Study Plan for
Critical Renewable Energy Storage Technology (CREST)

Introduction/Background

Now is the time to plan to integrate significant quantities of distributed renewable energy into the electricity grid. Concerns about climate change, the adoption of state-level renewable portfolio standards and incentives, and accelerated cost reductions are driving steep growth in U.S. renewable energy technologies. The number of distributed solar photovoltaic (PV) installations and wind farms are growing rapidly. The potential for concentrated solar power (CSP) also continues to grow. As renewable energy technologies mature, they can provide a significant share of our nation's electricity requirements. In addition, some renewable resources will be stranded, and hence without opportunity to connect to the grid via transmission or distribution lines. Nevertheless, as their market share grows, concerns about potential impacts on the stability and operation of the electricity grid may create barriers to their future expansion.

To facilitate more extensive adoption of renewable distributed electricity generation, the U.S. Department of Energy's (DOE) Solar Energy Technology Programs (SETP) launched its Renewable Systems Interconnection (RSI) studies during the spring of 2007. This effort addressed the technical and analytical challenges that might prevent high penetration levels of distributed renewable energy technologies. Because integration-related issues at the distribution system are likely to emerge first for PV technology, this initial RSI effort focuses on PV. A key goal of the RSI is to identify the research and development needed to build the foundation for a high-penetration renewable energy future, while enhancing the operation of the electricity grid. The RSI effort resulted in the completion of 14 studies and an executive summary.

Because of the variable nature of some renewable energies (namely solar and wind), an emerging theme from the initial RSI studies was the need for energy storage to improve reliability and power quality for distribution-level PV systems. Energy storage has also been a transmission-level challenge for the wind energy industry, which is attempting to offset the grid stability issues caused by wind variability. Energy storage can further enhance the potential of renewable energy by providing load shifting, peak shaving, dispatchability, and a means to bring stranded renewable energy into the grid. Current and planned CSP systems use thermal energy storage to extend the generation period beyond the peak solar incidence. Thermal energy storage is also used to aid both the heating and cooling of buildings. The current state of the art in energy storage technologies varies significantly between different technologies. The CREST studies aim to identify areas in which additional development is necessary to maximize the effectiveness of high penetration renewable energy.

This document defines a follow-on effort to the original RSI studies, with a more detailed focus on integrating renewable energy and storage technologies to meet the challenges of high penetration. The conclusions of the RSI studies will serve as a basis for the direction of the Critical Renewable Energy for Storage Technology (CREST) effort. A key difference between the two, however, is that while RSI has focused to date on high penetration of distributed PV, CREST will address issues and needs at both the transmission and distribution levels down to the end user, while considering such renewable technologies as wind and CSP, as well as address issues for stranded renewable resources.

Because CREST will address centralized renewable generation and distributed renewable generation, the CREST studies will be conducted across DOE programs in the Office of Energy Efficiency and Renewable Energy (EERE) and Office of Electricity Delivery and Energy Reliability (OE) (Figure 1). The centralized generation element will include grid integration solutions for large wind generation and CSP. The distributed generation element will focus mainly on solar PV implementation, while it also will address distributed wind, vehicle-to-grid (V2G), and other technologies that interconnect at the distribution level (<15kV). The technologies to be addressed through these studies include batteries, flywheels, capacitors, compressed air energy storage, pumped hydro, thermal energy storage, fuels and others.

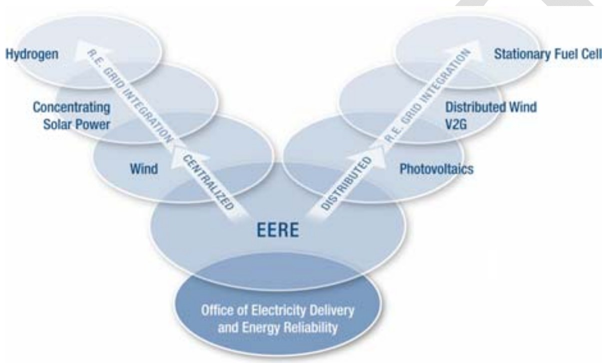

Figure 1. Renewable Energy Grid Integration (REGI) Elements to be addressed in the CREST Studies.

