Rocky Mountain Power
Exhibit RMP___(JAC-1)
Docket No. 16-035-36
Witness: James A. Campbell

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF UTAH

ROCKY MOUNTAIN POWER

Exhibit Accompanying Direct Testimony of James A. Campbell

Power Balance and Demand Response to Optimize Charging at Intermodal Hubs

March 2019

Rocky Mountain Power

Power Balance and Demand Response to Optimize Charging at Intermodal Hubs

Sustainable Transportation and Energy Plan

Utah Innovative Technology

Project Sponsor: Chad Teply

Revision: 1

Revision by: James Campbell

Date: January 10, 2019

1 Executive Summary

As part of the Sustainable Transportation Energy Plan (STEP), Rocky Mountain Power (The Company) requests $1,995,576 to develop a power balance and demand response system for multi modal vehicle charging at sites with high peak power demand. The primary goals are to reduce peak loads and increase utilization of charging equipment which should minimize both infrastructure upgrade and operating costs. This unique collaboration of the Company, USU's Sustainable Electrified Transportation Center (SELECT), and Utah Transit Authority (UTA) will demonstrate the ability to manage the challenges of meeting and coordinating expanding high power vehicle charging demands. The proposed system will be developed and evaluated at the Utah State University Electric Vehicle Roadway (USU EVR) research facility and test track and will be deployed and validated at the UTA Salt Lake City Intermodal Hub (Fig. 1). The UTA site will serve as a living laboratory for data collection and a model showcase of sustainable electrified transportation technology. The lessons learned should reduce the costs for both customers and the system as EV adoption becomes more widespread; thus, this project's objectives are to *develop best practices* for new technology function and deployment and to *evaluate the merit of the technology's application*.

Figure 1. Utah Transit Authority Intermodal Hub in Salt Lake City.

2 Power Balance and Demand Response

The Company proposes a comprehensive research, development and public demonstration project that will serve as a model for deployment of efficient large-scale, multi modal charging centers consisting of common grid and charging infrastructure with managed power load balancing and operating costs through demand response software and hardware strategies.

A primary challenge for high power electric vehicle (EV) charging is the

Figure 2. UTA Intermodal Hub aerial view showing current multi modal charging infrastructure.

independent deployment of charging for different vehicle types as shown at the Intermodal Hub in Fig. 2 (e.g., light and heavy duty vehicles, trains, buses) with a wide range of operational scenarios (e.g., transit/fixed routes, fleets, ride hailing, general use). The traditional approach is to evaluate worst-case conditions and require costly reconductoring and transformer and meter upgrades for each addition of charging equipment. This proposal introduces the innovative concept of combining the vast diversity of needs at an intermodal transit center to create multi-megawatt co-located, coordinated, and managed charging systems that guarantee through controls that worst-case analysis and costing is not required. The approach combines, at a single site, the electric needs of a light rail system, electric buses, interstate and urban passenger and truck traffic, park-and-ride customers, and first-and-last mile ride hailing and car share service providers. The combination of scheduled and unscheduled services, and high to low power and short to long term demands, creates an ideal opportunity to share grid infrastructure costs and actively manage grid impacts and demand charges without significantly impacting quality of service.

Research activities – Key research activities will lead to accomplishing the objectives of establishing best practices and evaluating the technology.

Algorithm development – To determine optimal scheduling of multi-modal electric demand, including TRAX light rail, e-bus opportunity and depot charging, commuter parking, ride hailing, and fleets, effort will be dedicated to evaluating and developing intelligent prediction algorithms. These Machine Learning (ML) tools will be used to 1) train the system on historical training datasets and continue the learning process with new data as the program progresses and 2) consider framework options such as Markov Decision Process (MDP) to model the charging control process and multiple Dynamic Programming (DP) options such as k-Nearest Neighbors, deep neural network, and shallow neural network to project optimal charge scheduling and demand response. The algorithm outputs will be used to optimize charge scheduling of the electric buses and to consider the potential impact for demand response pricing and incentives for public charging.

EV charge scheduling and prioritization tools – Central processing algorithms and remote apps will be developed that can be used by demand response participants. This development will leverage ML algorithms running on a central server to predict optimal charging times and power profiles. These will be developed first to prioritize bus charge scheduling for overhead high power charging and for depot charging. The effort will consider options to tie the approach into the dispatch system for electric buses and implications on bus routing and fleet management. The approach will then be extended to public charging scenarios and development of potential apps and associated incentive programs and demand response pricing to encourage truck, fleet and passenger vehicle charging that increases energy demand without increasing peak demand.

