ITEM #6
HRWC Board
March 27, 2014

ATTACHMENT

AMI Technology Assessment & Feasibility Study Consolidated Report

January 2014

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Acronyms

ALD	Acoustic leak detector
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AWWA	American Water Works Association
BPL	Broadband over power line
CARL	Current Annual Real Losses
CDPD	Cellular digital packet data
CIS	Customer information system
CMMS	Computer Material Management System
CRO	Customer request orders
CSR	Customer service representative
DCU	Data collector units
DMA	District Metering Area
DSS	Digital Spread Spectrum
EAM	Enterprise Asset Management
ERP	Enterprise resource planning
ESRI	Environmental Systems Research Institute
FRO	Field Read Order
FST	Field Service Technician
FTE	Full time employee
GIS	Geographic information system
GPRS	General packet radio service
HES	Headend system
HMI	Human-Machine Interface
ILI	Infrastructure Leakage Index
IP	Internet protocol
IT	Information technology
IWA	International Water Association
LAN	Local area network
LED	Light emitting diode
MDMS / MDM	Meter Data Management System
MDUS	Meter Data Unification and Synchronization
MHZ	Megahertz
MIU	Meter interface unit
MPLS	Multiprotocol label switching
MWO	Maintenance/Repair Work Order
NRW	Non-revenue water
OLE	Object Link Embedded

OPC	OSIsoft Process Control
OT	Operations Technology
RF	Radio frequency
RFP	Request for proposal
ROI	Return on investment
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
UARL	Unavoidable Annual Real Losses
UHF	Ultra-high frequency
VDO	Vacancy Disconnect Order
VPN	Virtual private network
WAN	Wide area network
WMS	Work Management

SAP Modules:

ECC	ERP Core Component
IS-U	Industry solution for utilities
CCS	Customer Care Services

1 Executive Summary

In August of 2013, Halifax Regional Water Commission (Halifax Water) contracted Excergy Corporation (Excergy) to study the feasibility of transitioning to an Advanced Metering Infrastructure (AMI) system to read its meters. The tasks in the study (Figure 1-1 Study Tasks) were completed between August and December 2013.

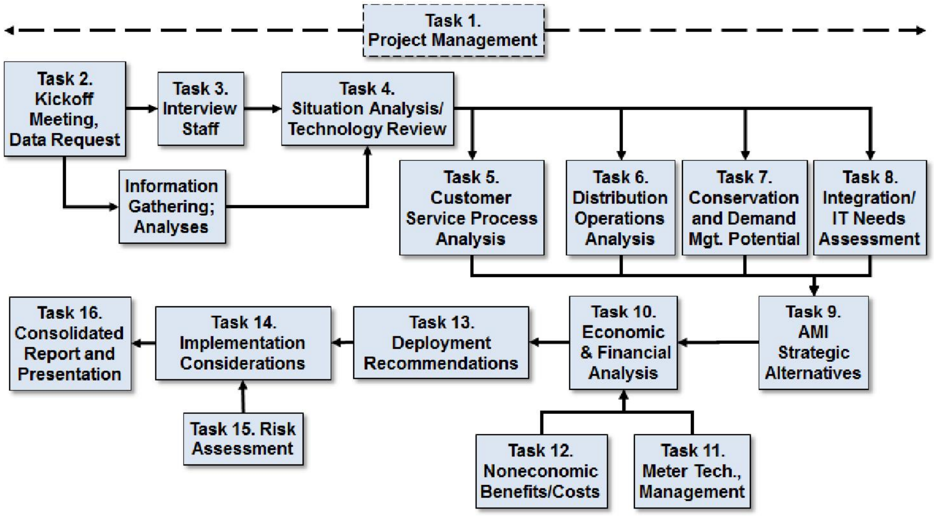

Figure 1-1 Study Tasks

AMI enables meters to be read remotely from a central location using radio enabled meter interface units (MIUs). Automatic Meter Reading (AMR) enables meters to be read from mobile data collector units (DCUs) in close proximity to the meters. AMI systems typically obtain hourly meter readings, while AMR systems provide readings when the meter reader passes by with the DCU.

With AMI, DCUs are installed throughout the service territory on poles, buildings, water tanks, or towers. The MIUs communicate with DCUs to capture the readings and other data that then are retransmitted back to a utility's offices through a communications network. The higher volume of data provides opportunities for customers to better manage their water usage and for the utility to provide a higher level of customer service, as well as enhance its operational efficiency.

AMI's value depends on whether it is used to streamline and enhance customer service and provide valuable information to engineering, water resources management, distribution, operations, and other functional areas of a utility. Beyond the benefits of automation, such as ensuring that all bills are based on timely and accurate readings and reducing the cost of customer service operations, AMI enables Halifax Water to provide more customized and information-rich services to customers, improve cash flow, better manage resources, enhance conservation, better manage collections, improve fairness among customers, and better manage assets.

Halifax Water's meters are read using a mix of technologies: (1) visual observation and recording of the reading from a remote display register into a handheld computer; (2) capture of the reading electronically into the handheld unit through a probe and touchpad located on the outside of the customer's premises, and (3) transmission of the reading by an MIU to a mobile or handheld DCU. At present, each technology covers roughly a third of Halifax Water's meter population, and they are relatively uniformly dispersed geographically throughout the service territory .

Halifax Water is currently converting meters to AMR "opportunistically" when a meter fails or other access is required, as well as when meters are changed for age or total consumption limits. Halifax Water spends about $1.3 million (M) annually on such meter replacements. At this rate, it will take approximately 10 years before all of Halifax Water's meters are on AMR. Converting to AMR through this opportunistic approach, however, requires readers to walk all routes that still have any meters with remote registers or touchpad. This significantly delays capturing all the benefits of AMR until all the routes are converted.

1.1 Interview Findings

Excergy conducted interviews with Halifax Water staff to identify areas of potential improvements from implementing a new metering system, as well as expectations for a new metering system, and concerns about such a project. Several interviewees expressed concern about the ability of Halifax Water to support an AMI project in light of the many other infrastructure projects required for continued operation. An AMI project would have to represent a significant and demonstrable financial benefit to Halifax Water.

Staff emphasized that there were many business processes that rely too much on paper, and expressed a desire for an AMI system to address many manual and labour-intensive processes with automation.

The interviews identified many AMI-based improvements and capabilities. Key to this was enabling Halifax Water to easily move to monthly billing of all customers. The staff expressed a strong interest in the ability of the system to provide increased customer service through proactively notifying customers of excessive usage and leaks.

Project concerns centered on making sure that if Halifax Water were to undertake an AMI project, it's managers need to create an environment of support across the organization. A concern would be the potential impacts to staffing levels and how to address them.

The interviews revealed that there was a concern with the ability of the organization to support a project of the scope of AMI. The interviewees emphasized that an AMI project would require strong project management. Internal resources are stretched already, and the interviewees expressed concerns that there would be enough support internally for an AMI project.

1.2 Impacts to the Organization

The AMI Feasibility Study (the Study) identified four key customer service processes that would be significantly impacted by AMI:

1. On-cycle billing, including capturing meter readings, reviewing them to ensure accuracy, re-reading meters if necessary, and billing customers. AMI removes the need to physically visit the meter and manually input the reading.
2. High bill complaints from customers about bills thought to be excessive or inaccurate. This process can be impacted by AMI through better and more detailed data to address customer's questions, to identify potential high usage, and contact the customer before (s)he gets a high bill.
3. Move-In/Move-Out, the process that captures final meter reads and starting reads for new accounts tied to a customer's premises. With AMI, such reads can be captured exactly when needed without a field visit. In addition, the system can monitor the meter on a daily basis for unauthorized usage.
4. Collections, including collecting past due bills and processing shut-offs due to non-payment. AMI enables proactive notification before excessive usage presents a financial burden to the customer. AMI also enables the utility to monitor unauthorized usage on accounts that have been disconnected for non-payment.

Figure 1-2summarizes the expected annual reduction in annual person-hours attributed to AMI for these four processes among Halifax Water customer service, metering, and billing personnel.

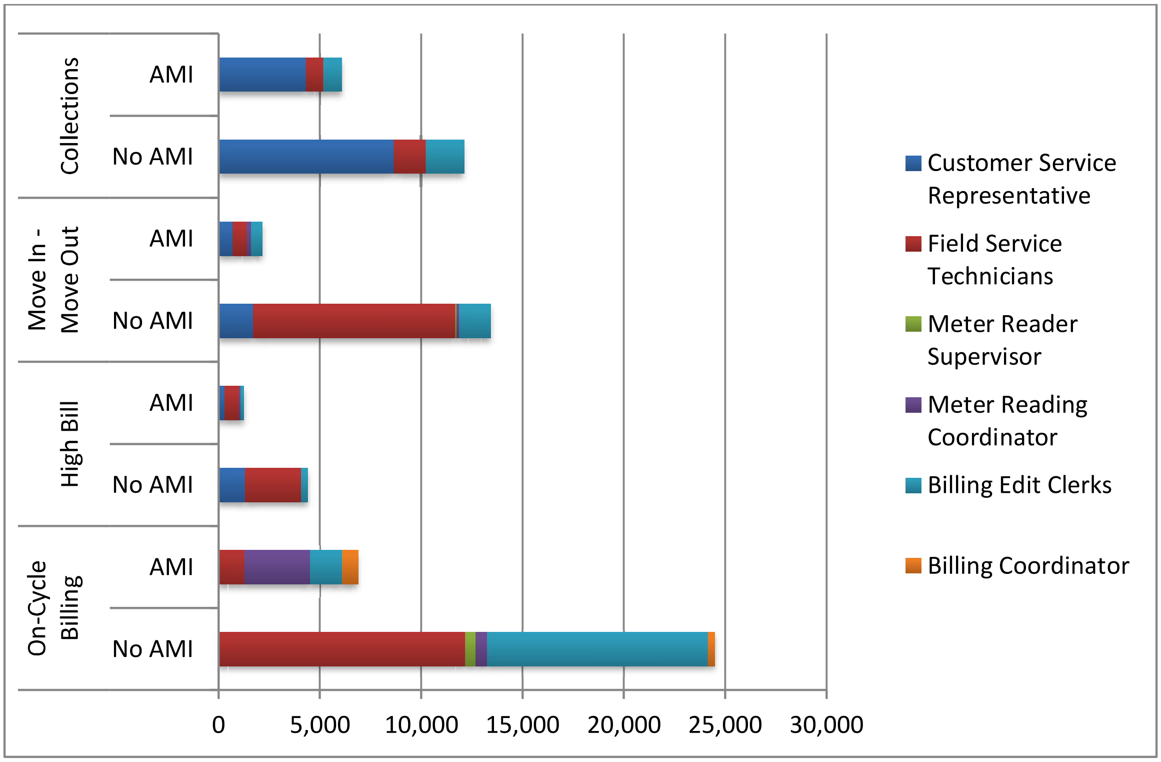

Figure 1-2 Impacts to Customer Service Annual Hourly Effort

1.3 Impacts to Distribution Operations

With AMI, daily collection of time-synchronized consumption data from AMI meters would enable daily comparisons of the measurements from the district meters (acquired via Halifax Water's Supervisory Control and Data Acquisition (SCADA) system) with the sum of the measurements from the revenue meters within each district metered area (DMA). For any time period, a significant difference between the two quantities or change in the difference could indicate leakage in the area.

Water AMI systems also support acoustic leak detectors (ALDs). However, the potential payback from an investment in ALDs in conjunction with an AMI system may be limited for two reasons:

1. Although there is benefit in energy savings and cost of treatment for saved water through the leak detection efforts, due to Halifax Water's relatively abundant water supply, the benefit of saving water resources is less likely to be as much a concern or priority.
2. Halifax Water already does an extremely good job of non-revenue water (NRW) monitoring and management. While ALDs might improve the accuracy, and

possibly identify leaks on the system faster, the incremental benefit might not be worth the cost.

While the contribution of ALD's to the AMI business case may be limited and unquantifiable, Halifax Water should investigate the use of ALD's, especially in the West region's low and Intermediate DMA's, where higher night flows and other conditions make it more difficult to pinpoint leaks. It should be noted that AMI could support Halifax Water in meeting it's Corporate Balanced Scorecard Goal of target leakage of not more than 185 litres per service connection per day.

1.4 Strategic Alternatives

After analysis of the Halifax Water's meter population, and what is required to migrate to AMR versus migrating to AMI, the following strategy options were developed for examination in this Study.

- Strategy 0 – Current Environment of moving to AMR over the next 10 years by converting to AMR at the current pace of the meter change program with internal resources.
- Strategy 1 – AMR Quarterly: Initiate a project to move to AMR over three years with meter exchanges outsourced. Maintaining the quarterly reads on the non-commercial accounts under three-quarters of an inch (¾").
- Strategy 2 – AMR Monthly: Initiate a project to move to AMR over three years with meter exchanges outsourced. All accounts would be converted to monthly billing.
- Strategy 3 – AMI Monthly: Initiate a project to move to AMI over three years with meter exchanges outsourced. All accounts would be converted to monthly billing.

Figure 1-3 Strategic Alternatives depicts the interplay and comparisons between the alternative strategies used to develop the recommendations.

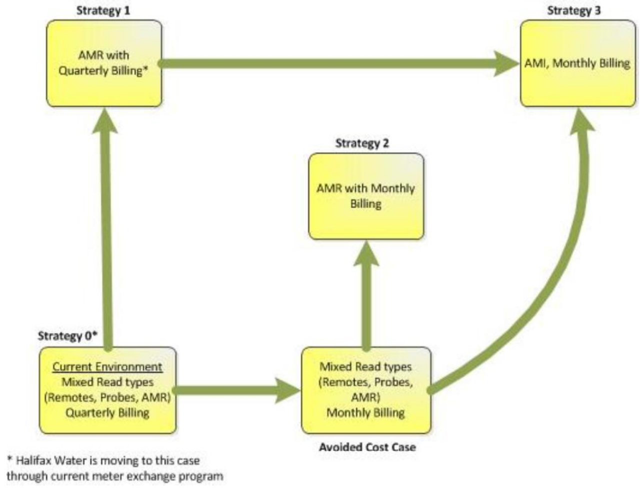

Figure 1-3 Strategic Alternatives

1.5 Economic Analysis

The following tables summarize the financial analysis of the three Strategic Alternatives identified by the study.

Table 1-1 – Estimated Project Costs

	Strategy 1 AMR Quarterly	Strategy 2 AMR Monthly	Strategy 3 AMI Monthly
All Meters*	82,336	82,336	82,336
Select: Bills/Years	4	12	12
Capital Cost			
Meters and Assoc. Misc. Materials	$3,400,000	$3,400,000	$3,500,000
Installation Costs Allocable to Meters	$1,100,000	$1,100,000	$1,110,000
Electronics and Assoc. Materials	$3,900,000	$4,000,000	$7,700,000
Installation Costs Allocable to Electronics	$1,600,000	$1,600,000	$3,150,000
Administration and Start-up Costs	$700,000	$700,000	$1,800,000
Grand Total System Cost	**$10,700,000**	**$10,800,000**	**$17,260,000**
Salvage on Old Meters	($121,000)	($121,000)	($124,000)
Savings on Normal Meter Turnover	($2,122,000)	($2,122,000)	($2,122,000)
Net Total System Cost	**$8,457,000**	**$8,557,000**	**$15,014,000**

* Includes Urban Core and Aerotech/Airport Systems

Table 1-2 - Project Annual Savings

	Strategy 1 AMR Quarterly	Strategy 2 AMR Monthly	Strategy 3 AMI Monthly
Annual System Operating Costs			
Maintenance and Repair	$119,155	$121,819	$145,020
Operating Costs	$15,000	$15,000	$132,000
Total Annual O&M Cost	**$134,155**	**$136,819**	**$277,020**
Annual Operating Costs/Savings			
Manpower Savings	$301,252	$1,501,031	$1,880,203
Vehicle and Other Savings	$52,670	$229,320	$331,240
Monthly Billing Costs	$0	($175,601)	($175,601)
Domestic Leak Detection	$0	$0	$26,831
Total Annual Savings	$353,922	$1,554,749	$2,062,673
Under-Registration Recovery	$1,175,460	$1,175,460	$1,175,460
Total Revenue Plus Savings	$1,529,381	$2,730,209	$3,238,132
Net Annual Savings	**$1,395,226**	**$2,593,390**	**$2,961,113**

Table 1-3 Cash Flow Comparison

	Strategy 1 AMR Quarterly	Strategy 2 AMR Monthly	Strategy 3 AMI Monthly
Simple Payback Period Calculation	6.0	3.2	5.0
NPV	(265)	12,028	9,845
IRR	2.8%	38.4%	18.2%

Under Strategy “0”, Halifax Water will spend approximately $10.9 M over the next ten years replacing meters and installing AMR devices without capturing significant economies of scale in operating efficiency.

Conclusions and Recommendations

Before it can make a final decision on AMI, Halifax Water needs to determine if there is a need or a business driver for all of customers to be read and billed on a monthly basis. An analysis of monthly billing was beyond the scope of this Study. While an AMI system can support either quarterly or monthly billing, AMI is not cost-justified under a quarterly billing scenario. Excergy is of the opinion that Halifax Water must determine if it will be moving to monthly billing. Absent monthly billing an AMR system is recommended, but implemented on an accelerated rate – over not more than three years.

If there is a move to monthly billing, AMI can provide not only an acceptable return on investment (ROI), but also will provide Halifax Water the extensive set of process improvements and customer service enhancements, as well as many non-economic benefits that increase the stature of Halifax Water in the community.

2 Introduction

Halifax Water is at a crossroads. The issue under consideration in this Study is whether Halifax Water should take advantage of AMI technology. The Study identifies identify how this technology would impact the organization financially and operationally. A primary consideration is whether Halifax Water should change direction to AMI or continue the migration to AMR. To help determine the direction, Halifax Water contracted Excergy to help it evaluate the feasibility of AMI.

The Study presents a thorough and thoughtful analysis of the costs and the benefits of AMI technologies, and recommendations for Halifax Water's consideration. The Study covers costs and benefits, including service enhancement and resource management as well as operational benefits, to the customer service department and distribution operations. A positive net present value outcome from the AMI business case analysis was not presumed, and the Study was designed to present a clearly stated and defensible analysis of AMI specific to Halifax Water conditions.

The Study approach was designed to:

- Leverage Halifax Water staff's experience and existing knowledge of meter reading systems, as well as its own meter reading, meter management, information technology (IT), water efficiency, and financial and customer service practices.
- Provide expertise and guide and facilitate an independent Halifax Water-oriented evaluation process based on Halifax Water's current and future needs for data, so that the Halifax Water's managers have a firm basis for their decisions.
- Begin with a wide review of alternatives followed by an elimination process.
- Help forge consensus and buy-in among Halifax Water staff, as AMI affects several operating and support areas and requires considerable resources.

2.1 Report Format

This report is the consolidated results of the Study efforts, memos, technical papers, and findings. Sixteen tasks were completed between August and December 2013. Excergy is pleased to present this Consolidated Report as the final task for the Study and appreciates the opportunity to meet and work with the very professional and thoughtful personnel of Halifax Water. We especially appreciate their time and effort to participate in the various workshops and inputs for the analysis.

3 Employee Interviews

Excergy consultants conducted 17 one-hour interviews with individual Halifax Water employees on June 18 and 19, 2013. The employees interviewed and the Excergy interviewers are listed on the worksheet named "Interview Participants". Each interviewee was encouraged to share thoughts, questions, concerns, and ideas within three categories:

1. Observations, Challenges, Biggest Issues, and Bottlenecks
2. Desired AMI Capabilities
3. Potential Project Issues

Following completion of the employee interviews, the Excergy consultants consolidated the employee inputs from their respective interview notes, organized the inputs within the three categories listed above, and prepared material for use during a post-interview workshop.

3.1 Post-Interview Workshop

The post-interview workshop was conducted on June 20, 2013. The purpose of the workshop was to present, discuss, and rank the importance of the employees' inputs within each of the three categories listed above. The employees who participated in the post-interview workshop are listed on the worksheet named "Workshop Participants". Following presentation and discussion of the consolidated inputs for a category, each workshop participant was asked to cast four votes for the inputs that he/she felt were most important. A participant could distribute his/her four votes in whatever manner best represented his/her point of view (i.e. one vote for each of four inputs, four votes for one input).

3.2 Interview Findings

The interviews identified a concern that the organization could support an AMI project in light of the many other infrastructure projects that are required for continued operation. This highlights the need for an AMI project to have a significant and demonstrable financial benefit to Halifax Water.

Staff emphasized that there were still many processes that rely too much on paper and manual tasks, and identified a desire for an AMI system to address many manual tasks and labour intensive processes with automation and increased accuracy. The interviewees also emphasized that a project would require strong project management.

The interviews identified many improvements and capabilities that AMI could provide. Key to this was to enable Halifax Water to easily move to monthly billing of all customers because the meter read data would be available without the need for readers to physically visit the meters. The staff expressed a strong interest in the ability of the system to provide increased customer service through pro-actively notifying customers of excessive usage and leaks.

Project concerns centered on making sure that if Halifax Water were to undertake an AMI project, the organization would be supportive. A concern would be the impacts to staffing levels and how to address any potential reductions.

The interviews revealed a concern with the ability of the organization to support a project of the scope of AMI. Internal resources are stretched already, and the interviewees expressed concerns if there would be enough support internally for an AMI project.

3.3 Results

- The employees' inputs and the counts of the inputs' respective ranking votes are summarized in each of the three tables that can be found in Appendix 1:
    - Inputs by Category and Input Number
    - Inputs by Category and Vote Count
    - Inputs by Vote Count

4 Advanced Metering Technology[1]

This document provides a review of AMI technology for the water industry. The information is meant to provide an understanding of the technology, and ways the AMI technology can be used to provide benefits for water processes.

AMI systems allow meters to be read remotely from a central location. AMR allows meters to be read from mobile devices that are in relatively close proximity to the meter, for example, in a nearby vehicle. Today's advanced metering systems available to Halifax Water are exclusively radio based. Decreasing costs and advances in encryption technology allow multiple devices to share common frequencies. Different radio-based products operate on either licensed or unlicensed frequencies. A license covers the use of a specific frequency in a given area. The licensed band normally permits a higher power signal, which enables greater distance between the transmitter and receiver units. Unlicensed radio frequency (RF) systems operate under greater government-imposed frequency and power level constraints. Moreover, since the same band is shared by other applications (cordless telephones, security systems, etc.), specialized modulation and encryption techniques are incorporated in most unlicensed systems to minimize interference.

Advanced metering systems are typically characterized by the technology and reading method used to get the data from the transmitter at the meter, known as a MIU[2], to a nearby DCU; this is known as the "first hop." For example, if data is captured by a 900 megahertz (MHz) low-power one-way transmission from an MIU to a local fixed data collector, then that is used to characterize the system, regardless of how data collectors communicate with the utility's offices or with each other. It is the combination of technology in the meter, the MIU, and the infrastructure network that creates functionality. The components of an AMI system are shown in Figure 4-1 Advanced Metering System Components.

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[1] Much of the material in this section is taken from the Water Research Foundation report *Advanced Metering Infrastructure—Best Practices of Water Utilities*. Copyright ©2011

[2] Each manufacturer has its own name acronym for the MIU (e.g., MXU, NTU, MTU, ERT).

