk storage unit, but the ISEP experience and studies show it is not the only one. Accomplishing bulk storage will require the tapping of the full range of storage's attributes, benefits, and value:

- Off-peak to on-peak price arbitrage (intrinsic value).
- Option value to address price and quantity variability (extrinsic value).
- Fast startup, multiple daily startups/shutdowns, and fast ramping (ancillary services).
- 100% dispatchability of off-peak load (to improve capacity factors and reduce cycling of conventional plants, and reduce curtailment of renewable resources).
- Ability to enable more renewable resources than could be accomplished without storage.
- Transmission deferral.

A storage owner or participant must be ready and capable to innovate if they hope to achieve the full benefits of such a project. As described in Section 5, many of the necessary market mechanisms to enable storage do not currently exist.

10.2.3 MISO Markets and Tariffs

The ISEP project was focused on future operation in the MISO market. Although specific market operating rules vary among the various ISOs, the conceptual lessons-learned about what it takes to make bulk storage happen in MISO would likely apply to other ISO markets as well.

MISO is working on various storage studies and tariffs.

The MISO efforts need to result in tariffs that can enable the full range of beneficial storage attributes and full value of storage for the storage owners and the MISO region as described in Sections 3 and 5. This would include ancillary services tariffs, and coordination with various legislative initiatives providing incentives for additional renewables (and related storage) development. If storage owners cannot otherwise achieve the full extrinsic value of their facilities, creation or participation in an electric options market would be useful.

Another market concept that deserves consideration is the creation of a market product involving "firm" or "firmed" renewable energy, with both energy and capacity components. Historically, renewables have been thought of as primarily an energy resource because it is intermittent. Combinations of renewables and storage could provide renewable energy capacity value. This combination should be valued and priced as a premium product compared to conventional energy sources, similar to organic produce sold in supermarkets.

As described in Section 5, existing computer resource planning models do not do a good job calculating the potential benefits of storage. MISO is working on improved modeling techniques, but more improvements need to happen before the models. In the meantime, the authors suggest that MISO policy toward encouraging storage, particularly to address increasing levels of intermittent renewables on the regional system, should drive modeling improvements, rather than modeling shortcomings suggesting MISO storage policy.

It is recognized that from a practical perspective, MISO probably needs a specific new proposed bulk storage project of material scale that would help drive the need for proved tariffs, markets, and planning models. Doing such development in the abstract without an actual specific project to focus on is difficult, and would probably be (rightfully) assigned a low work priority.

10.2.4 Legislation

The need for storage is growing, at least in part, as a result of legislatively driven incentives for renewable energy development, and for the same reasons storage should be similarly encouraged by legislation. Simply, storage enables existing renewables (and other resources) to operate better, and it enables more renewables to be built than could be accomplished otherwise.

Legislation at the federal level for storage should include:

- Passage of the STORAGE 2011 Act or something similar, including ITCs for investor-owned bulk storage owners and CREB financing for public power entities.
- If a national RES or Clean Energy Standard is passed, then bulk storage that demonstrably enables renewables operation and development should itself be classified as a renewable or clean energy resource, and thereby eligible itself for RECs or CECs.

Legislation at the state level for storage should include:

- Recognition of the role of bulk storage in enabling renewables development and achieving state RES.
- For those bulk storage facilities that demonstrably enable renewable operation and development, their storage energy should be, in whole or in part depending on the project-specific circumstances, credited against the owners' state RES requirements and eligible for RECs of their own.

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