Requirements Engineering:
On-Premises Utilities Management Dashboard

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Executive Summary

Energy Management is an oft-overlooked part of the broader corporate sustainability discussion, which often focuses on high-tech, pre-packaged solutions to reducing energy usage in facilities, such as lights with built-in occupancy sensors. While those solutions can be very effective and can minimize the need for personnel interaction, replacing every light in the offices of a large manufacturing facility is both an expensive endeavor and one that probably does not have the highest return on investment when compared to more mundane efforts. This project proposes a customized energy management system that utilizes existing (legacy) equipment and utility monitoring systems. The goal is to move away from a maintenance culture that is incentivized to close all tickets quickly to one that prioritizes work according to the value the task has for the company. Value can be derived from both reduction in utilities waste and improved workflow efficiency for maintenance teams. The first iteration of this system focuses on ensuring that HVAC systems remain within standard heating and cooling setpoints and dead bands, and that HVAC and lights are both scheduled and operating within similar timeframes for the same area. An Energy Management System, like the one being developed for this project, can save significant energy and money over time.

Keywords: energy management, proactive maintenance, smart buildings, real-time cost analysis, big data, software development

1. PROJECT CHARTER

Justification

Environmental sustainability and maintenance are often viewed as cost-centers of a business, due to the perception that those activities are separate from core profit-centers. However, the simplest and most effective sustainability efforts focus on reducing resource consumption by improving equipment operating efficiency. Similarly, proactive maintenance efforts cost less than responding to emergent maintenance efforts due to delays in routine maintenance, and well-maintained equipment operates more efficiently than poorly maintained equipment. The goal of this project is to provide a means to estimate the cost of deferred maintenance activities in terms of both US dollars and utility consumption, to better prioritize maintenance activities and improve building efficiency, thereby reducing operating costs.

Objectives and Constraints

Objectives:

- Enable cost-informed prioritization of routine and proactive building operations and maintenance activities.
- Implement a technology solution that is likely to be adopted by key users.
- Indicate areas of the facility with high utility (electricity, natural gas, compressed air, steam, water) consumption in absolute and relative terms over variable timespans.
- Generate priority list of highest value maintenance activities.
- Provide obvious, positive feedback to maintenance and engineering personnel

regarding the impact of successfully completing jobs.
- Ability to generate financial and environmental sustainability metrics spreadsheet/slide for sharing with upper management.

Constraints:

- Cost estimates of maintenance issues will be limited to associated utilities cost, not production loss due to downtime of critical facilities equipment.
- The software must not be used to supersede prioritization of maintenance activities deemed either Production- or Safety-Critical.
- The intended use of the software is prioritization of routine and proactive maintenance activities only.
- Limited to using existing metering and associated infrastructure for data analysis.
- Must pull maintenance data from existing database.
- The ROI of the project must be less than one year.

Scope
Create a web-based application that prioritizes non-critical maintenance activities according to three sustainability criteria (energy consumption, water consumption, carbon dioxide emissions) and estimated cost savings.

Primary Stakeholders
The primary stakeholders of this project are operations and maintenance engineering and maintenance personnel and budget-holders (low level: maintenance and engineering management; high-level: operations and maintenance director).

Risks
Risks to this project include programming team experience and availability, compatibility issues between existing (legacy) building monitoring and control systems and software, and a technology-averse maintenance personnel culture as a potential barrier to meaningful system adoption.

Benefits
Upon successful completion and adoption of this software development project, meaningful (utility) cost estimates of maintenance issues will allow meaningful prioritization and reduction of both cost and utilities waste (improved environmental sustainability metrics).

Budget Overview
TABLE 1. HIGH-LEVEL BUDGET OVERVIEW.

BUDGET ITEM	COST (US $)
Total Budget	**445,000**
Software Development Hours	400,000
Facilities Engineering Support Hours	25,000
Maintenance Support Hours	10,000
Server Infrastructure	5,000
Support Software	5,000

2. ELICITATION

Elicitation Methodology
First, I will get overarching business directives from the Operations and Maintenance Director, either directly or from a management liaison, including budget and schedule. Then, I will brainstorm some draft requirements from my own experience as an industrial Energy Manager and Mechanical Engineer, which I will validate by interviewing engineering and maintenance management for issues with existing processes. I will also get a list of expected use cases and user types from management. Finally, I will interview technical and maintenance personnel to understand what will maximize the likelihood of successful adoption of the system by the primary users, who have the most potential to sway the success or failure of the initiative.