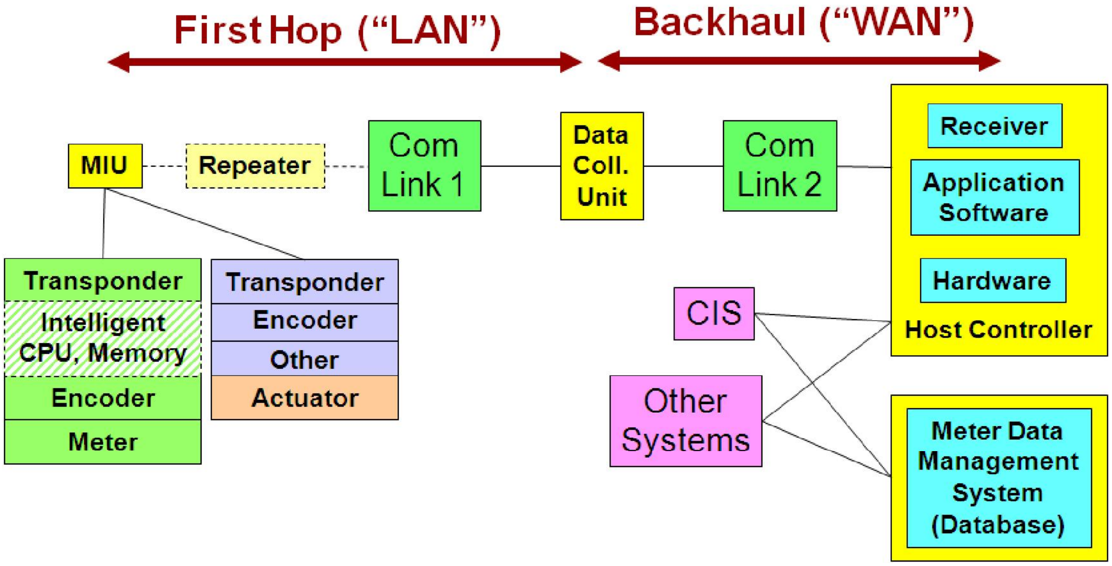

Figure 4-1 Advanced Metering System Components

While some AMR systems collect a single read from the MIU upon query, or when the data collection device comes in proximity, many AMR systems and all AMI systems collect interval (e.g., hourly) data. The interval data may be synchronized (e.g., all readings are taken at the same time). AMI systems may be "one-way" or "two-way." Two-way systems enable the system to make on-demand reads, send control signals, firmware updates, and time synchronization signals to the MIU at the meter. Most AMI vendors are providing two-way communications, which provide the ability to update firmware with much less effort and costs.

In addition to reading meters, AMI systems may also have other devices. Sensors, such as acoustic leak detectors, can passively gather information and send it along periodically. Actuators, such as remote shut-off valves, behave in response to instructions.

4.1 Mobile AMR

Mobile reading systems are often called AMR. As opposed to a fixed network AMI, a mobile AMR system requires a utility employee, walking or driving a vehicle near the meter, to collect the data from the MIU. This data collection is captured with either a hand-held device, or a vehicle-mounted DCU. Vehicle mounted units have more power and storage capacity and are used for normal on-cycle meter reading. In the commonly-used one-way (or "bubble up") mode, the MIU simply transmits the latest cumulative reading and other information such as tamper flags every few seconds. In the alert-and-respond (or "wake-up") mode, the MIU listens for a signal from the DCU, upon which it powers up, reads the meter, transmits the meter information, and returns to a low power state. Data is retrieved from the handheld unit either by placing it in a data cradle or removing a storage device (typically a memory card). Data is typically retrieved from the mobile unit by a similar medium.

Normally, a vehicle-mounted AMR data collector can capture all readings within proximity of its antenna while driving at a rate of 40 to 55 kilometers (km) per hour. The number of vehicle-mounted collectors needed is a function of how the driving routes are laid out, the frequency of reads desired, the need for backup units, etc.

(Photo courtesy Badger Meter)

Figure 4-2 Mobile AMR Receiver

With newer mobile radio systems, the MIU samples the meter frequently (as often as every 15 minutes), and stores some or all of that information (up to two months of hourly data). This provides granular data which can be analyzed to identify potential leaks through flags provided with the meter readings, or provide consumption profiles. The meter reader is able to download this data from the MIU, either by walking up to the MIU, or by transmitting a special signal to a specific MIU, requesting all the stored consumption information be transferred.

While AMR systems can provide the utility with the interval read data, AMR systems require the process of route scheduling, and require meter readers to drive or walk the routes, with greater greenhouse gas emissions and opportunities for accidents than with AMI.

Halifax Water has indicated in the customer process workshops that one concern is meeting the scheduled read dates. In the case of illness, weather, or other circumstances, a read schedule must be met to ensure the billing period does not exceed the allowed days for monthly or quarterly billing.

4.2 Fixed Network AMI

With fixed network AMI systems, either upon being alerted or at pre-programmed intervals, MIUs at customers' premises transmit meter readings to nearby permanently positioned DCUs, which in turn relay the readings back to the utility's offices. Fixed network MIUs typically collect readings from the meter several times per day (often hourly) and transmit them at least once per day. Fixed radio DCUs may relay this information to the utility's offices from one to several times per day.

Some AMI systems rely on a relatively large number of DCUs closely spaced on power poles or rooftops. More localized collectors enable lower power consumption by MIUs for radio transmission. The distance between the MIU and the data collector might be less than one mile. Other systems (sometimes referred to as "tower-based" AMI) use fewer collectors located on tall towers or buildings. A combination of proprietary radio frequencies (on which there is little interference or noise), higher mounted collectors, and higher powered transmitters (MIUs operate at two to eight watts of signal, depending on the manufacturer, compared to a fraction of that for some fixed AMR systems) enables greater distances from the DCU, typically several miles.

Some vendors use repeaters in their systems between MIUs and data collection units. The repeaters collect data locally and retransmit the signals at higher power, bridging the communication between the MIU endpoints and the data collection unit. Repeaters are less expensive than data collection units and do not need to be installed as high, thereby reducing overall system cost.

Fixed radio AMI systems provide higher levels of data transmission but are more expensive than mobile systems. To be economically viable, fixed radio systems require a relatively high concentration of MIUs per data collector to justify the capital and operating costs of the collectors and the communications system needed to relay the data from the collectors back to the utility's offices. Fixed network systems also require that DCUs be deployed at strategic locations to collect data from the MIUs. The use of rooftops or power poles of third parties can be costly if access to these locations must be rented.

In some cases, MIUs are designed to transmit using cellular telephone technology, in which case the wireless company's cell towers substitute for DCUs.

4.2.1 Partial Mesh Network

One variant of fixed network AMI uses a mesh network. In mesh networks, MIUs ("nodes" in network terms) themselves serve as relaying devices for data and instructions. Some vendors' offer a hybrid of such MIUs mixed with fixed data collectors (referred to as a "partial mesh network"). Information "hops" from MIU to MIU until the destination (typically the closest data collection unit) is reached.

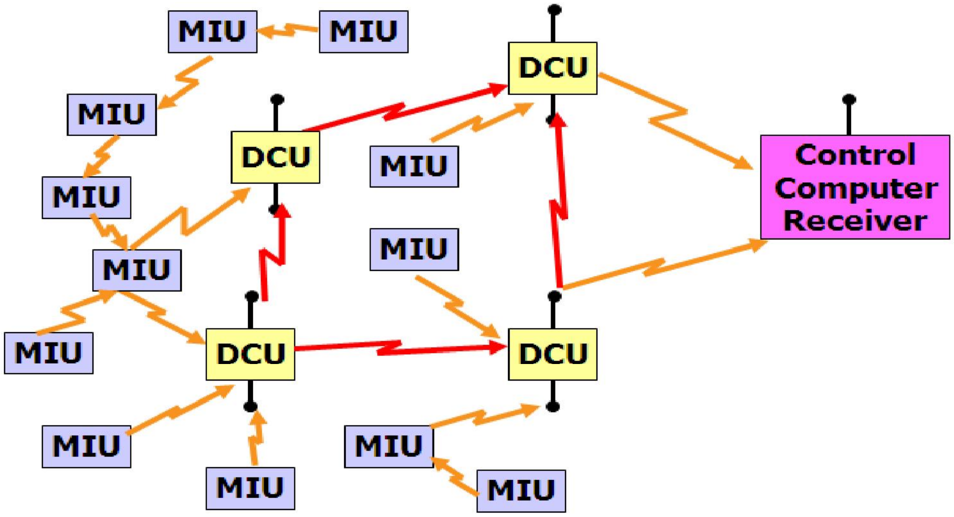

Figure 4-3 Partial Mesh Network AMI

As an MIU is installed, it identifies the neighboring MIUs needed to communicate information to a data collection unit. The MIUs hear each other's broadcasts and a ("self-organizing") network is automatically formed. Using this technology, any MIU can link to any other MIU nearby and the network can determine an optimum path to a data collector. Mesh networks will route information around an obstruction (a hill, for example). Adding more MIUs is easy, and the scale of the network can be increased without extensive network management.

If an MIU breaks down or a connection is poor, the MIUs automatically create an alternate routing (known as "self-healing"). Since the timing of their transmissions must be synchronized, mesh networks are inherently two-way, so requests to resend missing or corrupted data, as well as other information, can be sent to MIUs. In some schemes, the MIUs all power up together for a brief period, send messages, and power down. As a result, depending on the number of hops and the volume of information, data may take some time (perhaps several hours) to get to a collector. To conserve power, battery-powered wireless mesh networks use a store-and-forward scheme. To support the overhead messaging, information processing, and routing tables, mesh networks require more microprocessor power and memory in each MIU. Mesh network MIUs can collect a large amount of information (e.g., consumption profiles) and parse it into shorter messages, which can eventually be reassembled by the network software.

There are numerous competing schemes for routing packets of information across mesh networks. Typically, for each MIU there is a routing table of the MIUs it can best communicate with, which can be dynamically updated to account for new or "lost" MIUs.

Most mesh networks use low power transmissions in the unlicensed bands and MIUs must be reasonably close together (typical ranges are up to 1,000 feet). Using the relaying scheme, a data collector can cover greater distances than some networks that rely on local data collectors. However, too many hops may begin to introduce error and slow down the network's effective communication rate. Avoiding excessive hops requires good initial planning of DCU locations.

4.2.2 Meter Interface Units

All advanced metering systems incorporate an MIU, which may be separate from, integrated into, or attached to the meter register or index. The MIU either interrogates the encoded register of the meter, or accumulates electronic pulses corresponding to consumption from the meter, and transmits this and other information (such as identification (ID) numbers or tamper flags). Most MIUs are equipped with some tamper resistant features, and may generate electronic "flags" if tampering (such as a cut wire, a tilted meter, a tilted register, or the application of a strong magnet near the register) has occurred.

The MIU must have a unique ID number that is transmitted with the meter readings and other data. One or more of the customer information system (CIS), the AMI control computer, or a meter data management (MDM) database associates an MIU with a particular meter. If the MIU has multiple ports (to handle compound meters, or multiple meters at the same location), the system must also associate a unique port number with each meter. Some manufacturers' MIUs do not transmit the ID number generated by the meter register; for others, the MIU regularly checks if the ID number coming from the meter register matches the one that was programmed into it or that it first read during installation. This helps the utility determine if a meter was changed at a particular location.

Water meter registers are connected to stand-alone MIUs using a cable. Stand-alone MIUs are sometimes square or rectangular boxes, a few inches on each side and usually not more than two inches thick. Some new styles of MIUs are more cylindrical with protruding antennae. See examples in figures below. MIUs are designed to operate over a wide range of temperatures and in conditions subject to continuous or repeated submergence, and their cases are resistant to petroleum products. The circuitry is often encapsulated or coated to resist corrosion. Most MIUs have some resistance to induced current surges (e.g., from nearby lightning or stray electrical currents).

Figure 4-4 Itron MIU

Figure 4-5 Alcara MIU

For outside set installations, some manufacturers make mounting brackets to enable the same MIU to be installed in a water meter pit and against a floor joist or wall. Some MIUs, or the MIU supporting brackets, are designed to be mounted on a length of polyvinyl chloride (PVC) pipe or steel reinforcing bar in a meter pit. Other MIUs are mounted either through the lid or attached with a bracket.

4.2.2.1 Water Meter Pit Lid Considerations

A cast iron lid and supporting ring of a water meter pit will diminish transmission signal strength. Some MIUs are powerful enough to overcome this, particularly for a mobile AMR system in which the data collector can be brought closer to a weak signal. For fixed AMI systems, and to increase the range on mobile AMR systems, the MIU may be mounted with its antenna protruding through the iron lid, or a nonferrous lid may be used. Cast iron lids can be drilled so the MIU fits through them, or pre-cast with a hole. Pre-cast lids may also be designed with an inset around the hole so the antenna does not protrude above the lid surface.

Nonferrous lids can be plastic reinforced concrete or a plastic composite, and can be designed to withstand traffic. Some are equipped with brackets to hold the MIU close to the top of the meter pit. Lighter composite lids may be more easily dislodged than heavy cast iron lids, so some utilities prefer locking composite lids, even though the original lids may not have been locking. This may require modification of the lid ring or collar. Lid replacement can add significant cost to a typical AMI project, however Halifax Water has a small number outside-set meters, so lids would not represent a significant cost.

4.2.2.2 MIU Batteries

MIUs are equipped with lithium batteries designed to last 10 to 20 years, depending on the MIU model and its frequency of transmission. To produce extra power during transmission, some MIUs couple a capacitor to the battery. The capacitor can discharge rapidly and be recharged more slowly by the battery. If the MIU is set to transmit above certain design parameters, it will wear its battery out prematurely. For example, an MIU designed to transmit a simple reading twice per day will run down its battery quickly if reprogrammed to transmit every 15 minutes.

Lithium batteries maintain the same output voltage almost until they are exhausted, at which point the voltage drops rapidly. Some MIUs contain remaining battery life indicators, which provide at least some warning of impending battery failure; because of the nature of lithium batteries, this may be only a few months. Battery life is affected by age, extremes of temperature (particularly heat), and fluctuations in temperature, and the cumulative amount of current drawn. MIU batteries are rarely field replaceable. MIU warranties are typically tied to battery life. For an initial period, manufacturers' warranties will replace the MIU with a new MIU for no cost (equipment only). Past a certain age, manufacturers will replace the MIU under a pro-rated warranty at a cost based on the "list" price (often substantially higher than what the utility might have paid for the MIU).

4.2.3 Data Collection Units and Backhaul

Data collectors are typically mounted on light or utility poles, rooftops, or on top of water tanks. Depending on the vendor and local operating conditions, they may be configured to use alternating current (AC) electrical power or direct current (DC) solar cells.

Transferring information from data collectors to the AMI control computer at the utility's facilities (referred to as backhaul) requires a wide area network (WAN). AMI vendors do not typically provide the WAN. Instead, they work with the utility to identify and use locally provided telecommunications facilities. Backhaul may be accomplished over any of several wireless communications systems, including general packet radio service (GPRS), cellular digital packet data (CDPD), IEEE 802.11 (Wi-Fi), 802.16 (WiMax)[1], 802.15.4 (Zigbee), or 802.15.3 (ultra-wideband) networks. Backhaul can also be provided over fiber optics, landline switched telephone networks, Ethernet, or even broadband over power line (BPL) systems. Most AMI vendors are flexible concerning backhaul options.

With current water utility AMI systems, the amount of data being passed in a given time period is not high, so not much bandwidth is required. Many utilities opt for GSM[2], GPRS, or 1xRTT cell phone technology for backhaul. Some utilities have considered building a private dedicated wireless network. Still others have found an existing wireless network they can adapt to AMI. In a few cases, cities have developed multi-function wireless communications systems (e.g., city-wide Wi-Fi, which can be used for police and fire communications, mobile computing, and public access points as well as AMI backhaul) in conjunction with AMI deployment. The City of Corpus Christi Utilities Department, Texas, purchased a Wi-Fi network as part of their AMI. This enabled other city departments (police, fire, etc.) to have a communications system paid for by the utilities department. The City of Glendale, California, also purchased a Wi-Fi network as part of their AMI for water and electric to backhaul from the data collection units and, on a limited basis, provide a virtual local area network (LAN) for communication of SCADA data. The City of New York deployed a broadband communication system for city services, and its AMI system was able to use this for backhaul communications.

Backhaul over commercial networks such as cell phone service or private, proprietary, or dedicated networks will generally require monthly service charges. These networks are continuously being upgraded (and sometimes replaced) in a competitive environment, and the utility needs to ensure that such changes do not cause problems for its AMI equipment or create unanticipated additional costs. Public networks may also be subject to congestion and “dead spots,” as well as varying standards for disaster recovery and security, with which the utility may not be comfortable.

Communication between the endpoint (either the meter itself or the MIU) and the utility’s offices directly using internet protocol is possible if broadband communication capability is widespread through the utility’s service area. However, there is a limited selection of commercially available water meter AMI devices that provide this capability, and these products have been heretofore used in low density circumstances (e.g., for isolated meters).

Internet protocol requires more power-intensive handshaking, security, and other communication “overhead” than dedicated systems. Therefore it is generally not

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[1] WiMax is a competing technology that provides higher bandwidth over greater distances but costs more than WiFi.

[2] GSM - Global system for Mobile Communications

considered practical from a power management perspective for water AMI endpoints, as they are battery powered. However, one smaller water meter manufacturer (Capstone) has developed an Internet protocol (IP) meter, which uses water flowing through the chamber to generate electric power needed to support the IP protocol. Other vendors are exploring similar technology.

Halifax Water may want to pursue discussions with HRM, Nova Scotia Power, Heritage Gas, and/or the East Hants water utility concerning options to cooperate on the network communications.

4.3 Meter Data Management

Halifax Water will need new MDM capabilities to realize the full benefits of an AMI investment. With an AMI, the volume, frequency, resolution, and types of data collected from Halifax Water's meters (e.g., consumption profile data, meter tamper flags, leak flags) would be vastly different from today's meter data; consequently, the company will need more resources and processes for meter data storage, data management, analysis, and presentation. Most MDM solutions are built around a database engine, such as Microsoft SQLServer or Oracle. Upgrading Halifax Water's current CIS and billing solutions, utilizing SAP's IS-U applications suite, might suitably fulfill the new MDM requirements. Another option would be a separate Meter Data Management System (MDMS).

The selected MDM solution will have to process large amounts of data quickly, as data could be arriving from the AMI continuously. It must make correct information instantaneously accessible to customer service representatives (CSRs), and it must respond quickly to queries and "billing research" while timely processing incoming data. The meter reading database stores the reading data received from the control computer and makes it available to the CIS, various other information systems, and users through interfaces on the utility's network. The meter reading database may keep an on-line history of consumption data (e.g., hourly data for two or three years) for all accounts. The oldest data will be written to archival. Some vendor's databases will maintain additional information (e.g., the geographic coordinates of meters, or the meter register numbers).

MDM software typically provides standard reports, query capability, and the ability to create customized reports. In some cases, a third-party report generator is used. Reports cover current status and reading history of individual and selectable groups of accounts. For example, an operator can query a single meter reading by entering a specific account, meter, or MIU ID number into the software's user interface. The operator could also request meter reading data available over a specified time period.

4.3.1 MDM Functionality

However it is implemented, the MDM solution must provide capabilities for validating, estimating, and editing meter data. The MDM software automates the meter data validation and estimation, calculates billing determinants derived from the meter data, and provides user interfaces for manual data edits when necessary.

In addition to the database and interface functions mentioned above, an MDM solution can:

- broker commands between the CIS and the AMI, such as on-demand readings;
- manage the relationships between customer accounts, meters, and other assets (e.g., sections of mains);
- screen AMI data and ID numbers for lack of correlation or other anomalies, such as no zero flow, an indication of a possible customer-side leak;
- identify readings as good, stale, bad, partial, or missing;
- replace bad or missing meter readings with estimates;
- support data warehousing and data mart capabilities so various users may access historical meter reading and other data;
- perform special analyses, such as composite consumption profiles for all the customers in a given subgroup (e.g., type or location);
- manage some customer service functions, such as virtual or "soft" turn-offs and "watchdog" functions, and
- interface with key utility information systems, such as distribution system models, SCADA, an asset management system, work order management systems, and a geographic information system (GIS), to analyze system performance or monitor system losses and to provide data for distribution system planning and engineering.

The MDM solution may be required to manage additional customer data not ordinarily handled by the CIS. For example, does the metered location have a swimming pool or an in-ground irrigation system? How much irrigable area is there? How many square feet is the building? What section of pipe is the point of demand of this service connection tied to?

Some water utilities have built their MDM solutions in-house. Many have purchased it from their AMI vendor. Rarely, utilities might purchase it from a third-party provider. In some cases, rather than purchasing the solution outright, utilities choose to contract a hosted MDM service.

An MDM solution should be able to accept meter reading and related data from any meter reading system the utility has (or acquires) and should be able to interface with any legacy or vendor-supplied IT system (CIS, GIS, CMMS, SCADA, etc.), serving as the single repository of data for AMI-related information. If meters are moved from one reading technology to another over time, the change must be seamless.

4.3.2 Web Portals

Some utilities have developed applications to enable customers to access their own consumption history and profiles through a web page application that extracts data from the meter reading database. These “web portals” can provide the customer with information that may reduce the number of calls to the utility because the customer is able to view data that may answer their question without calling the utility. Web portals with consumption history and profiles may also promote conservation through customer behaviour modification based upon consumption information.

4.4 Water Meters

4.4.1 Meter Registers

Water meters employ a wide variety of technologies. An AMI-enabled water meter must have some method of communicating its meter reading and other information to an MIU. The rotation of a drive shaft, the turn of a magnet, the accumulated reading, or the movement of the sweep hand must be converted into digital format.

4.4.1.1 Electronic Pulse Registers[1]

Several water meter register models generate low current pulses that can be accumulated by an MIU. They may be characterized as either passive or active, depending on whether they require external electrical power (as opposed to mechanical power from the meter). Passive devices include reed switches. Active devices include Wiegand wire sensors and piezoelectric switches. All of these solid state designs offer long life and reliability. Since digital pulse registers were first introduced in the 1980s, millions have been installed in combination with AMR devices and have proven to be highly reliable and cost effective. However, if there are disruptions to the signal (distorted pulses, noisy lines, cut wires, etc.), the reading transmitted by the MIU may not match the reading on the meter register.

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[1] Sometimes referred to by meter manufacturers as “digital encoders.”

4.4.1.2 Magnetic Reed Switches

Magnetic reed switches are hermetically sealed glass capsules which contain a pair of contacts that close when in proximity to a magnet mounted on the drive train. In one manufacturer's design, a 10-position magnet located in the register rotates in front of the reed switch located on the electronic circuit board. Each position on the magnet is equivalent to one-tenth of the meter's sweep hand, providing 1 gallon or 0.1 cubic feet or liter resolution for smaller sized meters. Another manufacturer senses a magnet embedded in the register's sweep hand. By using more than one sensor, the device can sense reverse rotation (due to backflow or tamper). Reed switches feature long life and low cost, and have been very popular in the metering industry. A reed switch is incorporated into the circuits of some meter registers to indicate possible tampering with a magnet, setting a flag in the AMI system.

4.4.1.3 Piezoelectric Sensor

A piezoelectric sensor is mounted on a circuit board of one meter positioned against a 10-tooth rotary cam tied to the gear train. As the sensor "drops" off the cam "shelf," the piezoelectric crystal generates a small electrical pulse from the release of mechanical strain, which is used to close an electronic switch. The piezoelectric switch pulses to one-tenth of the sweep hand, providing reading resolution of 1 gallon or 0.1 cubic feet or Liter for small sized meters.

4.4.1.4 Wiegand Sensor

A Wiegand sensor is based on a thin ferromagnetic wire that is cold-processed to create a soft magnetic core and a hardened surface shell with a higher magnetic coercivity. When it is moved past a magnetic field, the wire will very rapidly switch polarity and then reverse again, generating a strong, short electrical pulse without any additional external power being supplied. The pulse can be detected by a coil wrapped around the wire.