Grid distribution analysis and system simulation model development – The developed system will model electric demands across the multi modal network with agent based solutions (e.g., Fig. 3) for fleets and ride hailing as well as deterministic models for bus and train routes. This new understanding will be merged with localized **grid distribution circuit models,** which will be leveraged to evaluate potential impacts for demand response and scheduling control. The model will be used to directly compare worst-case analysis solutions with the proposed managed solution. The simulation testbed will be used to evaluate both the planned early stage deployment with two or three overhead bus chargers and limited public charging and a long term vision for broad deployment with six overhead chargers, 27 or more electric buses and depot chargers, and public charging for truck and passenger vehicles. The model can also be leveraged as a planning tool for future multi modal sites, such as additional TRAX stations along I-15.

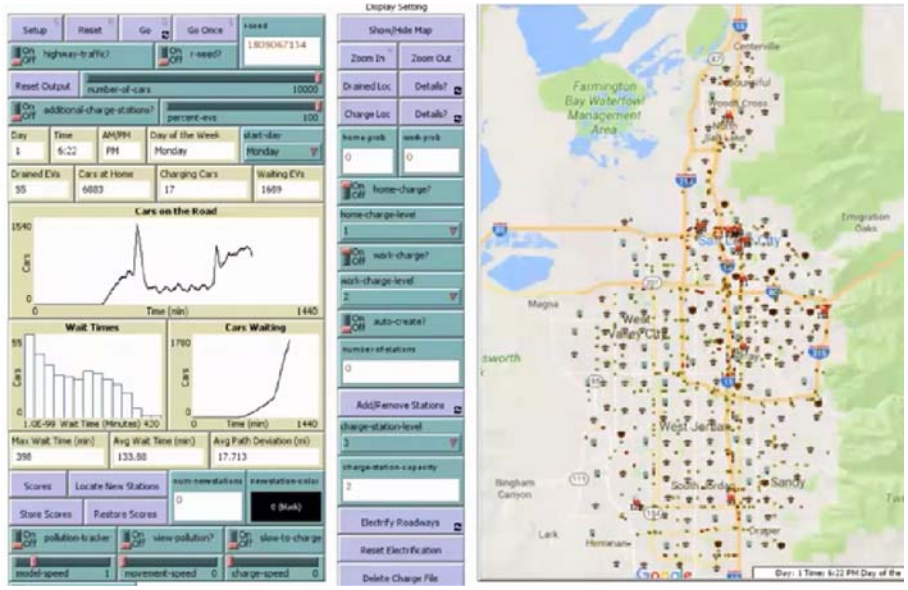

Figure 3. Sample of agent based simulation showing vehicles traveling through the Salt Lake valley along with their proximity to and use of charging infrastructure (courtesy Dr. John Salmon, Brigham Young University).

Hardware system development and demonstration – This project will develop specifications and design primary processing and data servers and software for the intermodal system, which will include a bid and procurement process for system hardware as well as programing and evaluating the hardware system at USU's EVR research facility and test track prior to deployment at UTA sites. A similar process will be followed for on-vehicle and grid monitors.

Figure 4. USU EVR capabilities include 750 kW utility, 4,800 sq ft dual high bay, quarter mile test track, L2 and 50kW DC fast charging, DC & AC microgrid, 100 kWh on-site energy storage, and 120kW solar array.

System testbed – Prior to public deployment, a scaled version of the engineered system will be set up at the EVR facility (Fig 4.), tying into its solar power enabled microgrid. The EVR's research capability has much of the testing equipment required, including electric and autonomous test vehicle platforms such as a 22-passenger electric bus and electric Ford Focus, a broad EV charging network with a DC fast charger, multiple L2 chargers, and a wireless charging system, and battery loads that can be used to emulate the train and facility loads.

The project's hardware will be coded and tested at the EVR in parallel with development of control algorithms and software designed to anticipate grid impact and manage power demand for common charging hardware across varying vehicle charging modes and demand profiles. This initial deployment with the test vehicles in the EVR's controlled test environment will provide both algorithm development opportunity and hardware insights that will feed into a larger scale, full deployment. For example, scheduling charging for the EVR's electric bus (simulating a transit vehicle on fixed route) on the facility's test track, in combination with regular charging of the EVR's electric Ford Focus (simulating a ride hailing vehicle on a regular charging schedule) along with random charging from EVs that use the EVR's chargers will provide a realistic test bed to develop initial best practices and system evaluation.