As the introduction to the RSI study guide states: "A critical goal of carrying out the RSI Study, described below, is to help DOE define a research agenda that will enable it to work with utilities and industry to facilitate the widespread market penetration of renewable energy technologies, including storage systems, advanced power electronics, and controls into the U.S. electricity grid." The same holds for CREST. The objective of the reports described herein is to engage the stakeholder community and identify pathways for storage technologies to facilitate the high penetration of renewable energy systems across a variety of applications in our grid infrastructure.

Key issues related to the integration of renewable energy and storage on the power grid include:

- Understanding utility planning, modeling, and analysis needs related to high levels of integrated storage with renewable energy systems, and developing solutions to address current gaps.
- Developing methods to quantify the value of added storage at the transmission, distribution and stranded levels – to utilities, to customers, and in the interests of overall national energy security.
- Identifying, developing, and utilizing key prototype testbeds and field deployments to evaluate key characteristics of new renewable energy systems with integrated storage.
- Assessing the impact of integrated storage on utility business models and rate structures, such as time-of-use, peak-shaving, and the operation of spinning reserve.

- Addressing technology development needs to facilitate the large-scale integration of storage technologies into renewable systems and our grid infrastructure, both at the level of the storage technologies themselves and at an overall systems level.
- Developing and validating remote monitoring and dispatch control platforms that will optimize renewable energy and storage system benefits. Such platforms would include software, sensors, and demand response controls, and would integrate utility control and financial information in concert with advanced grid technologies to assure high quality and stable power delivery.
- Developing a comprehensive demonstration plan to ensure successful simulation, demonstration, and validation with utilities and industry stakeholders.

This plan defines the set of studies that will be conducted to lay the groundwork for DOE to work with industry and academia in addressing these issues. As a complement to the RSI studies completed in 2007, these CREST studies will expand on earlier conclusions and provide direction for programmatic investment in the development of integrated renewable-storage systems. We anticipate that each study area will produce two reports: one focused on transmission-level systems (i.e. transmission interconnected wind and large scale CSP systems) and a study focused on distribution-level systems both on the utility and customer sides of the meter (distributed PV, distributed wind, small scale solar thermal and building applications).

Study Area Descriptions

Study Area 1: Utility and Customer Value Propositions and Analysis

Guiding Question: "What value to utilities/wholesalers/load serving entities (LSEs) and customers/retail can be derived, under today's environment and a future carbon-constrained environment, from incorporating storage technologies into renewable energy systems?"
Subordinate Questions:

- *How much flexibility and value can storage deliver to the grid to facilitate greater use of renewable energy technologies? What are the costs and the benefits of this flexibility?*
- *How cost-effective is the value proposition identified for utilities and customers? That is, what costs will utilities pay and what costs will C/I/R customers pay for the values from renewable energy storage systems to achieve large-scale market penetration?*
- *How are grid operations (unit commitment, capacity requirements, transmission and distribution losses, etc.) affected by various levels of storage and what is the effect on the operation of other generation technologies?*
- *For grid architectures with large-scale deployment of (a) centralized storage at the transmission level, and/or (b) distributed PV with storage:*
    - *What is the quantifiable value to the utility (investor owned utilities (IOUs), municipal utilities, co-ops)?*
    - *What is the value to the Independent System Operators/Regional Transmission Operators (ISO/RTO)?*
    - *What is the value to the customer (commercial, industrial, and residential)?*
- *How does the large-scale inclusion of storage affect utility business models? What business models exist to address related questions?*

- *What are the main competing technologies to energy storage? (Load control, utility operation, etc.) What are the criteria decision logics for choosing between these various technologies?*
- *What are the advantages/disadvantages of localized versus centralized energy storage, in regard specifically to renewable systems?*
- *How can a single renewable energy storage system address multiple applications to generate multiple revenue streams?*
- *How does the introduction of renewable systems with energy storage into the utility grid vary with the location and level of penetration? For example, how does it vary at the transmission vs. distribution level, in terms of power and energy production?*
- *Is hybridization/matching of different energy storage technologies or energy storage and conventional reserve to optimize cost or performance feasible or beneficial?*
- *Which coordinated optimization/conservation efforts provide the most beneficial impact on the size and required performance of energy storage systems in renewable/distributed generation, such as communications/intelligence to control loads, dispatch and/or optimize generation, or to anticipate needs or changes?*

