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Attorneys for Rocky Mountain Power

BEFORE THE PUBLIC SERVICE COMMISSION OF UTAH

IN THE MATTER OF THE APPLICATION OF ROCKY MOUNTAIN POWER TO IMPLEMENT PROGRAMS AUTHORIZED BY THE SUSTAINABLE TRANSPORTATION AND ENERGY ACT	))))))	Docket No. 16-035-36

APPLICATION TO IMPLEMENT PROGRAMS AUTHORIZED BY THE SUSTAINABLE TRANSPORTATION AND ENERGY PLAN ACT

Rocky Mountain Power, a division of PacifiCorp ("Company" or "Rocky Mountain Power"), hereby submits this application ("Application") to the Public Service Commission of Utah ("Commission") pursuant to Utah Code Annotated ("U.C.A.") § 54-20-101, *et seq.*, also known as Senate Bill 115 - the Sustainable Transportation and Energy Plan Act ("STEP"), signed into law March 29, 2016, requesting authorization to implement programs authorized by STEP. The Company respectfully requests that the Commission keep this Docket open for the duration of the 5-year STEP pilot program to allow for additional related filings to be made in a single consolidated Docket.

Enclosed for filing are an original and ten (10) copies of proposed tariff sheets associated with the following schedules in Tariff P.S.C.U. No. 50 of PacifiCorp, d.b.a. Rocky Mountain Power, applicable to electric service in the State of Utah:

- Index of Electric Service Regulations (revised)
- Schedule 195, Sustainable Transportation and Energy Plan (STEP Cost Adjustment) (revised from current Schedule 195 Solar Incentive Program Cost Adjustment)
- Schedule 193, Demand Side Management (DSM) Cost Adjustment (revised)
- Regulation No. 13, Sustainable Transportation and Energy Program (STEP) Commercial Line Extension Pilot Program (new)
- Schedule 107, Utah Solar Incentive Program (revised)

The proposed tariff sheets are included as Attachment 1 to this Application. Pursuant to the requirement of Rule R746-405-2(D), the Company states that the proposed tariff sheets do not constitute a violation of state law or Commission rule. The Company respectfully requests an effective date of January 1, 2017, for these tariff changes.

The Company is seeking authorization from the Commission specifically in this Application for tariff revisions to implement the following pursuant to STEP:

(1) beginning January 1, 2017, revised Schedule 195 rates, which will collect $10 million per year, and will be combined on customer bills with Schedule 193 rates that recover the cost of demand side management ("DSM"), including the cost of amortizing a deferred DSM balance, in a combined line item charge pursuant to U.C.A. § 54-7-12.8(3);

(2) establish and fund a regulatory liability pursuant to U.C.A. § 54-7-12.8(5)(a)(ii), via a component of the line item charge described above, and use the regulatory liability to depreciate thermal generation plant pursuant to U.C.A. § 54-7-12.8(5)(a)(iii);

(3) implement an Electric Vehicle ("EV") Incentive Pilot Program pursuant to U.C.A. § 54-20-103 and approval of a new tariff Schedule 120, which will be submitted following discussions with interested parties in a working group;

(4) establish a Clean Coal Technology Program pursuant to U.C.A § 54-20-104;

(5) implement two Innovative Utility Program projects pursuant to U.C.A. § 54-20-105(1)(c) and (h) for: (1) an advanced substation metering project, and (2) a solar and energy storage technology project;

(6) establish a program to curtail emissions from a thermal generation plant in the Salt Lake non-attainment area during a non-attainment event as defined by the Division of Air Quality, pursuant to U.C.A. § 54-20-105(1)(e);

(7) implement a new commercial line extension pilot program pursuant to U.C.A. § 54-20-105(1)(d) through a new tariff Electric Service Regulation No. 13; and

(8) modify the Utah Solar Incentive Program ("USIP") through revisions to tariff Schedule No. 107 as of December 31, 2016, pursuant to U.C.A. § 54-7-12.8(4), to stop accepting new applications for incentives, with forecast unrecovered USIP costs included in the proposed rates in Schedule 195.

The Company commits to filing a report with the Commission, no later than October 31, 2020, to provide input to the Commission for its report and recommendations for the Sustainable Transportation and Energy Plan. In accordance with U.C.A. § 54-20-106, the Commission is required to file a report on STEP with the Utah Legislature before the first day of the legislative session in the final year of the pilot program.

In support of these programs, the Company is proposing the following budget in Table 1 for implementation of the STEP programs:

Table 1 STEP Funding Budget

	2017	2018	2019	2020	2021	Total	Annual Average
EV Charging Infrastructure	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$10,000,000	$2,000,000
Clean Coal Technologies							
Woody Waste Co-Fire	$612,841	$177,032				$789,873	
Emerging CO2 Capture	$381,557	$668,301	$125,000			$1,174,857	
Sequestration Site Characterization - Phase 1	$150,000					$150,000	
CO2 Enhanced Coal Bed Methane Recovery		$62,500	$75,000	$62,500	$75,000	$275,000	
Solar Thermal Assessment			$65,083	$83,083	$38,833	$187,000	
NOX Neural Net Implementation	$547,806	$178,924	$216,719	$32,000	$32,000	$1,007,449	
Advanced NOX Control	$100,000	$320,411	$775,000	$220,411		$1,415,821	
Subtotal Clean Coal Technologies	$1,792,204	$1,407,167	$1,256,802	$397,994	$145,833	$5,000,000	$1,000,000
Innovative Utility Programs							
Battery Storage - Solar	$500,000	$2,350,000		$2,200,000		$5,050,000	
Substation Metering	$500,000	$350,000	$250,000			$1,100,000	
Gadsby Emissions Curtailment	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000	
Line Extension	$1,000,000	$1,000,000	$500,000			$2,500,000	
Other Innovative Technology [(a)]			$2,000,000	$3,500,000	$2,350,000	$7,850,000	
Subtotal Innovative Utility Programs	$2,100,000	$3,800,000	$2,850,000	$5,800,000	$2,450,000	$17,000,000	$3,400,000
USIP	$2,584,112	$2,584,112	$2,584,112	$2,584,112	$2,584,112	$12,920,558	$2,584,112
Conservation, Efficiency and Other New Technology Programs [(a)]	$1,015,888	$1,015,888	$1,015,888	$1,015,888	$1,015,888	$5,079,442	$1,015,888
Five Years Projected STEP Fund Use	$9,492,204	$10,807,167	$9,706,802	$11,797,994	$8,195,833	$50,000,000	$10,000,000

(a) The Company will file for Commission approval as part of this open docket for future innovative technology projects and other new technology programs once identified.

In support of its Application, Rocky Mountain Power states as follows:

1. Rocky Mountain Power is a division of PacifiCorp, an Oregon corporation, which provides electric service to retail customers through its Rocky Mountain Power division in the states of Utah, Wyoming, and Idaho, and through its Pacific Power division in the states of Oregon, California, and Washington.

2. Rocky Mountain Power is a public utility in the state of Utah and is subject to the Commission's jurisdiction with respect to its prices and terms of electric service to retail customers in Utah. Rocky Mountain Power's principal place of business in Utah is 1407 West North Temple, Suite 310, Salt Lake City, Utah, 84116.

3. Communications regarding this filing should be addressed to:

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1407 West North Temple, Suite 330
Salt Lake City, Utah 84116
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In addition, Rocky Mountain Power requests that all data requests regarding this application be sent in Microsoft Word or plain text format to the following:

By email (preferred): datarequest@pacificorp.com

By regular mail: Data Request Response Center
PacifiCorp
825 NE Multnomah, Suite 2000
Portland, Oregon 97232

Informal questions may be directed to Bob Lively, Utah Regulatory Affairs Manager at (801) 220-4052.

Line Item Charge Authorized by U.C.A. § 54-7-12.8(3)

4. STEP allows the Commission to authorize a large-scale electric utility to implement tariffs to provide funding for a sustainable transportation and energy plan pilot program, and then implement a variety of specified programs using the funding.

5. Rocky Mountain Power hereby submits with this application an original and ten (10) copies of proposed revisions to tariff Schedule 195 and Schedule 193, included with this Application as Attachment 1. Currently, Schedule 195 recovers costs associated with the Utah Solar Incentive Program ("USIP") and Schedule 193 recovers costs associated with DSM. With this Application, the Company proposes revisions to Schedule 195 to collect the $10 million in STEP funding authorized pursuant to U.C.A. § 54-7-12.8. Pursuant to U.C.A. § 54-7-12.8(6)(c), the STEP Cost Adjustment on Schedule 195 includes the estimated unrecovered costs for USIP, which are approximately $2.6 million per year of the annual $10 million STEP funding. The Company proposes to allocate the STEP funding (and unrecovered USIP costs included therein) on an equal percentage basis, resulting in a net impact of 0.2 percent to each electric service rate schedule. The proposed rates for contract customers on Schedule 195 reflect only recovery of the unrecovered USIP costs, as required by U.C.A. § 54-7-12.8(8). Allocation of the unrecovered USIP costs to the contract customers is consistent with prior approved allocation for USIP to these customers. The Company proposes to implement the Commission approved line item charge authorized pursuant to U.C.A. §

54-7-12.8(3), by combining the rates from Schedule 195 and Schedule 193 on customer bills, beginning January 1, 2017.

6. In accordance with U.C.A. § 54-7-12.8(2)(b), the Company requests authorization, beginning January 1, 2017, to capitalize the annual costs incurred for DSM, and amortize annual DSM expenditures over a ten year period and apply a carrying charge to the unamortized balance that is equal to the Company's pretax weighted average cost of capital approved in the Company's most recent general rate proceeding. Unamortized DSM costs will be carried in a regulatory asset balancing account. The Company further requests authorization, in accordance with U.C.A. § 54-7-12.8(5)(a), for authorization to allocate the difference between DSM tariff collections and the DSM amortization expense to a regulatory liability fund that will be used for thermal plant depreciation subject to Commission authorization pursuant to U.C.A. § 54-7-12.8(5)(b)(i).

7. The regulatory asset and regulatory liability described in paragraph 6 above will be subject to the same carrying charge, equal to the utility's pretax weighted average cost of capital approved by the Commission in the Company's most recent general rate proceeding, as required by U.C.A. § 54-7-12.8(5)(c).

8. Pursuant to U.C.A. § 54-7-12.8(6) and (7), beginning January 1, 2017, as described more fully below, the Company will establish a balancing account(s) to track the $10 million annual collection through the line item charge for STEP pilot programs in the following manner: (1) $2 million for the electric vehicle incentive program; (2) $1 million for clean coal technology research; (3) $3.4 million for innovative utility programs including commercial line extensions, solar generation, battery storage, coal

generation plant emissions curtailment, or other programs that may be proposed later; and (4) $2.6 million to be applied first to unrecovered costs from the Utah Solar Incentive Program, which will be discontinued for new participants; then applied to other conservation, efficiency or other new technology programs that may be authorized by the Commission pursuant to U.C.A. § 54-7-12.8(6)(d).

9. As more fully described in the Future Step Initiatives section below, the Company expects to request additional authorization in the future for expenditures of STEP funding pursuant to U.C.A. § 54-20-105 under this Docket, based on the recommendations received through collaboration with stakeholders, or as additional information becomes available to the Company.

10. During the pilot program period, the balancing account(s) will contain the $10 million annual collections; program expenditures and administrative costs; unrecovered Utah Solar Incentive Program costs; and a carrying charge in an amount determined by the Commission. The Company proposes the carrying charge amount as determined in Docket No. 15-035-69.

11. The Company respectfully requests approval of the line item charge, the revisions to Schedules 193 and 195, the accounting treatments, and the carrying charges as described in this section.

Utah Solar Incentive Program

12. Pursuant to U.C.A. § 54-7-12.8(4), the Application includes proposed changes to Schedule 107, Solar Incentive Program, to terminate the Utah Solar Incentive Program ("USIP") for new participants as of December 31, 2016. The proposed tariff revisions limit participation in USIP to customers that have accepted an incentive as of

December 31, 2016. While closed to new participants, the Company proposes to allow the tariff to remain in effect until incentives to all existing participants have been disbursed. The Company respectfully requests approval of the revised tariff Schedule 107 and authorization to terminate USIP for new participants, as described above.

Electric Vehicle Incentive Program

13. Pursuant to U.C.A. § 54-20-103, the Company is requesting authorization of funding for an electric vehicle incentive program, the Plug-in Electric Vehicle ("PEV") Pilot Program, which will be implemented through a new tariff Schedule No. 120. The proposed PEV Pilot Program ("PEV Program") is designed to promote customer choice in plug-in electric vehicle charging equipment infrastructure. The Company requests that the Commission authorize the PEV Program to use up to $2 million per year as provided for in U.C.A. § 54-7-12.8(6)(b)(i) during the pilot program period. Through a future filing the Company will propose an effective date for the new tariff to begin implementing the incentives. For January 1, 2017, the Company is seeking authorization for the funding, based on the budget outlined below, in order to begin the administrative work and development of a marketing plan prior to the effective date of the incentives. For reference, the proposed tariff sheets are included as Exhibit A to this Application.

14. The proposed PEV Program components are listed below, with further explanation provided in subsequent sections.

- A portion of the PEV Program budget will be allocated annually to administration, outreach and awareness for PEVs, and potential grant opportunities to leverage available funds for increased PEV infrastructure and outreach.

- The Company intends to issue a Request for Proposals ("RFP") to select a vendor to administer the PEV Program.
- The Company proposes to provide prescriptive incentives for Residential and Non-Residential AC Level 2 Chargers and DC Fast Chargers, as well as custom incentives for projects/partnerships that may be submitted to the Company for consideration. The prescriptive incentives are intended to provide an easy path for customers by allowing them to purchase a charger and receive an incentive. The custom incentives are intended for complex projects that require funding assistance and provide PEV infrastructure benefits.
- The PEV Program budget will consist of up to $2 million per year for five years.

15. The Company intends to market the PEV Program and provide education on the system impacts and benefits to customers. This includes development of a website containing detailed information about the PEV Program and tools for customers to better understand impacts on the grid and appropriate charging behavior. The Company may consider an outreach partner to perform strategic PEV outreach and awareness, which may include social media components such as a mobile application to assist customers with their charging decisions.

16. The Company intends to issue an RFP to select a vendor to administer the PEV Program. No funds will be spent until the program has been authorized by the Commission. The PEV Program administrator may be responsible for items such as:

- Customer engagement;
- Continual improvements of PEV Program operations and customer satisfaction;
- Incentive processing and call-center operations;
- PEV Program specific customer communication and outreach;
- Reviewing custom applications and providing recommendations; and
- Outreach and communications

17. Through this PEV Program, the Company proposes to incentivize residential and non-residential AC Level 2 Chargers, DC Fast Chargers, and custom projects:

- *Residential AC Level 2 Charger Prescriptive Incentive* - This measure will promote Level 2 Charger infrastructure among residential customers and the purchase of PEVs. The Company proposes to have a maximum "up to" incentive amount of $200 per charger for this offering for flexibility, but have an initial offering of $100 when the program becomes effective as this amount is expected to drive participation. Incentives will be capped at 50 percent of the total charger cost. Subject to further discussions with interested parties, as discussed below, the PEV Program may require residential customers to sign up for a time of use pricing pilot, if available, in order to be eligible for this incentive. Other special conditions regarding this incentive include, but are not limited to, the following:

i. To be eligible for an incentive, Customers must submit a Program Administrator approved post-purchase application and meet all PEV Program requirements.
ii. Incentives will be available on a first come first serve basis with an annual cap.
iii. The Company and its agents reserve the right to inspect installation.

- *Non-Residential AC Level 2 Charger Prescriptive Incentive* - This measure will promote new AC Level 2 Charger infrastructure among businesses and multi-family dwellings. The Company proposes to have a maximum "up to" incentive amount of $3,000 per charger for this measure for flexibility, but have an initial offering of $1,500 per charger when the PEV Program becomes effective as this amount is expected to drive participation. Incentives will be capped at 75 percent of the total charger cost. Subject to further discussions with interested parties, as discussed below, the PEV program may require non-residential customers to sign up for a time of use pricing pilot, if available, in order to be eligible for this incentive. Other special conditions regarding this incentive may include, but are not limited to, the following:

i. Customers must submit a PEV Program Administrator approved post-purchase application and meet all PEV Program requirements.
ii. Incentives will be available on a first come first serve basis with an annual cap.

iii. The Company and its agents reserve the right to inspect installations.

- *DC Fast Charger Prescriptive Incentive* - This measure will promote new DC Fast Charger infrastructure across Utah. The Company is proposing to require DC Fast Chargers to be made available for public use and to require that charger data be made available to the Company to be eligible for this incentive. The Company proposes to have a maximum “up to” incentive amount of $30,000 per charger for this measure for flexibility, but have an initial offering of $20,000 per charger when the PEV Program becomes effective as this amount is expected to drive participation. Incentives will be capped at 75 percent of the total charger and installation costs. Special conditions regarding this incentive include, but are not limited to, the following:

    i. To be eligible for an incentive, Customers must submit a PEV Program Administrator approved application(s), provide all required documentation, and receive pre-approval.

    ii. Equipment purchased or installed prior to receipt of the Company’s pre-approval may not be eligible for incentives.

    iii. Pre-approval criteria may include, but is not limited to:

        a. Location variables such as proximity to other DC Fast Chargers;
        b. Overall benefits to the public;
        c. Costs of project and incentive amount;
        d. Technology being used;
        e. Consent to provide charger usage data;
        f. Availability to the public; and

g. Selection committee

iv. Incentives will be available on a first come first serve basis with an annual cap.

v. The Company and its agents reserve the right to inspect installations.

- *Grant-Based Custom Projects and Partnerships* - This measure will allow customers to submit applications for a specific project or partnership that will support PEV infrastructure. Special conditions regarding this incentive include, but are not limited to, the following:

i. To be eligible for a custom incentive, Customers must submit a PEV Program Administrator approved application(s), provide all required documentation, and go through a selection process.

ii. The selection process may include, but is not limited to:

a. Location variables such as proximity to other charging infrastructure;
b. Overall benefits to the public;
c. Costs of project and incentive amount;
d. Technology being used;
e. Consent to provide charger usage data;
f. Availability to the public;
g. Selection committee;
h. Matching funds;
i. Innovative partnerships and projects that support plug-in electric vehicle infrastructure and education; and
j. Development of DC fast charging corridors

iii. Custom projects may be selected on a quarterly basis and will be limited to available funding.

iv. The Company and its agents reserve the right to inspect installations.

v. Participants with new construction may submit an application for pre-approval, but will be held to all applicable timelines.

18. To manage the annual budget of $2 million, the Company proposes to make residential/non-residential AC Level 2 Charger and DC Fast Charger incentives available up to the cap listed in Table 2 below through September 30th of each year and then re-allocate any remaining funds from those measures to Grant-Based Custom Projects and Partnerships. Customers may still submit applications for AC Level 2 and DC Fast Chargers after September 30th. However, applications at that point will be considered as part of the subsequent PEV Program year.

19. The Company's estimated budget for the first year of the PEV Program is outlined in Table 2 below:

Table 2 - Annual Incentive Caps and Estimated 2017 Budget

PEV Program Year	Incentive Measure	Annual Incentive Caps	Administrative/Outreach & Awareness Costs	Total
2017	Residential AC Level 2 Chargers	$100,000*	Up to $500,000	---
	Non-Residential AC Level 2 Chargers	$400,000*		
	DC Fast Chargers	$400,000*		
	Grant-based custom projects and partnerships	$600,000**		
Total	---	$1,500,000	$500,000	$2,000,000

*This is the maximum amount of funds that may be spent on these measures annually.
**After September 30th each year, any remaining funds below the caps from Residential/Non-Residential AC Level 2 and DC Fast Charger incentives may be re-allocated to Grant-based custom projects and partnerships, increasing its incentive cap for the calendar year.

20. Given that this is a pilot program, incentive allocations from Table 2 above are subject to change. As the PEV Program progresses, it will become more apparent where the most opportunity is to benefit customers and the public interest with PEV

infrastructure. The Company will adjust funding for incentives and outreach as the PEV Program progresses and will file for Commission approval to remove, or add measures as necessary.

21. In accordance with U.C.A. § 54-20-103(3)(a), (b), and (c), the Company met with the Division of Public Utilities, Office of Consumer Services, Division of Air Quality, and several other interested parties on May 10, 2016, to discuss concepts for consideration in developing the PEV Program. On July 26, 2016, the Company circulated a draft Program Tariff and Advice Letter to the aforementioned parties for review and feedback. Feedback was received from several parties on or about August 12, 2016. All feedback and recommendations received were taken under consideration for this filing.

22. U.C.A. § 54-20-103(1)(b) provides that the electric vehicle incentive program include time of use pricing for electric vehicle charging. Time of use rates encourage off-peak hour charging and more efficient utilization of the energy system. The Company has been evaluating time of use rate designs for residential customers that charge PEVs at home and for non-residential public PEV charging.

23. As discussed below, the Company proposes to host a series of working group discussions with interested parties to advise on the development of time of use pricing pilots that may be implemented in conjunction with the PEV Program incentives. The Company anticipates making a filing by the end of 2016. Based on these discussions, the Company will file the proposed Schedule 120 to implement the PEV Program incentives, with supporting testimony if necessary, with an effective date on or before July 1, 2017.

24. In accordance with U.C.A. 54-20-103(3)(d), the Company filed a Notice of Intent to File STEP Act Initiatives and requested the Commission issue a public notice to allow any additional persons not previously involved to file a request for notice with the Commission of their desire to provide input on the Company's proposed PEV Program. The Commission issued a public notice August 19, 2016. To date, one party has filed notice with the Commission of their desire to provide input on the Company's proposed PEV Program prior to this filing.

25. The Company respectfully requests authorization for funding of the PEV Program, as described in this section.

Clean Coal Technology Program

26. In accordance with U.C.A. § 54-20-104, the Company is requesting authorization of a program to investigate, analyze, and implement clean coal technology. Pursuant to U.C.A. § 54-7-12.8(6)(b)(ii)(A), the budget for this program is an annual average of $1 million per year over the five year STEP pilot period. A more detailed program description is attached as Exhibit B. The program is supported by the Direct Testimony of K. Ian Andrews.

27. For implementation of this program, the Company has assembled a clean coal research team, which includes personnel from the Company's coal-fired generation units and generation technical services, and University of Utah, Brigham Young University, and Utah State University professors from the chemical engineering and mechanical engineering departments, the Utah Office of Energy Development, the University of Utah Geosciences Institute, the Utah Science and Technology Research Initiative, Reaction Engineering, and Sustainable Energy Solutions.

28. The clean coal research team has held multiple workshops and webinars on low nitrogen oxide ("NO_X") emissions control technologies. The team has identified key areas of research in the areas of carbon dioxide ("CO_2") capture and sequestration and NO_X emissions control. The team has also identified entities that may assist in implementing the initiatives.

29. The clean coal research team has identified key areas of research that will be given priority, as well as additional areas of research that may lead to future projects. The Company has evaluated several proposals submitted by the clean coal research team. In evaluation of the proposals, the Company focused on technologies that benefit customers, advance technology or commercial implementation of technology, and/or reduce emissions, with preference given to the following: (1) technology demonstrations; (2) initiatives that will advance existing technology; (3) projects located in Utah; and (4) projects that can leverage additional available funding from the United States Department of Energy or state and local governments.

30. The Company is proposing to implement five CO_2 capture and sequestration projects and studies, each of which is described in more detail below:

(1) a Utah woody waste co-firing test;

(2) a cryogenic capture demonstration project;

(3) a solar thermal augmentation study;

(4) a study evaluating regional/commercial use of CO_2 for enhanced coal bed methane recovery; and

(5) co-funding the University of Utah's pre-feasibility assessment of a commercial scale CO_2 capture site.

31. The Utah woody waste co-firing test project will apply two Utah-based technologies that process woody waste. Each co-firing test will consist of a single 18 hour co-firing test at the Hunter 3 coal fired generation facility using both processes. The objective of the test is that no adverse plugging or fouling of the boiler occurs. The benefit will be to determine the feasibility of potential periodic removal of Utah's woody waste. A coal milling study associated with this project is currently being performed. The University of Utah submitted the project proposal, led by Dr. Eric Eddings.

32. The cryogenic capture demonstration project is a long term (six to nine months) availability test of cryogenic capture at either the Hunter or Huntington plant. This long term availability test of the technology is viewed as a next step to facilitate United States Department of Energy funding to design, construct, install, and test a pilot scale (five to ten megawatt) facility. Sustainable Energy Solutions submitted the project proposal.

33. The solar thermal augmentation study will evaluate the feasibility, cost, environmental benefit, and land requirements of solar thermal augmentation to produce steam at the Hunter facility. Brigham Young University submitted the project proposal, led by Dr. Brian Iverson.

34. The regional/commercial use of CO_2 for enhanced coal bed methane recovery study will evaluate the potential for captured CO_2 from Emery County coal-fired generation plants for use in enhanced coal bed methane recovery. The University of Utah Earth Geosciences Institute submitted the project proposal, led by Dr. John McLennan.

35. The pre-feasibility assessment of a commercial scale CO_2 capture site project will provide co-funding toward the University of Utah's proposed pre-feasibility study to evaluate the potential for a commercial scale geological CO_2 sequestration facility in a geologic formation adjacent to the Hunter plant that lies under the San Rafael swell. The project, if awarded, will leverage up to $1.2 million in funding from the United States Department of Energy. The University of Utah tendered a proposal to the United States Department of Energy on August 30, 2016, submission due date. Dr. Andrew Sweeney and Dr. Brian J. McPherson are the leads.

36. The Company is proposing to implement two NO_X emission control projects: (1) a neural net controls demonstration project; and (2) a utility scale demonstration project to evaluate advanced technologies to reduce NO_X emissions.

37. The neural net controls demonstration project will develop and install neural network software at Huntington Unit 2. The benefit will be targeted NO_X emissions and potentially heat rate reductions. The implementation schedule will be aligned with infrastructure upgrades, including coal pipe flow, oxygen, carbon monoxide, NO_X and furnace exit gas temperature monitors. University of Utah submitted a draft proposal, led by Dr. Kody Powell.

38. The Company is in the process of preparing a request for proposal that will be issued in 2017 to potential technology providers to achieve economic reductions in NO_X emissions. Technologies may include advanced combustion controls, selective non-catalytic reductions, low cost catalysis and novel chemical conversion processes. There are several potential technology providers that will be invited to participate in the request for proposal.

39. The proposed budget for each identified project for clean coal technologies is shown in Table 1 above.

40. The Company respectfully requests authorization of the program to investigate, analyze, and implement clean coal technology, as described in this section.

Advanced Substation Metering, Innovative Utility Program

41. Under U.C.A. § 54-20-105(1)(c), which allows the Commission to authorize the Company to implement a battery storage or electric grid related project, and U.C. A. § 54-20-105(1)(h), which allows the Commission to authorize the Company to implement other innovative technology programs that the Commission determines are in the interest of the large-scale electric utility's customers, the Company proposes to implement an Advanced Substation Metering project. The Advanced Substation Metering project will enable the Company to purchase and install advanced substation meters at approximately 50 circuits connected to distribution substations in order to enable greater data visibility of the distribution system and integration of distributed generation resources. The Company is proposing a budget of $1.1 million over the five-year STEP pilot for this project.

42. As more fully described in the Advanced Substation Metering Program document, which is provided as Exhibit C to this Application, and supported by the direct testimony of Douglas L. Marx, the substation monitoring and measurement of various electrical quantities will provide information necessary for the development of a more progressive electric grid, in particular for the integration of distributed generation resources.

43. Data collection and analysis at substations will be of paramount importance as the Company continues to integrate the rapid growth of distributed energy resources into its system. The advanced substation metering program will:

- Provide visibility on power flow, loading levels, load shape, and event information needed to develop thorough interconnection studies, help determine safe switching procedures and cost effective capital improvement plans.
- Provide a greater understanding of innovative solutions that will allow the Company to make the grid more progressive.
- Allow the Company to study how single phase distributed energy resources can exacerbate load imbalance on a distribution circuit, causing three phase voltage imbalance issues and increasing the potential for unintended circuit breaker operations from elevated neutral currents.
- Allow the Company to determine if there are detrimental impacts on transient and steady state voltage levels due to growing interaction between distributed energy resources and distribution system equipment.
- Provide a greater understanding of how the production levels on a circuit can accurately determine the need for effective grounding and fault clearing control schemes, which if not installed appropriately can cause temporary over-voltages to customers or circuits improperly protected during fault conditions.

- Allow the Company to determine how potential harmonic issues from inverter-based distributed energy resources can cause customer motor damage and interfere with high frequency communications.
- Review the need for measurement of per-phase vector quantities to improve optimization opportunities for capital costs and system losses.

44. The Company anticipates that the benefits that will accrue to the Company and its customers include:

- Enablement of increasing levels of distributed energy resources on the power grid in an affordable and reliable way by providing increased visibility on loading levels, load shape and event information needed to develop thorough interconnection studies and hosting capacities for customers; determining safe switching procedures; and, cost effective capital improvement plans.
- Assistance in preventing load imbalance on a distribution circuit caused by single phase distributed energy resources, which can result in three phase voltage imbalance issues and increasing potential for unintended circuit breaker operations from elevated neutral currents.
- Insight into harmonic issues caused by distributed energy resources, thereby enabling the Company to take appropriate steps to resolve issues, if any, in a proactive way.
- Improved optimization opportunities for capital costs and system losses by providing measurements of per-phase vector quantities for voltage and current.

- Identification of service quality issues early, thereby allowing timely development and implementation of cost effective mitigation.
- Enhanced understanding of intermittent generation resources and their impact on the power grid.
- Reduction in time delays of approvals for customers seeking distributed generation interconnections.
- Ability to provide customers with circuit information with a higher level of accuracy.
- Identification and control of risks associated with the integration of significant penetration of distributed energy resources. This includes controlling claims from power quality issues, customer equipment failure, utility/customer equipment damage or impact on customer generation levels.

45. The Company proposes to begin implementing the program on January 1, 2017. The installations of the advanced substation metering equipment will be scheduled according to prioritized need starting with areas with high penetrations of distributed energy resources. The Company anticipates the final in-service date to be December 2019.

46. The Company respectfully requests authorization to implement the advanced substation metering program as described in this section.

Solar and Energy Storage Technology, Innovative Utility Program

47. Pursuant to U.C.A. § 54-20-105(1)(c), the Company requests that the Commission authorize the Company to use $5.05 million of the STEP funding to install a stationary battery system, to be connected to one or both of the 12.5 kilovolt distribution

circuits connected to a Company-owned substation in central Utah. In addition, the Company proposes to utilize an additional $1.95 million from Blue Sky community funds to install a large-scale, company-owned solar project in conjunction with the battery installation. The storage and solar technology is expected to defer or eliminate the need for traditional capital investments, and will reduce the loading on the power transformer, improve voltage conditions and mitigate costs associated with connection on the 69 kilovolt bus at the substation. The proposed program is described in more detail in the Solar and Energy Storage Technology Program document, which is attached to this Application as Confidential Exhibit D, and which is supported by the testimony of Douglas L. Marx.

48. During summer peak loading periods, the Company experiences voltage drops on some transmission lines. The Company consistently implements reliability and power quality enhancements on its transmission and distribution system and adheres to the standards established by ANSI for both normal and emergency operation. The operating voltage thresholds are designed to protect Company and customer-owned equipment from inadvertent mis-operation or damage due to voltage excursions.

49. To correct the voltage issues experienced during peak loading conditions on a 69 kilovolt transmission line in central Utah, the Company proposes to connect a stationary battery system and a Company-owned solar facility to one or both of the 12.5 kilovolt distribution circuits connected to a central Utah substation. This will reduce the loading on the power transformer, improve voltage conditions and mitigate costs associated with connection on the 69 kilovolt bus at the substation, while also giving the Company experience with this new type of technology solution. The system will be sized

to handle the initial voltage corrections, and be expandable to provide additional correction as load growth in the area creates further voltage excursions. The total battery storage system will be approximately five (5) megawatt-hours, the solar system size will be approximately 650 kilowatts, and the site for the facility will occupy five to seven acres depending upon which technologies are chosen.

50. The program will provide a number of benefits to the Company and its customers in the area of the solar energy and battery storage project, including: (1) reducing load on the transformer at the substation, ensuring the voltage on the transmission line does not drop below ANSI standards; (2) providing high-speed reactive power support to ensure load rejection in the area does not impact voltage levels; (3) deferring the need for traditional capital investment; (4) enabling the Company to get first-hand operational experience with control algorithms and efficiency levels associated with energy storage combined with solar; (5) enabling the Company to become familiar with and utilize innovative technologies to provide customers with solutions to power quality issues; and (6) providing an opportunity for the Company to meet requests from its Blue Sky customers for physical "steel in the ground" renewable facilities.

51. The proposed project meets the goal of providing benefits for the Company and its customers. The project will allow the Company to expand renewable energy and innovative technology options to improve service to customers, and to prepare for enhanced deployment of clean energy sources. In addition, the project will provide savings by deferring capital investment, and improving utilization of grid assets. The Company respectfully requests authorization to implement the solar and battery storage innovative utility technology program, as described in this section.

Emissions Curtailment Program

52. The Company is proposing an emissions curtailment program pursuant to U.C.A. 54-20-105(1)(e), under which the Commission may authorize "a program to curtail emissions from thermal generation plant in the Salt Lake non-attainment area during a non-attainment event as defined by the Division of Air Quality."

53. Air quality is a challenging issue that Utah is dealing with and this proposed program will address this issue by establishing a process where the Company would curtail the Gadsby Power Plant during winter inversion air quality events as defined by the Utah Division of Air Quality ("UDAQ"). Funds collected from the line item charge authorized by U.C.A. § 54-7-12.8(6) would be used to reimburse Rocky Mountain Power for the incremental net power costs incurred for the curtailment during the five-year pilot program. The curtailment program budget is a total of $500,000; once the funds are exhausted the program will be discontinued.

54. The Gadsby Power Plant is 100 percent owned and operated by the Company. It is designed to burn oil derivatives, natural gas, or coal. The program would apply only to Units 1-3, which are conventional natural gas fired boilers. The three units have a net capacity rating of 64 megawatts ("MW"), 69 MW, and 104.5 MW for a total of 237.5 MW. The Gadsby Power Plant is typically used for spinning reserve and peak load.

55. Under the proposed program, which is described more fully in the Gadsby Emissions Curtailment Program document, included as Exhibit E to this Application and which is supported through the direct testimony of Company witness James Campbell, the UDAQ would issue air quality alerts to the Company when the ambient air quality along the Wasatch Front is at or near unhealthy levels, and the Company would curtail

these units until the air quality alerts are lifted by the UDAQ, or until the impact of the curtailment(s) reaches the maximum level of funding. If the plants are curtailed, the Company would incur an economic loss from both not operating the resource, and purchasing replacement generation and capacity to meet system needs. Gadsby is a system resource, so the economic loss would impact all six states in which the Company serves. To ensure no state is unfairly impacted by the program, STEP funds would be used to compensate the system for the incremental cost.

56. UDAQ will provide five days' notice when air quality actions will be issued. The Company will evaluate the system to determine that there are no emergency or reliability issues that could be impacted by curtailing. At two days out, UDAQ will issue a second notice of upcoming air quality action alert. Assuming there are no reliability or emergency issues, the Company will curtail Gadsby's steam operations. The Company needs 48 hours to effectively reposition its fuel supply. The steam units will stay curtailed, subject to funding, until UDAQ releases its air quality action alert.

57. In the event that the Gadsby Power Plant was scheduled to operate and was curtailed, the economic loss will be calculated by performing dispatch modeling analysis with the resource in the model and with the resource absent to evaluate the net power cost impact of curtailment. If Gadsby is not scheduled to operate during an air quality event, then no action is taken and there is no incremental cost or economic loss. The Company respectfully requests the Commission authorize implementation of the emissions curtailment program, and the expenditure of up to $500,000, as described above.

Commercial Line Extension Pilot Program

58. Pursuant to U.C.A. § 54-20-105(1)(d), the Company proposes to implement a Commercial Line Extension Pilot Program through a new tariff Regulation No. 13, included in Attachment 1. This Commercial Line Extension Pilot Program is designed to promote economic development by supporting installation of electrical infrastructure within commercial developments. The program is supported by the direct testimony of Company witness F. Robert Stewart.

59. When the electrical infrastructure backbone is installed for an entire development in one job, as opposed to incremental installations that occur when the infrastructure backbone is installed one piece at a time as different lots are developed, the cost is reduced, and the design is improved, for the following reasons: (1) the mobilization cost occurs once, versus multiple times; (2) the design incorporates the redundancy of loop feeds which only occurs, if at all, after full build out of the developments when done piecemeal; (3) the backbone conductor (backbone conductor being the conductors over which electricity flows to the lots and from which each lot takes power) is appropriately sized to serve all the lots, not just the lot requesting service; (4) the design and installation occur before permanent surface improvement have been made, and when the other utilities are being installed so joint trenches can be used, and space conflicts worked out; and (5) when the backbone is installed after all other utilities are installed, the cost to install increases due to permanent surface improvements and often there is not adequate remaining space in the public utility easements for switch gear and sectionalizing cabinets. The tariff will incentivize all of these efficiencies.

60. The tariff will also encourage electrical vehicle use by providing for electrical conduit extensions to parking areas that have been identified as potential electrical vehicle charging station locations. The Company requests authorization from the Commission to spend $2,500,000 over the five-year pilot program period, on the Commercial Line Extension Pilot Program, as more fully described below.

61. The Company's proposed tariff will use a portion of the STEP funds to provide line extension funding for commercial developers within the boundaries of a commercial (non-residential) development or mixed commercial/residential development ("mixed use development"). The funds would apply equally for non-residential developments as well as the non-residential portion of mixed use developments.

62. The proposed funding will be applied towards primary voltage non-residential "backbone" infrastructure costs within the development which the developer would otherwise be required to pay. Backbone infrastructure are primary lines that will serve as network facilities and do not include direct assigned facilities or terminal facilities (tap lines, transformers and services), and are not eligible for an allowance under the Company's line extension Regulation No. 12, Section 4. The funding will provide 20 percent of these eligible backbone costs, with the developer paying 80 percent.

63. The estimated costs are $500,000 per year, with an allocated amount of $2,500,000 total for the five-year term of the STEP pilot period. The funds will be applied towards non-residential backbone costs in developments until the total allocated amount is used, or five years have expired, whichever comes first.

64. The funds will be applied by the Company for each application by developers for installation of backbone in non-residential developments where the developer is responsible for the backbone costs. No request by the developer, other than the request for backbone within the development, will be necessary.

65. However, the developer will be required to enter into a line extension agreement with the Company for the backbone to be installed, and pay the costs in excess of the 20 percent incentive backbone funds provided in the tariff. In addition, these contracts that include the STEP 20 percent incentive may require the developer to install underground conduit from primary voltage junction points to designated parking areas for the purpose of future electrical vehicle charging infrastructure. No individual development will receive more than $50,000 in STEP funds.

66. The Company will maintain a record of each work order where STEP funds are used. The work order number links the use of the funds to the job details of where and how the funds are used. Additionally, an internal account has been established for all Program fund expenditures so current to-date allocations can be queried at any time.

67. On July 22, 2016, the Company met with developers to discuss the proposed program. On July 28, 2016, the Company met with the Division of Public Utilities, the Office of Consumer Services, and other interested parties to provide an overview of the proposed Line Extension Pilot Program. Feedback received from external stakeholder discussions has been considered and incorporated where appropriate.

68. The Company respectfully requests approval of the proposed tariff Regulation No. 13, and authorization to implement the commercial line extension program, as described above.

Future STEP Working Groups

69. As part of the on-going STEP implementation, the Company is establishing two additional working groups: one to evaluate innovative utility program funding opportunities and one to advise on the development of time-of-use pilots to encourage off-peak hour charging of PEVs.

70. First, the Company is establishing an innovative utility technology program working group to evaluate opportunities and standards for other Utah innovative utility technology programs, pursuant to U.C.A. § 54-20-105. Other Utah innovative utility technology programs may include, but are not limited to, distributed energy storage, PEVs and related charging infrastructure, and clean coal technology.

71. As innovative technology options increase, there will likely be opportunities for the Company to collaborate with outside groups, municipalities, national labs, United States Department of Energy, and technology companies to craft innovative solutions for the benefit of customers. This working group will help the Company find and evaluate solutions that could optimize the use of the electric grid and ensure that programs are designed to be in the interest of all Utah customers.

72. The Company expects to request future authorization of STEP funding pursuant to U.C.A. § 54-20-105 under this Docket, based on the recommendations of the working group, or as additional information becomes available to the Company otherwise. There is approximately $12.9 million in the STEP budget over the five year

pilot period that is not yet assigned to a specific project request that the Company will bring back to the Commission for further consideration when beneficial projects are identified.

73. Second, based on discussions with the Utah Division of Public Utilities, Office of Consumer Services, and other interested parties, and pursuant to U.C.A. § 54-20-103(1)(b), the Company plans to initiate a working group to review potential time of use pricing for residential customers and, potentially, non-residential public PEV charging stations.

74. Accordingly, the Company believes that it is in the interest of its customers for a review of potential time of use options to occur in a series of stakeholder meetings. The Company anticipates setting up a series of meetings that will enable the Company to file a proposed residential time of use pilot by January 1, 2017. In conjunction with the pricing pilot, the Company will file for approval of PEV Program incentives, as discussed above.

75. While the Company anticipates the primary focus of the time of use working group to be the review of time-of-use pricing options for residential customers, the work group will also consider whether a pilot or modifications for non-residential PEV charging is necessary or appropriate.

Scheduling

76. Based on discussions with the Division of Public Utilities and the Office of Consumer Services, the Company proposes that the Commission set a schedule that staggers parties' comments and/or reply comments by topic, over a period of several months to mitigate the burden that the review of this filing will entail. The Company

respectfully requests the following effective dates for each program and tariff listed below, with identification of reasons where circumstances require a specific effective date:

Program	Effective Date Requested	Reason
Electric Vehicle Incentive Program	January 1, 2017	1) Statutory annual program budget exists pursuant to U.C.A. § 54-7-12.8(6)(b)(i); opportunity lost if not used. 2) Requires request for proposal to set-up administration of pilot program.
Clean Coal Technologies	January 1, 2017	1) Maximize clean coal technology study period for benefit of customers. 2) Some components require Request for Proposals from vendors.
Battery Storage - Solar	January 1, 2017	1) Land negotiations and purchase required. 2) Requires Request for Proposal for equipment.
Gadsby Emissions Curtailment	January 1, 2017	1) Early winter 2017 months (January through March) applicable period.
Line Extension (Regulation No. 13)	January 1, 2017	1) Effective date subject to scheduling conference.
Substation Metering	January 1, 2017	1) Effective date subject to scheduling conference.

Tariff Schedule No.	Effective Date Requested	Reason
195	January 1, 2017	Statutory obligation pursuant to U.C.A. § 54-7-12.8(3).
193	January 1, 2017	Statutory obligation pursuant to U.C.A. § 54-7-12.8(3).
120	On or before July 1, 2017	1) Effective date subject to scheduling conference and time of use working group. 2) Statutory authorization before July 1, 2017 pursuant to U.C.A. § 54-20-103(1).
Regulation 13	January 1, 2017	1) Effective date subject to scheduling conference.
107	December 31, 2016	Statutory obligation to end USIP Pilot by December 31, 2016 pursuant to U.C.A. § 54-7-12.8(4).

The Company respectfully requests the Commission order a scheduling conference to be held one week after filing, on September 19, 2016.