4.4.1.5 Dial-Position Encoders

Dial-position encoders[1] were first introduced in the 1960's and have evolved considerably. Millions of mechanical encoders have been installed for both "touchpad" applications and advanced metering systems. Dial position encoders are passive devices, requiring an external power source. Various dial-position encoders will transmit from five "and a half" (the sixth digit being either 1-5 or 6-0) to eight digits, as well as an ID number, a make and model code, and some error flags. Older designs used mechanical contacts; new designs use "contactless" technology.

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[1] Often referred to by meter manufacturers as "absolute" encoders.

4.4.1.6 Mechanical Encoders

Mechanical (contact) encoders transmit the actual positions of the register's odometer wheels upon interrogation without depending on an external counter to totalize the registration. A mechanical encoder employs a group of switches or sensors to produce a unique digital "word" for each position of a wheel. A microprocessor scans the register's wheel positions, reads a factory-set ID number "burned" into the register's memory, and automatically transfers the data, as well as an ID number, in serial format in response to a power and clocking signal from the reading device. A drawback to the mechanical encoder is its complexity; the "brush" design contains several small parts and can be subject to contact problems or contamination on pads and brushes. Mechanical wipers and contacts are also a source of friction that can result in wear of the brushes and pads, and add to the load on the meter's measuring element. If a wheel on the encoder is between two digits at the time of the reading, a temporary error may occur. In recent years, mechanical encoders have been replaced by non-contact encoders to improve reliability.

4.4.1.7 Magnetic Field Position Sensing

In the magnetic field position sensing design, a coil/capacitor assembly on each wheel resonates at a different frequency, depending on the capacitor value, in response to an applied magnetic field. The frequency is detected and processed to determine the position of each wheel, which is converted to a numerical value.

4.4.1.8 Optical Encoding

At least one meter encoder uses light emitting diodes (LEDs) that shine light though a series of slots in the odometer wheels of the register. Light from the LEDs is picked up on the opposite side of the wheel by light pipes connected to phototransistors on the register's circuit board, which converts the light patterns to numbers. Another encoder utilizes strategically positioned LEDs that illuminate the register's odometer digits for reading. A microprocessor receives images from strategically positioned retinas focusing on the digits through polymer lenses and processes them with optical character recognition.

4.4.1.9 Electronic Registers

In these registers, the gear train is replaced by electronic sensing of either the primary (leading) magnet in the measuring chamber or the register (follower) magnet. Electronic pulse counting is done by a microprocessor within the register. The pulses are stored in a non-volatile memory register. In one manufacturer's device, Wiegand sensors are used to register the magnet's rotation. By using two sensors, this register can detect the direction of flow; reverse flow would provide an indication of backflow or tampering. If the register time-samples its data at frequent intervals, it can provide flow rate and leak detection information.

4.4.2 *"No Moving Part" Meters*

New technologies, including ultrasonic and electromagnetic meters, have recently been introduced to the small water meter market. Using technology formerly available only on large sized meters, these no-moving-part designs are alternatives to the traditional inference or positive displacement measuring principles.

Based the Doppler shift principle, ultrasonic meters (such as the Figure 4-6 Badger Emeter (A Small Ultrasonic Meter) pictured below) continually calculate flow rate and consumption based on the measurement of signals sent in rapid succession in both forward and reverse directions. If a fluid is moving towards a transducer, the frequency of the received signal will increase. As fluid moves away from a transducer, the frequency of the received signal will decrease. The frequency difference can be used to calculate the fluid flow speed. Using the Continuity Equation, the flow is calculated as the product of area and average velocity.

Figure 4-6 Badger Emeter (A Small Ultrasonic Meter)

The Sensus iPerl® (see Figure 4-7 Sensus iPerl Meter) is a small electromagnetic meter. It measures the velocity of water based on Faraday's principle that an electrically conductive fluid moving in a magnetic field causes the induction of a voltage across the conductor. The magnetic field is created by energized coils outside the tube through which the water flows. Electrodes mounted in the pipe wall detect the voltage. The voltage produced is directly proportional to the velocity, and, again using the Continuity Equation, flow rate is calculated. The meter's electronics convert the amplitude modulated signal into a series of coded pulses for digital processing.

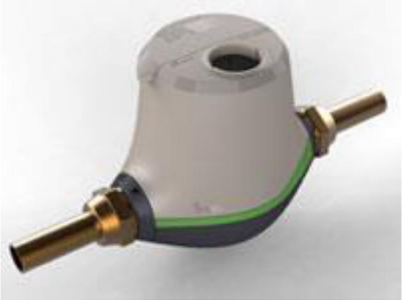


Figure 4-7 Sensus iPerl Meter

Another technology, fluid oscillation, has been available to the small meter market for many years, but heretofore has not been widely adopted. In this meter design, a jet of water emerging from a nozzle or conduit follows a nearby surface and attaches to it (Conada effect). A portion of the flow is diverted through a feedback passage, however, and pushes the stream toward a sidewall on the opposite side of the meter body, which also has a feedback passage through which a portion of the flow is diverted. The fluid from this feedback passage pushes the stream back toward the sidewall to which it was initially attached, and the self-initiating, self-sustaining process is repeated. Sensors in the feedback passages detect the presence and absence of flow. The frequency of the pulse signals is proportional to the volumetric flow rate. At least one manufacturer of fluid oscillating meters is now offering an option for replaceable batteries.

No-moving-parts meter designs require no calibration. They are touted as being accurate over a wider range of flows than traditional designs, in particular, for their ability to measure very low flows. For example, a ¾" Badger Emeter specifies accurate readings at a flow rate of 0.05 gallons per minute (gpm), whereas the ¾" Badger positive displacement meter (and all manufacturers similar meters which meet the American Water Works Association (AWWA) C700 specification) is accurate to 0.25 gpm. In addition, there are no moving parts to wear over time, so the expectation is that the meter will be just as accurate at year 10 or year 15 as it was at initial deployment. Since ultrasonic and electromagnetic meters have no restrictions in the flow tube, head loss through the meter is lower than mechanical meters, so they may be more suitable for residential fire service applications. Electromagnetic and ultrasonic meters can measure flow in both directions with equal accuracy. The electronic display of the meters can indicate total consumption, rate of flow, flow direction (in the case of ultrasonic and electromagnetic meters), and alarms. This kind of data may align well with the communications capabilities of AMI systems.

No-moving-parts found in the ultrasonic and electromagnetic meters also allows for these meters to be installed in virtually any orientation, whereas positive displacement meters must be installed horizontally. This allows increased flexibility as to where the meters can be deployed, and results in less space required for apartment bank deployments.

These meters are also considerably lighter and smaller in volume than traditional positive displacement meters. They require less space to store and take up less room in meter pits, allowing for easier installation and removal.

At the moment, these new meter design are more costly than typical AMI-compatible positive displacement meters. Simplified construction should eventually result in lower meter costs. While initial quality concerns have arisen, the reliability of these meters should be improved over mechanical meters with moving parts.

These ultrasonic and magnetic meters incorporate solid-state electronics and long-life batteries to support their relatively high power consumption. Manufacturers are estimating the battery life at 10 to 20 years. The batteries are not replaceable. At present, the life of the batteries in these meters can only be estimated, and warranty considerations will be important. Also at the moment, there are no AWWA design standards specific to these meters; however, they are guaranteed by their manufacturers to meet AWWA meter accuracy standards.

4.4.3 Meter Register-MIU Compatibility

Every manufacturer of meters offers AMI products, and would prefer to have the selection of their meter product favor the selection of their AMI system, and vice versa. Conversely, some AMI vendors have no meter products, and generally will work with any meter they are allowed to read. Halifax Water might prefer to have a choice of AMI options, and not be locked into the purchase of one system because the utility has a predominant number of one or two makes of meter. Conversely, having picked an AMI system, Halifax Water should prefer not to be locked into only one make and model of meter; the fewer the choices, the higher are likely to be the prices of meters and/or AMI components. Halifax Water should also be concerned that the meters it buys or chooses to keep will work with its AMI well into the future.

The degree of compatibility between meter registers and MIUs has a bearing on overall AMI deployment costs, depending on whether Halifax Water replaces a meter or retrofits it, as well as the cost of labour (meter change out is more expensive than retrofit) and the price of components. Sometimes a vendor may charge almost as much for a new register as for a new meter, particularly if it helps to sell an AMI, which uses that vendor's meter. The degree of interoperability between meter registers and MIUs may be categorized as follows:

A. No programming or modifying of the MIU or meter register needed. Either the MIU is default programmed to read the particular meter register, or the MIU can sense the make and model of the meter, and adjust accordingly.

B. Requires “normal” programming of MIU. This may be part of normal initialization of every MIU, or some reprogramming is required for a particular make and model of meter register. However, the MIU manufacturer has incorporated this step into normal installation.

C. Technically feasible, requires modifying the meter register or MIU through special reprogramming, wiring changes, or the insertion of a component.

D. Technically infeasible; physical or electronic incompatibilities prevent any interoperability.

In addition, there are varying degrees of vendor support. These might be categorized as:

1. Cross-licensed, fully compatible. The manufacturers of both meter and MIU guarantee that their product will function properly with the other. Changes to one product (e.g., an updated version of firmware) are unlikely to affect interoperability.
2. Works, but with some loss of functionality. The interoperability is understood by both manufacturers to work, but with some loss of features or performance. Some meter models with more functionality built-in (“smart” meters), such as identifying backflow, may need to forward additional data, and not all MIUs may be permitted or be capable of storing and transmitting this data intact. Some meter manufacturers that also sell AMI systems will limit the functions of their meters that are available to the MIUs of competing AMI vendors.
3. Should work but not licensed or supported. Although the MIU and meter will work together, either or both manufacturers will not uphold the warranties.

Halifax Water may want to incorporate these guidelines in an evaluation of any AMI vendor proposals or in future meter purchases.

4.5 Resolution

The MIU is characterized by how often it transmits, as well as how often it samples the meter reading in the case of dial-position encoders. For example, a mobile system MIU might sample the meter every hour and transmit the reading every 12 seconds. This means that a mobile data collector traveling in the vicinity of the MIU at normal speeds will likely receive the signal. A fixed AMI MIU might read the meter every hour and transmit the readings once per day.

For a given meter size, if not enough significant digits of the reading is transmitted from the register, then too frequent readings will not be useful. For example, suppose a small meter is on a residential water service that uses an average of 0.5 m^3 per day (average usage ~ 23L per hour), ranging from 0 m^3 an hour to 0.4 m^3 an hour, and the transmit resolution of the meter register is 100 liters. If it is read on an hourly basis, the meter consumption from hour to hour will read 0 or some increment of 100 liters. Hourly readings might not provide very useful information on load profile unless averaged over a long period of time. Detection of continuous low flow consumption at some fraction of 100 liters per hour through the meter (a possible leak) with this resolution might not be meaningful unless the AMI can accumulate hourly information in “buckets” over extended periods or aggregate several consecutive reads. In the case above, a meter with a resolution of 1 or 10 liters would be recommended in order to identify small customer-side leaks. Ideally, the meter resolution, meter sampling interval and data transmission interval should be matched based on the expected rates of consumption through the meter.

4.6 Acoustic Leak Detection

Several companies manufacture ALDs for water distribution systems, and provide the software and analytical services to help water utilities identify leaks. Retrieving the data from these devices quickly and inexpensively using AMI is key to making them effective. Each AMI vendor has a relationship with one or more ALD manufacturers, and offers ALD products and services.

Different ALD technologies rely on different deployment strategies. In one type, as exemplified by the FlowMetrix MLOG®, an ALD device can be strapped to the service pipe either in the meter pit or inside the customer’s premises upstream of the meter to allow a sensor mounted on the bottom of the ALD unit to make contact with the pipe. The ALD is connected to either a separate AMI MIU or the second port of a dual port MIU. Figure 4-8 Wired Acoustic Monitor and Encoder Meter shows both the acoustic monitor and the nearby meter with wiring leading to a transmitter that is located in the floor joists above the customer’s basement. Given the sensitivity of the devices and the manner in which acoustic noise travels in pipe, units are placed on one out of every few service lines, or one for every 150 meters (m) of metal distribution system pipe or 75 m of plastic pipe. The percentage of services equipped with ALDs needed to cover the entire distribution system will vary depending on the density of services, the pipe materials in use, and the distribution system layout. This type of ALD monitor is designed to provide data for many years and remain in one location. The units are expected to last 15 years when wired to the nearby AMI transmitter.

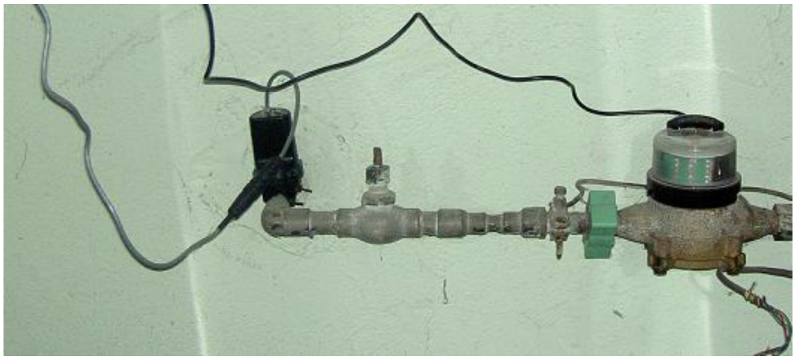


Figure 4-8 Wired Acoustic Monitor and Encoder Meter

Another technology, as exemplified by the Permalog® device, involves mounting monitoring devices on the stems of distribution system valves. Held in place by a magnet, these devices have their own transmitters, and incorporate a replaceable 10-year battery. Figure 4-9 Magnetic Mounted ALD Incorporating Radio Transmitter shows an ALD incorporating a radio transmitter.

Figure 4-9 Magnetic Mounted ALD Incorporating Radio Transmitter

While the MLOG device is designed to remain on customers' service lines near the meter, other devices such as the Permalog could be deployed in a limited area (say one of Halifax Water's pumping districts) for a period of time, and then redeployed to another area (called the "lift and shift" strategy). Moveable sensors are generally more sophisticated and sensitive acoustic devices. This makes them better able to detect leaks and therefore more expensive than permanently mounted sensors, and they usually contain their own radio transmitters. This approach can reduce capital costs, although it would not provide continuous monitoring of the entire distribution system, and would require periodic labour costs for moving the devices.

"First generation" ALDs detect leak noise in their vicinity. The monitoring units do not pinpoint a precise location of a leak but identify areas to investigate. Field investigations are necessary to confirm the presence of the leak and pinpoint its location using acoustic correlation devices.

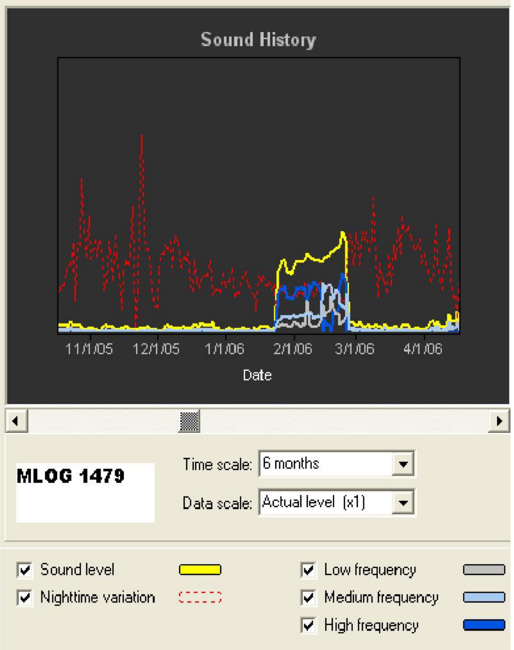
“Second generation” ALDs, as exemplified by the Gutterman ZoneScan® monitor, use time synchronized AMI MIUs to obtain data from multiple ALDs at the same instant. This enables more precise location of leaks.

Typically, each ALD is programmed to operate for a few hours in 10-minute intervals during a quiet time of each day. The ALD selects the sound from the least noisy interval as well as the noisiest interval. It transmits the quietest value based on several frequency ranges, as well as the difference between the quietest and the noisiest intervals, to the connected MIU, which stores the data and relays it during normal transmission.

In typical operation, the ALDs devices transit over the AMI communications network to the acoustic leak detection system which provides data to the utility’s non-revenue water (NRW) staff for analysis. Alternatively, the data can be analyzed by the acoustic leak detection system vendor as a service, and alerts sent directly to the utility when potential leaks are detected. The data can be reviewed weekly or bi-weekly to identify locations suggested by the software as potential leak areas. From the list of probable leak “suspects” (identified in software maps and lists) the NRW staff can examine the individual unit leak noise history to see if the pattern of noise warrants a field investigation. Figure 4-10shows the start and repair of a leak detected by ALDs. The total minimum noise is the sum of noise at three frequencies: low (indicative of plastic pipe leaks), medium (indicative of ferrous pipe leaks), and high (indicative of metallic service line leaks). The leak is characterized by a sudden increase in total noise and the sudden decrease that coincides with the date of repair.

Once in place, the leak detection system can “learn” about and rule out extraneous noise, such as transformer or pump hum. When an extraneous noise source can be identified, the system software remembers it for a particular ALD. The software watches for changes in noise levels. Acoustic leak systems can be characterized by their efficiency, in terms of avoiding false positives, and capturing all leaks. An acoustic leak detection system might identify 75 percent or more of all leaks.

The major benefits of an AMI-based acoustic leak detection system entail learning about leaks earlier, when they are small and less costly to repair. When small leaks are detected earlier, the utility can be more strategic and proactive in deploying repair crews, thereby saving money. A significant percentage of leaks do not reach the surface for a long time, if at all. Leaks may run into storm drains, sewer pipes, watercourses, underground channels, or porous soils. ALDs can help find these. Small leaks tend to enlarge over time through continued erosion of the pipe and destabilization of soil surrounding the pipe. Small and large leaks, and the destabilization of the pipe bed from erosion by the water, account for a significant portion of pipe splits and other main breaks.



MLOG 1479

Time scale: 6 months

Data scale: Actual level (x1)

Figure 4-10 Software Display of Leak Noise History

AMI-based acoustic leak detection is relatively new. Over the next few years, vendors and utilities will increase their experience and knowledge base. Leak detection is increasingly being incorporated into AMI request for proposal (RFP) specifications.

4.7 Additional Features Under Development

Several vendors have been looking to add additional features to their AMI systems which have the potential to provide significant benefits as well as increase integration with other IT systems.

Of these, motorized valves that can be actuated by remote command to shut-off/turn-on service are becoming available. Initially, these devices were outside the meter lay length and required plumbing as well as the likelihood of a meter pit box swap. Just coming to market are valves that are incorporated within the lay length of the meters and integral with the meter/register/MIU such that no additional plumbing is required. Such devices have the potential to address problem accounts that regularly fall behind in payments and require frequent service shut-off. Additionally, remote valves could be actuated in the event of when customer side leak is identified by the MDM solution, and the customer cannot be reached.

Another additional component about to launch is remote pressure monitoring via the MIU. It is the nature of water systems to be constructed in pressure zones, and within these zones the distribution system will have areas of high pressure near the lower elevations of each zone and low pressure near the top edges. High pressure can create additional stresses on both distribution system piping and on the customer side of the meter, especially at night during low demand periods when system pressure tends to be highest. Remote pressure sensors can be deployed at regular intervals within the pressure zone, perhaps as frequently as one per five homes, to provide useful system information. These include applications beyond identifying dangerously high pressure, including initiation of pressure relief valves to optimize pressure; model calibration; and ID of system blockage, closed valves, and hydraulic inefficiencies.

5 Customer Service Process Analysis

Excergy consultants conducted a series of workshops and meetings where Halifax Water staff and Excergy consultants described Halifax Water's existing customer service and metering processes and then predicted how an AMI would affect those processes. The process labour metrics included in this section are a key part of the data set needed for the subsequent economic and financial analysis. Four core processes were analyzed in light of AMI impacts:

1. On-Cycle Billing
2. High Bill Complaint
3. Move In/Move Out (includes vacancy monitoring)
4. Collections

These four processes were chosen because they represent areas where effort in the customer service arena that can be influenced by AMI through increased read accuracy, and better and more highly detailed data that AMI provides.

5.1 Process Analysis Methodology

To develop and define the potential impacts AMI would have on Halifax Water customer processes a series of workshops were held at the Cowie Hill location on July 23rd to 24th.

The steps for the analysis were:

- Identify the "context" of the process
    - The Actors of the process – identify what job positions are involved
    - The Systems Actors – identify which IT systems are used in the process
    - The Input conditions – what conditions initiate the process
    - The Output conditions – what condition signify completion of the process
- Identify each step – walk through the process from initiation to finish, identify the activity and action at each step
    - Each step documented in the process flow diagram
- Identify metrics of current processes – for each step possible, identify significant metrics of effort
- Identify AMI impacts to the current processes

  - Review each action or activity, rework the process to identify if AMI has an impact and to what extent

- Develop metrics of effort with AMI implemented – estimate and quantify the influence of AMI on each impacted action or activity
- Compare metrics to determine extent of change
- Feed results into the Economic and Financial Analysis (Task 10)

5.1.1 Key AMI ASSUMPTIONS

The analysis establishes an understanding of how an AMI system and the AMI data can improve or impact the processes identified. AMI is an enabling technology that presents an opportunity to provide data to the customer service organization not available before. To ascertain AMI impacts it was necessary to establish an understanding of the potential AMI environment. Those assumptions were:

- All customer meters are AMI-enabled [1]
- All customers are billed monthly
- Each AMI device records consumption in hourly intervals
- The AMI master station would daily collect each meter's register reading and hourly interval data
- The AMI meters are not equipped with remotely controllable service connect/disconnect valves (potential benefit when the technology is proven – but not assumed in the exercise)
- The AMI system would employ a well-integrated MDM solution as its primary interface with Halifax Water's other information and automation systems (CIS, Billing, Computerized Maintenance Management System (CMMS), SCADA, etc.)

5.2 Overall Results of the Process Analysis

The results of the process analysis are summarized in this section. The detailed steps and process flows are included in an addendum to this report.

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[1] *Note: Halifax Water does have a small group of unmetered water customers. For purposes of this study it is assumed they remain unmetered.

Table 5-1shows the expected number of hours of reduced efforts for each position identified in the workshops that is part of a process. These numbers summarize the four processes. The results of each process are documented in the sections following.

These numbers show a decrease in full time employees (FTE) that is not indicative of a reduction on headcount in all these areas, but merely a way to identify the potential financial benefits in the Economic and Financial Analysis (Task 10); however a conservative approach in the financial analysis may not take all the reductions herein identified.

These hours can be reallocated to other Halifax Water operations, such as a meter maintenance or testing program that may not be completed under the current workload and staffing. However, there can be opportunity for Halifax Water to reduce the number of FTE through attrition and normal turnover, especially in the meter reading department. That department experiences extensive turnover today, and as the personnel rolls over; those positions may be left unfilled to meet new FTE headcounts.

Table 5-1 Overall Results from the Customer Service Process Analysis

	Without AMI		With AMI		Deltas		
	Total Hrs per Position w/o AMI	# FTE	Total Hrs per Position w/ AMI	# FTE	∆ Hours	∆ Amt. FTE	∆ Pct. of FTE
Customer Service Representative	11,740	6	5,347	3	-6,393	-3	-54%
Field Service Technicians	26,528	13	3,538	2	-22,989	-11	-87%
Meter Reader Supervisor	544	0	0	0	-544	0	-100%
Meter Reading Coordinator	683	0	3,534	2	2,852	1	418%
Billing Edit Clerks	14,598	7	3,139	2	-11,459	-6	-78%
Billing Coordinator	325	0	780	0	455	0	140%
All Customer Service and Metering Personnel	54,417	26	16,338	8	-38,079	-18	-70%

5.3 On-Cycle Billing Process Analysis

5.3.1 AMI Benefits Affecting On-Cycle Billing

The following benefits were identified and used for assumptions of impacts to the On-Cycle Billing process analysis during the workshop:

- Reduced labour for investigating implausible readings
- Reduced labour for estimated readings
- Reduced labour and transportation for check reading orders
- Reduced labour and transportation for meter maintenance/repair orders
- Elimination of efforts for read route management
- Elimination of labour for meter reading coordination – i.e. personnel assignments and route coverage due to absence of reader
- Elimination of meter reading labour, transportation, and carbon output dedicated to monthly and quarterly reads
- Automated movement and management of meter reading data from meters to billing
- Daily collection of hourly interval data via a fixed two-way radio network
- Shorter period between consumption and billing
- Fewer meter reading errors

These assumptions were evaluated in the workshop. While AMI can eliminate efforts for reading the meters, the final analysis left a small amount of effort to account for a level of support for verification of reads and accounts.