The following reports will be developed to address these questions:

Report 1: High Penetration Transmission-Scale Renewable Energy Storage Systems: Value to Utilities and Customers

Report 2: High Penetration Distribution-Scale Renewable Energy Storage Systems: Value to Utilities and Customers

The renewable energy community is in general agreement that the addition of storage incurs added costs to a renewable system while also providing added benefits. This report(s) will examine the value proposition for energy storage systems combined with renewable generation. All levels of storage, from transmission-connected bulk energy storage to thermal storage at CSP generating stations, to distributed storage on the electrical grid to owner-managed thermal and electrical storage at the owners' site will be investigated. The value proposition will be examined for both regulated and non-regulated environments. The report will catalog the existing tools available for this analysis and identify gaps in knowledge and techniques of energy storage value determination. Preliminary findings of high value applications will be reported.

Study Area 2: Modeling and Analysis
Guiding Question: "What modeling and analysis tools are needed to adequately assess the role and value of including storage in high-penetration renewable energy systems?"
Subordinate Questions:

- *What models currently exist that can be applied to high-penetration renewable energy systems without and with energy storage?*
- *What modeling developments and improvements need to be done to analyze renewable energy storage systems, both economically and technically?*
- *What are the characteristics of the analysis tools that are needed?*

- *What modeling tools are available and what capabilities need to be developed to model the penetration of renewable systems using plug-in hybrid and vehicle-to-grid technologies for energy storage?*

The following reports will be developed to address these questions:

Report 3: High Penetration Transmission-Scale Renewable Energy Storage Systems: Modeling and Analysis Status and Needs

This report will identify current modeling/simulation techniques and needs for understanding the impacts and benefits of energy storage at the transmission level to facilitate high penetrations for renewable systems. This report will discuss simulation tools that are available for transmission system planning and operation (performance and reliability). It will discuss the simulation tool characteristics and determine model availability for the various types of energy storage used at this level. The report will cover both technical and economic modeling and analysis and discuss what potential improvements should be developed to increase usability and renewable energy penetration.

Report 4: High Penetration Distribution-Scale Renewable Energy Storage Systems: Modeling and Analysis Status and Needs

This report will identify current modeling/ simulation techniques and needs for understanding the impacts and benefits of energy storage at the distribution level and below to allow for high penetrations for renewable systems. This report will discuss simulation tools that are available for distribution system planning and operation (performance and reliability) as well as customer operations. It will discuss the simulation tool characteristics and determine model availability for the various types of energy storage used at this level. The report will cover both technical and economic modeling and analysis and discuss what potential improvements should be developed to increase usability and renewable energy penetration.

Study Area 3: Storage Technologies and Systems Integration
Guiding Question: "What technology developments are needed for cost-effective mass deployment of storage in renewable energy systems?"
Subordinate Questions:

- *What are the requirements for utility, commercial, industrial, and residential scale applications in terms of energy, power, size, cost, efficiency, lifetime, cycle life, charge and discharge rates, maintenance, reliability, etc.?*
- *Where do current energy storage systems fall short of these requirements?*
- *What type of energy storage technologies need to be developed for renewable applications?*
- *What are the shortcomings of current energy storage technologies in meeting the requirements of renewable energy technology and distributed generation applications?*
- *How can the renewable energy industry leverage current energy storage R&D in other application areas?*
- *What promising advanced or innovative energy storage technologies are on the horizon – near-term and long-term?*

- *What technologies and research need to be developed to support the integration of energy storage with renewable technologies?*
- *How do we make effective use of stranded renewable assets through conversion to more effective storage media like fuels?*

The following reports will be developed to address these questions:

Report 5: High Penetration Renewable Energy Storage Systems: Storage Technologies -

This report will examine the current state of the art as well as R&D directions for energy storage systems combined with renewable energy generation. Application requirements will be summarized and compared with existing technologies to identify gaps and potential areas for new research. Although technical requirements will dominate the report, cost, maintenance and siting issues will also be addressed. Research ongoing in other application areas will be examined for potential use in renewable applications.