Authorization Requests Summary

77. The Company respectfully requests the Commission authorize the STEP programs as presented in this Application and authorize the currently requested use of STEP funds of $37,070,558 over a five-year period to be utilized as shown in the following Table 3:

Table 3 - STEP Requested Funding

STEP Program Components	Total Requested	Unassigned	Total STEP
EV Charging Infrastructure	**$ 10,000,000**	**$ —**	**$ 10,000,000**
Clean Coal Technologies			
Woody Waste Co-Fire	789,873		
Emerging CO2 Capture	1,174,857		
Sequestration Site Characterization - Phase 1	150,000		
CO2 Enhanced Coal Bed Methane Recovery	275,000		
Solar Thermal Assessment	187,000		
NOX Neural Net Implementation	1,007,449		
Advanced NOX Control	1,415,821		
Subtotal Clean Coal Technologies	**5,000,000**	**—**	**5,000,000**
Innovative Utility Programs			
Battery Storage - Solar	5,050,000		
Substation Metering	1,100,000		
Gadsby Emissions Curtailment	500,000		
Line Extension	2,500,000		
Other Innovative Technology (a)	—	7,850,000	
Subtotal Innovative Utility Programs	**9,150,000**	**7,850,000**	**17,000,000**
USIP	**12,920,558**		**12,920,558**
Conservation, Efficiency, or New Technology		**5,079,442**	**5,079,442**
Five Years Projected STEP Fund Use	**$ 37,070,558**	**$ 12,929,442**	**$ 50,000,000**

Future applications in this Docket will address the request for approval of additional programs or use of the unassigned funding of $12.9 million shown in Table 3 above.

WHEREFORE, Rocky Mountain Power respectfully requests that the Commission approve this Application and the proposed programs and tariff sheets, as filed, with an effective date of January 1, 2017.

DATED this 12th day of September 2016.

Respectfully submitted,

ROCKY MOUNTAIN POWER

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Attorneys for Rocky Mountain Power

Rocky Mountain Power
Attachment 1
Docket No. 16-035-36

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF UTAH

ROCKY MOUNTAIN POWER

Attachment 1
Proposed Tariff Sheets

September 2016

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ELECTRIC SERVICE REGULATIONS

STATE OF UTAH

ROCKY MOUNTAIN POWER

ELECTRIC SERVICE SCHEDULE NO. 195

STATE OF UTAH

**Sustainable Transportation and Energy Plan (STEP)
Cost Adjustment**

PURPOSE: The Sustainable Transportation and Energy Plan Cost Adjustment is designed to recover the costs incurred by the Company pursuant Utah Code Annotated § 54-7-12.8(3)(b) and (8).

APPLICATION: This Schedule shall be applicable to all Customers taking service under the Company's electric service schedules, including Customers under contract rates subject to U.C.A. § 54-7-12.8(8).

TERM: The term of the STEP Cost Adjustment shall be from January 1, 2017 until all authorized costs have been collected.

(continued)

ELECTRIC SERVICE SCHEDULE NO. 195 - Continued

MONTHLY BILL: In addition to the Monthly Charges contained in the Customer's applicable schedule, all monthly bills shall have the following percentage increases applied to the Power Charge, Energy Charge, Facilities Charge and Voltage Discount of the Customer's applicable schedule and the applicable charges or credits of Schedule 94 and Schedule 98. The adjustment associated with this schedule shall be shown in conjunction with the adjustment for Schedule 193 on a single line item of the Customer's bill.

Schedule 1	0.57%
Schedule 2	0.57%
Schedule 3	0.57%
Schedule 6	0.53%
Schedule 6A	0.55%
Schedule 6B	0.53%
Schedule 7*	0.52%
Schedule 8	0.52%
Schedule 9	0.52%
Schedule 9A	0.53%
Schedule 10	0.54%
Schedule 11*	0.52%
Schedule 12*	0.52%
Schedule 15 (Traffic and Other Signal Systems)	0.68%
Schedule 15 (Metered Outdoor Nighttime Lighting)	0.68%
Schedule 21	0.53%
Schedule 23	0.56%
Schedule 31**	0.54%
Schedule 32***	0.54%
Contract 1	0.13%
Contract 2	0.01%
Contract 3****	$154,410/month

* The Adjustment for Schedules 7, 11 and 12 shall be applied to the Charge Per Lamp.

** The Adjustment for Schedule 31 Customers shall be applied to Facilities Charges, Back-up Power Charges, and Excess Power Charges in addition to the applicable general service schedule charges.

*** The Adjustment for Schedule 32 Customers shall be applied to Delivery Facilities Charges and Daily Power Charges in addition to the applicable general service schedule charges.

**** The Adjustment for Contract 3 Customers shall be a fixed amount of $154,410 per month.

ELECTRIC SERVICE SCHEDULE NO. 193 - Continued

MONTHLY BILL: In addition to the Monthly Charges contained in the Customer's applicable schedule, all monthly bills shall have the following percentage increases applied to the Power Charge, Energy Charge, Facilities Charge and Voltage Discount of the Customer's applicable schedule and the applicable charges or credits of Schedule 94 and Schedule 98.

Schedule 1	4.33%
Schedule 2	4.33%
Schedule 3	4.33%
Schedule 6	4.07%
Schedule 6A	4.18%
Schedule 6B	4.07%
Schedule 7*	4.00%
Schedule 8	4.01%
Schedule 9	4.01%
Schedule 9A	4.03%
Schedule 10	4.11%
Schedule 11*	4.00%
Schedule 12*	4.00%
Schedule 15 (Traffic and Other Signal Systems)	5.22%
Schedule 15 (Metered Outdoor Nighttime Lighting)	5.23%
Schedule 21	4.06%
Schedule 23	4.30%
Schedule 31**	4.09%
Schedule 32***	4.09%

* The Adjustment for Schedules 7, 11 and 12 shall be applied to the Charge per Lamp.

** The Adjustment for Schedule 31 customers shall be applied to Facilities Charges, Back-up Power Charges, and Excess Power Charges in addition to the applicable general service schedule charges.

*** The Adjustment for Schedule 32 customers shall be applied to Delivery Facilities Charges and Daily Power Charges in addition to the applicable general service schedule charges.

(N)

ROCKY MOUNTAIN POWER

ELECTRIC SERVICE REGULATION NO. 13

STATE OF UTAH

Sustainable Transportation and Energy Program (STEP)

Commercial Line Extension Pilot Program

APPLICABLE: All new commercial and industrial developments and the non-residential portion of new mixed residential and non-residential developments.

PURPOSE: Reduce developer's costs within developments for which they are requesting installation of primary voltage backbone facilities. Promote use of electric vehicles by facilitating installation of electric vehicle charging stations.

DESCRIPTION: For primary voltage backbone within the development for non-residential loads, for which the developer is paying an advance under Regulation 12, Section 4(b). This portion of the developer's advance will be reduced by 20%, or $50,000, whichever is less.

PROVISIONS OF SERVICE: To be eligible for the 20% reduction in their advance the developer must enter into a line extension contract as provided in Regulation 12. If the development is to be constructed in phases, the backbone request must be for installation of the backbone for that phase, otherwise it must be for installation of the backbone for the entire development. In either case the design will include capacity for future development. Developers that are building on lots may be required to install conduit from either Company or Developer primary voltage power source(s) to future electric vehicle charging locations on their property.

The 20% reduction will be applied to all applicable backbone costs for as long as funds are available to provide the 20% payment, but not for applications completed after December 31, 2021.

(N)

ROCKY MOUNTAIN POWER

ELECTRIC SERVICE SCHEDULE NO. 107

STATE OF UTAH

Solar Incentive Program

APPLICABLE: All customers that have accepted an incentive under the Solar Incentive Program as of December 31, 2016.

DEFINITIONS:

Approved Program Calculator
A tool used to compute the estimated production (kW) for a System associated with the Program. The tool will take into consideration the generating capability of the equipment, the efficiency of the inverter, and other design factors of the System including location, azimuth, tilt, shading and mounting method.

Capacity Reservation
Capacity Reservation means Company acceptance of an application under the Program for a specific level of system capacity based on Program Sector.

Customer
Customer means a single electricity delivery point.

Program
The Solar Incentive Program as described in the Schedule.

Program Year
For 2012/2013, the Program Year shall be October 12, 2012 through December 31, 2013. All other Program Years shall be the calendar year.

Program Sector
A Program Sector is a means of classifying systems eligible for incentives based on system and customer attributes. Three categories of systems will be eligible for distinct incentive levels and available capacities, including the Residential System Program Sector, Small Non-Residential System Programs Sector, and Large Non-Residential System Program Sector.

Program Administrator
Qualified person or entity hired by the Company to administer this Program.

System
System means a solar photovoltaic installation at Customer's project site.

(continued)

ELECTRIC SERVICE SCHEDULE NO. 107 - Continued

PROGRAM PROCESS: (continued)

3. **Capacity Reservation:** Based on their positions in the lottery queue and dependent on remaining available capacity listed in Table 2, Customers will receive Capacity Reservations from the Company.
4. **Deposit Requirement:** Customers in receipt of a Capacity Reservation are required to submit a deposit to secure their Capacity Reservation, based on the size of the proposed project. The deposit amount is the greater of $100 or $20 per kW. Deposits must be paid within 14 calendar days of receipt of a Capacity Reservation. If the deposit is not paid within 14 calendar days of receipt of a Capacity Reservation, the Capacity Reservation will expire.
5. **Interconnection Application:** Within two months of securing a Capacity Reservation, Customer must submit a completed Interconnection Application that meets all requirements of Utah Administrative Code R746-312. If the Interconnection Application is not submitted by Customer within two months of receipt of the Capacity Reservation, the Capacity Reservation will expire and the deposit will be forfeit.
6. **Interconnection Timeline:** Residential and Small Non-Residential Systems have 12 months from the Customer's receipt of Capacity Reservation to interconnect. Due to added complexity, Large Non-Residential Systems have 18 months from Customer's receipt of Capacity Reservation to interconnect. If the project does not complete interconnection within the applicable timeline, the Capacity Reservation will expire and the deposit will be forfeit.
7. **Incentive Claim Form:** After the interconnection is complete, Customer must complete and submit an Incentive Claim Form. Customer will also be required to submit a form documenting successful government inspection of the facility from the authority having jurisdiction and either a copy of invoices reflecting the purchase of the System or the contract controlling the financial terms of the installation transaction. All Forms and instructions will be available on the Company's website.
8. **Deposit Refund:** After interconnection, the deposit will be refunded to Customer within 60 days.
9. **Incentives Subject to Available Capacity:** Incentives listed in Table 1 are subject to available capacities listed in Table 2 and will be provided for qualifying equipment inspected and interconnected within the applicable Interconnection Timeline.
10. **Incentive roll-over:** If subscribed funds are less than the budgeted amount in any Program Year, the remaining Program Sector-specific funds will roll over to the next Program Year (but not beyond Program Year 2016) such that all funds approved under this Program may be fully allocated within the four-year Program.

(continued)

ELECTRIC SERVICE SCHEDULE NO. 107 - Continued

INCENTIVES: Customer incentives by Program Year and Program Sector are listed in Table 1 and subject to available capacities listed in Table 2. Incentives will be paid based on the expected output of the installed solar PV system as calculated by an Approved Program Calculator. Incentives will be paid per Watt in alternating current (AC).

Table 1. Program Incentive Levels

Program Year	Residential Systems (≤ 4kW)	Small Non-Residential Systems (≤ 25kW)	Large Non-Residential Systems (> 25 kW- ≤ 1,000 kW)
2012/2013	$1.25/Watt ($_{AC}$)	$1.00/Watt ($_{AC}$)	$0.80/Watt ($_{AC}$)
2014	$1.20/Watt ($_{AC}$)	$0.95/Watt ($_{AC}$)	$0.75/Watt ($_{AC}$)
2015	$1.15/Watt ($_{AC}$)	$0.90/Watt ($_{AC}$)	$0.70/Watt ($_{AC}$)
2016	$1.10/Watt ($_{AC}$)	$0.85/Watt ($_{AC}$)	$0.65/Watt ($_{AC}$)

Table 2. Available Capacity

Program Year	Residential Systems (≤ 4kW)	Small Non-Residential Systems (≤ 25kW)	Large Non-Residential Systems (> 25 kW- ≤ 1,000 kW)
2012/2013	500 kW($_{AC}$)	3,000 kW($_{AC}$)	3,000 kW($_{AC}$)
2014	500 kW($_{AC}$)	3,500 kW($_{AC}$)	6,000 kW($_{AC}$)
2015	500 kW($_{AC}$)	4,000 kW($_{AC}$)	8,500 kW($_{AC}$)
2016	500 kW($_{AC}$)	4,500 kW($_{AC}$)	10,000 kW($_{AC}$)
2017	500 kW($_{AC}$)	5,000 kW($_{AC}$)	10,000 kW($_{AC}$)

The payment amount will equal the incentive level that corresponds with the Program Year during which the application was submitted multiplied by the estimated (AC) output of the system. The AC output of each system will be estimated in kilowatts (kW) based on the installation characteristics and design factor and calculated using an Approved Program Calculator.

For Residential and Small Non-Residential projects, the incentive will be paid within 60 days of the receipt of an approved incentive claim form submitted after the project is interconnected.

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ELECTRIC SERVICE REGULATIONS

STATE OF UTAH

ROCKY MOUNTAIN POWER

ELECTRIC SERVICE SCHEDULE NO. 195

STATE OF UTAH

Solar Incentive Program Sustainable Transportation and Energy Plan (STEP)

Cost Adjustment

PURPOSE: The Solar Incentive Sustainable Transportation and Energy Plan Cost Adjustment is designed to recover the costs incurred by the Company associated with the Solar Incentive Program pursuant Utah Code Annotated § 54-7-12.8(3)(b) and (8).

APPLICATION: This Schedule shall be applicable to all Customers taking service under the Company's electric service schedules, including Customers under contract rates subject to U.C.A. § 54-7-12.8(8). The collection of costs related to the Solar Incentive Plan from customers paying contract rates shall be governed by the terms of the contract.

TERM: The term of the Solar Incentive Program STEP Cost Adjustment shall be from October 12, 2012January 1, 2017, through the term of the approved Solar Incentive Program until all authorized costs have been collected.

(continued)

ELECTRIC SERVICE SCHEDULE NO. 195 - Continued

MONTHLY BILL: In addition to the Monthly Charges contained in the Customer's applicable schedule, all monthly bills shall have the following charges added percentage increases applied to the Power Charge, Energy Charges, Facilities Charge and Voltage Discount of the Customer's applicable schedule and the applicable charges or credits of Schedule 94 and Schedule 98. Energy Charges displayed on Customers' bills shall be the combined value of the charges under this Schedule plus the Energy Charges of the Customer's applicable schedule. The collection of costs related to the Solar Incentive Plan from customers paying contract rates shall be governed by the terms of the contractThe adjustment associated with this schedule shall be shown in conjunction with the adjustment for Schedule 193 on a single line item of the Customer's bill.

Schedule 1	0.57%0.0356¢ per kWh for all kWh
Schedule 2	0.57%0.0356¢ per kWh for all kWh
Schedule 3	0.57%0.0356¢ per kWh for all kWh
Schedule 6	0.53%0.0277¢ per kWh for all kWh
Schedule 6A	0.55%0.0386¢ per kWh for all kWh
Schedule 6B	0.53%0.0277¢ per kWh for all kWh
Schedule 7*	0.52%0.0822¢ per kWh for all kWh
Schedule 8	0.52%0.0248¢ per kWh for all kWh
Schedule 9	0.52%0.0175¢ per kWh for all kWh
Schedule 9A	0.53%0.0247¢ per kWh for all kWh
Schedule 10	0.54%0.0255¢ per kWh for all kWh
Schedule 11*	0.52%0.1018¢ per kWh for all kWh
Schedule 12*	0.52%0.0250¢ per kWh for all kWh
Schedule 15 (Traffic and Other Signal Systems)	0.68%0.0374¢ per kWh for all kWh
Schedule 15 (Metered Outdoor Nighttime Lighting)	0.68%0.0249¢ per kWh for all kWh
Schedule 21	0.53%0.0378¢ per kWh for all kWh
Schedule 23	0.56%0.0329¢ per kWh for all kWh
Schedule 31	** 0.54%
Schedule 32	*** 0.54%
Contract 1	0.13%
Contract 2	0.01%
Contract 3****	$154,410/month

* The Adjustment for Schedules 7, 11 and 12 shall be applied to the Charge Per Lamp.

** The Adjustment for Schedule 31 Customers shall be applied to Facilities Charges, Back-up Power Charges, and Excess Power Charges in addition to the applicable general service schedule charges.

*** The Adjustment for Schedules 31 and 32 cCustomers shall be equal applied to Delivery Facilities Charges and Daily Power Charges in addition to the applicable general service schedule charges under this schedule.

**** The Adjustment for Contract 3 Customers shall be a fixed amount of $154,410 per month.

Issued by authority of Report and Order of the Public Service Commission of Utah in Docket No. 14-035-T0216-035-36

FILED: April 3, 2015September 12, 2016 **EFFECTIVE**: April 1, 2015January 1, 2017

ELECTRIC SERVICE SCHEDULE NO. 193 - Continued

MONTHLY BILL: In addition to the Monthly Charges contained in the Customer's applicable schedule, all monthly bills shall have the following percentage increases applied to the Power Charge, Energy Charge, Facilities Charge and Voltage Discount of the Customer's applicable schedule and the applicable charges or credits of Schedule 94~~,~~ and Schedule 98 ~~and Schedule 195~~.

Schedule 1	4.33%
Schedule 2	4.33%
Schedule 3	4.33%
Schedule 6	4.07%
Schedule 6A	4.18%
Schedule 6B	4.07%
Schedule 7*	4.00%
Schedule 8	4.01%
Schedule 9	4.01%
Schedule 9A	4.03%
Schedule 10	4.11%
Schedule 11*	4.00%
Schedule 12*	4.00%
Schedule 15 (Traffic and Other Signal Systems)	5.22%
Schedule 15 (Metered Outdoor Nighttime Lighting)	5.23%
Schedule 21	4.06%
Schedule 23	4.30%
Schedule 31**	4.09%
Schedule 32***	4.09%

* The Adjustment for Schedules 7, 11 and 12 shall be applied to the Charge per Lamp.

** The Adjustment for Schedule 31 customers shall be applied to Facilities Charges, Back-up Power Charges, and Excess Power Charges in addition to the applicable general service schedule charges.

*** The Adjustment for Schedule 32 customers shall be applied to Delivery Facilities Charges and Daily Power Charges in addition to the applicable general service schedule charges.

ROCKY MOUNTAIN POWER

ELECTRIC SERVICE SCHEDULE NO. 107

STATE OF UTAH

Solar Incentive Program

APPLICABLE: All customers that have accepted an incentive under the Solar Incentive Program as of December 31, 2016served by the Company in the State of Utah billed on all retail rate schedules and Special Contract Customers whose bills are subject to Schedule 195 the Solar Incentive Program Surcharge.

DEFINITIONS:

Approved Program Calculator
A tool used to compute the estimated production (kW) for a System associated with the Program. The tool will take into consideration the generating capability of the equipment, the efficiency of the inverter, and other design factors of the System including location, azimuth, tilt, shading and mounting method.

Capacity Reservation
Capacity Reservation means Company acceptance of an application under the Program for a specific level of system capacity based on Program Sector.

Customer
Customer means a single electricity delivery point.

Program
The Solar Incentive Program as described in the Schedule.

Program Year
For 2012/2013, the Program Year shall be October 12, 2012 through December 31, 2013. All other Program Years shall be the calendar year.

Program Sector
A Program Sector is a means of classifying systems eligible for incentives based on system and customer attributes. Three categories of systems will be eligible for distinct incentive levels and available capacities, including the Residential System Program Sector, Small Non-Residential System Programs Sector, and Large Non-Residential System Program Sector.

Program Administrator
Qualified person or entity hired by the Company to administer this Program.

System
System means a solar photovoltaic installation at Customer's project site.

(continued)

ELECTRIC SERVICE SCHEDULE NO. 107 - Continued

PROGRAM PROCESS: (continued)

3. **Capacity Reservation:** Based on their positions in the lottery queue and dependent on remaining available capacity listed in Table 2, Customers will receive Capacity Reservations from the Company.
4. **Deposit Requirement:** Customers in receipt of a Capacity Reservation are required to submit a deposit to secure their Capacity Reservation, based on the size of the proposed project. The deposit amount is the greater of $100 or $20 per kW. Deposits must be paid within 14 calendar days of receipt of a Capacity Reservation. If the deposit is not paid within 14 calendar days of receipt of a Capacity Reservation, the Capacity Reservation will expire.
5. **Interconnection Application:** Within two months of securing a Capacity Reservation, Customer must submit a completed Interconnection Application that meets all requirements of Utah Administrative Code R746-312. If the Interconnection Application is not submitted by Customer within two months of receipt of the Capacity Reservation, the Capacity Reservation will expire and the deposit will be forfeit.
6. **Interconnection Timeline:** Residential and Small Non-Residential Systems have 12 months from the Customer's receipt of Capacity Reservation to interconnect. Due to added complexity, Large Non-Residential Systems have 18 months from Customer's receipt of Capacity Reservation to interconnect. If the project does not complete interconnection within the applicable timeline, the Capacity Reservation will expire and the deposit will be forfeit.
7. **Incentive Claim Form:** After the interconnection is complete, Customer must complete and submit an Incentive Claim Form. Customer will also be required to submit a form documenting successful government inspection of the facility from the authority having jurisdiction and either a copy of invoices reflecting the purchase of the System or the contract controlling the financial terms of the installation transaction. All Forms and instructions will be available on the Company's website.
8. **Deposit Refund:** After interconnection, the deposit will be refunded to Customer within 60 days.
9. **Incentives Subject to Available Capacity:** Incentives listed in Table 1 are subject to available capacities listed in Table 2 and will be provided for qualifying equipment inspected and interconnected within the applicable Interconnection Timeline.
10. **Incentive roll-over:** If subscribed funds are less than the budgeted amount in any Program Year, the remaining Program Sector-specific funds will roll over to the next Program Year (but not beyond Program Year ~~2017~~2016) such that all funds approved under this Program may be fully allocated within the ~~five~~four-year Program.

(continued)

ELECTRIC SERVICE SCHEDULE NO. 107 - Continued

INCENTIVES: Customer incentives by Program Year and Program Sector are listed in Table 1 and subject to available capacities listed in Table 2. Incentives will be paid based on the expected output of the installed solar PV system as calculated by an Approved Program Calculator. Incentives will be paid per Watt in alternating current (AC).

Table 1. Program Incentive Levels

Program Year	Residential Systems (≤ 4kW)	Small Non-Residential Systems (≤ 25kW)	Large Non-Residential Systems (> 25 kW- ≤ 1,000 kW)
2012/2013	$1.25/Watt ($_{AC}$)	$1.00/Watt ($_{AC}$)	$0.80/Watt ($_{AC}$)
2014	$1.20/Watt ($_{AC}$)	$0.95/Watt ($_{AC}$)	$0.75/Watt ($_{AC}$)
2015	$1.15/Watt ($_{AC}$)	$0.90/Watt ($_{AC}$)	$0.70/Watt ($_{AC}$)
2016	$1.10/Watt ($_{AC}$)	$0.85/Watt ($_{AC}$)	$0.65/Watt ($_{AC}$)
~~2017~~	~~$1.05/Watt ($_{AC}$)~~	~~$0.80/Watt ($_{AC}$)~~	~~$0.60/Watt ($_{AC}$)~~

Table 2. Available Capacity

Program Year	Residential Systems (≤ 4kW)	Small Non-Residential Systems (≤ 25kW)	Large Non-Residential Systems (> 25 kW- ≤ 1,000 kW)
2012/2013	500 kW($_{AC}$)	3,000 kW($_{AC}$)	3,000 kW($_{AC}$)
2014	500 kW($_{AC}$)	3,500 kW($_{AC}$)	6,000 kW($_{AC}$)
2015	500 kW($_{AC}$)	4,000 kW($_{AC}$)	8,500 kW($_{AC}$)
2016	500 kW($_{AC}$)	4,500 kW($_{AC}$)	10,000 kW($_{AC}$)
2017	500 kW($_{AC}$)	5,000 kW($_{AC}$)	10,000 kW($_{AC}$)

The payment amount will equal the incentive level that corresponds with the Program Year during which the application was submitted multiplied by the estimated (AC) output of the system. The AC output of each system will be estimated in kilowatts (kW) based on the installation characteristics and design factor and calculated using an Approved Program Calculator.

For Residential and Small Non-Residential projects, the incentive will be paid within 60 days of the receipt of an approved incentive claim form submitted after the project is interconnected.

(continued)

Rocky Mountain Power
Exhibit A
Docket No. 16-035-36

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF UTAH

ROCKY MOUNTAIN POWER

Exhibit A
Draft Plug-in Electric Vehicle Incentive Pilot Program
Schedule 120

September 2016

ROCKY MOUNTAIN POWER

ELECTRIC SERVICE SCHEDULE NO. 120

STATE OF UTAH

Plug-in Electric Vehicle Incentive Pilot Program

PURPOSE: This Schedule is intended to promote plug-in electric vehicle charging infrastructure.

APPLICABLE: To Rocky Mountain Power and all Customers taking service under the Company's General Service Schedules 1, 2, 3, 6, 6A, 6B, 8, 9, 9A, 10, 12, 15, 21, 23, and Supplementary Service under Schedule 31.

CUSTOMER PARTICIPATION: Customer participation is voluntary and is initiated by following the participation procedures on the Company website. The Company shall have the right to qualify participants, at its discretion, based on criteria the Company considers necessary to ensure the effective operation of the measures, utility system, and program budget. Program details and requirements can be viewed on the Company's website at www.rockymountainpower.net/pev.

Table 1 – Plug-in Electric Vehicle (PEV) Infrastructure Offerings

Category	Measure	Incentives "up to"
Plug-in Electric Vehicle Charging Stations	Residential AC Level 2 Charger	$200 per charger up to 50% of total charger cost
	Non-Residential AC Level 2 Charger	$3,000 per charger up to 75% of total charger cost
	DC Fast Charger	$30,000 per charger up to 75% of total charger and installation costs
	Grant-based custom projects and partnerships	Custom

(continued)

ELECTRIC SERVICE SCHEDULE NO. 120 – Continued

AVAILABILITY: Availability for incentives listed in Table 1 above is subject to available funds. Availability of funds will be listed on the Company website and updated on a monthly basis.

SPECIAL CONDITIONS:

Residential AC Level 2 Charger Prescriptive Incentive

1. To be eligible for an incentive, Customers must submit a Program Administrator approved post-purchase application and meet all Program requirements.
2. Incentives will be available on a first come first serve basis with an annual cap.
3. The Company and its agents reserve the right to inspect installations.

Non-Residential AC Level 2 Charger Prescriptive Incentive

1. To be eligible for an incentive, Customers must submit a Program Administrator approved post-purchase application and meet all Program requirements.
2. Incentives will be available on a first come first serve with annual cap.
3. The Company and its agents reserve the right to inspect installations.

DC Fast Charger Prescriptive Incentive

1. To be eligible for an incentive, Customers must submit a Program Administrator approved application(s), provide all required documentation, and receive pre-approval.
2. Equipment purchased or installed prior to receipt of the Company's pre-approval may not be eligible for incentives.
3. Pre-approval criteria may include, but is not limited to:
    a. Location variables such as proximity to other DC Fast Chargers;
    b. Overall benefits to the public;
    c. Costs of project and incentive amount;
    d. Technology being used;
    e. Consent to provide charger usage data;
    f. Availability to the public; and
    g. Selection committee
4. Incentives will be available on a first come first serve with annual cap.
5. The Company and its agents reserve the right to inspect installations.

(continued)

ELECTRIC SERVICE SCHEDULE NO. 120 – Continued

SPECIAL CONDITIONS: (continued)

Grant-Based Custom Projects and Partnerships Incentive

1. To be eligible for a custom incentive, Customers must submit a Program Administrator approved application(s), provide all required documentation, and go through a selection process.
2. The selection process may include, but is not limited to:
   a. Location variables such as proximity to other charging infrastructure;
   b. Overall benefits to the public;
   c. Costs of project and incentive amount;
   d. Technology being used;
   e. Consent to provide charger usage data;
   f. Availability to the public;
   g. Selection committee;
   h. Matching funds;
   i. Innovative partnerships and projects that support plug-in electric vehicle infrastructure and education; and
   j. Development of DC fast charging corridors
3. Custom projects may be selected on a quarterly basis and will be limited to available funding.
4. The Company and its agents reserve the right to inspect installations.
5. Participants with new construction may submit an application for pre-approval, but will be held to all applicable timelines.

TERM: This Schedule terminates January 1, 2022, unless modified by order of the Public Service Commission of Utah.

ELECTRIC SERVICE REGULATIONS: Service under this Schedule will be in accordance with the terms of the Electric Service Agreement between the Customer and the Company. The Electric Service Regulations of the Company on file with and approved by the Public Service Commission of the State of Utah, including future applicable amendments, will be considered as forming a part of and incorporated in said Agreement.

Rocky Mountain Power
Exhibit B
Docket No. 16-035-36

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF UTAH

ROCKY MOUNTAIN POWER

Exhibit B
Clean Coal Technology Program

September 2016

Rocky Mountain Power

Clean Coal Technology Program

Sustainable Transportation and Energy Plan

Clean Coal Research Team

Sustainable Transportation Energy Plan (STEP)
Clean Coal Research Technology

1 Executive Summary

The Sustainable Transportation Energy Plan (STEP), a result of SB 115 codified in Utah statute in 2016, authorizes Rocky Mountain Power (the Company) to spend up an annual average of $1.0 million over a five year period "to investigate, analyze, and research clean coal technology" (Senate Bill 115, Section 54-20-104). "'Clean Coal technology' means a technology that may be researched, developed, or used for reducing emissions or the rate of emissions from a thermal electric generation plant that used coal as a fuel source" (Senate Bill 115, Section 54-2-1). To meet that objective, the Company proposes to allocate these funds across a number of projects that focus on the capture, reduction and sequestration of carbon dioxide (CO_2) and the reduction of nitrogen oxides (NOx). Funding will go towards specific projects that will be performed or assisted by Utah universities, Utah companies developing woody-waste biomass-based fuels, and a Utah company with a promising CO_2 capture technology that may result in lower capture costs in comparison to traditional methods.

The currently proposed program of Clean Coal Research projects are as follows:

1) a co-firing test of woody-waste (biomass) materials at the Company's Hunter Unit 3,
2) co-funding of a long term availability test of Sustainable Energy Solutions' cryogenic capture technology at either the Hunter or Huntington Plant,
3) co-funding of USTAR's Phase 1 effort to perform pre-feasibility study for commercial sequestration sites with co-funding by the United States Department of Energy,
4) a study to evaluate the potential for CO_2 to be used for regional enhanced coal bed methane recovery with sequestration,
5) a study to evaluate the performance and cost effectiveness of integrating solar thermal capture technologies at Hunter 3,
6) the application of an advanced neural network control system at Huntington Unit 2 for the reduction of NOx, and
7) implementation of a utility scale demonstration of alternative technologies that result in material decreases in NOx emissions without the use of Selective Catalytic Reduction (SCR).

2 Purpose and Necessity

The proposed projects and studies, which are further described in this document, were selected to meet the statutory requirements of the STEP legislation. These projects and studies were selected to address further reductions in NOx emissions from the Hunter and Huntington plants, reduce emissions from other sources and to further develop and evaluate technologies and processes for capturing and storing CO_2 which may be an element in an overall strategy to meet the state's goals under the federal Clean Power Plan.

The proposed projects and studies were identified through an exhaustive process that solicited and incorporated input from the Clean Coal Research team (see Appendix G for a list of participants). This team consisted of engineering faculty from the University of Utah, Brigham Young University, Utah State University, the Utah Science Technology and Research (USTAR), Utah Governor's Office for Energy Development, Utah technology companies and the Company's plant, technical services and resource development groups. Selected areas of demonstration or study focused specifically on the following:

1) CO_2 capture,
2) CO_2 sequestration (i.e. long term geologic storage), and
3) CO_2 and NOx emissions reductions from targeted facilities.

Overall criteria in the selection process of projects were multi-faceted and are intended to include the following key objectives:

1) need for physical demonstrations, if applicable and practicable,
2) advance existing/emerging technologies, 3) actively involve Utah universities and companies to perform the work,
3) leveraging other funding, if available and applicable.

The proposed Clean Coal Research projects/studies, type of project and project category are identified in Table 1.

<u>Table 1</u>
<u>Clean Coal Research Proposed Projects & Studies and Classifications</u>

Project/Study	**Type of Project**	**Category**
Co-firing test of woody-waste (biomass) materials-Hunter 3	Demonstration	CO_2 reduction & particulate matter (PM) reduction associated with wildfires and avoided coal burn
Co-funding of a long term availability test of Sustainable Energy Solutions' Cryogenic Carbon Capture™ technology	Demonstration, co-funding	CO_2 capture
Co-funding of University of Utah's Phase 1 pre-feasibility study of commercial CO_2 sequestration sites in Utah	Study, co-funding	CO_2 sequestration
Evaluate the potential for CO_2 to be used for regional enhanced	Study	CO_2 sequestration

coal bed methane recovery		
Evaluate the feasibility of solar thermal integration on Hunter 3	Study	CO_2 reduction
Advanced neural network control system at Huntington 2	Demonstration	NOx reduction (and partial CO_2 reduction)
Utility scale demonstration of alternative NOx emissions controls	Demonstration/ Study	NOx reduction

The Key Research Objectives are summarized in Table 2.

Table 2

Clean Coal Research - Proposed Projects & Key Research Objectives

Project/Study	**Key Research Objectives**
Co-firing test of woody-waste (biomass) materials-Hunter 3	1. Technical, economic and environmental assessment of biomass co-firing 2. Demonstration of co-firing capability with major changes to material handling equipment and processes 3. Identify processes that minimize cost of fuel processing without negative impacts on operations
Co-funding of a long term availability test of Sustainable Energy Solutions' CO_2 Cryogenic Capture™ technology	1. Demonstrate ability to achieve long term capture capability and operation 2. Economic assessment of utility-scale implementation of technology 3. Capture capabilities of other emissions
Co-funding of University of Utah's Phase 1 pre-feasibility study of commercial CO_2 sequestration sites in Utah	1. Team formation to address technical/non-technical (regulatory, legislative, technical, policy, commercial & financial) challenges 2. Plan development to address economic feasibility and public acceptance 3. High level technical evaluation of the geology of the sequestration sites
Evaluate the potential for CO_2 to be used for regional enhanced coal bed methane recovery	1. Determine if local coal beds are conducive to enhanced CH_4 recovery using CO_2 2. Evaluate the feasibility of permanent CO_2 sequestration used in enhanced coal bed methane recovery 3. Evaluate potential for reduced seismicity compared to deep saline well injection
Evaluate the feasibility of solar	1. Determine performance and economic feasibility of

thermal integration - Hunter Plant	solar thermal assisted steam generation 2. Identify land requirements
Advanced neural network control system at Huntington 2	1. Deploy an open system artificial neural network software program targeting NOx emissions and net heat rate reductions 2. Document emissions reductions & heat rate improvements 3. Modify the neural network to accommodate changes in ramp rates and reduced load operating conditions.
Utility scale demonstration of alternative NOx emissions control technologies	1. Assess alternative options for implementation of one or more NOx reduction technologies that in combination achieve similar emissions rates expected from a Selective Catalytic Reduction system 2. Select one or more NOx emissions technologies that appear to be capable of meeting the primary objective and, where indicated and further testing is required, install a slip stream or full stream demonstration of the technology. 3. Assess the economic feasibility of full scale implementation of the technolog(ies) compared to other available options for these units.

The individual projects are summarized in the next section, Project Descriptions.

3 Project Descriptions

Co-firing Tests of Woody-waste (biomass) Materials in Hunter Unit 3

This proposed project consists of two 18-hour co-firing tests of processed woody waste (biomass) to be fired in the Hunter Unit 3 boiler. The target heat input from woody waste material is 10% of the required total fuel input of the Unit 3 boiler. The processed woody waste will come from Utah forests and will consist of pinion-juniper, fir, aspen and other woods that have been cut down or removed to reduce fire danger, improve or maintain avian habitats and watersheds, or to remove dead trees. Additional wood resources include scrap and waste material from logging operations. Two types of processed woody waste will be tested. The primary objective of these tests will be to determine whether these processed biomass fuels can effectively be used as "drop-in" replacements in lieu of burning coal. In addition to displacing coal and its attendant CO_2 and NOx emissions, using these processed woody waste materials will have the benefit of minimizing particulate matter emissions associated with either controlled or uncontrolled burns of collected forest materials. Performing these tests will also be used as a mechanism to further evaluate and demonstrate these Utah-based technologies.

Amaron Energy (www.amaronenergy.com) and AEG Coalswitch (www.active-energy.com/aeg-coalswitch) are two Utah companies that have developed technologies to process/upgrade woody waste materials into biomass products that have properties that are similar to coal. The two companies use processes that are fundamentally different to create their biomass products. Independent 18-hour co-firing tests will be performed on each of the two biomass products at the Hunter Plant to determine how they perform as replacement fuels for coal.

The Amaron process consists of a torrefaction process in which the material is ground, sorted and heated in a low-oxygen environment to approximately 400-600 degrees Fahrenheit in a "torrefier" (fundamentally an indirect-fired rotating kiln). This produces a "coal like" material with a heating value of approximately 8,500-10,000 British thermal units per pound; this material can be pelletized which will enhance transportation and handling characteristics. Further testing will be required to determine if pelletization, which also adds cost, is needed.

The AEG Coalswitch process consists of a "steam explosion" process in which the woody waste material is ground, sorted, washed and heated by being exposed to high pressure steam (400-550 pounds per square inch) for approximately 15 minutes. The steam pressure is then released in a very short period of time (milliseconds); as a consequence, the woody material is deconstructed with high lignin content. This material is then rinsed, compressed and dried. This process also produces a "coal like" material with a heating value of approximately 8,500-10,000 British thermal units per pound. This material, too, can be pelletized. Further testing will be required to determine if the additional pelletization step is needed.

The testing process will include a complete analysis of the biomass fuel. Testing will be performed to assess the material's handling characteristics to ensure that it can be reliably handled by the existing boiler's coal handling, milling and conveying systems. Testing will be performed to ensure that co-combustion of the material does not have a deleterious effect on the boiler operation (undue slagging, fouling or coating of fabric filter bags).

To facilitate the proposed woody waste co-firing project, the University of Utah has been commissioned by Rocky Mountain Power to evaluate milling characteristics of these two processed fuels; this work is ongoing and is being performed at the University of Utah's combustion facility. This milling study is not being funded by STEP. For the performance of the co-firing test itself, Rocky Mountain Power will enter into separate contracts with Amaron and AEG Coalswitch for the supply and delivery of the processed material.

The University of Utah, together with Rocky Mountain Power will develop the test protocol, monitor and record the test, evaluate emissions, and perform specific fuel and ash analyses. The University of Utah will prepare summary final reports on these potential fuels to both reduce coal consumption and to provide a mechanism within the State of Utah where woody waste material can be periodically put to beneficial use without the particulate emissions associated with open burning.

For more information on the planned scope of work, refer to Appendix A, "Biomass Co-firing Proposal – University of Utah", which is a copy of the proposal submitted by the University of Utah with participation by Brigham Young University.

Co-funding of a Long Term Availability Test of Sustainable Energy Solutions' CO_2 Cryogenic Carbon Capture™ Technology

The proposed joint project uses the existing skid-scale version of Sustainable Energy Solutions' (SES) Cryogenic Carbon Capture™ (CCC) technology and supporting facilities to improve operational issues based on experience in a recent series of field tests, including preliminary short term field tests that were performed at Rocky Mountain Power's Dave Johnston plant in 2014. Rocky Mountain Power did not materially contribute to these short term tests at the Dave Johnston Plant other than to provide space and small amounts of electric energy and cooling water and making the field connections. The proposed STEP project (Phase I) will consist of modifying the test skid and performing a series of long term operational tests. This will be followed by the design, construction, and operation of a pilot facility based on the same scaled up technology (Phase II). The Phase I field tests will occur at either the Hunter or Huntington plants. Phase II will be a separate funding effort outside of the STEP program and is anticipated to be materially supported by the United States Department of Energy.

SES is a Utah company dedicated to the development of a low-cost CO_2 capture technology with an emphasis on retrofit potential (www.sesinnovation.com). The United States Department of Energy and State of Wyoming sponsored projects have shown the potential for the CCC process to cost half of current post-combustion technologies. The technology has demonstrated very high CO_2 removal efficiencies as well as the capability of removing criteria pollutants such as mercury and oxides of nitrogen and sulfur during recent field tests. These tests indicated several aspects of CCC that could be modified and optimized to improve longer-term reliability and efficiency. These modifications will be tested at the SES facility, after which the test skid will be deployed at the Hunter or Huntington plants to perform multiple long term tests (at least one greater than 500 continuous hours of run time with many more cumulative hours of run time) over a period of up to nine-months. Reliability is a critical requirement for Phase II of the technology development, which scales up this promising technology to 5-10 megawatts-electric equivalent. Phase I will be also co-funded by the US Department of Energy, Tri-State Generation and Transmission and the Electric Power Research Institute. The total project value of Phase I will be up to six million dollars of which Rocky Mountain Power will provide funding of approximately one million dollars. The US DOE indicates that demonstrated reliability and availability testing during Phase I will be a key factor in their consideration to fund a scale up of the technology (Phase II).

Expenditures made towards Phase I would be applied towards modifying the existing test skid, SES salaries and expenses during the testing phase, on-site consumables and insurances at Rocky Mountain Power's plant. Rocky Mountain Power would engage the services of a third party engineering firm to provide an assessment of the costs for implementing the technology on a retrofit basis on a utility scale (i.e. a nominal 450 megawatt-electric coal-fired facility).

SES is negotiating with the US DOE for Phase I of this project. As part of that proposal to the US DOE, SES has indicated cost sharing and participation by the following entities:

1) Tri-State Generation and Transmission Association - Tri-state is a rural electric power producer in the Midwest that has demonstrated keen interest in SES's. Tri-State provides advisory roles, financial support and dedicates a portion of their staff to SES Phase 2 program.
2) National Rural Electric Cooperative Association (NRECA) - NRECA represents the rural cooperatives and is highly supportive of this work in an effort to evaluate and mature this technology.
3) Rocky Mountain Power –Rocky Mountain Power, as part of the STEP program, has committed to host a pilot-scale facility and financially support the development of this technology.
4) Electric Power Research Institute (EPRI) - EPRI is involved in a technical and economic evaluation of cryogenic capture and is providing cost share to SES's Phase 2 program.
5) Brigham Young University (BYU) - BYU provides fundamental science and engineering support, including Aspen modeling and laboratory experiments, to this project. BYU also provides cost share to SES's Phase 2 program.

For more detailed information, please refer to Appendix B, "Cryogenic CO_2 Capture Testing Proposal – Sustainable Energy Solutions" which has a copy of the proposal and budget submitted by Sustainable Energy Solutions.

Co-funding of University of Utah Phase 1 Pre-feasibility Study of Commercial CO_2 Sequestration Sites in Utah

For this project, Rocky Mountain Power proposes to co-fund and participate in the University of Utah's pre-feasibility study to evaluate the development of commercial scale carbon capture and sequestration (CCS) storage in Utah. This pre-feasibility study is being pursued in response to a Funding Opportunity Announcement (FOA Number DE-FOA-00001584) issued on June 23, 2016 also known as the Carbon Storage Assurance Facility Enterprise (CarbonSAFE). If selected by the US DOE, the University of Utah, and its co-participants, would receive up to $1.2 million to perform the pre-feasibility study. The ability to identify locations that are suitable for commercial scale CO_2 geologic sequestration is a critical issue that must be addressed to reduce the carbon footprint of coal-fired generating stations. The University of Utah and the other participating entities would contribute at least another $150,000 in direct funding or cost share, thereby meeting the 20% minimum participation required by the USDOE to receive funding. This project's objectives, significant leveraged co-funding, and relatively small cost are consistent with the objectives of STEP. This Phase I effort is the first of a series of FOAs the US DOE intends to issue. The US DOE has planned for four phases which are as follows: a) Phase I-Integrated CCS Prefeasibility (this STEP project with an expected duration of 18 months), b) Phase II-Storage Complex Feasibility (expected duration of two years), c) Phase III-Site Characterization (expected duration of two years) and d) Phase IV-Permitting and Construction (with an expected duration of 3.5 years).

For Phase I of this overall program, the US DOE intends to fund up to 12 pre-feasibility studies across the US, with up to $1.2 million per study. In the event the University of Utah proposal is not selected, the $150,000 earmarked for this study would be re-allocated to the NOx feasibility/demonstration project.