Documentation Methodology
The requirements will be documented in alignment with the Requirement Engineering Management process outlined in Chapter 6 of Tsui (2014), with the definition stated in an embedded Business Requirements Document as outlined by Boogard (2022). Requirements will be analyzed according to Viewpoints-oriented Requirements Defintion.

Requirements Validation Methodology
Initial validation will be completed in the form of a Feasibility Study as outlined by MyMG Team (2012).

Assuming adequate feasibility, requirements will be continuously validated through biweekly, iterative prototype reviews with the customer throughout the development process. During those reviews, enforcing scope boundaries will be the number one priority, with the application of an appropriate change management process, when scope change is necessary.

3. REQUIREMENTS

Stakeholders and Viewpoints

S-1) Upper Management

- V-1.1) ROI < 1 Year for Approval.
- V-1.2) Sustainability metrics tied to their employee evaluation/bonus.
- V-1.3) Want to improve satisfaction with Operations and Maintenance Department services to the rest of the business.
- V-1.4) Department is viewed as a cost-center and is an early target for job cuts. Reducing hard-to-vary (utility) costs saves jobs and enables the department to continue providing adequate service.

S-2) Engineering Management

- V-2.1) Owns the utility bill/utilities management department.
- V-2.2) Ability to reduce utility bill is dependent on successful coordination between engineering and maintenance.
- V-2.3) Need ability to quantify dollar value of foregone/delayed maintenance on energy-intensive systems.
- V-2.4) Can allocate one representative from each of the following engineering roles for up to one hour per week: energy/utility manager, electrical, mechanical, HVAC technician.
- V-2.5) $10,000/year budget for additional/recurring infrastructure/software needs.

S-3) Maintenance Management

- V-3.1) Quantitative prioritization currently based on the time a job is open, rather than cost/hour a maintenance need is unmet.
- V-3.2) Institutional knowledge that certain areas of the facility are critically under-maintained, but lack data to justify focusing on those areas instead of low-value, emergent jobs.
- V-3.3) Understaffed, need to maximize effectiveness of maintenance hours.
- V-3.4) Safety- and Production-Critical maintenance calls will always take precedence, and should not be considered in prioritization scheme.
- V-3.5) No more than half an hour per discipline (HVAC, plumbing, electrician, utility) can be spent supporting this project per week.
- V-3.6) Significant percentage of maintenance staff is technology-averse and value intuition over data. Only Leads should have access.

S-4) Energy Engineer

- V-4.1) Primary responsibility for executing sustainability goals.
- V-4.2) Needs ROI in terms of both dollars and utilities—some sustainability targets have very long ROIs in terms of dollars due to low cost of the utility (e.g. water)—to prioritize overall sustainability program.
- V-4.3) Utility rates change on a regular basis and need to be easily editable by the energy engineer.
- V-4.4) Resource for rules of thumb regarding how much operating a type of equipment costs. HVAC and lighting are highest priority.

S-5) Maintenance Leads (HVAC, Plumbing, Electricians, Utility)

- V-5.1) Assign jobs to other maintenance personnel – own execution of priority list.

S-6) HVAC Engineering Technicians

- V-6.1) Require the system has read-only access from SCADA and Building Integration systems.

S-7) Maintenance Analysts

- V-7.1) Require the system has read-only access from maintenance database.

Functions Derived from Viewpoints

The Requirements Traceability Matrix for the following functions is located in Appendix A.

F-1) Pull Maintenance Data (Read-Only)

F-2) Pull On-Site Utility Metering Data (Read-Only)

- F-2.1) Lighting Runtime Data
- F-2.2) Compressed Air Meters
- F-2.3) Domestic Water Meters
- F-2.4) Steam Meters
- F-2.5) Chilled Water Meters
- F-2.6) Natural Gas Meters

F-3) Pull On-Site Equipment Performance Data (Read-Only)

- F-3.1) HVAC Temperature Setpoints
- F-3.2) HVAC Runtime Data
- F-3.3) Space Temperature

F-3.4) Outside Air Temperature

F-4) Given formulas, perform energy usage estimations for several classes of equipment

F-5) Enable dynamic input of utility rates.

F-6) Display utility rates currently used in calculations.

F-7) Display ranking of top 10 highest-value maintenance jobs for each sustainability metric (energy, water, carbon emissions) plus the cost metric.

F-8) Generate and export metrics spreadsheet showing monthly maintenance jobs completed and money, energy, water, and greenhouse gas emissions saved.