Report 6: High Penetration Renewable Energy Storage Systems: Systems Integration –

This report will examine issues in integrating renewable energy storage systems into the existing grid and infrastructure. Thermal, electrical, and mechanical storage systems will be addressed. Preliminary integration specifications will be generated which will serve as starting places for future interconnection standards-forming committees.

Study Area 4: Test & Demonstration Programs
Guiding Question: "What test and demonstration activities are required to evaluate energy storage for renewable applications?"

- *What testing of storage systems needs to be done for renewable applications?*
- *What are the data requirements for the performance of various energy storage technologies?*
- *What laboratory and field capabilities currently exist to address the testing of new renewable energy and storage integrations? What are the gaps, and what capabilities must be developed?*
- *What type of test protocols need to be developed for specific renewable applications?*
- *What types of field demonstrations of energy storage for renewable technologies are needed?*
- *What is the scalability for laboratory testing and for field testing of renewable energy systems with energy storage?*

The following reports will be developed to address these questions:

Report 7: High Penetration Transmission-Scale Renewable Energy Storage Systems: Test & Demonstration Programs

This report will develop test and demonstration activities for large-scale energy storage to increase the amount of renewables (wind, CSP, large-scale PV) integrated into the transmission system. This study will provide information needed to support program planning for testing (lab and field) and demonstration of transmission-scale renewables integrated with energy storage and controls working synergistically with utility systems. A review of fielded testing conducted to date, along with a detailed description of the elements that should be included in a successful field test and demonstration program will be defined. The report will also define what data parameters need to be collected on field tests and demonstration systems to provide input to the modeling and analysis work in this area.

Report 8: High Penetration Distribution-Scale Renewable Energy Storage Systems: Test & Demonstration Programs

This report will develop test and demonstration activities for small to medium scale energy storage to increase the amount of renewables integrated into the distribution system on both sides of the meter. This study will provide information needed to support program planning for testing (lab and field) and demonstration of small to medium scale renewables integrated with energy storage and controls working synergistically with utility and building systems. A review of fielded testing conducted to date, along with a detailed description of the elements that should be included in a successful field test and demonstration program will be defined. The report will also define what data parameters need to be collected on field tests and demonstration systems to provide input to the modeling and analysis work in this area.

Study Area 5: Regulatory Enablers
Guiding Question: "What regulatory framework is needed to enable mass deployment of renewable energy storage systems?"
Subordinate Questions:

- *How are current regulatory rules and rate structures helping or hurting implementation of renewable energy storage systems? How do regulatory rules need to be revised to enable renewable energy storage systems?*
- *What standards and codes are in place for storage in renewable/distributed generation?*
- *What standards and codes must be developed or modified to enable storage in renewable/distributed generation?*
- *What, if any international differences/issues exist that would impact standards/markets/deployment of energy storage with renewable/distributed generation?*
- *What safety hazards must be addressed?*
- *What environment impacts must be addressed?*

The following reports will be developed to address these questions:

Report 9: High Penetration Transmission & Distribution-Scale Renewable Energy Storage Systems: Regulatory Enablers

This report will examine the current regulatory treatment of renewable energy storage systems in the Federal and in major state regulatory agencies. Policies which favor energy storage and policies which are barriers to energy storage will be identified. Areas of confusion and conflict regarding energy storage will be identified. This report will also examine rate structures in major areas to determine their affect on the introduction of renewable energy storage systems. Discrepancies between the treatment of renewable energy generation systems and energy storage systems will be documented. This report will document existing tax treatments of renewable energy and energy storage systems at the Federal and major state levels. The report will identify changes in policy, tax and regulatory arenas that would result in equal treatment of renewable and energy storage systems.