Other participants in the study effort with the University of Utah and Rocky Mountain Power include: University of Utah Law School, Utah Geological Survey, Sandia National Labs, Utah Department of Environmental Quality, Schlumberger Carbon Services, Los Alamos National Lab and New Mexico Tech.

The following are excerpts from the US DOE Funding Opportunity Announcement DE-FOA-0001584 that more fully describes the objectives and requirements of the prefeasibility study effort:

> "One of the key gaps in the critical path toward Carbon Capture and Sequestration (CCS) deployment is the development of commercial-scale (50+ million metric tons CO_2) geologic storage sites for CO_2 from industrial sources. There has been relatively little effort by the private sector to identify and certify (i.e., regulatory permit) geologic storage sites that are capable of storing commercial-scale volumes of CO_2, primarily because of the lack of immediate economic incentives. As a result, commercial-scale CO_2 sources that want to develop CCS projects face the risk of not finding a suitable saline storage site for their captured CO_2.
>
> CarbonSAFE is an effort to develop an integrated CCS storage complex constructed and permitted for operation in the 2025 timeframe over a series of sequential phases of development: Integrated CCS Pre-Feasibility, Storage Complex Feasibility, Site Characterization, and Permitting and Construction. Subject to availability of funds, a series of FOAs are planned to accomplish this mission. This FOA, DE-FOA-0001584 - Integrated CCS Pre-Feasibility, is the first in a series of planned FOAs and focuses on the initial phase

of development of the commercial-scale CO_2 storage site.

The overall purpose of this FOA is to conduct pre-feasibility for a commercial-scale CO_2 geological storage complex and demonstrate that the storage sites within the complex have the potential to store CO_2 emissions safely, permanently and economically. Successful applicants to this FOA will identify and perform a pre-feasibility study on a storage complex capable of storing 50+ million metric tons of industrially-sourced CO_2. This FOA will provide funding for the initial stages of development of the commercial-scale CO_2 geological storage, which will include the following activities:

- Formation of a CCS coordination team capable of addressing any regulatory, legislative, technical, public policy, commercial, financial, etc. challenges specific to commercial-scale deployment of the CO_2 storage project.
- Develop a plan for the storage complex and storage site(s) that address the challenges including but not limited to a strategy that would enable an integrated capture and storage project to be economically feasible and publicly acceptable.
- Perform a high-level technical sub-basinal evaluation to identify a potential storage complex with storage site(s), including a description of the geology and risks associated with the potential storage site. Identify and evaluate potential CO_2 sources."

This particular research project was not part of the original list of projects under consideration by the Clean Coal Research group. This item was added after reviewing the Funding Opportunity Announcement from the United States Department of Energy that was issued on June 23, 2016.

For more information on the University of Utah's plan, refer to Appendix C, "CarbonSAFE Proposal – University of Utah."

Evaluate the Potential for CO_2 for Regional Enhanced Coal Bed Methane Recovery

This project would perform a feasibility study to evaluate opportunities to use CO_2 for beneficial use for enhanced natural gas recovery from coal seams, specifically coal seams in the Emery County area. As part of this study, an assessment will be made of the capability of local coal seams to concurrently sequester CO_2.

CO_2 has the potential to be used for enhancing natural gas recovery from coal beds ("coal bed methane") in much the same way it is currently used for enhanced oil recovery. Significant research effort has been undertaken across the United States to identify cost effective CO_2

capture technologies. SaskPower's Boundary Dam project and Petra Nova's WA Parrish project are large utility scale projects that have been constructed or are under construction to use CO_2 injections for enhanced oil recovery.

This proposed project will focus on the potential for recovering coal bed methane in the areas surrounding the Hunter and Huntington power plants which have abundant coal bed methane resources. The project will study options to use CO_2 for enhanced recovery of coal bed methane and the geologic sequestration capacity of the coal seams in the region. The proposed study objectives are:

1) Provide a technical, economic and environmental study on the costs and benefits of this technology, including transportation of CO_2 from a specific source to a specific coal bed methane sequestration area.
2) Determine whether local coal beds are conducive to enhanced CO_2 methane recovery.
3) Propose new technologies for improving CO_2 injection efficiency.

This study concept was developed and defined by the Clean Coal Research team during the development and research area identification phase.

The proposed study would be performed by the University of Utah and the University's Energy & Geoscience Institute. For more detailed information, please refer to Appendix D, "Application/Feasibility for Regional/Commercial Use of CO_2 for Enhanced Coal Bed Methane Recovery," which is a copy of the proposal submitted by the University of Utah - Energy & Geoscience Institute.

Feasibility Assessment of Solar Thermal Integration - Hunter Plant

This proposed project would investigate the potential of integrating solar thermal collection to provide steam and/or feedwater heating into the Hunter 3 boiler/feedwater cycle. Integration of a solar thermal collection system would have the benefit of minimizing coal consumption and the attendant emissions associated with reduced coal use. The study would focus on the application of parabolic solar troughs and would also consider power tower collection systems.

Factors that will be evaluated in the study are:

- Site specific costs and benefits of solar thermal integration at the Hunter Plant
- Steam/feedwater injection points in the boiler feedwater cycle and those impacts on performance,
- Impact on coal consumption and associated emissions,
- Land requirements

The study would be specific to the Hunter Plant, taking into account the solar insolation at that location.

For more information, refer to the proposal in Appendix E, "Solar Thermal Integration, Hunter Plant - Brigham Young University."

Advanced Neural Network Control System at Huntington 2

For this Clean Coal research project it is proposed to install and evaluate a neural network software system on Huntington Unit 2. The project would consist of installing and enhancing third party neural optimization software. The initial objective would be to target combustions with a primary objective of reducing NOx emissions followed by a reduction in the other emissions associated with combustion and then balancing those reductions with unit efficiency improvement. Along with combustion optimization there are other plant processes that may benefit from neural network optimization. This study will explore neural network optimization of those processes as well. Initial combustion study results are anticipated within the first year of the project and additional process objectives will be added during the long-term study of the neural network over the course of the five year STEP program.

For this project, the University of Utah will partner with Rocky Mountain Power and the software provider to install, demonstrate and fundamentally research artificial intelligence technology to improve emissions of coal-fired power systems. The computer software is based on artificial neural networks. Artificial neural networks are data-driven modeling techniques used to mathematically describe complex processes, such as coal combustion for power generation. Artificial neural networks are used to "learn" a specific process, particularly the relationships between inputs (e.g., flow rates, damper positions, etc.) and critical outputs (e.g., NOx emissions, boiler efficiency, etc.), through a mathematical model-fitting routine. Using this model of a process, optimization routines can be used to determine the optimal combination of inputs to give a desired output (e.g., finding the conditions that minimize NOx emissions, maximize efficiency, or a combination of both). Because the process is continually changing as conditions change, the software is used to continuously update the model and re-solve for optimum conditions.

The proposed project has a number of advantages that increase its likelihood of success: 1) the technology has been successfully demonstrated elsewhere, 2) there are a number of research opportunities to improve the technology, specifically as they may apply dynamic optimization due to fast ramping of the plant, 3) the project is relatively low cost, 4) the technology is scalable to other similar units, and 5) the proposed primary research team members are experienced in neural networks and process optimization and are local to Emery County.

Rocky Mountain Power would contract with the University of Utah for setup and implementation of the model, periodic upkeep of the model and assistance in periodic training of plant operators. Rocky Mountain Power would acquire the initial license from the software vendor and will likely renew the annual license fees over the duration of the five-year STEP program provided satisfactory and repeatable improvement is demonstrated.

This project was initiated by Rocky Mountain Power's technical services team and endorsed by the Clean Coal Research team during the development and research area identification phase.

For more information, refer to Appendix F, "Advanced Neural Net Controls - University of Utah," which is a copy of the proposal submitted by the University of Utah with participation by Brigham Young University.

Utility Scale Demonstration of Alternative NOx Emissions Control Technologies

This particular Clean Coal research project is proposed to perform one or more slip stream or full scale demonstration tests of one or more NOx emissions control technologies at the Huntington Plant. The objective of this test program will be to determine if there are one or more emerging NOx control technologies either on a standalone or combined basis that could be installed at the plant that could achieve NOx emissions rates similar to those expected with selective catalytic reduction system (SCR) and at significantly lower cost than an SCR system. The United States Environmental Protection Agency (US EPA) has mandated that PacifiCorp install SCR systems on Hunter Units 1&2 and Huntington Units 1&2 within five years. These four units are fundamentally similar; it is expected that this process would help inform a NOx reduction implementation strategy for these affected units. The targeted NOx emissions rate with an SCR system is 0.07 pounds of NOx per million British thermal units.

STEP Clean Coal research monies will be used to fund all or a portion of these NOx emission control tests. In order to identify which technologies will be tested, a Request for Proposal (RFP) process will be conducted in 2017. Criteria that will be used to select technologies include: 1) an assessment of whether the technology can be installed at full scale, 2) previous operational experience, which includes scale, duration and performance, 3) permitting impacts, 4) expected capital and operating and maintenance costs, 5) an assessment of the long term reliability of the technology and ability to achieve the target emissions rate and 6) the ability of the underlying technology company to provide commercially viable performance warrantees/guarantees. Prior to distribution of the RFP, a Request for Information (RFI) would be issued to determine interest, identify any technology consolidation or partnering opportunities and prepare a short list of potential technology providers for the RFP.

Prior to issuing the RFP for NOx control technologies, it will be necessary to prepare a thorough inventory of one of the four boilers and the backend environmental control equipment. This inventory will need to include all major boiler process conditions including flows, pressures, typical operating states, temperatures, concentrations, materials of construction and fuel composition. A complete and accurate set of detailed drawings of the boiler and environmental control equipment would need to be compiled. As part of that inventory effort, a computation fluid dynamic model may need to be prepared, especially for applications of SNCR technologies.

A number of prospective technologies are currently under consideration; others will be reviewed through the end of 2016. Individual technologies that are currently being considered include: advanced combustion controls, SNCR systems (both with and without chemical enhancers such as hydrogen peroxide), ozone injection and catalytically treated fabric filter bags.

4 Benefits, Public Interest Justification and Compliance with SB115

Seven Clean Coal Research studies and projects have been identified and budgets proposed. These projects and studies were reviewed and prioritized by the Clean Coal Research team during the development and research identification phase. These selected projects meet SB115's definition of Clean Coal technology and its objective "to investigate, analyze, and research clean coal technology" (Senate Bill 115, Section 54-20-104). The benefits of each project are identified in the individual project descriptions found in the previous section.

The selected projects are intended to meet multiple objectives, and include:

1) demonstration projects that will result in measurable reduced emissions,
2) investment in promising technologies and applications that may advance technologies that when fully developed and applied in utility scale that will allow for coal-fired generation resources to operate with reduced carbon emissions,
3) funding and providing opportunities for industry-targeted areas of research that can be performed by Utah's universities, and
4) promotion of Utah's clean energy technology companies.

5 Alternatives Considered

Alternative technologies/studies/projects that were also considered as being potential areas of research under the Clean Coal Research program (but were eliminated from consideration due to their speculative nature or lack of direct tie to the clean coal research legislative intent) are as follows:

- Plant demand side management (VFDs, high efficiency motor retrofits, lighting upgrades, partial turbine upgrades)
- Site specific CO_2 capture studies with conventional amine-based technologiesCO_2 injection characterization studies
- Reduced load operation and enhanced ramping studies
- Solid-supported amines
  Development of catalysts for converting CO_2 into products (beneficial use)

6 Major Project Milestones

The major project milestones for each project can be found in Appendix H.

7 Program Closure, Retirement and Removal Information

In 2021, at the end of the 5-year period, the Company will report back to the Utah Public Service Commission regarding the actual expenditures made for each project, provide a report summarizing the overall study objectives, work performed, findings and results, lessons learned and recommendations for future action. In cases where a project is completed earlier than 2021 (i.e. the Woody Waste Co-firing demonstration at Hunter 3), a report will be prepared and submitted within 120 days of the completion of the project. If the Commission determines that additional reporting would be beneficial, the Company will comply with those requirements.

8 Planned Budgeted Costs

Table 3 identifies the proposed annual expenditures for each of the Clean Coal Research projects. Some minor adjustments in year-to-year spending for each project may occur. Any available excess funds that become available because actual costs are lower than currently forecast will be allocated to the Advanced NOx Controls Technology project.

Table 3

Clean Coal Research – Proposed Project – Estimated Annual Expenditures

	2017	**2018**	**2019**	**2020**	**2021**	**Total**
Woody Waste Co-firing	$612,841	$177,032	$ -	$ -	$ -	$789,873
CO_2-Capture (CCC)	$381,557	$668,301	$125,000	$ -	$ -	$1,174,857
US DOE Sequestration Site Characterization - Phase 1	$150,000	$ -	$ -	$ -	$ -	$150,000
CO_2-Enhanced Coal Bed Methane	$ -	$62,500	$75,000	$62,500	$75,000	$275,000
Solar Thermal Assessment	$ -	$ -	$65,083	$83,083	$38,833	$187,000
Neural Net Implementation	$547,806	$178,924	$216,719	$32,000	$32,000	$1,007,449
Advanced NOx Controls	$100,000	$320,411	$775,000	$220,411	$ -	$1,415,821
	$1,792,204	**$1,407,167**	**$1,256,802**	**$397,994**	**$145,833**	**$5,000,000**

9 Accounting

Costs for each individual project will be monitored and tracked separately. The individual projects will roll up to the Clean Coal Research project created by the company's accounting group under the Sustainable Transportation and Energy Plan. Only costs spent on outside contracted goods and services will be covered by the Clean Coal Research funding. Internal Rocky Mountain Power labor costs will be funded through normal operations.

10 Procurement and Project Delivery Strategy

The Clean Coal STEP initiative is fundamentally a series of research projects in which the proposed plan is to work directly with universities and technology developers and suppliers that provide unique products and services. As such, this directed research program is not conducive to using typical competitive bidding practices. It is expected that the work for each project will be clearly defined and costs for that work negotiated with the entity that will perform the work. With the exception of the Advanced NOx Controls Technologies project, where the potential technologies and/or providers have not yet been identified, it is proposed to award the work to the entity (or entities) stated in the individual project definitions (See Appendices A-F). Typical Rocky Mountain Power contractual commercial terms and conditions will be applied to the extent possible. Applicable engineering specification and design standards will be applied as well as the Company's plant specific health, safety and environmental requirements.

Each project will have its own Rocky Mountain Power project manager.

APPENDICES

- Appendix A - Biomass Co-firing Proposal - University of Utah
- Appendix B - Cryogenic CO_2 Capture Testing Proposal - Sustainable Energy Solutions
- Appendix C - CarbonSAFE Proposal - University of Utah
- Appendix D - Application/Feasibility for Regional/Commercial Use of CO_2 for Enhanced Coal Bed Methane Recovery – University of Utah Earth Geosciences Institute
- Appendix E - Solar Thermal Integration, Hunter Plant - Brigham Young University
- Appendix F - Advanced Neural Net Controls - University of Utah
- Appendix G – Clean Coal Research Team
- Appendix H - Major Project Milestones

APPENDICES

Appendix A

Biomass Co-firing Proposal

University of Utah

Technical Assistance in Support of Biomass Co-firing Demonstration
A Proposal to PacifiCorp

Introduction

PacifiCorp is considering the demonstration of biomass co-firing with pulverized coal at their Hunter plant as one of multiple CO_2 reduction strategies to be evaluated using legislative funding from SB115-54-20-104. This funding is specifically targeted for "a program to investigate, analyze and research clean coal technology."

Faculty members from the University of Utah have considerable experience with coal and biomass/coal co-firing, and are interested in providing technical assistance in support of the proposed biomass co-firing demonstration. Specifically, we are interested in assisting with the planning of the co-firing demonstration, as well as making measurements during the execution of the demonstration, and assisting in the analysis of data obtained during the testing. In addition, we envision several research tasks in support of the demonstration that can be carried out at our Industrial Combustion and Gasification Research Facility.

It is our understanding that the production of the required biomass fuel will be contracted directly with the two proposed suppliers, Amaron Energy and AEG/CoalSwitch. Therefore, our proposed efforts will focus only the technical support tasks. Brigham Young University will also participate in some of the proposed tasks, as well as potentially proposing an additional task, and these efforts will be incorporated into this proposal once they have been identified.

Project Objectives

The primary objectives for the University of Utah participation in the biomass co-firing demonstration are as follows:

1) Assess the mechanical stability and hydrophobicity or water resistance of the two candidate biomass fuels.
2) Perform on-site sampling of particulate matter (PM) in various size ranges during the Hunter plant demonstration. Other measurements may also be taken (e.g., deposition probes, Hg, etc.) if deemed feasible during the campaign.
3) Assist in the analysis of plant data relating to pollutant emissions, boiler performance
4) Perform laboratory studies of the combustion performance of the biomass/coal blends
5) Assessment of PM, CO_2 and other emissions avoided when burning forest biomass in the Hunter plant vs. a forest fire. What are the relative environmental impacts?

Detailed Work Plan

Tasks to be performed by University of Utah personnel, in collaboration with PacifiCorp personnel, are discussed in detail below. Since this proposal is a draft and the overall scope of work has yet to be finalized, limited detail is provided at this stage.

Task 1. Biomass Fuel Handling and Stability ***(UofU)***

This task will explore the potential hazards of the handling of the two different types of biomass fuels. Will the pellets be hydrophobic or at least water resistant? To what degree? Will dry storage facilities be required? How much dust is generated from each during handling (conveying/transfer points, movement around yard, off-loading from transport, etc.). What is the mechanical strength of the respective fuels (how much attrition/dust formation during handling)?

Some quantitative assessment of these attributes can be made prior to the full-scale demonstration using the material provided to the UofU for the milling trials, and this information could prove very helpful in preparing for the Hunter plant demonstration.

Task 2. On-site (Hunter Plant) Measurements During Co-firing Demonstration ***(UofU and BYU)***

In this task, the University of Utah and Brigham Young University will develop and adapt existing hardware for the measurement of particle size distribution and deposition rate during baseline operation and the biomass co-firing demonstration. U of U will build an isokinetic dilution sampling probe that will be long enough to extract particle samples from Hunter, Unit 3 boiler at a location near the primary superheat pendants. BYU will build two temperature controlled deposit sample probes to be installed at the same location in the furnace. Personnel from the U of U and BYU will travel to the plant and take particle size distribution and deposition rate data for several days before and during the biomass co-firing tests. The U of U will also take size segregated particle samples and will later analyze them for chemical composition. These data will be digested and a report will be written for PacifiCorp detailing the difference in mineral matter behavior between the baseline and demonstration periods. These data will also be available for comparison with pilot-scale data for similar operating conditions.

Task 3. Analysis of Boiler Operating, Emissions and Performance Data ***(BYU)***

BYU will visit Hunter, Unit 3 and collect operational data from PacifiCorp engineers and from the DCS system for the periods before and during the biomass co-firing demonstration. These data will be used to build a process model within Aspen of Hunter, Unit 3 for baseline operation and for the biomass co-firing test. This model will be used to evaluate differences in operation between the two period of operation and a report will be written for PacifiCorp detailing these results.

Task 4. Combustion Performance Evaluations ***(UofU)***

Laboratory-scale studies would be carried out to specifically target investigations of pollutant emission levels and ash/deposit properties for the two biomass co-fire blends, as compared to the baseline coal operation. We would use small-scale (100 KW) combustion tests to explore differences in the deposition behavior, flyash characteristics and NOx, SO_2, CO and CO_2 performance for the two different biomass fuels (after pulverizing). Operating conditions representative of Hunter plant operation would be used.

We would use a specially-designed deposition probe and our existing, state-of-the-art aerosol sampling and measurement equipment. We would follow up with similar measurements during the field trials, as described in Task 2.

A recent publication of a biomass co-firing study showed some reduction in NOx beyond that which can be attributed simply to fuel N reduction, or introduction of volatiles (they used biomass char). Thus, there may be an additional NOx benefit due to use of biomass, that could be assessed simultaneously with the ash/deposition study.

These two issues (deposition and NOx behavior) are the subjects of two new NSF grants on biomass co-firing awarded to the University of Utah, so we would be able to leverage those funds to make these studies relatively inexpensive. We could potentially measure other pollutant levels of interest to PacifiCorp at the same time, such as Hg, to quantify any differences between baseline coal firing and co-firing with the two different biomass fuels. We would also quantify LOI levels in flyash, as well as particle size distributions and elemental composition.

All of this information could be obtained in advance of the co-firing demonstration, and could provide guidance for test plans with the full-scale demonstration.

Task 5. Air Quality Assessment of Biomass Co-firing ***(UofU)***

One motivating factor for use of biomass from forest thinning operations is the perceived reduction in particulate matter pollution due to large-scale forest fires in overgrown areas, or from open burning of slash piles of cleared forest materials. This task will assess the environmental impact of displacing coal by burning this biomass in a controlled manner at the Hunter plant, as opposed to open burn or uncontrolled forest fires. Assessment will be made of the relative impact on particulate matter emissions, regional haze, CO_2, VOC, and NOx emissions, air toxics, or other environmental considerations.

The assessment will also consider the following life-cycle stages: extraction, transport, and combustion of the coal; harvesting, transporting, processing, and combustion of the biomass; and combustion of biomass by controlled burns. An overall evaluation of the differences in greenhouse gas emissions and net energy return will also be included.

Project Schedule:

Estimated timelines for each task are shown in the table below. The schedule assumes that the co-firing demonstration at the Hunter Plant would occur sometime in Q5 or Q6 of the program. The schedule can be flexible, to accommodate the needs and objectives of the program.

	Task Description	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
Task 1	Biomass Fuel Handling and Stability								
Task 2	On-site Measurements During Hunter Demonstration								

Task 3	Analysis of Boiler Operating, Emissions and Performance Data								
Task 4	Combustion Performance Evaluations								
Task 5	Air Quality Assessment of Biomass Co-firing								

Budget Estimates:

Estimated budget totals are provided for each task are provided below.

	Task Description	**UofU**	**BYU**	**Total Cost**
Task 1	Biomass Fuel Handling and Stability	$19,243		$19,243
Task 2	On-site Measurements During Hunter Demonstration	$41,785	$37,800	$79,585
Task 3	Analysis of Boiler Operating, Emissions and Performance Data		$25,100	$25,100
Task 4	Combustion Performance Evaluations	$73,864		$73,864
Task 5	Air Quality Assessment of Biomass Co-firing	$25,200		$25,200
Totals		**$160,092**	**$62,900**	**$222,992**

Appendix B

Cryogenic CO_2 Capture Testing Proposal

Sustainable Energy Solutions

Draft Cryogenic Carbon Capture Demonstration Budget

Overview

This document outlines a draft budget for Rocky Mountain Power's (RMP) involvement in the development of Cryogenic Carbon Capture. There are two phases to the proposed involvement, the first phase involves leveraging an existing test system to mature the technology for scale up to a larger pilot scale. This phase will involve some modifications to the existing system and extended testing at a RMP facility. The second phase will involve designing, engineering, building and testing a larger pilot system at a RMP facility. SES anticipates requesting about $1,174,857 from RMP of the total nearly $6 million project in 2017-2018 for the first phase project and up to $3 million in cost share from RMP of the total $20 million project in 2018-2021. The remaining funding for these projects will come from DOE, and other project partners including Tri-State Generation the Electric Power Research Institute and the National Rural Electric Coop Association.

Objective

This document outlines a rough draft of the budget we anticipate requesting from RMP for support in developing the promising Cryogenic Carbon Capture technology. This technology has many promising features including the potential to reduce the cost and energy requirements of carbon capture vs. existing technologies by more than 50%, easily retrofitting to existing plants, robustly handling contaminants like SOX, NOX, and Mercury, adding no additional water demand to the plant, and providing integrated energy storage for load leveling or improved intermittent renewable management. The purpose of this document is not to provide a detailed technology description, more information can be found at http://sesinnovation.com/.

The proposed budget is divided into two phases. The first phase leverages an existing field demonstration system as part of a proposed DOE project to mature the technology and gather critical information in preparation for a scale-up. This first phase will involve several project partners including SES, EPRI, Tri-State, and DOE. The second phase will be a collaborative project between SES, DOE, RMP and others to scale up the technology and demonstrate it at (5-10 MWe). Both of these phases represent significant steps in maturing the Cryogenic Carbon Capture Technology and preparing it for full-scale deployment by 2025.

Field Demonstration Phase

This phase involves improving and development of some key aspects of the technology to increase reliability, efficiency, and scalability of the process. This step also involves extending experimental continuous run times of the current 1 tonne/day demonstration system from about 50 hours to 500 hours in preparation for scale up and bringing cumulative run time up even higher. This step will also involve real-world case studies and refining the techno-economic analysis of the process. We are in agreement with DOE and other stakeholders that this is a critical step for advancing the technology and establishing the scalability and large-scale potential of the technology. Some pictures and diagrams related to this testing are found in the appendix.

The development work will take place during the end of 2016 and 2017 with the field testing being performed in 2018. The appendix contains a summary of the development tasks that will be performed as part of the larger project that will be funded mostly by the US DOE.

The total period of performance for this phase will be about 2.5 years. SES is proposing nine-months of on-site testing at a RMP Plant in Utah starting in 2018. The exact testing dates will be determined later as part of a collaborative pre-run phase and in conjunction with the larger project.

Field Demonstration Phase Budget

A separate proposal has been sent to DOE for the majority of the work required in this phase. While DOE will fund the majority of the development work, some RMP funds are being requested to help with development. Similarly, RMP will pay for the majority of the field testing, but DOE will also contribute a significant portion. The budget below outlines direct costs associated with that development and testing that we will request from RMP this budget of about $1,174,857 will be part of a larger roughly $6 million project funded mostly by DOE and will allow RMP to leverage its money to get a significant return on these research dollars. SES may adjust the scope of the RMP portion of the budget within the larger project if this is deemed beneficial to the overall project. This budget does not include the cost of utilities at the plant, or any modifications required at the plant. We anticipate the cost of connecting to electricity and flue gas will be minimal and don't anticipate needing any additional structural support in place for this small test system. There is a possibility for RMP to get involved to a greater extent in this phase if that is determined to be of benefit.

This budget is divided into a pre-run and development and a field test phase. The pre-run and development phase will begin in the first quarter of 2017 and will involve minor funding of the development work outlined in the appendix, planning with RMP, site visits to potential host sites, hazard and environmental identification and reviews with RMP, sharing of detailed information regarding flue-gas composition, permitting, etc. This phase will also involve pre-run preparations of the skid including any necessary modifications for pre-treatment of the flue-gas, preparing electrical, water, and flue-gas lines of appropriate lengths, and purchase of spare parts and equipment for the anticipated extended runs.

Cryogenic Carbon Capture Demonstration				
	Total	**2017**	**2018**	**2019**
Pre-Run and Development Budget	**$515,700**	$356,557	$159,144	
Field Test Run				
Lodging, M&I Expenses	**$76,190**		$ 76,190	
Transportation	**$17,100**		$ 17,100	
Salaries	**$255,487**		$255,487	
Loading & Transportation	**$7,000**		$ 7,000	
Liability Insurance	**$45,000**		$ 45,000	
Supplies & Consumables	**$0**		$ 0	
Temporary on-site work space	**$20,000**		$ 20,000	
Water Treatment & Disposal	**$10,000**		$ 10,000	
Overhead for Supplies and Travel	**$53,380**		$ 53,380	
Consulting	**$75,000**	$25,000	$25,000	$25,000
Capital Cost Assessment (Scale Up)	**$100,000**			$100,000
Total	**$1,174,857**	$381,557	$668,301	$125,000

Scaled-Up Pilot Phase

Following the Field Demonstration Phase, SES will be prepared to scale up the technology to a 5-10 MWe pilot demonstration. While the objective of the smaller-scale field demonstration phase will be to demonstrate the scalability of the technology, the scaled-up pilot phase will have the objective of showing better energy performance than currently available technology even at a full scale. This phase will involve designing, engineering, and building a new system at a scale that will be a slip stream from an existing plant, but will be commercial scale for many small industrial applications. This project will cost about $20-25 million total and will begin in 2018-2019. The majority of this funding will come from other sources, but SES will be looking for up to $3 million in funding from RMP as a partner in this project.

Appendix

Development Tasks

Task 2.0 – Drying

Objective

The objective of this task is to decrease the energy consumption and CO_2 absorption in the final flue gas drying stages of CCC.

Planned Approach

The Recipient will investigate state-of-the-art adsorption and phase change drying processes as well as alternative drying techniques. The Recipient will explore several approaches theoretically using its in-house software and process analysis system - Thermodynamic Analysis and Design Software (TAD) and Sustainable Thermodynamic Energy Process Software (STEPS), literature available from similar processes, and industrial experience. The Recipient will explore the most promising approach experimentally using the Cryogenic unit-operations bench (CUB) and compare the performance with the theoretical expectation. If necessary, the Recipient will explore some of the other approaches experimentally. The Recipient will strive to achieve agreement between theoretical and experimental analyses in determining the optimal solution.

Task 3.0 – Dissolved Carbon Dioxide

Objective

The objective of this task is to eliminate the accumulation of dissolved CO_2, solid CO_2, and other possible impurities in the CCC process.

Planned Approach

The Recipient will investigate options to mitigate potential heat exchanger fouling. The Recipient will explore each option theoretically using publicly available experimental data sets, its in-house software and process analysis system - TAD and STEPS, literature available from similar processes, and industrial experience. The Recipient will explore the most promising approach experimentally using the CUB, thermodynamic test cell (TTC), and small-scale flow reactor (SSFR) and existing heat exchanger systems and compare the performance with the theoretical expectation. If necessary, The Recipient will explore multiple approaches experimentally. The Recipient will strive to achieve agreement between theoretical and experimental analyses in determining the optimal solution.

Task 4.0 – Solid–Liquid Separation

Objective

The objective of this task is to improve the reliability and performance and to decrease the energy consumption of the solid–liquid separation process.

Planned Approach

The Recipient will investigate several alternative solid–liquid separation operations that could improve this unit operation. The Recipient will explore each alternative theoretically using its in-house software and process analysis system – TADS and STEPS, literature available from similar processes, and especially information from industrial applications of this equipment. The Recipient will explore the most promising approach experimentally using the CUB and the CCC-ECL™ skid and compare the performance with the theoretical expectation. If necessary, The Recipient will explore additional approaches experimentally. The Recipient will strive to achieve agreement between theoretical and experimental analyses in determining the optimal solution.

Task 5.0 – Heat Exchanger Testing

Objective

The objective of this task is to explore the relative merits of the three desublimating heat exchanger designs in a commercial-scale implementation of CCC.

Planned Approach

The Recipient will analyze the previously tested spray tower and fluid bed heat exchanger designs theoretically using its in-house software and process analysis system – TADS and STEPS. The existing versions of these heat exchangers will then be modified or replaced as needed. This also includes theoretical and experimental analyses of the patent-pending dynamic heat exchangers. All heat exchangers that show significant theoretical performance improvements will be tested using the CUB with CO_2-laden light gases. The CCC-ECL™ will provide the test bed if effective testing requires more integrated unit operations than are available in the CUB. All systems will be compared based on efficiency, reliability, and scalability and overall process techno-economics. Additional figures of merit for this task:

1. Footprint
2. Pressure drop
3. Complications to the balance of process

The Recipient will compare the performance with the theoretical expectation. The Recipient will strive to achieve agreement between theoretical and experimental analyses in determining the optimal solution.

Task 6.0 – Instrumentation and Controls

Objective

The objective of this task is to extend the skid testing time through improved controls, instrumentation, and unit operations.

Planned Approach

The Recipient will modify the CCC-ECL™ skid to implement measurements and controls that can be used to improve several aspects of the process, including:

1. solids loading in the slurry,
2. CO_2 content in the melter, and
3. pressure drop across the solids separator into the melter.

The Recipient will implement additional controls and measurement points as necessary to provide as complete automation as possible and to provide the data needed for detailed comparisons and forensic analysis with process simulation software. Additional figures of merit specific to this task include:

1. amount of operator attention/intervention required
2. ability to follow flow transients and upsets

Task 7.0 – Light-Gas Dispersal

Objective

The objective of this task is to explore issues with light-gas dispersal when the gas temperature is near room temperature.

Planned Approach

The Recipient will investigate several options for managing the light gas stream produced by the CCC process. The Recipient will explore each option theoretically using its in-house software and process analysis system – TADS and STEPS, and literature available from similar processes. The Recipient will explore the most promising approach experimentally using the CUB and compare the performance with the theoretical expectation. If necessary, the Recipient will explore some of the other approaches experimentally. The Recipient will strive to achieve agreement between theoretical and experimental analyses in determining the optimal solution.

Task 8.0 – Multi-Pollutant Capture

Objective

The objective of this task is to develop models that describe CCC capture of pollutants other than CO_2 and to validate these models with experimental data.

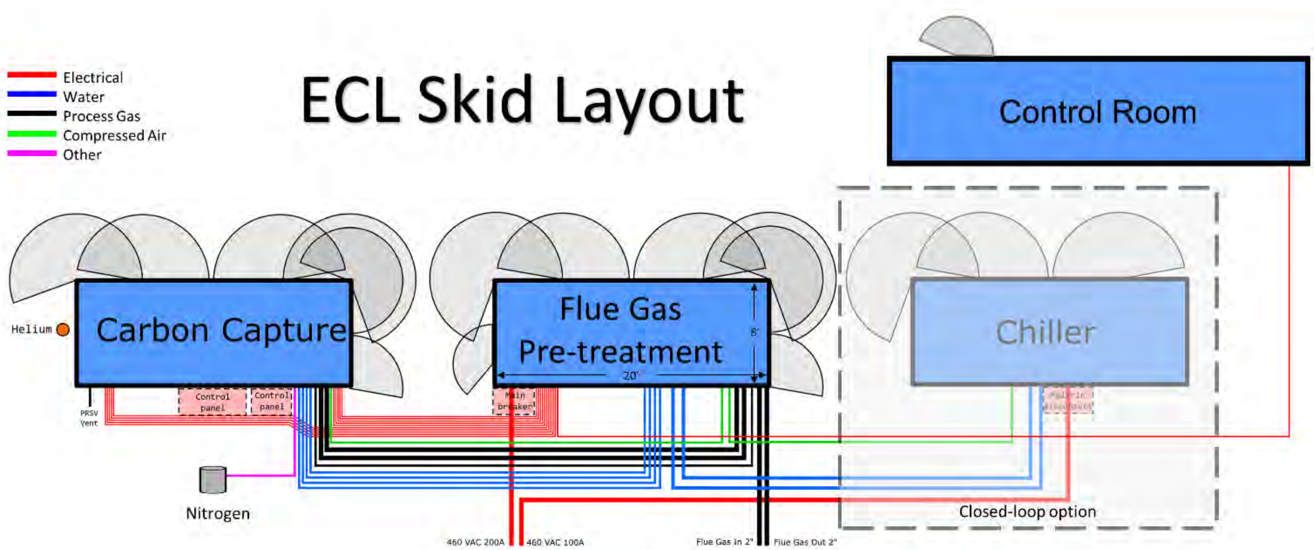
Planned Approach

The Recipient will develop predictive capability for the fate of sulfur dioxide (SO_2), nitrogen oxide (NO), nitrogen dioxide (NO_2), mercury (Hg), particular matter particles that are 2.5 to 10 micrometers in diameter (PM_{10}), particulate matter particles that are 2.5 micrometers in diameter or smaller ($PM_{2.5}$), and hydrogen chloride (HCl) that is verified by experimental measurements using the equipment discussed below and existing analyzers. The Recipient does not possess analyzers, nor does the Recipient believe analyzers exist anywhere, that can make on-line Hg measurements at the levels Hg should occur in the anticipated outlet stream. Even accumulation measurements have fallen short of detecting Hg. Therefore, the Hg data will be largely theoretical or extrapolations of higher concentration data.

The Recipient's analyses will be based on modifications to the exiting in-house process modeling software. Additionally, the Recipient will use a sub-Recipient to develop Aspen models to facilitate communication of results. Experimental data, which will include data from the Recipient's unit operations bench CUB and possibly the small-scale flow reactor at the sub-Recipient's facilities, will validate the analyses. Analyzers will include gas chromatograph (GC), mass spectrometer (MS), Fourier transform infrared spectroscopy (FTIR) spectrometer, nondispersive infrared sensor (NDIR) systems for composition and a Coriolis meter for determining solids loading in the slurry. These systems will provide species composition of the liquid and vapor phases, including possibly two liquid phases, at conditions of interest to the process. The solid phase is assumed to be pure CO_2 and has not yet been reliably sampled under pressurized, cryogenic conditions. It is not clear that solid sampling is necessary, but a measure of the amount of solids would be beneficial. The Recipient anticipates developing thermodynamic expressions for the multi-phase, multi-component analyses and chemical kinetic expressions for some of the gas species. The Recipient has already established miscibility gaps under some conditions in the solid–liquid-liquid-vapor hydrocarbon-CO_2 liquid system near the CO_2 melting point and pressure-sensitive kinetic constraints in the NO (but not NO_2) and possibly the SO_2 capture rates. These behaviors illustrate the potential complexity of both the thermodynamic and kinetic behavior of these systems.

Pictures and Diagrams

Pictures of Field Demonstration Unit and Diagram of 3-skids that house the field demonstration unit in addition to a mobile, temporary on-site work space.



Q&A from Previous Email

1. A brief description of what SES next development/pilot test steps would be to advance the technology?
    a. There are two development steps that we would like Pacificorp to consider:
        i. The near term step involves improving some key aspects of the technology to increase reliability, efficiency, and scalability of the process. This step also

involves extending experimental continuous run times of the current 1 tonne/day demonstration system from about 50 hours to 500 hours in preparation for scale up and bringing cumulative run time up even higher. This step will also involve real-world case studies and refining the techno-economic analysis of the process. We are in agreement with DOE and other stakeholders that this is a critical step for advancing the technology and establishing the scalability and large-scale potential of the technology.

ii. The following development step will be a 5-10 MWe pilot system that will demonstrate better energy performance than projections for full-scale amine systems and long-term performance and reliability.

2. Time required to perform additional pilot testing
    a. We are currently performing some design modifications and operational optimizations along with some short-term test runs for the current 1 tonne/day system, this will take about 12-months. Following these modifications we would like to perform field tests resulting in a minimum continuous demonstration of 500 hours, and many more cumulative hours of demonstration time. This will involve 6-9 months of testing on-site at a host power plant. All together phase will take about two years to complete.
    b. The 5-10 MWe pilot demonstration system will then take approximately 3 years with about 12-months of engineering and design work, 12-months of construction and fabrication, and 12-months for demonstration. The demonstration time could continue beyond this, but would not be necessary to evaluate the technology.
3. A summary of the costs to perform additional pilot testing to advance the technology?
    a. The modifications and additional testing for the 1-tonne/day system described above will cost about $3.5 million with some of this funding potentially coming from DOE or other sources.
4. The 5-10 MWe pilot project as described above will cost $15-25 million depending on the scope of the demonstration and size of the unit selected. We anticipate that a significant portion of this funding could also come from DOE, but will not be available until late 2018.

5. Physical requirements for the next stage of pilot testing:
    a. The table below outlines physical requirements for both systems:

	Skid-Scale 1-tonne/day system	**5 MWe Pilot Scale System**
Power Requirement	250 kVA peak @ 480 VAC	1.4 MW at 4700 VAC

	200A for the main system 100A for the water chiller	
Water requirements	None (closed loop)	700 GPM at 59 degF (Additional cooling water if temperature is higher)
Facility	None (operated from control room in skid)	TBD
Concrete Pad	Space for 3x 8’x20’ conex shipping containers weighing approximately 17,000 lbs each.	55’x55’ footprint <150 lb/ft^2

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Larry L. Baxter

Education

1983 - 89 Brigham Young University Provo, UT

Ph.D. Chemical Engineering (major)

- Dissertation title: Turbulent Transport of Particles
- Outstanding Graduate Student Program at Sandia National Laboratories' Combustion Research Facility (6 months)

1977-78, 1980-83 Brigham Young University Provo, UT

BS Chemical Engineering (major), Chemistry (minor), Mathematics (minor) – graduate with high honors

- Kimball scholar (most prestigious academic scholarship offered at BYU)
- President of American Institute of Chemical Engineers student chapter – recipient of outstanding student chapter award
- Member of Tau Beta Pi and Sigma Xi

Professional experience

2000-present Brigham Young University Provo, UT

Professor, Chemical Engineering

- J. J. Christensen Professor for Thermochemical Sciences (2000-2005).
- Research focus: sustainable energy systems – includes substantial experimental and theoretical activities.
- $37M (PI) in research funding awarded including SES awards, 27 grad students, 330 UG students, > 100 journal papers, book chapters, encyclopedia articles, etc., 12 patents/patent applications

2007-present Sustainable Energy Solutions, LLC Orem, UT

Cofounder, Technical Director

- Developing carbon capture technology for CO_2-containing effluents that is approximately 50% cheaper and more energy efficiency than leading alternatives, as independently confirmed large international engineering firms and national labs.
- Demonstrated process at power plants at scales up to 1 ton CO_2 per day.

1987-2000 Sandia National Laboratories Livermore, CA

Member/Sr. Member/Principal Member of Technical Staff

- PI for Multifuel Combustor Laboratory – by far most frequently visited laboratory at Sandia's Combustion Research Facility
- Developed world-wide expertise in low-grade fuel experimental and theoretical combustion
- Hosted over 60 long-term visitors

Memberships

- ASME National Nominating Committee (2005-2008)
- Member AIChE (lifetime), ASME (lifetime), and ASTM

Volunteer

- 2 meetings/wk + 1 weekend a month with various youth groups (for 22 years)
- Helped organize 2-year "Introduction to Engineering" course in local high school
- Founding member of Computer Academy, Oakland Technical High School
- Precinct chairman for political party
- Member of lay ecclesiastical leadership

Courses Taught

Undergraduate: Fluid Mechanics, Separations, Career Skills, Freshman Seminar, Unit Operations Lab, Energy Engineering, Nuclear Engineering, Statistics for Engineers

Graduate: Combustion, Directed Studies (review of graduate thermodynamics, kinetics, and transport), Writing, Statistics for Engineers, Seminars

Recent Awards

Year	*Organization*	*Award*	*Citation*
2005	Western States Catalysis Club	1st Place Best Paper Award	Guo, X. C. Bartholomew, W. Hecker, and L. Baxter, Field and laboratory results of SCR deactivation suring low-rank coal and biomass-coal cofiring combustion, Feb, 2004
2005	Combustion Institute	Bernard Lewis Fellowship	Sustainable Energy and Biomass Combustion Visiting Lecturer Fellowship
2005	BYU College of Engineering and Technology	Outreach Award	UG Student-selected Education Award – College Level
2006	BYU College of Engineering and Technology	Outstanding Faculty Award	College/department-selected award – one per department
2008	BYU	Wesley P. Lloyd Outstanding Graduate Educator	University-wide award given annually to one faculty member for outstanding graduate education (course work, research, and thesis advising)
2008	Electric Power Conference	Invited US Keynote Speaker – Biomass Cofiring	Invited US speaker to international colloquium on biomass utilization
2008	American Association for the Advancement of Science	Invited Keynote Speaker – Gasification	Invited US speaker to international conference
2009	Brigham Young University College of Engineering and Technology	Outstanding Researcher	College-wide award for research accomplishments – one in the college
2009	Utah Technology Council	Innovation Award	1st place state-wide competition for innovative small businesses in energy
2009	Stoel-Rives	Concept to Company	2nd place state-wide competition for innovative small businesses
2009	Canadian Research Council	Keynote Speaker	Renewable Energy Options for Biomass
2010	Brigham Young University	Karl G. Maeser	Extraordinary research and creative work (campus wide)
2010	Korean Government	Keynote Speaker	Green Energy Conference (only US keynote speaker)
2013	Province of Alberta, Canada	DB Robinson Lecturer	Provincial award given to one person each year for contributions to engineering
2016	Utah Valley Magazine	Fab 40 Recipient	
2016	Edison Award (Edison Universe)	Gold (highest award, 1 given per category per year)	Cryogenic Carbon Capture™ nearly eliminates all emissions from fossil-fueled power plants at half the cost of alternatives while enabling greater adoption of solar and wind through built in, grid-scale energy storage.