5.3.2 On-Cycle Billing Process Analysis Results

Table 5-2 shows the results of the process analysis. These figures indicate a large benefit to the billing process from AMI, mainly through reduction in meter reading efforts and billing corrections due to the reduction in reading errors which are introduced through manual reads. Re-read orders due to inaccurate input will be reduced to zero with an AMI system.

Table 5-2 On-Cycle Billing Process Analysis Results

	On-Cycle Billing Process Annual Labour Hours			
	Without AMI	With AMI	D Amt.	D Pct.
Customer Service Representative	0	0	0	0%
Field Service Technicians	12,206	1,300	-10,906	-89%
Meter Reader Supervisor	500	0	-500	-100%
Meter Reading Coordinator	555	3,220	2,665	480%
Billing Edit Clerks	10,914	1,588	-9,326	-85%
Billing Coordinator	325	780	455	140%
All Customer Service and Metering Personnel	24,500	6,888	-17,612	-72%

5.3.3 On-Cycle Billing Process Notes:

- Halifax Water currently bills on Mondays only.
  - Five to seven thousand bills per week
- Reading orders are generated in SAP on the Thursday or Friday prior to the week when the meters are read.
- Halifax Water is using Neptune's N-Sight Meter Reading Management Software.
- Approximately 4,000 commercial, industrial, and institutional customers are read and billed monthly.
- Approximately 2,500 budget-plan customers are read quarterly and billed monthly.
  - Real reads are collected on budget anniversary months and are managed manually.
- Halifax Water periodically uses RouteSmart application software for optimizing meter reading routes.
- Meter Reading Coordinator plans reading routes.

- 12 to 19 routes are read each week (~15 routes per week x 12 weeks per quarter = 180 routes per quarter = 720 routes per year)
- Each handheld (in its dock) is manually queried by the Meter Reading Coordinator at the end of the day
- For quarterly billing, bills are generated three weeks after the corresponding meter reading orders are issued.
  - Readings are collected in the first week
  - Readings are validated in the second week
  - Invalid readings are corrected during the third week
- For monthly billing, bills are generated 1.5 weeks after the corresponding meter reading orders are issued.
- Halifax Water always bills on the basis of the reading when the reading value appears high (but not implausible).
- Halifax Water always bills on the basis of an estimate when a reading value appears low.
- Meter reading routes are maintained weekly to accommodate new accounts, disconnected accounts, etc.
- Monthly reads are all performed using RF drive-by.
  - Drive-by readings are collected by dedicated staff to minimize errors and ensure timeliness
- 84 to 102 days are allowed for quarterly billing period.
- 28 to 32 days are allowed for monthly billing period.
- An iDoc report for every route is printed daily from SAP and delivered manually to Billing Edit.
- Validation process running in SAP checks meter reading values to detect:
  - Register rollover
  - Zero reading
  - Comparatively high readings
  - Comparatively low readings

- SAP sets a reading's status to "implausible" when the reading fails validation.
- Billing Edit investigates implausible readings.
- Billing simulation is final check before billing is finalized for a cycle. This process looks for other errors that are not caught or identified in the previous check.

5.4 High Bill Complaint Process Analysis

5.4.1 AMI Benefits Affecting the High Bill Process

A utility experiences high bill complaints when customers either have high bills from leaks, do not understanding their level of usage, or when misreads slip through the implausible validation process.

AMI can allow Halifax Water to address the causes of a high bill before the customer sees a bill or calls the utility. In the case of a high bill from a leak on the customer's side, Halifax Water can monitor the daily reads and identify potential leaks through the data. This allows for a proactive call to the customer to inform him of a potential leak.

If it is not a leak, but the result of excessive usage, Halifax Water can also institute a proactive response and inform the customer before the bill becomes too onerous–or at the least inform the customer of the potential of a high bill on the next cycle.

One concern related to proactive notification is the assumption of liability by Halifax Water; for example, if Halifax Water failed to proactively notify a customer of a potential leak. Halifax Water will need to understand the implication of these proactive efforts and identify the impacts of potentially creating higher customer expectations and accepting responsibility if these are instituted in the organization.

Both examples above can be augmented through web presentment of the daily consumption to the customer. If Halifax Water chooses a web tool with AMI, customers would able to monitor their water usage and take ownership of their own consumption habits.

With AMI, the automation of the reads will also reduce any human-induced errors and prevent the high bill call due to a misread of the meter. While Halifax Water does an outstanding job of catching implausible bills, these can be reduced further with AMI.

In addition to these benefits, the analysis incorporated the following benefits in the process evaluation efforts:

- More first call resolution of customers' concerns
- Fewer high bill complaints

- Fewer escalations of high bill complaints due to first call resolution improvements
- Fewer bill adjustments
- Faster detection of anomalous high consumption
- Proactive responses to anomalous high consumption
- Fewer truck rolls for Check Reading Orders

5.4.2 High Bill Process Analysis Results

Table 5-3 shows the results of the process analysis. These figures indicate a large benefit to the High Bill process from AMI, mainly through reduction in meter reading errors and billing corrections due to the reduction in manual reads, which introduce reading errors. Re-Read orders due to inaccurate input will be reduced to zero with AMI.

Table 5-3 High Bill Process Analysis Results

	High Bill Process Annual Labour Hours			
	Without AMI	With AMI	D Amt.	D Pct.
Customer Service Representative	1,342	317	-1,025	-76%
Field Service Technicians	2,750	700	-2,050	-75%
Meter Reader Supervisor	0	0	0	0%
Meter Reading Coordinator	0	67	67	670000%
Billing Edit Clerks	313	142	-171	-55%
Billing Coordinator	0	0	0	0%
All Customer Service and Metering Personnel	4,404	1,225	-3,179	-72%

5.4.3 High Bill Process Notes

- 30 percent of customer request orders (CROs) reveal reading errors on original reads.
- A waste notice is sent to a customer when the customer’s consumption is abnormally high (as judged by the Billing Edit Clerk). No subsequent notices are sent.

- Approximately two Meter Maintenance/Repair Work Orders (MWOs) per week.
- Re-bills due to bad meters are minimal.
- Will AMI create an obligation to act on excess consumption situations?

5.5 Move In/Move Out Process Analysis

5.5.1 AMI Benefits Affecting the Move-In/Move-Out Process:

- Faster detection of unauthorized consumption at disconnected service points
- Ability to capture a read for the effective date without physical read of the meter
    - Greatly reduced truck rolls needed for final read orders
- Reduced truck rolls needed for service check orders and vacancy monitoring
- Large reduction in associated meter maintenance/repair orders
- Less work needed for detecting and correcting anomalous final readings

5.5.2 Move-In/Move-Out Process Analysis Results

Table 5-4shows the results of the process analysis. These figures indicate a large benefit to the Move-In/Move-Out process from AMI, mainly through reduction in the need for a truck roll to capture final and start reads for changes in account owner.

Table 5-4 Move-in/Move-out Process Analysis Results

	Move In/Move Out Process Annual Labour Hours			
	Without AMI	With AMI	D Amt.	D Pct.
Customer Service Representative	1,731	697	-1,035	-60%
Field Service Technicians	9,980	697	-9,283	-93%
Meter Reader Supervisor	44	0	-44	-100%
Meter Reading Coordinator	128	248	120	94%
Billing Edit Clerks	1,551	501	-1,050	-68%
Billing Coordinator	0	0	0	0%
All Customer Service and Metering Personnel	13,434	2,142	-11,292	-84%

5.5.3 Move-In/Move-Out Process Notes

- BlackBerry application for final read (one BlackBerry for each region) – reading is keyed into the BlackBerry – more reading errors in the winter.
- Approximately 65 percent of initial Move-In/Move-Out calls are received before the planned move.
- Approximately 35 percent of initial Move-In/Move-Out calls are received after the planned move; requires a back-dated read.
- Back-dated reads require paper-based final read forms.
- Metering Supervisor distributes Field Read Orders (FROs) to readers daily.
- Float Relief Clerk pro-rates consumption to stated move date.
- Re-Bills are often needed (approximately 10 percent of the 35 percent = approximately 4 percent of MIMOs = approximately 320 per year)
- 8,028 move-outs initiated, 300 reversed in most recent fiscal year.
- Vacancy monitoring process begins in SAP on the move out date.

- Vacancy Disconnect Order (VDO) is initiated by SAP when a move-in customer is not identified within five days of the move out date.
- SAP prints VDOs at Region Metering Offices.
- Each region's Field Service Technician (FST) IV picks up and executes the VDOs.
- If property appears vacant, FST disconnects and takes final reading.
- If not vacant, FST takes a reading and leaves a turn-off notification card.
- FST disconnects and takes final read if no new customer is confirmed within 48 hours of first visit.
- SAP creates a remove meter order when a property is vacant more than 90 days.

5.6 Collections Process and Analylsis

5.6.1 *AMI Benefits Affecting the Collections Process*

- Fewer unpaid bills
- Lower bad debt write-off
- Faster detection of unauthorized consumption at disconnect service points
- Fewer Disconnect Orders
- No Service Check Orders
- Fewer truck rolls for Disconnect Orders
- No truck rolls for Service Check Orders

5.6.2 *Collections Process Analysis Results*

Table 5-5 shows the results of the process analysis. These figures indicate some benefit to the Collections process from AMI, mainly through reduction in collection orders. Some of this benefit is a result of the assumption of monthly reading, and any benefits resulting from that would need to be examined if quarterly billing is continued.

The ability for the AMI to monitor for usage does provide a real benefit in reduced truck rolls to investigate unauthorized usage if a premise has been shut-off due to collections.

Table 5-5 Collections Process Analysis Results

	Collections Process Annual Labour Hours			
	Without AMI	With AMI	D Amt.	D Pct.
Customer Service Representative	8,667	4,333	-4,333	-50%
Field Service Technicians	1,592	842	-750	-47%
Meter Reader Supervisor	0	0	0	0%
Meter Reading Coordinator	0	0	0	0%
Billing Edit Clerks	1,821	908	-913	-50%
Billing Coordinator	0	0	0	0%
All Customer Service and Metering Personnel	12,079	6,083	-5,996	-50%

5.7 Customer Process Conclusions

The results of the efforts to determine how AMI could impact the customer service processes resulted in a significant reduction in the hours for reading, This was an expected benefit and core to AMI technology benefit realization. However there were additional labour reductions in the move-in/move out process as a result of the reduction in the need to visit the meter for final billing and start billing reads. Reductions in effort for collections were much less than anticipated. This was due to the need to make visits for shut-off. A greater reduction on effort can be realized If the policy on collections was revised to reduce the need for an in-person visit. Most savings in collections can be attributed to vacancy monitoring through the AMI once the account has been shut off.

6 Distribution Operations Analysis

6.1 AMI in Distribution Operations

AMI has the ability to provide powerful new tools for NRW management. Data from ALDs attached to service lines or valve stems can be transmitted to the Distribution Operations department using the AMI system. This data can provide Halifax Water with an early indication of leaks. Often, catching leaks earlier means the cost to repair damage and the surrounding landscape (i.e. street repairs) is less.

With AMI, Halifax Water could also compare all of the consumption in a district-metered area over a specific period to net production, and focus NRW efforts on areas where the difference was relatively high or had changed.

6.2 Workshop Overview

A non-revenue water workshop was conducted as a guided discussion led by Excergy's consultants. The participants were encouraged to share their knowledge, ideas, and questions concerning water distribution operations with and without the capabilities provided by an AMI. Most of the discussion focused on the means and methods used to detect, locate, and quantify water losses in the distribution system. The role of pressure management in water loss control was also discussed briefly. The information from the workshop, organized by topic, is compiled below.

6.2.1 Water Losses

Based on an Infrastructure Leakage Index (ILI) value of 2.5, the Commission's overall water loss performance level is considered best in class, particularly in a North American context.

- Calculated in the Commission's most recent year-end water audit;
- Using International Water Association (IWA's) methodology for calculating and describing water loss performance; and
- assumes an average meter under-registration of 1 percent for services smaller than 3 inches and 2 percent for services 3 inches and larger.

At the sub regional level, water loss performance is:

- "Excellent" in the Central region (ILI = 0.8);
- "Excellent" in the East region (ILI =1.6);

- “Good” in the West region (ILI = 4.6).

The large majority of known leaks (92 percent) are found on cast iron pipes and fittings. Cast iron pipes and fittings comprise approximately 44 percent of the water infrastructure.

Compared to the East and Central regions, the transmission and distribution lines in the West region are generally older and built with more cast iron pipe.

The Commission is “doing an excellent job” of managing its real losses.

6.2.2 Metering and Telemetry

- The average accuracy of the Commission’s small and large revenue meters is undetermined; consequently the Commission cannot confidently assess the volume and cost of its apparent losses.
- The existing meter test data for all meter sizes are insufficient for accurately determining average meter accuracies.
- Testing of large meters has been on hold in recent years. When a meter is reported as non-registering, Halifax Water replaces the Unitized Metering Element (UME) and performs maintenance as needed.
- The assumed averages for meter under-registration used in the Commission’s latest end-of-year water audit could be significantly less than, or more than, the actual averages.
- District Metering Area (DMA) meters are suitably accurate magnetic meters, are monitored via SCADA, and measure with cubic meter resolution.
- SCADA is used to monitor and record consumption, flow, and pressure at many of the Commission’s large accounts.

6.2.3 Leak Detection

- The participants do not believe that faster leak detection will significantly reduce the cost of leak repairs – the large majority of leaks are found and repaired before the leakage damages more of the system.
- Detecting, locating, and quantifying leaks in downtown Halifax is more difficult.
- High ambient noise hampers acoustic leak detection.
- Highly variable consumption at night limits the effectiveness of night flow analyses.

- Existing revenue meter data does not support DMA loss analyses.
- The East and Central regions do not have any leak detection crew working full time.
- East, West, and Central regional superintendents direct their crews' activities on the basis of their system knowledge and the district meter data acquired daily from the Commission's SCADA system. A significant increase in the volume measured overnight by a district meter indicates a possible leak downstream from the meter.
- The West region has one crew on part time leak detection duty during the summer months and two full time leak detection crews during the winter months.
- System operators use the Commission's SCADA system to monitor pressure sensors located strategically throughout the water system. A sudden drop in pressure at a sensor indicates a possible leak.

6.2.4 Pressure Management

- Advanced Pressure Management through flow modulation is implemented in one area of Dartmouth. More is planned.
- Adding well-placed pressure sensors throughout the system would enable better pressure management.

6.2.5 AMI Applications and Effects

- The participants agreed that the greatest financial benefit related to NRW will come from improving the accuracy of the billing data collected from the revenue meters.
- The participants are not sure about the cost-effectiveness of AMI-enabled ALDs in Halifax Water's case. They would want to implement a pilot to evaluate the technology.
- The participants expressed interest in testing an AMI-enabled ALD hydrant cap from Mueller.
- Daily collection of time-synchronized consumption data from AMI meters would enable daily comparisons of the measurements from the district meters (acquired via SCADA) with the sum of the measurements from the revenue meters within each district meter's area. For any time period, a significant difference between the two quantities will reveal leakage in the area.
- AMI meters could enable real-time alerts and time-series measurement data for backflow.

- System-wide availability of an AMI communications network could enable cost-effective deployment and use of more extensive pressure monitoring.

6.3 Analysis

The purpose of this analysis was to produce a reasonably accurate forecast of AMI benefits affecting the Commission's distribution operations. The analysis focused on NRW as this is the area where significant benefits are most likely.

6.3.1 Metrics

This analysis employs the approved 2014 rates for water/wastewater (assuming full AMI implementation is completed in or soon after 2016) and the cost, volume, and meter accuracy metrics used in, calculated in, and/or derived from the Commission's most recent end-of-year water audit, dated March 31, 2013:

- Production Cost of Finished Water: $0.053 per meters cubed ($m^3$)
- Consumption Rate for Water in 2016: $0.731/$m^3$
- Wastewater Discharge Rate in 2016: $1.658/$m^3$
- Average Meter Under-Registration Percent for Meters 3 Inches and Larger: 2.0 percent
- Average Meter Under-Registration Percent for Meters Under 3 Inches: 1.0 percent
- Total Water Losses (Apparent Losses + Real Losses): 6,295,681 m^3
- Apparent Water Loss from Under-Registering Meters 3 Inches and Larger: 245,077 m^3
- Apparent Water Loss from Under-Registering Meters Under 3 Inches: 246,953 m^3
- Annual Apparent Water Loss From Illegal Connections: 107,446 m^3
- Current Annual Real Losses (CARL): 5,696,000 m^3
- Unavoidable Annual Real Losses (UARL): 2,321,000 m^3
- Potentially Recoverable Annual Real Losses: 3,375,000 m^3

6.3.2 Assumptions

The following assumptions simplify this analysis while maintaining the usefulness of its results:

- 100 percent of customer meters will be AMI-enabled.

- 9,500 AMI-enabled ALDs will be installed throughout the distribution infrastructure (one ALD for every 10 service and hydrant connections).
- Following project completion, average meter accuracy for all meters will be near 100 percent with the error from over-registering meters effectively cancelling-out the error from under-registering meters.
- The AMI will collect each meter's register and interval data at least once daily.
- All meter register and interval data will be time-stamped and time synchronized.
- All meters will be capable of recording water consumption in interval periods down to 15 minutes or less.
- Analytics applied to AMI meter data will enable a 75 percent reduction of water losses from illegal connections.
- Analytics applied to ALD data, AMI meter data, DMA boundary meter data, and increased pressure management data may enable 15 to 20 percent reduction of annual real water losses by the potential to detect/locate leaks quicker.
- The labour associated with detecting and locating leaks will decrease following AMI implementation.
  - Assume a permanent reduction from the current level of nine FTEs (includes Regional Superintendents' time) to six FTEs.
  - Assume the average annual cost (including benefits) per FTE is $60,000 in Year 1 and increases linearly to $120,000 in Year 20.
- Faster leak detecting/locating will not result in lower average material and labour costs for leak repairs (per management input during the workshop).
- Planned meter asset life = 20 years.
- The water consumption rate is expected to decline 1.5 percent per year.
- Average meter under-registration progresses linearly from 0 percent for all meter sizes in Year 1 to 2 percent for large meters (3 inches and up) and 1 percent for small meters (under 3 inches) in Year 20.
- Total annual volumes of water consumed and wastewater discharged is expected to drop 2.5 percent per year over the next 15 years.
- Customer growth of 1% per year is expected.

- 4 percent average interest rate over the 20 year life of the meters.

6.3.3 AMI Impact on Apparent Losses

Based on the above metrics and assumptions, improved meter accuracy and effective use of AMI meter data will eliminate 545,753 m^3 of annual apparent losses in the first full year of operation.

Apparent Water Loss from Under-Registering Meters 3 Inches and Larger: 245,077 m^3

Apparent Water Loss from Under-Registering Meters Under 3 Inches: 246,953 m^3

50 percent of Annual Apparent Water Loss from Illegal Connections[1]: 53,723 m^3

Reduced Volume of Apparent Losses in Year 1: 501,030 m^3

Reduced Volume of Apparent Losses in Year 20: 50,103 m^3

Consumption Rate for Water in Years 1 to 20: \$0.731/m^3

Wastewater Discharge Rate in Years 1 to 20: \$1.658/m^3

Revenue Lost per Cubic Meter of Apparent Water Loss, Years 1 to 20: \$2.389/m^3

6.3.4 AMI Impact on Real Losses

- CARL: 5,696,000 m^3
- UARL: 2,321,000 m^3
- Potentially Recoverable Annual Real Losses (CARL – UARL): 3,375,000 m^3
- 15%[2] of Potentially Recoverable Annual Real Losses (Losses): 506,250 m^3
- Production Cost of Finished Water (Production): \$0.053/m^3
- Avoided Annual Cost of Real Losses (Losses x Production): \$26,831 (\$536,625 over 20 years)

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[1] AMI not expected to reduce losses through illegal connections

[2] Expected benefit is 15-20% - 15% used for a conservative measure

6.3.5 AMI Impact on Leak Detection/Location Labour

- Potential reduction of Labour for Detecting and Locating Leaks (Leaks): 3 FTEs
- Average Year 1 Cost per FTE (C_1): $60,000
- Average Year 20 Cost per FTE (C_{20}): $120,000
- Year 1 Labour Cost Avoided (Leaks xC_1): $180,000
- Year 20 Labour Cost Avoided (L xC_{20}): $360,000

6.4 Conclusion

Water AMI systems support ALDs. With AMI, daily collection of time-synchronized consumption data from AMI meters would enable daily comparisons of the measurements from the district meters (acquired via SCADA) with the sum of the measurements from the revenue meters within each district meter's area. For any time period, a significant difference between the two quantities will reveal leakage in the area.

There is potential payback on the deployment of ALDs, however for Halifax Water these benefits may be limited for two reasons:

1. This benefit is most pronounced where water resources are an issue. With the relatively abundant Halifax water supply, the benefit is less likely to be as much a concern or priority. However there is still a benefit, albeit minor, in the savings of energy, and cost for treatment on saved water through the leak detection efforts.
2. Halifax Water already does an extremely good job of DMA management and monitoring of usage comparisons. While ALDs might improve the accuracy, and possibly identify leaks on the system faster, it is still not certain that this benefit would be of significance.

Any limited AMI benefits associated with detecting and reducing NRW can provide a benefit to the financial analysis. The financial analysis of this benefit are applied in the Economic and Financial Analysis section.

In light of the limited and unquantifiable benefit, it is the impact that can be attributed to the business case is uncertain. Halifax Water should investigate the use of ALDs and evaluate their effectiveness, especially in the low and intermediate DMA's of the West Region where background noise makes it difficult to locate and pinpoint leaks using traditional methods.

It should be noted AMI could support Halifax Water in meeting its Corporate Balanced Scorecard Goal of leakage allowance of 185 liters per service connection per day.

6.5 Task 6 Workshop

Date:	July 25, 2013
Time:	8:30 am – 12:30 pm
Location:	450 Cowie Hill Road, Halifax
Halifax Water Participants:	Tim Burbine – Water Services, Central Dave Hiscock – Water Services, East Barry McMullin – Water Services, West Graham McDonald – Technical Services, Water Debby Leonard – Customer Services and Finance Corey Whalen - Metering
Excergy Consultants:	Mark Johnson Andy Owens

7 Task 7 – Consumer and Demand Response

Demand Response is a term that has been adopted by some water utilities from the AMI/Smart Grid concept for electric utilities, and refers to changes in consumption patterns in response to price and information signals from the utility. Depending upon their circumstances, water utilities may have different objectives for demand response. In some circumstances, when supply is scarce, either chronically or in times of drought, the utility may need its customers to curtail usage. For some utilities, a large peak-to-average production ratio (also known as the load factor) means that facilities may have to be built for storage and distribution that are used to much less than their full capacity except for short periods, resulting in capital inefficiency. Such facilities might be built larger and sooner than would be needed with a better system load factor. Improving the system load factor means that capital will be used more efficiently. Some utilities also face much higher treatment and pumping costs during peak periods.