These functions are prioritized in Appendix B.

4. SOLUTION

The proposed solution is to create a web-based application that pulls data from existing equipment and utility monitoring, as well as open and closed jobs data from the maintenance database. That data will be run through parameters to determine where energy savings are available, based on common energy saving scenarios, such as the lights and HVAC heating and cooling running on different occupied schedules. The web interface will display a list of top ten maintenance jobs to complete for energy, water, carbon emission, and cost savings. To improve accuracy of the cost savings calculations, the web interface will allow a user to update cost values for the different utilities, including efficiency for steam and compressed air operations. Finally, savings from closed jobs can be captured through an automatic reporting system, for ease of sharing utilities management and cost savings metrics with upper management.

Use Cases

Use Case 1: Maintenance Lead checks priority log to assign high-value maintenance work.

Use Case 2: Energy Manager generates Utility and Cost savings report to share with upper management.

Use Case 3: Energy Manager updates utility cost data.

The Use Case Diagram is available in Appendix C.

Component Diagram

The Component Diagram is available in Appendix D.

Communication Diagram

A Communication Diagram is available in Appendix E.

5. FEASIBILITY

Economic Feasibility

It is economically feasible to develop a few specific features and interfaces with specific utility and machine systems, and then allow the savings from those features to accumulate in order to justify future releases. Depending on the audience, it may be difficult to justify a monitoring system as delivering savings, because the thought is that the system is not doing the saving; the work performed does the saving. To keep this project viable, especial effort must be made to document and differentiate the before state and the after state for maintenance workflows and prioritization.

Technical Feasibility

There may be insufficient metering to adequately perform some operations desired by the customer, especially regarding some of the utilities generated on-site (compressed air, chilled water, steam). While these do not represent most of the high-impact, single service maintenance jobs, they do represent very high impact routine maintenance and tuning efforts, and are worth tracking in a comprehensive energy management system.

Operational Feasibility

Currently, downloads from the maintenance database are refreshed on a 24 hour basis, which means that the priority list will be prioritizing old jobs, until a solution to get real-time data is developed/discovered.

Schedule Feasibility

In order to get an initial release out on time and on budget, it will most likely be necessary to truncate the list of features, especially given additional technical feasibility concerns. The Minimum Viable Product is the one that delivers a priority list of high-value cost savings. Focusing on HVAC and lighting will probably be the most viable, due to the highest likelihood of sufficient monitoring for meaningful data analysis. A copy of the draft schedule is available in Appendix E.

Contractual Feasibility

There are no known barriers to contractual feasibility.

6. COST-BENEFIT ANALYSIS

Direct Costs
See Table 1.

Indirect Costs

- Recurring Server Infrastructure Costs
- Possible need for Middleware license(s) to interface with existing controls systems

Direct Benefits

- $0.07/kWh Electricity saved
- $7.00/MMBtu Natural Gas saved
- $1.08/1000 cu. ft. Water saved
- Load reduction incentives from local utility

Indirect Benefits

- Improved maintenance prioritization
- Priority based on value added, instead of incentivizing closing tickets.
- Promotes company culture of going home before the lights go out.

To hit the requested one year ROI, this project must save:

- 6,357 MWh Electricity, or
- 63,471 MMBtu Natural Gas, or
- 412 Million cu. ft. of Water, or
- 3,000 maintenance and engineering personnel hours, or
- Some combination thereof.

In a large manufacturing facility, this will be a difficult metric to hit, but not impossible, if recommendations from the prioritization algorithm are diligently followed.

7. SPECIFICATION

Size and Complexity
This is a high complexity project, due to the breadth of data sources required for proper analysis. There is a high potential for the future development of additional features, because seeing the cost savings of the basic analysis may incentivize additional equipment and utility metering and open potential for more analysis modes.

Follow-On Release
Follow-on Release Schedule:

- 2022-Q4: Compressed Air Monitoring Integration for determining changes in base load
- 2023-Q1: HVAC Set-Point Flags and Energy Savings Calculations

Expected Customer Support Activities
Currently, there is no IT team embedded within the Operations and Maintenance organization. Software releases for this product must be

Developer Experience
The lead developer on this project has some experience developing C# and Python console applications, Blazor web-apps, and administering SQL and noSQL databases.

9. AGREEMENT AND ACCEPTANCE

The Agreement and Acceptance signature table is located in Appendix F.