Appendix C

CarbonSAFE Proposal

University of Utah

CarbonSAFE Rocky Mountains Phase I: Ensuring Safe Subsurface Storage of CO_2 in the Intermountain West

The Rocky Mountains of the western U.S. (Figure 1) contain and produce over 50% of all coal in the country (U.S. Energy Information Administration, 2014). Coal-fired power plants dominate the Rocky Mountain region (Figure 2), and that coal-power provides over **XX** GW of electricity for the intermountain west. Natural gas prices are low in 2016, but extensive pipeline networks will be required for switching fuels from coal to natural gas; and, prices for natural gas may not remain low. For the time being, perhaps decades to come, coal will be the least expensive option due to existing plants and coal transport systems, and extensive coal resources in the Rocky Mountain states.

Figure 1. Outline (red shade) of the Rocky Mountains in the western U.S. The focus of this proposal are power plants depicted in Figure 2, with the Hunter Plant as the prime example and case study site.

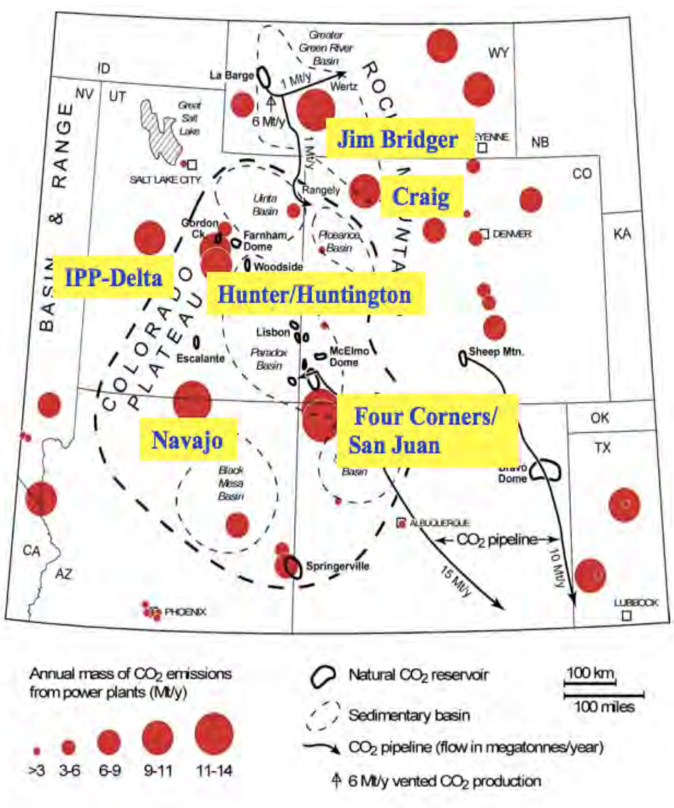

Figure 2. Location of major sources of CO2 emissions from fossil fuel power plants in the Southern Rocky Mountains-Colorado Plateau, with size of the red dots proportional to emissions (in millions tons/year, after Hovorka, 1999). The six largest power plant sites are labeled, including the Hunter Power Plant (near the Huntington Plant, also owned and operated by PacifiCorp and Rocky Mountain Power). Source of graphic: PacifiCorp, 2003.

CarbonSAFE Rocky Mountains Phase I will form of a CCS coordination team capable of addressing regulatory, legislative, technical, public policy, commercial, financial, and other challenges specific to commercial-scale deployment of CO_2 storage for both existing coal-fired power plants in the Rocky Mountain states as well as new plants powered either by coal or natural gas. CarbonSAFE Rocky Mountains Phase I will review and assert the best storage targets for power plants in the region. The project team will develop an optimized plan based on an operating power plant in central Utah, the Hunter Plant near Castle Dale, Utah, a 1.3 GW power plant owned and operated by PacifiCorp and Rocky Mountain Power. The plan will compare and contrast the range of possible injection sites and storage reservoirs, and identify those permutations with minimum risk, maximum storage efficiency, and minimum cost. The plan will include but not be limited to a strategy that would enable an integrated capture and storage project that is economically feasible and publicly acceptable. The CarbonSAFE Rocky Mountains Phase I CCS coordination team will conduct a high-level technical sub-basinal evaluation for potential storage sites near the Hunter plant. A major hypothesis of this proposal is that the optimum storage site for the Hunter plant is the power plant site itself, which would minimize CO_2 transport costs and optimize regulatory planning. However, all practical storage (injection) sites will be identified and compared using a state-of-the-art systems analysis of competing costs as well as regulatory and technical requirements including permitting, capture, compression, transport, injection and monitoring.

The primary outcome of the CarbonSAFE Rocky Mountains Phase I project will be a template protocol for existing and future coal-fired and natural-gas-fired plants in the Rocky Mountain states, with PacifiCorp's Hunter Plant as the representative example of a typical generating station in the Rocky Mountain west.

CarbonSAFE Rocky Mountains Phase I Team and Roles

PacifiCorp	Plant Operator and Power Sector Requirements
Utah Geological Survey	Geologic Characterization
New Mexico Tech	Seismic and Geologic Characterization
Los Alamos National Lab	Systems Analysis (Economic-Technical)
Sandia National Lab	Caprock Characterization
Schlumberger Carbon Services	Injection/Monitoring Well Design and Risk Assessment
University of Utah	Project Management, Simulation and Risk Assessment
University of Utah Law School	Legislative and Other Policy Requirements
Utah Department of Env. Quality	UIC and Other Permitting Requirements
Stakeholder Advisory Board (Under Assembly)	Advice on Non-technical CCS Requirements and Public Relations

References

U.S. Energy Information Administration, 2014, Annual Coal Report 2014, full text downloadable at http://www.eia.gov/coal/annual/pdf/acr.pdf.

PacifiCorp, 2003, http://www.pacificorp.com/content/dam/pacificorp/doc/Environment/Stakeholder_Groups/IGCC_1.pdf.

BRIAN J. O. L. MCPHERSON

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University of Utah
Salt Lake City, Utah 84112
Email: b.j.mcpherson@utah.edu

EDUCATION and TRAINING

Ph.D. in Geophysics, *1996*, University of Utah, Salt Lake City.
Dissertation: *Three-Dimensional Model of the Geologic and Hydrodynamic History of the Uinta Basin, Utah: Analysis of Overpressures and Oil Migration*.
Advisors: David S. Chapman (University of Utah) and John D. Bredehoeft (USGS)
M.S. in Geophysics, *1992*, University of Utah, Salt Lake City,
Thesis: *Geothermal Analysis of the Powder River Basin, Wyoming*
Advisor: David S. Chapman
B.S. in Geophysics, *1989*, University of Oklahoma, Norman
Senior Thesis: *Annealing of etchable fission-track damage in F-, OH-, Cl- and Sr-apatite*
Advisor: Kevin D. Crowley

RECENT APPOINTMENTS

USTAR Professor of Civil and Environmental Engineering, *August, 2006* **-** *Present***,** Department of Civil and Environmental Engineering, University of Utah (faculty post endowed by USTAR, the Utah Science, Technology and Research initiative).

TEN RELATED PUBLICATIONS

Dai, Z, R Middleton, H Viwanathan, J Fessenden-Rahn, J Bauman, R Pawar, S-Y Lee, and *B McPherson*. **2014**. "An integrated framework for optimizing CO2 sequestration and enhancing oil recovery." **Environmental Science and Technology Letters**, 1:49-54, American Chemical Society, http://pubs.acs.org/doi/abs/10.1021/ez4001033.

Tian, H., F. Pan, T. Xu, and *B.J. McPherson*, **2014**. Impacts of hydrological heterogeneities on caprock mineral alteration and containment of CO2 in geological storage sites. **International Journal of Greenhouse Gas Control,** 24: 30–42, http://dx.doi.org/10.1016/j.ijggc.2014.02.018.

Moodie, N., *McPherson, B*., Lee, S., and Mandalaparty, P., **2015**, Fundamental analysis of heterogeneity and relative permeability on CO2 storage and plume migration, **Transport in Porous Media, 104(2): 2-26**, http://dx.doi.org/10.1007/s11242-014-0377-5.

Lee, S. J., *McPherson, B. J.,* Vasquez, F. G., **2015**, Leakage pathway estimation using iTOUGH2 in a multiphase flow system for geologic CO2 storage, **Environ Earth Sci** (2015) 74:5111-5128, http://dx.doi.org/10.1007/s12665-015-4523-3.

Han, W. S., *McPherson, B.J.*, **2009**, Optimizing geologic CO2 sequestration by injection in deep saline formations below oil reservoirs. *Energy Conversion and Management*, Vol. 50, No.10, 2570-2582, doi:10.1016/j.enconman.2009.06.008.

White, M.D., *B.J. McPherson*, R.B. Grigg, W. Ampomah, M.S. Appold, **2014**, Numerical Simulation of Carbon Dioxide Injection in the Western Section of the Farnsworth Unit, **Energy Procedia**, Volume 63, 2014, Pages 7891-7912, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2014.11.825.

McPherson, B. J. O. L. and Sundquist, E. T., **2009**, editors, Carbon Sequestration and its Role in the Global Carbon Cycle, AGU Monograph Series, Publisher: American Geophysical Union, Washington, D.C., doi:10.1029/2009gm01308.

Weon Shik Han and *Brian J. McPherson*, **2008**, Comparison of Two Different Equations of

State for Application of Carbon Dioxide Sequestration, Advances in Water Resources, v. 31, p. 877–890, http://dx.doi.org/10.1016/j.advwatres.2008.01.011.

Han, Weon Shik, *McPherson, B.J*., P.C. Lichtner, Wang, F.P., **2010**, Evaluation of CO2 trapping mechanisms at the SACROC northern platform, Permian basin, Texas, site of 35 years of CO2 injection. American Journal of Science, 310, 282-324, doi:10.2745/04.2010.03.

Heath, J. E., Dewers, T. A., *McPherson, B. J. O. L*., Petrusak, R., Chidsey, T. C., Rinehart, A. J., and Mozley, P. S., **2011**, Pore networks in continental and marine mudstones: Characteristics and controls on sealing behavior, Geosphere, 7, 429–454, doi: 10.1130/GES00619.1.

SYNERGISTIC ACTIVITIES

Dr. McPherson is Director of the Southwest Regional Partnership on Carbon Sequestration. Dr. McPherson formed the Southwest Partnership project in 2003, one of seven regional partnerships funded by the U.S. Department of Energy to evaluate the science and technology of storage of atmospheric carbon in underground geological formations and in surface soil and vegetation. More information about the project is accessible online.

Appendix D

Application/Feasibility for Regional/Commercial Use of CO_2 for Enhanced Coal Bed Methane Recovery

University of Utah -

Earth Geosciences Institute

Application/Feasibility for Regional/Commercial Use of CO2 for Enhanced Coal Bed Methane Recovery (Study)

Department of Chemical Engineering and Energy & Geoscience Institute
University of Utah

Synopsis:

Long-term sequestration is a desirable complement to above ground technologies for improving plant efficiency and highgrading carbon dioxide streams. CO2 has a preferential adsorptive affinity to methane that is present in coal below ground. If carbon dioxide is injected into unmineable coal seams in Utah, it preferentially displaces (and allows production) methane and replaces the methane within the coal. Methane is produced from - and carbon dioxide is sequestered in - deep, unmineable coals.

Objectives:

Evaluate opportunities in Carbon and Emery Counties to:

1. Use CO_2 or flue gas beneficially to produce natural gas from coalbed seams.
2. Concurrently, permanently sequester the carbon dioxide or flue gas that has been locally generated.

Background:

Coalbed methane has been a viable natural gas production string since the 1980s. Unlike conventional natural gas stored by compressibility in pore space, methane in coal is physically adsorbed to the surface of the coal. Following production of the water that is in the cleats in the coal, reduction in pressure will encourage the methane to desorb and be produced. Hydraulic fracturing is often required to provide conductive pathways for this desorbed gas to move to the wellbore. This is shown by the isotherm in Figure 1. That figure shows a reduced adsorptive capacity for methane as the pressure in the reservoir is reduced. This means that as the reservoir pressure depletes during production, methane will be produced.

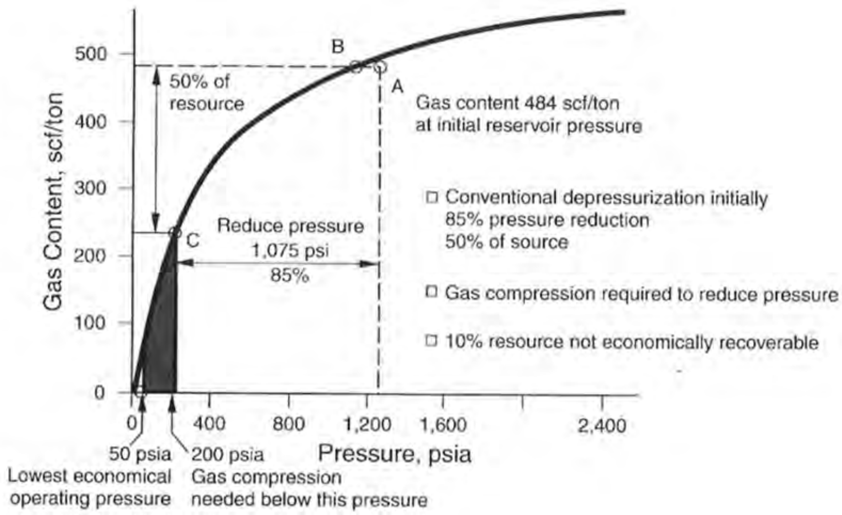

Figure 1. This is an example of an isotherm for methane stored by adsorption in a typical coal. As can be seen by the name the temperature is constant. In fact, the adsorptive potential reduces as temperature increases. At constant temperature 1) the amount of methane adsorbed increases as the pressure (representing the reservoir pressure) increases, and 2) reciprocally, as the pressure decreases methane will be produced because the reservoir's adsorptive capacity is reduced. Notice that a significant quantity of methane remains (and will not be produced) at lower pressures. (courtesy of Halliburton)

The bulk of the production requires significant drawdown (and ultimately depletion). In fact, the shaded area in Figure 1 schematically denotes the pressure in the wellbore below which artificial lift (pumping or compression) would need to be implemented to recover the substantial volumes of remaining gas – with attendant costs. Figure 2 shows an example of declining production in a prominent Utah coalbed methane play. Other examples throughout the state and the country are similar. One initial question to keep in mind is *"How can this residual gas be recovered more economically?"*

Insight into possible methods can be gained by comparing the adsorptive capacity of different gases. Figure 3 demonstrates that carbon dioxide has a greater affinity (more gas will be adsorbed at a particular temperature and pressure) than methane. In fact, carbon dioxide will displace methane from coal. This means that if you inject carbon dioxide into a methane-saturated coalbed, the carbon dioxide will be adsorbed and methane desorbed/produced.

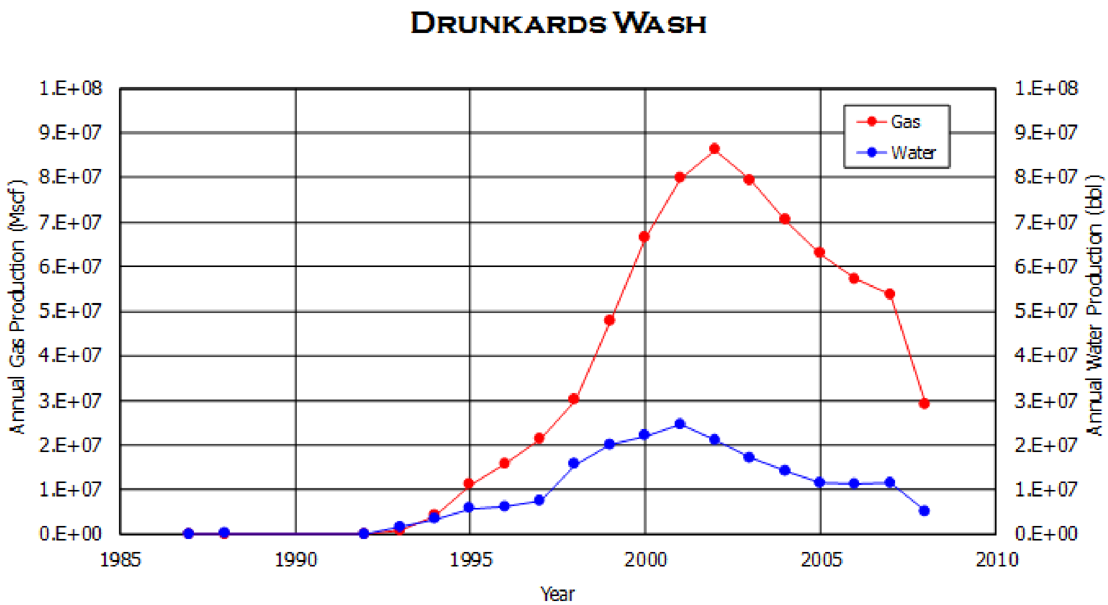

Figure 2. Quarterly production data from the Drunkard's Wash field in Carbon County Utah. There are various reasons for the decline some of them related to depletion, some related to gas pricing. Regardless, there is methane remaining in-situ.

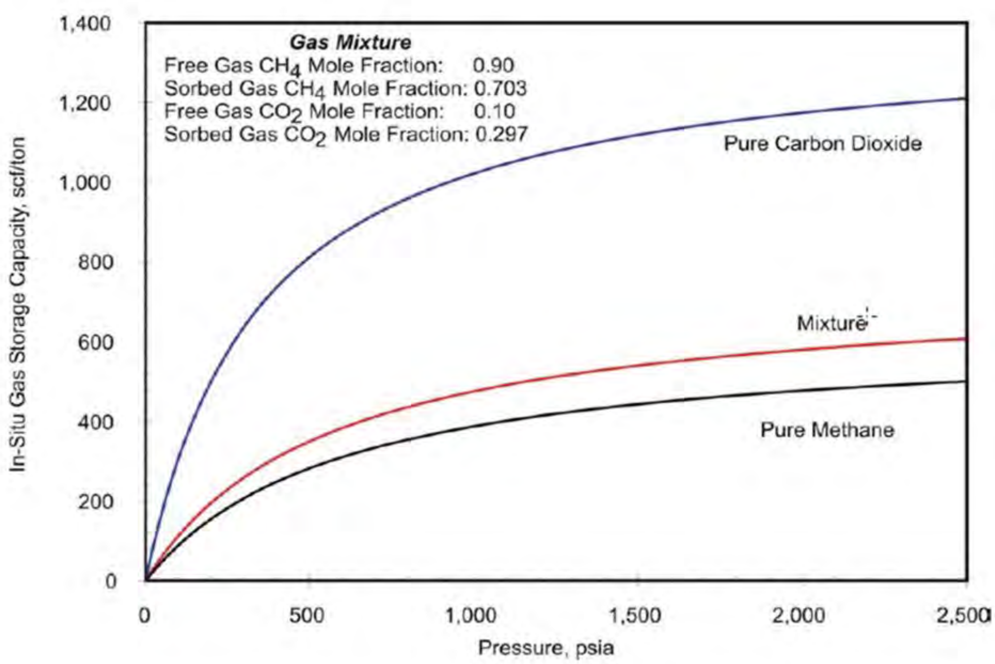

Figure 3. Isotherms on nominally equivalent samples where the sorbates varied from methane to carbon dioxide. A blend falls between the two extremes. Two features stand out. The first is that substantially more carbon dioxide is adsorbed in this coal than methane. The second aspect is that there is a tremendous affinity for carbon dioxide at low temperatures.

Recognizing the potential for carbon dioxide replacing methane in situ, pilot testing was undertaken several decades ago. For example:

- Burlington Resources (ConocoPhillips) carried out long-term CO2/N2 Injection into the Allison and Tiffany Units, San Juan Basin. Figure 4 shows data from the Allison pilot.
- Nitrogen functions somewhat differently than carbon dioxide. The process is methane stripping (partial pressure of methane reduced causing desorption to achieve partial pressure equilibration). Since nitrogen is not adsorbed, there is likely to be more rapid breakthrough of the injected gas from the injection well into the production well. This is undesirable because the pathway developed is a short circuit and less of the reservoir is exposed to the injectate (recovery of the methane is reduced. Data from the nitrogen pilot in the Tiffany unit are shown in Figure 5.
- Carbon Dioxide results in methane displacement by preferential adsorption.
- BP (Amoco) has strong patent positions (may have expired)
- ARC Alberta Innovates)– Fenn-Big Valley, Alberta; and China
- Southwest Partnership Fruitland Coal injection project
- Likely more recent pilots and testing programs.

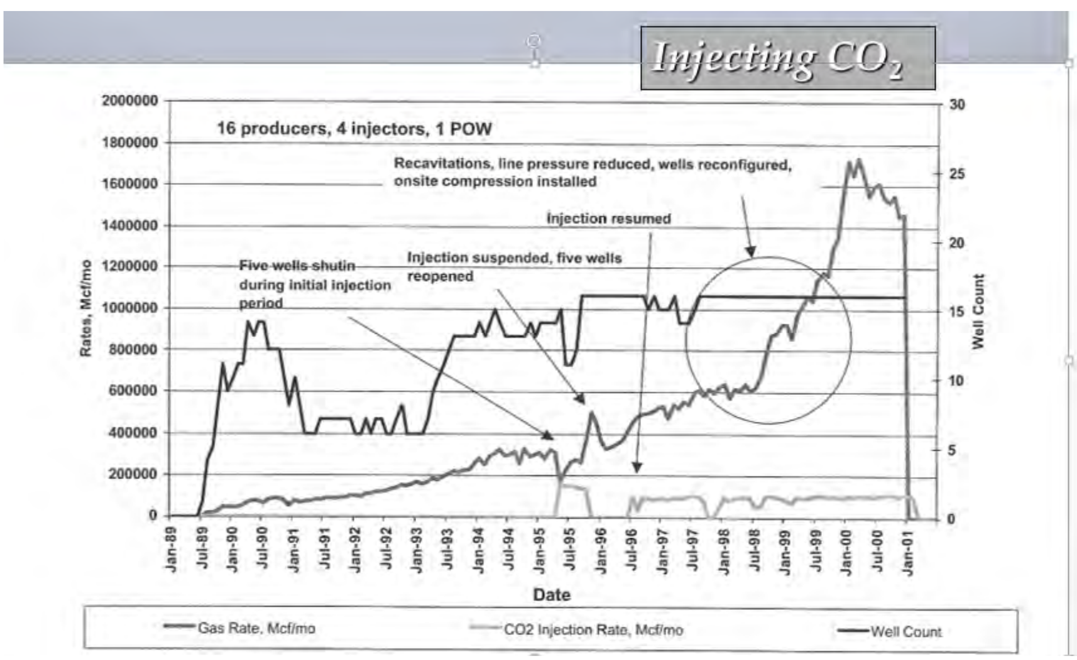

Figure 4. Over the course of 5 years, 4.7 Bcf of CO2 were injected and there was an incremental recovery of 1.5 Bcf of natural gas. These data are from the Allison Unit and the CO2:CH4 ratio was 3.1:1.0.

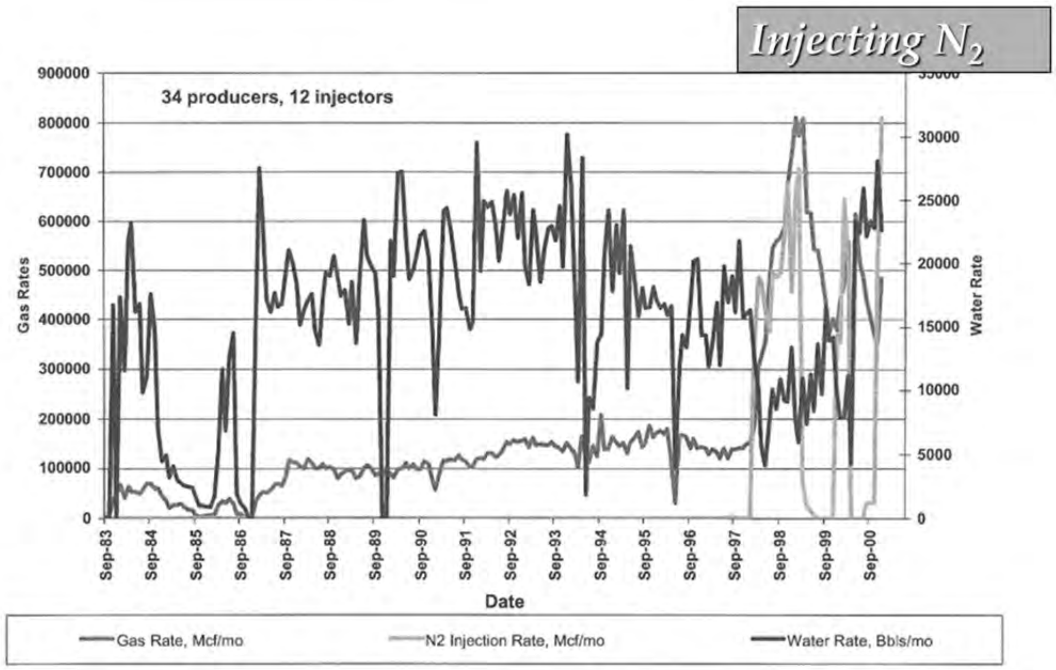

Figure 5. Nitrogen was injected into the Tiffany Unit. N2 injected over 4 years. There was a fivefold increase in methane production but early breakthrough occurred in 11 or 12 wells.

Challenges:

It seems that there is an elegant way – by injecting CO2 – to displace residual methane and sequester the CO2. This is true but there are some hurdles. The major hurdles are:

1. **Volumetrics:** The available subsurface volume will need to be assessed.
2. **Swelling:** CO2 adsorption causes the coal matrix to swell. Matrix swelling is accommodated by reduction in the cleat dimensions. The cleats provide permeability. The matrix swell therefore reduces the cleat permeability. Override may follow – the CO2 going elsewhere in a vertical setting. There are numerous possible mitigations to this and it is certainly not an insurmountable problem.
3. **Sequestration:** The CO2 in tertiary recovery programs like this is not permanently sequestered. If there is a wellbore penetration or a seal failure, it can be released. Hence, this activity needs to be hybridized with technology to permanently sequester the CO2. These include WAG stages (water after gas) where water is injected to inhibit or restrict desorption, injecting treated water

to encourage precipitation and cementation of cleat systems, and other methods.

4. **Induced Seismicity:** All injection zones will need to be certified to de-risk the occurrence of induced seismicity.
5. **Breakthrough:** The efficacy and sequestration potential of flue gas is uncertain.

Opportunities

A multi-task study program would be relevant. They can be sequential (some could logically be concurrent) and there would be logical Go-NoGo milestones.

Task	Description	Duration (person-months)	Amount
1	**Resource Evaluation:** From public domain sources (UGS data in particular) summarize the possible injection locations, capacities, advantages and challenges	6	\$25,000
2	**Bench Scale Demonstrations:** Using CO2, flue gas (and N2 alone) carry out bench scale demonstration measurements to assess sorptive capacities and permeability modification in representative Utah coals.	12	\$75,000
3	**Permanent Sequestration:** How can CO2 be more permanently be sequestered in coal seams?	12	\$75,000
4	**Economic Viability:** First order estimate of economics of sequestration offset partially by methane production.	6	\$25,000
5	**Simulations:** Based on Tasks 1 through 3 to confirm storage capacity	12	\$50,000
6	**Pilot Program:** Five spot injection and monitoring program	TBD	TBD

Assessment of Benefits

This study will

1. Provide a complete **technical, economic and environmental study** on the costs and benefits including a specific CO2 source (power plant) with transportation to a specific coal bed methane source.

2. Determine whether **local coalbeds are conducive** to enhanced CO_2 methane recovery
3. Propose new technologies for **improving injection efficiency** and attempt to identify supplementary funding opportunities for field scale evaluation.
4. Confirm that the risk of **induced seismicity will be reduced** in comparison to carbon dioxide injection into deep saline aquifers (without "voidage/injectate" volume compensation).

Assessment of Costs

This study will provide cost estimates to install enhanced recovery injection and production facilities.

Assessment of Technical Challenges

This study will assess:

1. **Effectiveness of methane capture and purification** required of the gas stream prior to injection. If flue gas can be tolerated, there could be some advantages. The advantage being not necessarily that NOx can be sequestered but that the presence of nitrogen may enable moving CO_2 deeper into the coal (speculation at this point).
2. The true **capacity** for carbon dioxide storage in coals in-situ has not been established. Continuous injection below fracturing pressure may not be a realistic scenario. The potential for refined injection procedures including fracturing, water stages, and in particular horizontal wells, might alleviate the mismatch between a necessarily large and constant CO_2 supply and the sequestration volume in the coals.
3. **Seal integrity and permanence of sequestration** are always a concern for subsurface storage. Effective monitoring is required. Injection of water, particularly calcified water after periodic injection of carbon dioxide could afford mineralization and more permanent sequestration. Predicting, monitoring, and mitigating leakage is a common theme of all subsurface storage operations.
4. **Coal swelling** impacts on coal-bed methane production. The experience in the past has been that chemisorption and associated swelling have reduced cleat permeability. Tactical changes in the injection strategy – multiple horizontal wells, with water diversion stages and pressures above fracturing are envisioned to effectively provide conformal injection and storage of CO_2 through the bulk of the reservoir.
5. **Logistics and feasibility of piping CO_2** to injection equipment from a plant environment to the injection facility.
6. **A reviewer proposed a very perceptive question. "**Is this within the general scope of the STEP funding? This is a very large and broad area for R&D. Will having a

study done with these funds make much difference in the long run to the advancement of adsorption or methane recovery?" The point is well taken and a focused study can only accomplish so much. However, the physics of adsorption are fairly well understood, as are the limitations that have been demonstrated by previous pilots. The goal is to assess storage capacity and opportunities. To put this in context, horizontal drilling changed the perspective of shale gas and oil production. Similar arguments might be made for carbon dioxide sequestration in coal. Additionally, non-traditional injection technologies (injection above fracturing pressure, sequential injection of water, mineralization encouragement and others) are likely to dramatically increase storage capacity.

Milestones:

Milestone	**Date from Announcement of Award/Funding Available**
Contracts with PacifiCorp complete	1 month
Commence Task 1 (Resource Evaluation)	1 month
Draft Test Program Submitted	1 month
Revised Program Submitted Formalizing Experimental Matrix and Other Research Tasks	1.5 months
Annual Report I Presented/Submitted	13 months
Annual Report II Presented/Submitted	25 months
Annual Report III Presented/Submitted	37 months
Concept for Future In-Situ Pilot Testing	43 months
Final Report Presented/Submitted	49 months
Initiation of Proposal and Fund Raising for Future Five Spot Pilot Plant	49 months or sooner if appropriate

Summary

Since October 2009, John McLennan has been an Associate Professor in the Department of Chemical Engineering at the University of Utah. He is the ad hoc director of the Masters of Science degree program in Petroleum Engineering; a degree awarded through the Department of Chemical Engineering at the University of Utah. He has been a Senior Research Scientist at the Energy & Geoscience Institute and a Research Professor in the Department of Chemical Engineering at the University of Utah, since January 2008. He has a Ph.D. in Civil Engineering from the University of Toronto, in 1980.

He has more than thirty-five years of experience in geomechanics with petroleum service and technology companies. He worked nine years for Dowell Schlumberger in their Denver, Tulsa and Houston facilities. Later, with TerraTek in Salt Lake City, Advantek International in Houston, and ASRC Energy Services in Anchorage, he worked on projects concerned with coalbed methane recovery, rock mechanical properties determinations, produced water and drill cuttings reinjection, as well as casing design issues related to compaction. Recent work has focused on optimized gas production from shales and unconsolidated formations, fluid-rock interactions, geothermal energy recovery, in-situ microbial generation of natural gas and high temperature rock testing.

Experience

October 2009 — **USTAR Associate Professor,** Department of Chemical Engineering, University of Utah and **Senior Research Scientist,** Energy & Geoscience Center, University of Utah

January 2008 — **Research Professor,** Energy & Geoscience Institute, Departments of Civil and Chemical Engineering, University of Utah

Within the Energy & Geoscience Institute promote geomechanics and fundamental research in unconventional hydrocarbons, and engineered geothermal systems. Within the Department of Chemical Engineering, participate in two RPSEA programs (one on gas production from low permeability sands and one on flow assurance).

2003 - 2008 — **Technical Director,** ASRC Energy Services E & P Technology, Anchorage, AK

2001 - 2002 — **Executive Vice President,** Advantek International Corporation, Salt Lake City, UT

Involved with projects ranging from individual consulting efforts to participation in large consortium projects concerning produced water reinjection, compaction/subsidence and wellbore integrity. Central participant in corporate strategy to consolidate numerical and analytical tools, historical experience, correlations and risk analysis in overall knowledge-based packages for planning, drilling, completing, stimulating and managing reservoirs. Other projects encompass software development; evaluations, predictions, back-analyses and recommendations for exploitation strategies; and formulation of Best Practices.

1989 - 2001 — **Executive Vice President,** TerraTek, Inc., Salt Lake City, UT

Vice President — 1992-1999, Management of field and laboratory routine and special core analysis, geology, computerized tomography and rock mechanics investigations for oil/gas, coal and civil construction projects. Supervision of approximately 25 scientists, engineers, technicians and support staff. Coordination of sales, marketing and relevant accounting/project tracking activities. Technical participation in high profile and new venture projects including multiple projects for the Gas Research Institute. Rock Mechanics Short Courses for clients.

Vice President, Engineering Testing and Simulations — 1989-1992
Management of field and laboratory rock mechanics investigations for oil/gas, coal, and civil construction projects.

1987 - 1989 **Program Leader, Rock and Fracture Mechanics,** Dowell Schlumberger Inc., Tulsa, OK

Manage rock and fracture mechanics development effort (4 scientists and 1 technician). Development of technology for production prediction from horizontal wellbores. Development of technology for fracturing and matrix acidizing deviated wellbores (theoretical, numerical and field validation). Supervise upgrade of laboratory testing and analysis capabilities for rock mechanics testing. Large-scale laboratory polyaxial testing for the assessment of deviated wellbore fracturing, acid fracturing and in-situ stress measurement. Interaction with development chemists for design of field-testing for product evaluation. Evaluation of the influence of perforations on hydraulic fracture initiation. Technical review of research efforts on wellbore stability, poroelasticity and fundamental fracture mechanics. Fracture design, back-analysis and trouble-shooting for high-profile field operations. Lecturer in Schlumberger Educational Services Advanced Reservoir Stimulation client schools.

1986 - 1987 **Technical Center Manager,** Dowell Schlumberger Inc., Denver, CO

Manage $1,000,000 customer service laboratory. Provide field support, including laboratory testing, treatment fluid design and formation evaluation for all of Dowell Schlumberger's North American operations. Fracture and acidizing design, back-analysis, trouble-shooting and customer interface for high profile field operations.

1981 - 1985 **Senior Research Engineer, Rock Mechanics,** Dowell Schlumberger Inc., Tulsa OK
Fundamental fracturing research on fluid loss during hydraulic fracturing. Fundamental research on correlation between static and dynamic mechanical properties with application to stress prediction. Develop a pseudo-three-dimensional hydraulic fracturing code, modeling fracture growth and proppant placement. Formation evaluations, treatment designs and optimizations. Dowell Schlumberger internal reports, client confidential reports; and public-domain publications as listed subsequently.

1980 - 1981 **Senior Engineer,** TTI Geotechnical Resources Ltd., Calgary, Alberta Canada
Open two-man Canadian office for U.S. Corporation. Field supervision and data analysis for four hydraulic fracturing stress measurement programs in Canada, and assistance on hydraulic fracturing stress measurements at two localities in the United States. Technical review of fracturing and stability response of oil sands.

EDUCATION

- B.A.Sc. Geological Engineering, University of Toronto, 1974
- M.A.Sc. Civil Engineering (Soil Mechanics), University of Toronto, 1976
- Ph.D. Civil Engineering (Rock Mechanics), University of Toronto, 1980

PUBLICATIONS

1. McLennan, J.D.: "Study and Analysis of Lateral Pressure in Two Granular Materials," M.A.Sc. Thesis, University of Toronto, Dec. 1975.
2. McLennan, J.D. and Roegiers, J-C.: "Stress Conditions Around the Niagara Gorge," Proc. 3rd Symp. Eng. Applications to Solid Mechanics, Toronto, 1976.
3. Roegiers, J-C. and McLennan, J.D.: "Rock Mechanics Problems Associated with Hot Dry Rock Geothermal Energy Extraction," Proc. Hot Dry Rock Geothermal Workshop, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, LA-7470-C, April 1978.
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8. McLennan, J.D.: "Hydraulic Fracturing: "A Fracture Mechanics Approach," Ph.D. Thesis, University of Toronto, Department of Civil Engineering, December 1980.
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13. McLennan, J.D. and Roegiers, J-C.: "How Instantaneous are Instantaneous Shut-in Pressures," paper SPE 11064 presented at the 1982 (57th) SPE Annual Fall Technical Conference and Exhibition, SPE/AIME, New Orleans, LA, September 1982.
14. Roegiers, J-C., McLennan, J.D. and Murphy, D.L.: "Influence of Preexisting Discontinuities on the Hydraulic Fracturing Propagation Process," First Japan-United States Symposium on Hydraulic Fracturing and Geothermal Energy, Tokyo, November 1982.
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DISCLOSURES

1. Diesel Microemulsion Biofuels. Status: Pending. Type: Parent/Utility. Inventors: Thu Thi Le Nguyen, Melisa Saleb Ramallo, John D. McLennan, Jacob Isaac Kalunakaahele Abraham. File date 05/10/2012. Assignee: The University of Utah. Country: United States.
2. Optimization of Biogenic Methane Production from Hydrocarbon Sources. Status: Pending. Type: Provisional. Inventors: D. Jack Adams, Michael L. Free, John D. McLennan, Jack (John R.) Hamilton. File date 04/10/2012. Assignee: The University of Utah. Country: United States.
3. Periodic Symmetry Defined Bioreactors. Status: Pending. Type: Provisional. Inventors: Leonard F. Pease, Swomitra K. Mohanty, John D. McLennan, Anthony Butterfield, Samuel Doane, Rete Browning, Tyler Lee. File date 02/18/2014. Assignee: The University of Utah. Country: United States.
4. Encapsulation and Time Release of Microbe Loaded Porous Proppant, U-6049. 11/02/2015. Inventors: Taylor David. Sparks, John D. McLennan, Kyu-Bum Han, John Fuertez, Assignee: The University of Utah. Country: United States.
5. Porous Proppant for Delivering Bacteria, U-6110. 02/22/2016. Inventors: Taylor David. Sparks, John D. McLennan, Kyu-Bum Han, Assignee: The University of Utah. Country: United States.

ORGANIZATIONS AND SOCIETIES

- Society of Petroleum Engineers, Member and 2007 Chairperson of Salt Lake Section, Currently Program Chair
- Society of Professional Well Log Analysts, Member
- American Institute of Chemical Engineers, Member
- American Rock Mechanics Association, Board of Directors, President

GRADUATE STUDENTS

Joshua Thompson	MS Chemical Engineering	2010
John Gregory	ME Chemical Engineering	2011
Chad Wilding	ME Chemical Engineering	2011
Trevor Stoddard	MS Chemical Engineering	2011
Dan Brinton	MS Chemical Engineering	2011

Eric Brauser	Ph.D. Chemical Engineering	2015
Walter Glauser	MS Chemical Engineering	2015
Alan Walker	MS Petroleum Engineering	2015
Jacob Abraham	MS Petroleum Engineering	2015
Jacob Bradford	Ph.D. Chemical Engineering	2016 Summer
Thang Tran	Ph.D. Chemical Engineering	2016 Winter
Eric Edelman	MS Petroleum Engineering	2016 Spring
Shuo Zhang	MS Petroleum Engineering	2016 Spring
Yili Zhao	MS Petroleum Engineering	2016 Spring
Bryan Forbes	MS Petroleum Engineering	2016 Spring
John Fuertez	Ph.D. Chemical Engineering	2016 Winter
Raili Taylor	Ph.D. Chemical Engineering	2017
Joshua Zannoni	Ph.D. Chemical Engineering	2017
David Shaw	Ph.D. Chemical Engineering	2017
Jeff Easton	Ph.D. Chemical Engineering	2018
Shashank Tiwari	Ph.D. Chemical Engineering	2019
David Brown	MS Petroleum Engineering	
Brandon Palmer	MS Petroleum Engineering	
Kevin Kincaid	MS Petroleum Engineering	
James Schloss	MS Petroleum Engineering	
Arturo Acosta	MS Petroleum Engineering	
Garrett Schultz	MS Petroleum Engineering	
Joel Tetteh	MS Petroleum Engineering	

Appendix E

Solar Thermal Integration, Hunter Plant

Brigham Young University

Solar Augmentation of Coal-Fired Power Plant

Brian Iverson, BYU
Kody Powell, U of U

The Hunter power plant, located near Castledale, UT burns approximately 4.5 million tons of coal/year to operate as a 1.32 GW_e power plant. PacifiCorp has expressed interest in considering the costs and benefits to offsetting some of the coal energy source with solar-thermal energy. This preliminary outline provides a possible framework for solar augmentation of PacifiCorp's plant. Solar augmentation of existing coal-fired power plants is a topic that has been researched by U.S. national laboratories [1]. For existing coal or natural gas combined cycle power plants in UT, it has been shown that 1.4 GW_e of energy could be created through solar-augmentation (neglecting sites that have only fair potential).

We propose the study of solar-augmentation to the Hunter plant through the use of parabolic trough or power tower solar collection. Figure 1 illustrates two potential locations where thermal energy from solar-augmentation may integrate with an existing steam power cycle for coal. The locations differ when considering the type of solar energy collection (trough, tower) due to different max temperatures achievable from the collection mechanism. Typically, a max collection temperature near 380 °C for parabolic trough and 540 °C for power towers is expected with increases achieved in the recent 5 years.

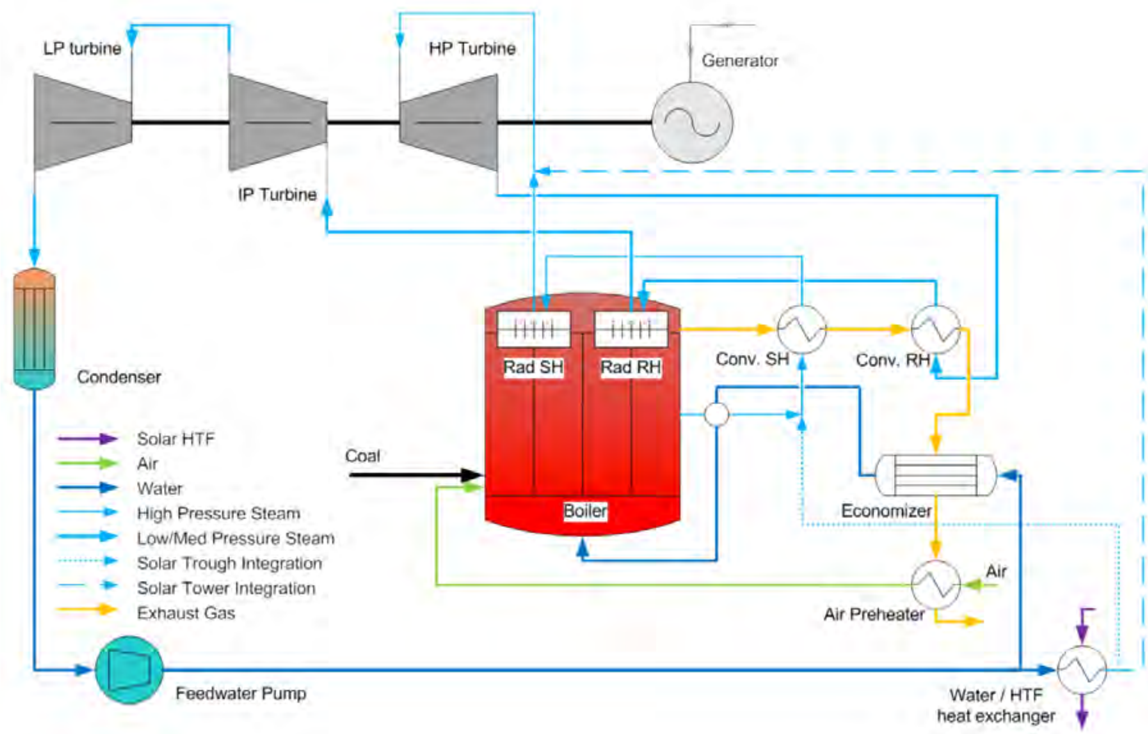

Figure 1. Schematic of solar steam integration into coal plant by solar trough or tower concentration platforms. SH = superheater, RH = reheater (from [1])

The proposed work will investigate the following aspects of solar integration at Hunter:

- Solar resource: Direct normal insolation (DNI) is the primary energy source for solar thermal energy collection and average DNI values at or above 7 $kWh/m^2/day$ have the highest possible potential for solar-augmentation. A plant with a DNI below 4 $kWh/m^2/day$ may not be worth considering.