AMI for water utilities can affect consumer behaviour by providing updates to the customer on daily use and consumption. This “feedback loop” to consumers on their use throughout the month could reduce the overall demand on a water system, thereby benefitting the utility. However, the reduction in revenues may need to be offset by other revenue sources.

Halifax Water is in the envious position of having a strong water supply. Any conservation and demand response efforts might be off-set by a reduction in revenues to the point of diminishing returns. The greatest benefit to Halifax Water would be a reduction in load on the wastewater system - which is somewhat strained - and by a reduction in chemical and electrical costs for water treatment and processing.

8 IT Review and Memorandum

8.1 Synopsis

As part of the Study, information was shared during an on-site workshop about the integration opportunities and constraints related to implementing an AMI. Following a brief overview of the Workshop, this section describes Halifax Water's current information systems, reviews the current plans for information systems, and presents Information Technology and Operational Technology planning considerations related to implementing and integrating an AMI.

When informed by the contents herein, readers will have a better basis for understanding and acting on the following points:

1. Implementing a productive AMI at Halifax Water is technically feasible.
2. The degree of AMI productivity achieved depends on the extent to which AMI data and capabilities are employed by the organization's business and operating processes. Those processes are supported by multiple applications and databases running on multiple systems in multiple locations; consequently, integration is essential.
3. All feasible AMI strategies have distinct technical characteristics that will either enable or hinder cost-effective integration between the AMI and other Halifax Water systems. With each feasible strategy, the integration resources of the AMI solution must interact with integration resources in the other systems. In many cases, an interaction will require the transport, translation, and/or coordination services of a separate integration solution.
4. A unified enterprise integration policy and framework will greatly improve the prospects for implementing a productive, well-integrated AMI. This is not yet a reality at Halifax Water, where current practices involve loosely coordinated development of ad hoc interfaces.
5. A well matched MDM solution facilitates cost-effective integration between an AMI and other systems.
6. A MDM solution can be implemented through use of a distinct, self-contained MDMS or the solution can be created by integrating processes and data in multiple systems.
7. The timing and structure of an AMI implementation should be a well aligned part of the organization's plans for future technology and business process changes. For example, utility best practices recognize MDM as an essential, foundational

process that should be operational prior to deploying an AMI. Other foundations include AMI-related additions and changes to the systems, data, interfaces, people, and work processes that enable Halifax Water's customer service, billing, and asset management functions.

8. Some water AMI products were developed as primarily standalone systems with limited provisions for integration with other utility systems. Those integration limitations could be a barrier to achieving some significant potential benefits.
9. Many current AMI and MDM products were developed with a strong focus on electric utility functions and generally include abundant provisions for integration interfaces with other electric utility systems. The generic aspects of many of those functions and interfaces are highly relevant to a water utility; consequently, some of those products have been successfully adapted for water utilities (often by the water division of a multi-service utility). In some instances, they are more elaborate than needed for water utility functions. Some recent MDM products are specifically water-oriented.
10. Adapting a product's electric utility functions and interfaces for use by a water utility will generally require time and expense for modifying the product's configuration, data model, interfaces, and/or code.

8.2 Workshop Overview

Excergy's Consultant facilitated a sequence of discussions concerning integration of an AMI implementation with the information systems supporting the Commission's business and operating processes. The group's discussions focused first on characterizing the existing and currently planned system frameworks; then, the group considered some of the ways that an AMI implementation might affect – or be affected by – those frameworks.

Date: August 13, 2013

Time: 8:30 am – 3:00 pm

Location: 450 Cowie Hill Road, Halifax

Halifax Water Participants: Reid Campbell – Water Services
Graham McDonald – Technical Services, Water
Harold MacNeil – Engineering Information
Daya Pillay – Information Services
Terry Thorne – Information Services
Debby Leonard – Customer Services and Finance
Corey Whalen – Metering

Fred Roumilhac – IBM, SAP Support Services (by phone)

Excergy Consultants: Andy Owens

8.3 Existing Information Technology / Operations Technology Environment

8.3.1 SAP

Halifax Water is using a dedicated instance of the SAP Enterprise Resource Planning (ERP) ERP Core Component (ECC) 6.0 that is running on a shared system platform located remotely at the Provincial Data Center. This instance of SAP ECC 6.0 is currently being upgraded to the next enhancement package, EhP5.

Within its ECC environment, Halifax Water is using SAP's industry solution for utilities (IS-U), an application component that can support most business processes and utility services of a utility company. Core IS-U capabilities include master data management, device management, and billing. The current IS-U implementation is integrated with SAP's Customer Care Services (CCS) component and supports management and billing for residential, commercial and industrial customers.

Other ECC 6.0 components used by Halifax Water include:

- Financial Accounting for general ledger, accounts payable, accounts receivable, and cash management.
- Controlling for cost center accounting, budgeting, and funds management.
- Materials Management for procurement and inventory management.
- Plant Maintenance for work orders and scheduling.
- Human Resource (HR) Management for organization and payroll functions.

- IBM provides SAP system administration services for Halifax Water.
- Fred Roumilhac of IBM is a SAP subject matter expert assigned to Halifax Water.
- Application configuration, development, and enhancement activities are performed by SAP.
- Integration between SAP IS-U/CCS and other information systems are minimal.
- Daily file exchanges between SAP IS-U/CCS and the Neptune N_Sight meter reading management server, comprising meter reading requests from SAP and results from N_Sight, are performed via a custom interface that uses Neptune text file formats. The exchanges of reading requests and results are initiated manually.
- A custom interface enables collection of final readings from a custom applet in BlackBerry smart phones that communicate directly with SAP IS-U/CCS via cellular data links. The links are secured by a “Relay Server” located at the Provincial Data Center.
- SAP IS-U/CCS generates bill production files that are then sent to Saint Joseph’s Print Group, an outside provider of bill printing and mailing services.
- Halifax Water’s users access the SAP applications via SAP Web Application Servers located at the Provincial Data Center.

8.3.2 Neptune N_Sight R900 Meter Reading System

The existing R900 system manages quarterly and monthly meter data collection by several means:

- Meter readers on foot use handheld computers that enable quarterly meter data acquisition by manual data entry (keyed), through an inductive probe (probed), and via a low-power RF transmission from the meter.
- Meter readers in vehicles equipped with mobile receivers collect monthly meter data as they drive by meters that are equipped with low-power radio transmitters – commonly referred to as AMR.
- The handheld and mobile data collectors communicate with the host server from remote office locations using the corporate network.

The system is set up in a client/server configuration where:

- The host software runs on a dedicated windows server located at Halifax Water's facility on Cowie Hill Road.
- The host software runs the system's application processes, manages the system database, controls communications with the data collection devices, and provides browser-based system access to administrators and users.
- The software's built-in provisions for interfaces with external systems are very limited.

8.3.3 Enterprise Network

- Halifax Water's enterprise data communications network comprises local area networks (LANs) at 16 facilities that are interconnected mostly by a wide area network (WAN).
- The facility LANs are made up of one or more wired and/or wireless (Wi-Fi) Ethernet segments that are tied together locally by network routers and/or switches.
- The WAN, provided by Eastlink, is implemented in the form of a multiprotocol label switching (MPLS) network infrastructure virtual private network (VPN) that operates within Eastlink's MPLS network infrastructure.
- Fourteen of the facilities are connected to Eastlink's MPLS network via 100 megabyte (MB) access links; the operations depot in Sackville is connected via a 1 gigabyte (GB) access link, 11 Riverview, and 88 Lockview connect utilizing Eastlink's VPN service
- The corporate campus at Cowie Hill Road is connected with 10 GB of access link capacity and 455 Cowie Hill is connected directly via fibre between the two buildings.
- Halifax Water's current level of WAN utilization is in the range of 5 percent to 20 percent.

8.3.4 SCADA Network

Halifax Water's SCADA system for the water distribution infrastructure employs network resources that convey data communications between five separately located Human-Machine Interface (HMI) servers and their respective groups of Remote Terminal Units (RTUs).

- Each HMI server comprises a Microsoft Windows server platform running SurfLine SCADA software Trihedral's VTScada HMI software that:

- acquires, logs, processes, and presents measurement, status, and event data from remote sensors;
- creates and manages alarm notifications when the acquired data indicate problem conditions; and
- enables water system operators to remotely control water and wastewater system components.

The locations and uses of the HMI servers are as follows:

- Pockwock Water Treatment Plant: monitors and controls water distribution facilities at 49 sites in the Western Region.
- Lake Major Water Treatment Plant: monitors and controls water distribution facilities at 44 sites in the Eastern Region.
- Mann Street Depot: monitors and controls water distribution and wastewater collection facilities at 103 sites in the Central Region.
- Cowie Hill Depot: monitors and controls wastewater collection facilities at 67 sites in the Western Region.
- Bisset Road Depot: monitors and controls wastewater collection facilities at 70 sites in the Eastern Region.

The SCADA network is radio-based and comprises a combination of unlicensed 900 megahertz (MHz) Digital Spread Spectrum (DSS) radios and licensed ultra-high frequency (UHF) radios, providing continuous two-way data communications for SCADA RTUs serving both the water distribution and wastewater collection systems.

- The UHF radios provide low-speed (1200 bytes per second (bps)) serial data communications over individually licensed, point-to-point, radio links between the HMI servers and older vintage SurfLine RTUs. Those RTUs require use of a communications protocol and data format that is archaic and vendor-proprietary.
- The DSS radios provide HMI servers with medium-speed (80 to 115 kilobits per second (kbps)), point-to-multipoint, Ethernet data communications links with upgraded Schneider RTUs that employ a standard communications protocol with encryption.

Halifax Water is in the midst of a major, multi-year SCADA upgrade that includes replacing all of the SurfLine RTUs and their UHF radios with Schneider RTUs and DSS radios. As of mid-2013, DSS radios were deployed at 95 RTU sites and 16 repeater sites in the Western, Central, and Eastern regions and at three of the HMI server locations (Pockwock, Lake Major, and Mann Street). UHF radios remained in use at 238 RTU sites and 29 repeater sites in the Western, Central, and Eastern regions and at all five of the HMI server locations listed above.

- All SCADA HMI servers periodically export their time-series data (measurements, status flags, events, and alarms) to an OSIsoft PI System via Halifax Water's enterprise network.

8.3.5 OSIsoft PI System

The PI System serves as the master repository for 5,000 process data points from all Halifax Water SCADA systems (water and wastewater). Each SCADA HMI Server communicates with the PI System via an interface that complies with the Object Link Embedded (OLE) for Process Control (OPC) standard for secure intersystem data access across a network. The PI System operates on a single Windows server located at the Water Operations Depot in Sackville.

PI Server software provides the foundation for the PI System's capabilities. The software collects, archives, and distributes real-time data from multiple, diverse sources. In addition to running the core PI Server software, Halifax Water's PI System employs the following add-on software modules:

- PI ProcessBook: Enables design and implementation of display graphics for visualizing PI System data.
- PI DataLink: A Microsoft Excel add-on that enables a user to retrieve information from the PI Server directly into a spreadsheet. Excel's computational, graphic, and formatting capabilities provide tools for gathering, monitoring, analyzing, and reporting PI data.
- PI WebParts: Provides users Web-based access to graphical and tabular presentations of PI System data.

Halifax Water uses the PI System to provide its operators and managers with tools for monitoring and managing water losses, along with visualizing and analyzing the operation and performance of the water distribution system, waste water collection system, water and waste water treatment facilities.

8.3.6 Geographic Information System

Halifax Water's GIS is an enterprise system which delivers GIS data and application services to approximately 200 users within the organization.

The system is based on the Environmental Systems Research Institute (ESRI) ArcGIS platform hosted by a dedicated system instance running in a multi-level server environment located at the Halifax Regional Municipality (HRM).

The system's geodatabase contains geospatial and attribute data for water, wastewater, and storm water assets (valves, hydrants, service connections, manholes, catch basins, pumping stations).

Halifax Water also has access to topological and other information layers through agreements with HRM and Province of Nova Scotia.

8.3.7 Meter Upgrade Program

Halifax Water is part of the way through a multi-year water meter upgrade program that is budgeted for installing roughly 10,000 AMR-enabled residential meters in each of the next five years. At this point in the program, Halifax Water has installed more than 31,000 AMR meters.

- The MIU on each of those installed meters is equipped with a radio transmitter that periodically (every few seconds) transmits the latest set of data from the meter (register reading, interval values, flags). The data transmitted by the MIU can be received by a handheld or mobile, data collector. The MIUs are not equipped with radio receivers; consequently, they cannot support the two-way communications required by an AMI.
- 12,734 of the installed meters are equipped with external, wall-mounted radio modules that may be suitable for communicating with fixed-base data collectors.
- 18,627 of the AMR meters are equipped with internal radio modules that will generally have limited range (when installed below grade) and are most suitable for data collection by handheld and/or mobile data collectors.

8.3.8 Other Info

Halifax currently lacks an enterprise-level policy and architecture for integrating its information systems.

8.4 IT/OT Development Plans

8.4.1 SAP

Halifax Water plans to continue using the existing SAP applications for the foreseeable future, with maintenance/version upgrades, configuration changes, and functional enhancements being installed as needed.

Significant SAP modifications and integrations will be needed to support Halifax Water's current plans for new and enhanced information systems.

8.4.2 Computerized Maintenance Management System

Halifax Water is in the early stages of planning implementation of a CMMS that is intended to improve the organization's capabilities and performance in the following areas:

- collecting, consolidating, managing, processing, and distributing information describing the status, condition, attributes, and work associated with all water, wastewater, and storm water system assets;
- receiving and responding to customers' calls; and
- managing cross-functional workflows associated with asset management and customer services.

The planned scope of CMMS functions will require extensive integration with other information systems (SAP, GIS, and Document Management).

The CMMS project is considered Halifax Water's most important IT initiative, with major investments in development and implementation planned over the next five years.

- HRM is currently issuing an RFP for an Enterprise Asset Management (EAM) solution that might (or might not) be a suitable resource for fulfilling some of Halifax Water's CMMS objectives.
- Halifax Water and HRM are collaborating on development of a uniform data model and uniform semantics for assets.

8.4.3 GIS Data Program

Halifax Water is expanding and enhancing the GIS information base to achieve full coverage of all water, wastewater, and storm water assets. The goal is to substantially improve system data analysis, operational and business decision- making, and documentation of system knowledge. The program is a major ongoing initiative with significant development planned over the next several years.

8.4.4 Electronic Document Management System

The planned Electronic Document Management System (EDMS) will serve as Halifax Water's enterprise repository for unstructured data (document files, spreadsheets, reports, presentations, graphics, photos, scanned documents, etc.). Much of the system's value will be achieved through integration with several of Halifax Water's other information systems (SAP, CMMS, GIS, etc.). System development is planned to begin in 2014 with phased implementation of capabilities expected through 2016 and beyond.

8.4.5 SCADA Upgrade

The current SCADA Upgrade Master Plan encompasses replacing all SCADA RTUs and replacing the radio network that provides data communications links between the RTUs and their respective SCADA HMI servers. The plan also includes adding OPC Systems (opcsystems.com) data access connections and processing/visualization tools for several (or perhaps all) of the Wastewater Division's HMI Servers.

Completion of the current Master Plan is expected in Fiscal Year 2016-17; at which time the Master Plan will be updated based on the capabilities achieved and future requirements.

8.4.6 Electronic Billing/Payment

Workshop participants indicated that electronic billing and payment capabilities will probably be developed and implemented in the 2015 to 2016 timeframe. No details regarding possible implementation strategies.

Implementation will require developing and/or configuring new capabilities in SAP's customer accounting, billing, and web server components.

8.4.7 Customer Portal

Workshop participants indicated that a customer web portal will possibly be developed and implemented in the 2015 to 2016 timeframe. Customer portal applications commonly include service arrangements, account status, bill payment, billing history, historical consumption profiles, and current consumption data. No details regarding possible implementation strategies.

Implementation will require developing and/or configuring new capabilities in SAP's customer care, billing, and web server components.

8.5 AMI Considerations

8.5.1 SAP

SAP's application suite for utilities (IS-U/CCS) can be enhanced by adding a business function module that enables productive use of an AMI by SAP's utility application components. The utilities business function module for AMI, named ISU_AMI, provides capabilities supporting the following AMI-related functions:

- coordinating meter data collection
- monitoring and managing AMI meters and devices
- information and transactions supporting customer service (i.e. on-demand readings)
- disconnect and reconnect customer services remotely
- processing consumption profiles using profile values from a MDMS
- time-of-use billing based on consumption interval data
- monitoring AMI communication and archiving service logs
- recording and managing meter and device event data
- executing business functions determined by business rules for event responses
- sending messages to meters or in-home displays

The ISU_AMI business function requires interoperation with an external MDMS that complies with SAP's published interface for Meter Data Unification and Synchronization (MDUS). At this time, SAP has certified MDUS interoperability with MDMS software from eMeter (Seimens), Itron, Oracle, and OSIsoft.

A MDUS compliant interface requires services provided by SAP's bundle of enterprise services for AMI (AMI-ES). Enterprise services provide a standards-based way of encapsulating and exposing enterprise functionality as a reusable business service that can be combined with other services to meet new requirements. The AMI- ES bundle provides enterprise services that allow information to flow back and forth between the meters, the metering system platform, and SAP back-end systems running in SAP ERP 6.0 (CIS, billing, asset management, work management, etc.).

The SAP backend systems use the services in the AMI- ES bundle to communicate with SAP's NetWeaver Process Integration (SAP PI), a component of the NetWeaver product group. Built on SAP Web Application Server, SAP PI enables standards-based exchanges of information among a company's internal software and systems and those of external parties, including non-SAP systems. SAP describes PI as an integration broker that mediates between entities with varying connectivity, format, and protocol requirements. When supporting AMI integration, SAP PI processes extensible markup language (XML) messages that transfer data between the SAP backend systems and the metering system platform.

When planning for AMI integration with SAP, it is important for a water utility to understand that the AMI and MDM functions and data elements in SAP's utility applications, and in the

MDUS interface, are designed, documented, and provided in the context of electric utility applications. Nonetheless, most of the solution set has generic capabilities that are highly relevant to a water utility and can likely be well-adapted for water utility applications. Extra time and expense would be needed for identifying, characterizing, implementing, and supporting the necessary adaptations. Alternatively there are MD products for water utilities that are less expensive and would probably require fewer adaptations.

8.5.2 Neptune ARB N_Sight R900 System

Depending on the functional and performance capabilities required to achieve Halifax Water's goals, the existing ARB N_Sight R900 software could be part of a suitable solution strategy. When enabled by a network of Neptune's stationary RF receivers (R900 Gateway), the N_Sight R900 host software can act as a "fixed-base AMR" that manages daily collection of meter readings and condition data transmitted from compatible R900 MIUs and from ALDs equipped with compatible RF transmitters. This approach employs a one-way communications solution that can support monthly billing, off-cycle meter readings, virtual disconnects, daily collection of hourly consumption profiles, and daily detection of customer leaks, tampers, and backflows. Following, are some important considerations:

- The R900 software is designed specifically for water metering; will concurrently support data collection by fixed-base AMR, mobile AMR, and handheld data collectors
- The R900 system was designed for mobile AMR, and because many of Halifax Water's R900 MIUS are integrated with meter registers and installed below grade, a large number of data collectors might be required.
- Neptune plans to release a version of their N_Sight IQ product that will interoperate with the R900 software. N_Sight IQ is implemented as a cloud-based application system (software as a service) that provides long-term meter data retention and management, analytics, reporting, web presentment for utility employees, and a customer web portal.
- Neither the R900 software or N_SIGHT IQ supports an MDUS-compliant interface for interoperation with SAP's utility applications; consequently, custom interfaces would be needed for nearly all information exchanges between the two vendors' systems.
- OSIsoft has not developed a headend system (HES) interface for Neptune's AMR or AMI systems; consequently, custom interfaces would be needed for nearly all information exchanges between the two vendors' systems.

8.5.3 Enterprise Network

The LANs and WAN comprising Halifax Water's enterprise network are well suited for providing the core of the network needed for carrying communications between an AMI HES and the AMI data collectors (also known as, the backhaul network). The WAN node locations are well distributed across the company's territory; there is more than enough capacity to support an AMI's comparatively modest needs; and, the standards-based network technology is up-to-date, highly resilient, and readily compatible with the large majority of AMI offerings.

To access and use the Enterprise Network, most AMI solutions would need intermediate backhaul links for connecting WAN nodes with the AMI data collectors in their vicinity. These intermediate links could be implemented in any number of ways using public carrier services and/or or company owned assets.

Another alternative for AMI backhaul communications would be to add the AMI data collectors as nodes in the Halifax Water VPN that runs on EastLink's MPLS infrastructure. The feasibility of this approach would depend on a number of factors including: availability of MPLS service at the data collector locations, the number of data collectors, and the cost of MPLS service.

8.5.4 SCADA Network

Parts of the SCADA network that have been upgraded with the FreeWave DSS radios could support backhaul communications between AMI data collectors and the Enterprise Network's WAN nodes. However, this approach should be evaluated carefully as shared use of the same radios (and their attached Ethernet segments) for both SCADA and AMI might cause unacceptable reliability/performance risks for critical SCADA communications. An alternative approach, involving less potential risk but more radios, would use the same DSS radio technology for providing a separate, parallel intermediate backhaul network dedicated to AMI. Significantly, a solution that employs the same DSS radio product(s) would use field-proven technology that is known to perform well in Nova Scotia and would simplify network management and maintenance. Note that network planners should determine whether the DSS radio's performance capabilities will be an adequate AMI solution for data collectors that communicate with large numbers of meters (for example, a Sensus Tower Gateway Base Station can support tens of thousands of endpoints).

8.5.5 OSIsoft PI System

With the appropriate add-ons, the PI System can operate as an MDUS-compliant MDMS that can readily support AMI/MDM related interactions with SAP's utility applications. To operate as a MDMS, the PI System employs one or more AMI interface packages that enable several types of interaction between the PI System and one or more AMI headend systems. At this time, OSIsoft has developed and certified vendor-specific interface packages for the AMI headend systems from Silver Springs Networks, Grid Net, Trilliant, and Elster. OSIsoft has also developed and certified an AMI interface package that uses MultiSpeak, a specification/standard that defines the details of data exchanges between software applications that support the processes commonly applied at electric utilities; thus, the PI System can also interoperate with AMI headends that support MultiSpeak.

As is the case with SAP, it is important for a water utility to understand that the AMI/MDM functions and data elements in the PI System environment, and in the MDUS interface, are designed, documented, and provided in the context of electric utility applications. Similar to SAP, the PI System's generic AMI/MDM capabilities are, nonetheless, highly relevant to a water utility and can likely be well-adapted for water utility applications (with extra time and expense needed for identifying, characterizing, implementing, and supporting the necessary adaptations).

Further, with some other software enhancements, and some data model modifications, the PI System could provide Halifax Water with a single operational data repository that enables effective integration and use of AMI data as a tool for managing water operations. Necessary changes to the existing system would most likely include adding the PI Asset Framework module which provides capabilities for organizing, analyzing, presenting, and acting on multi-dimensional data (device data, GIS coordinates, measurements, status, events, etc.) for a large and diverse set of operational assets, including AMI meters. If the PI System concurrently acts as the MDMS, then the AMI data needed for an operational data repository is already residing in the system and can be provided internally. Or, if MDM is performed by a separate MDMS, then the PI Server would use one of several possible interface options for interacting with the MDMS.

Finally, Halifax Water's technical familiarity and productive experience with its PI System warrant consideration as AMI and MDM strategy options are developed and evaluated.