10. REFERENCES

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APPENDIX A

REQUIREMENTS TRACEABILITY MATRIX

TABLE 2. REQUIREMENTS TRACEABILITY MATRIX WITH HIGH-LEVEL FUNCTIONS.

Requirement Identifier	Reqs Tested	REQ1 F-1	REQ1 F-2	REQ1 F-3	REQ1 F-4	REQ1 F-5	REQ1 F-6	REQ1 F-7	REQ1 F-8
Test Cases									
Tested Implicitly									
Test Scheme to Be Created in IP03									
…									

APPENDIX B

PRIORITY TABLE

TABLE 3. SUBJECTIVELY GENERATED PRIORITY TABLE.

Requirement Number	Brief Requirement Description	Requirement Source	Requirement Priority	Requirement Status
F-1	Pull Maintenance Data	Pre-requisite for F-4	1	
F-2	Pull Utility Metering Data	Pre-requisite for F-4	2	
F-3	Pull Equipment Data	Pre-requisite for F-4	2	
F-4	Energy Savings Algorithms	Requirements Document	1	
F-5	Utility Rate Input	Requirements Document	4	
F-6	Display Utility Rates	Requirements Document	3	
F-7	Display Top 10 Savings Jobs	Requirements Document	1	
F-8	Export Savings Data	Requirements Document	5	