- Land resource: Previous work has shown that existing fossil plants can accept a design-point maximum of between 10% and 20% of their total plant output from solar steam before reaching equipment or other design limitations [1]. Based on the assumption that 1 MW_e of solar requires 5 acres of land, a 100 MW plant could accept up to 10 to 20 MW_e of solar generation, which would require 50 to 100 acres of land or 0.5 to 1 acres per fossil plant megawatt. Further, land with a less than 3-5% slope is preferred for solar-augmentation or extensive grating is required.
- Efficiency: Solar-use efficiency is the measure of how many megawatts of solar electricity are generated per solar thermal megawatt integrated into the fossil plant. Solar-use efficiency can decrease with increasing solar contribution. Conditions up to the maximum amount of solar integration will be considered. A power plant model will be generated or NREL's System Advisor Model (SAM) will be used for evaluating performance.
- Type of solar augmentation: Trough and tower methods of solar thermal energy collection will be considered to determine optimum solar-integration conditions.
- Costs: Costs associated with additional hardware or plant subsystems will be provided and analyzed in a cost/benefit study.

Additional aspects may also be considered with planning development. However, the above encompasses the major points of understanding required to advise on the usefulness of augmenting the Hunter plant with a solar resource.

Some initial questions to be answered:

- What is the age of the Hunter plant?
- What is the current capacity factor of the Hunter plant?

Budget:

Student (2 years): $38k
Summer internship at National Lab (student): $7k
Tuition (2 years): $11k
Faculty (summer month each year for 2 years): $30k
Supplies (databases, computer programs): $3k
Travel (lab site visit, conference attendance): $6.5k
Indirect costs: $41.5k
Optional national lab support (NREL, Sandia): $15k
Total: $150k

Bio: Brian Iverson completed his PhD at Purdue University in 2008 and currently teaches at Brigham Young University. His area of specialty is heat transfer. Brian worked as a part of the concentrating solar power team at Sandia National Laboratories from 2009-2012 and has published extensively in several aspects of solar power generation from collection [2-4], to storage [5-11], to system performance [4, 12-14].

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[6] Iverson, B. D., Flueckiger, S. M., and Ehrhart, B. D., 2011, "Trough heat collection element deformation and solar intercept impact," SolarPACES, September 20-23, 2011, Granada, Spain.

[7] Kolb, G. J., Ho, C., Iverson, B. D., Moss, T. A., and Siegel, N. P., 2010, "Freeze-thaw tests of trough receivers employing a molten salt working fluid," ASME Energy Sustainability, May 17-22, 2010, Phoenix, AZ.

[8] Iverson, B. D., Broome, S. T., and Siegel, N. P., 2010, "Temperature dependent mechanical property testing of nitrate thermal storage salts," SolarPACES, September 21-24, 2010, Perpignan, France.

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[11] Iverson, B. D., Broome, S. T., Kruizenga, A. M., and Cordaro, J. G., 2012, "Thermal and mechanical properties of nitrate thermal storage salts in the solid-phase," *Solar Energy*, Vol. 86, pp. 2897-2911.

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[13] Dunham, M. T. and Iverson, B. D., 2014, "High-efficiency thermodynamic power cycles for concentrated solar power systems," *Renewable and Sustainable Energy Reviews*, Vol. 30, pp. 758-770.

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Education

Ph.D. Mechanical Engineering, 2008
Purdue University, West Lafayette, IN
Thesis: "Traveling-Wave Electrohydrodynamic Micropumping in a Temperature Gradient"
Advisor: Suresh V. Garimella

M.S. Mechanical Engineering, 2004
Purdue University, West Lafayette, IN
Thesis: "Heat and Mass Transport in Heat Pipe Wick Structures"
Advisor: Suresh V. Garimella

B.S. Mechanical Engineering – Magna Cum Laude, 2002
Brigham Young University, Provo, UT
Research: "Thermally Developing Electroosmotic Convection in Rectangular Microchannels"
Advisors: Brent W. Webb and R. Daniel Maynes

Professional Positions

Assistant Professor, Nov 2012 – present
Brigham Young University, Provo UT
Exploit high aspect ratio structures for enhancement and control of heat and mass transport.
Graduate committee member.
Mentor student research.
Conduct undergraduate and graduate courses in thermal science.

Senior Member of Technical Staff, 2009 – 2012
Sandia National Laboratories, Albuquerque NM
Investigate alternative power cycles and compatible collection and storage of solar thermal energy.
Characterize behavior of freeze event recovery for deployment of molten salt in trough CSP.
Analyze molten salt feasibility in line-focus concentrated solar power systems.
Examine the effects of trough receiver tube bending on solar intercept.
Measure solid-phase, thermal and mechanical properties of thermal energy storage salts.
Identify thermal ratcheting scenarios and bed properties for thermocline thermal storage tanks.
Model flux sensor for solar tracking; implement design and characterize transient solar response.
Administer seminar series for staff education, collaboration, awareness and preparedness.
Provide technical monitoring and support for DOE's Funding Opportunity Announcements (FOA).
Examine thermal energy storage for power tower and dish-based concentrated solar energy systems.
Model optical error sources and relative impact on flux distributions

Post-Doctoral Researcher, January 2009 – August 2009
NSF Cooling Technologies Research Center, Purdue University
Investigate thin-film thermal transport for organic/Si interfacial contact resistance.

Perform local thermal measurements with a modified scanning thermal microscopy technique.
Characterize composites, thin-films and embedded structures with thermal imaging.
Explore separation mechanisms and membrane technology for biological and energy applications.

Research Assistant, 2002 - 2008
NSF Cooling Technologies Research Center, Purdue University
Conduct electronics cooling research with industry leaders at pre-competitive level.
Perform finite element modeling of micropump with moving boundaries and ion generation.
Present at NSF Industry/University Cooperative Research Center (I/UCRC) conferences.
Design and fabricate integrated electrohydrodynamic micropumps.
Test wicking capabilities of flat heat pipes wick structures.
Analyze/characterize benefits of wick design from testing results.
Perform literature searches and publish research findings.

Teaching Assistant, Heat and Mass Transfer, January – May 2008
Purdue University
Prepare lectures and teach course material in the absence of the professor.
Hold regular office hours for student consultation and one-on-one instruction.
Prepare exam material and grade exams.

Visiting Researcher, May 2007 – August 2007
Research Triangle Institute International, NC
Fabricate solution-based organic photovoltaic cells and identify improvement mechanisms.
Develop processing steps and construct PbS quantum dot solution photovoltaic cells.
Establish Streptavidin/Biotin binding force measurement methodology for microcantilevers.
Measure piezoelectric response signals in vibrating microcantilever devices.

Research Assistant, Thermal Science, 2001 - 2002
Brigham Young University
Obtain analytical solution for thermally developing flow in electroosmotic pumping.
Design and implement testing apparatus for electroosmotic flow in microtubules.
Collect research results and publish findings.

Teaching Assistant, Applied Thermodynamics, Summer 2001
Brigham Young University
Conduct student laboratory sessions for diesel and refrigeration cycles.
Assist students in analyzing experimental data.
Compile existing lab knowledge and write TA training manual.

Engineering Intern, 2000 - 2001
Geneva Steel, Vineyard UT
Plan preliminary stages of new projects including walking beam furnace.
Design and revise parts/machinery using CAD tools, manage project prints.

Tutor, 1996 - 1997
Utah Valley State College Partnership, UT
Tutor “at-risk” high school students in English, Math, History, and supporting coursework.
Monitor student academic progress.
Coordinate communication with parents, education leaders and student.

Publications

*Advised student

Books

1. Iverson, B. D. and Garimella, S. V., Integrated Micropumping: Traveling-wave electrohydrodynamics induced in a temperature gradient, Saarbrücken, LAP Lambert Academic Publishing, 2010.

Journal Articles

1. Blanc, M. J.*, Mulford, R. B.*, Jones, M. R., and Iverson, B. D., 2016, "Infrared visualization of the cavity effect using origami-inspired surfaces," *Journal of Heat Transfer*, Vol. 138, pp. 020901.
2. Mulford, R. B.*, Jones, M. R., and Iverson, B. D., 2016, "Dynamic control of radiative surface properties with origami-inspired design," *Journal of Heat Transfer*, Vol. 138, pp. 032701.
3. Marr, K. M.*, Chen, B., Mootz, E., Geder, J., Pruessner, M., Melde, B., Vanfleet, R. R., Iverson, B. D., and Claussen, J. C., 2015, "High aspect ratio, carbon nanotube membranes decorated with Pt nanoparticle urchins for small scale underwater vehicle propulsion via H_2O_2 decomposition," *ACS Nano*, DOI: 10.1021/acsnano.5b02124.
4. Iverson, B. D., Bauer, S. J., and Flueckiger, S. M.*, 2014, "Thermocline bed properties for deformation analysis," *Journal of Solar Energy Engineering*, Vol. 136, pp. 041002.
5. Ho, C. K. and Iverson, B. D., 2014, "Review of high-temperature central receiver designs for concentrating solar power," *Renewable & Sustainable Energy Reviews*, Vol. 29, pp. 835-846.
6. Flueckiger, S. M.*, Iverson, B. D., Garimella, S. V., and Pacheco, J. E., 2014, "System-level simulation of a solar power tower plant with thermocline thermal energy storage," *Applied Energy*, Vol. 113, pp. 86-96.
7. Flueckiger, S. M.*, Iverson, B. D., and Garimella, S. V., 2014, "Economic optimization of a concentrating solar power plant with molten-salt thermocline storage," *Journal of Solar Energy Engineering*, Vol. 136, pp. 011016.
8. Dunham, M. T.* and Iverson, B. D., 2014, "High-efficiency thermodynamic power cycles for concentrated solar power systems," *Renewable and Sustainable Energy Reviews*, Vol. 30, pp. 758-770.
9. Iverson, B. D., Conboy, T. M., Pasch, J. J., and Kruizenga, A. M., 2013, "Supercritical CO2 Brayton cycles for solar-thermal energy," *Applied Energy*, Vol. 111, pp. 957-970.
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11. Iverson, B. D., Blendell, J. E., and Garimella, S. V., 2010, "Note: Thermal analog to atomic force microscopy force-displacement measurements for nanoscale interfacial contact resistance," *Review of Scientific Instruments*, Vol. 81.
12. Iverson, B. D., Cremaschi, L., and Garimella, S. V., 2009, "Effects of discrete-electrode configuration on traveling-wave electrohydrodynamic pumping," *Microfluidics and Nanofluidics*, Vol. 6, pp. 221-230.
13. Iverson, B. D. and Garimella, S. V., 2009, "Experimental characterization of induction electrohydrodynamics for integrated microchannel pumping," *Journal of Micromechanics and Microengineering*, Vol. 19.
14. Icoz, K., Iverson, B. D., and Savran, C., 2008, "Noise analysis and sensitivity enhancement in immunomagnetic nanomechanical biosensors," *Applied Physics Letters*, Vol. 93.
15. Iverson, B. D. and Garimella, S. V., 2008, "Recent advances in microscale pumping technologies: A review and evaluation," *Microfluidics and Nanofluidics*, Vol. 5, pp. 145-174.
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transport in heat pipe wick structures," *Journal of Thermophysics and Heat Transfer*, Vol. 21, pp. 392-404.

17. Iverson, B. D., Maynes, D., and Webb, B. W., 2004, "Thermally developing electroosmotic convection in rectangular microchannels with vanishing Debye-layer thickness," *Journal of Thermophysics and Heat Transfer*, Vol. 18, pp. 486-493.

Journal Articles in Review

Conference Papers and Refereed Publications

1. Blanc, M. J.*, Mulford, R. B.*, Jones, M. R., and Iverson, B. D., 2015, "Visualization of the cavity effect present for origami-inspired surfaces with IR imaging," Heat Transfer Gallery, ASTFE Thermal and Fluids Engineering Summer Conference, August 15-20, 2015, New York, NY.
2. Mulford, R. B.*, Jones, M. R., and Iverson, B. D., 2015, "Net radiative heat exchange of an origami-inspired, variable emissivity surface," ASTFE Thermal and Fluids Engineering Summer Conference, August 9-12, 2015, New York, NY.
3. Mulford, R. B.*, Christensen, L. M.*, Jones, M. R., and Iverson, B. D., "Dynamic control of radiative surface properties with origami-inspired design," ASME International Mechanical Engineering Congress and Exposition, Montreal, Canada, November 14-20, 2014.
4. Flueckiger, S. M.*, Iverson, B. D., and Garimella, S. G., "Simulation of a concentrating solar power plant with molten-salt thermocline storage for optimized annual performance," Energy Sustainability, Minneapolis, MN, July 14-19, 2013.
5. Iverson, B. D., Flueckiger, S. M.*, and Ehrhart, B. D.*, 2011, "Trough heat collection element deformation and solar intercept impact," SolarPACES, Granada, Spain, September 20-23, 2011.
6. Iverson, B. D., Cordaro, J. G., and Kruizenga, A. M., 2011, "Thermal property testing of nitrate thermal storage salts in the solid-phase," ASME International Conference on Energy Sustainability, Washington D.C., August 7-10, 2011.
7. Iverson, B. D., Broome, S.T., and Siegel, N. P., 2010, "Temperature dependent mechanical property testing of nitrate thermal storage salts," SolarPACES, Perpignan, France, September 21-24, 2010.
8. Iverson, B. D., Andraka. C. E., Yellowhair, J. and Ho, C. K., 2010, "Optical error impacts on flux distribution for a dish concentrator using probabilistic modeling," SolarPACES, Perpignan, France, September 21-24, 2010.
9. Ho, C. K., Mancini, T. R., Kolb, G. J., Siegel, N. P., Iverson, B. D. and Gary, J., 2010, "Development of a power-tower technology roadmap for DOE," SolarPACES, Perpignan, France, September 21-24, 2010.
10. Andraka, C. E., Yellowhair, J. and Iverson, B. D., 2010, "A parametric study of the impact of various error contributions on the flux distribution of a solar dish concentrator," ASME International Conference on Energy Sustainability, Phoenix, AZ, May 17-22, 2010.
11. Kolb, G., Ho, C., Iverson, B. D., Moss, T., and Siegel, N., 2010, "Freeze-thaw tests of trough receivers employing a molten salt working fluid," ASME International Conference on Energy Sustainability, Phoenix, AZ, May 17-22, 2010.
12. Iverson, B. D. and Garimella, S. V., 2008 "Performance characterization of a traveling-wave electrohydrodynamic micropump," ASME International Mechanical Engineering Congress and Exposition, Boston, MA, October 31 – November 6, 2008.
13. Cremaschi, L., Iverson, B. D., Garimella, S. V., 2006, "Enhanced electrohydrodynamic pumping for the microscale," ASME International Mechanical Engineering Congress and Exposition, Chicago, IL, November 5-10, 2006.
14. Iverson, B. D., Singhal, V., and Garimella, S. V., 2006, "Micropumping technologies for electronics cooling," Electronics Cooling, Vol. 12, No. 2.
15. Acikalin, T., Iverson, B. D., Garimella, S. V., Raman, A. and Petroski, J., 2004, "Numerical

investigation of the flow and heat transfer due to a miniature piezoelectric fan," ASME International Mechanical Engineering Congress and Exposition, Anaheim, CA, November 2004.

16. Iverson, B. D. and Garimella, S.V., 2004, "Experimental measurements of heat and mass transport in heat pipe wicks," ASME Heat Transfer/Fluids Engineering Summer Conference, Charlotte, NC, July 11-15, 2004.

Abstract Reviewed Conference Presentation Only

1. Brownlee, B. J.*, Marr, K. M.*, Claussen, J. C., and Iverson, B. D., 2016, "Enhancement of rransport-limited chemical reactions via functionalized carbon nanotube microarray membranes," ASME International Conference on Nanochannels, Microchannels and Minichannels, July 10-14, 2016, Washington, DC.
2. Lee, M. L., Ghosh, A., Tolley, L. T., Hawkins, A. R., Iverson, B. D., and Tolley, H. D., 2016, "Microchip Thermal Gradient Gas Chromatography," 40th Intern. Symp. on Capillary Chromatography, May 29-June 3, 2016, Riva del Garda, Italy.
3. Mulford, R. B.*, Blanc, M. J.*, Jones, M. R., and Iverson, B. D., 2015, "Total heat emission from an origami-inspired variable emissivity device," ASME International Mechanical Engineering Congress and Exposition, Houston, TX, November 13-19, 2015 (Poster).
4. Stevens, K. A.*, Maynes, D. R., Crockett, J., Iverson, B. D., "The effect of superhydrophobicity on two-phase channel flow," American Physical Society, 68th Annual DFD Meeting, Boston, MA, November 22-24, 2015.
5. Cowley, A.*, Maynes, D., Crockett, J., Iverson, B. D., "Inertial effects on heat transfer in superhydrophobic microchannels," American Physical Society, 68th Annual DFD Meeting, Boston, MA, November 22-24, 2015.
6. Lund, J. M.*, Syme, D. B.*, Vanfleet, R. R., Davis, R., Jensen, B. D., and Iverson, B. D., "Carbon Nanotube-Templated, Porous Films for Thermal Isolation," AVS 62nd International Symposium and Exhibition, October 18-23, 2015, San Jose, CA.
7. Boyer, N.*, Syme, D.*, Rowley, J.*, Davis, R. Vanfleet, R., Iverson, B. D., Harker, M., and Creighton, R., "Carbon Nanotube Sheets from Horizontally Aligned Carbon Nanotubes," AVS 62nd International Symposium and Exhibition, October 18-23, 2015, San Jose, CA.
8. Mulford, R. B.*, Jones, M. R., and Iverson, B. D., 2015, "Dynamic radiative surface properties with origami-inspired topography," NASA Thermal & Fluids Analysis Workshop, August 3-7, 2015, Silver Spring, MD.
9. Marr, K. M.*, Claussen, J. C., and Iverson, B. D., "Enhanced Monopropellant Fuel Decomposition by High Aspect Ratio, Catalytic CNT Structures for Propulsion of Small Scale Underwater Vehicles," American Physical Society, 67th Annual DFD Meeting, San Francisco, CA, November 23-25, 2014, DFD14-2014-002818.
10. Mulford, R. B.*, Christensen, L. G.*, Iverson, B. D., Jones, M. R., and Howell, L. L., "Dynamic Thermal Management of Radiation through Origami-Inspired Design," Spacecraft Thermal Control Workshop, Aerospace Corporation, El Segundo, CA. March 25-27, 2014.
11. Park, J.*, Delimont, I.*, Mulford, R.*, Christensen, L.*, Howell, L., Iverson, B. D., and Jones, M., "Dynamic control of radiation-based thermal management through origami-inspired design," International Mechanical Engineering Congress and Exposition, November 15-21, 2013 (Poster).
12. Marr, K. M.*, and Iverson, B. D., "High aspect ratio sensing platforms for flowing environments," International Mechanical Engineering Congress and Exposition, November 15-21, 2013 (Poster).
13. Iverson, B. D., and Garimella, S. G., "Induction Electrohydrodynamic Pumping in a Temperature Field," Frontiers in Scalable Nanostructured Materials and Interfaces, West Lafayette, IN, March 10-12, 2009 (Poster).

Invited Talks

1. Iverson, B. D., "Education for Life: Faith in Scholarship," Brigham Young University, ME Graduate Seminar, April 4, 2016.
2. Iverson, B. D., "Transport Enhancement of Rate-Limited Chemical Reactions *via* Pt-Decorated, Carbon Nanotube Microarray Membranes," Utah State University, December 3, 2015.
3. Iverson, B. D., "Context is Everything - Literature Reviews and Writing," ME Graduate Student Seminar, Brigham Young University, October 26, 2015.
4. Iverson, B. D., "Transport Enhancement of Rate-Limited Chemical Reactions *via* Pt-Decorated, Carbon Nanotube Microarray Membranes," Purdue University, October 5, 2015.
5. Iverson, B. D., "Context is Everything - Literature Reviews and Writing," ME Graduate Student Seminar, Brigham Young University, March 30, 2015.
6. Iverson, B. D., "Introduction to Microfluidics," Mechanical Engineering 550 Guest Lecture, Brigham Young University, December 5, 2014.
7. Iverson, B. D., "Solving Proximity Challenges of Sensor Miniaturization through High Aspect Ratio, Carbon Nanotube Scaffolds," NASA Goddard, Greenbelt MD, October 8, 2014.
8. Iverson, B. D., "Solving Proximity Challenges of Sensor Miniaturization through High Aspect Ratio, Carbon Nanotube Scaffolds," Army Research Lab, Adelphi MD, October 8, 2014.
9. Iverson, B. D. and Zuber, P., "Literature Reviews," Brigham Young University, ME Graduate Student Seminar, joint presentation, March 10, 2014.
10. Brigham Young University, Energy Portfolio Panel Discussion, December 12, 2013. Panel member.
11. Iverson, B. D., "Thermal Energy Storage in Concentrating Solar Power Systems," Brigham Young University, Department of Mechanical Engineering, February 27, 2012, Provo UT.
12. Iverson, B. D., Garimella, S. G., and Blendell, J. "Thermal Contact Resistance at Silicon-Organic Material Interfaces," Intel Thermal Work Group, July 28, 2009, Chandler, AZ.
13. Iverson, B. D., "Integrated Micropumping for Thermal Management and Microfluidic Biodevices," Texas A&M University, June 25, 2009, College Station, TX.
14. Iverson, B. D., "Integrated Micropumping for Thermal Management and Microfluidic Biodevices," Sandia National Laboratories, Solar Thermal Test Facility, February 17, 2009, Albuquerque, NM.
15. Iverson, B. D., "Enhanced Electrohydrodynamic Micropumping," Research Triangle Institute International, Group Seminar, August 8, 2007, Durham, NC.
16. Iverson, B. D. and Garimella, S. G., "Enhanced Electrohydrodynamic Micropumping," Indiana Chapter of International Microelectronics and Packaging Society (IMAPS) Vendor's Day and Mini-Symposium, April 30, 2007, Indianapolis, IN.
17. Iverson, B. D., and Garimella, S.G., "Heat Pipes for Heat Spreading," Japan Society of Mechanical Engineering Project Meeting 2003, October 13-17, 2003, Tokyo, Japan. Heat sink conference fostering international thermal management interaction.

Non-Refereed Publications

1. Stevens, K. A.*, Crockett, J., Maynes, D. R. and Iverson, B. D., "Two-phase pressure drop in superhydrophobic channels," Utah NASA Space Grant Consortium, May 2015.
2. Mulford, R. B.*, Jones, M. R. and Iverson B. D., "Dynamic control of radiative surface properties with origami-inspired design," Utah NASA Space Grant Consortium, May 2015.

Patent and Provisional Patent Submissions

1. Vanfleet, R. R., Davis, R. C., Syme, D., and Iverson, B. D., Aligned and laterally oriented, carbon nanotube thin films, Provisional Patent, submitted March 2015.
2. Iverson, B. D., Marr, K. M., Convective Enhanced Sensing with High Surface Area Flow Structures, Convective enhanced sensing with high surface area flow structures, Provisional Patent, submitted November 2014.
3. Claussen, J. C., and Iverson, B. D., A micro-scale vehicle having a propulsion device, Provisional

Patent, submitted October 2014. Patent Application No. 14/877,594.

4. Howell, L. L., Iverson, B. D., and Jones, M. R., Dynamic Control of Spectral Radiative Properties through Compliant Surfaces, Provisional Patent, submitted November 2013.

Honors and Awards

Professional

- Advances in Engineering featured our work as a key scientific article (September 2014), from: Iverson *et al.*, 2014, *Journal of Solar Energy Engineering*, Vol. 136, pp. 041002. https://advanceseng.com/mechanical-engineering/thermocline-bed-properties-deformation-analysis/
- Renewable Energy Global Innovation Series featured our work as a key scientific article (January 2014), from: Iverson, B. D., Conboy, T. M., Pasch, J. J., and Kruizenga, A. M., 2013, "Supercritical CO_2 Brayton cycles for solar-thermal energy," *Applied Energy*, Vol. 111, pp. 957-970. http://reginnovations.org/key-scientific-articles/supercritical-co2-brayton-cycles-solar-thermal-energy/
- New Mexico Small Business Assistance Program outstanding innovation award supporting SAVSU Technologies (May 2012)
- One of the top 5 cited articles from Microfluidics and Nanofluidics from 2008-2009 (July 2011): Iverson, B. D. and Garimella, S.V., 2008 "Recent advances in microscale pumping technologies: a review and evaluation," Microfluidics and Nanofluidics, Vol. 5, No. 2, pp. 145-174.
- Spot Award, performance award for significant accomplishment, Sandia National Laboratories (December 2010)
- Best Paper/Presentation of Session Award, Indiana Chapter of International Microelectronics and Packaging Society Vendor's Day and Mini-Symposium (April 30, 2007)
- Best Poster, Cooling Technologies Research Center review meeting (2005, 2006, 2009)
- National Defense Science and Engineering Graduate Fellowship Honorable Mention (2003)
- National Science Foundation Graduate Research Fellowship Honorable Mention (2003)
- Perfect score on GRE Quantitative (2002)
- Professional Nominations: Tau Beta Pi, Golden Key Honor Society, Phi Kappa Phi (2000-2001)

Academic

- Winkelman Fellowship for PhD studies, Purdue University (2005-2007)
- Ingersoll Rand Fellowship for graduate studies, Purdue University (2002-2004)
- Magna Cum Laude distinction, Brigham Young University, Provo UT (2002)
- Karl G. Maeser Scholarship, Brigham Young University, Provo UT (2001-2002)
- Alvina S. Barrett Scholarship, Brigham Young University, Provo UT (2000-2001)
- University Scholarship, Brigham Young University, Provo UT (1996-1997, 1999-2000)

Regional/Local

- Academic All-State Soccer Team, Division 5A, UT (1996)
- Sterling Scholar, West Jordan High School, UT (1996)
- Eagle Scout, Boy Scouts of America (1996)

Visibility

- ACS Nano podcast, August 20, 2015, Topic: Micro Underwater Vehicle Propulsion
    - Link: http://pubs.acs.org/subscribe/journals/ancac3/audio/ancac3-0815.mp3
- Guest on "Top of the Mind," with Julie Rose, BYU Radio, July 13, 2015. Topic: Micro Underwater Vehicle Propulsion.

- Link: http://www.byuradio.org/episode/b980e1ac-e5d0-4619-b3e0-f4d2cee375f3?playhead=5189&autoplay=true

Advisement

Graduate Student Advisement

- Ben Brownlee, PhD thesis in progress, Brigham Young University, 2015-
- Kimberly Stevens, PhD thesis in progress, Brigham Young University, 2014-
- Derric Syme, MS thesis in progress, Brigham Young University, 2014-
- Rydge Mulford, PhD thesis in progress, Brigham Young University, 2014-
- Kevin Marr, MS, Brigham Young University, 2013-2015

Undergraduate Student Advisement

- Taylor Davis, "Microfabrication and device construction," Brigham Young University, March 2016 - present.
- Chad Gudmendsen, "Electrodeposition and biofunctionalization," Brigham Young University, January 2016 – present.
- Courtney Nordgran, "Superhydrophobic two-phase flow measurements," Brigham Young University, September 2015 – April 2016.
- Michael Farnsworth, "3D control of origami surfaces", Brigham Young University, July 2015 – May 2016.
- Shane Rahrle, "3-omega measurement techniques for thin-films," Brigham Young University, July 2015 – May 2016.
- Mitchell Blanc, "Origami-based, radiative surface property control," Brigham Young University, May 2015 – April 2016.
- Jonathan Erickson, "Two-phase flow visualization," Brigham Young University, September 2014 – June 2015.
- Ben Brownlee, "Detection of low H_2O_2 concentrations," Brigham Young University, September 2014 – May 2015.
- Carson Storey, "Through flow experimental setup for chemical sensing," Brigham Young University, July 2014 – June 2015.
- Bennett Myres, "Thermal conductivity detectors for gas chromatography," Brigham Young University, January – April 2014.
- Derric Syme, "Aligned CNT composites," Brigham Young University, November 2013 – May 2014
- Luke Christensen, "Dynamic radiation control with origami-based surfaces," Brigham Young University, Sept 2013- May 2014.
- Rydge Mulford, "Dynamic radiation control with origami-based surfaces," Brigham Young University, Sept 2013- May 2014.
- Isaac Delimont, "Dynamic radiation control with origami-based surfaces," Brigham Young University, June-Aug 2013.
- Jared Park, "Dynamic radiation control with origami-based surfaces," Brigham Young University, June-November 2013.
- Kevin Marr, "Porous anodic alumina templates," Brigham Young University, Jan-April 2013.

Project-Related Student Advisement

- Marc T. Dunham, "High-efficiency thermodynamic power cycles for concentrated solar power systems" Graduate Student Intern, Stanford University, 2012-2013.
- Scott M. Flueckiger, Freeze event recovery in parabolic trough, thermocline-bed property characterization and thermocline storage, Graduate Student Intern, Purdue University, 2011-2013.

- Brian D. Ehrhart, Critical Skills Master's Program, Sandia National Laboratories, 2011.

Student Awards

- Ben Brownlee, Utah NASA Space Grant Consortium Fellowship, $6k, 2016-2017.
- Kim Stevens, Utah NASA Space Grant Consortium Fellowship, $6k, 2016-2017.
- Ben Brownlee, NSF Fellowship Honorable Mention, 2016.
- Michael Farnsworth, ORCA Fellowship, BYU, $1.5k, 2016.
- Kim Stevens, Utah NASA Space Grant Consortium Fellowship, $7k, 2015-2016.
- Ben Brownlee, College of Engineering and Technology Fellow, BYU, $10k, 2015-2016.
- Rydge Mulford, NASA Space Technology Research Fellowship, $200k, 2015-2018.
- Ben Brownlee, ORCA Fellowship, BYU, $1.5k, 2015.
- Carson Storey, ORCA Fellowship, BYU, $1.5k, 2015.
- Rydge Mulford, 3-Minute Thesis Department and College Winner, BYU, $1.5k, 2015.
- Rydge Mulford, Utah NASA Space Grant Consortium Fellowship, $4k, 2014-2015.

Thesis Committee Advisement

- David Miller (Julie Crockett), July 2015-
- Alden Yellowhorse (Larry Howell), April 2014-
- Adam Cowley (Dan Maynes), April 2013-
- Matthew Searle (Dan Maynes), April 2013-
- Cristian Clavijo (Dan Maynes), April 2013-
- Jason Lund (Brian Jensen), January 2013-
- David Clark (Matthew Jones), February 2013-
- John Sessions (Brian Jensen), PhD Defense, March 2016
- Tyler Macbeth (Matthew Jones), Masters Defense, August 2015
- Daniel Ellis (Dale Tree), Masters Defense, July 2015
- Kim Stevens (Scott Thomson), Masters Defense, June 2015
- Travis Moore (Matthew Jones), PhD Defense, September 2014
- Jeremy Osguthorpe (Matthew Jones), Masters Defense, August 2013
- Daniel Tovar (Dale Tree), Masters Defense, August 2013

Funding Activities

Awarded

1. Co-PI for "Passive Inspection CubeSat (PIC)," NASA Undergraduate Student Instrument Project (USIP) Student Flight Research, $200,000 over 2 years, submitted November 2015 (Long, D., Iverson, B. D., Warnick, K., Wilde, D., Wirthlin, M.).
2. Co-PI for "Carbon Nanotube Fabrication Approaches Enabling Portable Gas Chromatography Systems," Brigham Young University Mentoring Environment Grant (MEG), $20k over 2 years, awarded December 2015 (Jensen, B., Iverson, B. D., Vanfleet, R. R.).
3. Co-PI for "Experimental Analysis of Fluid and Thermal Transport on Superhydrophobic Surfaces," Brigham Young University Mentoring Environment Grant (MEG), $19,950 over 2 years, awarded December 2015 (Crockett, J., Iverson, B. D., Maynes R. D.).
4. PI for "High Aspect Ratio CNT Structures for Electrode Sensors," Iowa State University, $7,000 over 6 months, awarded November 2015 (Iverson, B. D.)
5. Co-PI for "Droplet Formation and Removal Characteristics on Superhydrophobic Nano and Microstructured Surfaces," Moxtek, $35,348 over 1 year, awarded June 2015, (Crockett, J., Iverson B. D., Maynes, D.).
6. PI for "Dynamic Control of Radiative Surface Properties with Origami-Inspired Design," NASA

Space Technology Research Fellowship for Rydge Mulford, $30,000 over 3 years (Faculty Advisor Allowance; total award worth $222,000 over 3 years), awarded April 2015, (Mulford, R. B., Iverson, B. D.).

7. PI for "Dynamic Control of Surface Radiative Properties through Actuation of Origami-Inspired Surface Topographies," NASA EPSCoR of Utah, $24,851 over 1 year, awarded October 2014, (Iverson, B. D., Jones, M. R.).
8. PI for "Increasing Sensor Signal Strength of Glucose Detection in Amperometric Sensors, Research Initiation Grant, Brigham Young University, $10k over 1 years, awarded July 2014, (Iverson, B. D.)
9. Co-PI for "Droplet Mobility in Superhydrophobic Channels," Utah NASA Space Grant Consortium, Faculty Research Infrastructure Award Program, $21,500 over 1 year, awarded May 2014, (Crockett, J., Iverson, B. D., Maynes, D.).
10. PI for "Dynamic control of radiative absorption and emission through tunable, origami-based geometries," New Faculty Research Proposal, College of Engineering and Technology, Brigham Young University, $10,000 over 1 year, awarded August 2013 (Iverson, B. D.).

Previous to BYU

- Sunshot Lab Proposal Development Process (2012)
  PI for: "Heat exchangers for efficient thermal to electric conversion at high-temperature"
- Sunshot FOA, Department of Energy (2011)
  PI for: "High-temperature enabling receivers for advanced solar-thermal power cycles"
- High Energy Advanced Thermal Storage, ARPA-E (2011)
  Contributed as sub-PI for the following two submissions (both accepted for full-proposals):
  "High performance thermal storage solutions for dish-Stirling systems"
  "Thermal-wave energy storage system"
- Annual Operating Plan, Sandia National Laboratories (2010-2011)
  Prepared sections for submission to the U.S. Department of Energy.
- Indiana 21st Century Microscale Cooling Extension (2006-2007)
  Assisted in a successful $2M grant proposal submitted to the state of Indiana for extension funding of a microscale cooling joint project with Delphi Electronics, Kokomo, IN.
- Cooling Technologies Research Center (2005-2007)
  Proposed new and continuing projects for this NSF funded Industry/University Cooperative Research Center (I/UCRC) in the areas of heat pipe technology and micropumping.
- Air Force Research Lab (2006)
  Prepared supporting material for an AFRL Power Center grant.
- Multidisciplinary University Research Initiative (2006)
  Submitted supporting documents and data for this collaborative grant proposal.
- Office of Naval Research Proposal Abstract (2006)
  Prepared a white paper for submission to ONR regarding an EHD micropump for integrated electronics cooling.

Professional Activities

Courses Taught

- Heat Transfer ME EN 340 (W13, F13, Sp14, F14, Sp15, F15, Sp16)
- Convective Heat Transfer ME EN 643 (W14, W16)
- Intermediate Heat Transfer ME EN 540 (W15)
- Mentored Projects ME EN 497R (W13, F13, W14, Su14, F14, W15, Sp15, F15, W16)
- Capstone Senior Design Coach 475/476
  - 2015-2016 Stryker Plasma Stability Fixture

  - 2014-2015 Union Pacific Refrigerated Boxcar Airflow Distribution

Skills

- Device Fabrication and Characterization: Atomic force microscopy, scanning electron microscopy, mask design, lithography, cleanroom safety and procedures, isotropic/anisotropic etching, RIE etching, solution processing, glove box organic processing, thin-film deposition, oxidation
- Software: SolTRACE, CIRCE, Fluent, Gambit, Comsol, AutoCAD, MATLAB, Engineering Equation Solver, Mathcad
- Other: Proficient Japanese, interpersonal skills

Professional Training (Life-Long Learning)

- Speed Networking, August 25, 2015, Brigham Young University
- BYU Grant Writing Bootcamp, May 2015
- BYU Teaching and Learning Seminar
  - "Confessions of a converted lecturer," Eric Mazur, Harvard, March 4, 2015
  - "Teaching the truth," February 3, 2015
  - "Why motives matter," "Increasing Autonomy," December 12, 2014
  - "Homework sized projects, real-world practice," November 4, 2014
  - "Rethinking Exams – Assessing our Assessment," March 4, 2014
  - "Course Organization," February 12, 2014
  - "Conditioning and Retention," December 13, 2013
  - "Partial Credit," November 5, 2013
  - "Communicating expectations and assessment," March 5, 2013
  - "Immediacy," February 5, 2013
- MATLAB for Data Processing and Visualization, April 14, 2010

Professional Societies

- American Society of Thermal and Fluid Engineers
- American Society of Mechanical Engineers
  - Committee Member of Heat Transfer in Energy Systems (K-6)
  - Committee Member Elect of Nanoscale Transport Phenomena (K-9)
- Golden Key National Honor Society
- Tau Beta Pi, Engineering Honor Society

Consulting Activities

- Infinia Corporation, Ogden UT, May 2013. Reviewed thermal energy storage proposal and identified concerns using mineral oil as a heat transfer fluid and highly conductive materials in thermocline beds.

Service

Professional

- Sweet Talk seminar, mentoring freshman mechanical engineering students, March 25, 2016.
- Heat Transfer ME 340 Course Committee Chair, 2015-present
- BYU ORCA Grant Reviewer, 5 proposals, December 2015.
- Grad Expo 2015, graduate student recruiting fair, October 4-5, 2015.
- Session Chair (2 sessions), ASTFE Thermal and Fluids Engineering Summer Conference,

August 9-12, 2015.

- BYU Graduate Studies Fellowship Reviewer, 2 proposals, March 2015.
- Sweet Talk seminar, mentoring freshman mechanical engineering students, February 20, 2015.
- BYU Mechanical Engineering Department 3-Minute Thesis Competition, Organizer
  Held January 26, 2015.
- BYU writing group participant, 2013-present
- BYU ORCA Grant Reviewer, 10 proposals, November 2014.
- Heat Transfer Qualifying Exam Committee, Fall 2014.
- Sweet Talk seminar, mentoring freshman mechanical engineering students, September 5, 2014.
- BYU Graduate Studies Graduate Fellowship Reviewer, 2 proposals, March 2014
- Heat Transfer Qualifying Exam Committee, Winter 2014.
- BYU College of Engineering and Technology 3-Minute Thesis Competition, Judge
  Held January 30, 2014
- BYU Mechanical Engineering Department 3-Minute Thesis Competition, Organizer
  Held December 9, 2013
- BYU ORCA Grant Reviewer, 10 proposals, November 2013.
- Graduate committee, BYU Mechanical Engineering, 2013 – present
  Organized Graduate Seminar Series
  Instituted online community for reporting
  Facilitated schedule and hosted speakers
  Evaluated graduate student applicants twice yearly
  Advised on department fellowship selection
- Curriculum Development Committee, 2013-present
  Engineering practice, 1 credit junior course
- Heat Transfer Qualifying Exam Committee, Fall 2013.
- Sweet Talk seminar, mentoring freshman mechanical engineering students, September 27, 2013.
- Sweet Talk seminar, mentoring freshman mechanical engineering students, April 12, 2013.
- Session Chair, CSP Storage Technologies, ASME Energy Sustainability, July 14-19, 2013.
- Made from Concentrate, CSP seminar chair, Sandia National Laboratories, (2012)
- Session Chair, CSP Power Tower Technologies, ASME Energy Sustainability (2011)
- Equipment and Process User Program “Super User,” Birck Nanotechnology Center (2009)
  Advise users and staff of equipment function for training and troubleshooting.
- Volunteer and lab tour guide for Purdue University graduate student recruiting weekends (2003-2008)
- Professional Development Committee Chair for the Nanotechnology Student Advisory Council, Birck Nanotechnology Center, Purdue University (2006-2007)
  Organized resume and curriculum vitae workshop, February 15, 2007.
  Organized industry and faculty career path seminar, April 12, 2007.
- Volunteer Birck Nanotechnology Center escort and lab tour guide, Purdue University (2006-2007)
- Tau Beta Pi, Membership Committee Chair for Utah, Beta Chapter (2001-2002)
- Paper/Funding Reviews:
  Applied Physics Letters, 1 paper, June 2016.
  Journal of Heat Transfer, 1 paper, May 2016.
  International Journal of Heat and Mass Transfer, 1 paper, May 2016.
  Journal of Heat Transfer, 1 paper, April 2016.
  Energy, 1 paper, February 2016.
  ACS Applied Materials and Interfaces, 1 paper, February 2016.
  Solar Energy, 1 paper, November 2015.
  Journal of Heat Transfer, 16 photogallery submissions, September 2015.
  Applied Thermal Engineering, 1 paper, September 2015
  Journal of Heat Transfer, 1 paper, August 2015.
  ASTFE Thermal Fluids Engineering Summer Conference, 2 papers, April 2015.

DOE SBIR/STTR Grant Applications, 2 papers, March 2015.
Journal of Solar Energy Engineering, 1 paper, March 2015.
ACS Applied Materials and Interfaces, 1 paper, March 2015.
Applied Energy, 1 paper, January 2015.
Journal of Electronic Packaging, 1 paper, August 2014.
ACS Applied Materials and Interfaces, 1 paper, August 2014.
International Journal of Heat and Mass Transfer, 1 paper, August 2014.
Journal of Electronic Packaging, 1 paper, July 2014.
Experimental Heat Transfer, 1 paper, June 2014.
Journal of Fluids Engineering, 1 paper, June 2014.
International Journal of Electrical Power and Energy Systems, 1 paper, May 2014.
ASME International Mechanical Engineering Congress and Exposition, 2 papers, May 2014.
Sensors and Actuators B: Physical, 1 paper, March 2014.
International Journal of Heat and Mass Transfer, 1 paper, March 2014.
Journal of Solar Energy Engineering, 1 paper, January 2014.
ASME Turbo Expo 2014, 1 paper, November 2013.
Journal of Fluids Engineering, 1 paper, November 2013.
Energy Conversion and Management, 1 paper, September 2013.
Solar Energy, 1 paper, August 2013.
Solar Energy, 1 paper, June 2013.
ASME International Mechanical Engineering Congress and Exposition, 1 paper, May 2013.
Renewable and Sustainable Energy Reviews, 1 paper, May 2013.
ASME Summer Heat Transfer Conference 2013, 1 paper, March 2013.
DOE SBIR/STTR Grant Applications, 1 paper, March 2013.
ASME Turbo Expo 2013, 1 paper, December 2012.
Energy Sustainability 2012, 1 paper, March 2012.
Materials Science and Engineering B, 1 paper, September 2011.
Applied Energy, 1 paper, September 2011.
International Journal of Heat and Mass Transfer, 1 paper, August 2011.
Energy Sustainability 2011, 2 papers, April 2011.
Journal of Solar Energy Engineering, 1 paper, January 2011.
SBIR/STTR Grant Applications, 3 papers, January 2011.
Journal of Micromechanics and Microengineering, 1 paper, May 2010.
Journal of Heat Transfer, 1 paper, February 2010.
Solar Energy, 1 paper, February 2010.
Journal of Micromechanics and Microengineering, 1 paper, June 2009.
International Journal of Refrigeration, 1 paper, May 2009.
Journal of Fluids Engineering, 1 paper, December 2008.
Electronics Packaging Technology Conference, 1 paper, October 2008.
Journal of Electronic Packaging, 1 paper, July 2008.
Journal of Heat Transfer, 1 paper, June 2008.
Microfluidics and Nanofluidics, 1 paper, May 2008.
ITherm 2008 Conference, 1 paper, January 2008.
Microfluidics and Nanofluidics, 1 paper, November 2007.
ASME International Mechanical Engineering Congress and Exposition, 1 paper, 2005.