8.5.6 Geographic Information System

Prior to deploying an AMI, Halifax Water could enable future efficiencies by creating new layers - or modifying existing layers - for capturing, managing, and presenting data associated with the AMI meters, other AMI endpoints (i.e. acoustic leak detectors), and AMI network components. With ESRI's broad and well-proven proven provisions for standards-based interfaces, Halifax Water would then be in a good position to implement useful AMI-related interactions between the GIS and applications running in other systems (CIS/Billing, Asset Management, Pressure Management, Water Loss Analytics, Work Management, MDMS, etc.).

8.5.7 Computerized Maintenance Management System

Workshop participants predicted that the workload for the CMMS project will severely limit availability of staff resources (IT, Technical Services, Operations) for concurrently planning, managing, and/or executing other IT/OT projects, including an AMI (if planned). However, the administrative and financial mechanics that would go with launching an AMI project require a significant amount of time; consequently, if the CMMS project progresses as currently planned, then the project could be well on its way to completion before an AMI project would begin to need some of the same staff resources. This means the effect on starting AMI implementation could be minor.

With the CMMS project in its early planning stages, it is important to note that the planned project scope includes implementing asset management, work management, workflow coordination, and call center support capabilities that are foundational for a well-integrated AMI/MDM solution. If Halifax Water decides to implement an integrated AMI/MDM, then its value will be substantially affected by the strategies and provisions for its integration with the CMMS.

8.5.8 Electronic Document Management System

The EDMS could be used as the main repository for unstructured content that is related to and/or generated by an AMI and MDMS. The set of possible content types includes photos, drawings, report graphs and tables, scanned images, map files, document files, audio, and video. With exposure of effective integration services, the content items in the EDMS could be made accessible for incorporation by applications running on other systems (SAP, PI Server, GIS, etc.). Likewise, those other systems could automatically deliver AMI-related content to the EDMS for archiving.

9 Strategic Alternatives

This section presents Excergy's evaluation of Halifax Water's meter population and its current reading processes and an analysis of strategic alternatives based on the data provided, based on discussions with Halifax Water staff throughout the feasibility interactions.

9.1 Meter Population Analysis

9.1.1 Reading Types

Halifax Water has three different meter reading technologies, relatively evenly dispersed throughout its service territory.

Essentially all of Halifax Water's meters are inside set, with registers designed for remote access through the following methods:

- Keyed – These meters have pulse generator registers with remote display registers on the outside of customers' premises that require manual read and input into a reading handheld device.
- Probed (Touchpad) – These meters have dial position ("absolute") encoder registers connected to a magnetic inductance touchpad device. The meter is read using a probe incorporated in the handheld meter reading device that is placed on the touchpad
- RF – These meters have a radio device that transmits the reads through a radio signal to a drive- or walk-by reader.

The numbers of each reading type are shown in the following figure:

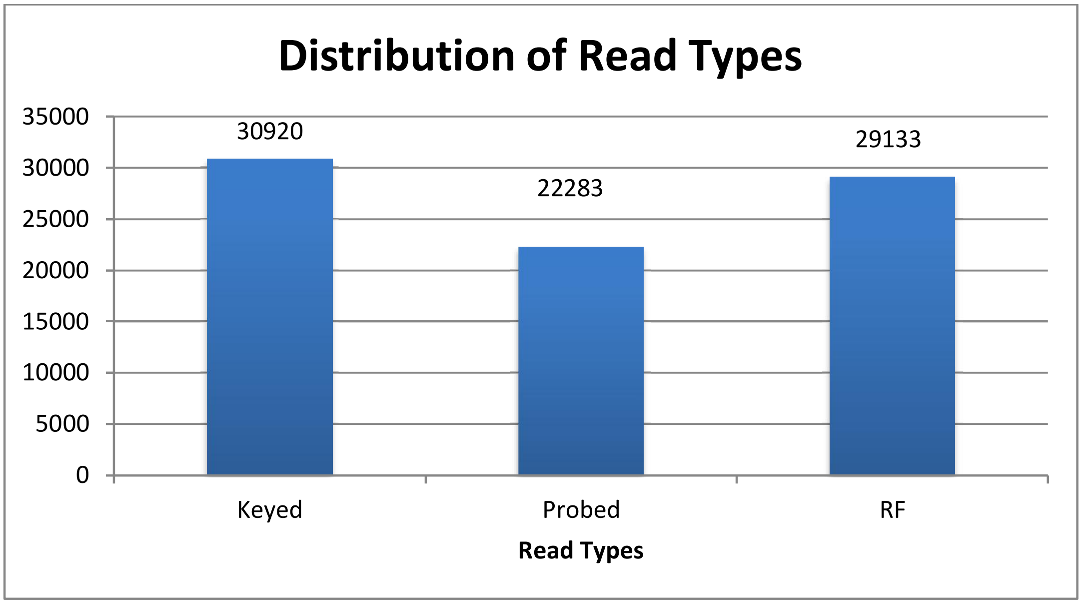

Figure 9-1 - Number of Read Types (as of March 31, 2013)

In addition to the relatively equal split among read types, a spatial analysis showed a relatively uniform geographic dispersion of the reading types. This distribution of meter reading technologies is operationally inefficient for Halifax Water meter readers. Readers are required to walk a route to capture reads from the display, or touchpad. This creates an environment where the reader has to capture the reads differently from house to house depending on the read type. Figure 9-2 shows a representative neighbourhood of the mixed reading types of meters in the current environment.

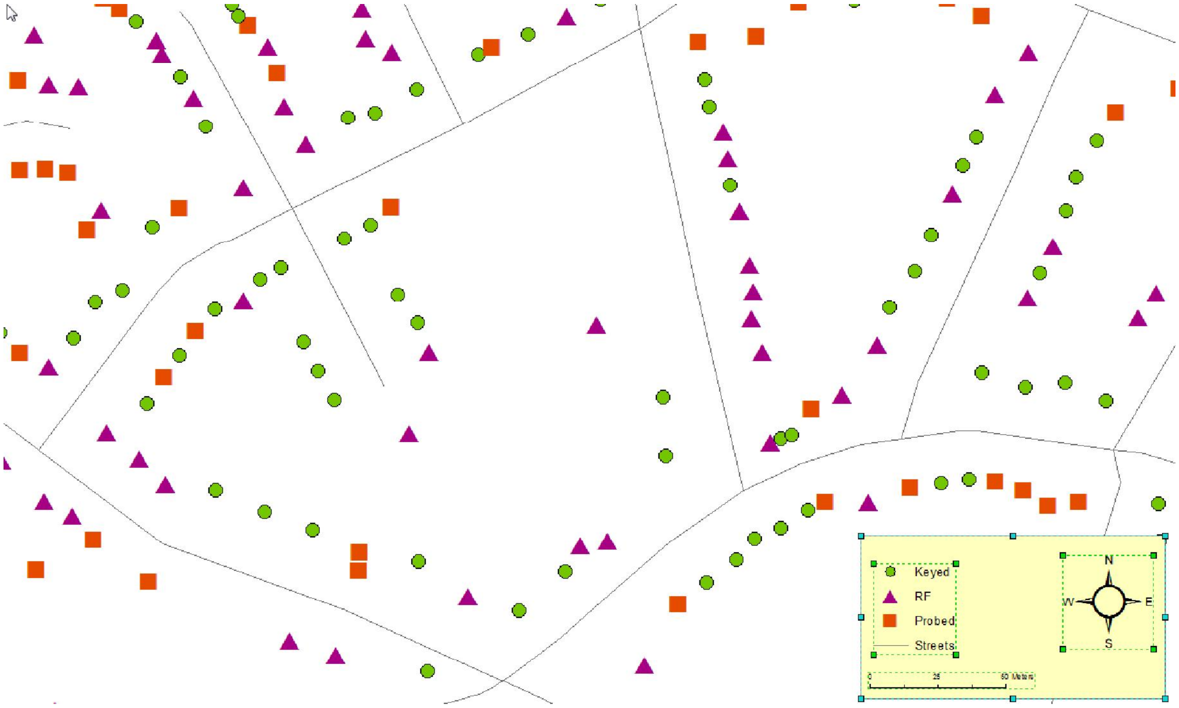

Figure 9-2 Mixed reading types snapshot

9.1.2 Meter Population by Age and Manufacturer

In addition to the three read types, the meter population is a mixture of manufacturers, as Halifax Water has bought from different vendors over the years. Most recently Halifax Water has purchased the majority of its meters from Neptune. The meters are split among the following manufacturers: Neptune, Kent, Badger, and Sensus. There is also a population of meters that the manufacturer is unknown. A manufacturer of these meters was not in the historical data merged to the current data. The distribution of meters by manufacturer and age indicate better than half the meters have been installed since 2000. Figure 9-3 hows the distribution of meter manufacturers by age of install.

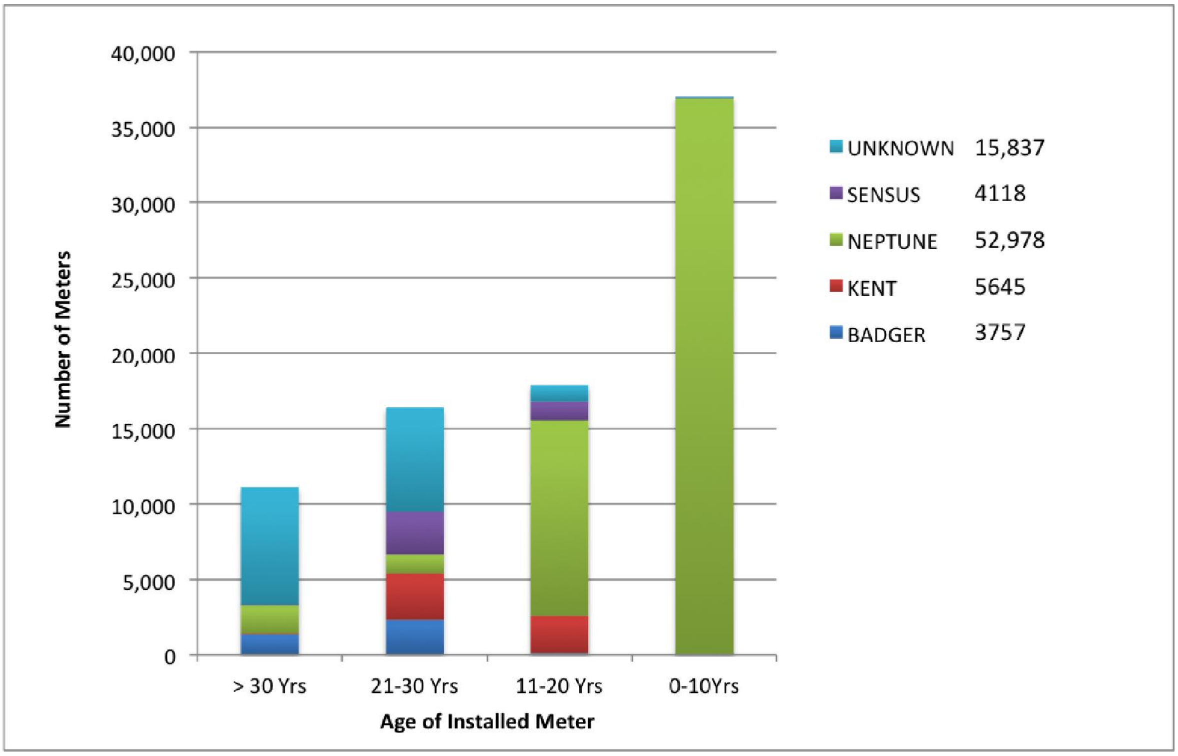

Figure 9-3 Meter Population by Manufacturer - As of 20/6/13

Halifax Water metering department is slowly changing the reading technology over to AMR in conjunction with the age-change replacement of meters, new installs, and the maintenance of large meters and failed meters. In recent years, Halifax Water has been installing the Neptune R900i model for the smaller (mainly 5/8 inch) meters, and to date has approximately 19,000 R900i 5/8 inch meters installed. These units have the AMR radio integrated with the meter.

While Neptune indicates the Neptune R900i can be utilized on a fixed network system, the power of the radio does not provide a strong enough signal to reach beyond a block or so, especially when installed inside a structure or in a basement. This design is recommended for drive-by AMR systems, and is typically not practical for AMI unless the density of transmitters and data collectors is high.

In addition to the Neptune R900i, Halifax Water has installed approximately 13,000 Neptune R900 units on all makes of various sized meters. These meter interface devices use the same radio as the R900i, but are not integrated with the meter and can be wall mounted. While they might be used on an AMI system, these units are often installed inside structures and in basements, thereby reducing the radio range of these installations.

9.1.3 Meter Population by Manufacturer Type

The spread of meter manufacturers across meter population can be relevant in determining a strategy of deployment. Information presented at the Strategic Alternatives workshop indicated the meter population to be somewhat locally focused, whereby Central has a higher concentration of Badger meters, Dartmouth has more Kent meters, and the majority of meters in Halifax are Neptune. This information, along with a strategy of deploying by route, can be used in the planning of the deployment of a project.

9.1.4 Meter Population Quality and Accuracy

An analysis of the weighted accuracy at high and flow rates of a sample of meters tested by Halifax Water suggests that the meters on the Halifax Water system hold their accuracy for a relatively long time. The tested meters accuracy remains over 35 years. This may be a result of the water quality in the system, however no analysis was made to confirm water quality impacts to longevity of the meters.

The meter test data provided showed the following results:

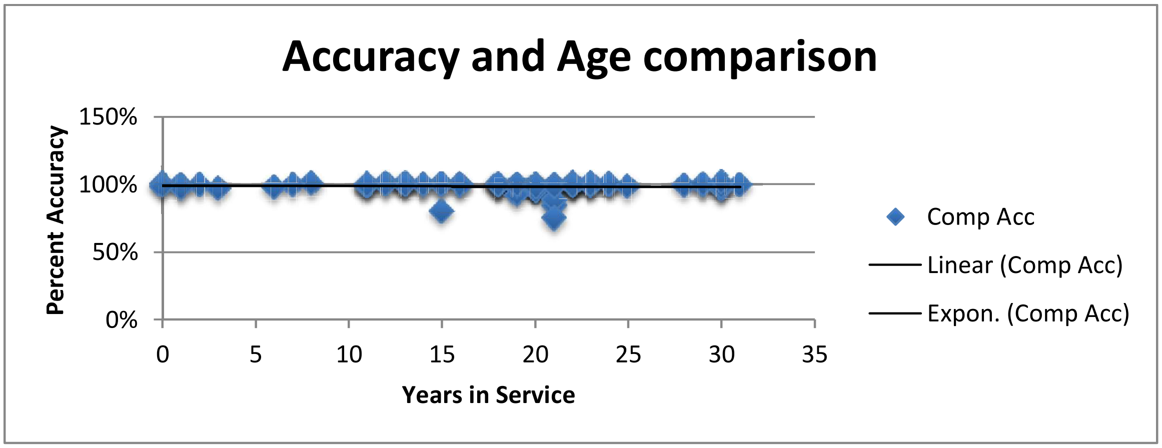

Figure 9-4 Meter Accuracy Compared to Age

9.2 Assumptions Used in Development of Strategies

Based upon the above evaluation of the meter population, the following assumptions were used in developing our strategic alternative presented in the next section, and in the recommendations. In addition, these assumptions are used to determine the meter replacement numbers for the business case evaluations in the Economic and Financial Analysis section.

9.2.1 Strategy Assumptions – Small Meters

- All Badger, Sensus, Kent/AMCO, and “unknown” meters will be replaced to reduce the number of different makes of meters and move to a consistent format for AMR.
    - These meters will need new wiring; will replace meter, wiring.
- The test data indicates meters are holding their accuracy; therefore any Neptune meter installed 2000 or later will be kept.
    - Meters with AMR radio kept, wire kept, and touchpads and remote displays replaced.

9.2.2 Strategy Assumptions – Large Meters

- Replace any meters with remote display registers.
- Keep meters with probes; replace probe with AMR/AMI.
- All meters read by AMR will be kept.

9.2.3 Strategy Assumptions – Reading Technology

- Neptune R900 and R900i meter interface units are mobile (AMR) reading only, unless “targeted[1].
- Wires to Remotes
    - With the exception of R900i meters which are installed without wiring to the outside, of meters installed since 1995, assume 90 percent of three-wire cable can be reused.
- Assume any wire installed prior to 1996 was a two-conductor and will be replaced.
    - Assumed wire after 1996 is three-wire
    - Assumed approximately 10 percent of wires installed after 1996 will need to be replaced due to failures/cuts.

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[1] Neptune sales literature indicates these can be used with a nearby gateway, however we recommend that these devices do not support a fixed network due to radio signal strength from inside a structure.

9.3 Strategic Alternatives

Based upon the analysis of the meter population and factors derived from the data and workshops, Excergy proposed three strategic alternatives to be evaluated in the Economic and Financial Analysis against the “current situation” strategy.

- Strategy 0 – Current Environment of moving to AMR over the next 10 years by converting to AMR in conjunection with the current pace of the meter age change program, using internal resources.
- Strategy 1 – AMR Quarterly: Initiate a project to move to AMR over three years or less with meter exchanges outsourced to an installation contractor. Maintain quarterly reading on the non-commercial accounts under ¾”.
- Strategy 2 – AMR Monthly: Initiate a project to move to AMR over three years or less with meter exchanges outsourced. Move all accounts to monthly billing.
- Strategy 3 – AMI Monthly: Initiate a project to move to AMI over three years or less with meter exchanges outsourced to an installation contractor. Move all accounts to monthly billing.

The relationship of these alternatives is depicted in Figure 9-5

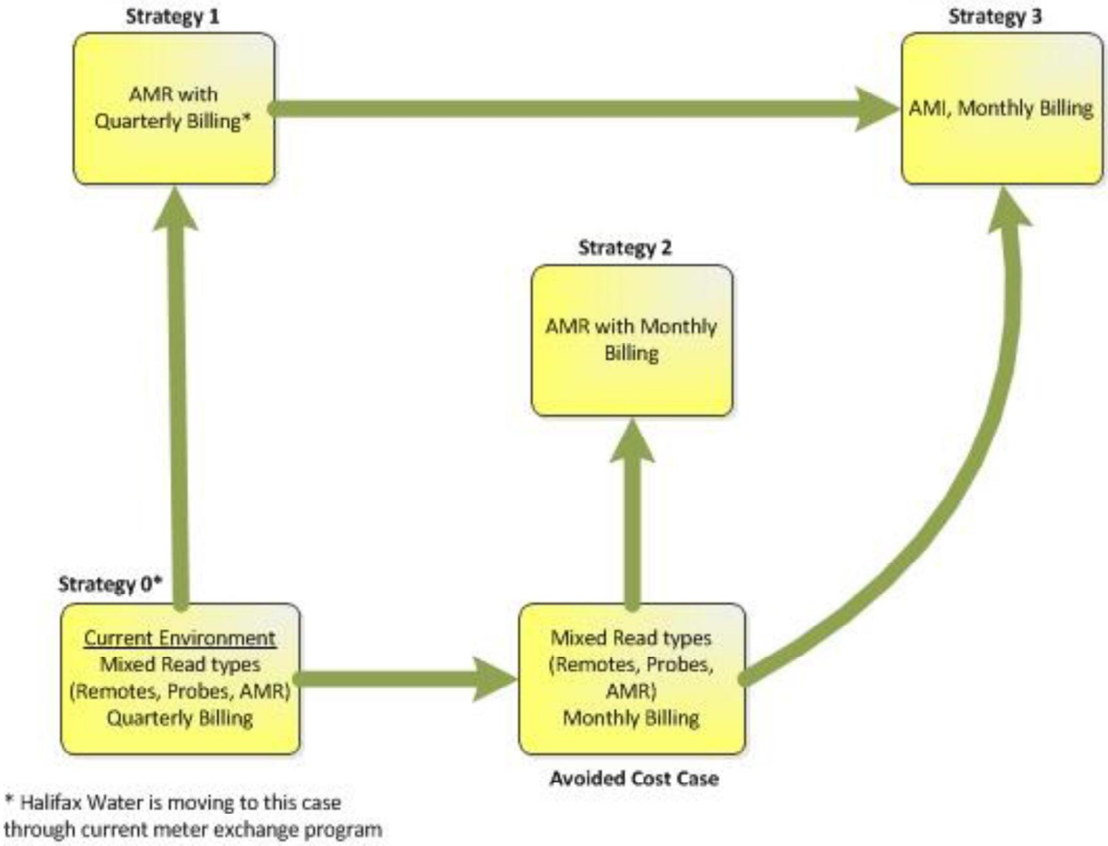

Figure 9-5 Strategic Alternatives

9.4 Avoided Cost Base Case for Strategy 2 and 3

A different set of assumption is used for the avoided costs to be used in the economic and financial analysis depending on whether quarterly or monthly meter reading is being considered. For monthly meter reading with its current mix of technologies, Halifax Water would have to hire twice again as many meter readers as it has now. to determine the benefits over moving to AMR under Strategy 0, but moving to a monthly read cycle. The Avoided Cost Base Case will be applied to Strategy 2 to demonstrate the financial impacts and potential benefits of moving to AMR with a rapid deployment and billing monthly. It will also be used in Strategy 3, to show impacts and potential benefits of moving to AMI and billing monthly.

9.5 Strategy 0 – Current Environment

The Halifax Water meter department is currently underway with a conversion of the meters to AMR. This is a mixed conversion, with meters changed opportunistically when a meter fails or other access is required, as well as a meter change out program with a budget of approximately $1.3M annually. This is Strategy “0” – continue with the current environment. Anticipated spending on this program is $10.9M over the next 10 years.

As a baseline strategy, Halifax Water could continue to install Neptune meters and mobile AMR MIUs everywhere they are not currently installed, creating a homogenous system. In fact this is the direction Halifax Water is currently heading, albeit slowly. There are operational advantages to standardizing on an AMR system.

The Halifax Feasibility Study team is performing an additional analysis of this option, using the current rate of transition based upon age-change meter replacements. Therefore Strategy 0 is included as an Avoided Cost case for Strategy 1, in the Economic and Financial Analysis.

This strategy will:

- Move to all AMR meters with internal resources over approximately 10 years
  - Convert to AMR through periodic and trouble generation (as required) of maintenance of meters, or
  - Through the meter exchange program of approximately 5,000 meters per year
- This strategy will continue to read and bill quarterly for existing quarterly billed accounts, but will read all meters using drive-by routes.
- The Assumed Staffing for this strategy
  - No staffing changes from existing until all meters are AMR because there is not a geographic component to the conversion. The meters are addressed as issues arrive, or appointments can be made to exchange

Some of the considerations of this strategy are:

- Battery Life on the AMR units is expected to be 16 years. This essentially is a 16 year age change (based upon R900i battery life). When addressing battery change out on the R900i, it makes sense to replace the complete meter. Access to the meter is difficult and it is best to replace when access is granted to address the battery.
- Replace all meters not on AMR. When needed for maintenance and on a programed change out schedule of approximately 5,000 to 6,000 meters per year.
  - 53,000 x $207 = $10.9M
  - Anticipated benefits of AMR reads will be slower to be realized versus three years in Strategy 1.

- Meter changes are geographically scattered. The current program has meters on AMR scattered across the service territory. This does not lend itself to allowing reads off AMR without the mixed need to a) key the read from meters with remote readout displays, and b) read the meters equipped with touchpads with the probe. Therefore no benefit on a route is realized until the complete route is converted to AMR at the end of the program (approximately 10 years in the future)
    - Versus route by route, this would allow for that route to be read by AMR drive-by.
- Lose flexibility to move to AMI. With the meters on the R900i or the R900 wall mount in the basement, Halifax Water will lose flexibility to move to AMI. While the R900 radio can be read from a collector, the density of collectors due to the low power and interference from the building structure reduces the range the radio to a degree that the collector network is inefficient and costly to maintain, making this option financially unviable.