Intermodal Hub deployment – The UTA Intermodal Hub is ideally located just off of I-15 and I-80 (Fig. 5) and a few blocks from downtown SLC, with public transit service from UTA's TRAX light rail with routes to the airport and downtown, UTA FrontRunner commuter train, and Amtrak and Greyhound service. The site already includes sufficient public parking and areas for queuing of ride hailing providers and charging fleet vehicles, and includes easy access to downtown SLC amenities and attractions. The project leverages expected UTA deployment of six 450+ kW chargers for electric buses; multiple 50-150kW DC fast chargers, primarily targeting short-stop passenger vehicles, fleet vehicles, and ride hailing providers; Level 2 AC chargers for park-and-ride customers leaving SLC and interstate traffic visiting SLC; and site planning and simulation for future expansion of megawatt electric truck charging.

Figure 5. UTA's Intermodal Hub ideally located near downtown SLC and Interstate corridors.

Since the routes of buses in and out of the intermodal hub are known, the power consumption needs can be determined within certain parameters. Thus, bus charging needs can be managed in coordination with trains and other anticipated power needs (relative to actual charging) for ride hailing, private cars, etc. This management approach can be adjusted in real time through the ML demand response strategies under development. The project will add in charging of light, medium and heavy duty trucks (LDV-HDV) from local fleets to expand the broader application of software/hardware under load management through demand response.

Planned vehicles – The project vehicles include light rail trains, fleet operated public buses, and passenger vehicles located at the deployment site. As part of this project, UTA will have three e-buses in service by April, 2019, with three e-bus routes: (1) Intermodal Hub to University of Utah with five e-buses, (2) rotator through downtown with five e-buses, and (3) a connector to Park City with 10 e-buses. UTA has requested an additional 27 electric buses to rotate into service over the next several years at the deployment site, including Xcelsior Charge New Flyer electric buses with 454 kWh battery that will be the initial high power load at the site. UTA will purchase additional Proterra buses with 600 kWh capacity during the project's performance period. The project will also work with local EV fleets. All the chargers at all power levels will be compatible with and available for use by public vehicles, including existing 50 kW and future higher power EVs. A site level commercial grid energy management system will coordinate power demand between the electric buses and passenger vehicles, the TRAX light rail system, and the Intermodal Hub facilities.

3 Purpose and Necessity

The current state-of-the-art includes up to 400 kW chargers and the planned release of compatible vehicles over the next three years. The primary challenge is the high cost of grid infrastructure and operation and the associated need for high levels of utilization. This project addresses the challenge by introducing the concept of the Power Balance and Demand Response Intermodal Hub together with key research components to adaptively manage power flow between the grid and various EV charging needs. The project will leverage a data-driven methodology for forecasting charging demand and expand to consider scheduled routes and demands for TRAX light rail, e-bus route schedules, and vehicle-to-infrastructure communication to inform the Intermodal Hub energy management system of future charging intentions as well as anticipated needs. Adaptive control algorithms based on the forecasting tool will incorporate ML techniques and will be realized with the control hardware. Additionally, cybersecurity measures will be built into the network from the beginning at the grid interface and site level and at the charger/user interface level.

4 Benefits

Potential project impact – A key outcome of this project will be a "roadmap" for high power electric vehicle charging complexes that leverage existing infrastructure from dominant peak loads such as TRAX to support a host of additional multi modal vehicle charging needs at minimal cost. The roadmap guides the confluence of accommodating different vehicle types with combined known loading and scheduling of charging (expected and variable) and peak pricing/surge charging to level peak demand loading on the grid.

The system will serve as a model for deployment of highly efficient and intelligent power management systems to additional UTA and Company sites. It also enables leadership in managing charging demands that can disseminated to other agencies regionally, nationally and globally.

Future funding for expanded deployment could include installations at the airport, Park City, and the UTA Ogden and Orem Depots.