Outreach

- Utah STEM Fest, hands on experiences with science and technology to encourage young interest, February 2-4, 2016.

- Wasatch Elementary Science Presentation, Provo School District, "Why is that bugs can stand on water? – surface tension and hydrophobicity," November 17, 2014.

Community

- AYSO Soccer Coach, Albuquerque, NM (2011-2012)
- AYSO Referee, Albuquerque, NM (2010-2011)
- Webelos Den Leader, Boy Scouts of America (2010-2011)
- Premier Soccer Academy Coach, Albuquerque, NM (Spring 2010)
- English Conversation Facilitator, Daily Dose Program, NC (Summer 2007)
- Volunteer missionary, Okayama, Japan, The Church of Jesus Christ of Latter-Day Saints (1997-1999)
- BYU Honor Code Committee Volunteer (1996-1997)

Appendix F

Advanced Neural Net Controls

University of Utah

Research Proposal

CLEAN COAL ENABLED BY ARTIFICIAL INTELLIGENCE

A research project for the Utah Sustainable Transportation and Energy Plan

PacifiCorp Contact
Glenn Pinterich (Project Manager)
PacifiCorp
Huntington Power Station
Huntington, Utah 84528
glenn.pinterich@pacificorp.com

University Contact
Prof. Kody Powell (Principal Investigator)
The University of Utah
Department of Chemical Engineering
50 S Central Campus Dr., Rm 3290G
Salt Lake City, Utah 84112
801-581-3957
kody.powell@utah.edu

Participating Members

Participant	**Organization**	**Role**
Glenn Pinterich	PacifiCorp – Huntington Power Station	Project Manager
Michael Dayton	PacifiCorp – North Temple Office	Technical Advisor
Ian Andrews	PacifiCorp – North Temple Office	Project Oversight
Prof. Kody Powell	U. of Utah Dept. of Chemical Engineering	Principal Investigator
Jake Tuttle	U. of Utah Dept. of Chemical Engineering	Graduate Researcher
Brad Radl	Taber International / Griffin Open Systems	Vendor/Tech. Support
Prof. John Hedengren	BYU Dept. of Chemical Engineering	Technical Advisor

Proposed University of Utah Budget: **$395,205**

Contents

PROJECT SUMMARY

The University of Utah will partner with PacifiCorp's Huntington power station and Taber International/Griffin Open Systems to install, demonstrate, and fundamentally research artificial intelligence technologies to improve emissions of coal-fired power systems. The software-based technology provided by Griffin Open Systems™ is primarily based on artificial neural networks (ANNs), which are proven data-driven modeling techniques used to mathematically describe complex processes, such as coal combustion for power generation. ANNs are used to mathematically "learn" the process, particularly the relationships between inputs (e.g., valve positions, flow rates, damper positions, etc.) and important outputs (e.g., NO_x generation rate, plant efficiency, power output, etc.), through a mathematical model-fitting routine. Using this empirical mathematic model of the process, rigorous optimization routines can be used to determine the optimal combination of inputs to give a desired change in an output (e.g., finding the conditions that minimize NO_x emissions, maximize efficiency, or a combination of both). Because the process is continually changing as conditions change, the software is used to continuously update the model and re-solve for optimality.

The proposed project is ideal in a number of ways: 1) The project has an assurance of success as the base technology has been commercially demonstrated and will have the engineering support of a vendor with decades of experience in coal plant optimization. 2) There are many research opportunities to improve the technology on the topics of intelligent model fitting and dynamic optimization through transient operation due to fast ramping of the plant (caused by increased renewables on the grid). 3) The project is extremely low cost as it is completely software-based and does not require a large capital project to retrofit the plant. 4) The technology is immediately scalable to other units. 5) The technology will have an indefinite emissions benefit if the plant chooses to extend to a permanent software license. 6) The primary research team members are experienced in neural networks and process optimization and are local to Emery County (home of the plant site). They have a vested interest in the plant's performance and will spend a significant amount of time on-site to ensure the project's success.

BACKGROUND

Overview of Artificial Neural Networks in Coal Combustion Optimization

Optimizing a process entails selecting the best combination of input (decision) variables that give an optimal value of an output variable (i.e., maximizing efficiency, maximizing profit, or minimizing cost). Real-time optimization (RTO) is commonly used in many industries and is an ideal technology to implement because of its high benefit-to-cost ratio, as it only requires software while using existing plant instrumentation and control systems [1–3]. RTO requires the use of an accurate mathematical model of the process so that the model can be solved in real-time to determine the optimal operating conditions of the plant. The process of coal combustion for power generation is so complex that physics-based models are too computationally intensive to be solved in real-time. Because of this, data-driven, empirical models (such as ANNs) are typically used for RTO of coal plants [4–7]. ANNs have proven to be very effective at predicting plant performance, with studies indicating an **average error of 1.35% or less for prediction of output variables** [8].

An artificial neural network is a type of mathematical modeling structure. ANNs are designed to mimic the human brain's mechanism for learning and retaining information by storing it in chemical and electrical signals, which increase in response to environmental stimulii. A simplified structure of an ANN is shown in Figure 1. In this figure, *u* represents the inputs (e.g., valve positions, temperature set points, excess O_2, etc.) and *y* represents the output, of which there can be many (NOx emissions, heat rate, etc.). The greek letters (ϕ and Ω) are mathematical "activation" functions, which produce a certain response to the inputs and the weighting parameters (*w* and *W*). When given a set of real data from the plant, the weighting parameters can be adjusted using a rigorous mathematical model-fitting routine so that the model's outputs (*y*) closely match the plant data, which the model is trying to predict [9]. As the process changes, new weighting parameters can be found so that the model stays accurate, despite an ever-changing process. While the figure shows a very basic representation of a neural network model structure (known as a three layer perceptron), there are many different types and configurations of neural network models, depending on the application. The models can also be combined with other types of models or algorithms in a hybrid configuration.

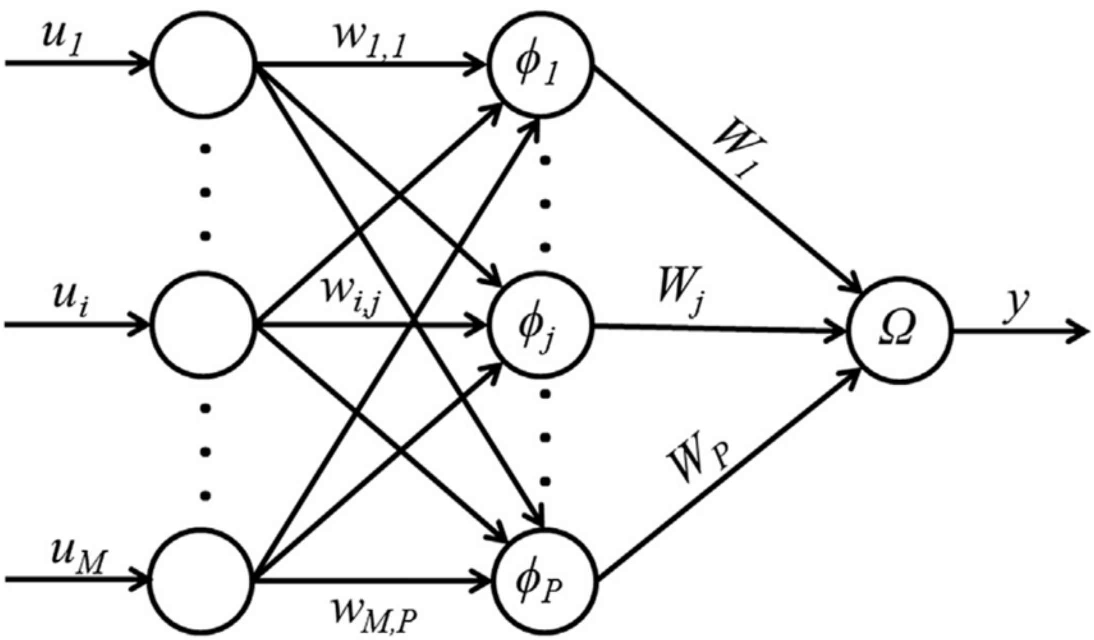

Figure 1: A visual representation of an artificial neural network (ANN). The ANN takes in inputs (*u*) to predict a specified output (*y*) using groups of mathematical functions (ϕ and Ω). The weights (*w* and *W*) are adjusted algorithmically so that the output matches plant data as closely as possible. Figure available from Powell et al. [9]**.**

ANNs for NOx Emissions Minimization and Efficiency Improvements

Once an accurate model of the process is found, the model is solved using a mathematical optimization routine to determine the set of inputs (*u*) that give the best output (*y*). If the objective is to mimizine NOx in a coal plant, for example, the ANN model can be solved to determine the optimal process inputs that give minimal NOx, given the current set of environmental conditions. This has been done with much success industrially. **Studies have shown NOx reductions of up to 48% and CO reductions of 75%** [10].

Similarly, neural network optimizers focused on **heat rate improvements save an estimated 0.5-1.5%**, which means a proportional amount of fuel and CO_2 emissions savings [11]. A preliminary estimate of the savings that could be achieved by a typical coal power plant using neural network optimization technology is summarized in Table 1. These projections for the Huntington Plant are for two units operating at full load, so it should be noted that the initial research project will only focus on a single unit. However, the results would be scalable by deploying the software to multiple units in the future. The software application must also be tuned so that it achieves an ideal balance between NOx emissions minimization and efficiency maximization, whose optimal solutions may not perfectly coincide.

Table 1: Preliminary estimates of anticipated annual savings for two units at full load at the Huntington plant using by neural network RTO with heat rate minimization as the primary objective.

Description	**Quantity**
Plant Output	895 MWe
Heat Rate [12]	10080 Btu/kWh
Fuel cost per unit energy [13]	$1.63 per MMBtu
Fuel cost per year	$130,000,000 per year
Projected heat rate improvement [11]	0.5-1.5 %
Projected savings for full-load operation	$650K-$1.9M per year
Projected CO_2 savings [14]	40,000-122,000 tons/yr

Overview of Research Challenges

Although neural network optimization technology has proven to be an effective and low cost clean coal technology, there are still many opportunities to improve the technology. One of the key issues is that the process can drift over time, which makes the model less accurate and the optimization results less relevant. Although the existing technology employs methods to continuously update the model, changes in the process, such as the loss of sensors or actuators or sudden shifts in operating conditions can cause adversely impact the model's accuracy. This in turn causes deactivation of the software application by plant operators, which eliminates any potential emissions benefit. To keep the model evergreen and ensure long-term operator adoption, intelligent model adaptation routines are needed. These routines would continuously monitor the process's health, statistically detect anomalies, and systematically make changes to the process inputs so that the model can "re-learn" the response. Currently, the technology requires a trained engineer to initialize the model, including finding the best model structure, given the current set of functioning sensors and actuators. Continuous re-fitting of the model can change the model parameters to keep the model accurate, but it generally does not change the model's structure. Methodologies for continuously monitoring the health of the process, the model, and any instrumentation are needed. By keeping the model up to date by re-fitting, intelligently updating the model structure, or alerting an engineer or operator when the process needs physical maintenance, the software can have long-term operator adoption and require minimal manpower to sustain.

Another critical research topic has a arisen as a result of increased penetration of variable renewable power sources on the grid in recent years. Solar and wind energy are intermittent in nature and their fluctuations generally cause fuel-based power plants to ramp up and down to maintain the frequency on the grid. In California, major grid instabilities are projected as a result of unprecedented amounts of renewables on the grid, which will cause fuel-based plants to ramp up and down at somewhat extreme ramp rates [15,16]. Projections show that increased penetration of intermittent renewables causes (what once were considered) baseload power sources (coal and nuclear) to change loads with rapid ramping in order to enable renewables, as Figure 2 demonstrates [17]. From an optimization point of view, extreme ramping like that shown in the figure makes it much more difficult to optimize. Real-time optmization is generally based on the idea of steady-state operation of a process, which is the assumption that the process is relatively constant for at least a short period of time. A dynamically-changing process is more difficult to optimize as the operating conditions of the plant are always shifting. By extending the neural network model to be dynamic, optimization can be performed over a time horizon, rather than at a single instance in time. The proposed researchers have expertise in dynamic optimization [18–21] and believe this is an area where a significant impact can be made in research and in efficient grid operation. Dynamic optimization of a ramping coal plant would become a renewable energy-enabling technology because it could be used to maintain grid stability even under extreme ramping conditions.

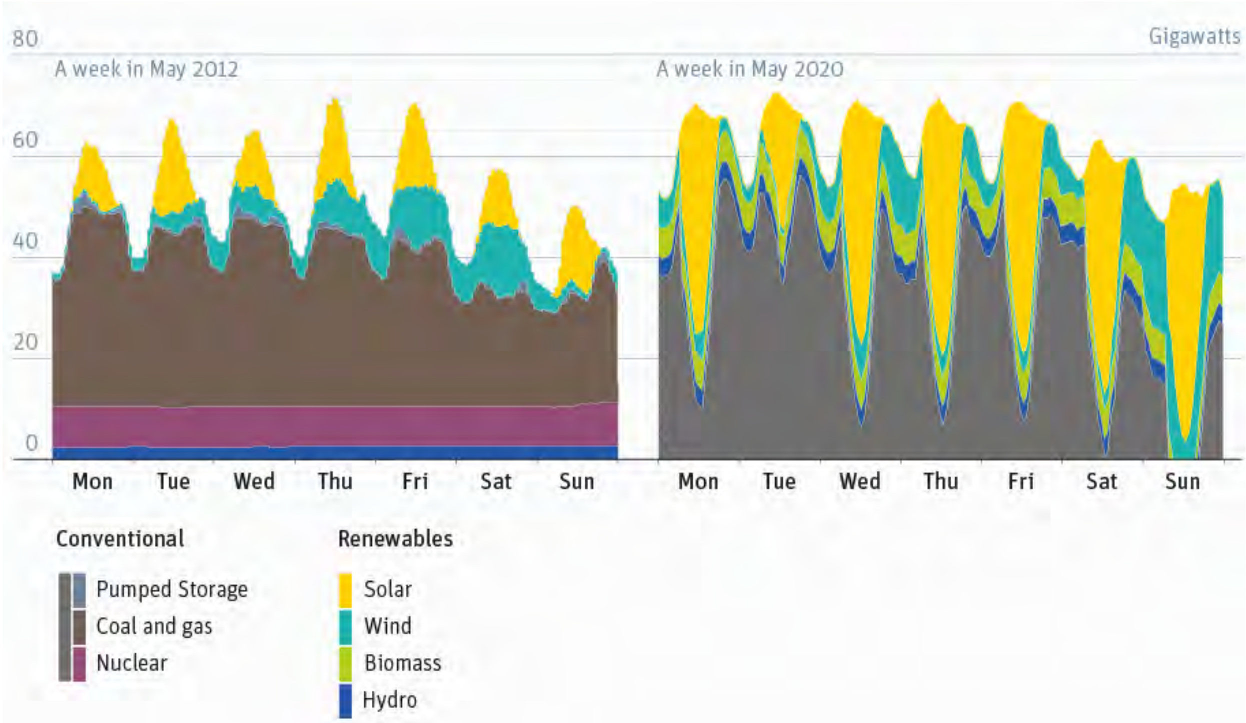

Figure 2: Load profiles for 2012 and projected in 2020 with high renewable penetration. Optimization under rapid ramping conditions is a key research objective. Figure available from [17]**.**

Another major opportunity for improving plant operations is in optimizing the many auxiliary processes required for power generation. While neural network optimization technology is predominantly used for combustion optimization in the boiler, auxiliary units such as cooling towers, scrubbers, the generator, etc, can also be optimized to improve the efficiency of the entire operation, not only the boiler. At low load, auxiliary power consumption can increase heat rate by up to 21% compared to full-load operation [22]. Modeling and optimizing these auxiliary processes via neural network technology, therefore, will provide additional opportunities to improve the overall efficiency of the plant.

OBJECTIVES AND DELIVERABLES

The proposed project represents an ideal combination of safe and potentially transformative. It will leverage existing, proven technology to ensure measurable emissions reductions, but will also explore cutting-edge research topics to improve the software in the face of new operational challenges. The objectives of the project are summarized in the following sections.

1. Install and Support Artificial Intelligence Software

The primary objective of the project will be to successfully deploy the neural network software application as well as the Griffin Intelligent Sootblowing application and ensure their adoption and long-term use. This will be accomplished by working with Taber International, who will provide up-front engineering services to install the Griffin Open Systems neural network optimization software and work through any technical issues related to its deployment. The sub-contract to Taber/Griffin will include maintenance and licensing fees and ensure their ongoing support of the software application. The University of Utah researchers will work closely with Taber to master the software so that they can provide additional support to maintain and improve the application. The University of Utah researchers will spend a significant amount of time on-site at the Huntington Plant to become well-acquainted with the process and the personnel. A graduate student researcher will spend the summer months working full-time at the site and will also work full-time at the site once graduate coursework has been completed. University personnel will provide ongoing training to plant personnel on how to use the software. They will also continually monitor the application (on site or remotely) and implement modifications and improvements as they are developed. For the duration of the project, university personnel will be on call to ensure a high service factor and long-term adoption for the software.

2. Document Emissions Reductions and Heat Rate Improvements

As a clean coal research and development project, a critical objective will be to measure and document the emissions and heat rate improvements that can be attributed to the use of the neural network software. Using previous years as a baseline, the plant's performance will be tracked and reported on each year. As the implementation of optimization software is a learning process (for the personnel as well as for the software), a gradual improvement in plant emissions are anticipated as recommendations and improvements are progressively implemented. Research personnel will formally report to PacifiCorp management from the plant and from the North Temple Office on a quarterly basis to present recent results and discuss ongoing improvement recommendations. The research team will also release a final report at the project's conclusion to report on the progress made during the three-year research project.

3. Address Fundamental Research Challenges

At its core, the research project is an artificial intelligence project, which presents many fundamental research challenges. Specific to coal-fired power, some of the key research issues to be addressed are finding methods to keep the model evergreen using intelligent model adaptation as the plant's processes drift or change over time. While the Griffin software currently has a continuous "learning" feature where the model is re-fit periodically every few hours, long-term issues may arise as sensors or actuators degrade and become unreliable or new instrumentation is added. Fundamental process changes like these would typically require a new model structure to account for more or fewer inputs. During the project, intelligent methods for finding a new model structure and fitting the model will be explored on a simulation basis by the research team. These may be tested in the live plant application pending a thorough review process and approval from plant personnel.

A related key research objective will be intelligent process and application health monitoring. To address this objective, the researchers will explore statistical methods to detect when the process or the model have faults that may be caused by malfunctioning equipment or performance degradation over time. In these instances, action taken by plant engineering or maintenance personnel would be required and an automated response by the software would not be sufficient. Upon development and inclusion of adequate fault detection methods, the research team will explore automated alerting of plant personnel and study the impact this might have on efficiency and equipment lifetime.

The research team will go beyond neural network optimization of the combustion process in the boiler and will explore opportunities to improve overall efficiency by applying the neural network optimization technology to the plant's auxiliary processes, including pumps, fans, and compressors. Where variable frequency drives (VFDs) are available, the team will explore optimization of these process components to determine the optimal speed that results in reduced overall power consumption. Major auxiliary process equipment that the team will explore optimizing includes cooling towers, the flue gas desulphurization unit (scrubber), electrostatic precipitators, and the generators. Working with the Griffin Intelligent Sootblowing application, the project team will also study optimal sootblowing so that the boiler process efficiency is maximized while minimizing the use of auxiliary steam to accomplish this periodic maintenance task.

Another major challenge facing the coal power plants worldwide is the rapid ramping that is required as intermittent renewable energy becomes more and more prevalent on the grid. Dynamic optimization so that a plant can still perform optimally even during changing load will be addressed by the research team. These potential enhancements to the software will be developed offline in a simulation environment and will be introduced to the plant only if success at the simulation level proves to be effective. This will also require approval from plant personnel before any modifications are implemented.

As in any process automation application, the more sensor data that is available, the better. As the team works to install and develop the optimization application, they will also explore the use of additional or upgraded sensors to improve plant operations. Where appropriate, recommendations including a detailed cost/benefit analysis will be made to plant personnel.

While challenging, the research that emerges as a result of approaching these problems could have an impact far beyond a single power plant. With fuel-fired power plants around the world facing similar issues with transient operation due to intermittent renewables on the grid, solutions to these problems have the potential to have a substantial impact on society.

Project Deliverables by Organization

Table 2: Description of deliverables from each participating entity.

PacifiCorp
• *Provide project oversight* • *Provide training/guidance on utility-scale coal combustion optimization* • *Provide guidance on performance metrics to be monitored and the direction of the optimizer implementation* • *Provide feedback on report conclusions.* • *Establish KPI's for success, e.g., NOx <0.15 lbs/mmbtu, CO less than Permitted value, 0.75% Net Unit Heat Rate (NUHR) reduction, etc.* • *Provide office for U of U student/faculty* • *Provide and prepare server for optimizer, communication link, DCS modifications*
University of Utah

- *Perform parametric study of the test unit throughout the entire process; prior to installation of the optimizer, during the installation, during the learning phase and after the optimizer is online to test the effectiveness of the various inputs. This study would at a minimum identify the most effective control loops to be available for the neural network combustion optimizer. It will also identify the need of additional instrumentation and controls.*
- *Assist PacifiCorp and Taber Int. personnel with the installation/implementation of the optimizer. Evaluate the neural network in operation and provide recommendations for improvement and process control expansion e.g., adding additional control loops, expand usage to include auxiliary plant processes like; cooling tower fan control, scrubber control, or any process that has remotely controlled parameters. In that vein also evaluate which process might benefit for the addition of remote control that could be optimized.*
- *Assist PacifiCorp (and possibly 3rd party tuners) personnel with unit optimization and evaluate the effects of that optimization and how the optimizer responds to that optimization.*
- *Evaluate factors that may discourage system usage e.g., poor human machine interface, excessive maintenance, lack understanding or distrust of "intelligent" control, insufficient instrumentation and or controls. Where possible identify mitigation opportunities for the identified problems and aid in their implementation.*
- *Provide additional ongoing training to plant operators and other plant personnel in the operation of neural network optimization*
- *Help to establish KPI's for success, e.g., NOx <0.15 lbs/mmbtu, CO less than Permitted value, 0.75% Net Unit Heat Rate (NUHR) reduction, etc.*
- *Report on the performance of the neural network optimizer with regard to usage level, benefit received, benefits lost and improvement recommendations*
- *Provide year round onsite coverage (have personnel on site at least two days a week once application has been commissioned)*

Taber International

- *Provide software*
- *Provide engineering support for installation*
- *Provide engineering product support*
- *Provide best practice guidance based on installed base experience*
- *Provide training for software implementation and modification*

Brigham Young University

- *Provide additional technical guidance on research aspects of project*

TIMELINE

The proposed project is for a duration of three years, which will be required to reach the above-specified objectives. While the software can be installed in a matter of weeks, optimizing its usage may take years. This includes a long run-time to ensure that plant operations personnel become comfortable with its use through training and troubleshooting, identifying opportunities to improve the software's functionality through improved sensors and actuators in the process, and exploring techniques to better model and optimize the process. The fundamental research objectives are also challenging problems that are long-term in nature and will require multiple years to develop and possibly implement.

For the duration of the project, the research team will prioritize spending as much time on site as possible. When project personnel are not living in proximity of the plant (primarily due to required university coursework in Salt Lake City), they will continue research including providing remote support, on call support, and will make regularly scheduled visits to the plant site. An approximate schedule is included in Table 3.

Table 3: An approximate project schedule indicating the anticipated number of days on site per month in each period.

Period	***Approximate Days On Site/Month***	***Objectives***
Preparation Work		
Jan. 2017 – Apr. 2017	2	• Student learns Griffin Open Systems Software and develops test applications for simulated processes • Plant repairs/installs instrumentation + server and prepares for software installation • Scheduling with Taber/Griffin for engineering services is complete • Multiple visits by student researcher and adviser to get acquainted with process, site personnel, and installation progress • Possible Ameren site visit by U of U and PacifiCorp
Installation and initial data collection		
May 2017- Aug. 2017	20	• Installation of Griffin Combustion Optimization and Intelligent Sootblowing applications completed in mid-May • Student researcher is on site 40 hrs/wk to oversee installation, work with operators to identify any adoption issues, begin data collection, and identify any potential issues with software application
Ongoing research project		
Sept. 2017- Apr. 2018	8	• Remote monitoring / on call application support • Continuous improvement of application through programming enhancements, instrumentation improvement recommendations, operator training, interface enhancements • Documentation of improvement for emissions, fuel savings, etc. • Research into dynamic optimization through plant power set-point transitions • Final report on project
May 2018- Aug. 2018	20	
Sept. 1 2018- Apr. 2019	8-20	
May 2019- Dec 2019	10-20	

BUDGET

The University of Utah portion of the budget for the project is $395,205 and is summarized in Table 4. The budget includes salaries for university personnel including one-month of salary per year for the project PI and eighteen months per year for graduate researchers. Travel, living, and per diem costs are also included. The researcher support and travel funds will assure that university personnel can spend an adequate amount of time on site to develop and support the application for the duration of the project.

Table 4: The University of Utah budget summary for the project, which includes university personnel salaries and benefits, travel costs, and all overhead charges.

	2017	*2018*	*2019*	***Total***
Salaries w/ overhead	$90,985	$92,805	$94,661	**$278,451**
Travel, living expenses, and per diem w/ overhead	$37,698	$37,698	$41,358	**$116,754**
Total	**$128,683**	**$130,503**	**$136,019**	**$395,205**

The comprehensive budget will be managed and distributed by PacifiCorp and also includes $320,000 in up-front costs for Taber International for engineering services ($160,000) and a single unit license ($160,000) and a total of $96,000 for three years of licensing fees for the software from Griffin Open Systems. Engineering services entail multiple trips to the site from Taber personnel to install the software and ensure that everything is running correctly. Return trips will be made to make adjustments as necessary and will include training for plant personnel. These upfront costs ensure turnkey use of the software. Annual maintenance fees of $32,000 per year will be distributed to Griffin Open Systems for use of the Griffin neural network Combustion Optimization and Intelligent Sootblowing software applications. At the end of the project, the licensing fee may be applied toward a permanent corporate license, which has a cost total of $1,000,000 (PacifiCorp would be required to supply the remaining $840,000).

PROJECT TEAM

PacifiCorp engineering personnel, led by Glenn Pinterich at the Huntington Plant, will provide project management and oversight. PacifiCorp's engineering team will provide technical expertise in the process and will have responsibility for all final decisions on the project.

In addition to PacifiCorp personnel, the proposed project team has both the expertise and vested interest in the project to ensure success. The Principal Investigator, Prof. Kody Powell, has worked previously for ExxonMobil Research and Engineering as an expert in advanced control and optimization of utility networks. His background includes developing model predictive control (MPC) and real-time optimization (RTO) applications for combined heat and power systems for ExxonMobil refineries and chemical plants across the country. Prof. Powell has developed neural network models used for predicting energy demands for a district energy system [9] and he also has expertise in dynamic optimization, with research focused on developing novel dynamic optimization algorithms to take advantage of energy storage [18,21,23]. Prof. Powell is a native of Huntington, Utah and has a strong desire to do research projects which can benefit the people of Emery County.

Jake Tuttle is a student researcher in the Department of Chemical Engineering at the University of Utah and is committed to pursuing a Ph.D. Jake is also a native of Emery County and is excited about the prospect of living in Emery County while completing his graduate research work. Jake is currently near the top of his class in chemical engineering and holds a 3.92 GPA. He has experience in Java Programming (which Griffin Open Systems is based on).

Brad Radl is the founder, President, and Chief Technology Officer of Taber International and Griffin Open Systems. His companies have decades of experience in coal power plant optimization. His companies, based in Chardon, Ohio, provide engineering services, installation, licensing, and maintenance of their software products. Griffin Open Systems Combustion Optimization is based on neural network technology, but provides an open platform that can be easily customized by plant personnel. His software products have proven to be very effective at reducing NOx and improving heat rate and plants for decades [24].

Prof. John Hedengren is a professor in Chemical Engineering at Brigham Young University. He has worked for ExxonMobil Chemical and PAS, Inc. as an advanced control and optimization expert. Prof. Hedengren's research is focused on advanced control and optimization of upstream oil operations, unmanned aerial vehicles, and energy systems. Prof. Hedengren has developed his own dynamic optimization software, which has been used in a number of industrial and research application areas [21]. Prof. Hedengren will serve on the project as an additional technical advisor.

CONCLUSION

The proposed project is an ideal opportunity to deploy and demonstrate clean coal technology with a high probability of success and a very high benefit-to-cost. This software-based technology does not require major capital expenses, as most clean coal technologies would, and can be permanently adopted by the Huntington Plant and easily scaled across the entire PacifiCorp fleet. Although the technology is essentially turnkey, there are still many improvements to be made in a research project, including documenting the emissions benefits and improving the technology with intelligent model-fitting routines for long-term operator adoption and optimizing under ramping conditions to better enable renewable energy technologies on the grid. The technology has proven to be effective at reducing both NOx and CO_2 emissions and will make a positive impact on plant operations. Because the research project is focused on artificial intelligence in a power generation facility, the research has potential to extend beyond coal plants and be applied to combined cycle power generation processes and even technologies outside of the power industry.

Members of the project team have deep roots in Emery County and will be able to spend large portions of the project actually working in the plant. This will ensure that the software is effective and that plant operators are comfortable using the technology, so that high service factors can be achieved to reduce emissions to the fullest extent possible. The project team will have a vested interest in doing whatever they can to improve operations at the Huntington plant.

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WORK EXPERIENCE

The University of Utah Department of Chemical Engineering, SLC, UT 2016-Present
Assistant Professor in Energy Systems Research
Research in energy systems with a specialty in modeling, optimization, advanced control, and energy storage

ExxonMobil Research and Engineering, The Woodlands, TX 2015
Real-Time Optimization Research and Development Engineer
Real-time optimization development and global support for refining and chemical plant utility networks, first principles process modeling and estimation for fault detection

ExxonMobil Refining and Supply, Baytown, TX 2013-2015
Senior Engineer in Advanced Control and Optimization
Model predictive control, real-time optimization, and distributed control system development for refinery-wide utilities, gasoline blending, environmental

The University of Texas at Austin – Utilities and Energy Management 2012 – 2013
Project Leader for Large-Scale Utilities Optimization Project
Dynamic real-time optimization of campus-wide utilities (electricity heating, and cooling), energy demand forecasting, model development for gas and steam turbines, waste heat boilers, centrifugal chillers, cooling towers, energy storage system

ExxonMobil Research and Engineering, Baytown, TX 2011
Internship in Model Predictive Control and Real-Time Optimization
Evaluated advanced control software packages, developed algorithms for model predictive control and state estimation

Fairchild Semiconductor, West Jordan, UT 2006 – 2009
Process Engineering Co-Op
Planned and executed projects and experiments related to diffusion and chemical and physical vapor deposition processes

TEACHING

The University of Utah
Heat Transfer (anticipated) 2016
Advanced Data Analytics in Smart Manufacturing (anticipated) 2017

The University of Texas at Austin

Teaching Assistant – Optimization 2013

Co-Instructor – Senior Unit Operations Lab 2009-2012

Teaching Assistant – Energy Technology and Policy 2011

EDUCATION

The University of Texas at Austin, Austin, TX

Ph.D. in Chemical Engineering 2013

Dissertation: "Dynamic Optimization of Energy Systems with Thermal Energy Storage"

The University of Utah, Salt Lake City, UT

B.S. in Chemical Engineering, Chemistry Minor 2009

Magna cum Laude

AWARDS

Cockrell School of Engineering Fellowship 2009-2013
The University of Texas at Austin

Graduate Research Fellowship 2009-2012
The National Science Foundation

Oblad Silver Medal of Excellence 2009
The University of Utah Department of Chemical Engineering

Outstanding Senior Award 2009
AIChE University of Utah Chapter

Presidential Scholarship and Oblad Energy Scholarship 2002-2009
The University of Utah

PEER-REVIEWED JOURNAL PUBLICATIONS

[13] "Thermal energy storage to minimize cost and improve efficiency of a polygeneration district energy system in a real-time electricity market"
K.M. Powell, A. Sriprasad, W.J. Cole, T.F. Edgar
Energy, In Press 2016

[12] "A continuous formulation for logical decisions in differential algebraic systems using mathematical programs with complementarity constraints"
K.M. Powell, A.N. Eaton, J.D. Hedengren, T.F. Edgar
Processes, Volume 4, pp. 7 2016

[11] "Energy intensification using thermal storage"
T.F. Edgar, **K.M. Powell**
Current Opinion in Chemical Engineering, Volume 9, pp. 83-88 2015

[10] "Heating, cooling, and electrical load forecasting for a large-scale district energy system"
K.M. Powell, A. Sriprasad, W.J. Cole, T.F. Edgar
Energy, Volume 74, pp. 877-885 2014

[9] "Nonlinear modeling, estimation, and predictive control in APMonitor"
J.D. Hedengren, R.A. Shishavan, **K.M. Powell**, T.F. Edgar
Computers and Chemical Engineering, Volume 70, pp. 133-148 2014

[8] "Dynamic optimization of a hybrid solar thermal and fossil fuel system"
K.M. Powell, J.D. Hedengren, T.F. Edgar
Solar Energy, Volume 108, pp. 210-218 2014

[7] "Reduced-order residential home modeling for model predictive control"
W.J. Cole, **K.M. Powell**, E.T. Hale, T.F. Edgar
Energy and Buildings, Volume 74, pp. 69-77 2014

[6] "Turbine inlet cooling with thermal energy storage"
W.J. Cole, J.D. Rhodes, **K.M. Powell**, T.F. Edgar
International Journal of Energy Research, Volume 38, pp. 151-161 2014

[5] "An adaptive-grid model for dynamic simulation of thermocline energy storage systems"
K.M. Powell, T.F. Edgar
Energy Conversion and Management, Volume 76, pp. 865-873 2013

[4] "Optimal chiller loading in a district cooling system with thermal energy storage"
K.M. Powell, W.J. Cole, U.F. Ekarika, T.F. Edgar
Energy, Volume 50, pp. 445-453 2013

[3] "Improved large-scale process cooling operation through energy optimization"
K. Kapoor, **K.M. Powell**, W.J. Cole, J.S. Kim, T.F. Edgar
Processes, Volume 1, pp. 312-329 2013

[2] "Modeling and control of a solar thermal power plant with thermal energy storage"
K.M. Powell, T.F. Edgar
Chemical Engineering Science, Volume 71, pp. 138-145 2012

[1] "Optimization and advanced control of thermal energy storage systems"
W.J. Cole, **K.M. Powell**, T.F. Edgar
Reviews in Chemical Engineering, Volume 28, pp. 81-99 2012

SELECT CONFERENCE PRESENTATIONS

"Thermal energy storage to enhance hybrid energy systems"
K.M. Powell
Nuclear Hybrid Energy Systems CORE Workshop, INL, Idaho Falls, ID 2013

"Dynamic optimization of a solar thermal energy system using weather forecasts"
K.M. Powell (presenter), J.D. Hedengren, T.F. Edgar
*Proceedings of the 2013 American Control Conference**, Washington DC 2013

"Nonlinear model predictive control for a heavy-duty gas turbine power plant"
J.S. Kim, **K.M. Powell** (presenter), T.F. Edgar
*Proceedings of the 2013 American Control Conference**, Washington DC 2013

"A process systems approach to teaching distillation"
K.M. Powell (presenter), T.F. Edgar
AIChE Annual Meeting, Pittsburgh, *PA* 2012

"Dynamic optimization of solar thermal systems with storage"
K.M. Powell (presenter), J.D. Hedengren, T.F. Edgar
AIChE Annual Meeting, Pittsburgh, *PA* 2012

"Control of a large-scale solar thermal energy storage system"
K.M. Powell (presenter), J.D. Hedengren, T.F. Edgar
*Proceedings of the 2011 American Control Conference**, San Francisco, CA 2011
*includes peer-reviewed paper

GRANTS

National Science Foundation Graduate Research Fellowship Program, "Measurement Techniques and Improved Control Systems for Rapid Thermal Annealing Processes Used for Printed Thin Film Solar Cells", 2009-2012, K.M. Powell (PI), $121,500.

The University of Texas at Austin Office of Sustainability, "Optimization of the Campus Cooling System to Reduce Energy Usage" 2012-2013, K. M. Powell (PI), T. F. Edgar, K. Kuretich, W. J. Cole, R. Thompson, J. Hedengren, K. Kapoor, J. Mojica, A. Sriprasad, J. Kim (co-PI's), $36,930

Appendix G

Clean Coal Research Team Members

APPENDIX G
Clean Coal Research Team

The following individuals and their respective organizations listed below participated in the Clean Coal Research development phase to identify candidate Areas of Research, research objectives and to prioritize candidate projects/studies:

Brad Adams, Brigham Young University
Foster Agblevor, Utah State University
Morris Argyle, Brigham Young University
Larry Baxter, Brigham Young University
Alair Emory, Utah Governor's Office of Energy Development
Eric Eddings, University of Utah
Kevin Fry, Reaction Engineering Inc.
Andrew Fry, University of Utah (now with Brigham Young University)
Alex Hietsoi, Utah State University
Brian Iverson, Brigham Young University
John McLennan, University of Utah – Earth Geosciences Institute
Brian McPherson, University of Utah - USTAR
Kody Powell, University of Utah
Andrew Sweeney, USTAR
Phil Smith, University of Utah
Dale Tree, Brigham Young University
Tyson Todd, USTAR
Jost Wendt, University of Utah
Kevin Whitty, University of Utah
Ian Andrews, Rocky Mountain Power
Larry Bruno, Rocky Mountain Power
Ken Clark, Rocky Mountain Power
Mike Dayton, Rocky Mountain Power
Glen Pinterich, Rocky Mountain Power
Laren Huntsman, Rocky Mountain Power
Greg Hunter, Rocky Mountain Power

Participation also by: Jeff Caldwell (Amaron), Ralph Coates (Amaron), Russ Taylor (AEG Coalswitch), Phil Scalzo (AEG Coalswitch), Kyler Stitt (Sustainable Energy Solutions); Burdick Trapper (Rocky Mountain Power) and Jake Tuttle (University of Utah)

Appendix H

Major Project Milestones

Appendix A - Biomass Co-Firing Test

Entity	Milestone Title/Description	Estimated Date
UofU	Contracts with PacifiCorp complete with UofU	Jan-17
PacifiCorp	Contracts with fuel suppliers complete	Feb-17
PacifiCorp	Owner's Engineer selected	Feb-17
UofU	Test Plan – Lab-scale Combustion Performance Evaluation	Mar-17
UofU	Draft Report on Biomass Fuel Handling and Stability	Apr-17
UofU	Complete Design & Construction of Isokinetic Particle Sampling Probe	Jun-17
BYU	Complete Design & Construction of Temperature-controlled Deposit Sample Probes	Jun-17
Fuel Suppliers	Delivery of processed Biomass Fuel	Jul-17
PacifiCorp	Testing acknowledgement from Utah DAQ	Jun-17
UofU	Lab-scale Combustion Performance Interim Report	Jul-17
PacifiCorp	Perform Biomass Testing at Hunter Unit 3	Aug-17
UofU/BYU	Draft Report – Analysis of Measurements from Hunter Plant Testing	Dec-17
UofU	Lab-scale Combustion Performance Draft Final Report	Nov-17
UofU	Air Quality Assessment Draft Report	Sep-17
Owner's Engineer	Draft Assessment Report Issued	Sep-17
Owner's Engineer	Final Assessment Report Issued	Nov-17
BYU	Draft Report on Analysis of Boiler Operating, Emissions and Performance Data	Jun-18

Appendix B - Cryogenic Carbon Capture Testing

	Milestone Title/Description	Start Date	Planned Completion Date
	Planning Phase		
	Site selection	1/1/2017	3/15/2017
Major Milestone	Contract with PacifiCorp complete		**2/1/2017**
	Draft Test Program Development	2/2/2017	3/1/2017
Major Milestone	Final Test Program	3/1/2017	**3/15/2017**
	Development Phase		
	Development Work (in conjunction with NETL Phase I plan)	3/1/2017	10/1/2017
Major Milestone	Phase I development completed		**10/1/2017**
Major Milestone	Testing acknowledgement from Utah DAQ		**12/15/2017**
	Mobilization for demonstration (on-site electrical and flue gas access)	10/1/2017	2/15/2018
	Field Demonstration Phase		
Major Milestone	SES Demonstration Unit setup on site	3/15/2018	**4/15/2018**
	Site Testing	4/15/2018	12/1/2018
Major Milestone	Site Testing Completed		**12/1/2018**
	SES Demonstration Unit Demobilization	12/1/2018	12/15/2018
	Reporting Phase		
Major Milestone	Draft Report		**2/15/2019**
Major Milestone	Final Report Submitted		**2/28/2019**

Appendix C - CarbonSAFE Pre-Feasbility Study

Milestone Title/Description	Planned Completion Date
CCS Team Commitments	3/1/2017
Catalog of Project Challenges	3/1/2017
Update Project Management Plan	4/1/2017
Update Data Management Plan	4/1/2017
Project Kickoff Meeting	2/1/2017
Project Review Meeting	Once Annually
Quarterly Progress Reports to DOE	Quarterly
Data Submission to NETL-EDX	Quarterly
Final Report	6/20/2018
Feasibility Sub-Plan for Practical Challenges	1/1/2018
Feasibility Sub-Plan for Public and Economic Acceptability	1/1/2018
Detailed Plan for Long-Term Liability for Stored CO_2	5/1/2018
Finalize Ranked List of Site Options	5/1/2018
Compile Initial Area of Review	9/1/2017
Initial MVA Plan	5/1/2018
Compile Risk Registry	3/1/2018
Initial Risk Mitigation Plan	5/1/2018
Compile Catalog of Accessible Information (Data) and Resources	2/1/2017
CO_2 Source Assessment	5/1/2018
Initial CO_2 Management Strategy	5/1/2018
CarbonSAFE Rocky Mountains Phase II Proposal	12/1/2017

Appendix D - CO_2 Enhanced Coal Bed Methane Study

Milestone Title/Description	Date from Announcement of Award/Funding Available
Notice to Proceed Start Date (Assumed)	1/1/2018
Contracts with PacifiCorp complete	1/31/2018
Commence Resource Evaluation	1/31/2018
Draft Test Program Submitted	1/31/2018
Revised Program Submitted Formalizing Experimental Matrix and Other Research Tasks	2/15/2018
Annual Report I Presented/Submitted	1/31/2019
Annual Report II Presented/Submitted	1/31/2020
Annual Report III Presented/Submitted	1/30/2021
Develop Concept for Future In-Situ Pilot Testing	7/1/2021
Final Report Presented/Submitted	10/31/2021

Appendix E - Solar Thermal Assessment (Hunter Plant)

Milestone Title/Description	Date from Announcement of Award/Funding Available
Contract between BYU and PacifiCorp complete (Assumed start date)	1/1/2019
Contract between Owner's Engineer and PacifiCorp complete	3/2/2019
Commencement of study	5/1/2019
Draft of proposed study objectives	5/31/2019
Final proposed study objectives	6/30/2019
Solar resource study draft complete	7/31/2019
Land resource study draft complete	12/30/2019
Select steam/feedwater injection points	4/30/2020
Cycle efficiency draft calculations complete	6/29/2020
Coal consumption offset and solar augmentation cost estimates draft complete	12/29/2020
Draft final report submitted	2/28/2021
Final report submitted	6/29/2021

Appendix F - Neural Net Optimization Implementation

Milestone Title/Description	Estimated Completion Date
Contracts with PacifiCorp complete (U of U and Griffin/Taber)	1/15/2017
Project Kick off Meeting	1/20/2017
Instrumentation upgrades complete	4/30/2017
Unit base line optimization and parametric study begins	5/1/2017
Combustion optimization and intelligent soot-blowing software installation with Taber begins	6/1/2017
Base line data collection complete	7/31/2017
Initial installation period complete	8/31/2017
Annual progress report complete for Year 1	1/31/2018
Operator Training	5/31/2018
Parametric study on optimization of auxiliary systems complete	8/31/2018
Annual progress report complete for Year 2	1/31/2019
Exploratory study on dynamic optimization with set point ramping complete	8/31/2019
Final study on impact on emissions complete	12/31/2019
Final report complete and submitted to PacifiCorp	1/31/2020

Appendix G - Low NOx Technology Testing

Milestone Title/Description	Estimated Completion Date
Assumed Start Date	1/15/2017
Contract for Owner's Engineer	3/1/2017
Preparation of Baseline Information Complete	2/14/2017
Prepare Assesment Criteria and Testing Criteria	3/16/2017
Boiler CFD model Complete	5/1/2017
Preparation of Request for Information	5/1/2017
Issue Request for Information	5/16/2017
RFIs received and Assessment Complete	7/16/2017
RFP Commercial documents Complete	7/1/2017
Issue Request for Proposal	7/24/2017
RFP Responses Received	9/22/2017
RFP Proposals Assessment	10/8/2017
Economic/Technical Feasibililty of Technologies	12/7/2017
Prepare List of Recommended Technologies and Test Program	12/23/2017
Execute Commerical Documents with selected technologies	2/6/2018
Testing acknowledgement from Utah DAQ	2/22/2018
Site Mobilization (as required)	3/9/2018
Site Testing	9/7/2018
Technology Assessment Complete	11/7/2018
Draft Report-Technology Recommendations issued	12/23/2018
Final Report Issued	2/22/2019

Rocky Mountain Power
Exhibit C
Docket No. 16-035-36

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF UTAH

ROCKY MOUNTAIN POWER

Exhibit C
Advanced Substation Metering Program

September 2016

Rocky Mountain Power

Advanced Substation Metering Program

Sustainable Transportation and Energy Plan

Utah Innovative Technologies Team

1 Executive Summary

As part of the Sustainable Transportation Energy Plan (STEP), a Utah statute, Rocky Mountain Power (the Company) should authorize $1,100,000 to deploy an advanced substation metering program that includes, but is not limited to, installing advanced meters at approximately fifty circuits connected to distribution substations in Utah where limited or no existing communications exist. This project will enable higher data visibility on the distribution system by providing for the installation of advanced meters, setting up remote communication paths with all installed meters and the purchase of a data management and analytics tool to automatically collect, analyze, interpret and report on the available data. This program will allow for the development of a more progressive grid.