APPENDIX C

USE CASE DIAGRAM

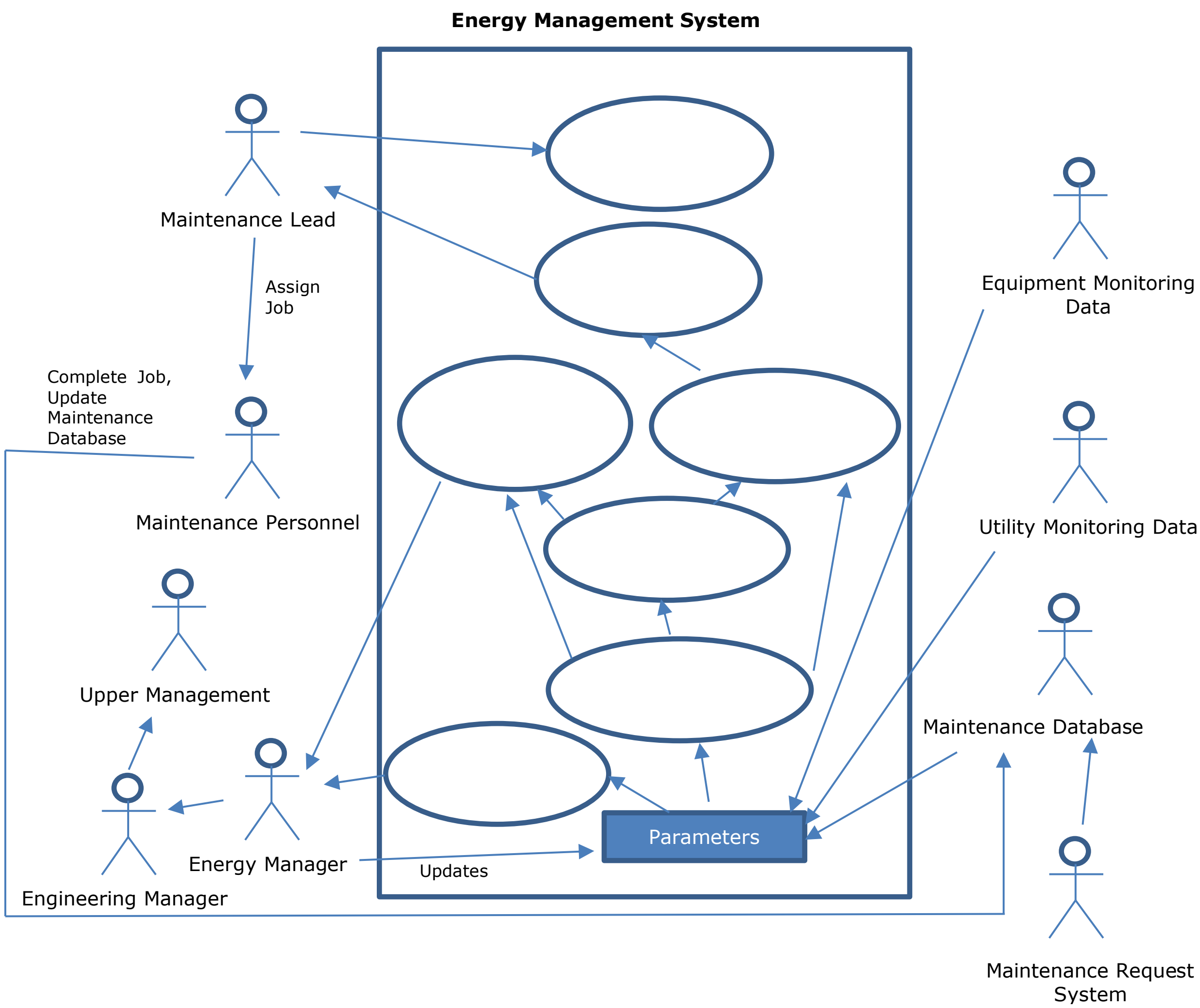

FIGURE 1. USE CASE DIAGRAM

APPENDIX D

COMPONENT DIAGRAM

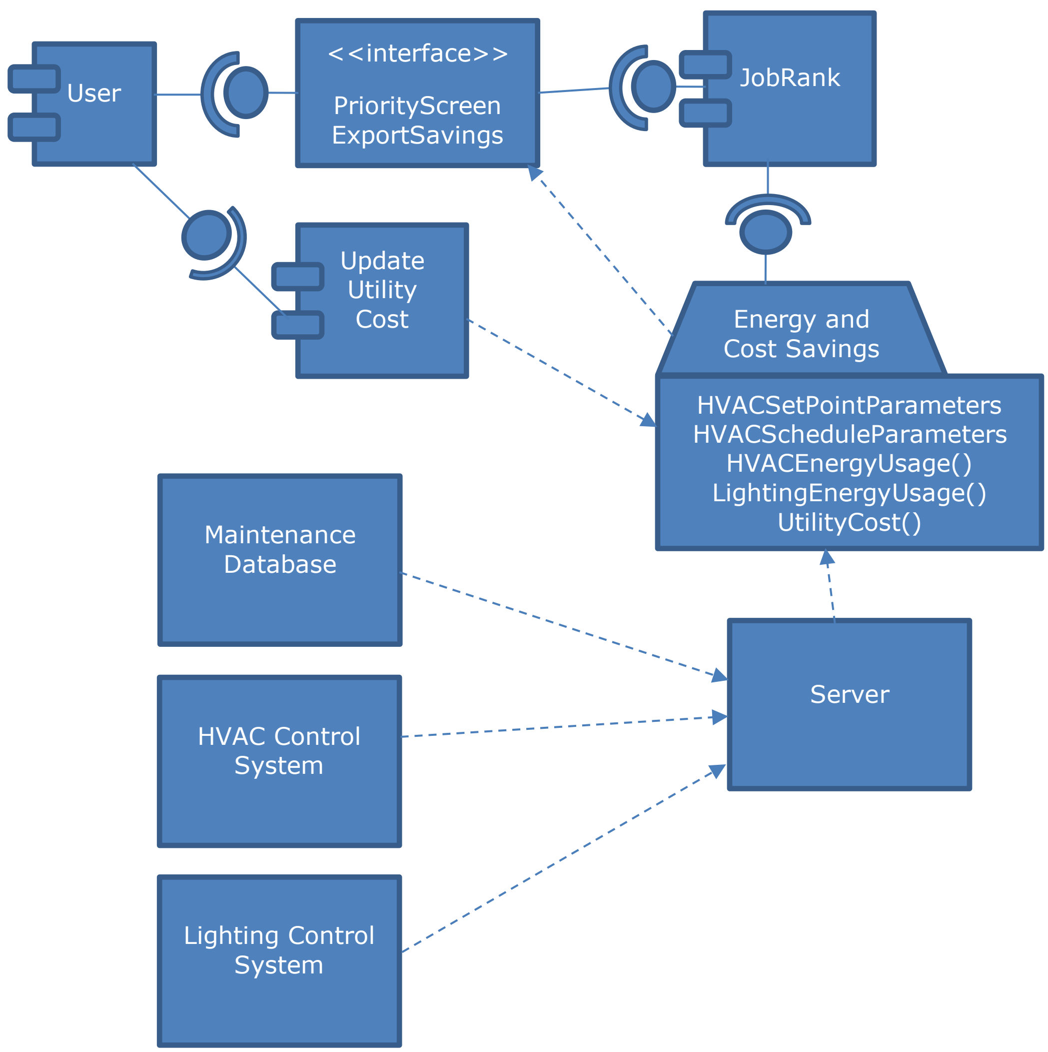

Figure 2. Component diagram.