5 Public Interest Justification

- Lends to adoption and deployment of electric vehicles that will help to dramatically reduce tailpipe emissions and increase Wasatch Front air quality
- Helps UTA expedite a more rapid conversion to electric vehicles
- Enables a greater understanding of these innovative solutions as the Company continues to make the grid more progressive

- Provides the Company, Utah Public Service Commission, and other stakeholders with information regarding the capabilities of power balancing and demand response technology
- Enables the Company to become familiar with and utilize innovative technologies to provide customers with solutions to power management issues
- Provides guidance to the company's distribution engineers to enhance the company's distribution planning process
- Continues helping the Company to experience rapid growth in power management requests and considers innovative technologies a valuable tool to improve service to customers
- Provides a better understanding of high power multi modal vehicle charging setting and will potentially assist in improved utilization of grid assets leading to cost savings for customers
- Aligns with the goals of the STEP program to support the greater use of renewable energy

6 Project Team

The strength of this team exists in its diverse and comprehensive partnerships between industry, metro transit, and university research capability, along with successful collaboration history and access to state-of-the-art facilities.

- **Rocky Mountain Power**, will provide expertise and insights into grid infrastructure and operating costs and cybersecurity and grid connection requirements.
- **USU**, as lead of the SELECT Center, has extensive experience in EV charging infrastructure and grid integration and assist with direct MV connection and site planning, modeling and control. The SELECT team has extensive experience successfully managing multi-million dollar, multi-university and industry partner contracts from DOE, DOD, and industry funding sources.
- Established in 1970, **UTA** serves more than 80% of Utah's population with commuter rail, light rail, buses, ride share, paratransit and more, and will be providing access to the SLC Intermodal Hub and its power and communication networks.

7 Legislative Compliance with SB115

The power balancing and the demand response project 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.

8 Alternatives Considered

The default alternative is to apply traditional worst-case analysis and costing to all new charging equipment at the intermodal hub and future sites. This results in very high upfront costs and variable ongoing high demand charge costs. One alternative is to purchase and install on-site energy storage with grid tied inverters to perform peak load shedding. This requires on-site energy storage that exceeds, by a safe margin, the peak power and energy demand for the TRAX and the overhead chargers. This approach is likely to also have high upfront and operating costs for similar reasons to the worst-case solution. The energy storage and grid tied inverters are rated for full peak to average power but have low utilization and are only used during the worst-case peak loading events. The batteries will age with cycling and must be maintained. They also present a safety hazard, will require review and certification with the fire marshal, and may require rezoning. Solar power can also be added on-site to reduce grid demand during sunlight, but without a managed solution would still require a worst-case analysis and costing for the peak loads on the system.

The proposed approach may be combined in the future with energy storage and solar power to provide critical load backup and a local load for the variable renewable source. The algorithms could be further adapted to predict solar power levels and to minimize the upfront cost and ongoing aging of the battery pack while balancing the managed system loads.

9 Purpose and Necessity – Risk Analysis

Through cooperation with co-location, coordinated, managed operation with minimized grid impact and reduced overall cost, the project will catalyze intermodal integration, and its impact can be measured in terms of expediting and expanding the concept while spurring the advanced control innovations necessary for multi-modal charging and mitigating or curbing potential negative grid impacts. Such advancement can be leveraged to secure additional funding for the collaboration from U.S. Department of Energy and other sources as anticipated funding opportunities in these technology areas are announced.

Key technical risks/issues – Advancing charging technologies are expected to come to market in the very near term in advance of market vehicle introduction. Some electric buses, for example, currently charge at what is known as extreme fast charging (XFC) levels, but charging equipment for these buses is not standardized. This project will work closely with industry partners to both future proof for and manage the challenges of upgrading charging infrastructure in step with vehicle technology introduction.

The Company impacts without this project:

- Neglecting an emerging technology and failing to preemptively identify its associated impact to the distribution system could potentially put system reliability and power quality at risk.
- A higher cost solution with non-innovative technology will impede any efforts to learn from implementing progressive grid technologies.

10 Project Tasks and Deliverables

The project tasks and deliverable are detailed in this section. The overall project covers the research efforts described earlier and provides initial hardware and software development and evaluation in a controlled environment at the USU EVR and a final deployment phase in downtown SLC at the UTA Intermodal Hub.

The overall project development begins with an anticipated July 1, 2019 start and proceeds with the tasks and timeline as show in Table 1:

Table 1. Detailed project tasks and timeline.