2 Purpose and Necessity

Substation monitoring and measurement of various electrical quantities is seen by the Company and its customers as a necessity to provide for the integration of distributed energy resources into the existing electric grid. Enhanced monitoring helps resolve the following challenges for the Company and its customers:

- Limited visibility on power flow, loading levels, load shape, and event information needed to develop thorough interconnection studies, determining safe switching procedures and cost effective capital improvement plans.
- The company is in the process of striving to make the grid more progressive and this program will enable a greater understanding of these innovative solutions.
- Single phase distributed energy resources can exacerbate load imbalance on a distribution circuit, causing three phase voltage imbalance issues and increasing the potential for unintended circuit breaker operations from elevated neutral currents.
- Detrimental impacts on transient and steady state voltage levels due to growing interaction between distributed energy resources and distribution system equipment. Understanding the production levels on a circuit can accurately determine the need for effective grounding and fault clearing control schemes, which if not installed appropriately can cause temporary over voltages to customers or circuits improperly protected during fault conditions.
- Potential harmonic issues from inverter-based distributed energy resources can cause customer motor damage and interfere with high frequency communications.
- The need for measurement of per-phase vector quantities to improve optimization opportunities for capital costs and system losses.

3 Benefits

- Enable increasing levels of distributed energy resources on the power grid in an affordable and reliable way by providing increasing visibility on loading levels, load shape, and event information needed to develop thorough interconnection studies and hosting capacities for customers, determining safe switching procedures and cost effective capital improvement plans.
- Assists in preventing load imbalance on a distribution circuit caused by single phase distributed energy resources which can result in three phase voltage imbalance issues and increasing potential for unintended circuit breaker operations from elevated neutral currents.
- Understand harmonic issues caused by distributed energy resources and take appropriate steps to resolve issues, if any, in a proactive way.
- Improve optimization opportunities for capital costs and system losses by providing measurements of per-phase vector quantities for voltage and current.
- Identify service quality issues early and allow timely development and implementation of cost effective mitigation.
- Enhance understanding of intermittent generation resources and their impact on the power grid.
- Reduce time delays of approvals for customers seeking distributed generation interconnections.
- Provide customers with circuit information with a higher level of accuracy.
- Identify and control risks associated with the integration of significant penetration of distributed energy resources. This includes controlling claims from power quality issues, customer equipment failure, utility/customer equipment damage or impact on customer generation levels.

4 Public Interest Justification

In the state of Utah, Rocky Mountain Power continues to experience rapid growth in penetration levels of distributed energy resources. In fact, the rate of net energy metered interconnections has doubled annually. For example in 2012, 478 net metered customers interconnected to the Rocky Mountain Power system. We anticipate that close to 12,000 customers will interconnect in 2016. To further facilitate the integration of distributed energy resources of different types and sizes in a cohesive and cost effective manner, data collection at substations will be of paramount importance. This will create a win-win situation for both the Company and its customers in the following ways:

- **Modernized Grid:** Data collection, synthesis and interpretation is a cornerstone for building a smarter energy infrastructure that will enable accurate load/generation forecasting and planning as well as help understand the interaction between the power grid and the distributed energy resource units.

- **Higher Levels of Distributed Energy Resources**: Substation metering will provide the necessary data required to perform interconnection studies and help to seamlessly interconnect distributed energy resources in an affordable and reliable way.
- **Improved Customer Service**: Data availability will enable the Company provide prospective interconnection customers with ample circuit information to help them make effective decisions at lower costs. Additionally, enhanced data availability can improve outage restoration efforts.
- **Situational Awareness:** Information collected from substation metering will help boost situational awareness thereby enabling the Company to invest proactively to efficiently deliver affordable, reliable and energy to all customers.
- **Maintain Grid Integrity**: Communication-enabled substation metering products can maintain the integrity and reliability of the electrical system in the face of massive load characteristic changes being experienced with the increasing levels of distributed energy resources being interconnected to the distribution system.
- **Cybersecurity:** This program will comply with all NERC CIPS requirements.

5 Compliance with SB115

The substation metering program meets the legislative intent of SB115 54-20-105-1(h) that pertains to “any other technology program” in the best interest of the customers in the state of Utah. This project falls under the STEP’s discretionary allotment of funds as part of the Utah Innovative Technology category.

6 Alternatives Considered

- Alternatives considered that do not resolve the critical issues/needs:

— Line mounted ammeters were considered during evaluation; however, they do not provide direct access to voltage and harmonics measurements. These measurements are critical to ensure compliance with delivery thresholds and for any power flow or power quality analysis.

— Do nothing. However this will not provide the company with the information needed to develop a more progressive grid.

7 Purpose and Necessity – Risk Analysis

Company Impacts without this project:

- Lack of historical real-time circuit data on loading/generation levels and power quality introduces major assumptions and inaccuracies while developing interconnection studies, determining safe switching procedures, and cost effective capital improvement plans.
- Ignoring the changing load characteristics due to the advent of distributed energy resources on distribution circuits *may* lead to *unwarranted* capital expenditures in system upgrades and retrofits *or the absence of needed infrastructure to maintain a reliable system*.
- Performing advanced distribution planning studies such as "hosting capacity" analysis cannot be performed in the absence of detailed distribution circuit loading information.

Customer Impact without this project:

- Increasing levels of distributed energy resources in the absence of substation loading and power quality information might delay the assessment process of interconnection projects.
- Customers may have to pay for unnecessary equipment upgrades that could potentially be avoided in the presence of accurate substation metering.
- Increased customer dissatisfaction due to lack of interpretive data supporting the Company's requirements

Other Impacts:

- In an event that the circuit experiences power quality issues due to the presence of high levels of distributed energy resources, the Company will have no way of proactively addressing such issues.

8 <u>Major Project Milestones</u>

- Anticipated project start date or actual project start date: January 2017
- Final in-service date: December 2019

This project has multiple in-service dates related to the installation of the advanced meters and communications equipment at numerous substations. The installations will be scheduled according to a prioritized need starting with areas with high penetrations of distributed energy resources. Additional work will include installing the communication network and integrating the meters to the data management and analytical tool.

The project team is aware of the need to record the assets as technically complete in SAP as the assets are put into service. The Work Breakdown Structure (WBS) will be setup accordingly.

9 Program Closure, Retirement and Removal Information

In 2021, the Company will report back to the Utah Public Service Commission regarding lessons learned and how it plans to maintain and manage the infrastructure deployed as part of this program. If it is necessary to report more often to comply with the STEP statute or other reporting requirement, the Company will comply with those requirements.

10 Project Delivery Risk Factors

The project will be managed to mitigate typical project risks (design and construction resources, permitting material deliveries, weather, etc.) as it applies to scope, schedule, and budget. Appropriate documentation will be created, tracked and communicated to properly manage the project. The appropriate risk mitigation measures will be identified and resolved in the project development phase.

One critical and unusual project risk factor has been identified that will need special attention in the project development phase.

- There is a risk associated with the integration of data management software with the field-deployed substation metering devices

11 Target Costs

Costs	Prior Years	2017	2018	2019
10 Year Plan Budget:-STEP discretionary funding	N/A	$500,000	$350,000	$250,000
APR (Gross):	N/A	$500,000	$350,000	$250,000
- Reimbursements:	N/A	N/A	N/A	N/A
- Contingency:	N/A	N/A	N/A	N/A
APR (Net):	N/A	$500,000	$350,000	$250,000

12 Accounting Issues or Regulatory Recovery Issues

All expenses towards this project will be recovered through the accounting workflow setup for the Utah Innovative Technologies under the Sustainable Transportation and Energy Plan. For detailed information, refer the overarching Utah STEP Accounting document.

13 Financial Analysis

It is recommended to spend $1.1 million to deploy an advanced substation metering program that includes installing advanced meters and required communication at distribution substations in Utah where limited or no existing communications exist.

Project	2017	2018	2019	2020 - 2041	Total
Proposed Solution - Capital	$500,000	$350,000	$250,000	--	$1,100,000
Proposed Solution - OMAG	$4,800	$21,880	$25,000	$25,000/year	$601,680

The financial analysis was based on the following assumptions:

- The recommended solution includes $25K of OMAG per year after the assets are in-service (2019 - 2041).
- The financial analysis was completed over 25 years.
- The communication assets are allocated to Utah.
- The in-service date is December 2019.
- The financial analysis results presented below are based on the project's revenue requirement. This is based on a capital structure of 49% debt and 51% common with a 5.21% debt and a 9.74% common rate.
- A 1.29% Utah property tax rate was used.
- A 6.57% discount rate was used.
- A 37.95% tax rate was used.

Project	Dollars	Present Value of Revenue Requirements
OMAG	$601,680	$272,472

14 Procurement and Project Delivery Strategy

- In order to satisfy business requirements, ensure best value, and minimize risk, purchases and construction contracts shall be procured through a competitive bid process.
- Project specifications shall be developed in accordance with applicable engineering specifications and standard designs.
- Bidders shall be screened to meet credit and procurement requirements. This process is being managed by the PacifiCorp procurement department.
- Project delivery strategy to be determined by project team.
- A communications outreach plan will be followed to ensure an increase in customer understanding is achieved. The communications plan can be seen in appendix C.

15 Recommendation

- Purchase and install advanced substation meters at distribution substations with limited or no communications
- Ensure all substation meters installed as part of this program are enabled with remote communication capabilities
- Implement a data management system to automatically download, analyze and interpret data downloaded from all installed substation meters
- Develop a process to ensure all data collected is used to improve the interconnection study process in addition to improving long-term and short-term distribution and transmission planning studies

APPENDICES

- Appendix A – Initial List of distribution circuits
- Appendix B – Technical requirements
- Appendix C – Communication Plan

APPENDIX A – INITIAL LIST OF DISTRIBUTION CIRCUITS

The following table is the initial list of circuits that were selected based on existing communication capabilities at the substation and the level of distributed energy resources interconnected to the circuit:

Substation	Circuit	Area	DER (~kW)
AMERICAN FORK	AMF13	N Utah Co.	105
AMERICAN FORK	AMF12	N Utah Co.	71
BANGERTER	BGT17	Jordan Valley	1490
BLUFFDALE	BLF11	SL Valley	118
BRICKYARD	BRK11	Ogden	77
BROOKLAWN	BKL11	Dixie	2208
BUSH	BSH11	Tremonton	126
CASTO	CAS11	SL Valley	114
COLEMAN	CLM18	Dixie	78
DAMMERON VALLEY	DMR11	Dixie	100
DEWEYVILLE	DEW12	Tremonton	88
ENERY CITY	EMR11	Price	75
ENOCH	ENO11	Cedar	14021
ENOCH	ENO12	Cedar	3000
ENTERPRISE VALLEY	ENV12	Cedar	3500
ENTERPRISE VALLEY	ENV11	Cedar	200
HIGHLAND	HIG13	N Utah Co.	135
HIGHLAND	HIG12	N Utah Co.	121
HIGHLAND	HIG11	N Utah Co.	113
LINCOLN	LIN14	NUT	509
LINDON	LDN12	N Utah Co.	134
LINDON	LDN14	N Utah Co.	123
MIDDLETON	MDD24	Cedar	6000
MOAB CITY	MOA12	Moab	387
MORONI	MOR12	Richfield	81
MOUNTAIN GREEN	MTG11	S Ogden	126
NORTH LOGAN	NOL12	NUT	80
OAKLEY	OKY11	Park City	96
PARKSIDE	PKD03	N Utah Co.	156
PARKSIDE	PKD06	N Utah Co.	95
PARKSIDE	PKD02	N Utah Co.	90
PARKSIDE	PKD04	N Utah Co.	69
PARLEYS	PAR12	Park City	334
PARLEYS	PAR13	Park City	117
QUAIL CREEK	QUA12	Dixie	105
QUARRY	QRY14	SL Valley	300
RIDGELAND	RDG14	SL Valley	285
RIDGELAND	RDG12	SL Valley	265

ROCKVILLE	RCK11	Dixie	95
SALINA	SAL13	Richfield	1225
SANDY	SDY13	Jordan Valley	1770
SOUTH PARK	SPK13	SL Valley	83
SOUTHWEST	SWT12	SL Valley	83
SPANISH VALLEY	SPA11	Moab	50
SPRINGDALE	SPD11	Dixie	171
SUMMIT PARK	SUM11	Park City	223
TOOELE	TOO11	SL Valley	85
VERNAL	VER11	Vernal	71
Welfare	WLF11	S Utah Co.	600
WINCHESTER HILLS	WNC11	Dixie	73

APPENDIX B – TECHNICAL REQUIREMENTS

1) All installations will be engineered, prints issued, and as-built drawings processed.
2) Meters will use existing current transformers, potential transformers and meter panel cutouts where available. Panel modification will be limited to control costs.
    a. Alternate designs will be available where no convenient panel space is available, possible using transducer only versions of available meters.
3) All meters will be configured to measure and record all phase quantities in all quadrants.
4) Meters will be configured so that that the recorded phases are consistent with system vectors.
5) Installed stand-alone meters will be easily upgradable so that they can be incorporated into SCADA when it becomes available at the metering point at a future time.
6) The meters will support DNP and IEC 61850 Ethernet and provide at least six analog outputs each.
7) Meters will have the ability to record waveforms of all phases at the same time.
8) Meters will read and store internally per phase: kW, kVAR, current, power factor, frequency, accumulated energy, harmonics, and recorded waveforms generated when programed limits are exceeded.
9) Meters will have the ability to be read by cellular phone.
10) Meters will have adjustable data and storage rates to allow for different levels of granularity and data intervals.
11) Meters will have the ability for live and periodic data reads to be moved into MV90 so they can be transferred into the SCHOOL PI database.

APPENDIX C – COMMUNICATIONS PLAN

Utah Innovative Technologies

Plan will be customized to each Utah Innovative Technologies project

Project Team: Chad Ambrose, Erik Anderson, Ian Andrews, Ryan Anthon, Nathan Bailey, James Campbell, James Johnson, Bob Lively, Douglas Marx, Robert Meredith, Clay Monroe, Lucky Morse, Rohit Nair

Communications Team: Barb Modey, Paul Murphy

Background:

Utah Senate Bill 115, Sustainable Transportation and Energy Plan, was signed into law March 29, 2016. The legislation establishes a 5-year pilot program to provide mandated funding for electric vehicle infrastructure and clean coal research, and authorizes funding at the commission's discretion for solar development, utility-scale battery storage, and other innovative technology, economic development and air quality initiatives.

SB 115 also authorizes the development of a renewable energy tariff for large customer loads. The legislation also allows PacifiCorp to change its accounting for energy efficiency services and programs from expense to capital and to create a regulatory liability for accelerated depreciation of its coal-fired plants. The legislation also mandates full recovery of Utah's share of PacifiCorp's prudent costs of variable energy. The UPSC previously allowed PacifiCorp to recover only 70 percent of its incremental fuel, purchased power and other variable supply costs through an energy balancing account that are not fully in base rates.

Utah Innovative Technologies (UIT) has identified the following work streams:

- **Solar Incentive:** Deployment of a solar incentive for commercial customers wherein a direct benefit to identified distribution voltage circuits can be derived. These customers will be net energy metered. This benefit is reducing the circuit peak, thereby deferring capital spend and providing a public relations benefit for continuing an incentive program

- **Centralized Battery Systems:** Use of centralized battery systems (CBS) located on identified distribution circuits or substations where in a direct benefit can be achieved. This benefit includes, through the use of solar or grid energy to charge the battery system to be dispatched during circuit peak hours to reduce load on transformer and circuit equipment. This reduction will help defer capital spend on the circuit, may provide improved power quality and gives the utility and opportunity to understand the use of this innovative/emerging technology.

- **Special Pilot Projects:** Identification and targeting of special circumstances that require unique innovative technologies to improve circuit or substation performance. For example, the installation of high-end metering equipment with communications at locations with a high penetration of distributed energy resources. This will help the company better understand the impact of generation resources on loading patterns and other power quality and reliability impacts, if any.

The engineering team assigned to this initiative is identifying the most cost-effective and viable approach for implementation. The first year could be a battery-only option within a substation, or it may be a combination of battery and commercial customer solar incentives on specific circuits.

This communications plan focuses on the UIT initiatives within the larger STEP Communications Plan. It is intended to be a working document that will evolve as UIT initiatives change based on emerging needs, technology available and team evaluation.

Communication Objective:

To gain acceptance and understanding of the UIT project benefits and to position Rocky Mountain Power as an innovative solutions provider to integrate and provide renewable power options.

Target Audience (Stakeholders):

Regulators
Communities wherein substation metering will be installed
Regional Business managers
Opinion leaders and elected officials
Media and general public

Communication Strategy for target audience:

- Prepare communication materials that are transparent, contain clear facts, and present mutual benefits and opportunities for the identified measures on identified distribution circuits.
- Manage the conversation about why STEP funds are used for these enhancements, so we can establish the context around the benefits to all customers and to the environment, rather than the company being put on the defensive.

Core Messages:

- Rocky Mountain Power is providing options towards a sustainable energy future.
- Rocky Mountain Power's Innovative Technologies initiative will help bring renewable resources on-line where they are most needed and beneficial to the overall system. This will help hold down rates for all Utah customers by reducing the need for additional infrastructure upgrades.
- Rocky Mountain Power has identified key electrical circuits in Utah with significant distributed generation penetration and will install substation metering in order to better understand the impacts of distributed generation on the system. In addition, this understanding will greatly aid in providing customers and solar contractors with more precise distribution information upon application for interconnection.

Tactics:

Key Audience	Tactic	Timing	Responsible
Regional Business Managers	Attend regular staff meeting to **explain changes to RBMs** and answer questions about the substation metering initiative	Nov. 2016	Ambrose
Call Center Agents	Update t**alking points for agents** and net metering personnel at call center	Nov. 2016	Anderson Modey
Targeted communities	Develop a **handout/brochure** explaining the benefits of the substation metering initiative. This handout can be included with a direct mail letter and/or used in meetings.	TBD	Modey Nair Ambrose
Opinion leaders (media government officials, business leaders, community leaders)	Talking points, op-eds, news releases, fact sheets, direct contact with executives, government relations and regional business managers and external communications, **opportunities to proactively communicate the benefits of UIT**	TBD	Murphy Gravely

General public/press	Monitor social media channels for comments and discussion on UIT	Ongoing	Murphy Puglia
General employees	Develop an **article for employee newsletters**, and Utah intranet postings	TBD	Zukin
Utah employees	Host a **Power Hour** in SLC about Utah Innovative Technologies	TBD	Ambrose Belmonte
Regulators	Provide timely information to regulatory bodies.	Aug/Sept.2016	Lively
General public/press	After substation metering projects have been installed; arrange to have **press release; post to website; social media**	TBD	Murphy Modey Puglia

<u>Budget:</u>
Allocate roughly $30,000 per year for funding to cover mailings and collateral materials, photography and other communications.

Evaluation:

- Track ability to reach customers regarding the substation metering program
- Monitor abilities of customers and Company to benefit from the program
- Track public opinion and social media activity

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REDACTED
Rocky Mountain Power
Exhibit D
Docket No. 16-035-36

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF UTAH

ROCKY MOUNTAIN POWER

REDACTED
Exhibit D
Solar and Energy Storage Program

September 2016

Rocky Mountain Power

Solar and Energy Storage Technology Program

Sustainable Transportation and Energy Plan

Utah Innovative Technologies Team

1 Executive Summary

As part of the Sustainable Transportation Energy Plan, a Utah statute, Rocky Mountain Power (the Company) should authorize $5 million to install energy storage technology to resolve voltage issues on the [redacted] transmission line. An additional $2 million from Blue Sky community project funds will be utilized to install a large-scale, company-owned solar project. [redacted] substation is fed radially from [redacted] and all capacitive voltage correction factors have been exhausted. The storage technology will be installed on the [redacted] distribution system and will defer or eliminate the need for traditional capital investments in the form of upgraded poles, wires and/or substations estimated at $8-14 million.

2 Purpose and Necessity

Historically, during summer peak loading periods, the [redacted] transmission line voltage drops to 0.92 per unit of the nominal voltage and is forecasted to drop below the required ANSI standard[1] of 0.90 per unit by 2019. Rocky Mountain Power consistently implements reliability and power quality enhancements on its transmission and distribution system and adheres to the standards established by ANSI for both normal and emergency operation. These operating thresholds are designed to protect company and customer equipment from inadvertent miss-operation or damage due to voltage excursions.

To correct the voltage issues experienced during peak loading conditions, a stationary battery system will be connected to [redacted] the 12.5 kilovolt distribution circuit(s) that are connected to [redacted] substation. This reduces the loading on the power transformer, improves voltage conditions and will mitigate costs associated with connection on the [redacted] kilovolt bus at the substation. The system will be sized to handle the initial voltage corrections and be expandable to provide additional correction as load growth in the area creates further voltage excursions. The initial battery system will be installed with the appropriate protection and control, including remote communications, and will meet the following requirements:

Energy Storage

Energy Requirement .... Five (5) megawatt-hours

Solar

System Size .... 650 kilowatts

Site .... 5–7 acres (dependent on selected system)

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[1] American National Standard for Electric Power Systems and Equipment [Available online for purchase]: https://www.nema.org/Standards/Pages/American-National-Standard-for-Electric-Power-Systems-and-Equipment-Voltage-Ratings.aspx

3 Benefits

- The loading on the [redacted] kilovolt power transformer at [redacted] substation will be reduced thereby ensuring the line voltage on the [redacted] transmission line does not drop below 0.90 per unit.
- The company is in the process of striving to make the grid more progressive and this program will enable a greater understanding of these innovative solutions.
- Provides high-speed reactive power support to ensure load rejection in the area does not impact voltage levels on the transmission system.
- Reduces loading on the [redacted] substation power transformer, improves transmission line voltage and will defer the traditional capacity increase capital investment beyond fifteen years when using present growth rates in this area.
- Enables the Company to get first-hand operational experience with control algorithms and efficiency levels associated with energy storage combined with solar. This gained experience will prepare the company in advance of large scale integration of such technology/projects that are now becoming readily available options for customers as price declines.
- Enables the Company to become familiar with and utilize innovative technologies to provide customers with solutions to power quality issues.
- Opportunity to meet Blue Sky customer requests for “steel in the ground” physical solar projects.

4 Public Interest Justification

- The Company is expanding renewable energy and innovative technology options to improve service to customers.
- The Company is taking steps to prepare for an enhanced deployment of clean energy sources for its customers.
- Greenhouse gasses can be avoided through the use of solar.
- Better reliability and voltage profile as the proposed solution provides transmission support by providing real and reactive power.
- A “stepped in” approach is cost effective as the Company expects incrementally lower cost storage systems in the future.
- Savings for customers related to deferring capital investments for adding transmission capacity and installing transmission equipment. Compared to the alternative solutions, the proposed solution provides the highest internalized benefit i.e. a financial benefit that can be ‘captured’ or ‘realized’ in the form of deferred cost for transmission system upgrades.
- Energy arbitrage considering the energy storage device is expected to recharge during off-peak hours which often coincides with lower priced, high generation periods from the Company’s wind generation plants or during midday time periods when solar generation is

available.

- Improved utilization of grid assets leading to cost savings for customers.
- Reduction in transmission congestion during summer peak loading periods.
- Utilizing Blue Sky community project funds aligns with the goals of the program to support the greater use of renewable energy. This project could help prove the use of more renewable energy options to meet customers' infrastructure needs.

5 Legislative Compliance with SB115

The proposed solution for the [redacted] system meets the legislative intent of SB115 54-20-105-1(h) that pertains to "any other technology program" in the best interest of the customers in the state of Utah. This project falls under the STEP's discretionary allotment of funds as part of the Utah Innovative Technology category.

6 Alternatives Considered

Alternatives considered that resolve the critical issues/needs:

Alternative #1 – Rebuild the Transmission Line

Description
Rebuild the [redacted] transmission line using a larger, lower impedance conductor.

Advantages

1) Increased transmission capacity
2) Improved voltage profile
3) Reduction in transmission congestion during summer peak loading periods

Disadvantages

1) More expensive than proposed solution
2) Potential need for additional right-of-way requirements
3) Transmission line permitting risk in local jurisdictions
4) Public resistance to fixed-width easements
5) Temporary construction impacts

Block estimate
$8,000,000

Alternative #2: Build a new transmission substation

Description

Build a new transmission substation to connect the [redacted] transmission line to the [redacted] transmission line.

Advantages

1) Increased transmission capacity
2) Better reliability and power quality
3) Potential to add more transmission lines in future
4) Enable higher levels of renewable energy

Disadvantages:

1) More expensive than proposed solution
2) Permitting issues for land use
3) Permitting risk for new substation
4) Detailed environmental and engineering studies required to understand feasibility
5) Temporary construction impacts

Block estimate

$14,000,000

Alternative#3: Install energy storage system

Description

Install an eight megawatt-hour energy storage battery.

Advantages

1) Least cost solution
2) Expected customer acceptance for considering new technology alternatives
3) Enhanced brand equity for the Company
4) Smaller geographical footprint required
5) Allows the testing of innovative sustainable solutions to meet our customers growing needs.

Disadvantages

1) Does not increase the Company’s renewable energy footprint
2) Temporary construction impacts

Block estimate

$7,400,000

7 Purpose and Necessity – Risk Analysis

Company impacts without this project/solution:

- In the absence of the proposed solution, the Company will need to deploy higher cost and non-innovative technologies to maintain the voltage levels as required during peak summer loading conditions. Based on the projected load growth for the [redacted] transmission line, potential voltage issues could be experienced as early as 2019.

Customer impact without this project/solution:

- A higher cost solution with non-innovative technology will impede any efforts to learn from implementing progressive grid technologies.

8 Major Project Milestones

- Anticipated project start date: January 2017
- Final in-service date: December 2020

This project has multiple in-service dates related to installation of the energy storage equipment on the [redacted] distribution system. The installations will be scheduled according to need based on the loading profile and forecasted load growth for the area. Additional work will include installing the control algorithms, protection and control schemes and communication network to ensure the system is integrated to the Company's distribution system in a safe, efficient and reliable manner.

The timing of the project deployment is estimated as follows:

Year	System Size	Estimated Cost
2017	Purchase property and Owners Engineering (OE) expense	$0.5 million
2018	2 MWh- Battery	$1.6 million
2018	650 kW- Solar	$1.95 million
2018	Interconnection Costs	$0.75 million
2020	3 MWh- Battery	$2.2 million
Total Costs		$7.0 million

The project team is aware of the need to record the assets as technically complete in SAP as the assets are put into service. The Work Breakdown Structure (WBS) will be setup accordingly.

9 Environmental Permit Requirements and Community Permits

The Company will adhere to all national, state and local environmental regulatory requirements pertinent to installation of any distributed energy resource equipment. It is important to note that acquisition of land and any subsequent environmental permits might impact the timeline and budget of the project. The Company will also review the general plan for the [redacted] area and will comply with any local land use permitting requirements.

10 Blue Sky Program Funding

In 2018, the Blue Sky program may be able to provide $1.95 million for the Rocky Mountain Power-owned solar generation facility. These Blue Sky community project funds will pay for 100 percent of the solar installation. The funds will not be used to "buy down to competitive rates" due to the accounting complexity associated with this concept. Per the Utah Blue Sky tariff schedule 70, the Company will use Blue Sky funds under the Qualifying Initiatives section of schedule 70, item 2 which reads "Funding for research and development projects encouraging Renewable Energy in order to accelerate marketability of Renewable Energy technologies." The Company will not have a contribution towards this project thereby requiring the Renewable Energy Credits to be retired by the Company on behalf of the Blue Sky customers in Utah. While the Company will not earn a return on the asset, the funds will be treated similarly to contributions in aid of construction and the energy created by this Blue Sky program funded project will be supplied to all Utah customers. This solar facility will be a maximum of 650 kilowatts in capacity. The Operations Management Administration & General (OMAG) expense created by this asset will be passed through to Utah customers as it is maintained over its useful life. Therefore the only revenue requirement associated with the asset will be expenses related to OMAG.

Benefits of Company-Owned

Rocky Mountain Power does not typically own solar resources due to the Investment Tax Credit disadvantages for investor-owned utilities. However, the ownership of this project will provide first-hand experience dealing with utility-scale solar combined with an energy storage system that provides direct benefit to the company's customers. Furthermore, an increasing number of customers want to see renewable energy programs that support "steel in the ground," and this project provides Blue Sky customers with the opportunity to support this.

11 Procurement Process

The Company intends to competitively bid this project. As part of the process, the Company will issue a request for information (RFI) to a wide range of potential suppliers to gauge their interest in the project and assess their qualifications to provide quality products and/or engineer, procure and construct (EPC) the project. The RFI will be issued through the company's Ariba system. For the RFI, the company will reach out to known companies and energy storage trade groups to reach potential suppliers. From the RFI responses a list of preferred suppliers and select qualified EPC suppliers will be developed.

The request for proposal (RFP) will be issued to the selected EPC bidders through the Ariba system. RFP responses will be evaluated in the following areas:

- Technical feasibility to meet specified requirements
- Safety & environmental considerations
- Financial health
- Lifetime cost of ownership (capital, O&M, etc.)
- Warranty terms

The desired result of the RFP process is to acquire a quality system that provides reliable electricity at the best value for customers.

The Company may acquire the services of an owner's engineer (OE) under a separate contract. The OE will be responsible for development of technical specifications for battery energy storage systems (BESS) and integration of a BESS with solar generation, assisting in evaluating proposals and ensuring the EPC meets the specifications. The OE will be selected by the Company based on expertise on utility scale energy storage and experience in the PacifiCorp territory.

The following table shows the expected timeline of the RFP process.

Action	**Start date**	**Completion date**
Select OE	August 2016	December 2016
Develop Specifications	January 2017	May 2017
Issue RFI	May 2017	June 2017
Select bidders	July 2017	August 2017
Issue RFP	August 2017	September 2017
Evaluate bids	October 2017	November 2017
Award the project	November 2017	December 2017
Project construction	January 2018	June 2018 and June 2020

12 <u>Program Closure, Retirement and Removal Information</u>

In 2021, the Company will report back to the Utah Public Service Commission regarding lessons learned. If it is necessary to report more often to comply with the STEP statute or other reporting requirement, the Company will comply with those requirements. Additionally, the Company will include in the annual reporting to the Utah Public Service Commission the accounting and performance of the Blue Sky solar project.

13 <u>Project Delivery Risk Factors</u>

The project will be managed to mitigate typical project risks (design and construction resources, permitting material deliveries, weather, etc.) as it applies to scope, schedule, and budget. Appropriate documentation will be created, tracked and communicated to properly manage the project. The appropriate risk mitigation measures will be identified and resolved in the project development phase.

A few critical and unusual project risk factors have been identified that will need special attention in the project development phase. There are risks associated with:

- Land acquisition and related permitting and interconnection issues.
- Any future changes in load profile, load shape and forecasted load growth will require additional distributed energy resource infrastructure, thereby impacting cost and timeline of the overall project.
- Public acceptance to install solar panels and multiple 40-feet containers of energy storage devices due to aesthetic concerns.
- The Company does not have any prior experience of interconnecting a utility-scale project that operates a combination of solar and energy storage device.
- Future availability of better alternative technology for lower costs.
- In the event the existing Blue Sky solar project funding fails to deliver, the Company may need to rely on additional STEP funds for the solar portion of the project.

14 Target Costs

Costs	Prior Years	2017	2018	2020
10 Year Plan Budget:- STEP discretionary funding	N/A	$500,000	$4,300,000	$2,200,000
Blue Sky Funding	N/A	N/A	$1,950,000	N/A
APR (Gross):	N/A	$500,000	$2,350,000	$2,200,000
- Reimbursements:	N/A	N/A	N/A	N/A
- Contingency:	N/A	N/A	N/A	N/A
APR (Net):	N/A	$500,000	$4,300,000	$2,200,000

15 Accounting Issues or Regulatory Recovery Issues

All expenses towards this project will be recovered through the accounting workflow setup for the Utah Innovative Technologies under the Sustainable Transportation and Energy Plan. For detailed information, refer the overarching Utah STEP Accounting document. In addition, because the Utah Blue Sky program will have accrued $2 million from Blue Sky customers, the accounting treatment to acquisition of the asset will be the same as the STEP accounting treatment.

16 Financial Analysis

It is recommended to spend $7.0 million to defer traditional capital investment for resolving voltage issues on the [redacted] transmission line using energy storage connected to the [redacted] 12.47 kilovolt distribution system.

Alternative #1 – Rebuild the transmission line using a low impedance conductor.
Estimated cost $8.0 million.

Alternative #2 – Rebuild a new transmission substation to connect the [redacted] transmission line [redacted] transmission line.
Estimated cost $14.0 million.

Alternative #3 - Install an 8 MWh energy storage device
Estimated cost $7.4 million.

The financial analysis was based on the following assumptions:

Project	2017	2018	2019	2020	Total
Recommended Solution (Battery + Solar)	$500,000	$4,300,000	--	$2,200,000	$7,000,000
Blue Sky Funds for Solar	--	*$1,950,000*	--	--	
STEP Funds for Battery + Interconnection	--	*$2,350,000*	--	*$2,200,000*	
Property Costs	*$100,000*	--	--	--	
Alternative #1 (Rebuild line)	$4,000,000	$4,000,000	--	--	$8,000,000
Alternative #2 (Circleville Sub)	$7,000,000	$7,000,000	--	--	$14,000,000
Alternative #3 (Battery Only)	$100,000	$2,500,000	--	$4,800,000	$7,400,000

- The financial analysis was completed over 15 years.
- Solar assets are depreciated over 5 years for tax and 25 years for book.
- Battery assets are depreciated over 20 years for tax and 20 years for book.
- Distribution assets are depreciated over 20 years for tax and 50 years for book.
- Land is depreciated over 0 years for tax and 0 years for book.
- Bonus depreciation of 40% applies to all assets placed in-service in 2018.
- All assets are allocated to Utah.
- The in-service date for assets with capital spend in 2017 and 2018 is June 2018.
- The in-service date for assets with capital spend in 2020 is December 2020.
- Battery OMAG costs were estimated for a Li-ion battery in Garfield County, Utah. The annual OMAG is approximately $16K.
- Annual solar OMAG is approximately $22K.
- Annual OMAG dollars for Alternatives #2 & #3 are 1% of the project capital dollars.
- The financial analysis results presented below are based on the project's revenue requirement. This is based on a capital structure of 49% debt and 51% common with a 5.21% debt and a 9.74% common rate.
- A 1.29% Utah property tax rate was used.
- A 6.57% discount rate was used.
- A 37.95% tax rate was used.

Project	OMAG	PVRR of OMAG	Capital Cost	Net Present Value
Recommended Solution (Battery Only)	$448,558	($313,509)	$7,000,000	($4,014,907)
Alternative #1 (Rebuild line)	$920,000	($632,501)	$8,000,000	($4,664,422)
Alternative #2 (Circleville Sub)	$1,610,000	($1,106,876)	$14,000,000	($8,162,738)
Alternative #3 (Battery + Solar)	$189,408	($132,441)	$7,400,000	($4,071,450)

17 Procurement and Project Delivery Strategy

- In order to satisfy business requirements, ensure best value, and minimize risk, the initial project shall be procured through a competitive engineer/procure/construct bid process.
- Project specifications shall be developed in accordance with applicable engineering specifications and standard designs.
- Bidders shall be screened to meet credit and procurement requirements. This process will be managed by the Company's project management department.
- Project delivery strategy to be determined by project team.
- The community outreach plan that leverages the benefits of this solution will include;
- A regional business manager to handle local community outreach.
- Company external communications will be managed by the Company's external communications team.
- A key stakeholder matrix will be created with assigned responsibilities to ensure that each critical contact is reached regarding the benefits of the solution.
- Social media will track the kick off, delivery and deployment of the solution as well.
- Customer and community outreach plan is provided in appendix C.

18 Recommendation

- Research and identify the lowest cost, best fit energy storage technology pertinent to this project
- Purchase a ten acre parcel (potentially less) of flat land in the [redacted] area in FY 2017
- Install a 2 megawatt-hour battery in FY 2018
- Install a 650 kilowatt ground-mounted solar in FY 2018
- Install a 3 megawatt-hour battery in FY 2020
- Interconnect the solar and energy storage plant to [redacted]

[redacted] distribution circuits

- Install all necessary equipment, including advanced metering, at [redacted] substation to accommodate the solar and energy storage projects

APPENDICES

- Appendix A – Engineering analysis
- Appendix B – Potential Site
- Appendix C – Communication Plan

APPENDIX A – ENGINEERING ANALYSIS

Executive Summary

The engineering analysis for the [redacted] project includes studying distributed energy resource solutions for a voltage-related issue. The study demonstrated that energy storage or energy storage combined with solar has the potential to provide the most cost effective solution when compared with traditional solutions.

Scope

The objective of the technical study is to assess a viable distributed energy technology that will offset the need for a traditional infrastructure solution to solve potential voltage problems on the [redacted] transmission line. The study included identifying and potential limitations or barriers to the solution including legal, regulatory, physical or operational constraints and compliance with all local, state and federal codes.

Technical Study

Site Selection

The [redacted] substation is a [redacted] kilovolt substation with one power transformer rated at [redacted] MVA. [redacted] distribution feeders [redacted] are connected to the substation. In 2015, the summer peak loading on the [redacted] substation transformer was [redacted] MVA. Based on available loading information for the past five years, the forecasted load growth is established at 1.8%.

Based on available data, during peak summer loading conditions, the [redacted] transmission line voltage will drop to 0.92 per unit of the nominal voltage and is forecasted to drop below 0.90 per unit in 2019.

Traditional Solution

The traditional solution to the voltage issue on the [redacted] transmission line is to either rebuild portions of the [redacted] transmission line using lower impedance conductors or build a nearby [redacted] substation. Both of the solutions are higher cost considering capital required to purchase, install and operate the necessary solar/energy storage equipment.

Distributed Energy Resource Analysis

Loading Analysis

Given the objective of maintaining the loading level on the [redacted] substation transformer at or below [redacted] megawatts, following the distributed energy resource implementation, a loading analysis was performed to quantify the needed resource. Figure 1 shows the substation loading recorded for 2015 as well as forecasted loads for FY 2034.

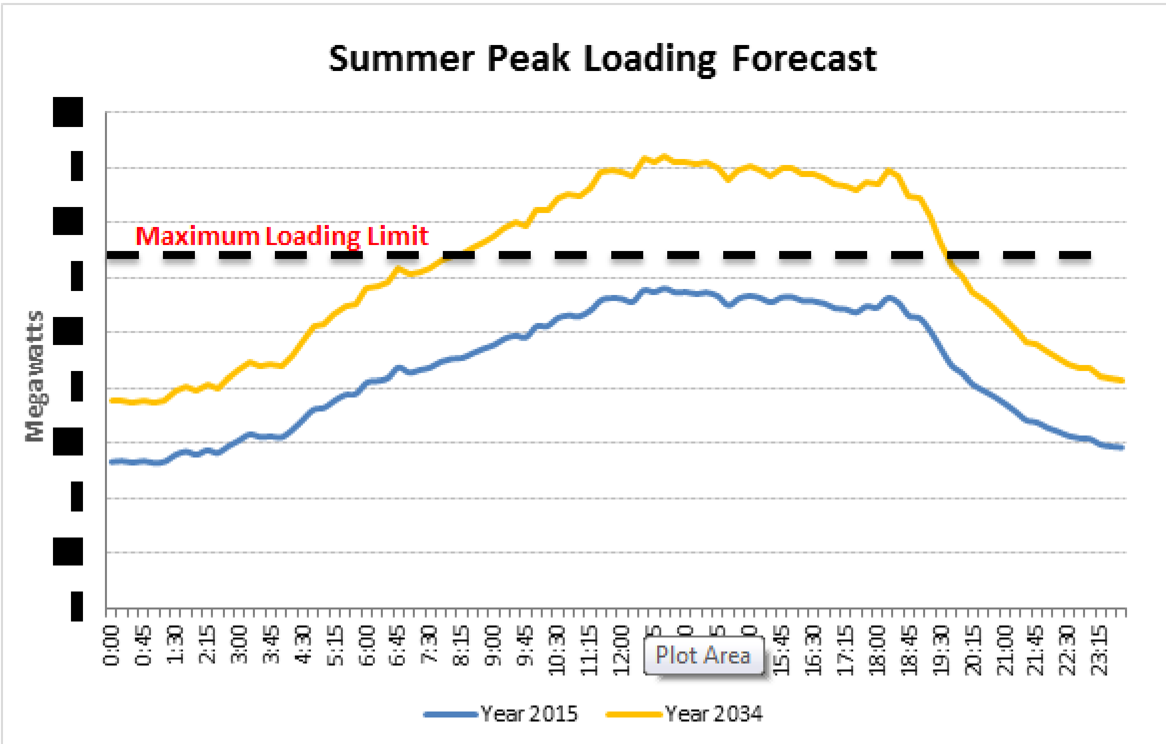

Figure : Summer peak loading forecast for [redacted] substation transformer

Distributed Energy Resource Technology Evaluation

The distributed energy resource analysis began with an evaluation of technologies that could feasibly attain the objective set forth in this study. Those evaluated were central energy storage and central energy storage combined with solar.

Energy Storage

Centralized energy storage is a feasible resolution/deferment to the [redacted] transmission line voltage issue. The technology and control systems are available for energy storage to be able to discharge to offset the requirement, and recharge during light loading periods. A 8 megawatt-hour installation will be required to solve the voltage issue until 2034. Figures 2 through 4 illustrates the impact of a 2 megawatt, 8 megawatt-hour energy storage device on the summer peak loading profile and confirms that the energy storage device solves the capacity issue during peak loading period and gets sufficient time to recharge during the light loading period. The evaluation of energy storage consists of sizing the equipment and identifying physical integration requirements.