An issue to consider with this approach is that to have a uniform system, Halifax Water would commit to a sole source supply situation with Neptune unless it committed to replacing the newer existing Neptune MIUs. A competitive procurement process and a strong contract would mitigate the risks associated with sole sourcing

9.6 Strategy 1 - AMR Quarterly

Strategy 1 is to move to AMR with maintaining quarterly reads on the accounts that are currently read quarterly. This strategy accelerates the meter replacement program to complete the transition to AMR within three years.

This strategy will:

- Move to all AMR meters with rapid deployment; rapid replacements under three years program using an outside installation vendor
    - This deployment will be performed on a route by route basis to achieve benefits as the program progresses by moving to mobile reads once a cycle has been converted
- This strategy will continue to read and bill quarterly for existing quarterly billed accounts, but will read all meters using drive-by routes. This will be achieved in three years versus 10 years in Strategy 0.

9.7 Strategy 2 - AMR Monthly

Strategy 2 is considered because Halifax Water is interested in the possibility of converting all customers to monthly reading and billing. Strategy 2 would move to AMR through a rapid deployment to AMR technologies through an outside vendor. This is the same effort at Strategy 1.

Halifax Water could move to a monthly billing process by adding more meter reading vehicles compared to reading quarterly in Strategy 1.

This would essentially require three times the number of manual meter readers, or three times the number of meter reading vehicles with mobile AMR. The volume of calls to Customer Service and the level of collection efforts may not change appreciably, but decrease a little, as customers' bills would be smaller. Conversion to monthly reading and billing may require a significant commitment of Halifax Water IT staff resources and extensive modifications to SAP programming, configuration, and procedures, as well as rate and policy changes (e.g., for collections practices). While a full examination of the costs of conversion to monthly billing is beyond the scope of this project, we will evaluate the meter reading costs associated with conversion to monthly billing using AMR.

The second Case Scenario is moving to AMR and moving to a monthly billing for all accounts.

This strategy will:

- Move to all AMR meters with rapid deployment – rapid replacements under 3 years program using an outside installation vendor
  - This deployment will be performed on a Route by Route basis to achieve benefits as the program progresses by moving to mobile reads once a cycle has been converted
- This strategy will move to read and bill monthly for all accounts, but will read all meters using drive-by routes. This will be achieved in 3 years versus 10 years in Strategy 0.

9.8 Strategy 3 - AMI Monthly

Strategy 3 is for Halifax Water to install an AMI system and to convert all meters to AMI to be read by the AMI data collectors on a fixed network. The strategy assumes the project to convert to AMI is performed with outside resources over a three years. This will allow Halifax Water to bill on whatever schedule is desired, as reads will be collected on a daily basis. In a conversion to monthly billing, industry experience has typically shown full AMI deployment can yield the greatest ROI over the life of the system. There is virtually no cost difference between *reading* meters monthly versus quarterly with an AMI system, although changing the *billing* frequency may have significant cost to mailing and processing efforts.

This strategy will:

- Move to all AMI meters with rapid deployment; rapid replacements in under three years using an outside installation vendor.
  - This deployment will be performed on a route by route basis to accommodate the install vendor resources and project controls.
- This strategy will convert all accounts to monthly reading and billing, but will read all meters using AMI infrastructure.

9.8.1 Hybrid Solution for Strategy 3

An alternative strategy discussed in the Strategic Alternative workshop is to replace all the non-AMR (touchpad and probe) devices with fixed network AMI devices, and not convert the already AMR devices.

In this case, were Halifax Water to leave the existing Neptune AMR MIUs, they would still be scattered throughout its service territory. They would require either motorized or walking readers, which would be inefficient since those devices are spread over almost all the meter reading routes. Moreover, those customers with the AMR meter interface devices would be provided a lower level of service than those with AMI meter interface devices (e.g., the Halifax Water would not have the ability to inform them of excessively high consumption or leaks before they got a high bill). Ideally, Halifax Water would replace all of its AMR devices at the time it deployed a new AMI system. Therefore, this option was deemed inferior to the above strategies, and was not considered further.

9.9 Recommendations

Regardless of the strategy chosen, we recommendation the following:

- Meters installed from 2000 until present be kept. Any benefits from accuracy improvements by changing out these meters are offset by the expense of replacing meters.
- The Neptune small meters installed from 2000 onward could be left in place. However, if the consumption measured by any such meter has dropped more than 25 percent in a year without an apparent explanation (such as customer turnover), Halifax Water should consider replacing the meter and testing it.
- With the advent of the integrated (R900i) units, a building requirement to provide wire access from the meter inside to an outside location was been retired. It is recommended that this requirement be reinstituted, as any AMI (or AMR) solution would be more reliable with antenna/radio units located outside on a building wall.

- As an alternative to installing and maintaining an AMI system in-house, Halifax Water might consider this as a hosted service. Some AMI vendors offer this service and it might be considered as an option.

- To help ensure a successful project, Halifax Water might should perform an audit of its accounts to validate the accuracy of data relating meters to premises and to customers.

- Because of the relatively uniform distribution the various meter reading technologies throughout Halifax Water service territory, there appears to be no distinct advantages in starting to replace any one type of technology (touchpads, probes) much before the other. Thus, with respect to an implementation strategy, greatest efficiencies would be achieved when a given geographic area (a route or a group of continuous routes) is saturated, such that the reading method is uniform–be it AMR or AMI. For example, with AMI, the savings are achieved when the Halifax Water no longer has to send a meter reader to a given route.

- Halifax Water should consider adopting a geographic strategy for installation, starting in one of its more densely populated areas (but not necessarily in the area with the oldest plumbing, as there are apt to be more installation problems during start up). Geographic concentration is also important because Halifax Water or its installation contractor would need to get inside customers' premises. The work is much easier to manage and inspect when installations are kept in close proximity.

9.10 Collaboration

As part of the strategic analysis, consideration of collaboration opportunities with other utilities must be considered. A portion of the workshops on October 30th and 31st was dedicated to discussion with Nova Scotia Power (NSP) and Heritage Gas.

The discussion identified the following considerations:

- NSP has been looking at AMI for the past five to six years, but does not have a completed business case to justify AMI at this time.

- It is difficult for NSP to justify non-economic benefits.

- Heritage Gas customer base is wide-spread and mainly large volume customers.

- Heritage Gas is providing large customers with daily consumption data, but is not hearing interest in daily and interval consumption data from most customers.

- There may be some interest in sharing reading/billing and mailing efforts.

- While an issue between some utilities elsewhere, operating under a single commission in the Halifax region allows for fewer issues with data confidentiality.
- If any collaboration shows economic benefits, the commission would support efforts.

While collaboration must be considered, the following issues may exist:

- Very few water utilities have been involved in shared AMI systems.
- Cultural difference between utilities often makes collaboration difficult.
- Most of the costs of an AMI system are related to metering, and thus do not promulgate economic benefits.
- Shared systems and comingled data can create complexities

As a result of this discussion, it was determined that there is interest in having further discussions. Excergy recommends that Halifax Water continue to communicate with the other utilities, specifically NSP, as decisions are made that may impact an AMI deployment.

9.11 Workshop Report

Date: October 30-31, 2013

Location: 450 Cowie Hill Road, Halifax

Halifax Water Participants:
Tim Burbine – Water Services, Central
Dave Hiscock – Water Services, East
Barry McMullin – Water Services, West
Graham McDonald – Technical Services, Water
Debby Leonard – Customer Services and Finance
Corey Whalen – Metering
Cathie O'Toole – Director Finance and Customer Service
Reid Campbell – Director Water Services
John Eisnor – Operations Engineer
Shiju Mathew – GIS Analyst

Excergy Consultants:
Mark Johnson
Andy Owens

Invited Guests
Ian McKillop – NSP
Craig Sutherland – NSP
Chris MacAulay – Heritage Gas

10 Economic and Financial Analysis

This section describes the economic and financial analyses created for the various strategies of Section 9 for AMI for HRWC.

10.1 Economic Model Development

The economic model focuses on hard cost and benefits that can be quantified in monetary terms. The savings created by AMR of AMI for Halifax Water are evaluated in terms of how the system can change the current baseline of work. Operational savings in meter reading, call center operations, billing, and field service that were identified in Task 4 were incorporated, as were the avoided costs associated with the current age-change of meters that are replaced with the accelerated AMR or AMI deployment strategies.

The model was designed to examine the three different strategies identified in Task 9 and facilitates changes in assumptions. Key assumptions and highlights of the model are presented in the following paragraphs.

10.1.1 Model Design

The economic model addresses the following considerations:

- Population of meters to be changed or retrofitted
- Meter and MIU costs
- Installation costs
- Salvage on old meters
- Meter maintenance avoided during installation
- Meter reading collection equipment
- MDMS Integration costs
- Project management costs
- Estimated annual operation and maintenance (O&M) costs, license fees, etc.
- Estimated communications and publicity costs
- Legal and consulting costs
- Vehicle reductions and other savings
- Staffing level adjustments defined from the efforts in Task 4
- Anticipated under-registration recovery from meters

- Anticipated distribution leak detection net savings
- The model calculates:
  - Multi-year parameters
  - Cost and savings impact (percentages) over time
  - Cash flow
  - Depreciation/residual values
  - Net present value/IRR
  - Financing costs
  - Discounted cash flow with financing

10.2 Deployment Assumptions

The following deployment assumptions are addressed specifically for each scenario:

10.2.1 Meters and MIUs

As identified in the Task 9 Strategy, of Halifax Water's approximately 83,000 meters, about 99 percent are in the "small" (2 inches and smaller) category as defined by the Study. Through the meter change-out program started in 2005 and changes done prior to that, there are ~43,000 meters that are Neptune meters installed since 2000.

The review of the test results on meters in the Halifax Water system show a longevity of the meters. Therefore, it was determined that meters installed since 2000 could remain on the system for some time come and reduce the economic impact of meter exchanges with no appreciable loss of benefits associated with recovering under-registration from old meters.

The meters equipped with AMI-compatible dial-position encoding registers would be left in place. Most of the existing meter registers are wired to a remote reading receptacle or touchpad with a three-wire cable (even if only two of the wires are used). Receptacles and touchpads will be replaced with AMR or AMI radio transmitters (MIUs) based upon scenario, in the same locations, using the existing wiring. However, a certain portion of the wiring, about 10 percent, may require the cabling between the meter and the outside of the house to be replaced.

10.2.1.1 Deployment Assumptions – Small Meters

- Small Meters categorized as 2 inches and smaller.
- Due to the meter test data results that show accuracy remains stable on the Halifax Water system, the model assumes replacement of meters older than 2000, unless otherwise indicated by type.

  - All Badger, Sensus, Kent/AMCO, and “unknown” meters will be replaced; new wiring.
  - Any Neptune meter installed 2006 or later will be kept; AMR radio kept; wire kept; touchpad replaced.
  - Any Neptune meter installed 2005 to 2000 will be kept; wire replaced.
  - Any Neptune meter installed 1999 or earlier will be replaced; wire replaced on meters older that 1995 (2-wire).two
- The Study recommends a business strategy to assume sole source to a Neptune meter population for a) volume discounting and b) inventory reduction.

10.2.1.2 Deployment Assumptions – Large Meters

- Large Meters categorized as above 2 inches.
- All meters read by “keyed in” method will be replaced.
- All meters read by AMR or probe will be kept.

10.2.1.3 Deployment Assumptions – Reading Technology

- Neptune R900 meter interface units are mobile (AMR) reading only, unless “targeted”.
- 90 percent of three-wire cable can be reused. Any wire installed since 1995 is three-wire and can be used if continuity has not been cut.

10.2.1.4 AMI Operational Benefits Assumptions

- The read will always be accurate.
- “Broken” MIUs will be repaired ahead of reading date.
- High consumption: flagged, customer notified before bill rendered; no free field inspections.
- Rereads for questionable high reads: Customer will already have been notified. Daily history available online.
- Low consumption: if no account turnover, call customer regarding change of circumstances. Otherwise, field visit (change meter).
- Initial and final reads: service stays on unless customer requests shut off. Usually no field visit. HRWC will have meter reading on property closing date.

10.2.1.5 AMR Operational Benefits Assumptions

- The read will always be accurate.
- Non-responding MIUs will require quick field visit to avoid estimate. Success depends on whether the MIU is outside.
- High consumption: daily consumption history available upon field visit.
- Rereads for questionable high reads: pull consumption data if meter reading is implausible.
- Low consumption: if no account turnover, call customer regarding change of circumstances. Otherwise, field visit (change meter).
- Initial and final reads: service stays on unless customer requests shut off. FS Tech must drive past premises for final read.
- Initial and final reads: service stays on unless customer requests shut off. Halifax Water will have drive-by meter reading on property closing date. Halifax Water may wish to assess implications of making this change and the customer communications required.

10.3 Strategy Analysis

10.3.1 Modeled Strategies

Three Strategies were chosen to reflect options that best suited the Halifax Water operational environment, and to present for the feasibility study practical options for comparison. This section details the financial analysis for the three strategies:

- Strategy 1 - AMR Mobile, with quarterly reading, three year deployment
- Strategy 2 – AMR Mobile with monthly reading, three year deployment
- Strategy 3 – AMI Fixed Network with monthly reading, three year deployment

The “Avoided Cost Base Case” for Strategies 2 and 3 is for read and billing monthly with current mixed environment of AMR drive-by, and walking reads. The base case for Strategy 1 should be the current changeover to AMR through age-change (slow deployment), as this is the default destination for the current environment.

10.3.2 Strategy 1 - AMR Quarterly Financial Analysis

The first strategy is to move to AMR with maintaining quarterly reads on the accounts that are currently read quarterly. Halifax Water is currently moving to this scenario by default through the meter program currently placing AMR meters and removing keyed and probed meters. The Study uses this strategy, but accelerates the meter replacement program to complete the transition to AMR within three years.

The Halifax Feasibility Study team is performing an additional analysis of this option, but using the current rate of transition based upon age-change meter replacements. That analysis is not part of this Study at this time.

The base case for this analysis is "business as usual". The current deployment of AMR meters with quarterly reading.

- Key benefits and impacts of this Strategy 1 are:
  - Reading Staff reduced to one
  - Reading Vehicle reduced to one
  - Potential to get reduced pricing on meters due to volume discounting/competitive bidding versus Strategy 0
  - Provides option of moving to a monthly billing once all meters are AMR
  - Provides Halifax Water time to consider option to move to a monthly reading and billing schedule with additional reading vans – at less cost than avoided costs base case of reading monthly with walking/hybrid routes
  - Meter Accuracy Improvements – no longer read or entry errors due to human mistakes – reduces billing prep, investigations truck-rolls
- The Assumed Staffing for Strategy 1
  - Assumed 2,500 reads per day per drive-by unit based upon industry norms and experience
  - 78,126 quarterly accounts read in 13 cycles (as of March 2013)
  - Average 19,500 reads per quarter
  - 19,500/2500 = 8 reading days per month
  - 0.5 FTE For Reading Quarterly Accounts in mobile unit
  - 4,210 monthly accounts read in three cycles (as of March 2013)
  - Average 1,400 reads per cycle – three days per month reading monthly accounts
  - Assumed 0.25 FTE required for monthly reads

10.3.3 Strategy 2 - AMR Monthly Financial Analysis

The second strategy is moving to AMR and moving to a monthly billing for all accounts.

For this strategy, we used an avoided cost base case predicated on performing and billing for monthly reads with the current mixed system of keyed reads, probed reads and RF reads.

- Key benefits and impacts of this Strategy 2 are:
  - Reading Staff requirements reduced by five due to driving versus walking to access remote register or touchpad
  - Ramped benefit as program progresses
  - Potential to get reduced pricing on meters due to volume discounting/competitive bidding versus Strategy 0
  - Decreased vehicles for Maintenance, Investigations, and Collections by one
  - Decreased vehicles for Reading by four
- Avoided Cost Base Case for AMR Monthly
  - Reading Staff increased three fold due to monthly reads
  - Vehicles and related equipment increased three fold to accommodate reading staff increase

Strategy 2 is summarized by:

- Move to all AMR meters – rapid replacements under a three year program
- Read and Bill Monthly
- Assumed Staffing
  - Assumed 2,500 reads per day per drive-by unit
  - 85,000(accounts)/16 (Read Cycles) = 5,312 Reads per day
  - 5,312/2,500 (reads per day per vehicle) = 2 reading vehicles per day required
  - Assumed two Field Service Technicians required for reading

10.3.4 Strategy 3 - AMI Monthly Financial Analysis

The third case strategy is moving to an all AMI fixed network solution. This is the strategy to determine the feasibility of moving to AMI.

Strategy 3 is summarized by:

- Move to all AMI meters
- Read daily

The key impacts of Strategy 3 are:

- Reading Staff reassigned/reallocated to maintenance
- Vehicles and related reading equipment reduced

Key Benefit of this Strategy 3:

- Accuracy improvements

- Anticipated reduction in high bill complaints
- Reduced truck-rolls
- Increased job satisfaction

Disadvantages

- Increased reliance on technology

10.3.5 Project Implementation Cost

Itemizes total cost of the specific strategy's (AMR/AMI) components at the meters (MIUs, replaced meters, and cabling), salvage value deducted for old meters that are removed from service. Includes installation labour and equipment (additional handheld units and vehicle mounted reading equipment). Also includes Project Management, including Halifax Water staffing and public relations and consulting assistance, as well as incidental related expenses. Table 10-1shows a comparison of the three strategies projects costs.

Table 10-1 – Estimated Project Costs

	Strategy 1 AMR Quarterly	Strategy 2 AMR Monthly	Strategy 3 AMI Monthly
All Meters	82,336	82,336	82,336
Select: Bills/Years	4	12	12
Capital Cost			
Meters and Assoc. Misc. Materials	$3,400,000	$3,400,000	$3,500,000
Installation Costs Allocable to Meters	$1,100,000	$1,100,000	$1,110,000
Electronics and Assoc. Materials	$3,900,000	$4,000,000	$7,700,000
Installation Costs Allocable to Electronics	$1,600,000	$1,600,000	$3,150,000
Administration, Start-up Costs	$700,000	$700,000	$1,800,000
Grand Total System Cost	**$10,700,000**	**$10,800,000**	**$17,260,000**
Salvage on Old Meters	($121,000)	($121,000)	($124,000)
Savings on Normal Meter Turnover	($2,122,000)	($2,122,000)	($2,122,000)
Net Total System Cost	**$8,457,000**	**$8,557,000**	**$15,014,000**

10.3.6 Costs and Savings

10.3.6.1 Operation and Maintenance

After installation, AMR/AMI components will require routine maintenance, and a small percentage of the installed devices can be expected to fail prematurely. Labour, materials, and incidentals to correct these failures are identified on an annually average.

Additional service costs must be borne annually to operate the system. Software requires annual service and licensing fees. These costs are totaled annually.

10.3.6.2 AMR Operation and Maintenance Savings

AMR and AMI systems will enable staffing savings through reduced meter reading efforts. By using the drive-by vehicle for the AMR read, more meters can be read in fewer hours. An AMI system will reduce reading efforts even more.

While Halifax Water does not intend to reduce staffing levels, the reduction in labour for the meter reading effort can be taken as a financial benefit for this business case, and the hours reduced deployed to other initiatives within the organization.

Staff reductions are accompanied by elimination of vehicles used by field staff, mostly related to meter reading and performing field work orders. The annual savings from vehicles is calculated, based upon the needs and requirements of each case.

The replacement of meters purchased before 2000 would eliminate the need for Halifax Water to replace meters due to age until the newer population of existing meters reaches the replacement age of 20 years. The result is a substantial post-project reduction in new meter purchases for about ten years., as well as a one-half reduction in meter maintenance labour. Together these would result in the identified annual savings. The model incorporates the suspension of the meter age change program for only the three years of the project installation.

10.3.6.3 Under-Registration Recovery from Meters

Meters lose accuracy slowly as they age, in almost all cases under-registering the metered flow. Replacement meters will be nearly 100 percent accurate, resulting in an immediate increase in metered sales and corresponding revenue. Halifax Water’s accuracy loss in small meters is very gradual, estimated at only 0.07 percent annually. Nevertheless, the result of the replacement of old meters is anticipated to yield an additional savings in revenue annually. A small number of large meters are planned for replacement as well, yielding additional savings of annual revenue. Table 10-2shows a comparison of the costs savings anticipated for each strategy.

Table 10-2 Projected Annual Savings

	Strategy 1 AMR Quarterly	Strategy 2 AMR Monthly	Strategy 3 AMI Monthly
Annual System Operating Costs			
Maintenance and Repair	$119,155	$121,819	$145,020
Operating Costs	$15,000	$15,000	$132,000

Total Annual O&M Cost	**$134,155**	**$136,819**	**$277,020**
Annual Operating Costs/Savings			
Manpower Savings	$301,252	$1,501,031	$1,880,203
Vehicle and Other Savings	$52,670	$229,320	$331,240
Monthly Billing Costs	$0	($175,601)	($175,601)
Domestic Leak Detection	$0	$0	$26,831
Total Annual Savings	$353,922	$1,554,749	$2,062,673
Under-Registration Recovery	$1,175,460	$1,175,460	$1,175,460
Total Revenue Plus Savings	$1,529,381	$2,730,209	$3,238,132
Net Annual Savings	**$1,395,226**	**$2,593,390**	**$2,961,113**

10.3.7 Multi-Year Discounted Cash Flow

A three-year implementation period results in a “phasing in” of both costs and savings. Accounting for mobilization and demobilization periods, approximately 30 percent of installations are expected to occur in both the first and last project year, with the remaining 40 percent occurring during the second year. Table 10-3 shows a comparison of the cash flow of each strategy.

Table 10-3 Cash Flow Comparison

	Strategy 1 AMR Quarterly	**Strategy 2 AMR Monthly**	**Strategy 3 AMI Monthly**
Simple Payback Period Calculation	6.0	3.2	5.0
NPV	(265)	12,028	9,845
IRR	2.8%	38.4%	18.2%

10.4 Workshop Report

Date:	November 13, 2013
Time:	8:30 am – 12:30 pm
Location:	450 Cowie Hill Road, Halifax
Halifax Water Participants:	Graham McDonald – Technical Services, Water Debby Leonard – Customer Services and Finance Corey Whalen – Metering Reid Campbell – Water Services Allan Campbell – Budget Supervisor
Excergy Consultants:	Don Schlenger Mark Johnson

11 Meter Technology Management

Revenue water meter technology has been undergoing continuous improvement over the last several years, but is now at a point of transition. Some manufacturers of dial-position encoder register have adopted newer non-contact technology (such as magnetic-field position-sensing, or optical recognition) to eliminate problems associated with long-term wear and to improve precision. In one meter, the register gear train is replaced by magnetic rotational sensing. These meters incorporate more transmitted digits (higher resolution) and more precision.

New technologies have recently been introduced to the small water meter market, including ultrasonic and electromagnetic meters. “No-moving-parts” meter designs require no calibration. They are touted as being accurate over a wider range of flows than traditional designs. These meters incorporate solid-state electronics and long-life batteries to support their relatively high power consumption.

At the moment, these new meter design are considerably more costly than typical AMI-compatible positive displacement meters. Simplified construction should eventually result in lower meter costs. While initial quality concerns have arisen, the reliability of these meters should be improved over mechanical meters with moving parts.

However, in any AMI business case analysis that involves potentially changing meter registers and some older meters, the utility must incorporate an analysis of the relative costs and benefits of changing some meters prematurely, and the increase in registered consumption from changing older meters. Typical impacts to meter accuracy, as well as Halifax Water’s own experience with meter aging and accuracy, were considered in the analysis.