Task 1 – Analysis and Planning *July 1, 2019 – December 31, 2019*
Multi modal charging analysis (power levels, vehicle types)
Distribution capacity/needs/impact analysis
City and suburban level planning of grid and transportation charging integration
Confirm study participants in addition to UTA (e.g., fleet, including delivery and ride hailing participant vehicles)
Task 2 – Distribution System Simulation Planning and Validation *October 1, 2019 – December 31, 2020*
Design initial intelligent prediction algorithms and demand response concepts
Develop system simulation models for charging network and agent-based vehicle response
Collect data from TRAX power feed and TRAX light rail cars; e-bus fleet; all charging equipment; fleet (including delivery and ride hailing participant vehicles) Data used for algorithm development and as machine learning training datasets
Perform systems level simulation analysis for early and broad deployment scenarios, validate benefit of managed approach when compared to worst-case design approach
Task 3 – Testbed for Software/Hardware Development and Integration *January 1, 2020 – March 30, 2021*
Specify, bid, and procure system hardware
Anticipate needs for and develop cyber security management Design for compatibility with and security of communication network
Write code and program algorithms on servers Algorithms include energy/load balancing and management Design for compatibility with AMI
Evaluate hardware system (with integrated software) at the USU EVR
Iterate algorithm designs and develop pilot demand response program
Task 4 – Deployment and Evaluation

October 1, 2020 – December 31, 2021
Integrate hardware and software systems with UTA and RMP equipment and cyber secure communication network
Deploy hardware system at the UTA multi-modal hub site through a phased approach in direct coordination with IT and operations at UTA
Finalize recruiting, engage work with participants for pilot demand response program
Integrate real-time data collection from all partners and participants into the hardware system
Evaluate power control and demand response performance; iterate algorithms; develop best practices and recommendations

Table 2 shows the project flow over its 30-month timeline by quarter.

Table 2. Summary of project tasks and timeline.

Project Task	**2019**		**2020**				**2021**			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Analysis and Planning	■	■								
Simulation Planning/Validation		■	■	■	■	■				
Testbed for Software/Hardware			■	■	■	■	■			
Deployment and Evaluation						■	■	■	■	■

11 Program Closure

In 2021, the Company will report back to the Utah Public Service Commission regarding lessons learned and the status of report recommendations. 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.

Post project completion, all equipment associated with the project installed at the USU EVR will be owned and operated by USU, and all equipment associated with the project installed at the SLC UTA Intermodal Hub will be owned and operated by UTA. The Company will reserve the right to access, participate in, and/or propose follow up projects involving the equipment.

12 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. Given the emerging technologies associated with the project, there is some risk of incompatibility between various components, which may introduce additional time in the deployment stage of the project. These risks will be identified in detailed project plans with appropriate timeframes to resolve.

13 Target Costs, Budget

Table 3 shows the anticipated budget for USU and the Company. See USU budget breakdown in Appendix A.

Table 3. Project budget by USU fiscal year.

Costs	FY 2019	FY 2020	FY 2021
Utah State University	$802,509.89	$877,745.90	$215,320.46
Rocky Mountain Power Internal Engineering and Project Management	13,333.33	73,333.33	13,333.33

14 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.

Procurement and Project Delivery Strategy

- Project specifications shall be developed in accordance with applicable engineering specifications and standard designs.
- Utah State University EVR shall procure equipment with approval from the Company project team and will be reimbursed for approved purchases.
- Project delivery strategy to be determined by project team as outlined in Project Tasks and Deliverables.

15 Recommendation

- Purchase and install required power balancing and demand response components and controls to operate the Utah State University EVR as a testbed.
- Purchase and install required power balancing and demand response components and controls for deployment at the UTA SLC Intermodal Hub.

APPENDIX A

USU Budget Summary by program year.

	2019	2020	2021	Total
Personnel				
> Salary	$206,705.81	$235,488.71	$117,744.37	$559,938.89
> Fringe	$37,273.94	$39,688.29	$19,844.14	$96,806.37
Calculated Direct Costs	$0.00	$0.00	$0.00	$0.00
Personnel Subtotal	$243,979.75	$275,177.00	$137,588.51	$656,745.26
Non-personnel				
> Equipment	$410,000.00	$390,000.00	$0.00	$800,000.00
> Travel	$4,900.00	$4,900.00	$0.00	$9,800.00
> Participant Support	$24,000.00	$24,000.00	$12,000.00	$60,000.00
> Other Direct	$5,265.00	$55,265.00	$2,632.50	$63,162.50
Calculated Direct Costs	$0.00	$0.00	$0.00	$0.00
Non-personnel Subtotal	$444,165.00	$474,165.00	$14,632.50	$932,962.50
Totals				
Total Direct Cost	$688,144.75	$749,342.00	$152,221.01	$1,589,707.76
Total F&A Costs	$114,365.14	$128,403.90	$63,099.45	$305,868.49
Totals Subtotal	$802,509.89	$877,745.90	$215,320.46	$1,895,576.25