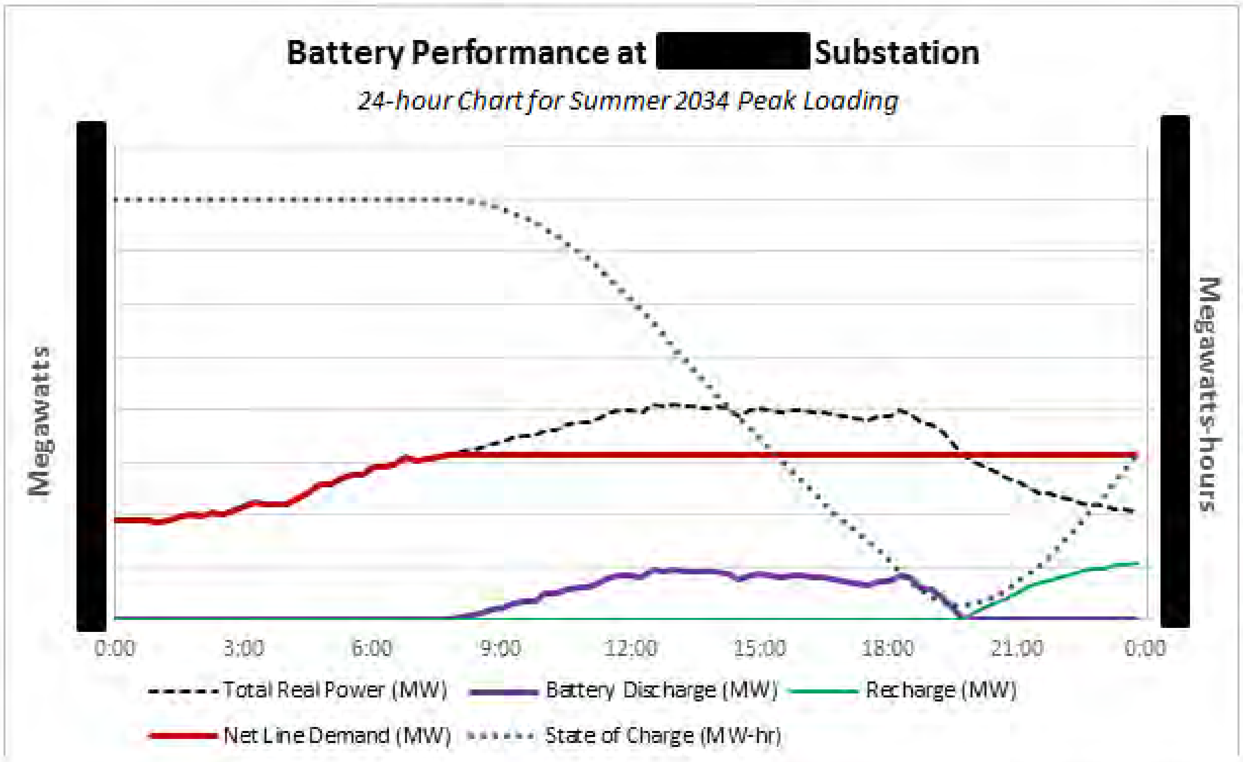

Figure 2: Daily peak loading performance for FY 2034 using 2 MW/8 MWh Battery

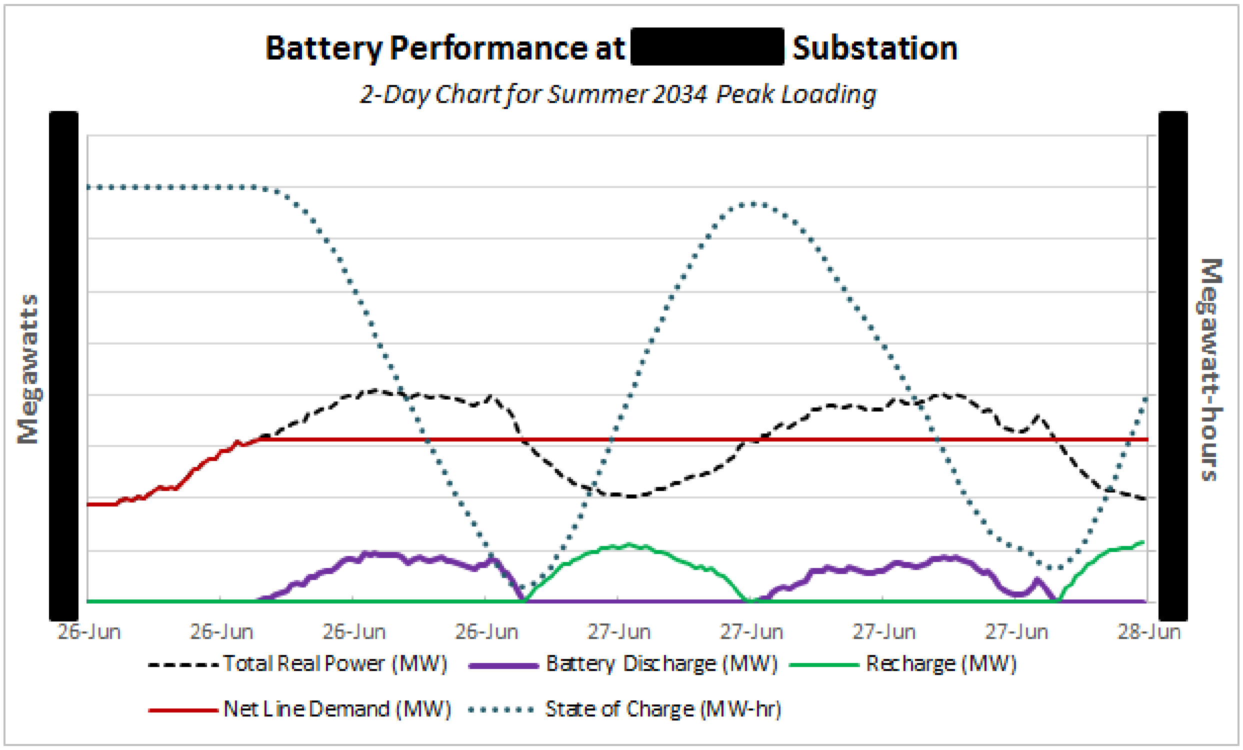

Figure 3: 2-Day peak loading performance for FY 2034 using 2 MW/8 MWh Battery

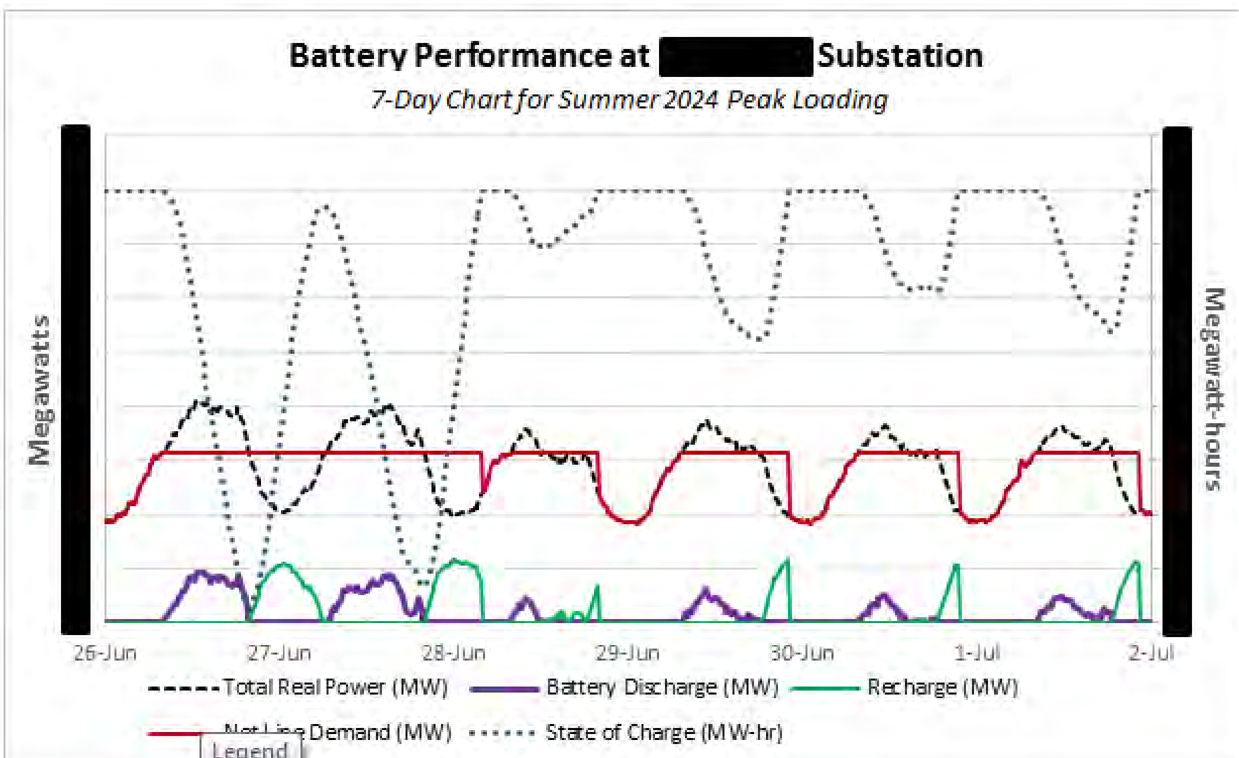

Figure 4: 7-Day peak loading performance for FY 2034 using 2 MW/8 MWh Battery

Solar and Energy Storage

Solar generation in conjunction with energy storage is technically a feasible solution. Using a solar profile based on data collected from the National Renewable Energy Laboratory database, a 650 kilowatt solar combined with a 5 megawatt-hour energy storage installation will help suffice energy and demand requirements until 2034. It is anticipated that this will reduce the size of energy storage required for the project. However, the installation of the solar generation will need an approx. $2 million investment in addition to the land required to setup the solar installation.

While technically feasible, the solar and energy storage combination project is least cost than an energy storage solution however there are several risks associated with the acquiring land and any future scaling of the project. Table 1 describes the basic requirements of the solar and energy storage necessary to defer any traditional investment until FY 2034.

Technical Requirements	
Energy Storage - Energy density requirement	5 megawatt-hours
Solar – Capacity requirements	650 kilowatts
Interconnection Equipment	Protection & Control, Communication, Power Transformer
Site Requirement	5 – 7 acres

Table : Technical Requirements for Energy Storage Solution

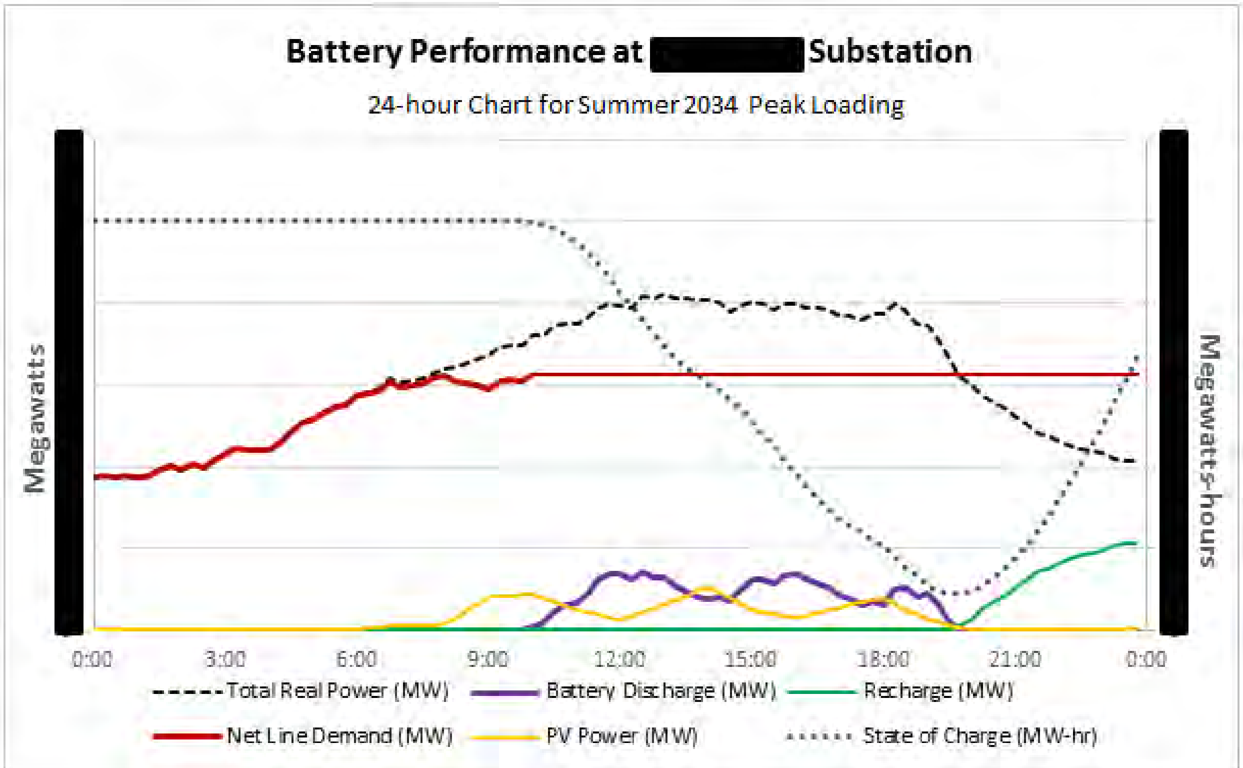

Figure 5: Daily peak loading performance for FY 2034 using 5MWh Battery and 650 kilowatt solar

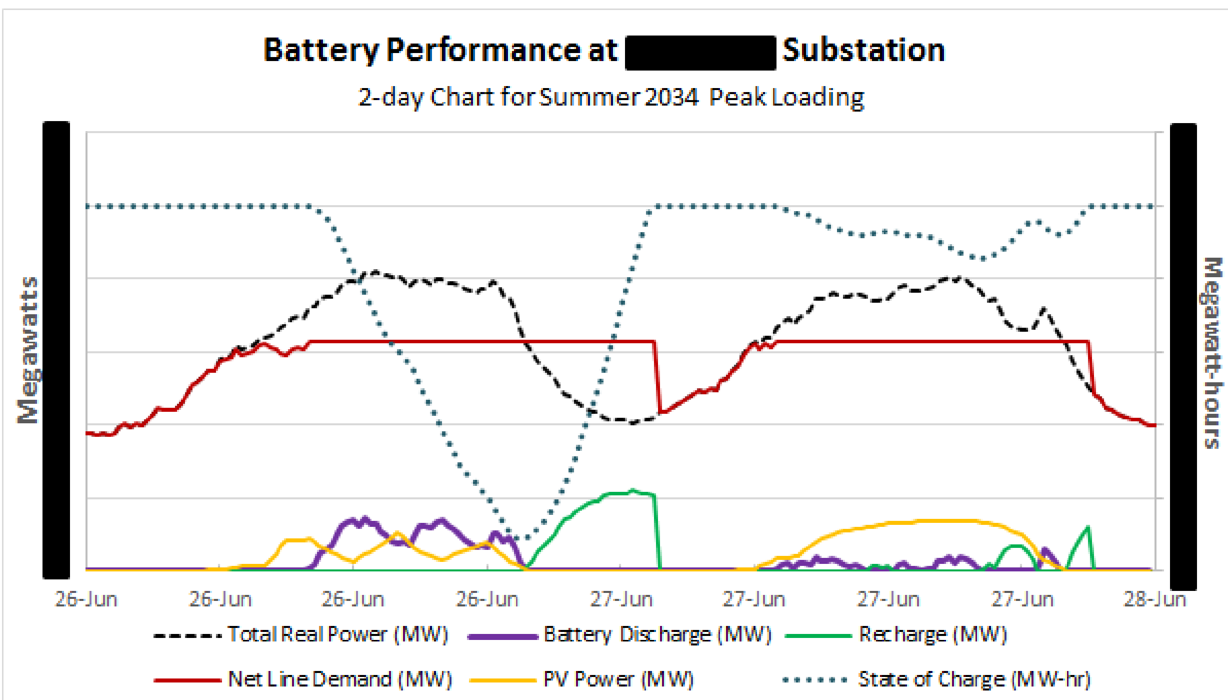

Figure 6: 2-Day peak loading performance for FY 2034 using 5MWh Battery and 650 kilowatt Solar

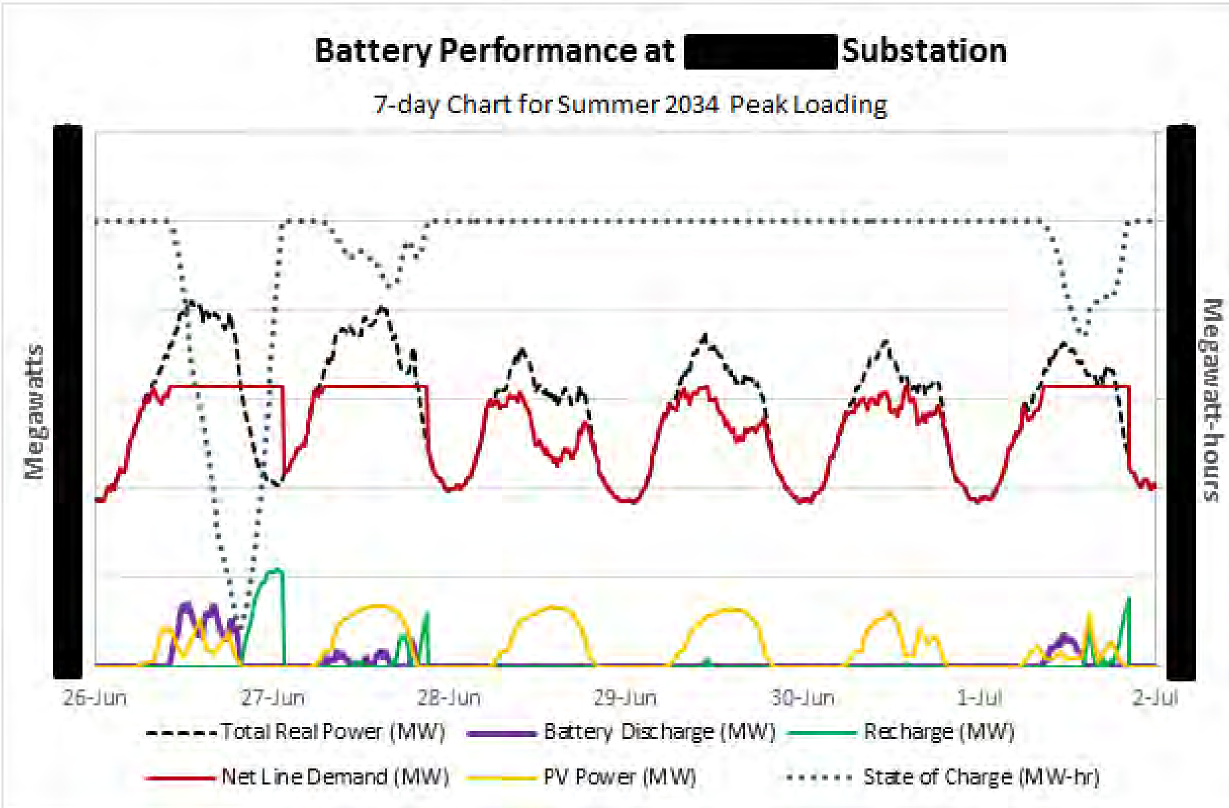

Figure 7: 7-Day peak loading performance for FY 2034 using 5MWh Battery and 650 kilowatt Solar

Risk Assessment

The interconnection of distributed energy resources adds an additional risk element to the operation of the distribution system. The intermittency of solar generation has the potential to exacerbate voltage and capacity issues during peak summer loading conditions. In comparison, an energy storage solution is much less risky considering it is completely unaffected by any weather or climatic intermittency. However, either of the proposed solutions will introduce risks associated with charge-discharge control scheme failures and other potential equipment failures. Load-shedding and load-transfer schemes needs to be developed to ensure any equipment failure will not affect safety, reliability and operability of the transmission and distribution system.

Recommendation

The technical analysis clearly illustrates the feasibility of using a distributed energy resource solution to resolve the voltage issue on the [redacted] transmission line. From a technical standpoint, both energy storage and solar- combined with energy storage solutions help to alleviate loading on the [redacted] substation transformer thereby improving the voltage profile of the transmission line. A detailed financial, engineering and policy analysis will help determine the least-cost best-fit distributed energy resource solution amongst the aforementioned two solutions.

APPENDIX B – POTENTIAL PROJECT SITE

[redacted]

APPENDIX C – COMMUNICATION PLAN

To be customized to specific Utah Innovative Technologies project

Utah Innovative Technologies
2016 Communications Plan

Project Team: Chad Ambrose, Erik Anderson, Ian Andrews, Ryan Anthon, Nathan Bailey, James Campbell, James Johnson, Bob Lively, Douglas Marx, Robert Meredith, Clay Monroe, Lucky Morse, Rohit Nair

Communications Team: Barb Modey, Paul Murphy, Berit Kling

Background:
Utah Senate Bill 115, Sustainable Transportation and Energy Plan, was signed into law March 29, 2016. The legislation establishes a 5-year pilot program to provide mandated funding for electric vehicle infrastructure and clean coal research, and authorizes funding at the commission's discretion for solar development, utility-scale battery storage, and other innovative technology, economic development and air quality initiatives.

SB 115 also authorizes the development of a renewable energy tariff for large customer loads. The legislation also allows PacifiCorp to change its accounting for energy efficiency services and programs from expense to capital and to create a regulatory liability for accelerated depreciation of its coal-fired plants. The legislation also mandates full recovery of Utah's share of PacifiCorp's prudent costs of variable energy. The UPSC previously allowed PacifiCorp to recover only 70 percent of its incremental fuel, purchased power and other variable supply costs through an energy balancing account that are not fully in base rates.

Utah Innovative Technologies (UIT) has identified the following work streams:

- **Solar Incentive:** Deployment of a solar incentive for commercial customers wherein a direct benefit to identified distribution voltage circuits can be derived. These customers will be net energy metered. This benefit is reducing the circuit peak, thereby deferring capital spend and providing a public relations benefit for continuing an incentive program

- **Centralized Battery Systems:** Use of centralized battery systems (CBS) located on identified distribution circuits or substations where in a direct benefit can be achieved. This benefit includes, through the use of solar or grid energy to charge the battery system to be dispatched during circuit peak hours to reduce load on transformer and circuit equipment. This reduction will help defer capital spend on the circuit, may provide improved power quality and gives the utility and opportunity to understand the use of this innovative/emerging technology.

- **Special Pilot Projects:** Identification and targeting of special circumstances that require unique innovative technologies to improve circuit or substation performance. For example, the installation of high-end metering equipment with communications at locations with a high penetration of distributed energy resources. This will help the company better understand the impact of generation resources on loading patterns and other power quality and reliability impacts, if any.

Utah Blue Sky program is available for the Company to use.

- Per the Utah Blue Sky tariff schedule 70, the Company will not have a co*ntribution towards this project thereby requiring* the R*enewable* E*nergy* C*redit*s *to* be retired on behalf of the Blue Sky customers in Utah.
- The Company will use Blue Sky funds under the “Qualifying Initiatives” section of Schedule 70, item 2 which reads, “Funding for research and development projects encouraging Renewable Energy in order to accelerate marketability of Renewable Energy technologies.”

The engineering team assigned to this initiative is identifying the most cost-effective and viable approach for implementation. The initiative combines battery storage with Company-owned solar. The solar will be funded by the Utah Blue Sky Solar program.

This communications plan focuses on the UIT initiatives within the larger STEP Communications Plan. It is intended to be a working document that will evolve as UIT initiatives change based on emerging needs, technology available and team evaluation.

Communication Objective:

To gain acceptance and understanding of the UIT project benefits, the use of Utah Blue Sky funds and to position Rocky Mountain Power as an innovative solutions provider to integrate and provide renewable power options.

Target Audience (Stakeholders):

Regulators
Community stakeholders
Regional Business managers
Opinion leaders and elected officials
Media and general public

Communication strategy for community stakeholders:

- Prepare communication materials that are transparent, contain clear facts, and present mutual benefits and opportunities for the identified customers and Rocky Mountain Power.
- Manage the communication with stakeholders to explain why Utah Blue Sky funds are being used for the solar project and how STEP funds are being effectively deployed for the battery and why using both programs creates a win-win outcome for customers.

Core Messages (customers):

- Rocky Mountain Power is providing options towards a sustainable energy future.
- Rocky Mountain Power's Innovative Technologies initiative will help bring innovative technologies on-line where they are most needed and beneficial to the overall system. This will help hold down rates for all Utah customers by reducing the need for additional infrastructure upgrades.
- Rocky Mountain Power's Blue Sky renewable energy program will help bring new cost-effective solar resources on-line for Utah customers.
- Rocky Mountain Power has identified key electrical circuits in Utah that provide an optimal opportunity for solar resources to reduce demand during peak hours.

Core Messages (regional business managers and other employees):

- Rocky Mountain Power is providing options towards a sustainable energy future.
- Utah Innovative Technologies supports battery storage technologies and solutions.
- Utah's Innovative Technologies initiative combined with the Utah Blue Sky program will help bring renewable resources on-line where they are most needed and beneficial to the overall system. This will help hold down rates for all Utah customers by reducing the need for additional infrastructure upgrades.
- Rocky Mountain Power has identified key electrical circuits in Utah that provide an optimal opportunity for solar resources to reduce demand during peak hours. The company will reach out to community stakeholders and customers served by these key circuits to help them understand the benefits.

Tactics:

Key Audience	Tactic	Timing	Responsible
Regional Business Managers	Attend regular staff meeting to **explain changes to RBMs** and answer questions about UIT and Blue Sky funding a company-owned project	Nov. 2016	Ambrose

Regulators	Company meets early and as often as necessary with regulating bodies to explain the program and benefits.	Sept. 2016	Lively
Interested parties	Update Blue Sky section of Rocky Mountain Power **website** to explain changes, update FAQs, etc.	Dec. 2016	Modey Kling
Blue Sky customers	Create materials for reaching out to Blue Sky customers and local customers in [redacted], Utah	TBD	Kling
Opinion leaders (media government officials, business leaders, community leaders)	Talking points, op-eds, news releases, fact sheets, direct contact with executives, government relations and regional business managers and external communications, **opportunities to proactively communicate the benefits of UIT and Blue Sky.**	TBD	Murphy Kling
General public/press	Monitor social media channels for comments and discussion on UIT and Blue Sky	Ongoing	Murphy Puglia Kling
General employees	Develop an **article for employee newsletters**, and Utah intranet postings	TBD	Zukin
Utah employees	Host a **Power Hour** in SLC about Utah Innovative Technologies	TBD	Ambrose Belmonte
General public/press	After solar projects have been installed; arrange to have ribbon cutting and or photography and **press release; post to website; social media**	TBD	Murphy Kling Puglia

Budget:

Allocate roughly $30,000 per year for funding to cover mailings and collateral materials, photography and other communications.

Evaluation:

- Track ability to attract eligible customers to participate so Rocky Mountain Power can meet generation goals on key circuits in a timely manner;
- Track public opinion and social media activity

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Rocky Mountain Power
Exhibit E
Docket No. 16-035-36

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF UTAH

ROCKY MOUNTAIN POWER

Exhibit E
Gadsby Emissions Curtailment Program

September 2016

Rocky Mountain Power

Gadsby Emissions Curtailment Program

Sustainable Transportation and Energy Plan

Innovative Utility Programs

1 Executive Summary

Air quality is one of the most challenging and important public policy issues facing the state of Utah. The Utah Sustainable Transportation and Energy Plan or "STEP" legislation allows for the Commission to authorize innovative utility programs that curtail emissions from thermal generation plants along the Wasatch Front. This program would establish a process where the Gadsby Power Plant would curtail its emissions during winter inversion air quality events as defined by the Utah Division of Air Quality ("UDAQ"). Funds collected under 54-20-105-1 will be used to cover costs of the curtailment during the 5 year pilot program period. The curtailment program is budgeted for a total $500,000. Once the funds are exhausted the program will cease to operate.

2 Purpose and Necessity

The Wasatch Front is currently in non-attainment of National Ambient Air Quality Standards for Particulate Matter 2.5 microns known as PM 2.5. According to the UDAQ[1], "the majority of Utah's PM2.5 is called secondary aerosol, meaning that it is not emitted directly as a particle, but is produced when gasses such as SO2, NOx, and volatile organic compounds (VOC) react with other gasses in the atmosphere, such as ammonia, to become tiny particles. Wintertime temperature inversions not only provide ideal conditions for the creation of secondary aerosols, they also act to trap air in valleys long enough for concentrations of PM2.5 to build up to levels that can be unhealthy.

Rocky Mountain Power (RMP) has designed a program where the company will voluntarily reduce the operation of the Gadsby Power Plant during winter inversions, which is located in the Salt Lake non-attainment area. The Gadsby Plant is 100%-owned and operated by RMP, and was originally designed to burn oil derivatives, natural gas, or coal. Two physical sections with vastly different electricity generation vintage and technologies make up the Gadsby Plant. The first group of units are conventional natural gas fired boilers, consisting of Units 1-3. These units represent the oldest operating units in RMP's thermal fleet, and were originally built in the 1950's. The units were then converted from a coal-fueled plant to a natural gas-fueled plant in the 1990's. Pipeline quality natural gas is now fired in the original boilers to generate steam, which generates electricity. The second group of units are aeroderivative gas turbines consisting

[1] See Utah Division of Air Quality 2014 Annual Report, Page 18

of Units 4-6. Units 4-6 are peaking units and are not being considered for this program.

Units 1, 2, and 3, which are being considered for the curtailment program, have a net capacity rating of 64 MW, 69 MW, and 104.5 MW, respectively for a total of 237.5 MW. The Gadsby Plant is typically used for two purposes: reserves and peak load. Reserves held at the Gadsby Plant allows other, lower heat rate (i.e. more efficient) units to be run at or near full capacity. The grid has a certain amount of generation that must be "held back" to meet reserve requirements, as determined by the grid reliability coordinator, Western Electric Coordinating Council (WECC).

The program would work in collaboration with the UDAQ so that the state would issue air quality alerts to RMP when the ambient air quality along the Wasatch Front is at or near unhealthy levels and then RMP would curtail the operation of the Gadsby Units, if operating, until the air quality alerts are lifted by the UDAQ. According to the Utah State Implementation Plan[2] for PM 2.5 developed by the UDAQ, Gadsby is a major emitting source of NOx (a PM 2.5 precursor) on a typical winter inversion weekday.

However, if RMP curtails operation at the Gadsby Power Plant there will be economic loss from both not operating the resource and purchasing replacement generation and capacity to meet system needs. Since Gadsby is a system resource, the economic loss would impact all the states in the PacifiCorp service territory that pay for the costs of Gadsby (5 of the 6 states served by the company). To ensure that no state is unfairly impacted from the voluntary air quality program, STEP funds would be used to compensate the system for the economic loss.

3 Program Description

The UDAQ issues action alerts when pollution is approaching unhealthy levels. These alerts proactively notify residents and businesses before pollution build-up so they can begin to reduce their emissions. When pollution levels reach 15 µg/m3 for PM2.5, DAQ issues a 'yellow' or voluntary action day, urging Utah residents to drive less and take other pollution reduction measures. At 25 µg/m3, 10 µg/m3 below the EPA health standard, DAQ issues a "red" or mandatory advisory prohibiting burning of wood and coal stoves or fireplaces. It is at the 25 µg/m3 level when RMP will take action to curtail the Gadsby Steam units.

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[2] Utah State Implementation Plan Control Measures for Area and Point Sources, Fine Particulate Matter, PM2.5 SIP for the Salt Lake City, UT Nonattainment Area Section IX. Part A.21 December 3, 2014

DAQ will provide 5 days-notice to RMP when air quality actions will be issued. RMP will evaluate the system to determine if there are reliability or emergency issues that could be impacted by curtailing Gadsby. At 2 days out, DAQ will issue a second notice of an upcoming air quality action alert. Assuming no issues, RMP will curtail Gadsby's steam operations. RMP needs at least 2 days or 48 hours to effectively reposition its fuel supply. The steam units will stay curtailed until DAQ releases its air quality action alert.

In the event that the plant was scheduled to operate and was curtailed, the economic loss must be calculated. RMP will perform dispatch modeling analyses with the resource in the model and with the resource absent to evaluate the Net Power Cost impact of curtailment. The Gadsby curtailment program is budgeted for a total of $500,000 for the entire 5 year pilot program period. Once the $500,000 is spent the program would end. If Gadsby is not scheduled to operate during an air quality event, then no action is taken and there is no economic loss.

4 Customer Interest Justification

Many of RMP's customers live in communities that are located within the non-attainment areas, including Salt Lake City which is where the Gadsby Power Plant is located. The primary benefit of curtailing Gadsby is the potential reduction of NOx emissions which contribute to the formation of PM 2.5. According to DAQ (see Appendix 1), the Gadsby's Power Plant may emit 0.437 tons of NOx per day during a typical winter inversion day, which makes Gadsby the 10^{th} largest emitter of NOx in the Salt Lake non-attainment area. This program would ensure that those emissions would not occur during periods of unhealthy air quality and not contribute pollutants to air sheds of non-attainment areas.

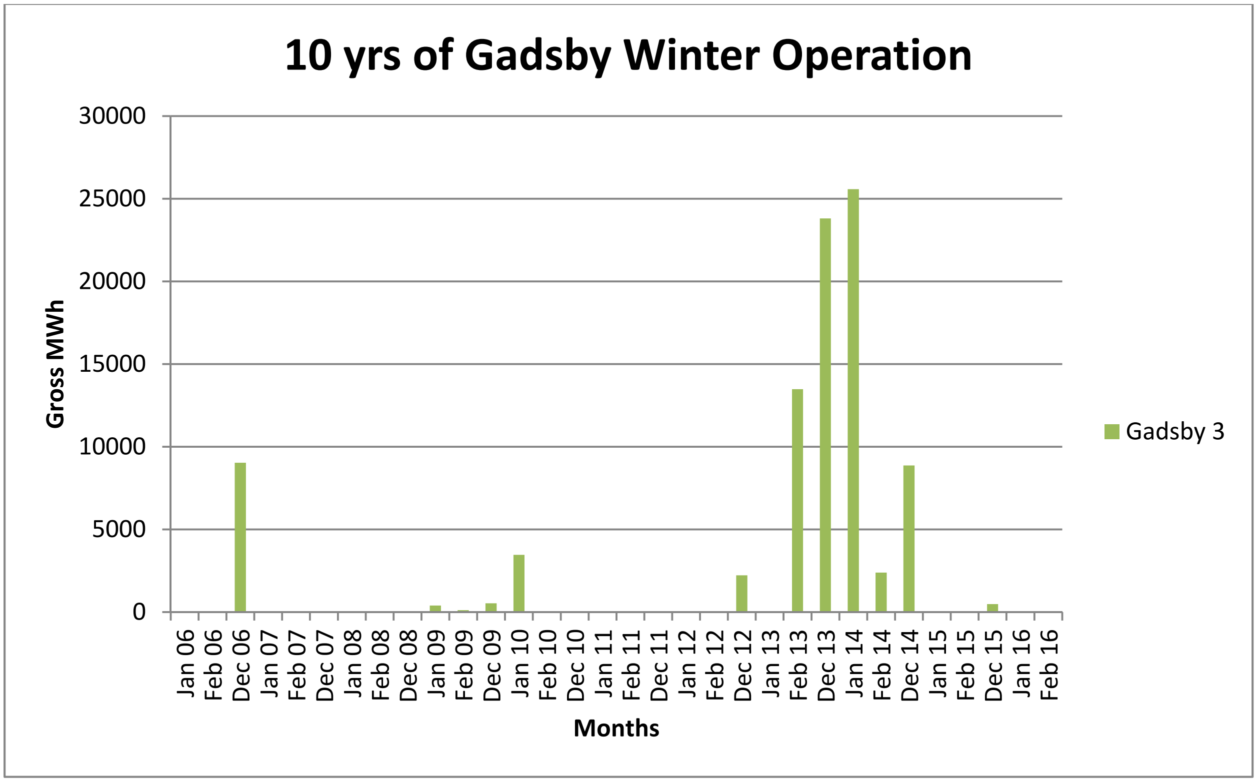
5 Compliance with SB115

The Gadsby curtailment program meets the legislative language of SB115 54-20-105-1(e) that pertains to "a program to curtail emissions from thermal generation plant in the Salt Lake non-attainment area during a non-attainment event as defined by the Division of Air Quality". This project falls under the STEP's innovative utility programs.

6 Program Costs

To evaluate the potential impact of curtailing, the historical operation of Gadsby was evaluated. Since Unit 3 is the largest and most dispatched Unit it was used as the proxy. The following chart (the data was taken from the Environmental Protection Agency's Clean Air Markets Data

Base) illustrates Gadsby Unit 3 winter operation (December, January, February) for the last ten years:



Although the Gadsby plant primarily operates in the summer months, Gadsby was dispatched in the winter of 2013 and 2014.

The typical inversions along the Wasatch Front last on average 3 weeks a year. To determine the projected scale of the economic loss, RMP performed a preliminary analysis using an economic dispatch model under three different scenarios involving Gadsby's curtailment during winter inversions. The initial analysis assumed Unit 3 was operating for 1,462 hours during the winter months (which corresponds with the winter of 2014). The three scenarios are as follows:

1) Gadsby does not run at all during Dec, Jan and Feb.

2) Gadsby does not run for 6 weeks (1 week in the end of Dec, all of Jan and 1 week in Feb).

3) Gadsby does not run for 3 weeks starting in the beginning of January.

Scenario 1 (3 months)			
	Scenario 0	Scenario 1	Gain/Loss
Fuel cost	($245,180,621)	($242,442,269)	$2,738,352
Implied sale/purchase	$45,674,281	$41,490,919	($4,183,362)
Start-up Cost	($1,096,140)	($985,910)	$110,230
		Net Gain/Loss	**($1,334,780)**

Scenario 2 (6 weeks)			
	Scenario 0	Scenario 2	Gain/Loss
Fuel cost	($245,180,621)	($243,932,024)	$1,248,596
Implied sale/purchase	$45,674,281	$43,816,871	($1,857,410)
Start-up Cost	($1,096,140)	($1,076,110)	$20,030
		Net Gain/Loss	**($588,783)**

Scenario 3 (3 weeks)			
	Scenario 0	Scenario 3	Gain/Loss
Fuel cost	($245,180,621)	($243,552,170)	$1,628,450
Implied sale/purchase	$45,674,281	$43,768,192	($1,906,088)
Start-up Cost	($1,096,140)	($1,049,040)	$47,100
		Net Gain/Loss	**($230,538)**

It is estimated that the economic loss from curtailing Gadsby's winter operation, when it is scheduled to operate, is roughly <u>$100,000 a week</u>. This amount can be used as a potential upper limit. Since typical inversions last 3 weeks $300,000 would most likely cover the costs if Gadsby 3 operated like it did during the winter of 2014 and air quality events occur. Since this amount is an upper limit and Gadsby usually does not operate during most winter months a budget of $500,000 should cover most of the expense during the 5 year pilot program.

7 <u>Accounting Issues or Regulatory Recovery Issues</u>

UDAQ will provide 5 days-notice to RMP when air quality actions will be issued. Energy Supply Management ("ESM") will then determine whether Gadsby should be curtailed. If curtailment is elected, ESM will use models to determine the incremental Net Power Cost ("NPC") impact of the curtailment. ESM will then enter the curtailment volume and cost in the Endur system, and provide notification to NPC and Load Forecast group, NPC Finance and ESM

Finance groups that a Gadsby curtailment has occurred. If a month-end accrual is required, NPC Finance will book the accrual. ESM Finance will book the actual curtailment costs. The entry is a debit to the corresponding STEP WBS (STEP balancing account) and a credit to NPC (since the decision to curtail Gadsby increases NPC, the credit from STEP funds makes NPC costs neutral for ratepayers). Since these STEP funds are recognized as a reduction to NPC, the corresponding STEP expenditures should not be included in the balancing account amortization expense or revenue.

Appendix 1
List of Point Sources in the Salt Lake Non-Attainment Area

Typical Winter Inversion Weekday Emissions (tpd)			2010_(R2) Baseline					2015_(R9) Growth & Control				
Source Category	NA-Area	Site	PM2.5	NOX	VOC	NH3	SO2	PM2_5	NOX	VOC	NH3	SO2
Point Sources	Salt Lake City, UT											
		ATK Thiokol Promontory	0.135	0.360	0.141	0.002	0.042	0.144	0.354	0.150	0.003	0.045
		Bountiful City Power	0.174	0.697	1.284	0.311	1.065	0.087	0.624	1.264	0.311	0.392
		Central Valley Water	0.000	0.005	0.001		0.000	0.082	0.209	0.049		0.002
		CER Generation II LLC - WVC	0.004	0.034	0.137	0.000	0.003	0.004	0.043	0.033	0.000	0.003
		Chemical Lime Company	0.015	0.039	0.005		0.002	0.015	0.039	0.005		0.002
		Chevron Refinery	0.036	0.043	0.001	0.000	0.034	0.008	0.058	0.002	0.000	0.044
		Flying J Refinery	0.501	2.991	0.663	0.026	1.774	0.105	1.950	1.234	0.022	1.092
		Geneva Rock Point of Mountain	0.069	0.269	0.050		0.037	0.084	0.323	0.060		0.026
		Great Salt Lake Minerals - Production Plant	0.132	0.249	0.023	0.002	0.018	0.107	0.304	0.061	0.003	0.026
		Hexcel Corporation Salt Lake Operations	0.048	0.217	0.180	0.079	0.024	0.103	0.102	0.111	0.129	0.009
		Hill Air Force Base Main	0.037	0.525	0.826	0.006	0.008	0.035	0.373	0.800	0.006	0.008
		Holly Refining Marketing	0.147	0.851	0.663	0.057	1.318	0.134	0.933	0.700	0.654	0.309
		Interstate Brick Brick	0.175	0.114	0.010		0.036					
		Kennecott Mine Concentrator	0.647	8.492	0.504	0.003	0.008	0.854	12.130	0.651	0.004	0.014
		Kennecott NC-UPP-Lab-Tailings	0.014	0.016	0.005	0.001	0.000	0.300	0.197	0.069	0.001	0.034
		Kennecott Smelter & Refinery	0.610	0.470	0.027	0.016	3.023	0.837	0.767	0.068	0.025	3.827
		Murray City Power	0.000	0.001	0.000		0.000					
		Nucor Steel	0.158	0.502	0.202	0.006	0.118	0.351	0.978	0.353	0.004	0.833
		Olympia Sales Co.	0.014	0.001	0.072	0.000	0.000	0.000	0.001	0.091	0.000	0.000
		Pacificorp Gadsby	0.067	0.443	0.031	0.065	0.006	0.067	0.437	0.031	0.065	0.006
		Pacificorp Little Mountain	0.021	1.014	0.007		0.011					
		Proctor & Gamble Paper Products Co.	0.099	0.043	0.067		0.003	0.575	0.674	0.654		0.007
		Silver Eagle Refining	0.011	0.246	0.359	0.012	0.003					
		Tesoro Refinery	0.710	1.162	0.806	0.011	2.808	0.272	1.297	1.005	0.010	0.819
		University of Utah	0.024	0.313	0.023	0.009	0.003	0.030	0.159	0.022	0.008	0.003
		Utility Trailer	0.002	0.117	0.215		0.001					
		Vulcraft	0.017	0.020	0.147	0.000	0.001	0.044	0.030	1.134	0.000	0.002
		Wasatch Integrated IE	0.019	0.903	0.033	0.039	0.292	0.024	0.832	0.042	0.049	0.371
		Salt Lake City, UT Total	**3.885**	**20.138**	**6.482**	**0.645**	**10.638**	**4.261**	**22.811**	**8.590**	**1.294**	**7.874**

Table 6.3, Point Source Emissions; Baseline and Projections with Growth and Control (taken from Control Measures for Area and Point Sources, Fine Particulate Matter, PM2.5 SIP for the Salt Lake City, UT Nonattainment Area Section IX. Part A.21)