APPENDIX E

COMMUNICATION DIAGRAM

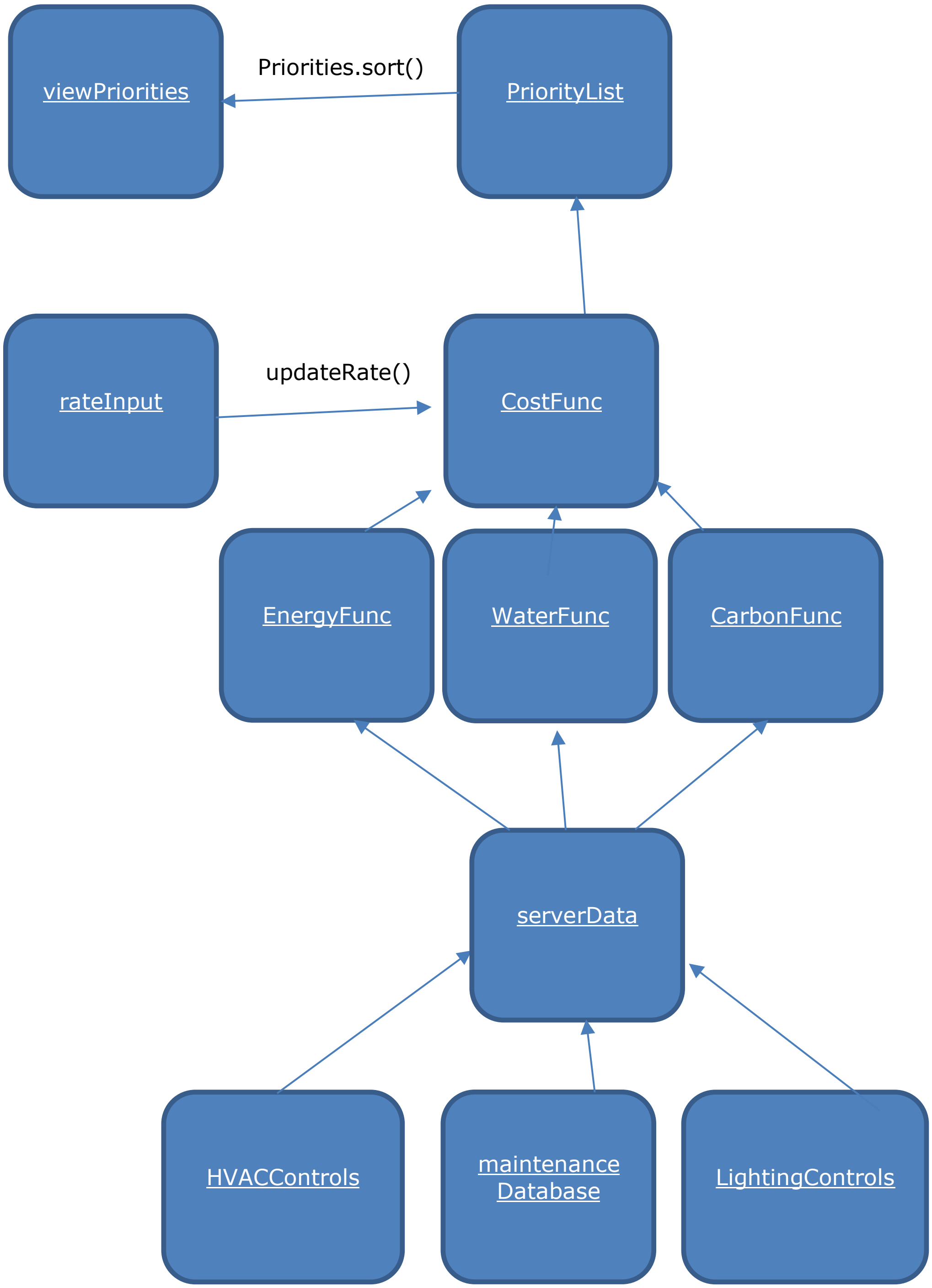

FIGURE 2. COMMUNICATION DIAGRAM.

APPENDIX F

Agreement and Acceptance Signature Table

Role	Company	Agreement Date	Agreement Signature	Acceptance Date	Acceptance Signature
Energy Manager					
Project Manager					
Maintenance Lead					
Maintenance Manager					
Engineering Manager					
Software Development Lead					
Supplier Management and Procurement					
Project Sponsor (Upper Mgmt.)					