The Study analyzed the meter population and identified the following recommendations for the potential AMI deployment of meters used in the strategy development and economic analysis:

11.1 Small Meters

- All Badger, Sensus, Kent/AMCO, and “unknown” meters should be replaced to reduce inventory and move to a consistent format for AMR
  - These meters will need new wiring – will replace Meter, Wiring
- The test data indicates meters are holding their accuracy, therefore any Neptune meter installed 2000 or later will be kept
  - Meters with AMR radio kept; wire kept; touchpad replaced

11.2 Large Meters

- Replace meters with touchpads
- Keep Meters with Probes, replace Probe with AMR/AMI
- All meters read by AMR will be kept

11.3 Reading Technology

- Neptune R900 and R900i meter interface units are mobile (AMR) reading only, unless "targeted[1]
- Wire to Remote
- Wires to Remotes
    - With the exception of R900i meters which are installed without wiring to the outside, meters installed since 1995 were installed with three 90 percent of three-wire cable can be reused
- Any wire prior to 1996 was a two-wire install and will be replaced
    - Assumed wire after 1996 is three wire
    - Assumed approximately 10 percent of wires installed after 1996 will need to be replaced due to failures/cuts

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[1] Neptune sales literature indicates these can be used with a nearby gateway, however we recommend that these devices do not support a fixed network due to radio signal strength from inside a structure.

12 Non-Economic Benefits

The purpose of this section is to identify benefits that Halifax Water can anticipate that do not present readily identifiable costs benefits, but provide intangible benefits to improve internal satisfaction to employees, and/or societal benefits to the community.

While economic/financial models deal well with only hard, direct costs and benefits, a business case can also consider environmental, and societal such as enhanced customer satisfaction and confidence, and reduced environmental impact. For example, associated environmental savings result from the reduction in vehicle usage. With fewer miles driven, there is a corresponding reduction in greenhouse gas emissions. Better leak management also reduces the demand for water treatment electric usage, resulting in lower power consumption, further reducing Halifax Water's carbon footprint. Reduced NRW can potentially impact the volume of wastewater that has to be treated.

The following are some non-economic benefits for Halifax Water AMI can provide:

- Environmental
  - Carbon Offset Value Reduction in carbon footprint due to elimination of utility vehicles (meter reading, meter operations, etc.). Green environment. Reduction in Carbon credits purchases.
- Improved customer programs
  - Proactive notice of high usage - monitoring and alerting customer of abnormal consumption
  - Customer choice and convenience (e.g. adjustable billing date, multiple billing dates, summary billing, etc.)
  - Improved internet based bill management programs (e.g. hourly, daily usage graphs/patterns)
  - Potential to offer flexible billing dates
  - Producing more bills based on real (rather than estimated) reads
  - Providing Halifax Water customers with more accurate customer information to address customer inquiries the first time
- Meter Reading as a Service – Potential to offer meter reading services for other utilities (NSP, Heritage Gas) within utility service territory. Increased revenue
- Operational Process Benefits

  - Improved forecast process with interval data provided daily on all meters
- Improved cash flow
  - Improve the monthly settlement process
  - Reduction in O&M required to operate settlement process
  - Operational cost reduction - more efficient settlement process utilizing interval data
  - Reduced Proration
  - Ability to bill monthly
  - Ability to change bill dates / reduce cycles to increase early month billing
- Finance and Accounting
  - Reduce the duration of the monthly closing process
  - Availability of interval data reduces need for estimation
  - More accurate calculation of unbilled revenue. Availability of interval data available daily eliminates need for estimated unbilled revenue.
  - More accurate earnings and budget forecasting. Availability of interval data available daily eliminates need for estimated earnings and forecasting.
  - Tighter controls for compliance. Availability of interval data available daily eliminates need for estimated earnings and forecasting.
  - Reduce audit fees with less reliance on estimates
    - Operational Cost Reduction - reduction in audit fees due to the use of actual data rather than estimated data
- Regulatory
  - Assist in rate design. Availability of interval data available daily for all customers eliminates the need to estimate impacts of new tariffs/rates.
  - Increase accuracy of loss calculations. Availability of interval data available daily eliminates reliance on estimated usage information for determining losses.
  - Increased accuracy of customer class allocations of cost of service. Availability of interval data available daily eliminates reliance on estimated customer class information.
- Employee and HR Benefits
  - Higher technical work; increases employee knowledge and satisfaction.

- Increased safety of personnel. Remotely obtaining meter data and reducing manual disconnect and reconnect processes lowers the likelihood of Halifax Water employees being placed into unsafe situations.

13 Deployment Recommendations

This document is a task deliverable for Task 13 – Deployment Recommendations delivered as part of the *AMI Technology Assessment and Feasibility Study* that Excergy is performing for the Halifax Water.

13.1 Deployment Strategies

There are three typical deployment strategies:

- Full Scale Deployment – Deploying to all meters across the service territory as quickly as possible.
- Strategic Deployment – So called “strategic” or “surgical” deployment of AMI entails installing it on limited groups of customers. These could include:
    - Hard to read meters – Focusing on these meters improves the “cost per read” by reducing the effort assigned to capture a read on meters that are difficult to access
    - High use, large meters. The utility might want to read its largest meters, where usage is highest, at frequent intervals.
    - Areas of high turnover. Areas that have a high degree of move-in /move-outs. AMI is especially suited for these areas to reduce truck-rolls for final reads. Halifax Water has some areas with a high concentration of students, and summer vacationers.
    - Areas of high leakage, focusing on these areas help keep better track of revenue and NRW, or install acoustic leak detectors.
    - New housing developments in a rapidly growing system. Reduces need to adjust read routes or add additional readers without affecting existing routes and cycles.
- Opportunistic Deployment – This is the current process Halifax Water is deploying to move to AMR. Using the age-change and failing meters, Halifax Water is replacing meters as they encounter them. In addition to this, Halifax Water is also working a replacement program with financial support of approximately $1.5M per year. The business case includes this program to leverage the financial expenditure to support the project. In addition to the age change, Halifax Water can exchange meters when:
    - The property is turning over, and an initial or final read, or a shut-off, is required
    - For all new construction
    - Upon customer request

- During field visits due to high bill investigations or re-reads, or suspicions of meter malfunction or tampering

13.2 Current State of Halifax Water meter population

Excergy reviewed supplied information on the meter population. The review identified the following:

Halifax Water has a mixture of meter reads types – Keyed, Probed (touchpads), and RF. This is a result of opportunistic deployment of technologies. Unfortunately before one technology was fully implemented (keyed to touchpads), RF with drive-by technology was initiated. The result is the meter population is nearly split equally between these three types. Deployment to replace Keyed or Probed meters to AMR or AMI technologies would not follow a tight concentration of effort.

The following recommended deployment strategies are based upon the evaluation of the meter types, age, and geographical distribution of meters.

13.3 Deployment Decisions

If Halifax Water is committed to quarterly reading, then it should consider converting all of its customers to drive-by AMR in a short time period (three years). It can do this by installing new Neptune radios on the meters that currently have touchpads and installing new Neptune meters equipped with integrated registers where it currently has Neptune remote visual readouts. This conversion should be done geographically, that is, converting all the non-AMR meters one route (or billing cycle-day) at a time, continuously rerouting the remaining manual meter readers. The AMR system would probably have to be acquired through negotiations with Neptune.

If at some later date Halifax Water decides to convert is billing to monthly, it can accommodate this with the AMR system by acquiring additional mobile collectors.

If, on the other hand, Halifax Water intended to convert to monthly billing for its customers within the next few years, it should convert all of its meter to fixed radio AMI over a three-year period. This may require replacing the integrated R900i registers on some meters. Fixed radio meter interface units would be installed on the outside of houses and buildings for all other meters, using existing touchpad wiring, and replacing existing remote register wiring. This deployment should also be geographic. A new AMI system would be acquired through competitive tender. This would provide the highest level of benefits to the Commission and its customers in terms of a combination of ROI, enhanced customer service and information to improve distribution operations, capital planning, and water and energy management.

Key Decision: The move to monthly billing or to stay on quarterly billing affect the feasibility of the study.

- Pros to stay on Quarterly and move to AMR:
  - Can proceed with RF conversion and move to monthly at future
  - Does not affect current processes
- Cons to AMR Quarterly:
  - Delays the benefits of AMI, including:
  - Labour savings
  - Functionality of alerts/alarms Backflow, leak detection, proactive on potential high bills

13.3.1 Stay with Current Technology for AMR

If Halifax Water stays with AMR, Excergy recommends installing any new or changed meters with outside MIU’s. With 900i and inside mounted antenna, it is necessary to gain access to the house for battery and MIU maintenance. In addition, if AMI does become a choice, it allows for easier replacement of the MIU.

- Pros
  - There is already a population of Neptune Meters (approximately 18,000)
- Cons:
  - 900i meters require access to the meter at the end of life for battery
  - Would need to pursue competitive pricing with possible change of vendor

If Halifax decides to continue with AMR, Excergy recommends that a competitive RFP for meter procurement be initiated. This allows for better pricing and can provide options to Halifax Water with regard to equipment choices. Halifax Water may choose to stay with Neptune meters, however a competitive price will benefit it.

13.3.2 Option 2 - Move to AMI

Excergy does not recommend AMI unless Halifax Water decides to move to monthly billing.

- Monthly
  - Move to AMI

  - Three year deployment
  - Competitive bid for materials
  - Will likely need 900i replacements
  - Convert touchpads and remote register displays to outside mounted radios
- Convert geographically as AMI network is expanded

13.4 Rate of Deployment

Regardless of Halifax Water moving to AMI or staying with AMR, Excergy recommends that any deployment be accelerated to realize the benefits and move toward a homogeneous meter population. The current situation of multiple read types with multiple meter models/manufacturers, with registers that are inaccurate, present a myriad of situations to field and customer service personnel. This creates an environment that lends itself to inefficient and inaccurate results.

The recommended rate of deployment for the meter population at Halifax Water is three years. This should be contracted out to an installation vendor that can provide strict quality controls, an appointment process, and reduced unit costs due to productivity savings and efficiencies.

13.5 Prerequisites and Planning

An AMI project is a large undertaking for a utility and requires detailed planning. Recommendations and suggested planning requirements are detailed in Task 14

– Implementation Considerations. However, prior to the actual implementation there are some areas Halifax Water should address.

13.5.1 IT Environment

AMI systems can interface with several IT systems within a utility, depending on what systems a utility has implemented or are considering. Typically an AMI will interface with CIS, Work Management (WMS), Asset Management (CMMS), and potentially SCADA for distribution benefits.

Excergy recommends that Halifax Water develop an IT strategic roadmap that includes all IT systems and identifies all the interfaces. Halifax Water needs to incorporate AMI into any strategic IT planning designs. Identify the integration strategy to any prospective vendor and require assurances that the AMI is compatible with Halifax environment.

Another important part to IT deployment planning is data management. AMI could inundate Halifax Water with data and a data management plan must be developed to ensure proper data security and quality is maintained. This data management plan should identify the system of record, and identify the process to capture (create), maintain (update, delete), and secure (backup and security processes) the data.

13.5.2 Human Resource Environment

It is important that Halifax Water identifies and reviews all processes that are impacted by AMI. While this study addressed four core customer service processes, there are many more processes that must be reviewed and modified, replaced, or eliminated to streamline and garner the benefits AMI promises.

Meter operations are another area that AMI will have a large impact. Halifax Water must define and document the future processes of installing the meters to ensure they are commissioned properly in the AMI system, the MDMS system, the CIS system, and CMMS system. Each time the meter or MIU is changed a process to ensure proper data alignment must be in place to maintain data quality.

Excergy recommends that Halifax Water define processes in concert with the data management design to ensure processes, people, and data, are populated - at the right time - by the right people - in the right system - for the right material.

14 Implementation Considerations

AMI implementation involves several coordinated dimensions. Astute implementation planning can mean the difference between a successful, well-accepted project and a poorly performing system. The integrity of the information created during AMI deployment is critical to employee and customer acceptance.

Implementing AMI requires coordination of thousands of work orders with customer service and billing operations. The integrity of the information created during AMI deployment is critical to project success. Implementation planning includes developing a deployment schedule, creating project control systems, establishing IT interfaces, enhancing field to office communications and redeploying staff. Several Halifax Water departments, and multiple teams, would be involved in AMI implementation planning. Major elements of successful implementation planning include:

- **Project Plan –** a detailed and specific project schedule to govern contract management and vendor procurement, software and integration development and testing, field deployment of the network and the meters, troubleshooting, data audit and acceptance testing. A good AMI Project Plan must include, at a minimum the following:
  - **Procurement Plan**
  - Program Management (optional, but recommended)
  - Meter vendor selection and procurement
  - Network vendor selection and procurement
  - Meter Installation vendor selection and procurement
  - Network Installation vendor selection and procurement (might be same vendor as Network Vendor)
  - **Organizational Change Management Plan**, which should include:
  - *Human Resources plan* to manage the transition of employees during and after the project. This plan includes the following efforts:
    - Business Process Redesign
    - Organizational structure to AMI operational impacts
    - A policy and procedure review, to ensure Halifax Water has the polices needed to ensure effective AMI deployment such as compelling access, handling inactive or delinquent accounts, and reconciling consumption concerns as old meters are replaced
    - *Training plan* for all utility employees involved in installation, managing contractors, operating and maintaining the system,

dealing with customers during installation and using the system data

- **Communications plan** for customers, employees and the general public;
- AMI System Development Plan
- IT integration plan covering key interfaces and initial applications;
- Testing Plan - acceptance test plan for software, components and the overall system;
- System Deployment Plan, which should include:
- Network Deployment Plan
- Meter Deployment Plan for installation of AMI meter technology which also includes an installation control system to ensure data is captured correctly and invoices are correct – whether this is an install vendor or done in-house[1]
- Meter Reading Transition Plan to ensure all meters are read smoothly as routes are converted to AMI
- Ongoing operation and maintenance plan, which includes
  - Periodic testing and preventive maintenance plan
  - Protocols for replacement or repair of system components

14.1 High-Level Project Plan

The following project plan includes the tasks and required plans that an AMI deployment needs for successful completion. As the details of the specific AMI deployment environment are identified, tasks must be added to coincide with the specific vendor or AMI software and integrations required.

<supplied as a separate document in .mpp format>

14.2 General Considerations

The following considerations are offered as items to help Halifax Water in the deployment and implementation efforts

1. Install Vendor

- Best to locate their office close to the water meter shop and locate installers deployment docks nearby too.
- Be absolutely sure to get the Work Order process fine-tuned and re-visit and update if possible. The efficiencies gained will pay off in many ways.

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[1] For Installation Vendor Selection, it is recommended that this be a key component in the RFP to ensure any potential install vendor utilizes a robust installation management tool.

2. Status Flags and Events: Watch them closely and build good processes to address them.
    - Some events detected are more useful than others. Communicate this often with the hardware/software vendors
    - Some events can report bad wiring by installer and a great tool for correcting issues with personnel practices
    - Train install vendor well to look for tampering signs and review often through regular meetings with the install crews
3. Remember you're pulling people off the streets to work the field and they'll need more guidance more often
4. Do not skimp on QA practices because they will come back at the end of the project as extra time, effort and cost than could otherwise be avoided
5. Ensure deployment vendor provides effective field foreman. Reinforce this with the management of the installation vendors.
6. Give the vendor the basic installs only that don't risk causing big errors, especially with large important customers.
7. Keep a focus on quality to the end of the project. A reduction in quality may develop toward the end of a project as installers may not be as vested or worry about corrective action/discipline
8. Prepare for hardware version updates. Multi-year projects likely see the model of hardware versions change throughout the deployment timeframe. Have an update plan ready.
9. Prepare for software version updates. Similar to hardware updates, software versions change during multi-year projects. Be prepared to perform updates to keep the meter population on like versions.
10. Some deployments need to handhelds to perform the work. 1-Work order handheld 2- Module programming handhelds. Look at using devices that allow the installers to use one handheld device for meter install and work management operations. You may be able to avoid 2 handhelds and reduce potential errors and reduce complexity.
11. Watch schedule timing. Sometimes items such as the start of the contract is late causing the start of installs to be delayed which results in rushing people to get caught up. There can be a risk if training is rushed and this can produce errors.

12. Performing communication pings of module to test the radio coverage/validity is good practice for troubleshooting.
13. Training: Sometimes some important items may get overlooked. When this becomes evident be sure to share in meetings with installers and reinforce the message.
14. Return Merchandise Authorizations (RMAs) of modules should be tracked closely. Keep an eye on quantities, issues and returns and invoices. Communicate often especially on recurring issues.
15. Watch modules for bad consumption values and test thoroughly for accuracy of every meter type.

- even with testing real world environmental issues will surface over time.
- Testing cannot be stressed enough

16. Watch very closely that your largest customers do not have issues that with a multiplier become huge issues.
17. There are many water meters that require specific modules. Document install requirements for each meter type and installation situation. Reinforce this practice often with the installers.
18. In many deployments there can be a several module program options and using the correct program for the correct type of installation is critical.
19. Watch end of project numbers of installs left over matching up with different sources. Install status numbers can vary based on timing of data updates. Areas that can have miss-aligned numbers based upon the status of a data update or exception: Installs completed in CIS vs. Vendor installer vs. Operations AMI head end or MDMS.

15 Risk Assessment

An AMR or AMI project for Halifax Water represents a significant capital investment. Arguably, the Commission is already in the process of deploying a particular AMR technology. A new metering system must deliver mission-critical information reliably and must operate over perhaps 15 to 20 years, during which circumstances (e.g., personnel, politics, economics, technology) can change. An AMI project would likely be high profile and impact a large number of stakeholders, including utility employees and customers. It would rely extensively upon technology (particularly radio communications), interfaces between information systems, and batteries. Although it is experienced with AMR technology installation, the Halifax Water staff would likely be inexperienced at executing many aspects of an AMI deployment. The project would require the coordination of a number of key players: the technology vendor, the meter vendor, the installation contractor, and the Commission's engineering, customer service and IT staff. All of these aspects create risks, and risk assessment should be part of any feasibility study. This section will focus on risks associated with AMI, although many of the same risks are associated with AMR.

AMI project risks fall into two broad but interrelated categories:

- Technology risks include obsolescence of the AMI equipment, premature battery failure, flaws in AMI project control software, excessive failure rates of system components, incursions into assigned radio frequencies, incompatibility with future meter registers or communication standards, inadequate performance of the system, insufficient safeguards to secure customer (and company) information, and loss or corruption of critical data.

- Business risk include instability of vendors, lack of employee buy-in, business case assumptions that change or fail to materialize, lack of ongoing system support and maintenance by either the utility's staff or the vendors, increased tampering and theft of service, failure to adequately integrate the AMI system with other utility information systems, failure to change business processes to completely take advantage of the technology, failure to reduce staffing and other costs where the system enables it, lack of acceptance by customers, and increased issues caused by reduced visual inspection by the Halifax Water staff of customers' premises. For example, poor customer acceptance can be caused by failure to adequately address customer concerns such as electromagnetic field radiation, privacy, or higher bills due to meter change outs.

Risk is the product of probability and consequence. A high probability failure with a very low consequence would carry little risk. A very low probability failure with a high consequence may also carry little risk, but caution is advised in reaching such a conclusion since probability is often much more difficult to estimate than consequence.

As part of project procurement and planning, the risks of an AMI implementation should be identified, their likelihood and potential impact assessed, the potential to prevent or mitigate them evaluated, and contingency plans developed where appropriate and responsibility assigned

Where significant risks exist, potential mitigation measures should be identified and those measures that are reasonably cost-effective in comparison to the mitigated risk should be implemented. The utility may develop preventive measures (e.g., go/no go decision points), mitigation (e.g., changes in the plan if aspects of it do not have the desired results), or decide to simply accept certain outcomes and their attendant cost or delay. Mitigation may be in the form of assignment to another party (e.g., the AMI vendor), but assignment of risk is not always effective, particularly if the assignee is unable to control the conditions that could lead to the potential failure, or if the risk is too great in comparison to the project benefits for the assignee.

Some project risks should be addressed throughout the steps leading up to deployment. Risk mitigation measures include: soliciting expertise; building a thorough business case incorporating reasonable estimates of potential savings and costs; involving all stakeholder groups; following a thorough and unbiased selection process; developing robust contracts and performance measures; providing appropriate safeguards to secure customer and company information through the data transmission process; establishing and maintaining schedules for visual inspections of meters and MIDs, implementing detailed project control procedures; and adopting comprehensive project management and communications plans.

Risks are slightly different for each of the strategies developed in this study. For example, the risks associated with the current R900i deployment strategy include: being tied to an mobile AMR option only; having a sole-source supply situation; effectively shortening the meter age in service, resulting in higher long term costs; and requiring access to the inside meter before the battery in an MIU wears out.

In a workshop segment with Halifax Water staff, a number of technological and business risks were identified and discussed. Excergy staff suggested the level of risk, while Halifax Water staff suggested the level of impact. Table 15-1 documents the identified risks, and suggested mitigation strategies for Halifax Water to use in developing a successful project plan and implementation.

Table 15-1 Technological and Business Risks with AMI Deployment

Risk	Level of Risk	Level of Impact	Mitigation Strategy
Technological Risks			
Technical obsolescence	M	L	Require ongoing support in contract
Lack of standards, interoperability	H	H	Require guarantees of interoperability in RFP and contract.
Bugs or interface problems in application and third party software	M	H	Design within integration strategy, i.e. use Enterprise Service Bus (ESB) or other integration strategy that provides the speed and functionality required for the requirements. Project gate: acceptance testing.
Premature battery failures	L	H	Contract and warranty.
Excessive failure rates; system failures, product recalls	L	H	Contract and warranty, including “make whole” provisions.
RF incursion	L	L	Sufficiently strong network for unlicensed. Federal protection for licensed.
“Future-ware;” untested products.	L	L	Due diligence - validation of verifiable functionality; warranties.
Business Risks			
Long-term viability of vendors	L	M	Due diligence; strong software agreements.
Lack of internal stakeholder buy-in	H	H	Generate success Organizational Change Management (OCM) and Communications planning
Lack of customer buy-in	H	H	Customer Communications Have questions in annual survey
Business case assumptions don’t hold – too aggressive on benefits	L	H	Have a conservative, yet accurate business case
Delays in project deployment (often due to integration and CIS issues)	M	M/H	Due diligence in integration design, good project management, dedicated IT resources
Lack of ongoing system support and maintenance	L	M	Good process design; identify who is responsible for system and data

Risk	Level of Risk	Level of Impact	Mitigation Strategy
Failure to integrate AMR with other systems. Developing integrated applications increases risk.	L	H	Develop IT Strategic Roadmap that identifies systems, integration points and development timing. Identify integration strategy and ensure staffing is sufficient
Institutional capacity to manage the project	M	H	Identify resources needed. Staff accordingly. Ensure overlapping projects do not create conflicts. Outsource project management.
Failure to change processes, policies and practices (e.g., collections with monthly billing)	M	M/H	Effective Communications Plan and change management plan. Identify policy impacts and allow time to develop, promote and wind approval of the changes.
Conflicts with HRM CMMS project	L	M	Address CMMS needs for Halifax Water and how HRM will impact Halifax Water project timing. Possibly create separate Halifax Water system.
Failure of URB to approve project	M	H	Build a strong business case
Impact of project impinges on HWRC's capital plan and financial health	M	M	Build strong business case. Delay or spread project to fit within CIP prioritization.
Labour relations problems with displacements and reclassifications or changes in job content	M	M?	Address through HR - Provide information and develop a strong Change Management Plan.

15.1 Conclusions

The scale, cost, and impact of an AMI project at Halifax Water will warrant the time and expense needed for a rigorous risk management process.

Responsibility for risk management should be assigned to a senior member of the organization who can independently judge the project's risks and mitigation plans without being influenced by any conflicts of interest.

A well implemented risk management process--based on a framework of formalized policies and procedures that are clearly specified and thoroughly documented – will enable the organization to regularly the monitor risk environment, continually evaluate the effectiveness of mitigation measures, and make appropriate adjustments as needed.